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Membrane device with integrated photoelectric system for producing drinking water and electricity

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ABSTRACT

This work is devoted to the design and testing of new type membrane devices, which are provided with photoelectric systems. The purpose is to design a system with the multiple recovery of solar energy, which can be used to produce drinking water, from seawater by the membrane distillation (MD) process, and electricity, using photoelectric elements. The schemes of the combined portable devices are presented. Photoelectric elements, which are integrated into the constructed modules, carry new functions, not limited to the production of electricity. The testing of the designed small pilot devices was conducted in field conditions, powered by solar energy, independent from electricity and other fuel sources. A hydrophobic, microporous, commercially available membranes from the Millipore Corporation (Billerica, MA) were used for the desalination of seawater. The dependence of the MD solar desalination device productivity on desalination stage number, the specific productivity of drinking water and electric power depending on different hours during the day, and the heat losses from the external surfaces of devices were investigated. Combined production of two products provides the opportunity to increase the efficiency of devices, to minimize the demand of ground area for the devices and to lower the cost of the products.

Keywords: Membrane distillation; Desalination of seawater; Combined solar device; PV

1. Introduction

Water and energy are the two most essential substances for sustaining life. There is an acute shortage of both, especially in third world countries. Supplementing the deficiency of good quality water resources has become an important, high priority task, especially in remote, arid and semi-arid regions. The shortage of drinking water in many parts of the world is often accompanied with the limit of traditional energy resources.

Seawater is an inexhaustible resource for acquiring pure water. The total dissolved solids (TDS), which on average is 15–45 g/L of seawater, must be decreased to the required norms for domestic, industrial and irrigation purposes.

Today seawater desalination is operated by fossil fuels, which are considered to be a non-renewable resources. Moreover, the extraction and burning of fossil fuels have caused severe damage to the environment, causing such ecological problems as air pollution, release of greenhouse gases (which contributes to climate change), and acid rain.

The sun is an inexhaustible clean energy source, and the total solar power is 1.75×10^{17} W, which is 10 times greater than existing organic fuel resources. In order to satisfy human energy demands with solar energy, 0.13% of the Earth's surface would suffice, even if the efficiency of the conversion of solar energy is only 5%.

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The photoelectric processes are the most applied technologies for generating electrical energy. Photoelectric elements absorb electromagnetic rays of light, both from infrared and visible spectra. Only a part of the visible spectrum is converted into electrical energy. Most of the absorbed radiation is not converted by solar cells, which results in an increase of the temperature of the elements and in a decrease of the electric efficiency. The amount of absorbed energy of a solar cell depends on the location, season, day, and hour. However, the thick clouds and other weather factors have the most significant influence on it.

The membrane distillation (MD) process is a prospective method for concentrating and desalinating the aqueous solutions using solar energy [1–3].

The principle of MD is the following by means of low potential energy on the both sides of the membrane, a temperature difference is established, which is considered to be the driving force for the process. The volatile molecules of solution (in this case molecules of water), originating from the evaporation of heated solution, pass through the membrane and condense on the cold side, resulting in an overall transmembrane flux. The molecules of water vapor transfer through the pores of the membrane from the high pressure side to the low pressure side. The heated aqueous solution cannot penetrate inside the hydrophobic membrane, so a vapor–liquid equilibrium is established on the entrance of each capillary pore [4]. The membrane's hydrophobicity determines the quality of produced water.

Depending on the methods of condensing and removing water, the different MD processes can be distinguished:

- Contacting membrane distillation (CMD) – On one side of the membrane we have the heated solution and on the other side distilled water. During this process we have evaporation and condensing processes in the pores of the membrane. The main disadvantage of the CMD in commercial application is its low energy efficiency. The CMD can be used for the separation of saline solutions [5,6].
- MD with an air gap (AGMD) – on one side of the membrane we have the heated solution. The vapor passing through the pores exits from the other side of the membrane then passes through a vapor air gap and finally condenses on the wall. The disadvantage of this method is the additional resistance of both the air gap and the layer of condensing water, which leads to lowering of the transmembrane fluxes. The AGMD is successfully used for the production of pure water and concentrating of all kinds of non-volatile dissolved solutes [7,8].
- MD in an inert environment (IEMD) – on one side of the membrane we have the heated solution. The vapor passes through the pores to an inert gas environment on the other side of the membrane. The process of separation of water vapor from the other gases then takes place. IEMD has a higher mass transfer efficiency than the AGMD. The process is particularly useful for the removal of volatile components and dissolved gases from liquid solutions [9,10].
- MD by vacuum (VMD) – on one side of the membrane we have the heated solution. The vapor passes through the pores to a zone of low atmospheric pressure, then condenses in coolers. The resistance of the vapor–air layers is strongly reduced by applying a vacuum. Compared with the other methods of MD, one of the advantages of this method is that the heat conduction losses from the membrane can be neglected. The method of VMD is very useful for the separation of volatile components from aqueous solutions and for the removal of dissolved gases from liquid solutions.

