# Increasing Water Temperature Using Asymmetric Compound Parabolic Concentrator System with Metal Plate-Coated Titanium Dioxide to Inhibit Microorganisms

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**Abstract:** In this research has studied and compared water temperature increasing by combining Asymmetric Compound Parabolic Concentrator (ACPC) with the coated and non-coated metal plate Titanium dioxide ($TiO_2$). The experiment is first divided into 2 sets. The first one is coated by $TiO_2$ and the second one is not. Then, put the metal plates at the base of the box containing water. Volume of the water is equal to 0.00198 kg. This experiment was carried out between 9.00 a.m. to 5.00 p.m. It was found that the increase of water temperature by combining the ACPC system with metal plate absorbing solar radiation coated by $TiO_2$ can restrain the microorganism from growing because $TiO_2$ is an oxide component which has special qualification to absorb solar radiation and exchange electron very well. It can also use to accelerate photocatalytic reaction. The water temperature on this research can be increased to the highest of 51°C including accumulated power of the system has the highest value of 0.15 kJ at 12.00 with solar radiation value 836 W/m$^2$. This temperature corresponds to the restrain of bacteria in waste water because it grows best at the temperature 35°C – 37°C and numbers of bacteria is reduced or stop growing at 45°C. Therefore, temperature increased and metal plate coated with $TiO_2$ can be applied to restrain the growth of bacteria effectively.

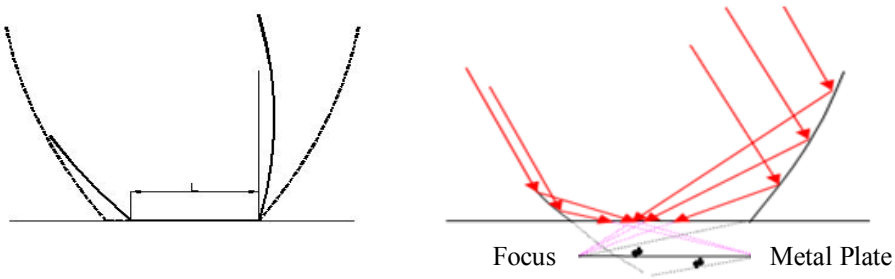
**Introduction:** Solar energy is considered a clean alternative energy. Thailand has used power from solar energy to produce electricity and heat by various technologies such as solar cell and Compound Parabolic Concentrator (CPC). All solar radiation panels have main purpose to collect radiation and employ heat from the solar to create the highest benefit in the most effective temperature as much as each panel can do. Therefore, many types of panel have been created at different temperature with high effectiveness. In 1984 Manrique reported advantage of the CPC is that it increase energy to the solar radiation target giving higher temperature and improve heat effectiveness by reducing area that the heat is lost at the radiation target compare to aperture area.[1] In total all heat will much less than flat plate. The CPC radiation panels can receive the solar radiation both direct and diffuse. However, the CPC is still having limitation. It must use the solar tracking system to be able to receive the radiation from different period and cannot receive diffuse radiation. Therefore, the idea of the ACPC was created to solve the problem. It can be used in all season and does not need to adjust angle by movement of the solar so it can receive more radiation.[1] $TiO_2$ that it is an oxide compound whose researchers around the world is really interested in due to its radiation qualification. Also, $TiO_2$ is still a popular semi-conductor substance to catalyze the reaction. Energy gap is similar to motivation energy of Ultraviolet (~ 380 nm). $TiO_2$ has special qualification to absorb radiation, exchange electron, not destroy by radiation, and not melt in water, reusable, high chemical stability, non-toxic and cheap. Other semi-conductors such as Zinc Oxide and Cadmium (II) Sulfide have similar qualification with $TiO_2$ but they are not popular because they are toxic and erode from radiation

process. The use of $TiO_2$ as a (Photocatalyst) in photocatalysis process can increase energy to the water and restrain the growth of bacteria in water as well.[2] When ultraviolet radiation from the sun is incident on the $TiO_2$ surface. It will create Oxidation reaction and give Hydroxide Radical ($^{-}OH$) and superoxide anion ($O_2^{-}$) which can decompose organic substance such as bacteria to be carbon dioxide and water.[3-4] The coating technique in this research is thermal spray technique because Thermal Spray is a surface engineering methodology by heating up surface of the samples. Materials can be in powder, wire or piece form and material to spray on can be metal, ceramic and other mixed materials. Sources of heat used in the coating is used from electrical ark combustion or plasma flame. The particles of material will move through the flame and dropped on the coated surface. The particles which move through the flame will have higher temperature and melt. In some cases, the particles will be only partly melted or not melted. The particles will be pushed to very high speed and hit the surface constantly until finally become a coating by Mostaghimi in 2003.[5] Moreover, advantage of the coating is that it can prevent erosion, prevent the surface to combine with oxygen, durable to high temperature and better adhesive to the surface.[6-7]

