

SYNTHESIS AND OPTIMIZATION OF CARBON NANOPARTICLES (C-DOTS) AS ABSORBER MATERIALS FOR SOLAR DISTILLATION APPLICATIONS

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ABSTRACT

Carbon nanoparticles (C-Dots) were synthesized using citric acid and urea as carbon and fuel source, and combustion reaction methods. The absorption spectral and morphology particles of C-Dots were investigated. The morphology describes the synthesis of small ($<1 \mu\text{m}$) and monodispersed C-Dots. Thus, the C-Dots solutions has absorption spectral range of about 86% at visible light spectral. This study suggests that the as-prepared carbon nanoparticles (C-Dots) with particle size and absorption spectral tunability might be utilized as solar energy absorber material.

ABSTRAK

Karbon nanopartikel (C-Dots) disintesis menggunakan asam sitrat dan urea sebagai sumber karbon dan bahan bakar, melalui reaksi pembakaran sederhana. Spektrum absorpsi dan morfologi partikel C-Dots diinvestigasi menggunakan UV-Vis Spectrometry dan analisis SEM. Hasil SEM menunjukkan bahwa morfologi partikel C-Dots sangat kecil ($<1 \mu\text{m}$) dan seragam. Selain itu, larutan C-Dots memiliki spektrum absorpsi pada rentang sekitar 86% pada daerah cahaya tampak. Hasil studi ini menunjukkan bahwa karbon nanopartikel (C-Dots) dengan ukuran partikel dan spektrum absorpsi yang dapat diatur, sehingga dapat digunakan sebagai material penyerap sinar matahari.

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Keywords: Carbon nanoparticles (C-Dots); simple heating process; solar distillation applications

INTRODUCTION

Water is a basic human needs. The need of water is progressively increasing along with the increase of population. It can be seen from the two things that depend on each other, quality and quantity. Most of water which is contained by the nature is not feasible to be used for the needs (Mahdi, Smith, & Sharif, 2011). Presence of water, especially in the big cities are often polluted by sources of various diseases and toxic chemicals so it unsuitable to be used. Whereas humans need the good quality water that is free of pollutants which may affect

the water conditions and also meet the health requirements (Mehta, Vyas, Bodar, & Lathiya, 2011).

There are several methods that can be used to produce pure water or to improve water quality such as distillation, electrolysis, flucolation-coagulation, biodegradation, photo-catalyst, ultra-filtration (Ghasemi, et al., 2014). But in the processing procedure the appropriate technology with the treated water conditions are required. The expensive equipment and its supporting systems are also required such as a huge electricity, appropriate chemicals, bacteria for the biodegradation process, as well as a catalyst in the process of photo-catalyst (Nasriah, 2013). The efficient utilization of solar energy for steam generator is a key factor for

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various applications, starting from large-scale power generation, houses cooling system and distillation/desalination system of sea water for drinking water purification, sterilization and cleaning system in remote areas, where the only source abundant energy is the sun (Asmara, 2012; Chen, et al., 2012). Basic principle of the distillation process is the use of black object or as the absorber of solar energy to heat water and produce steam, but its have low efficiency (Baker & Baker, 2010).

This research will be carried out the use of carbon nanoparticles to determine the effect on the improvement of the efficiency of the distillation process based on the warming by the sunlight. Carbon nanoparticles was used based on the properties of sunlight absorption which is good enough and also can absorb almost the entire wavelength range from UV to visible light (Mahen, Nuryadin, Iskandar, Abdullah, & Khairurrijal, 2014). Therefore the use of carbon nanoparticles are expected to increase the efficiency of absorption of sunlight in the distillation process based on warming of the sunlight.

METHODS

The carbon nanoparticles synthesis by mixing citric acid and urea with a certain ratio with water as solvent. The mixture is stirred to obtain a clear homogeneous precursor. Subsequently, the precursor is burned at 150 - 270 °C for one hour to obtain a powder of carbon black nanoparticles, as shown at Figure 1 (Nuryadin, 2015). The evaporation rate test using carbon nanoparticles in the distillation reactor, include the following steps:

- Drying 1 liter of sea water in the reactor distillation with and without the use of carbon nanoparticles.
- Measure the temperature of the water, and the environment by recording the temperature every 30 minutes.
- Measure the intensity of the sun light by using Solar Power Meter every 30 minutes.
- Measure the volume of water distilled after the drying process is completed.
- The retrieval processes for temperature and intensity data was carried out from 09.00 to 16.00.

