ISSN: 2148-9173 Vol: 9 Issue:3 September 2022

International Journal of Environment and Geoinformatics (IJEGEO) is an international, multidisciplinary, peer reviewed, open access journal.

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Abstracting and Indexing: TR DIZIN, DOAJ, Index Copernicus, OAJI, Scientific Indexing Services, International Scientific Indexing, Journal Factor, Google Scholar, Ulrich's Periodicals Directory, WorldCat, DRJI, ResearchBib, SOBIAD

International Journal of Environment and Geoinformatics 9(3): 027-035 (2022)

Research Article

System Proposal for Harvesting Raw Materials, Energy and Clean Water from Seas

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Received 28.11.2020
Accepted 04.01.2022

How to cite: Demir (2022). System Proposal for Harvesting Raw Materials, Energy and Clean Water from Seas, *International Journal of Environment and Geoinformatics (IJEGEO)*, 9(3): 027-035. doi. 10.30897/ijegeo.1029369

Abstract

This article proposes to obtain clean water, which can be a solution for the lack of precipitation and drought, which is expected to increase in the future, to obtain minerals from the seas as an alternative to today's expensive mining operations and to produce clean energy on a single system. The system described in this study aims to obtain mining products more easily, risk-free and cheaper by bringing a different perspective to the mining sector, which creates serious environmental problems today. In addition, an alternative to other systems that use various filters and chemicals while obtaining clean water from sea water has been introduced, and energy generation while obtaining clean water has been handled on the same system. While the prototype of the proposed facility has been realized, various suggestions and methods have been presented for the future success of the system.

Keywords: Clean water, Renewable energy, Mineral production, Environmental pollution

Introduction

Global warming is one of the biggest global disasters today. One of the most obvious effects of global warming is the decrease in precipitation. The negative effects of agriculture and thus nutrition are still observed today with decreasing precipitation. According to the projected World Resources Institute reports, it is expected that most of the countries in the middle belt will become water-poor countries in 2040 (Fig. 1). With decreasing precipitation, it is predicted that access to clean water will be more difficult in the coming years and there will be mass migrations (WRI, 2015; Kanlı and Başköy, 2018; Ülker et al., 2018).

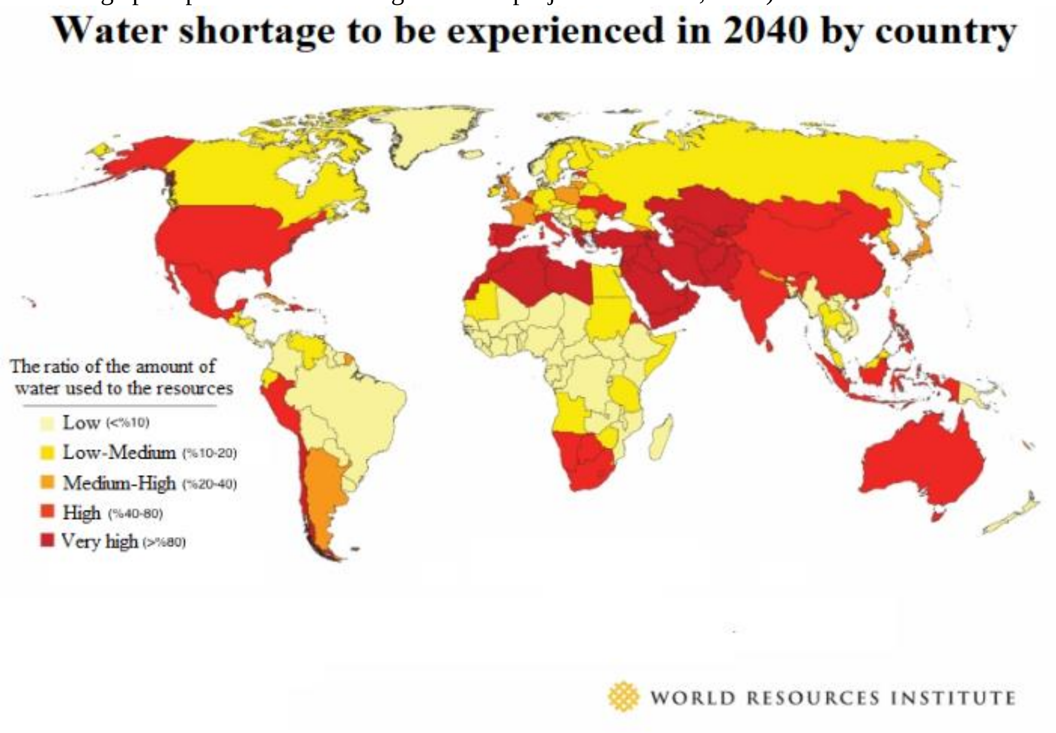


Fig. 1. The ratio of the amount of water used to the resources.

