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STUDY ON THE EFFECT OF MODIFIED COTTON AS FLOATING ABSORBER IN SOLAR DRIVEN DESALINATION PROCESS

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Abstract: Water is the most precious resource responsible for life on our planet. More than 1 billion people do not have access to a source of clean drinking water, and around 3 billion experience water scarcity at least a month per year. The ocean makes up 70 percent of the earth's surface and accounts for about 96 percent of the water on the planet. Desalination of the seawater resource has emerged as a promising technology to meet the current fresh water demands. At present solar energy is used widely for desalination and new and new renewable energy technologies are developed to meet the ever increasing demands for potable water. In floating absorber based solar steam generation, the infrared rays from sun are converted into heat energy and this energy is used to convert water into steam. Cotton can be used as a floating absorber due to its high capillarity, low thermal conductivity and porosity. Even though cotton has its advantages, it has a very high reflectivity of incident light and reflects about 60% of incoming radiations. Study on the evaporation performance of Graphene Oxide (GO) cotton absorber and uncoated cotton absorber shows GO coated cotton is 2.38 times better than uncoated cotton absorber. GO has high photothermal efficiency which converts almost 60% of incoming sunlight into heat energy. Polystyrene form used as a support helps in low heat transmission loss thereby localizing heat on top surface. The evaporation rate obtained in our study using GO coated cotton shows promising result comparable to other materials used as floating absorber in different studies. Water quality analysis conducted on the condensed water samples suggests the obtained purified water is potable.

***Index Terms* – Desalination, Solar steam generation, Graphene Oxide, Cotton, Polystyrene Foam.**

I. INTRODUCTION

Today nearly one billion people in the developing world don't have an access to clean and safe drinking water. Water scarcity is either the lack of enough water (quantity) or lack of access to safe water (quality). In the developing world, finding a reliable source of safe water is often time consuming and expensive. This is known as economic scarcity. Water is the basis of all life. All around the world, a lot of people spend their entire day searching for it. In places like sub-Saharan Africa, a lot of people are suffering from water borne diseases. Waterborne diseases caused by lack of sanitation and hygiene are one of the leading causes of death worldwide. For children under age five, waterborne diseases are a leading cause of death. Safe drinking water is critical to the development of a healthy child. Diarrhoea is one of the top three leading causes of child death and this is often triggered from consuming unclean water. Further, every two minutes a child dies either from consuming contaminated water or due to diarrhoea. A lack of access to safe water and sanitation significantly affects the health of women as well. In many parts of the world women and children are forced to carry water in cans from long distances which is physically straining. The physical strain of these activities impacts their health and if pregnant, the health of their unborn children. Every year about a million people die as a result of scarcity of good quality drinking water. Hence it is imperative to find an alternate source of water to meet our growing demands.

Desalination techniques like membrane process are costlier. Conventional techniques like solar steam generation are impractical due to its low efficiency. Recent researches shows floating absorber based solar steam generation have comparatively larger efficiency and thereby interfacial solar heating paved a new way for overcoming the shortcomings of conventional solar steam generation.

In this work, we present a one of a kind floating photo- thermal absorber (Graphene oxide coated cotton wound around polystyrene foam) designed using low cost easily available materials such as cotton cloth, Graphene oxide and polystyrene foam for high efficiency solar steam generation and further its application in seawater desalination. The solar still set up using GO coated cotton floating absorber was able to remove the salinity and bacteria of sea water to produce potable water conforming to WHO standards. Thus, our work provides a floating absorber having unique characteristics such low cost, high photo- thermal efficiency, scalability, and simplistic design for solar steam generation applications in small scale as well as large scale water projects.