It is clear from the above statements that at least one side of the membrane must be in a direct contact with the processing solution.

The membranes used in the MD process must meet the following requirements [11–13]:

- The membrane must be hydrophobic
- The membrane must not be wetted by the processing solution
- The membrane must be porous
- Only vapor must transfer through the membrane pores
- The membrane must not influence the vapor–liquid equilibrium between different components of the processing solution

Satisfactory conditions for the MD process are met by polypropylene (PP), polytetrafluoroethylene (PTFE), polyethylene and polyvinylidene fluoride polymeric compounds. The membranes, applicable for MD, must have low heat conductivity, narrow distribution of the pore size, porosity up to 80% and a 0.1–0.6 μm pore diameter. The thickness of the membrane must be as small as possible, in order to ensure high productivity. At the same time, the membrane must transfer only a small amount of heat by the conductivity mechanism. In practice, the membranes have a thickness of up to 300 μm. There is then a critical pressure of membrane penetration for each pore radius. A fluoroplastic membrane with a 0.2 μm pore diameter has a critical pressure of about 3 atm.

Depending on the pore size of the membrane, the process of MD is driven via mechanisms of molecular diffusion, Knudsen diffusion and Poiseuille viscous flow [4,12]. The MD flux J through the membrane driven by the pressure gradient is defined by:

$$J = K_m \Delta P \tag{1}$$

where K_m is the mass transfer coefficient (kg/m^2 s Pa), and ΔP is the difference in partial pressure between two sides of the membrane (Pa).

The heat transfer through the membrane is driven by the transfer of latent heat of evaporation and the heat conductivity through the membrane. The heat transfer through the membrane by conduction can be defined by the following equation:

$$QT = \frac{K}{L}\Delta T \tag{2}$$

where K is the heat conductivity coefficient (W/m K), and L is the membrane thickness (m). The heat conductivity coefficient can be defined by the following equation:

$$K = \varepsilon\lambda_g + (1 - \varepsilon)\,\lambda_m, \tag{3}$$

where ε is the membrane porosity, λ_g and λ_m are the gas and membrane material heat conductivity coefficients (W/m K), and ΔT is the difference in temperature between the two sides of the membrane (K).

The evaluation of all the processes of desalination leads to the conclusion that the MD processes have a very high potential due to the following reasons [13–17]:

- The desalination process is conducted under the low operating temperatures, which allows to apply low potential energy sources, such as solar energy or waste energy from various applications.
- The osmotic pressure does not affect the desalination process, in contrast to reverse osmosis, which allows applying MD for producing drinking water from highly concentrated saline solutions. The MD devices can be made from cheap polymeric materials.
- The membranes for MD are made from chemically sustainable polymers. Long-term operation of the membranes strongly reduces the cost of MD devices during utilization.
- As the permeate produced by the MD process has high purity, the MD modules could be applied not only for acquiring drinking water but also for medical and pharmacological purposes, as well as for industries, which need water of a specific quality.
- As the desalination process by MD is conducted through thin membrane layers, the MD modules have large operating surfaces allowing the MD modules to be very compact.

Generally, MD processes use the following types of membrane apparatuses: plate and frame, spiral wound, tubular, capillary and hollow fiber [18–20].

There are many publications devoted to the design and testing of various types of MD desalination modules. Initially, the desalination of seawater was conducted on plate-and-frame modules [21–26]. Satisfactory results had been obtained from the modules' performance, which were equipped with capillary and tubular hydrophobic membranes [27].

Each of these devices can be applied for acquiring pure drinking water from saline solutions via solar energy. The feed solution initially was heated by solar collectors. The heated solution was then directed to the MD desalination module by pumps.

