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Letter to editor

Erroneous equations used to assess the performance of a solar pond

Dear Editor,

With great interest, I examined the theoretical analysis section of the paper "*Performance assessment of a solar pond with and without shading effect*" by Mehmet Karakilcik, Ibrahim Dincer, Ismail Bozkurt, Ayhan Atiz, 65 (2013) 98–107 [1]. The numerical part of the study is based on shading area analysis in different solar pond zones. I believe an incorrect format of equation was used in calculating the shading length of the layers. Another part of the study is based on energy analysis of solar pond zones to determine the energy efficiencies of each zone. Also, I believe there are contradictions and wrong formats of equations in this part of the paper. The equations used to calculate the net solar energy which reached the surface of each layer (Q_{ns}) are incorrect. Also, the transmission function (h_I) and coefficient of transmission (β), do not only contradict the ones referred to in the article, but are also in wrong formats.

Unfortunately, these mistakes have been repeated in two other papers published in this journal together with inaccurate equations for the specific heat capacity and salinity of the zones; the 1st paper is "*The effect of sunny area ratios on the thermal performance of solar ponds*", Ismail Bozkurt, Mehmet Karakilcik, 91 (2015) 323–332 [2] while the 2nd paper is "*Investigation of turbidity effect on exergetic performance of solar ponds*", Ayhan Atiz, Ismail Bozkurt, Mehmet Karakilcik, Ibrahim Dincer, 87 (2014) 351–358 [3].

1. Mistake in calculating the shading length

In the paper, the equation used for calculating the shading length of the layers is:

$$S_I = [(\delta + (I-1)\Delta x)\tan\theta_{rf}] \tag{1}$$

where δ, thickness where the long wave solar energy is absorbed (m); I, number of layer that varies from 1 to 30; Δx, thickness of horizontal layers (m).

Firstly, the thickness of each layer in the calculations is 0.05 m, not 0.005 m. Secondly, although the thickness of δ is very small (5–6 mm) [4], it is believed that the shading length has no correlation with thickness of δ. Therefore, to determine the average shading area effect, the correct equation for shading length calculation in the intermediate plane (I) in each zone would be:

$$\text{Average shading length} \quad S_I = I\Delta x\tan\theta_{rf} \tag{2}$$

$$\text{Shading area for the UCZ} \quad A_{sh,\mathrm{UCZ}} = L_W S_{I=1} = L_W[\Delta x\tan\theta_{rf}] \tag{3}$$

$$\text{Shading area for the NCZ} \quad A_{sh,\mathrm{NCZ}} = L_W S_{I=8} = L_W[8\Delta x\tan\theta_{rf}] \tag{4}$$

$$\text{Shading area for the LCZ} \quad A_{sh,\mathrm{LCZ}} = L_W S_{I=22} = L_W[22\Delta x\tan\theta_{rf}] \tag{5}$$

Since fields marked in Fig. 1 must be corrected.

2. Wrong equations in calculating the energy efficiencies of each zone

2.1. The heat loss from side walls to outside (Q_{sw})

In the paper, the following equation was used to calculate Q_{sw}:

$$Q_{sw} = A_{01,\mathrm{zone}} R_{ps}(T_{\mathrm{zone}} - T_{sw,\mathrm{zone}}) \tag{6}$$

To determine the energy efficiency of the UCZ, $A_{01,\mathrm{UCZ}}$, which is the surface area of the painted metal sheet on the side walls was considered in the paper as ($8 \times 0.05 = 0.4\ \mathrm{m}^2$) which according to Fig. 1, would be ($4 \times (0.1 \times 2) = 0.8\ \mathrm{m}^2$).

Since the overall heat transfer equation is as follows [5]:

$$Q = AU\Delta T = \frac{\Delta T}{\sum R} \tag{7}$$

$$(\mathrm{W}) = (\mathrm{m}^2)\left(\frac{\mathrm{W}}{\mathrm{m}^2\ \mathrm{K}}\right)(\mathrm{K}) = \frac{\mathrm{K}}{\left(\frac{\mathrm{K}}{\mathrm{W}}\right)} \tag{8}$$

where U, the overall heat transfer coefficient $\left(\frac{\mathrm{W}}{\mathrm{m}^2\ \mathrm{K}}\right)$; R, the thermal resistance $\left(\frac{\mathrm{K}}{\mathrm{W}}\right)$.

