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Study on Gaining Fresh Water by Small Scale Reverse Osmosis Membrane with Photovoltaic Energy from Brackish Water

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Abstract Under frequent draughts and floods, many rainwater harvests as terraced paddy fields, dam- constructions, reservoirs, ponds, tanks, rivers and underground pools become more important. And the rapid urbanizations changed its water supply with much chlorine, which caused many water purifier users at home tap, and much drinkers of bottle water. And with many water treatments as by hollow fiber membrane, the final method for gaining freshwater becomes populous as desalination of clean sea water with advanced facility and cost-down innovation and improvement of Reverse Osmosis membrane, in the regions with many shortage of drinking water. And today small scale RO systems work at household tap as "water softner". This tool showed the practical desalination facility, as 1.0, 0.5, 0.25, and 0.1% salinity, with DC pump (60psi diaphragm, by 24V battery). With higher brackish raw water salinity, the more stronger vibrations were observed with smaller fresh water product. And the comparisons of battery charging facility by a new light and rollable photovoltaic sheet, a standard panel under sunshine condition and by commercial line, showed the practical uses with RO membrane with these photovoltaic chargers.

Keywords: Brackish water, desalination, photovoltaic film sheet, Reverse Osmosis membrane,

Introduction

The frequent droughts and floods have urged to construct better solutions for water and environment systems, as rainwater harvesting infrastructures, as small household tank with roof catchment, rooftop gardens, biotops, ponds, underground rainwater storage etc. in urban area, as well as traditional terrace fields, reservoirs and big dams. But the unexpected increase of water use with rapid urbanization and lifestyle change, caused the declining quality of drinking water as the water supply systems by slow sand filter changed into rapid one, which caused strong residual chlorine in drinking water supply. And as in Minqin County,Gansu Province,China, where some villages were suffered with brackish water, even in ground water, here the diluted salinity in water was checked by Electrical Conductivity (EC) as (irrigation water 2.9mS/cm, even in groundwater from 30m depth 1.3mS/cm) and very wide desertification was observed (Takeyama et al. 2002). Today many people equip water filter at tap and drink much bottled water. And many filters for water recycle use have been developed, as the polyethylene micro porous hollow fiber membrane modules as photo 1 purify the waste water, and make recycled water for agriculture with disinfection. For gaining fresh drinking water, different scale desalinization plants with the Reverse Osmosis membrane, were made in water shortage regions. Recently the downsized RO membrane tools are used in household with tap pressure. This paper deals with the application of a household size "water softner" with brackish water (gained diluted sea water) for practical fresh water making by pump, then the comparisons with battery power charging ability of commercial electric energy supply, or standard photovoltaic panel and a new most rollable lightweight solar charger (photovoltaic film sheet).

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Polyethylene microporous hollow fiber membrane

Some examinations showed that these hollow membrane filters As photo 1, 2 decreased Chemical Oxygen Demand into less than 5mg/L from over than 50mg/L (raw water) with avoided *Bacillus coli*. in Yokoyama Retarding Basin in Iwakuni City, and water in a rainwater catchment pond with much suspended soil with very low dissolved oxygen in a pond in Matsue City (Takeyama et al. 2004). And today these hollow fiber membrane tools have been improved to have smaller porous sizes as less than 0.1-0.03 μm, with making more cleaner water.

Photo 1 Hollow fiber membranes, in enlarged (http://www.mrc.co.jp/knowledge/tyukushimaku.html)

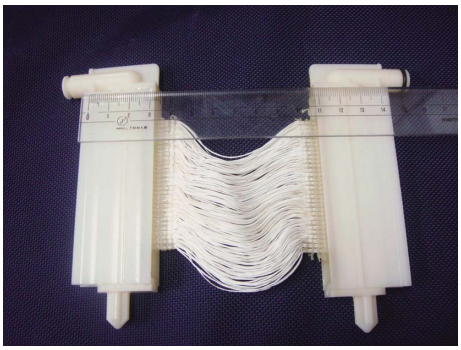

Photo 2 Hollow membranes filters with 0.4μm porous size

Desalination by R O membrane

High value added water production from deep seawater

Desalination by distillation for gaining drinking water has been made with co-product of salt, as in small rainfall regions. But some plants have some advantages for desalination from clean and deep seawater with much minerals, more value added co-productions, with rich water resources as in Toyama or Kochi Prefecture etc. Fig. 1 is the outline of the plant in Namerikawa City in Toyama, which has some advantages as steep gradient, there deep sea/cold water organisms has been made possible with many experimentations of mature fish cultivation and seed production utilizing the attributes of deep seawater, surface water and ground water.