Looking at today's systems that produce clean water, it is seen that they use various chemicals or expensive filter systems (IEEE Spectrum, 2010). However, such methods cannot be expected to be sufficient in obtaining large amounts of potable water. In addition, the production costs of filter systems that produce clean water from sea water are high and these filters must be changed regularly after a certain use (Uliana, 2021).

When we look at the causes of global warming, it is seen that after the industrial revolution, humanity turned to fossil resources to meet its energy needs (O'Carroll et al., 2019; Lelieveld et al, 2019). The use of fossil resources releases greenhouse gases that cause global warming. In addition, the methods used to obtain fossil resources cause other environmental disasters and pollution (Colborn et al, 2011; Alvares et al, 2012). Although there are hydroelectric power plants and nuclear power plants that are used in energy production and do not use fossil resources, these systems have different damages and risks to the environment. Wind turbines and solar panels, on the other hand, are less efficient and expensive per unit than other energy-generating systems (Thakur et al, 2016; Boztepe, 2021; Blackwood, 2016).

Fig. 2. Mining cause irreparable damage to the ecosystem

Another area that causes environmental disasters and damages the ecosystem is the mining industry. The raw material resources necessary for supporting the life of humanity and for industrial production are obtained from mining. Mining begins with the expensive research necessary to identify the mine sites. Then, the necessary expensive investments are made in the mining area and the ore is extracted by excavation works. In this case, destruction of pre-existing vegetation or forest cover is common. At this stage, it is sometimes seen that very deep crevices are formed in the mine site that when the mine site is closed, it may not be possible for the vegetation previously grown here to grow on the new surface (Widana, 2019). Looking at the terminated mine sites reveals damages that are difficult to repair by the ecosystem and will last for many years (Fig. 2). The use of environmentally harmful chemicals in mining operations is also a common occurrence. In this study, as an alternative to today's systems that obtain raw materials, energy and clean water, which have various problems, a facility study that meets these needs in a single system is suggested. Sea water, which covers about three quarters of the world, forms the basis of this study. Materials found in the earth's soil are also dissolved in sea water. In addition, sea water is used as a coolant in energy production, as in many power plants and to obtain a potable water source that provides the continuity of life.

Materials and Methods

Concept of Mineral-Energy-Water (MEW) Plant

Among the methods of obtaining energy, which is an indispensable factor in the life of humanity, thermal and natural gas power plants that use fossil resources that cause the most global warming, nuclear power plants that cause high risk and radioactive wastes, and hydroelectric power plants that disrupt natural life are used. Today, the global energy system is in the midst of a major transition to clean energy. The efforts of an ever-expanding number of countries and companies to reduce their greenhouse gas emissions to net zero call for the massive deployment of a wide range of clean energy technologies, many of which in turn rely on critical minerals such as copper, lithium, nickel, cobalt and rare earth elements (International Energy Agency, 2021). Most of today's power plants produce a single benefit. These systems work on the principle of consuming a product or energy while producing a benefit. In these methods, the existing natural resources are rapidly depleted, causing other natural problems to arise. MEW Plant is a system that uses sea water to obtain mineral, electrical energy and clean water from sea water through a single unit. MEW Plant, which can work with low operating costs without the need for any raw material costs other than the initial investment cost, and support the raw material needs of the mining and industrial sectors as well as obtaining clean water, is recommended as a reference for the solution of these problems in the future. Clean water is an indispensable factor for the continuation of life. When we look at the water resources in the world, 97.5% is salt water in the oceans. Of the remaining 2.5%, only 0.5% is usable, while more than 90% of freshwater is at the poles and underground. In this way, it is a fact that access to clean water carries serious risks even today. The main source of the system proposed here for the production of clean water is sea water, which covers ¾ of the world. There are clean drinking water and dissolved minerals in sea water that ensure the continuation of life (Fig 3). The sea water taken to the MEW Plant passes through the condensation chamber and ensures that this room, in which the condensation process is located, is kept constantly cold with the low temperature it needs. Sea water, which cools the condensing chamber and warms up a bit, is sent to the sudden evaporation chamber with an adjustable flow rate by means of the pump. The sudden evaporation chamber is a closed module in which the sun's rays are focused by the mirrors and reach high temperatures. Sea water entering this reservoir suddenly evaporates with the effect of high temperature and high pressure steam is obtained. By evaporation of sea water, minerals in sea water are collected in the reservoir. These minerals can be taken from this reservoir after certain working times and used as industrial raw materials by using the separation methods in the industry.

