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Temperature and Salinity Gradients Analysis for a Solar Pond Prototype

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Abstract. In this study, a solar pond prototype is used to analyze the temperature and salinity gradients of alternative energy source processes. The study used two types of solar pond to investigate the temperature and salinity of gradients from each solar pond. The first solar pond utilizes sunlight as a heat source that emitted directly on the solar pond and the second solar pond utilizes the spotlights as a direct heat source emitted on the solar pond. The first solar pond is made of a cylindrical plastic tank of 1.05 m tall, 0.8 m in diameter placed outdoors in direct sunlight and the second solar pond model is made of a trapezium plastic tank with a height of 0.9m, the upper diameter 0.54m and a bottom diameter of 0.49m placed indoors with floodlights. The gradient temperature salinity and temperature measurement in the fest solar pond are smaller than temperature in the second solar pond however, the T_3 temperature in the outdoor solar pond is larger than the indoor solar pond. The observation results show that the first solar pond generates the mean value of temperature and salinity of successive gradients 32 (°C); 30 % and the second solar pond has the average value of temperature and salinity of successive gradients 31 (°C); 28 %.

1. Introduction

Renewable energy is an important source of global energy because of rising crude oil prices due to the burning of fossil fuels. Any electricity generated from fossil and any other types of non-renewable fuels have the potential of polluting the environment. Besides, with limited fossil fuel sources and an increased demand for power to accommodate the increase in human population, power generation from renewable energy is the most promising solution to maintain sustainable electricity supply for the future [1]. The national energy policy aims to reduce fossil fuels-driven electricity, especially petroleum. Utilization of renewable energy is required for the sustainability of supply and national energy reserves. Indonesia as a maritime country has the longest coastline in the world, that is ± 80.791,42 Km and Indonesia is an archipelagic country as it has more than 5000 islands. This natural state is a great potential for the development of renewable energy, such as geothermal, micro hydro, wind, solar, or energy sourced from the sea that spread wide and very abundant [2]. One source of renewable alternative energy sourced from the sea that is currently undeveloped in Indonesia is solar pond. Indonesia geographically has enormous potential in developing solar ponds because Indonesia has a tropical climate that has considerable high solar intensity [3] and, as a maritime country which surrounded by sea, the availability of raw materials of salt water is huge [4]. Regardless of its simple technology, solar pond requires high complexity of equipment to be used [5, 6]. Development of renewable energy in this research used solar pond prototype to observe the temperature and salinity of

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sea water gradient. The first solar pond model made of cylindrical plastic tank with height 1.05 m, diameter 0.8 m which is placed outdoors directly get the rays solar and the second solar pond model is made of a trapezium-shaped plastic tank with a height of 0.9 m, an upper diameter of 0.54m and a bottom diameter of 0.49m placed indoors gets rays through a spotlight.

2. Literature Review

Solar pond is a salt water pond, which is capable of collecting solar thermal energy, and the resulting heat energy will be converted into electrical energy [7, 8]. This technology is a fundamental technology and very easy to use with enough land and proper design. The solar pond technology is aptly used in areas that have plenty of sunlight and solar ponds that are environmentally friendly and pollution-free [9]. Seawater so it can absorb the sun's heat more optimally. The sea water is accommodated in a pond called the solar pond. The sea water at the bottom of the solar pond that gets sunlight can absorb the heat of the sun naturally which resulting the rising of the temperature[10]. Sea water contains salt which would make the density increased when it is exposed to the sunlight. Hot ocean water will descend to the bottom of the solar pond, while the cold sea water will rise to the surface. This causes a temperature difference between the bottom of the solar pond and the surface of the solar pond, this temperature difference causes a different heat . This heat difference will be used as a source of electrical energy.

The solar pond is divided into three layers as shown in Figure 1 which consists of:

a. Upper Convective Zone; This zone is called the surface layer. This surface layer has the lowest gradient salinity level, and the temperature is close to ambient temperature. This coating is important to prevent the lower layers so that the temperature is not reduced due to the evaporation process and the influence of the wind.