In the paper, the parameter R was used instead of U, and this should be corrected. Also, the R dimension in the nomenclature section must be corrected. On the other hand, U in the paper was written without considering the resistance of glass-wool as:

$$U = \frac{1}{A\sum R} = \frac{K_P K_S}{S_p K_S + S_S K_P} \tag{9}$$

Since a layer of glass-wool as an insulating layer in 50 mm thickness is used on the painted walls, therefore, its resistance should also be considered:

$$\sum R = \frac{S_p}{AK_P} + \frac{S_S}{AK_S} + \frac{S_{gw}}{AK_{gw}} = \frac{S_p K_S + S_S K_P}{AK_P K_S} + \frac{S_{gw}}{AK_{gw}} \tag{10}$$

Here, K_P and K_S are thermal conductivities of the paint and iron-sheet while S_p and S_S are the corresponding thicknesses. Also, K_{gw} and S_{gw} are the thermal conductivity and thickness of the glass-wool, respectively.

Also, for conductive heat transfer through the walls, the temperature difference should be ($T_{\mathrm{zone}} - T_{\mathrm{out}}$) and not ($T_{\mathrm{zone}} - T_{sw,\mathrm{zone}}$) [6].

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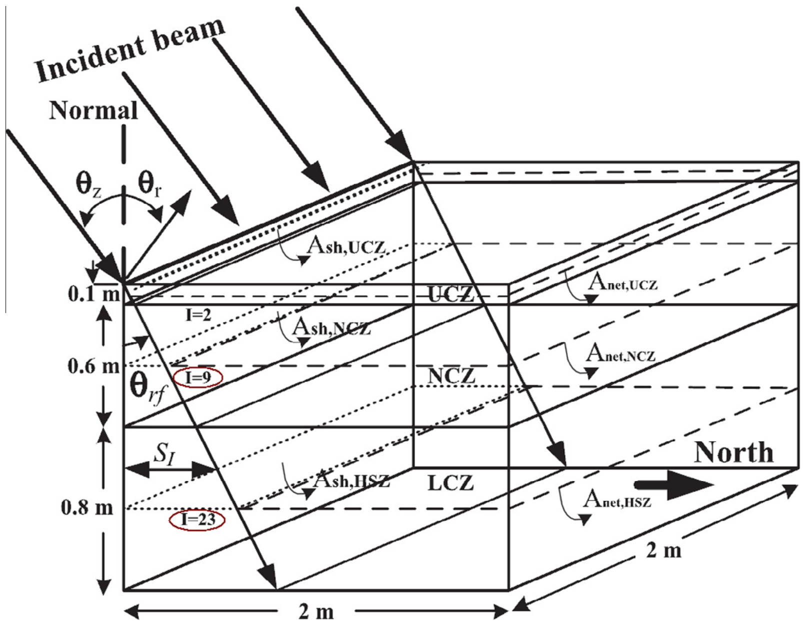

Fig. 1. Schematic representation of the rectangular solar pond.

2.2. Heat loss through the bottom of the pond

In the paper, the following equation was used to calculate $Q_{dw,\mathrm{LCZ}}$:

$$Q_{dw,\mathrm{LCZ}} = A_{dw,\mathrm{LCZ}} R_{ps}(T_{\mathrm{LCZ}} - T_{dw,\mathrm{LCZ}}) \tag{11}$$

Also in this equation, R should be replaced with U in accordance with what was mentioned above. The general equation for heat transfer through the bottom of the pond must be one of the following.