Element	Symbol	Concentration(mg/lt)	State of being dissolved	Total amount(tons)
Chlorine	Ca	1.95×10^4	Cl^-	2.57×10^{16}
Sodium	Na	1.077×10^4	Na^+	1.42×10^{16}
Magnesium	Mg	1.290×10^3	Mg^{+2}	1.71×10^{15}
Sulfur	S	9.05×10^2	SO_6^{-2} . $NaSO_4^-$	1.2×10^{15}
Calcium	Ca	4.12×10^2	Ca^{+2}	5.45×10^{14}
Potassium	K	3.0×10^2	K^+	5.02×10^{14}
Bromine	Br	67	Br^-	8.86×10^{13}
Carbon	C	28	HCO^{-3} . CO_3^{-2} . CO^2	3.7×10^{13}
Nitrogen	N	11.5	N_2(gaz) . NO_3^- . NO_2^- , NH_4	1.5×10^{13}
Strontium	Sr	8	Sr^{+2}	160×10^{13}
Oxygen	O	6	O_2(gaz)	7.93×10^{12}
Boron	B	4.4	$B(OH)_3$, $B(OH)_4^-$	5.82×10^{12}
Silicon	Si	2	$Si(OH)^4$	2.64×10^{12}
Fluorine	F	1.3	F^- . MgF^+	1.72×10^{12}
Argon	Ar	0.43	Ar(gaz)	5.68×10^{11}
Lithium	Li	0.18	Li^+	2.38×10^{11}
Rubidium	Rb	0.12	Rb^+	1.59×10^{11}
Phosphorus	P	6×10^{-2}	HPO_4^{-2} . PO_4^{-3} , $H_2PO_4^-$	7.93×10^{14}
Iodine	I	6×10^{-2}	IO_3^- . I^-	7.93×10^{10}
Barium	Ba	2×10^{-2}	Ba_2O	2.64×10^{10}
Molybdenum	Mo	1×10^{-2}	MoO_4^{-2}	1.32×10^{10}
Zinc	Zn	4.9×10^{-3}	$ZnOH^+$. Zn^{+2} . $ZnCO_3$	6.48×10^9
Arsenic	As	3.7×10^{-3}	$HAsO_4^{-2}$. $H_2AsO_4^-$	4.89×10^9
Uranium	U	3.2×10^{-3}	$UO_2(CO_3)_2^{-4}$	4.23×10^9
Vanadium	V	2.5×10^{-3}	$H_2VO_4^-$. $H_2VO_4^{-2}$	3.31×10^9
Aluminum	Al	2×10^{-3}	$Al(OH)_4^-$	2.64×10^9
Copper	Cu	2×10^{-3}	$CuCO_3$. $CuOH^+$	2.64×10^9
Iron	Fe	2×10^{-3}	$Fe(OH)_2^+$. $Fe(OH)_4^-$	2.64×10^9

Fig. 3. Minerals found in sea water.

The high-pressure steam created in the sudden evaporation chamber is sent to the steam turbine from there to generate electricity. While a small amount of the electricity produced is used for the needs of the power plant, the excess can be converted to grid electricity. The steam leaving the steam turbine is sent to the condensation chamber, which is cooled by sea water at the beginning of the process to be liquefied. The liquefied steam is water of high purity and is given to the network to be used for industrial and agricultural uses and consumption (Fig. 4). As it can be understood from this working structure, MEW Plant is a project proposal in which raw material production and rapid potable water production are carried out in a single system, as well as environmentally friendly energy production. It is aimed that the system will meet the clean water and agricultural water needs of regions experiencing drought. In this way, a solution proposal was presented for the famine that will occur in the future due to the effect of drought.