A large scale of investigations was carried out with an air gap spiral MD module and observation results were shown in the papers [28,29]. The desalination device was constructed like a sandwich packet and included a membrane of definite width and length, a porous support and a metallic sheet, situated in a shell. The spiral module was a cylinder of $H = 0.65$ m, $D = 0.4$ m if it was turned from the membrane of 10 m^2 area.

The scheme of the spiral seawater MD module operated by solar energy is shown in Fig. 1 [30,31].

Seawater was heated up to a definite operating temperature range (60°C–80°C) via the heat exchanger, which received solar energy absorbed by the solar collectors. Under these temperature conditions, the distillation process was conducted in the MD module. The temperature difference was established between transported by the feed pump and then heated up in the heat exchanger, seawater canals separated via air gap. Released water vapor passed through the porous membrane pores, which were considered to be the interface, through the air gap, and then condensed on a metallic sheet cooled by seawater. The permeate was generated and removed from the membrane module via the pump. Energy received from the sun was accumulated in a thermally insulated volume. Agent circulated via the pump. Preliminarily filtered seawater gathered in the tank. In the case of low productivity of drinking water, we can eliminate the heat exchanger from the technological schematic. In this case, circulating seawater is brought to the operating temperature directly in the solar collector. The devices included in the experimental setup are pumps, measuring, regulating and registering devices operated via electrical current produced by solar energy photovoltaic converters. During a day if the output was 100 L permeate, a 100 W power photovoltaic battery was enough to satisfy the performance of electrical devices.

The magnitude of specific productivity changes depending on the amount of solar radiation absorbed by the horizontal surface. The experimental observations performed in Israel demonstrated that the power of solar radiation during a period of time from January to July increased in curve shape from 5,500 up to 7,500 Wh/m^{2}d. Then it decreased to its initial value by December. In this case, a spiral module

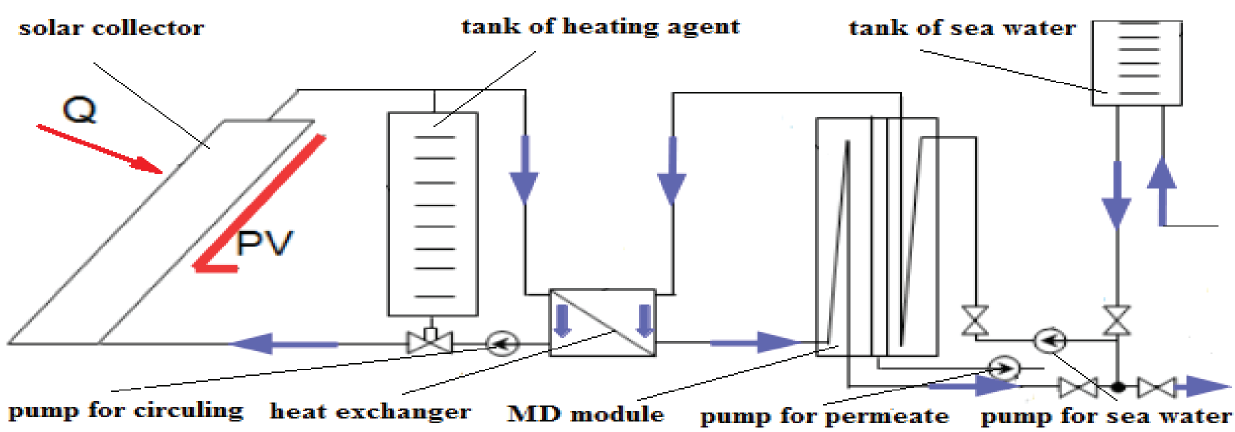

Fig. 1. Schematic of the spiral seawater MD module operating by solar energy.

of with a 7 m^2 area PTFE membrane was used, where the temperature of desalinating seawater was brought to 85°C, and was fed by a 12 m^2 area CuNi solar collector. The plant productivity depending on the season when the MD process was performed occurred to be 100 to 175 L/d. In this case, productivity per unit area of solar collector changes from 8 up to 14 L/m^2 d from January to July.

In remote areas, on small islands, in extreme conditions, in the case of small productivity, when we need a small size device, portable and with easy maintenance, setup of auxiliary devices such as measuring tools, automatic regulation mechanisms, tanks, photovoltaic current converters, heat exchangers and large amount of pumps makes applying of these types of desalination devices not applicable.