In this work, we propose to design the ACPC and compare water temperature with the ACPC which is the device to reflect solar radiation on the absorb surface in order to receive higher temperature. The result will be applied for a restrain of bacteria later on. Moreover, water temperature will be at the level that can stop the growth of other microorganisms.

**Methodology: Building Asymmetric Compound Parabolic Concentrator (ACPC)**

This research has been designed to have the sunlight reception angle of 21°, considering Bangkok's latitude of (π) 14°, the solar movement angle will be from -9.45° to 37.45°.Therefore, the CPC during the solar movement will be from -7° to 35°. The high of large panel is 0.50 m and of length 0.72 m, with its reflecting surface facing south. The high of small panel is 0.18 m and of length 0.72 m, with its reflecting surface facing north. Therefore, when the solar radiation touch CPC axis both north and south, it will be spread to the focal point on the flat surface (box containing water) between both panels (Figure 1). In building ACPC, there will be a stainless steel structure for more strength and stainless to reflect the solar radiation.




(A) (B)

**Figure 1.** (A) Asymmetric Compound Parabolic Concentrator
(B) Solar radiation of Asymmetric Compound Parabolic Concentrator

**Preparation of solar radiation by coating with Titanium dioxide**

Coating absorb plate with $TiO_2$ by Thermal Spray Technique to prevent erosion, prevent the surface to combine with oxygen, durable to high temperature and better adhesive to the surface, has the process as the followings. Coat $TiO_2$ on the stainless surface, the stainless has the size of 22x25 cm, 3 mm thick. Before coating, clean the stainless with thinner spray and bring them to sand shooting room to make the stainless surface more rougher so the coating substance can be better adhere on. Use $TiO_2$ AMPERIT ® 782.2 $TiO_2$ Fused $TiO_2$ Powder from H.C. Starck Company from the lab to perform Thermal Spray MTEC. Then, hold the samples to the base. Use plasma nozzle to spray $TiO_2$ powder which is already melted down. Distance from the plasma nozzle to the sample is equal to 3.5 in. next, install all devices as appropriate. Finally, coat the surface at the thickness of 250 nm (Table 1).

**Table 1**. Variable used in Titanium dioxide Coating by Thermal Spray technique

| Parameters | Value |
|---|---|
| Feed Rate (g/min) | 53 |
| Speed Robot (nm/s) | 400 |
| Arc Current (A) | 500 (~60-70 Volt) |
| Pressure (Psi) | 80, $H_2$ : 50, Ar: 100 |
| Flow Rate (Psi) | $H_2$ : 25, Ar: 100 |
| Cooling (Bar) | 1 |

The experiment was 2 sets, the first one is a metal plate coated $TiO_2$ and the second one is without coated $TiO_2$. The metal plate coated $TiO_2$ thick 250 nm using Thermal Spray technique. The basin was insulated with 5 mm thick acrylic plastic and of size 24x27 cm. Then, put a metal plate at the base of basin containing water. Which water has the volume of 0.00198 kg. Temperatures at various positions within the basin and the ACPC were measured by thermocouples (Type K, Accuracy ± 0.5 °C). Temperature and radiation were measured by Data logger (YOKOGAWA) model DX230-3-2 STYLE S4 every 2 seconds. The experiment was performed between 09.00 a.m. to 05.00 p.m. using ACPC to reflect radiation to increase heat energy to the surface (Figure 2). The aim of experiments was to determine. The aim of experiments was to determine the water temperature and metal plate temperature with-without coated $TiO_2$, the ACPC temperature and heat storage of 2 systems.