II. MATERIALS AND METHODS

2.1Materials

2.1.1Graphite

Graphite is a good conductor of heat and electricity and is widely used in pencil and lubricants. Its high conductivity makes it useful in electronic products such as electrodes, batteries, and solar panels. Graphite is crystalline with hexagonal structure, has low density (1900 - 2300 kg/m³) and is a soft allotrope of carbon. The acoustic and thermal properties of graphite are highly anisotropic, since phonons propagate quickly along the tightly bound planes, but are slow to travel from one plane to another. Graphite's high thermal stability and electrical and thermal conductivity facilitate its widespread use as electrodes and refractories in high temperature material processing applications. Graphite powder is an excellent photo-thermal material which can absorb light and convert to heat energy. This leads to localization of heat energy on the surface of the floating absorber.

2.1.2Cotton

Cotton fibers are natural hollow fibers; they are soft, cool, known as breathable fibers and absorbent. Cotton fibers can hold water 24–27 times their own weight. They are strong, dye absorbent and can stand up against abrasion wear and high temperature. Cotton is mainly selected as floating absorber as it is highly hydrophilic and allows a high degree of capillary action due to its porous structure. Another advantage of cotton is its high thermal stability and low thermal conductivity than most synthetic and natural fibers. It is a low cost environment friendly material. Cloth used for the study is 100% pure cotton.

2.1.3 Polystyrene

Polystyrene is a synthetic aromatic hydrocarbon polymer made from the monomer styrene. Polystyrene can be solid or foamed. Since the cotton absorbs water there is chance of sinking of cotton. For floating of GO coated cotton, polystyrene foam can be used. Polystyrene foams contains 95-98% of air and thus are good thermal insulators and are therefore often used as building insulation materials, such as in insulating concrete forms and structural insulated panel building systems.

2.2Methods

2.2.1 Preparation of Graphene oxide coated cotton cloth

In the first step, Graphene oxide is synthesized by Modified Hummers method. Graphite powder (2.5 g), $KMnO_4$ (7.5 g), and $NaNO_2$ (2.5g) were added slowly into 50 mL concentrated H_2SO_4 at below 5 °C under vigorous stirring using magnetic stirrer. The entire solution mixture was continuously stirred at 35 °C for 1 h to oxidize the graphite powder. Then, 100 mL de-mineralized water was added and heated up to 100 °C, and maintained for 15 min. After that, the suspension was poured into 300 mL of deionized water and 20 mL of H_2O_2 was added. Then, the mixture was cooled to room temperature and filtered using polycarbonate membrane filter. The obtained solid product was washed several times with 5 % aqueous HCl solution and deionized water, and finally dried to obtain graphene oxide powder To produce ethanol graphene oxide (E-GO) samples,1 mg graphene oxide is dissolved in 1 ml of ethanol solution (volume ratio 1:1) under ultrasonic for 1 hour. Pure Cotton is wrapped around the polystyrene foam using glue. The next step involves coating of Graphene oxide solution on the cotton cloth. The solution is coated on the cotton cloth using a small painting brush. The coated floating absorber was then allowed to dry under room temperature.