2. Design of portable devices for producing drinking water and electricity

Small, simple desalination devices working independently from fossil fuels and external electricity sources either do not exist or are very complicated and not profitable. Solar stills are the most common types of such devices, because they have practically no operation and maintenance requirements. However, their main drawback is low productivity, which is about 2–4 L/m^2 d, and they are not mobile [32]. The other devices have relatively high productivities 5–10 L/m^2 d; however, they are not portable and mobile [32].

The designed devices operated by MD technology are made to satisfy human requirements for electric power, potable water and thermal energy. Designed MD solar desalination devices are greenhouse box heat traps with a glass covering. The devices relate to MD variants with an air gap, where solar energy can be used more effectively. The air gap causes additional resistance to heat transfer, which reduces the amount of heat conducting across the membrane. The entire desalination process of seawater, which means heating, evaporating, condensing and the multistage use of heat, is established in a single device. A photoelectric transmission block is implemented in the form of a solar cell attached to the surface of the front thermal transmission layer of the distillation block, located in the combined solar powered device. The recuperative heat exchanger is installed underneath.

The constructions of the flat combined MD desalination device and pilot device are shown in Fig. 2.

The photoelectric transmission block consists of the absorber with photoelectric cells attached to the top and is installed in the front of the distillation block. The distillation block has an electric outlet for transferring electricity to the accumulator. There is an air gap between the absorber and the light transparent glass cover. The distillation block is implemented with the multistage membrane and is made of layers of successive similar stages. Each stage includes a layer of micropore membranes, which are covered with the support netting layers on both sides. The stages are separated from each other by condensing layers 6.

Each of the distillation block stages has a saline solution inlet pipe, a distillate outlet pipe and a concentrated saline solution outlet pipe. The front distillation layer, which is located towards incident solar rays, is bordered by the absorber, which has a grooved surface. The back distillation layer is the condensing layer, which has an identical structure to the absorber. The distillation block is bordered by the recuperation heat exchanger underneath. The device is closed by a cover and by heat-insulating material. The recuperation heat-exchanging block is implemented with the inlet and outlet pipes. The contacting surfaces of photoelectric cells and absorber are glued together with thermally conductive glue. The air gaps between the edges of the layers are hermetically sealed, for example, by hermetic silicon. The designed MD solar desalination devices can be fed by parabolic and parabolic cylindrical solar ray collectors.

3. Materials and methods

The following two types of flat pilot devices were designed and tested:

- The device without photoelectric solar elements: for the desalination of seawater with solar energy absorbed by the heat absorber.
- The combined device with photoelectric solar elements: part of the solar radiation is used for the desalination of seawater; the remaining solar radiation is converted into electricity.

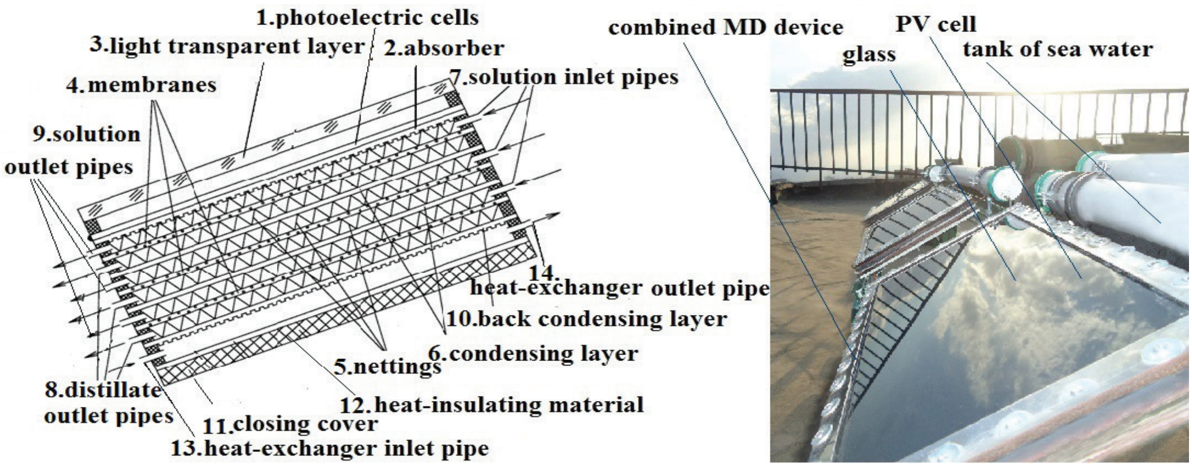

Fig. 2. The construction of the combined MD desalination device and its photograph.

