Műszaki Tudományos Közlemények vol. 9. (2018) 55–58.
https://doi.org/10.33894/mtk-2018.09.09
Hungarian: https://doi.org/10.33895/mtk-2018.09.09,
http://eda.eme.ro/handle/10598/30349

HEAT TRANSFER ON THE SURFACE OF AN OPEN POND BY EVAPORATION

Robert BOCSI[1], László HANÁK[2], Dóra RIPPEL-PETHŐ[3], Zoltán HODAI[4]

University of Pannonia, Faculty of Engineering, Institute of Chemical and Process Engineering, Department of Chemical Engineering Science, Veszprém, Hungary

[1] *bocsirobert@almos.uni-pannon.hu*

[2] *hanakl@almos.uni-pannon.hu*

[3] *pethod@almos.uni-pannon.hu*

[4] *hodaiz@almos.uni-pannon.hu*

Abstract

Modelling heat transfer problems are often carried out by using experimental data not only pure analytical methods. These solutions are affected by several parameters, so the deduction of formulas, based on complicated interactions, cannot be solved without theoretical knowledge. Our goal is on base of similarity theory building a model of heat transfer properties of an open pond that installed in climate of Hungary. In our work we have calculated heat transfer on the surface of an open pond by evaporation for the base of future studies.

Keywords: *heat transfer, evaporation, open pond.*

1. Introduction

Modelling heat transfer problems are often carried out by using experimental data not only purely analytical mathematical methods. These solutions are affected by several parameters, so the deduction of formulas based on complicated interactions that cannot be solved without theoretical base studies. This is a reason of using similarity theory. On the base of basic heat transfer functions similarity criteria are deducted. These equations contain quantities which should be measured. The following procedure is creating the connection between similarity criteria to solve the differential functions.

The arrows arrows show heat loss (+) or heat growth (-) for the pond (**Figure 1.**).

Many heat flows can be recognized in open pond systems. Some of them are necessarily calculated as growth for the system (radiation from Sun, mechanical energy, biochemical oxydation). Most of them depend on relation between pond and environmental conditions.

The heat flow between open liquid surface and air can be estimated by using the theory of two phenomena:

1. Heat flow between two phases because of temperature difference /*QFÁ*/. In this case the working force is the difference in temperature of the two phases.
2. Heat flow by the phase change /*QFP*/. This phenomenon is connected to the phase change of water by evaporation. In this case the working force is proportionate to the difference of humidity in the gas flow for aeration and the ambient air.

1.1. Heat flow by the temperature difference between two phases

Equation (1) is recommended for estimation in aerated waste treatment ponds:

$$Q_{FÁ} = \rho_{lev.} c_{p,lev.} h_v A (T_{sz} - T_{lev.}) \tag{1}$$

where

$\rho_{lev.}$ density of air, [kg/m³],
$c_{p,lev.}$ specific heat of air, [J/kgK],
h_v „vapour” transfer coefficient, [m/s]

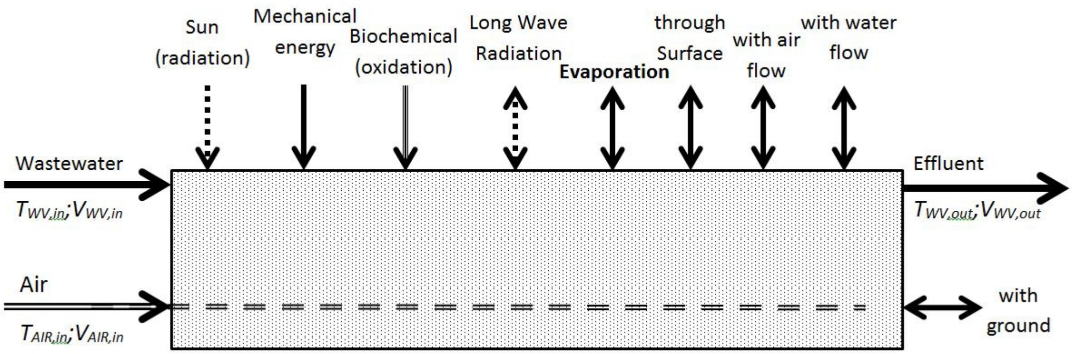

Figure 1. *Heat transfer flows between an open pond and its environment*

$$h_v = 392A^{-0,05}W/3600\times 24 \quad (2)$$

where W is wind speed, horizontal velocity of air [m/s] [1] [2]

In this case the heat transfer coefficient is approximately the same as it is for vapour phase. References can be found about these are equal because the Prandtl-number for evaporation and heat conveying is similar and those are function of wind speed.