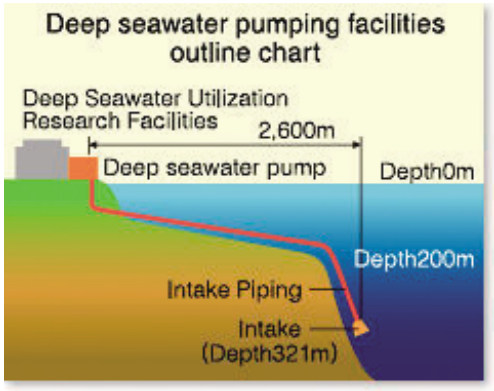

Fig. 1 Outline of deep seawater pumping in Toyama (http://www.t-deepsea.jp/english/jiten3.html)

With innovations and improvement, many desalination systems by RO membrane for gaining drinking water are working in water-lacking regions with small precipitation as Uoshima Island, Ehime Prefecture, Okinawa and Fukuoka City (the biggest scale desalination plant in Japan, as 50,000 m^3 / day fresh water is made with 8MPa pressure). And with many adoptions of "rapid filtration" in city water supply, the more residual chlorine then many houses and offices have equipped the expensive domestic water-purifiers, and used much bottled water. The domestic bottled water was more than 2million m^3 and 0.5 million m^3 was imported (2008). And the new system in future will make fresh water with cheaper cost, as less than US1 $ / m^3, and some oil rich area will get, even irrigation water, by these membrane systems.

Outline of a "water-softner" of RO membrane

Here is a small scale membrane process of Reverse Osmosis, named as "water-softners" as photo 3, made in USA. According to its manual, supply water pressure limit 40-100 psi (280-689kPa), 55L/day with city water supply tap pressure, and 90-95% rejection of TDS, and waste water per gallon of product water is 5gal. (18.9L) with city water sup-

Photo 3 Water softner with RO membrane (Whirlpool model WHER25)

ply tap. And it filters out sediment, chlorine taste and odor, lead, cysts, chemicals and total dissolved solids. And its premium filtration process filters particles 100,000 times smaller than a human hair, reducing up to 99% of many common contaminants, and residues from contaminants such as lead or mercury. Space-saving design uses filters to provide great tasting water. Carbon filtration systems reduce contaminants in the water, without worrying about residue from contaminants such as lead or mercury.

Experiment methods

1) At first examine the decreasing of tap water (ground water) with 0.6mS/cm EC value with chlorine and scale, which causes white color scale at bottom of kettle.
2) Ensure the recycle system from the first wasted water by 60psi diaphragm pump with 24V (12V×2 serial connection) car batteries.

Photo 4 Standard photovoltaic panel 167W, 15kg weight

Photo 5 DC 60psi diaphragm pump 24V

Photo 6 Rollable photovoltaic sheet 20W, 1kg weight

3) Brackish water (diluted seawater with this tap water) as raw water with this photo 5 pump.
4) Comparisons of the battery charging ability of commercial line charger, the standard photovoltaic panel as photo 4, and new light weight photovoltaic sheet as photo 6, which 305×1858mm and can roll around 3-inch diameter (the world's most rollable) and operating as 15.4V, 1.2A .

Results and Discussion

The water softner decreased EC value at tap from 0.6mS/cm to less than 50μS/cm. Next, the first "wasted water" was recycled into the softner by pump smoothly. But gaining fresh water by this system showed that with the higher filtration was examined with brackish water, (this ground water mixed with seawater) and connected with small pump (60psi) with two 12V batteries. And the comparisons of batteries charge ability, by commercial electric supply, a standard panel and a rollable sheet as photo 4, 6 were examined. And the membrane facility of this system was checked by the EC values of water at faucet. This test pressure was about 0.4 MPa. The ground water created scale at bottom of kettle. But Matsue City water supply has 70-78μS/cm EC and no scale. This RO product water is in Table 1, which shows the ratio with wasted water de-

Table 1. Example of ability of water softner with ground water of Shimane Univ. at tap (0.4MPa) water temp. 19.0-20.3 (℃) raw water had 0.6 mS/cm

RO Product Water (g/min)	Wasted Water (g/min)	RO Product water (EC: μS/cm)	WastedWater (EC: mS/cm)
36	252	32	0.57

pended on the product EC value and drain pipe location etc. This "wasted" water can be sent to RO system by pump and batteries. Here this diaphragm pump (60 psi) was used for recycle of this wasted water with smooth move of DC pump "Aquatic 550". With the higher salinity of raw water into this system, the more stronger vibrations as longer stopping time were observed, and this softner almost stopped with sea water about 2.5% salinity. But it worked with brackish raw water, as 1.0, 0.5, 0.25, and 0.1% salinity. (Here these condition were made by dilution by tap ground water with residual chlorine (EC : 0.6 mS/cm) or RO water (EC : 0.05 mS/cm)) as Fig. 2, 3. And two car batteries (38B19R ; 12V×2), were charged by different sources and these facilities were examined.