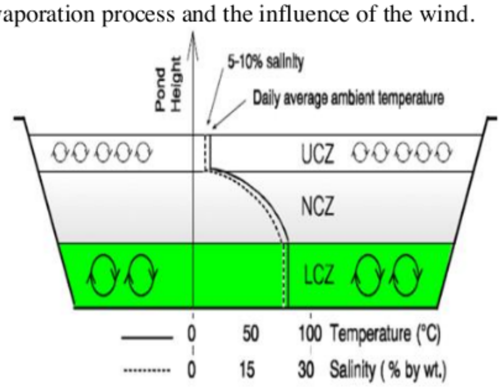

Figure 1. The division of zones in the solar pond is based on the salt content [1]

b. Non Convective Zone; This zone is referred to as the gradient layer or middle layer. This layer lies between the upper zone and the lower zone of the solar pond, at this layer the temperature and salinity of the gradient increases with the depth of the solar pond. This layer is not homogeneous and if the salinity of the gradient is large enough it will prevent a convective phenomenon.

c. The lower Convective zone; this zone is called a homogeneous layer, this homogeneous layer has a high temperature and salinity to produce high heat.

3. Research Methods

To analyze the temperature and salinity of the gradients of both solar pond models shown in Figure 2 and Figure 3. Gradient salinity data retrieval is conducted on the saltwater surface of both solar pond while the measurement of temperature data is performed at several points from both solar pond.

1. The first solar pond is made of a cylindrical plastic tank with a height of 1.05 m, a diameter of 0.8 m placed outside the room that directly receives sunlight. The thermometer is installed at 4 points:

T_0 (measuring ambient temperature), T_1 (measuring salt water temperature at a distance of 0.35 m from the surface of the solar pond), T_2 (measuring salt water temperature of 0[illegible] m from the surface of the solar pond), T_3 (measuring water temperature salt at a distance of 1.05 m from the surface of the solar pond) and gradient salinity measurements are performed on the surface of the solar pond. The measurement results are shown in Table 1.

2. The second solar pond is made of a trapezoidal plastic tank with a height of 0.9 m, an upper diameter of 0.54 m and a bottom diameter of 0.49 m placed in a room with an area of 12 m2. Measurements are made using spotlights as a heat source to obtain the temperature and salinity of the gradients in the solar pond.

Figure 2. The solar pond model is cylindrical shape

The thermometer is installed at 3 points: T_0 (measuring ambient temperature), T_1 (measuring the temperature of brine at a distance of 0.3 m from the surface of the solar pond), T_2 (measuring salt water temperature at a distance of 60cm from the surface of the solar pond), T_3 (measure the temperature of salt water at a distance of 90cm from the surface of the solar pond). The measurement results are shown in Table 2.

Figure 3. The solar pool model is a trapezoidal form

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Table 1. Measuring ambient temperature

Time	Date / T_0 (°C)											
	1-8-2017	2-8-2017	3-8-2017	4-8-2017	5-8-2017	6-8-2017	7-8-2017	8-8-2017	9-8-2017	10-8-2017	11-8-2017	12-8-2017
06.00	24	24	24	24	24	25	25	25	26	28	27	25
09.00	28	29	28	28	29	31	30	31	30	30	29	27
12.00	33	31	32	31	30	31	31	33	32	33	31	30
15.00	32	33	32	30	31	34	33	31	31	32	30	29
18.00	29	28	28	29	29	30	31	31	31	31	30	29

Table 2. The measurement of salt water temperature at a distance of 0.35 m from the surface of the solar pond

Time	Date / T_1 (°C)											
	1-8-2017	2-8-2017	3-8-2017	4-8-2017	5-8-2017	6-8-2017	7-8-2017	8-8-2017	9-8-2017	10-8-2017	11-8-2017	12-8-2017
06.00	32	32	29	29	29	29	29	29	29	30	29	28
09.00	29	30	29	29	29	29	30	30	30	30	29	28
12.00	32	32	31	31	32	32	31	31	33	31	31	30
15.00	33	33	33	33	33	33	33	32	33	32	31	30
18.00	32	32	31	32	32	32	32	33	32	31	31	30

Table 3. The measurements of water temperature salt at a distance of 1. 05 m from the surface of the solar pond

Time	Date / T_2 (°C)											
	1-8-2017	2-8-2017	3-8-2017	4-8-2017	5-8-2017	6-8-2017	7-8-2017	8-8-2017	9-8-2017	10-8-2017	11-8-2017	12-8-2017
06.00	31	31	30	30	30	30	30	30	30	31	29	29
09.00	30	31	30	30	30	30	31	31	31	31	30	29
12.00	33	33	32	32	33	33	32	32	33	32	32	30
15.00	34	34	34	34	34	34	33	34	35	34	32	31
18.00	33	33	33	33	33	33	33	32	34	32	31	30

Table 4. The measurements of water temperature salt at a distance of 1.05 m from the surface of the solar pond