If the bottom of a mini solar pond is in contact with air [6]:

$$Q_{\mathrm{bottom,LCZ}} = \frac{(T_{\mathrm{LCZ}} - T_{\mathrm{out}})}{\frac{1}{Ah_i} + \frac{\Delta x_{\mathrm{bottom}}}{AK_{\mathrm{bottom}}} + \frac{1}{Ah_o}} \tag{12}$$

If the bottom surface is placed on the ground [6]:

$$Q_{\mathrm{bottom,LCZ}} = \frac{(T_{\mathrm{LCZ}} - T_{\mathrm{ground}})}{\frac{1}{Ah_i} + \frac{\Delta x_{\mathrm{bottom}}}{AK_{\mathrm{bottom}}} + \frac{\Delta x_{\mathrm{ground}}}{AK_{\mathrm{ground}}}} \tag{13}$$

2.3. Thermal energy transfer from NCZ to UCZ ($Q_{NCZ\ to\ UCZ}$) and from LCZ to NCZ ($Q_{LCZtoNCZ}$)

In the paper, the following equations were used to calculate $Q_{\mathrm{NCZ\ to\ UCZ}}$ and $Q_{\mathrm{LCZ\ to\ NCZ}}$:

$$Q_{\mathrm{NCZ\ to\ UCZ}} = \frac{k_w A_{\mathrm{UCZ}}}{\Delta X_{\mathrm{UCZ}}}(T_{\mathrm{NCZ}} - T_{\mathrm{UCZ}}) \tag{14}$$

$$Q_{\mathrm{LCZ\ to\ NCZ}} = \frac{k_{w,\mathrm{NCZ}} A_{\mathrm{NCZ}}}{\Delta X_{\mathrm{LCZ}}}(T_{\mathrm{LCZ}} - T_{\mathrm{NCZ}}) \tag{15}$$

whereas, the energy transferred from NCZ to a convective zone (either UCZ or LCZ) when assimilating it to a flat surface was calculated using the following equation [6]:

$$Q_{\mathrm{int\ cond-conv}} = \frac{(T_{\mathrm{NCZ}} - T_{U/\mathrm{LCZ}})}{R_{\mathrm{conv}} + R_{\mathrm{cond}}} = \frac{(T_{\mathrm{NCZ}} - T_{U/\mathrm{LCZ}})}{\frac{1}{Ah_c} + \frac{\Delta x_{\mathrm{cond}}}{AK_{\mathrm{cond}}}} \tag{16}$$

Δx_{cond} is the thickness of the pond considered for calculation.

2.4. The heat loss from the upper layer to air (Q_{wa})

In the paper, the following equation was used to calculate Q_{wa}:

$$Q_{wa} = A_{\mathrm{UCZ}} U_{wa}(T_{\mathrm{UCZ}} - T_a) \tag{17}$$

U_{wa} is the overall heat transfer coefficient from UCZ to air (W/m^2 K). Where Q_{wa} is the rate of total heat loss from the pond due to radiation, convection and evaporation [6–9,4,10–13] as expressed below:

$$Q_{wa} = Q_{\mathrm{radiation}} + Q_{\mathrm{convection}} + Q_{\mathrm{evaporation}} \tag{18}$$

$$Q_w = h_r A_{\mathrm{UCZ}}(T_{\mathrm{UCZ}} - T_{\mathrm{sky}}) + h_c A_{\mathrm{UCZ}}(T_{\mathrm{UCZ}} - T_a) + h_e A_{\mathrm{UCZ}}(T_{\mathrm{UCZ}} - T_a) \tag{19}$$

$$Q_w = A_{\mathrm{UCZ}} U_{wa}(T_{\mathrm{UCZ}} - T_a) \tag{20}$$

Thereby

$$U_{wa} = f(h_r + h_c + h_e) \tag{21}$$

The amount and method of calculation of U_{wa} was not mentioned in the paper.

2.5. The net solar energy entering to each layer (Q_{ns})

In the paper, the following equation was used to calculate Q_{ns}:

$$Q_{ns} = \beta\ E\ A[1 - (1 - F)h(X_I - \delta)] \tag{22}$$

where β, entering rate of incident beam into water; E, total solar energy reaching the pond surface (W/m^2); F, absorbed energy percentage at a region of δ-thickness; δ, thickness where the long wave solar energy is absorbed (m); h_I, solar radiation ratio reaching the bottom of layer I.

At first, the solar energy (E) dimension is incorrect (J) in the nomenclature section and should be corrected to (W/m^2).

The equation used for β in the paper is: