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SOLAR DESALINATION USING NICKEL SULPHIDE AS PHOTOCATALYST

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ABSTRACT

An effective, convenient and inexpensive method for the purification of water has been investigated. Water is one of the principal elements, which influences economic, industrial and agricultural growth of mankind. The over utilization of groundwater, poor recharge, uncertainty of monsoon, poor aquifer conditions, absence of proper monitoring and management have gradually influenced the quality of water. A solar desalination plant was fabricated to utilize solar energy to obtain distilled water. The effect of photocatalyst nickel sulphide on the rate of production of distilled water and its quality was made. It was found that the rate of production of desalinated water increased to a remarkable extent. A comparative study of different parameters like pH, conductivity, concentration of anions and cations, etc. was made between raw water and desalinated water.

Key words: Solar desalination, Photocatalyst, Desalinated water, Solar energy, Solar still.

INTRODUCTION

Earth is the only planet in the solar system having an abundance of liquid water on its surface. Water is a basic need of human beings along with food and air. It is now assuming an important role in the world economy as it is said that "Water is essential for life, where there is no water, there is no life." There is a large escalation of demand for fresh water because of the rapid industrial growth and explosion of population all over the world. This leads to acute fresh water shortage since the natural sources of water can meet the demands to a very limited extent.

Water purity is of vital concern for mankind since it is directly linked with human welfare and where the demand of potable water exceeds the amount that fresh water source can meet; desalination of brackish water provides a reasonable fresh water source. Thus, it has become pertinent to do further research in this field to improve the desalination process.

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Different operational strategies for the variable operations of a simple reverse osmosis unit has been investigated by Pohl et al.[1] Modeling and optimization solar organic rankin cycle engine for reverse osmosis desalination has been proposed by Bruno et al.[2] Heat transfer performance of condenser tube in an MSF desalination system has been performed by Galal et al.[3] This spurred scientists to look for newer dimensions in this field. Huang et al.[4] has proposed an advanced treatment of wastewater by constructing a wet-l and/ultra-filtration/ reverse-osmosis process. A new regeneration approach to cation resins with aluminum salts and application of desalination by its mixed bed has been proposed by Liu et al.[5]

Electric mesh grid of sweater desalination based on rotation coupling electromagnetic theory has been studied by Chang et al.[6] Socio- economic and technical assessment of photovoltaic powered membrane desalination process for India has been proposed by Abrahan and Luthra[7] Chemical and microbiological quality of desalinated water, ground water and rain-fed cisterns in the Gaza strip, Palestine, has been studied by Khatib and Arafat[8] Desalination for preservation of murals by electromigration and regulated climate has been proposed by Dalgaard et al.[9] Electrosorptive desalination by carbon nanotubes, nanofibres electrodes and ion exchange membranes has been introduced by Li et al.[10] Sulfonated polyethersulfone were prepared as cation-exchange membranes; and characterized by Klayson et al.[11] Profio et al.[12] have proposed submerged hollow fiber ultra-filtration as seawater pretreatment in the logic of integrated membrane desalination system. Angerer Chappel[13] have designed a steel fiber reinforced segmental lining for the gold coast desalination tunnels. A comparison between TiO_2 and Fenton plus photo-Fenton in a solar pilot plant has been reported by Maldonado et al.[14] Application of the combined ultra-filtration and reverse osmosis for refinery wastewater reuse in Sinopec Yanshan Plant has been introduced by Wang et al.[15]

Wind turbine-inclined still collector integration with solar still for brackish water desalination has been proposed by Eltawil and Zhengming[16] Simulation model for spray flash desalination system has been constructed by Goto et al.[17] Effect of inclination of the external reflector of simple solar still in winter has been studied by Khalifa and Ibrahim[18] DC/DC converter has been applied by Yuan et al.[19] in photovoltaic-inclined thermal collector hybrid systems for brackish water desalination. Use of mesoporous conductive carbon black, to enhance performance of activated carbon electrodes in capactive deionization technology, has been suggested by Nadakatti et al.[20] Mutual action of copper (II) and a non-ionic surfactant (oxyethylated alcohol) on their simultaneous removal by a neutral hyper-cross-linked polystyrene adsorbent has been proposed by Kauscaronpediene and Selskiene[21] Use of photocatalysts like MnO_2, PbO_2 and CuO to improve the water quality by desalination was made by Patel *et al.*[22]

Although a lot of work has been done and many technological advances have emerged for desalination, but a little has been done to use photocatalyst to improve the water quality and to increase the desalination rate[22] (using conventional solar still and sulphides are used as photocatalyst). Hence, the present work has been undertaken.