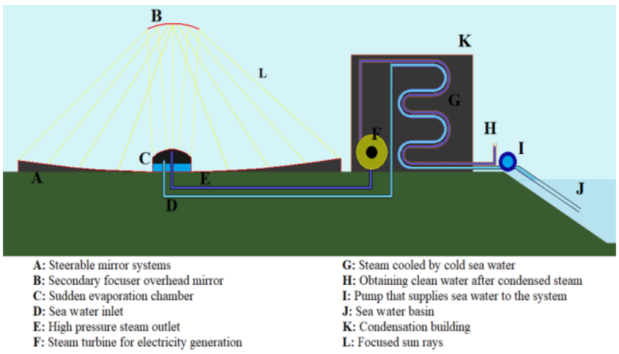


Fig. 4. Operating diagram of the MEW Plant

Prototype of MEW Plant

System operation has been achieved successfully by creating a prototype of the system proposed in this article (Fig. 5). Mirrors, focusing unit, sudden evaporation unit and cooling unit used in the prototype system are simulated at 1:400 scale compared to reality. In order to collect the sun rays on the prototype system, 1500 pieces of 1x1.5cm mirrors were placed on a 1m diameter concave plate and the system was simulated. The mirrors focus the sun's rays on the sudden evaporation unit. In order for the prototype to produce energy, water and mineral throughout the day, the focusing equipment was supported by a solar tracking system to follow the sun. A sudden evaporation unit has been placed at the focal point of the focusing unit for the sudden evaporation of sea water with high temperature. The sudden evaporation unit is made of chrome in order to be resistant to seawater corrosion and high temperature. Chrome material with a melting temperature of 1907 degrees Celsius can be preferred in the construction of systems with larger production volumes. There is a cover on the sudden evaporation unit in order to obtain the minerals in the sea water collected after a certain working period. After a certain working time, this cover is opened and it is possible to collect the minerals accumulated in the unit. The sudden evaporation unit is also a mineral collection chamber. In order to condense the water vapour obtained from sea water in the system, a copper pipe with high thermal conductivity is used at the system outlet. The copper pipe is formed in a helical structure, reduced in size and positioned in the cold seawater basin for modelling purposes. In this way, the condensation of water vapour is provided by cold sea water that has not yet entered the system.

High performance system operation is aimed by developing a control unit model in order to supervise and manage the productions of the MEW Plant. In this way, the right amount of sea water flow to the system has been achieved according to the temperature of the sudden evaporation unit and close to the morning and evening hours when the daylight is weak. A certain amount of sea water is injected into the system with a microcontroller-controlled water pump, according to the proposed model. It is essential that the injected water does not lower the temperature of the sudden evaporation chamber below the boiling point. For this reason, by adding a float to the sudden evaporation chamber, excessive sea water loading is prevented. In addition, the steam produced at the exit of the sudden evaporation unit is controlled by the steam pressure sensor. With the data obtained, the water transferred to the system by the water pump is injected with certain pulses. After the seawater is injected, the water flow is interrupted by the electronic solenoid valve located between the water pump and the sudden evaporation unit. The purpose of the solenoid valve is to prevent the steam created by the high temperature effect of the sea water sent to the sudden evaporation unit to create back pressure towards the water pump. In this way, the water vapour formed is provided to pass from the steam outlet pipe to the steam turbine (Fig. 6). During these processes, the pumping pulse (PWM) of the water pump is modelled with an equation related to the vapour pressure and temperature in the system:

Motor PWM (%) = (IP/EP) x C x (T/10)

IP: Sudden evaporation unit internal pressure
EP: External pressure
C: The optimum operating speed coefficient of the system
T: Sudden evaporation unit temperature

A pressure valve has been added to the steam outlet pipe of the sudden evaporation unit for system pressure regulation and correct control of the seawater pump. The pressure valve is added to create a certain internal vapour pressure of the system and to read the pressure information by the pressure sensor. The internal pressure (IP) of the sudden evaporation unit acts as the main control variable. The high internal pressure allows the evaporation rate to be measured. A high pressure here means that the system is operating at high productivity and more seawater can be injected into the system. If the internal pressure drops to a value close to the external pressure, it ensures that there is no sea water left to evaporate in the system and the pulse to be applied to the seawater engine in the next injection process is determined. Since the MEW Plant can be produced in different sizes, there may be changes in the system operating speed and production volume. For this reason, a system operating coefficient (C) is used in the water motor pulse for optimum operation of the system. The system coefficient depends on factors such as the geographical latitude where the MEW plant is installed, the size of the focusing unit, the internal volume of the sudden evaporation unit, sea water temperature, sunshine duration, water vapour condensing capacity. In addition, since the energy obtained from the sun's rays will be different during the year in the seasonal calendar periods in which the MEW Plant operates, there will be a coefficient that changes according to the months in the working calendar. In order to determine the operating coefficient of the system, the C coefficient is determined by assuming that the seawater motor pulse will operate at full speed in the zone with the highest pressure and temperature in the sudden evaporation unit in the system. Another variable affecting the pulse of the seawater pumping motor is the internal temperature of the sudden evaporator unit. An increase in the temperature of this unit means that more seawater will be pumped into the unit at fewer waiting intervals, in other words, more water vapour will be produced.