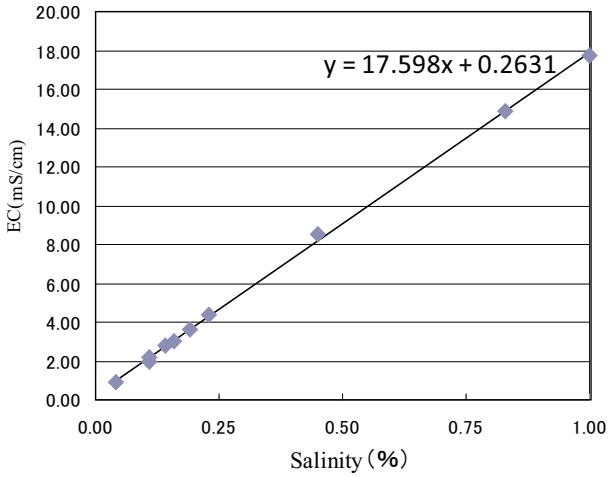

Fig. 2 Salinity indication with EC of diluted seawater by tap water (ground water with cholorine)

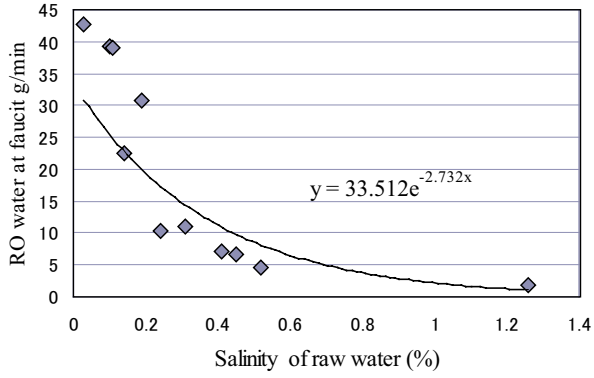

Fig. 3 RO freshwater product (EC : less then 0.05mS/cm) from brackish raw water (salinity 0.1 - 0.5 %) cases

Comparison of battery charging ability

This RO membrane fresh water product worked by DC pump recorded 4A with 24V. then the used energy was recharged as follows;

1) 12V battery charger with commercial line (moderate type) showed charging with 2-4A, according battery charged level.

2) The standard photovoltaic panel as 167W, showed that this panel could recharge two 12V batteries in serial connection under sunny weather near noon, but under cloudy weather less than 1A at one battery with controller's afford.

3) The rollable film sheet, set horizontally on veranda neat noon, charged 1.0-1.3 A under sunny weather, but in cloudy less than 0.3 A with 12.4V, at battery connection. These results means that light-weight rollable mobile sheet (Power Film) worked one third power of commercial power lined charger.

Conclusion

This examinations showed that the mall scale home use "water softner" using Reverse Osmosis membrane system could produce soft water from high hard water with tap pressure or diaphragm pump. And this system works for gaining safty soft water from the cleared water as by chemical clarification or hollow fiber membranes, even from low brackish water. And the battery energy can be charged by rollable light photovoltaic sheets, which is effective for gaing fresh and safe drinking water production (EC : 0.3 ~0.03mS/cm), under emergent conditions. This system shall contribute much for water-lack problems.

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抄　録

頻繁な渇水と洪水が発生は，従来の雨水貯留機能をさらに見直し，強化されている．また都市化の進行は，急速濾過処理による浄水場を増やし，増加した塩素処理の水に対し浄水器やペットボトル水の利用が増加し，中空糸膜を用いた水浄化・再利用や逆浸透膜を用いた海水淡水化などの利用も拡大している．技術の高度化と低価格化のもと，水道栓に直結して用いるような軟水製造型浄水器も普及してきた．0.4MPa 程度での利用は，生成される軟水の 5 倍程度が「廃棄水」パイプに流れたので，これを回収し，再度軟水製造を 60psi，直流 24V のダイヤフラムポンプを駆動して行った．またこのポンプの装置は海水を希釈した汽水から，軟水を得ることに応用できることが分った．このとき汽水の塩分濃度が高まると，ポンプの停止機能が作動して振動が発生し，装置と繋がるパイプを固定したがポンプの停止時間が長くなり製造される軟水の量は激減した．またここで用いたカーバッテリーの電力消費量の補充を，商用電源，普及しているソーラパネルと近年開発された軽量で，巻いて持ち運びが容易なソーラーフイルム（シート）で充電し，補充機能を比較した結果，シートは商用の 1/3 程度の機能が，一枚でも晴天・正午近くなど，条件の良い時は可能であること，このとき従来のソーラーパネルは，バッテリーを 2 個直列にして同時に充電できる能力があることなども確認された．このように従来の薬品混入や膜技術などによって清澄化された水は RO 膜処理を加えると，薄い汽水からも安全で無菌な浄水（EC：0.3～0.03mS/cm）が得られ，近年の軽量で持ち運び型の太陽光発電と共用すると世界の各地で応用できることが分かった．