Pilot devices are 55 cm long, 30 cm wide and 3–7 cm thick. The technical specification of the MD solar desalination devices are presented in Table 1.

PP layers are used in the desalination devices. Polystyrene is used as an insulating material. The desalination tests were performed on a sample taken from the Black Sea. The TDS were 17.5 g/L. The temperature of the seawater at the inlet of the device reached a maximum of 50°C during the day. The water was not initially treated before the desalination process.

The experimental observations of MD solar desalination devices were made in Yerevan city (Republic of Armenia), which has a geographical latitude of 40°11′00" N and a geographical longitude of 44°31′00"E. The city is 1,000 m above sea level. The annual average amount of solar radiation falling on a unit horizontal area is about 1,720 kWh/m^2.

The devices were oriented with their absorbing surfaces facing south and had a slope of 35°. The slope was chosen according to the land geographical position and was regulated by a special mechanism. The productivity of the distillate or the productivity of the desalination device was determined by measurement. The amount of distillate was gathered into a special reservoir separated by divisions. The tests were run from 9:00 am to 8:00 pm and the distillate was taken one time each hour during the day. The main tests were performed during July. The recorded ambient temperature was in the range of 25°C–37°C.

The intensity of solar radiation striking a horizontal surface was measured by the pyrometer "Apogee PYR-pA5" and was placed on the surface of the photoelectric elements in such manner that the face of the PV element was parallel to the pyrometer. The voltage and electric current were measured by the multimeter UNI-T (THERMOPROZESS Gruppe, Germany). The temperatures of the air, glass and solution during the tests were measured by thermocouple sets from Omega (KS TOOLS, Germany), which were affixed by thermal glue and adhesive tape, to ensure better heat transfer. The wind velocity was measured by the anemometer CEM HVAC DT-619. The total amount of dissolved salts was measured by the Hanna Instruments HI 86301 set with an accuracy of 1 mg/L.

The membranes applied for these tests were hydrophobic, porous and semipermeable, manufactured by the Millipore Corporation (product category: 237-hydrophobic, GPTFEPP membrane, catalog no. ZF1J051I10), which were resistant to most chemicals. The material of the membranes was PTFE, and the material of the support was PP. The thickness of support was175 μm, the pore size was 0.22 μm, and the porosity was 70%.

The staging coefficient is one the important parameters of evaluating the daily productivity of a multistage MD device, which is defined by the following equation:

$$\eta = \frac{\sum_{i=1}^{N} Ji}{J_1} \quad (4)$$

where $\sum_{i=0}^{N} ji$ is the total daily specific productivity of the desalination device by all N stages (kg/m^2 d), and J_1 is the daily specific productivity of the one-stage desalination device (kg/m^2 d).

The multistage desalination device and one-stage desalination device must operate under the same conditions to acquire accurate data for comparison. The staging coefficient is used to evaluate the heat recovery processes and to optimize the efficiency of the stages.

The pilot device consisting of a three-stage module combined with photoelectric solar elements with natural cooling by air is demonstrated in Fig. 3.

The operation of the device is based on the maximal use of solar energy. The heat transfer process proceeds in the following sequence:

- Penetration of sun rays through the glass to the heat absorber
- Heating of the heat absorber (solar cell) and heat transfer to seawater
- Heating of seawater transfer of vapor through the membrane pores and condensing on the condensing layer
- Flowing of the distillate film from the condensing layer surface and its removal from the combined device (first stage)

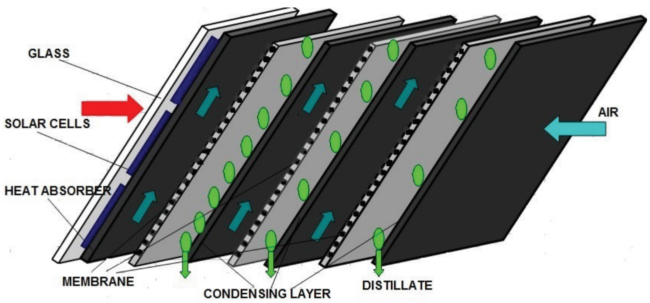

Fig. 3. Schematic of a three-stage pilot device combined with photoelectric solar elements with natural cooling by air.