EXPERIMENTAL

Construction of solar still

The vertical heights of the still are 515 and 160 mm, respectively. A glass cover of 4 mm was used as a transparent material. This glass cover with inclination of 60° is fixed to vertical wall of the solar still. At the lower end of the glass cover, a provision to collect the condensed water was made by PVC pipe with the help of an adhesive (m-seal trade mark) to ensure that no vapours will be lost. The body of the solar still is 12 mm thick of water proof board to provide minimum heat loss from the bottom as well as from the sides of the still. To reflect incident radiations into the basin, a mirror is fitted on the rear vertical wall (inside the solar still).

Two galvanized trays (563 × 263 × 50 mm) are placed inside the solar still and a galvanized plate (560 × 260 mm) containing a coat of photocatalyst was placed inside the tray. Using a rubber binder, the layer of photocatalyst was made on G. I. plate. 5 L water was placed in each tray. A provision for an inlet for raw water was made at the bottom and outlet for desalinated water was made at the vertical wall of the basin. The solar still was placed south facing just to receive maximum solar radiations throughout the year. The line diagram of the solar still is presented in Fig. 1.

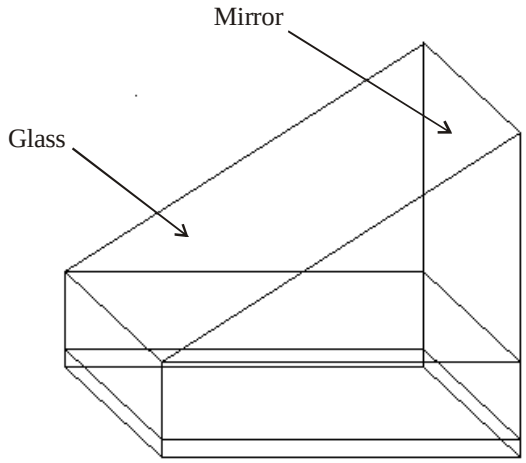

Fig. 1: Schematic diagram of solar desalination still

Area of the still = 598 (L) × 580 (W) mm^2, Height = 515 mm (back side) and 160 mm (front side); Galvanized tray size = 563 (L) × 263 (W) × 50 (H) mm^3; two trays are used; Total glass size = 580 × 698 × 4 mm^3; Effective area = 567 × 660 × 4 mm^3.

Procedure

Samples have been collected in the monsoon season from the Sirohi District, which is situated in the South of the Rajasthan State in India. All the reagents used are of AR grade. All the solutions are prepared in doubly distilled water. pH of the solution was measured employing a digital pH meter (Eutech-CyberScan 1000), while the conductivity was measured using digital conductivity meter (Eutech Instruments 611/612). The absorbances of the solutions are measured using UV-visible spectrophotometer (Systronics Spectrophotometer 106). Ion Selective Electrodes (Eutech Instruments) were used to measure the concentration of ions like fluoride, chloride, cadmium, etc. The analysis of water samples for its various parameters is done using standard methods for examination of water[23].

RESULTS AND DISCUSSION

As the solar desalination improves the quality of water, but the amount of water collected after desalination is relatively less and it may not fulfill the requirement. Secondly, some of the organic impurity also passes with desalinated water. To overcome these problems, the base of the tray is coated with metal sulphide so as to get not only the better quality of water but also a higher rate of desalinated water. It is a well known fact that metal sulphides act as photocatalyst and therefore, the use of NiS can assist from both these points of view. The total amount of water collected is measured everyday and also the rates of production of desalinated water at regular time interval. The results are reported in Fig. 2 and 3.

It was observed that the rates of production of desalinated water increases with increasing intensity of sunlight and it reaches an optimum after 2-3 h and thereafter, it decreases as sunset approaches. It may be explained on the basis that solar radiations are available maximum in midday while it decreases on either side[18]. It is clear from Fig. 2 that the use of metal sulphide NiS improves the rate of the desalinated water as compared to desalinated water production without photocatalyst.

As the period of exposure increases, the volume of desalinated water produced also increases (Fig. 3). In this case also, total desalinated water produced in presence of photocatalyst NiS was more as compared to without photocatalyst.