Time	Date / T_3 (°C)											
	1-8-2017	2-8-2017	3-8-2017	4-8-2017	5-8-2017	6-8-2017	7-8-2017	8-8-2017	9-8-2017	10-8-2017	11-8-2017	12-8-2017
06.00	30	30	31	31	29	29	30	30	30	30	30	29
09.00	30	31	30	30	31	29	30	32	31	31	30	29
12.00	33	33	32	33	33	32	32	32	33	32	31	30
15.00	34	34	33	34	34	34	34	34	34	33	32	31
18.00	33	32	32	33	33	33	33	33	33	31	30	31

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Table 5. The graph of salinity and temperature at some point versus time in the second solar pond

Time	Date / S (‰)											
	1-8-2017	2-8-2017	3-8-2017	4-8-2017	5-8-2017	6-8-2017	7-8-2017	8-8-2017	9-8-2017	10-8-2017	11-8-2017	12-8-2017
06.00	30	30	32	31	32	33	32	32	32	31	30	33
09.00	30	31	31	32	32	32	32	32	32	31	31	33
12.00	30	30	31	31	31	31	31	31	31	32	32	32
15.00	30	30	30	30	30	30	30	30	30	32	32	32
18.00	30	30	30	30	31	31	30	30	30	32	33	32

Table 1 is the first solar cell temperature measurement result. The temperature measurement results show that at 06.00 the average environmental temperature is 25 °C; 09.00 time average environment temperature is 29 ºC; at 12.00 the average environmental temperature is 32ºC; at 15.00 the average temperature of the environment is 32 °C and the time 18.00 the average environmental temperature is 30 °C.

Table 2 is the result of temperature measurement at the first solar pond at a distance of 0.35m from the water surface. The temperature measurement results show that at 06.00 the average temperature is 30 °C; at 09.00 the average temperature is 29 ºC; 12.00 the average temperature is 31 °C; at 15.00 the average temperature is 32 °C and the average temperature 18.00 is 32 °C.

Table 3 is the result of temperature measurement at the first solar pond at a distance of 0.7m from the water surface. The temperature measurement results show that at 06.00 the average temperature is 30 °C; at 09.00 the average temperature is 30 ºC; 12.00 the average temperature is 32 °C; at 15.00 the average temperature is 34 °C and the average temperature 18.00 is 33 °C.

Table 4 is the result of temperature measurement at the first solar pond at a distance of 1.05m from the water surface. The temperature measurement results show that at 06.00 the average temperature is 30 °C; at 09.00 the average temperature is 30 ºC; 12.00 the average temperature is 32 °C; at 15.00 the average temperature is 33 °C and the average temperature 18.00 is 32 °C.

Table 5 is the result of salinity measurements in the first solar pool on the water surface. Salinity results show that at 6:00 the average salinity is 32 (‰); at 09.00 the average salinity is 32 (‰); at 12.00 the average salinity is 31 (‰); at 15.00 the average salinity is 31 (‰) and at 18.00 the average salinity is 31 (‰).

Table 6. The measurements of ambient temperature

Time	Date / T_0 (ºC)											
	1-8-2017	2-8-2017	3-8-2017	4-8-2017	5-8-2017	6-8-2017	7-8-2017	8-8-2017	9-8-2017	10-8-2017	11-8-2017	12-8-2017
06.00	26	26	25	25	26	26	28	30	32	31	28	26
09.00	28	27	29	30	29	29	30	30	30	30	30	28
12.00	30	29	33	33	31	30	32	32	32	32	32	30
15.00	31	30	32	32	29	33	33	33	33	33	31	32
18.00	30	30	30	28	30	30	31	32	31	32	31	29

Table 7. The measurements of the temperature of brine at a distance of 0.3 m from the surface of the solar pond

Time	Date / T_1 (ºC)											
	1-8-2017	2-8-2017	3-8-2017	4-8-2017	5-8-2017	6-8-2017	7-8-2017	8-8-2017	9-8-2017	10-8-2017	11-8-2017	12-8-2017
06.00	29	29	31	31	30	32	33	39	32	31	30	32
09.00	29	33	33	33	32	33	34	41	34	40	32	34
12.00	33	33	35	35	34	34	36	42	35	41	33	36
15.00	35	37	36	36	36	35	38	42	37	42	36	37
18.00	36	38	38	37	38	38	39	42	39	43	39	38

Table 8. The measurement of the salt water temperature at a distance of 60cm from the surface of the solar pond