Table 1.
Technical specifications of the MD solar desalination devices

Sizes	Constructive elements and materials					
	Heat absorber, (black colored aluminum)	Semipermeable membrane	Light transparent glass	Support netting, aluminum with 2 mm × 2 mm pores	Heat transfer, condensation layer (aluminum)	Polycrystalline solar cell
Length, cm	50	50	50	50	50	5.2
Width, cm	25	25	25	25	25	3.8
Thickness, mm	2	0.275	4	0.5	1.5	0.25

- Transfer of the distillate latent evaporation heat from the condensing layer to seawater in the second stage
- Repeating of the processes

Seawater is supplied from the initial solution tank. Excess energy is transferred to the air environment on the last stage. It is obvious that the temperature potential decreases from stage to stage because the distillate releases an amount of heat from the system, equivalent to its enthalpy [33]. There are also heat losses from the body of device. The process continues until the solution temperature reaches the level after which the desalination process is unprofitable.

4. Results

The experimental data obtained in testing of the portable MD three-stage device without photoelectric elements for acquiring pure water is shown in Fig. 4. Here the black colored aluminum sheet serves as a heat absorber without a selective absorbing cover.

When running the experiments, the MD multistage devices reached their operating regime when the seawater in the first stage was heated up. A noticeable amount of distillate appeared after 10:00 am. Later on, the hourly specific productivity achieved its maximal value during the period from 2:00 pm to 4:00 pm.

The specific productivity from the desalination first stage sharply decreases after 3:00 pm and is lower than the specific productivity from the desalination second and third stages after 5:00 pm. Daily productivity from the desalination first stage is higher yet. The overall daily amount of the distillates obtained from each stage is equal to 3.0, 2.5 and 2.27 kg/m^2 d. The distillate yield of the MD three-stage devices falls to zero in the evening time. The sum of the overall hourly specific productivity from the three stages reaches its maximal value of 1.2 kg/m^2 d at 3:00 pm. The daily cumulative yield productivity is 7.8 kg/m^2 d. Here, 68% of this value is produced before 3:00 pm. The temperature of seawater in the device at 3:00 pm was 66°C, 62°C and 56°C, respectively, for first, second and third stages.

The dependence of experimental and calculated productivity on the stage number for one-stage, two-stage, and three-stage MD desalination devices is shown in Fig. 5.

Depending on the number of desalination stages, the production rate can be increased by a factor of 2–3. Depending on the growth of the number of desalination stages, the daily productivity is increased. The staging coefficient, which is defined by Eq. (4) for three stage MD device is 2.3. However, further increase of stage number does not results in the lowering of a growth rate of the productivity. Hence, the additional growth of the stage's number does not noticeably influence the daily productivity. The reason for such a phenomenon is the fact that the temperature of the seawater becomes close to the ambient temperature in layers. In the case of five stages the productivity is 11 kg/m^2 d.

The tests had been conducted on the designed and constructed pilot combined MD devices with photoelectric elements, in which the solar energy absorbed by the absorber was transferred to the seawater.

The devices, which produce electricity and drinking water, have the following advantages:

- In practice, the problems of clean water and electricity occur simultaneously for a certain area and the multi-functional devices for producing two products are desirable.
- The efficiency of the device increases if treated seawater cools the surface of the photoelectric elements. The increase of the temperature of photoelectric elements decreases the power of the panel because natural convection is not enough for cooling.
- The use of the multi-functional device allows for increasing the cost of the product.
- The test results of the four-stage portable combined MD device with integrated photoelectric elements are shown in Fig. 6.