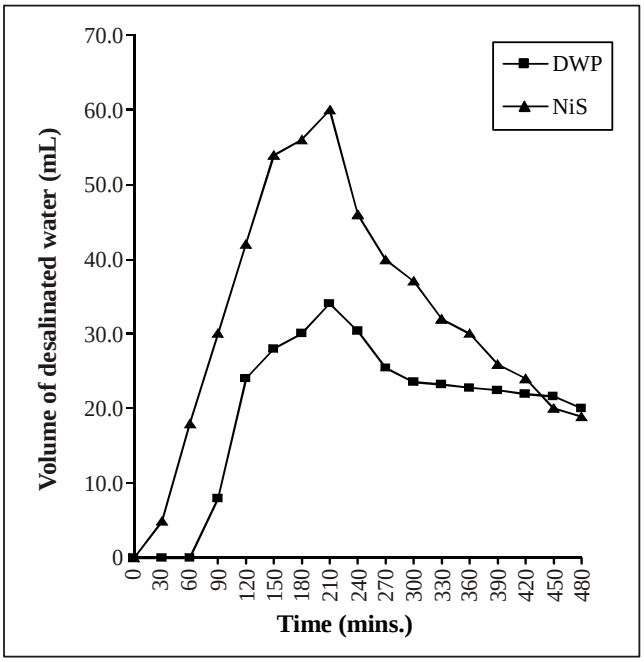

Fig. 2: Rate of production of desalinated water in presence of NiS

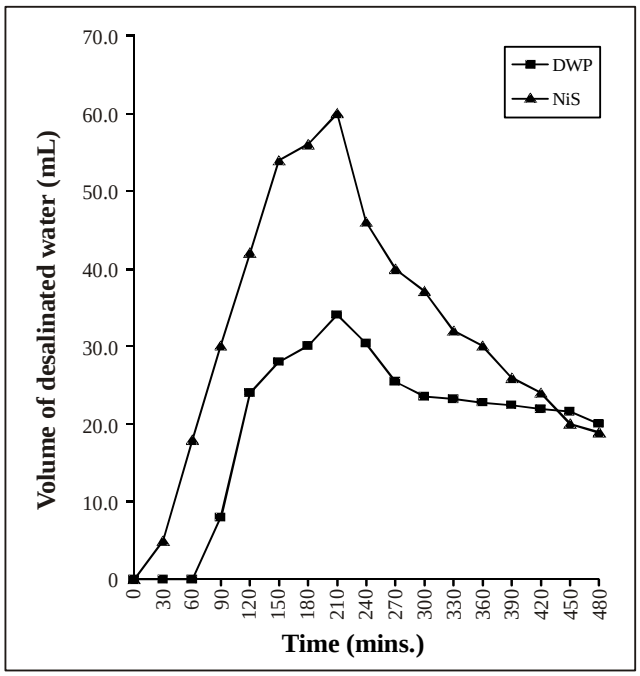

Fig. 3: Total volume of desalinated water in presence of NiS

Various parameters related to the quality of water are determined like pH, conductivity, TDS, fluoride, Fe, etc. The results obtained for raw water and water obtained after desalination using NiS sulphide as photocatalyst, are reported in Table 1.

Table 1: A comparative study of quality of water (with and without photocatalyst)

Parameter	Raw water	Desalinated water without use of photocatalyst	Desalinated water with use of photocatalyst – NiS
pH	8.2	7.2	7.1
Conductivity	0.954	0.739	0.050
TDS	1500.0	850.0	250.0
Free CO_2	18.0	10.0	2.0
Total alkalinity	160.0	32.0	15.0
Chloride	1050.0	85.0	38.0
Total hardness as $CaCO_3$	350.0	68.0	24.0
Calcium	63.0	8.4	3.3
Magnesium	70.0	14.5	5.0
Fluoride	5.00	2.0	1.5
Ammonium	0.048	0.060	0.106
Nitrate	48.0	12.0	6.4
Cadmium	0.010	0.006	0.005
Iron	1.2	0.8	0.5
Sulphate	62.4	60.6	44.5

CONCLUSION

The use of NiS not only gives better quality of water, but also increases the rate of production of desalined water. It lowers the pH of raw water and reduces TDS, free CO_2, conductivity and total alkalinity of raw water. Use of NiS also lowers chloride, fluoride, nitrate, calcium, magnesium, iron, cadmium contents and total hardness of raw water. This may be considered as an advanced step towards betterment of water quality to fulfill the need of population in rural area. To conclude, this concept is worthwhile as it produces drinking water without harming the environment using solar energy.

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