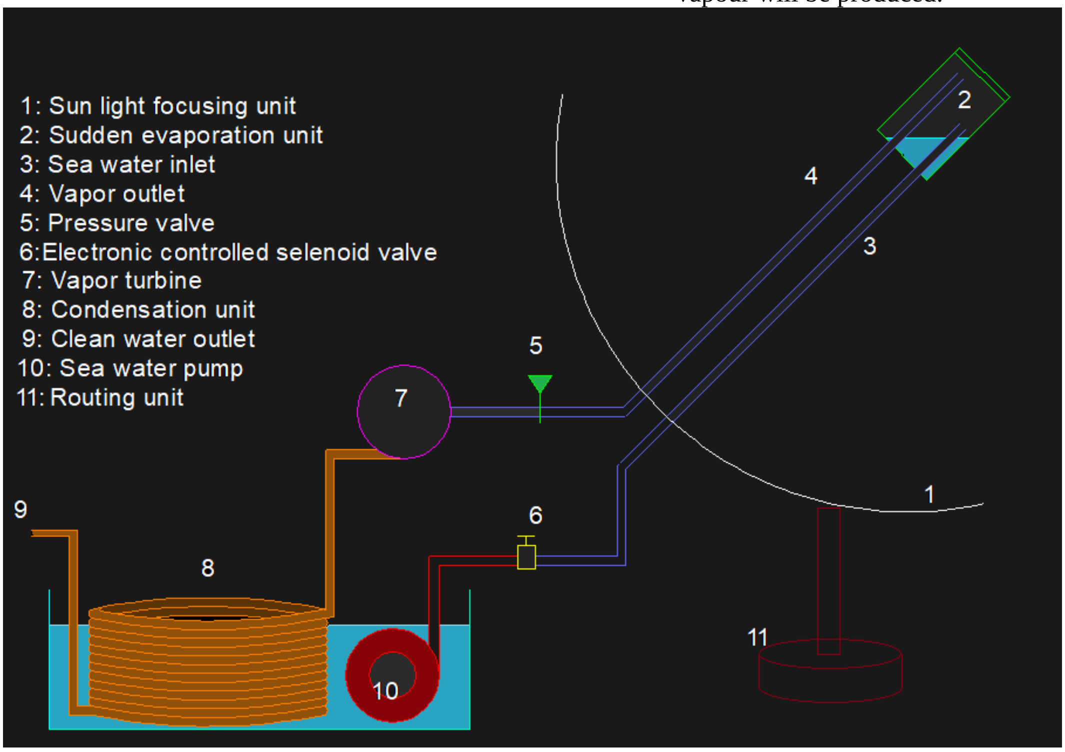


Fig. 5. Diagram of prototype system.

Fig. 6. Working prototype of the proposed system

Conclusion and Results

The prototype of the system whose theoretical study and modelling was mentioned was carried out (Fig. 6). The temperature of the sudden evaporation unit, which was heated by the sun's rays, reached 460°C in the tests carried out in the open air.

Since the sunlight focusing unit is a single unit, this system is located on the directing system to follow the sun. In the trials with the system, 10 litters of clean water was obtained after 9 hours of operation in the open air and mineral accumulation was obtained in the sudden evaporation chamber. The amount of mineral obtained was around 330 gr on average. The temperature of the system rises to the maximum level with the rise of the sun, and then the system temperature gradually decreases due to the lower energy rays coming from the descending sun (Fig. 7). Accordingly, it can be predicted that the system will be successful in the latitudes with the most sunshine duration. In fact, the most drought-ridden regions today are these latitudes and their surroundings. The values obtained here were obtained in the experiments carried out in the summer season. There may be differences in the results of the system in different sunshine durations.

Fig. 7. Temperature of sudden evaporation unit.