Time	Date / T_2 (ºC)											
	1-8-2017	2-8-2017	3-8-2017	4-8-2017	5-8-2017	6-8-2017	7-8-2017	8-8-2017	9-8-2017	10-8-2017	11-8-2017	12-8-2017
06.00	28	28	31	30	30	32	32	36	32	31	29	31
09.00	31	32	32	32	31	33	33	37	33	34	30	31
12.00	32	32	33	33	32	33	34	38	34	35	33	32
15.00	33	34	34	34	33	33	35	38	34	36	33	32
18.00	34	34	35	35	35	34	36	41	36	39	36	33

Table 9. The measurement of the temperature of salt water at a distance of 90cm from the surface of the solar pond

Time	Date / T_3 (ºC)											
	1-8-2017	2-8-2017	3-8-2017	4-8-2017	5-8-2017	6-8-2017	7-8-2017	8-8-2017	9-8-2017	10-8-2017	11-8-2017	12-8-2017
06.00	28	28	30	29	29	31	31	34	31	30	29	31
09.00	31	31	31	30	30	32	31	35	32	30	29	31
12.00	30	31	32	30	31	33	32	35	32	32	30	31
15.00	31	33	31	31	31	32	33	35	33	34	32	32
18.00	33	33	32	32	34	33	34	37	34	37	36	32

Table 10. The graph of salinity and temperature at some point versus time in the second solar pond

Time	Date / S (º/oo)											
	1-8-2017	2-8-2017	3-8-2017	4-8-2017	5-8-2017	6-8-2017	7-8-2017	8-8-2017	9-8-2017	10-8-2017	11-8-2017	12-8-2017
06.00	30	30	32	32	33	35	34	30	35	31	30	38
09.00	31	30	31	30	32	32	32	30	34	32	31	37
12.00	32	31	32	32	31	30	31	30	33	32	32	36
15.00	29	29	29	29	30	31	30	30	33	33	35	35
18.00	29	28	29	29	31	28	31	31	31	33	35	33

Table 6 is the first solar cell temperature measurement result. The temperature measurement results show that at 06.00 the average environmental temperature is 25 °C; 09.00 time average environment temperature is 29 ºC; at 12.00 the average environmental temperature is 32 ºC; at 15.00 the average

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temperature of the environment is 32 °C and the time 18.00 the average environmental temperature is 30 °C.

Table 7 is the result of temperature measurement at the first solar pond at a distance of 0.35m from the water surface. The temperature measurement results show that at 06.00 the average temperature is 30 °C; at 09.00 the average temperature is 29 ºC; 12.00 the average temperature is 31 °C; at 15.00 the average temperature is 32 °C and the average temperature 18.00 is 32 °C.

Table 8 is the result of temperature measurement at the first solar pond at a distance of 0.7m from the water surface. The temperature measurement results show that at 06.00 the average temperature is 30 °C; at 09.00 the average temperature is 30 ºC; 12.00 the average temperature is 32 °C; at 15.00 the average temperature is 34 °C and the average temperature 18.00 is 33 °C.

Table 9 is the result of temperature measurement at the first solar pond at a distance of 1.05m from the water surface. The temperature measurement results show that at 06.00 the average temperature is 30 °C; at 09.00 the average temperature is 30 ºC; 12.00 the average temperature is 32 °C; at 15.00 the average temperature is 33 °C and the average temperature 18.00 is 32 °C.

Table 10 is the result of salinity measurements in the first solar pool on the water surface. Salinity results show that at 6:00 the average salinity is 32 (‰); at 09.00 the average salinity is 32 (‰); at 12.00 the average salinity is 31 (‰); at 15.00 the average salinity is 31 (‰) and at 18.00 the average salinity is 31 (‰).

4. Results and Discussion

The results of gradient temperature and salinity measurements for 12 days have been presented in tables 1-5 for the first solar pool (outdoor) and in tables 6-10 for the indoor solar pool. Measurements were made five times at 06.00 hours; 09.00; 12.00; 15.00 and 18.00 hours are categorized as 1, 2, 3, 4 and 5 in the picture. The temperature and gradient salinity measurements expressed in Table 1-10 are represented as graphs shown in Figure. 4-10. Figure 4-7 shows the results of temperature measurements at each point versus time on outdoor solar pond and indoor solar pond. Figure 8 is a graph of salinity gradient versus time in the first solar pond (outdoor) and solar pond (indoor). Figure 9-10 is a temperature graph at some points and salinity gradient versus time in outdoor pond and indoor pond.