Wind speed is a vector type variable that shows variability in angle and magnitude also. The annual average wind speed in Hungary at 10 m altitude is 2-5 m/s

The actual magnitude of air velocity depends on local circumstances. These can be macro or micro type circumstances.

Macro type circumstance can be relief, regional geological formations, micro type can be biological formations (tree alley, bush), or effect of human activity (buildings, transportation lines). These are responsible for local variance of wind speed that occasionally can be different from annual average. [3]

1.2. Heat flow by evaporation on open surface of a pond

For the estimation of the magnitude of heat transfer between the surface of a wastewater pond and the moving air above it the main heat flow should be analyzed. This is heat transfer where the working force is derived from the difference of water vapour concentrations.

The estimation of this flow can be carried out by using similarity theorem by calculating dimensionless quantities that can be used for the calculus of a basic wastewater pond:

$$Q_{Fp} = \frac{D_{víz,lev.}}{L} 0{,}037\,\mathrm{Re}^{4/5}\, Sc^{1/3} A\left(C_{T_{sz}}{}^{*} - C_{T_{lev.}}\right) h_p \quad (3)$$

where

- Q_{Fp} - heat flow by evaporation on the surface, [W],
- $D_{víz,lev.}$ - diffusion coefficient of water vapour in air, [m²/s],
- L - typical geometry parameter, diameter of the pond, [m],
- Re - Reynolds-number
- Sc - Schmidt-number
- $C_{Tsz}*$ - saturation concentration of water vapour at the temperature of the liquid surface, [kg/m³],
- $C_{Tlev.}$ - water vapour concentration in ambient air, [kg/m³]
- $h_{p.}$ - enthalpy of evaporation of water, [J/kg]. [4] [5]

We have used monthly average relative humidity data in Hungary by 5 m/s of wind speed collected and published by Hungarian Meteorological Information Services (OMSZ). [3]

Air velocity has typical intensity maximum according to the seasons. The windiest period of the year is at the first half of spring. The lowest wind speed can be measured at the beginning of autumn.

For the estimation of the monthly heat flow the following equation (4) has been used.

$$Q_{Fp} = \frac{4{,}18}{3600\cdot 24}\cdot\Phi\cdot e^{0{,}0604T_{lev.}} WA^{0,95}$$
$$\Phi = \left(1{,}145\cdot 10^{6}\left(1-\frac{r_h}{100}\right) + 6{,}86\cdot 10^{4}\left(T_{sz} - T_{lev.}\right)\right) \quad (4)$$

where

- r_h - relative humidity of “input” airstream, [%]
- W - wind speed, [m/s],
- A - surface of the pond, [m²].

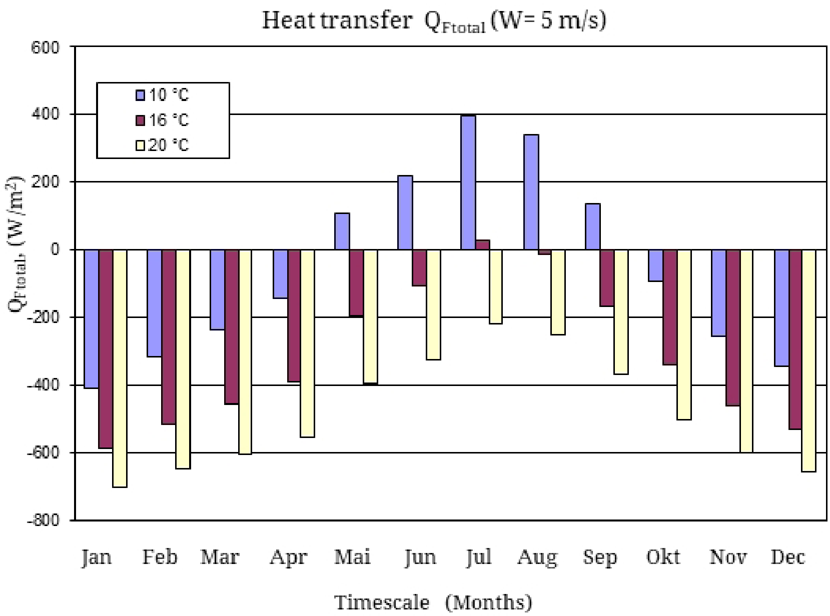

Figure 2. *Monthly change of heat flux on 1000 m² static surface of an open pond*

2. Evaluation of measured and calculated data

We have chosen a pond with 1000 m² surface for the calculations that is similar to a biological stage pond of an average small scale wastewater system.

The basic data for the calculations are the following:

A = 1000 m², the surface of the pond,
$\rho_{lev.}$ = 1.2 kg/m³, density of air,
$c_{p,lev.}$ = 1014 J/(kgK), specific heat of air,
W = 5 m/s, wind speed,
T_{sz} = 10 °C, 16 °C, 20°C, temperature of water in the pond,
$T_{lev.}$ = monthly average temperature of ambient air

The transferred heat flow that was the result of the calculations /*QFÁ* / was divided by the surface and we have reached the average heat flux on the surface of the pond [W/m²].

The results of the calculations can be found on **Figure 2.**

There is a minimum value of the flux that is between November and February. Average wind speed and temperature of ambient air is simultaneously responsible for this effect.

3. Conclusions

Many phenomena should be considered for the estimation of heat flows on the surface of open ponds. In our work we have carried out the evaluation of the heat transfer on stationary liquid surface. This is a critical point of the total heat transport from the pond.

We have evaluated the effect of ambient parameters on the heat flux, so we have left only those parameters as variables. These parameters have seasonal effect on the heat flow because of their seasonal change.

This work is a part of our research program that is to build a model for the evaluation of the effects of regional climate change on open pond systems, and the calculation of heat exchange between open ponds and environment.

Acknowledgements:

We acknowledge the financial support of Széchenyi 2020 under the GINOP-2.3.2-15-2016-00016GINOP-2.3.2-15-2016-00016.

References

[1] Novotny V., Krenkel P.A.: *Evaporation and heat balance in aerated basins*. AIChE Symp. Series, Water, 70/136. (1973) 150–159.
[2] Sedory P. E., Stentstrom M. K.: *A dynamic model for the prediction of aeration basin temperature,*

Journal of Environmental Engineering, 121/9. (1995) 609–618)
https://doi.org/10.1061/(ASCE)0733-9372(1995)121:9(609)

[3] Mezősi G.: *Climate of Hungary – Wind Conditions.* In: The Physical Geography of Hungary, Springer, Cham. 2017, 108-111.
https://doi.org/10.1007/978-3-319-45183-1_2

[4] Talati S. N., Stenstrom M. K.: *Aeration-Basin Heat Loss*, Journal of Environmental Engineering, 116/1. (1990)
https://doi.org/10.1061/(ASCE)0733-9372(1990)116:1(70)

[5] Ambrózy P., Mersich I.: *Magyarország éghajlati atlasza*, Országos Meteorológiai Szolgálat, 2001.

[6] Brønd S., Scherfig J.: *Dynamic temperature changes in nutrient removal plants*, Water Science and Technology, 30/2. (1994) 205–208.
https://doi.org/10.2166/wst.1994.0044

[7] Argaman Y., Adams C.F. jr.: *Comprehensive temperature model for aerated biological systems*. Progress in Water Technology, 9/1-2. (1977) 397–409.
https://doi.org/10.1016/B978-0-08-020902-9.50053-5

[8] Makinia J, Wells S., Zima P.: *Temperature Modeling in Activated Sludge Systems: A Case Study*. Water Environment Research, 77/6. (2005) 525–532.
https://doi.org/10.2175/106143005X67449

[9] Rho S-B.: *Temperature Prediction for the Wastewater Treatment Process using Heat Transfer Model*. Journal of the Korea Academia-Industrial cooperation Society, 15/3. (2014) 1795–1800.
https://doi.org/10.5762/KAIS.2014.15.3.1795,

[10] Fernández-Arévalo T., Lizarralde I., Grau P., Ayesa E.: *New systematic methodology for incorporating dynamic heat transfer modelling in multi-phase biochemical reactors*, Water Research, 60. (2014) 141–155.
https://doi.org/10.1016/j.watres.2014.04.034