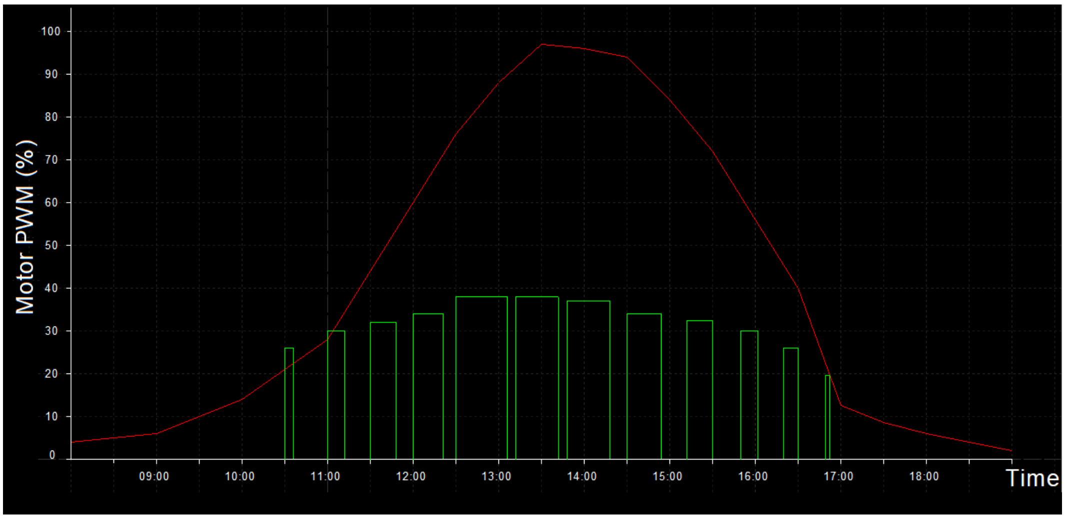


Fig.8. Sea water pump cycle

The main factors affecting the system temperature are the size of the solar focusing unit, geographic latitude and seasonal calendar. According to these features, it can be thought that the system will reach its highest operating performance in the summer periods when the most thirst and drought are experienced. In the trials, a working schedule was created between 09:00 in the morning and 18:00 in the evening for the system to work. Initial operation of the system starts just above 100 degrees Celsius, which is the boiling point of water. In order not to reduce the performance of the system, sea water is sent to the sudden evaporation chamber not continuously, but in certain quantities and under certain conditions. Otherwise, it may be possible for the continuously sent sea water to reduce the steam and mineral production by lowering the temperature of the sudden evaporation unit. It is important for correct operation to increase the temperature of the sudden evaporation unit after the water is taken into it. For this reason, the developed model is applied to adjust the amount and time of sea water sent to the system. Determination of the amount of sea water sent, the delivery time and time is determined by the internal pressure and temperature of the sudden evaporation unit. While the height of the system temperature determines the sending time of the sent sea water, the internal pressure determines the sending time and amount. While a certain amount of sea water entering the sudden evaporation unit reduces the temperature of this unit a little, it evaporates rapidly due to the environment that continues to heat up with the effect of sun rays. Looking at the operating time, it is seen that the pump that pumps sea water into the sudden evaporation chamber operates in long-term operating cycles (pumping amount) and short waiting times at noon, when the system collects the highest temperature (Fig 8). It is observed that the sea water pumping motor pumps water in shorter periods in the morning and evening hours and there are longer waiting times due to slower evaporation between operating periods.

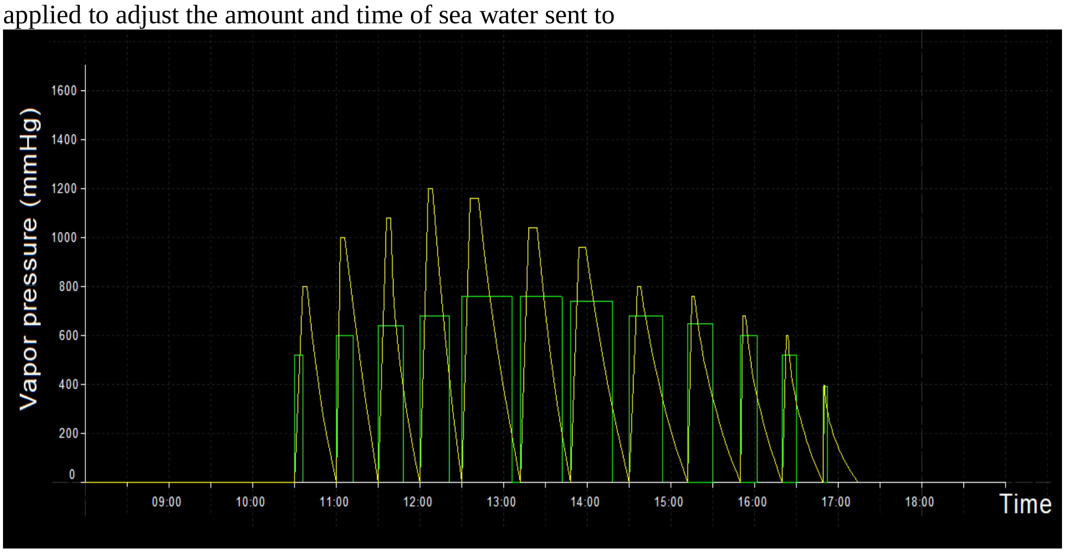


Fig. 9. Vapour pressure in sudden evaporation unit.

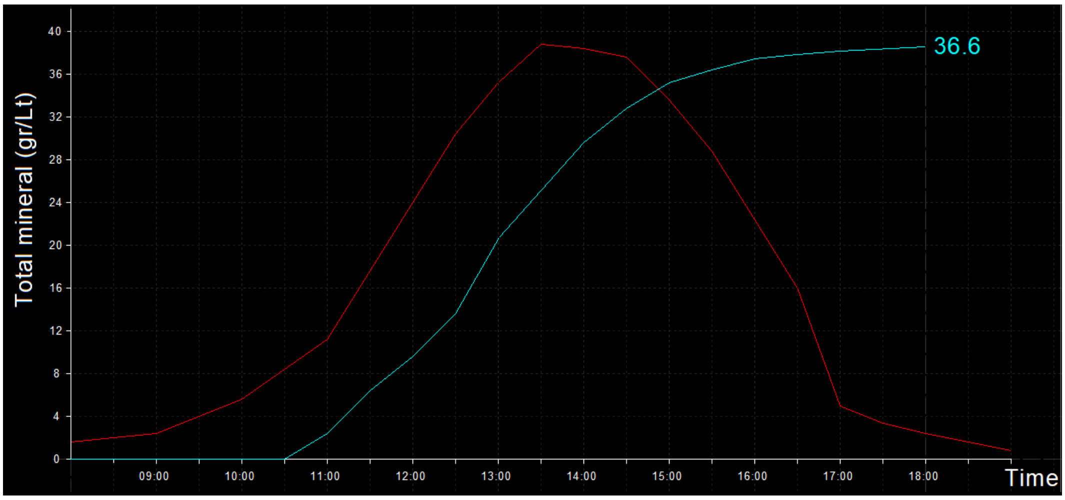


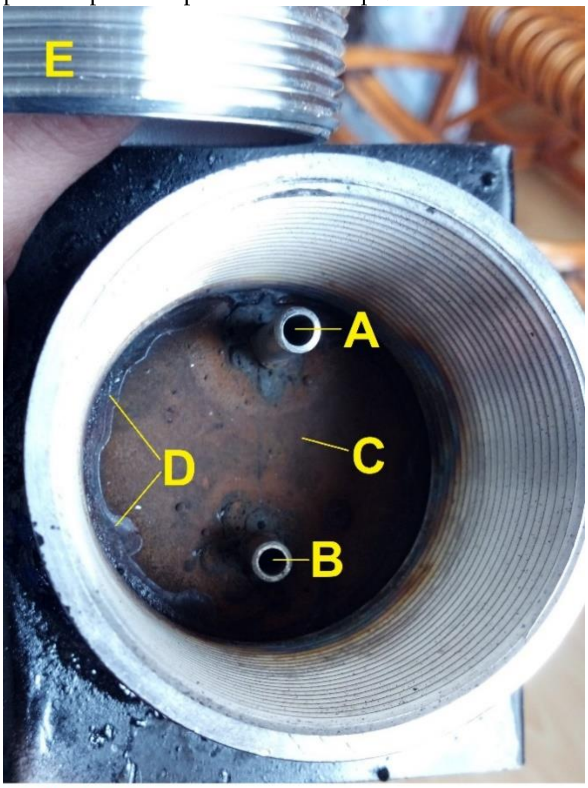
Fig. 10. Amount of total mineral

Considering the amount of steam obtained, it is observed that the most steam production makes a rapid vapour pressure increase at the first inlet of the sea water entering the sudden evaporation unit (Fig. 9). An electronically controlled solenoid valve has been added between the pump and the sudden evaporation unit in order to prevent the high pressure steam obtained from being directed back to the pump providing the sea water inlet. This valve is activated immediately after the seawater pump sends seawater to the unit. In this way, physical contact between the evaporated sea water and the cold sea water that has not yet entered the system is cut, thus preventing temperature loss. Looking at the graph in Figure 9, the vapour pressures occurring in each seawater pumping phase in the sudden evaporation unit are observed.

Although it is seen that the vapour pressure is the highest at noon of the day, it is observed that the steam pressure decreases in an interesting way in the afternoon compared to the hours before noon. The reason for this can be interpreted as the negative effect of the minerals collected in the sudden evaporation unit on the evaporation rate and vapour pressure after a while. If a solid or liquid that cannot evaporate into the liquid is added, this reduces the vapour pressure of the liquid into which they are thrown and makes it difficult to evaporate. For example, the salt thrown into the water prevents the evaporation of the water and raises the boiling point, causing it to evaporate more difficult. For this reason, instead of collecting the salt accumulated in the sudden evaporation unit in a few days or weekly periods, collecting it daily will be beneficial in evaporation of sea water and therefore in obtaining higher performance in clean water and mineral production.

The sea water entering the sudden evaporation chamber is directed to the steam outlet pipe, leaving the mineral in this unit due to the high temperature there. In the experiments carried out in the open air during the summer period, 36.6 g of mineral per litter was collected during the total daily working period (Fig. 10).

The decreasing working behaviour seen in the vapour pressure graph (Fig. 9) is also seen in the mineral production graph (Fig. 10). While the mineral extraction is high at the first operating time of the system, a decrease is observed in the mineral extraction rate in the following periods. The reason for this is that the minerals accumulated in the sudden evaporation unit reduce the evaporation rate of the sea water entering the system. In the long run, mineral coating of the interior of the unit may also have a negative effect on the transfer of the heat of the chrome unit to the sea water (Fig. 11). For this reason, it would be beneficial to collect the minerals accumulated in the unit for short periods in order to prevent possible performance drops.



A: Vapor outlet
B: Sea water inlet
C: The area where sun's rays focused
D: Collected minerals residues
E: Sudden evaporation unit cover

Fig. 11. View from inside the sudden evaporator unit

The steam obtained in the system is passed through the steam turbine before being condensed to obtain energy. In this way, it is seen that the system realizes three basic benefits as clean water production, mineral production and energy production. While the prototype has a single focusing unit, the mirrors in the real system will be larger and more numerous, and each must have an independent steering system to collect sunlight. In this way, performance can be increased by using more mirrors on larger areas and enlarging the installed system. More clean water, energy and minerals can be produced by faster processing of sea water in higher performance facilities to be established in larger areas. In order to obtain clean water from the steam obtained on the prototype, cold sea water that has not yet entered the system is used in the condensation of the steam. In this way, no additional energy is consumed for the steam condensation process. Considering the advantages of the system, low-cost clean water is produced in the world with the principle of water cycle (evaporation /precipitation) as an alternative to high-cost facilities that produce clean water from sea water using expensive chemicals and filters. Considering the facilities that produce clean water from sea water using filters, the filters used here must be changed at certain intervals, which increases the operating cost. Apart from the installation and low operating costs, there is no consumption of raw materials (coal, natural gas, nuclear fuel, etc.) that creates external costs for the operation of this facility. The system works with sea water, which is abundant in the world. While the sudden evaporation unit turns sea water into clean water, it is also the collection tank where the minerals in the sea water accumulate. The high temperature in this unit also ensures the removal of microorganisms in seawater without the need for any chemical treatment. After a certain working period, the material accumulated from this chamber can be taken out of the system. During the processing of sea water, the material obtained from sea water and the precious metals it contains can contribute to economic income and industrial raw materials (lithium, gold, calcium, etc.). Especially with the spread of electric vehicles in the future, the lithium needed for batteries can be obtained at low cost with this system. When the facility is expanded, agricultural production can be supported by contributing to agricultural irrigation (Fig. 12). The clean water obtained can be brought into the drinking water network after the necessary ventilation, ozonation or chlorination processes.

Fig. 12. Facility planning of MEW Plant on the sea side

The system, whose prototype work is described here, is proposed for the production of raw materials and clean energy, as well as the low-cost production of agricultural irrigation and drinking water for the countries close to the middle belt and most at risk of experiencing drought. With MEW Plants, the need for clean water, which is most needed in hot summer periods, can be met in these hot summer periods with the highest production efficiency. The system, which will be operated for a long time without the need for maintenance, raw materials and energy after the initial installation cost, will meet its own costs and will have financial returns after a while with the electrical energy to be produced and the materials to be obtained from sea water. The industry can be supported after the salt to be obtained from sea water and the minerals in it are obtained by using appropriate chemical separation methods. While the installation cost can increase or decrease in proportion to the size and production capacity of the MEW Plant, this cost will be covered over time as the system provides economic returns. Today, the decrease in access to clean drinking water and the depletion of natural resources threaten all humanity. MEW Plant, on the other hand, can be a solution to these problems with the electrical energy, clean water and mines to be produced within its body. When the facility is expanded, agricultural product production can be supported by contributing to agricultural irrigation.

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