(A) (B)

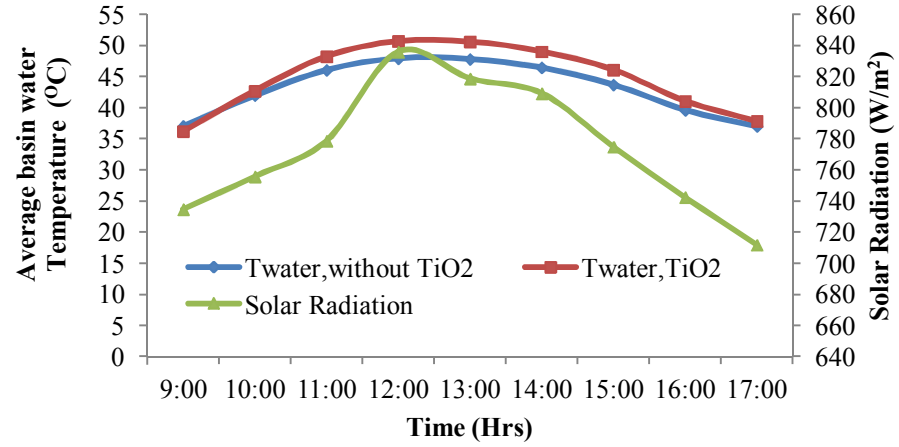
**Figure 2.** (A) Set 1 the system with a metal plate coated with $TiO_2$
(B) Set 2 the system with a metal plate without $TiO_2$.

Heat storage of this system is given as;

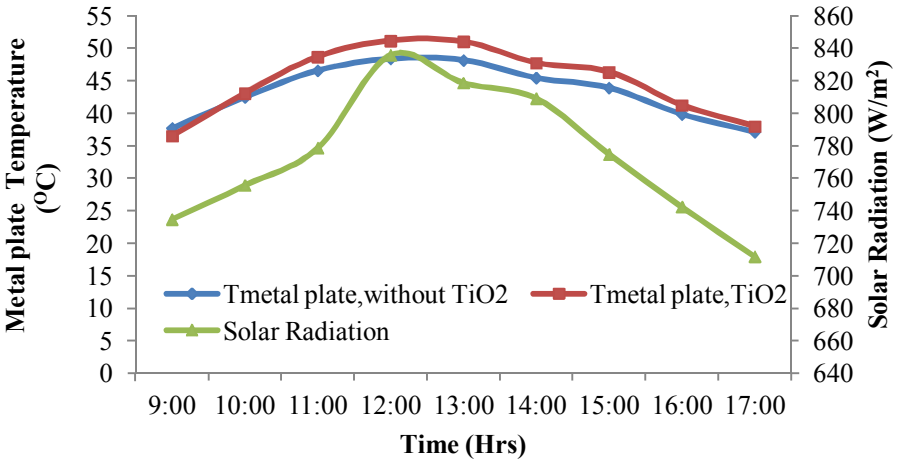
$$E = M \times C_{p,r} \times \Delta T$$

Where $E$ is heat storage of this system (kJ), $M$ is a volume of water (kg), $C_{p,r}$ is specific heat of water (kJ/kg K) and $\Delta T$ is Changed temperature of water (K)

**Results, Discussion Conclusion:** Water temperature with coating $TiO_2$ in set 1($T_{water, TiO2}$) is higher than those without coating $TiO_2$ in set 2 ($T_{water,without\ TiO2}$). The metal plate coated with $TiO_2$ has the highest water temperature at 51°C at 12.00 with solar radiation value of 836 W/m$^2$ (Figure 3(A)) because the metal plate of the absorber is in black color so it can absorb solar radiation very well. The metal plate coated by $TiO_2$ ($T_{metal\ plate,TiO2}$) has the highest temperature of 52 °C at 12.00 with the solar radiation value of 836 W/m$^2$. The metal plate without coated $TiO_2$ ($T_{metal\ plate,without\ TiO2}$) is polish. When the radiation hit the surface, it will reflect to outside. The metal plate without coated $TiO_2$ has the highest temperature at 47 °C at 12.00 with the solar radiation value of 836 W/m$^2$. We can see metal plate temperature is slowly go down causing water temperature to decrease accordingly (Figure 3(B))




(A)




(B)