The electricity produced by photoelectric elements can be used for powering household devices, as well as for other personal needs of the electricity. If the electric energy will be

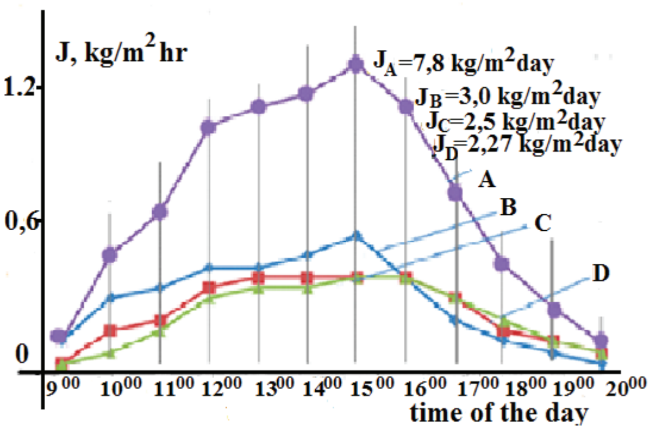

Fig. 4. The specific productivity of the MD solar desalination device depending on different hours of the day: A curve, cumulative yield; B curve, first-stage yield; C curve, second-stage yield; D curve, third-stage yield. The solar radiation per unit area is 6.61 kWh/m^2 d.

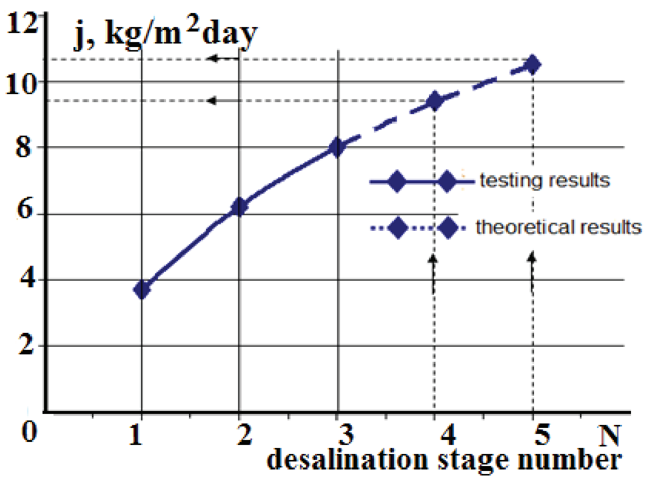

Fig. 5. The dependence of the MD device productivity on the desalination stage number. The solar radiation per unit area is 6.86 kWh/m^2 d.

used for the heating of seawater, the presence of the photoelectric elements will allow for extending the working interval of device operation.

The cumulative yield of a four-stage combined portable MD device is three times higher in comparison with the simple type solar still productivity, operating in parallel under the same conditions (Fig. 7).

The staging coefficient of the four-stage combined MD device compared with the simple type still device is increased by several times due to the multiple use of the solar radiation. The high efficiency of the combined device indicates that the latent heat of evaporation and condensing in the process is multiple times recovered.

One of the important problems for increasing the staging coefficient value is the lowering of heat losses from the device's external surfaces. As the driving force of the MD process is temperature difference, it is impossible to insulate the cold condensing side of the module, as it will cause the temperatures to be equal, hence the transmembrane fluxes will be stopped. Hence, it is necessary to minimize heat losses from the illuminated side of the device and direct the heat absorbed by the absorber to the cold side.

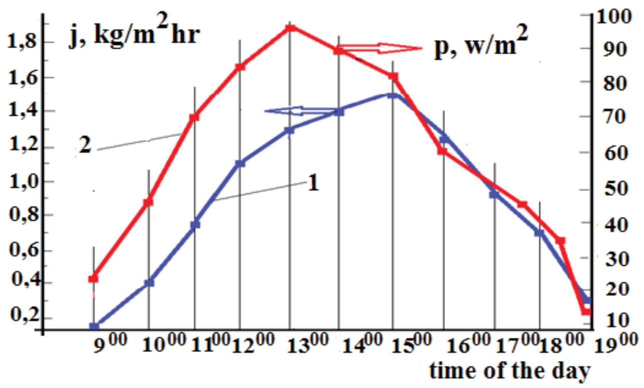

Fig. 6. The specific productivity (curve 1) and electric power (curve 2) of a combined MD device with photoelectric system, depending on different hours during the day. The solar radiation per unit area is 6.86 kW h/m^2 d.