The temperature versus time graph shown in Figure 4-6 shows the average temperature of an indoor pool greater than the average temperature in an outdoor pool, this is because the ambient temperature of indoor pond is cloistered while for outdoor pond is strongly influenced by weather and wind. However, the temperature graph (T3 = °C) in Figure 7 averages outdoor pool temperature is larger than average indoor pool temperature, this is due to the effects of ultraviolet rays of sunlight. For salinity gradient versus time value varies between outdoor solar pool and indoor solar pool, but in the outdoor solar pool the salinity value increases with time.

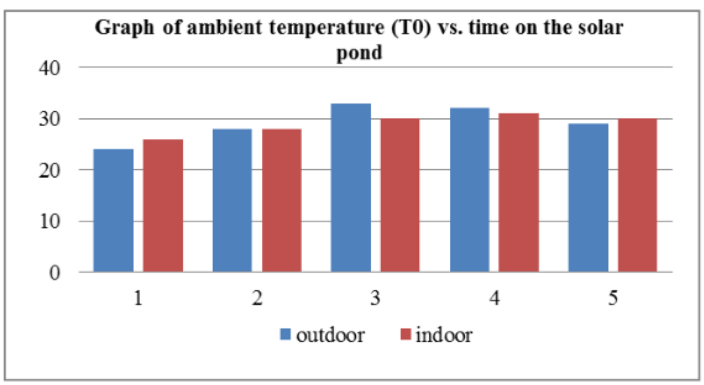

Figure 4. Graph between ambient temperature (T_0 = °C) versus time in the first solar pond and second solar pond

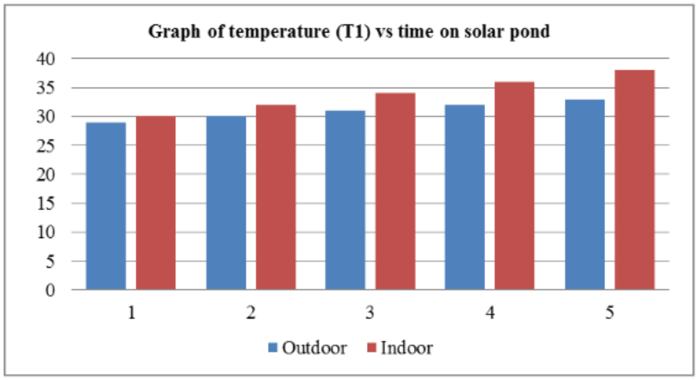

Figure 5. Graph between temperature (T_1 = °C) versus time in the first solar pond and second solar pond.

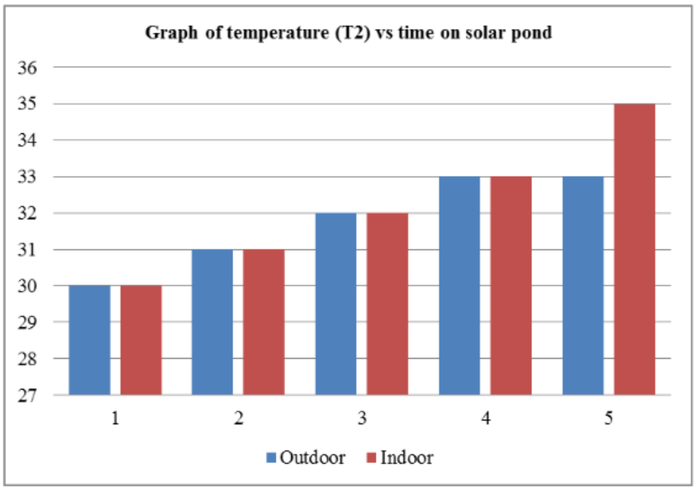

Figure 6. Graph between temperature (T_2 = °C) versus time in the first solar pond and second solar pond

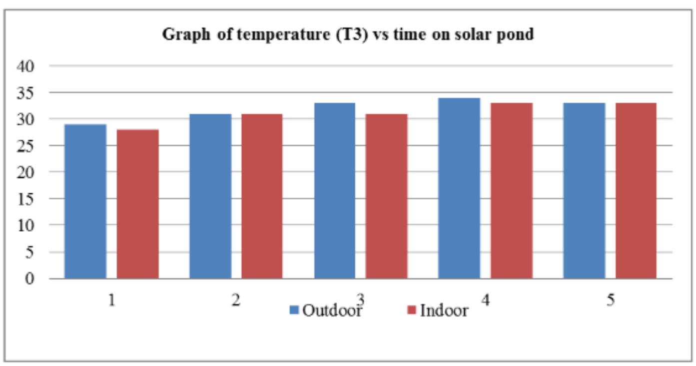

Figure 7. Graph between temperature (T_3 = °C) versus time in the first solar pond and second solar pond