To determine the effect of carbon nanoparticles variations to the optical properties of the solution and to determine morphology of C-Dots particles were characterized using UV-Vis spectroscopy and the scanning electron microscope (SEM).

RESULTS AND DISCUSSION

Absorption spectral of C-Dots solutions.

Carbon nanoparticles have been synthesized by using citric acid, urea and water. The carbon nanoparticle synthesis process is done by mixing citric acid and urea in water, with a ratio of citric acid/urea = 3/1. The solution was heated at 150-270 °C for \pm 1 hour, to obtain a carbon powder. The C-Dots solution by dissolved in 20 ml of water and C-Dots particles with various concentration from 0 to 0.4 g, as shown in Figure 2.

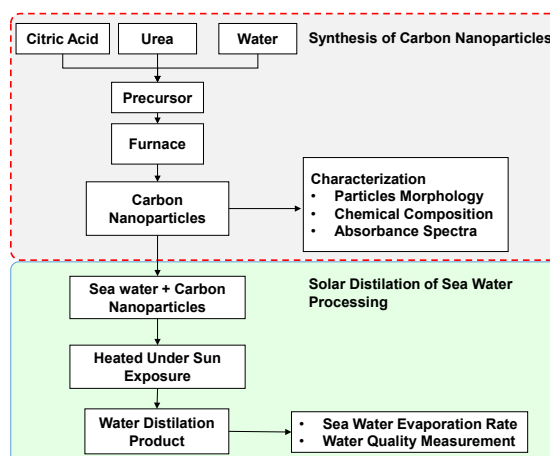


Figure 1. Synthesis and optimization proces of carbon nanoparticle as solar absorber material at solar distillation process.



Figure 2. Solution of carbon nanoparticles for various concentration, (A) 0 g; (B) 0.005 g; (C) 0,001 g; (D) 0.025 g; (E) 0.05 g; (F) 0.1 g; (G) 0.2 g; (H) 0.3 g; (I) 0.4 g, at 20 ml of sea water

The C-Dots characteristic absorption spectrum to visible light (sunlight) wavelength regions needs to be known in detail. The UV-Vis spectral measurements performed at various concentrations of C-Dots liquids, from 0 - 0.4 g in 20 ml of sea water (Figure 2). Results of UV-Vis spectrum measurement successfully showed absorption spectrum C-Dots and the predominantly in the range of visible light, especially in the range 400-800 nm (Figure 3). In addition, the absorption spectrum has shown that C-Dots liquids absorb infrared wa-

velengths, up to 60%. Thus, C-Dots solutions potentially to be developed as absorbing material and convert sunlight into heat.

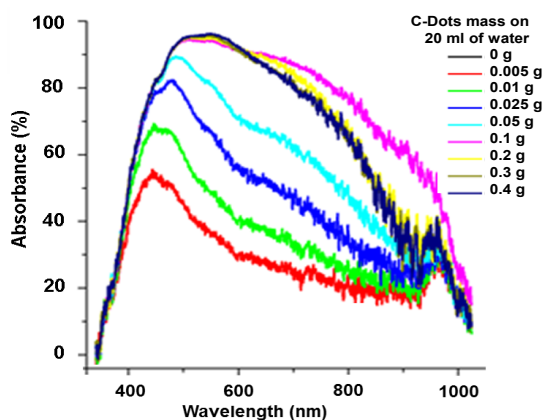


Figure 3. Absorbance spectra of carbon nanoparticles (C-Dots) solutions for various concentration.

Preliminary study of C-Dots solutions evaporation rate.

Preliminary studies to determine the effect C-Dots concentration on the rate of evaporation of sea water in the distillation process-based warming sunlight is necessary. Preliminary studies carried out by conducting exposure of visible light (solar simulator, up to 100 watt/m²) on C-Dots solution for several variations of concentration. During the study, weight measurements of each sample conducted to determine the changes of water mass and the amount of water that evaporated. The observation, as in Table 1 and Figure 4, shows that the addition of C-Dots to the sea water has to increase the evaporation rate up to 150%.

Thus, the visible light spectra has successfully absorbed by C-Dots particle and then the energy is used to evaporate the water. In addition, preliminary studies measuring the evaporation rate indicates successfully optimization C-Dots concentration where most optimum concentration in the range of 0.05 g in 20 ml (or 2.5 g C-Dots per Liter) of sea water. Physical concept that can be developed to analyze this phenomenon by Tindall effect and vapor diffusion processes in solution C-Dots. This is due, at low concentrations of light able to enter into the solution and completely absorbed. Whereas at high concentrations, light could not enter into the solution and the absorption of light is only on the surface of the solution C-Dots. However, were need to develop a better physical analysis to explain the effect of C-Dots solution concentration towards the absorption spectrum and the evaporation rate.

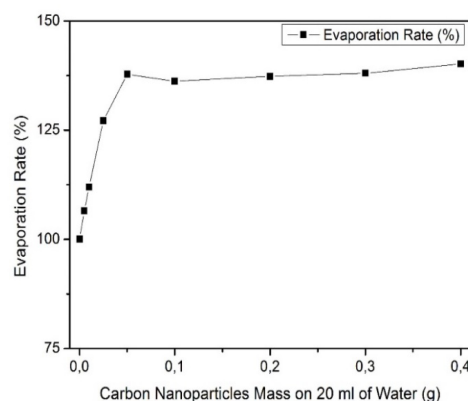


Figure 4. Water evaporation rate for various concentration of carbon nanoparticles (C-Dots) solutions.

Table 1. Evaporation rate observation with the addition of carbon nanoparticles on seawater.

C-Dots Solution concentrations*	Water mass quantity (g) for various of solar time exposure (WIB)						Evaporation rate (Δ)
	09:30	10:30	11:30	12:30	13:30	14:30	
-	71.88	70.96	69.63	68.16	66.51	64.51	7.37
0.005	72.30	71.40	70.05	68.52	66.71	65.07	7.23
0.01	71.79	70.69	68.99	67.72	65.84	63.84	7.95
0.025	72.67	70.36	69.36	67.24	65.13	62.63	10.04
0.05	72.21	70.84	68.81	66.92	64.14	61.57	10.64
0.1	73.15	71.65	69.82	67.67	65.08	62.51	10.64
0.2	71.78	70.43	68.29	66.29	63.74	61.27	10.51
0.3	71.67	70.38	68.33	66.11	63.24	61.19	10.48
0.4	71.35	70.90	68.74	66.25	63.24	61.41	10.94

*Note: C-Dots in 20 ml of sea water.

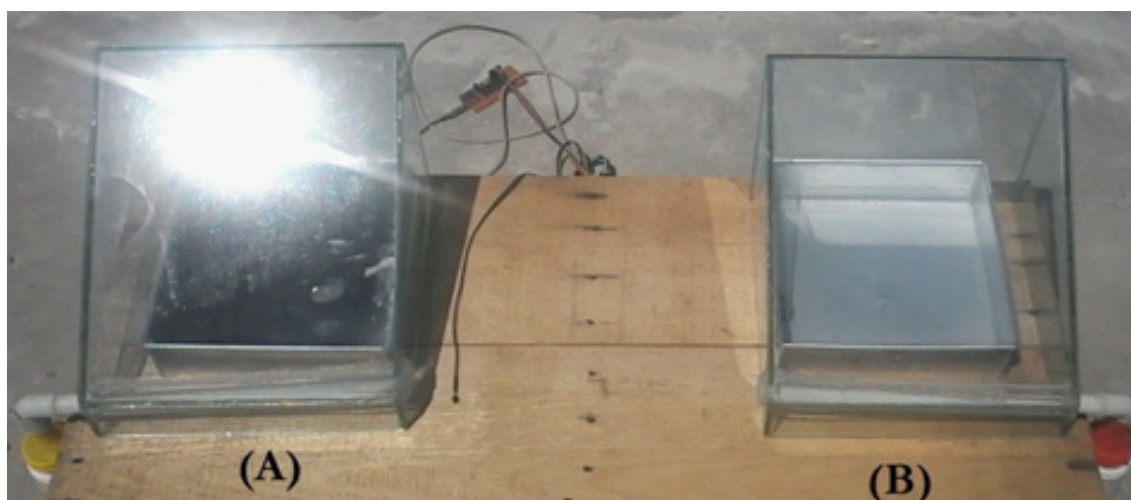


Figure 5. Solar distillation reactor (A) with the carbon nanoparticle, (B) without carbon nanoparticle addition.