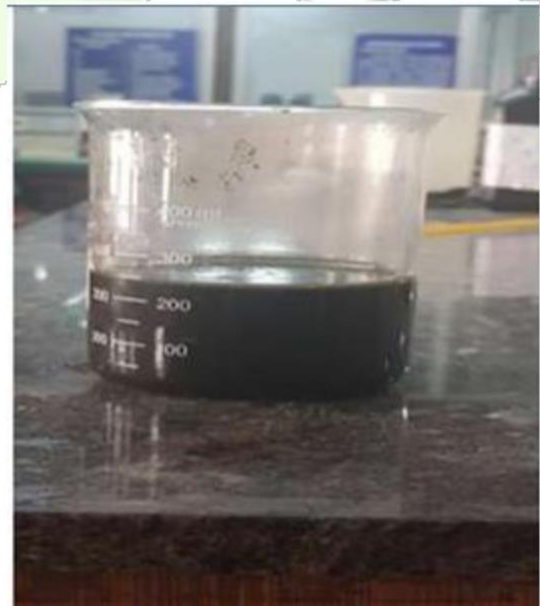

Fig.1. Graphene Oxide Solution

2.2.2 Construction of Solar Still

Two identical prototypes of the solar still are made for comparing the efficiency of GO coated cotton over uncoated cotton .Water desalination studies were performed under natural sunlight. A trapezoidal glass box with two separated compartments and covered with glass plane top was used. The base dimension of the setup is 30cm x20cm. The cross sectional view is shown in figure-2 below. The system has two compartments. The larger one is of dimension 20cm x20cm and smaller 10cm x 20cm. The sea water sample is placed in the larger compartment and the condensed water is collected in the smaller compartment. The compartments are covered by a slanting glass plate. In the first solar still setup uncoated cotton is placed and the second setup GO coated cotton is placed.

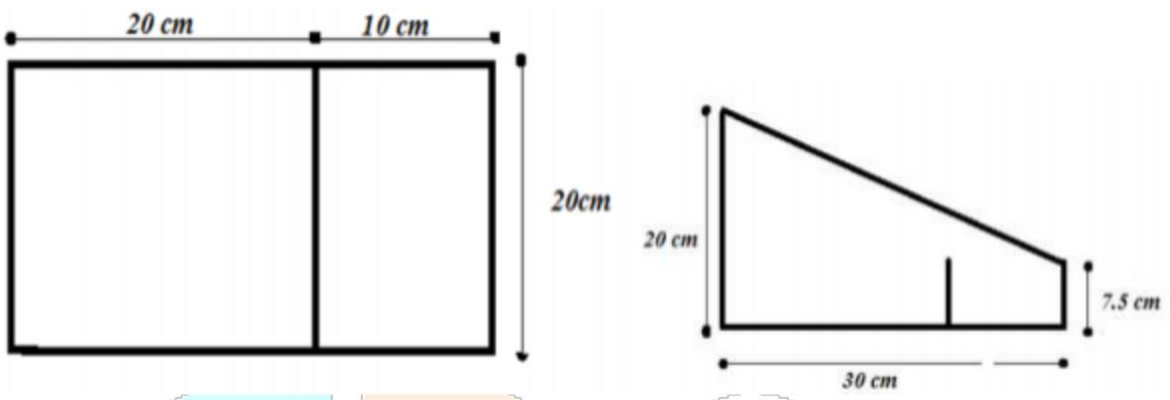

Fig.2. Solar still set up

2.2.3 Evaporation performance evaluation

The two solar set ups were placed under natural sunlight for six hours (10 am-4 pm) each day from January 2020 to March 2020 and the water evaporated is collected. Evaporation rate for each set up was calculated. The rate of evaporation obtained was calculated using volume and weight method. Volume of water in the smaller chamber is collected after six hours of sunlight exposure. Then mass of the water collected is measured using electronic balance. Evaporation rate (E) is calculated by using the equation given below.

E=Evaporation Rate in kg per m^2 per hr.

M= Mass of water collected after evaporation in kg.

S= Area of evaporating surface in m^2.

T= Time in hr.

During this study period humidity measured by using hygrometer, temperature using thermometer and secondary data of wind velocity is used (data from meteorological department).