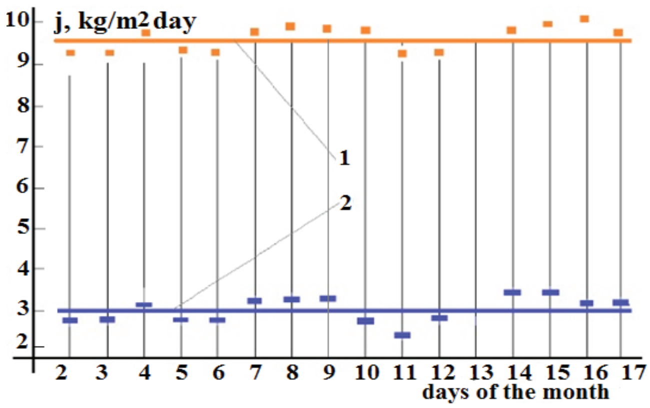

Fig. 7. The comparative values of daily specific productivity of the four-stage combined MD device (curve 1) and simple type solar still device (curve 2).

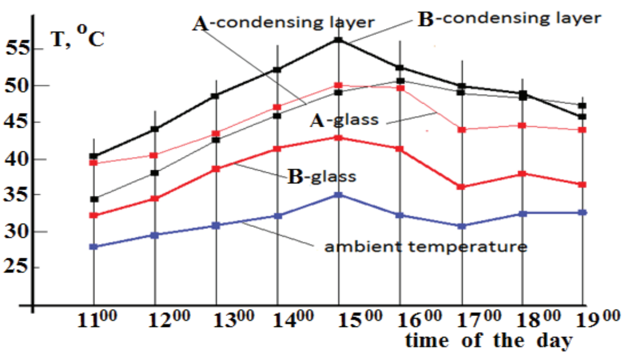

Fig. 8. The temperature changes of glass and back condensing layers depending on times of the day for combined MD devices (A) and (B). The solar radiation per unit area is 6,86 kWh/m^2 d.

Two types of two-stage combined MD devices have been tested:

- Photoelectric elements are covered on the illuminated side by one piece of glass.
- Photoelectric elements are covered on the illuminated side by two pieces of glass.

The air gap between pieces of glass provides a greenhouse effect and lowers heat losses from the heat absorbing surface to the ambient air.

The temperature changes of the different pieces of glass and condensing layers of the combined MD devices: (A) with one glass and (B) with two glasses, are introduced in Fig. 8.

The heat insulation strongly affects the productivity of the device with two layers of glass despite the fact that additional glass absorbs 8%–10% of the incident solar radiation. The temperature difference between the glass and the back condensing layer increases. It increases the specific productivity of the drinking water in the device (B), without increasing the desalination stage number. The specific productivity in device (A) is equal to J_A = 3.8 kg/m^2 d and in device *B* is J_B = 5.4 kg/m^2 d.

Pure water is produced in all series of experiments using the combined MD devices. The TDS is equal to 10 mg/L on average, which indicates that the membrane does not become wet during the desalination process and membrane defects like large size pores do not exist. The membranes manufactured by Millipore Corporation have shown stable productivity and a high level of selectivity.

5. Conclusions

The following types of MD devices have been designed and tested:

- Portable MD device with flat management for acquiring drinking water.
- Portable combined MD device with flat management for acquiring drinking water and electricity.

Seawater with TDS 17.5 g/L was used as feed. Recovery of the heat of condensation is integrated into the module design. The device has a high efficiency since the solar energy absorbed by the absorber is used multiple times with minimal losses. The use of a double glass cover noticeably increases the efficiency of the device up to 42%. The field tests show that the system produces about 10 kg/m^2 d, in the case of four-stage desalination. In the multistage MD solar devices, the optimum number of stages is between four and six. Depending on the number of stages, the production rate can be increased up to 3 times the production of a solar still type.

The devices for acquiring drinking water and generating electricity are combined into one compact and mobile device. The system is self-contained and independent from fossil fuels and external electricity sources.

The membranes manufactured by Millipore Corporation have demonstrated an excellent quality of water product.

The benefits of MD solar desalination devices are simple robust construction, small sizes, mobility, and independence from fossil fuels and external electricity sources. The advantages of multi-functional MD devices with photoelectric elements make these devices very attractive for a wide range of applications.

According to the investigation that has been conducted, it is clear that solar energy can be used for generating electricity and for the desalination of seawater with the help of simple portable devices, which can be applied in extreme conditions: on ships, in the army, in hospitals, and in remote areas.

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