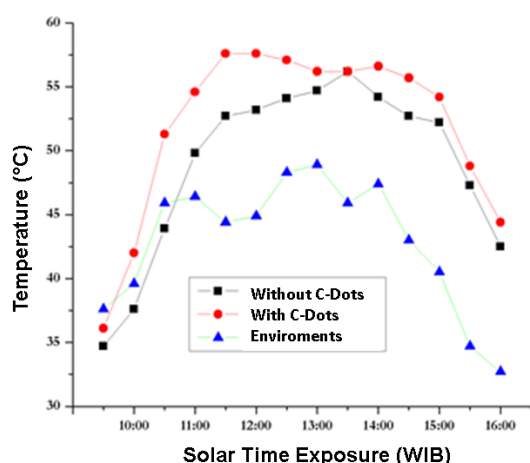


Figure 6. Temperature of Sea water and C-Dots solution as time function

Temperature Analysis of Solar Distillation Reactor.

Temperature is the most important factor in the productivity of the distillation process based on the sunlight warming. So that the temperature parameters measured in this study are the ambient and water sample temperature using solar distillation reactor, shows at Figure 5. The ambient temperature is the temperature in the outside of the glass, the measured ambient temperature is influenced by weather factors, as well as the region or geographical conditions that are relative and uncontrolled.

The observations temperatures are changing every day according to the amount of the received solar radiation. The magnitude of the environmental temperature, the tempe-

perature of water sample and the amount of the received solar intensity can be seen in Figure 6. The minimum temperature occurred when the weather is overcast. The temperature of the water samples did not decrease when the ambient temperature falls, this was caused by the characteristic of water which is a good heat storage. The three graphs also show that the addition of carbon nanoparticles also greatly affect the temperature of the water sample, the temperature of the solution with the addition of carbon nanoparticles is higher than the water samples. The water in the distillation reactor has a higher temperature than the environment. This was caused by the greenhouse effect. The sunlight has a wavelength (λ) between 0.15-4 μm , and only the wavelength (λ) between 0.32-2 μm that can penetrate the transparent glass with bringing its thermal energy. The sunlight can't be at and it will be confined in the inside of distillation reactor, the energy carried by sunlight will increase the temperature of the water inside the distillation reactor.

Morphology of C-Dots particles.

The SEM characterization conducted to determine the particle morphology CMs were used in this study. The SEM results of C-Dots particles managed to show a small (<1 μm) and monodisperse particle sizes (Figure 7). This characteristics lead to the high dispersion process of C-Dots particles in solution (sea water). A good dispersed of C-Dots particle in sea water is expected to increase the evaporation rate of seawater in solar distillation process (Abdullah, 2008).

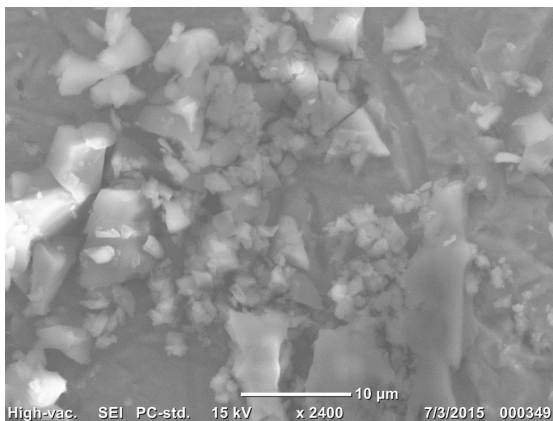


Figure 7. SEM image of C-Dots nanoparticle.

CONCLUSIONS

In this research carbon nanoparticles made of a mixture of citric acid ($C_6H_8O_7$), urea ($(NH_2)_2CO$) and distilled water have been successfully synthesized using a simple heating method. As a preliminary study of the experimental results showed that the addition of carbon nanoparticles could be produces pure water evaporation by 150% in pure water. Experiment results showed that the addition of carbon nanoparticles (C-Dots) in seawater provide a very significant influence on the improvement of the efficiency of the distillation process-based warming sunlight. Water produced from the distillation process based on the sun's warming is colorless and odorless.

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