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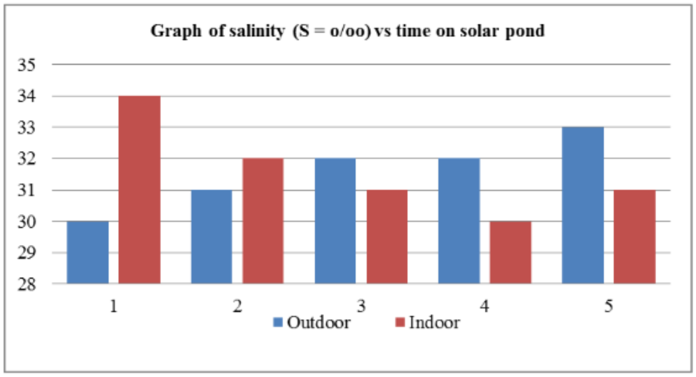

Figure 8. Graph between salinity (S = o/oo) versus time in the first solar pond and the second solar pond

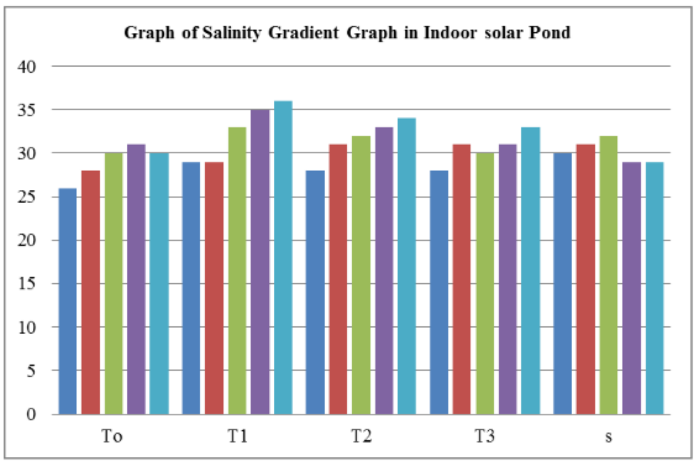

Figure 9. Graph of salinity and temperature at some point versus time in the second solar pond

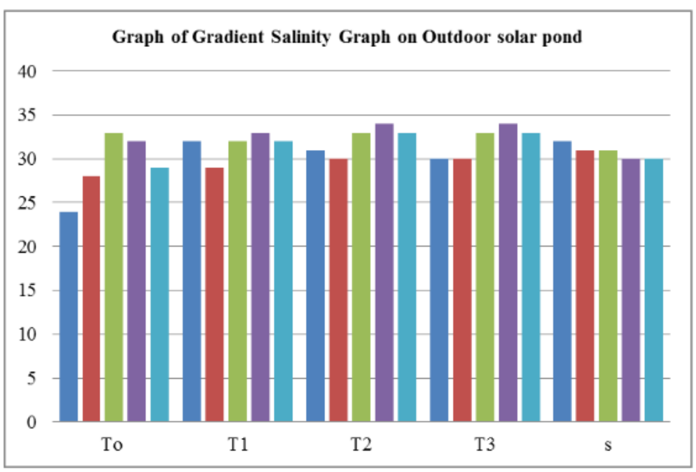

Figure 10. Graph of salinity and temperature at some point versus time in the first solar pond

5. Conclusion

The gradient temperature salinity and temperature measurement in the fest solar pond are smaller than temperature in the second solar pond, however the T_3 temperature in the outdoor solar pond is larger than the temperature in indoor solar pond. The observation results show that the first solar pond generates the mean value of temperature and salinity of successive gradients 32 (°C); 30 % and from the second solar pond the average value of temperature and salinity of successive gradients 31 (°C); 28 %.

Acknowlegment

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22	Submitted to Indian Institute of Technology Guwahati Student Paper	<%1
23	Submitted to Universiti Teknologi MARA Student Paper	<%1
24	G. S. Dhindsa, M. K. Mittal. "An investigation of double-glass-covered trapezoidal salt-gradient solar pond coupled with reflector", International Journal of Green Energy, 2017 Publication	<%1

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