**Figure3.** (A) Water temperature, solar radiation and time
(B) Metal plate temperature, solar radiation and time

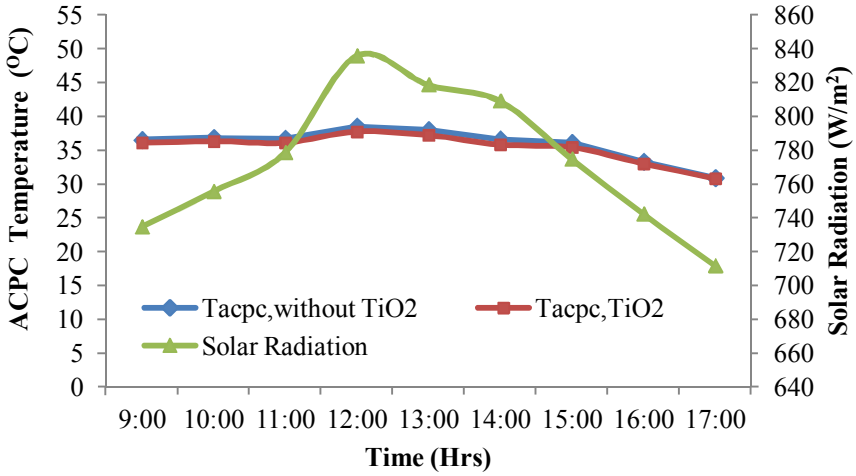



**Figure 4.** ACPC temperatures, solar radiation and time

And figure 3, we found that ACPC temperature of set 1 and set 2 are not so different because the solar radiation is closed, even though position of experiment devices are not the same. The highest temperatures of both combiners is 38.5°C during 12.00 – 1.00 p.m. with the solar radiation 819 – 836 W/m$^2$. Solar energy received from the solar radiation can increase water temperature and the combiners accordingly.

Moreover, from figure 4, the metal plate temperature and energy storage of the water heating solar radiation system by using ACPC combiner when the metal plate is coated by $TiO_2$ has more increased value. The metal plate ($T_{metal\ plate,TiO2}$) has the highest temperature of 51°C and heat storage of the system (Heat Storage,TiO2) has the highest value of 0.15 kJ during 12.00 – 1.00 p.m. with the solar radiation around 819 –836 W/m$^2$ and both systems has value in the same direction.

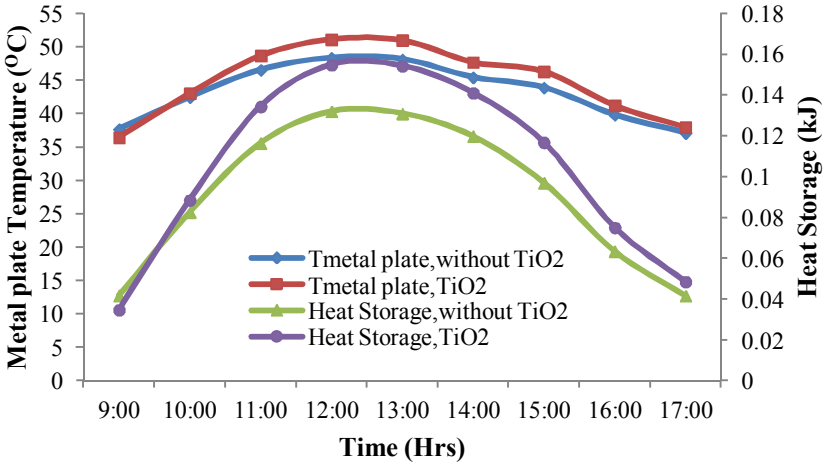



**Figure 4.** Metal plate temperature, heat storage of the system and time

- The Asymmetric Compound Parabolic Concentrator (ACPC) in this research is used in some parts of the year which are from 13 Jan – 24 May and 22 Jun – 20 Dec only. If the team wants to use in a longer period, it can be done by adjusting the angle $\theta_C$ to be wider depending on the latitude of experiment location. This design has many measurement steps and actual experimental scales are different by 5 times. Finally, making curve of the reflecting plate is difficult which can cause the deviation.

- Coating with $TiO_2$ by thermal spray technique is effective because it can coat a sample with big area. Materials used in the coating must be highly resisted to the heat. Otherwise, the sample can be distorted. Therefore, stainless used as an absorb surface in this research has a thickness of about 3 mm. Also, this technique helps $TiO_2$ powder to better adhere on the surface and more difficult to melt in the water. The thermal spray technique is better than Sol-Gel because we must prepare many substrates using many processes and in some cases, the substances are not adhering to the surface so we need to redo the process.

- Result of the coating with $TiO_2$ is that it can increase heat storage to the water and metal plate very well. This is the advantages of $TiO_2$ to help increase temperature of medium from Photo oxidation reaction in the water and cause Free radical to increase accumulated water temperature. Therefore, it can be effectively applied to restrain the growth of microorganism in the water in the future.

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