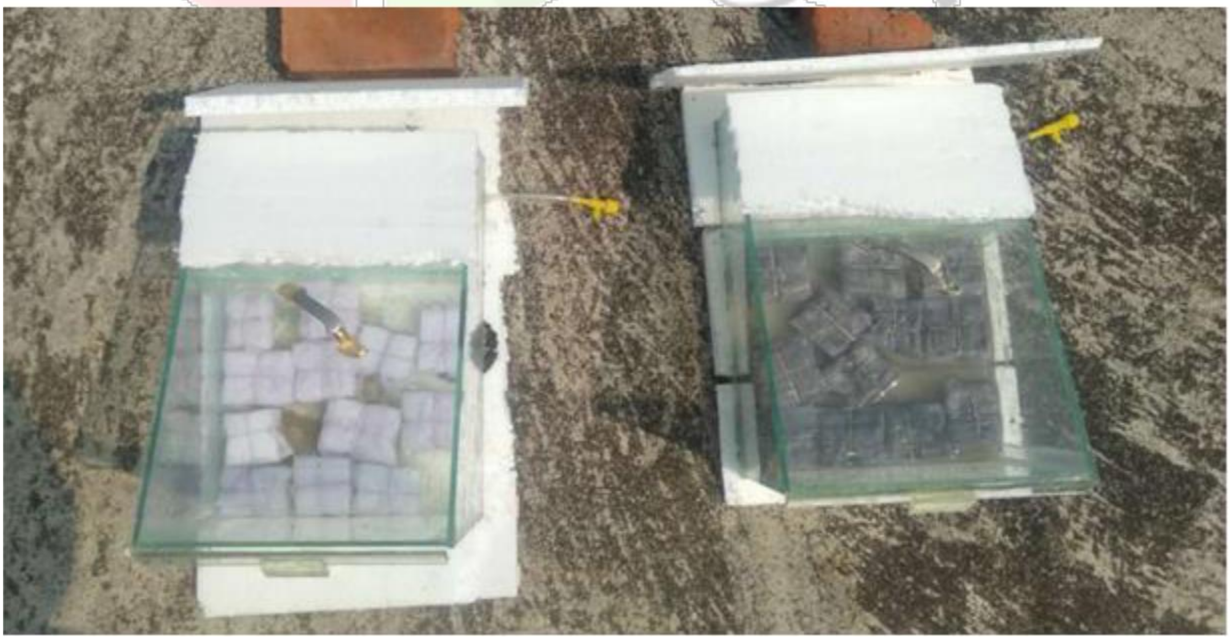

Fig.3. Solar still using GO coated and uncoated cotton

2.2.4 Analysis of Condensed Water using solar still

The chemical analysis of the water samples before and after treatment were carried out using flame photometry, inductively coupled plasma optical emission spectrometry, titration methods etc. The bacteriological analysis of water was carried out to find out the presence of bacterial colony forming unit using heterotrophic plate count (HPC) test. The obtained result were compared with IS 10500-2012 standards.

III. RESULTS AND DISCUSSION

3.1 Evaporation efficiency of GO Coated Cotton

Table 1. Evaporation performance of GO coated cotton and uncoated cotton absorbers

SL.No	Month	Evaporation Rate of GO coated cotton (kg/m^2 /hr)	Evaporation Rate of uncoated cotton (kg/m^2 /hr)
1	January	1.248± 0.162	0.524±0.058
2	February	1.358± 0.129	0.571±0.054
3	March	1.480± 0.144	0.619±0.056
	Average	1.362±0.145	0.5713±0.056

The results shows cotton coated with graphene oxide is 2.38 times more efficient than the uncoated cotton absorber. This is due to the high photothermal efficiency of graphene oxide which convert more light incident on the surface to heat which in turn results in localization of heat on the surface. Average evaporation rate obtained for graphene oxide coated cotton absorber is $1.362\pm0.145 kg/m^2$ /hr. Evaporation rate obtained for uncoated cotton absorber is $0.5713\pm0.056 kg/m^2$ /hr. The photo thermal efficiency of Graphene oxide increased the heat on the surface. GO has a high photo-thermal conversion capability, especially in the near-infrared wavelength region. Much of the energy from the Sun arrives on Earth in the form of infrared radiation. Sunlight is composed (by total energy) of about 50% infrared light, 40% visible light, and 10% ultraviolet light. Reduced GO has strong light absorption ability between 600 and 1100 nm(Infrared region). Localizing heat at the air water interface is essential to obtain excellent photo thermal efficiencies. For effective heat localization, the heat losses transmitted away from the hot spot should be kept minimum. Since conduction losses affect the photo thermal efficiency significantly, we have to use an insulator as a supporting medium for GO coated cloth and hence polystyrene foam is used as supporting medium. Since there is a lot of air in the gaps of polystyrene foam the transmission of heat energy to the base is difficult. Apart from its low thermal conductivity, polystyrene foam is rigid and non-porous which prevents direct contact of coated cotton cloth with underlying water. The foam also floats due to its extremely low density. It is readily available and most notably low cost which makes it idyllic as a thermal insulator. The hydrophilic uncoated cotton wrapped around the foam absorbs the underlying water and the absorbed water gets transported to the coated surface at the top through edges. This help in the prevention of the drying out of top surface of the absorber during the evaporation process. With this we can isolate the underlying fluid from the heat generated at the top surface and thus inhibit conduction loss of heat and enhance the evaporation rate.

3.2 Quality Analysis of condensed water sample

Table 2. Comparison of concentration of parameters in seawater and condensed water with IS10500 drinking water standards .

Parameters	Salinity (ppm)	Chloride (ppm)	Sulphate (ppm)	Phosphate (ppm)	Sodium (ppm)	Potassium (ppm)	Calcium (ppm)	Total Bacterial count(CFU/ ml)
IS 10500 drinking water standards	250	250	250	0.03	20	-	75	0
Average concentration of parameters in seawater	36900	18,980	2307	0.12	10,340	398	417	1125
Average concentration in condensed water	114	47	15	0	4	0	4	0

The water samples used in the study and condensed water obtained from the setup was compared. The salinity of sea water sample gets noticeably reduced to low levels by desalination. Salinity of sea water sample is about 36.9 ppt and the obtained salinity of condensed water is within acceptable limit of drinking water. The concentration of each ion in the purified water samples decreases significantly. The salinity values confirm the efficiency of solar driven steam generation using absorber and advocate its ability to produce potable water. There is no concentration of phosphate ion and potassium in condensed water sample. The chloride content is reduced largely which is within the acceptable drinking water limit. Sulphate content is reduced and the value obtained is within the acceptable limit. It would be true for traditional steam generation which involves boiling of bulk water as most of the bacteria are susceptible to temperature above 121°C. But in interfacial evaporation where the vapor temperature are less than 100°C in low sunlight. Number of bacteria plays an important role in defining water quality. According to Indian standards for drinking water there should be no colony forming unit (CFU/100mL) for total coliform. The HPC test results shows there is no colony forming units in condensed water sample which fit the guideline value.

IV. CONCLUSIONS

The study shows GO coated cotton as absorber in solar induced desalination process has better evaporation performance compared to uncoated cotton absorber. The performance of GO coated cotton absorber is 2.38 times better than uncoated cotton absorber. This is due to the high photothermal efficiency of graphene oxide. Graphene oxide has a high photothermal conversion capability, especially in the near-infrared wavelength region. Much of the energy from the Sun arrives on Earth in the form of infrared radiation. Reduced GO has strong light absorption ability between 600 and 1100 nm. Graphene oxide absorbs a large amount of incident light and converts it into heat. Localizing heat at the air water interface is essential to obtain excellent photo thermal efficiencies. For effective heat localization, the heat losses transmitted away from the hot spot (top surface) should be kept minimum. The polystyrene foam acts as an insulator and prevents the conduction of heat to water below and thus helps in localizing the trapped heat energy on the surface increasing the evaporation rate. The water quality analysis of the condensed water obtained from the solar still indicates that the analyzed parameters are adhering to drinking water quality standard as per IS 10500-2012. HPC test conducted in the condensed water sample showed absence of colony forming bacteria thus making it safe for drinking purpose. The different parameters like temperature, humidity, and wind speed have definite influence on the evaporation rate. From the study it can be concluded that the evaporation rate is directly related to temperature and wind velocity and inversely related to humidity. The cotton coated with GO is having a very high efficiency with respect to evaporation rate when compared to uncoated cotton. Thus by making use of cotton coated with reduced GO we are able to have a very cheap and sustainable material that can be used in solar still setup for efficient production of potable water from saline water.

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