Sigma J Eng & Nat Sci 35 (1), 2017, 119-131

Sigma Journal of Engineering and Natural Sciences
Sigma Mühendislik ve Fen Bilimleri Dergisi

**Research Article / Araştırma Makalesi**

# EXPERIMENTAL INVESTIGATION OF EVAPORATION FROM A HORIZONTAL FREE WATER SURFACE

**Mehmet İNAN*, Şevket ÖZGÜR ATAYILMAZ**

*Department of Mechanical Engineering, Yildiz Technical University, Besiktas-ISTANBUL*

**Received/Geliş: 28.07.2016 Revised/Düzeltme: 17.11.2016 Accepted/Kabul: 02.01.2017**

**ABSTRACT**

The aim of this work is to investigate of the evaporation from a horizontal free water surface under forced and free convection conditions. Experimental results were obtained in an installation consisting of a low speed wind tunnel and an evaporation tank. The status of free convection was provided at different temperature and relative humidity values of the ambient air. By changing the DC fan voltage, forced convection was ensured. Flows with Reynolds numbers varying between 6274 and 12667 were considered. Using the full factorial design which is a kind of design of experiment, relationship between evaporation rate and affecting parameters such as air flow velocity, air temperature and relative humidity were examined. Finally, an empirical correlation was derived by the experimental results. To validate the mathematical model were compared experimental measurements for the mass transfer at the free water surface and with available correlations in literature.
Evaporation rates calculated with obtained empirical correlation were compared with the values obtained by experimental results, it is observed that the calculated evaporation rates are within an error band of ±20%. The experimental results compared to the available correlations individually, a better level of agreement was obtained.
**Keywords:** Water evaporation rate, free surface, heat and mass transfer, forced convection, free convection, wind tunnel measurements.

## 1. INTRODUCTION

Water evaporation to air is an important phenomena in the field of heat and mass transfer. Many applications include water losses from water bodies to the ambient air. Evaporation calculations are required in a wide range of problems such as hydrology, agronomy, meteorology, swimming pools, cooling ponds, water purification plants and many other chemical, industrial, mechanical engineering systems.

Evaporation of water consists of two processes, forced evaporation due to the flow of moving air across the water surface and free evaporation is caused by the partial vapor pressure difference between free surface and the surrounding air. Combination of forced and free convection mechanisms can be applied for evaporation from free water surface in many technical systems. In the past, numerous experimental correlations and theoretical expressions were proposed for

* Corresponding Author/Sorumlu Yazar: e-mail/e-ileti: mehhmetinan@gmail.com, tel: (543) 743 99 16

finding rate of evaporation from a free water surface to the ambient air by researchers. However, these expressions contain significant discrepancies between them.

Many parameters such as water temperature, air temperature, relative humidity and air flow velocity have an effect on water evaporation from free surfaces [1]. In the open literature, several researchers have performed in this issue and some empirical correlation has been proposed. These are, Asdrubali [1], Tang and Etzion [2], Carrier [3], Smith et al. [5], Himus and Hinchley [6], Rowher [7], Pauken [8], Sartori [9], Raimundo [10], Marek and Straub [11] and many others.

It is stated that water evaporation rate is exactly proportional to the difference between the vapor pressure at surface water temperature and that air temperature. [2] Hence, most of empirical correlations in the literature were as below:

$$E = (A + BV)(P_w - \emptyset P_\infty)/h_{fg} \quad (1)$$

The best-known and used empirical correlation for water evaporation rates is the one proposed by Carrier [3] and then announced in the ASHRAE Application Handbook [4], as in Eq. (2):

$$E = (0.089 + 0.0782V)(P_w - \emptyset P_\infty)/h_{fg} \quad (2)$$

where V is the air flow velocity above water surface (m/s), $P_w$ and $P_\infty$ are saturated vapor pressure at water temperature and air temperature (Pa), respectively. The latent heat of vaporization is shown with $h_{fg}$ (kJ/kg). This equation can be used for air velocities between 0 and 0.7 m/s.

It was formed in evaporation tests in which air blown above water surface of unoccupied swimming pool. Since, Carrier's expression enormously overpredicted evaporation rate than expected, a few researchers recommended by evaluating water losses about this. Smith et al. [5] modified the Carrier' s correlation for indoor and outdoor swimming pools, by adding to it multiplier of 0.76.

Himus and Hinchley [6] carried out water evaporation from small containers with the help of wind tunnel measurements. During the experiments water temperature, air temperature, air relative humidity and air velocity were kept constant. Heat and mass transfer surface area varied between 0.02 and 0.07 $m^2$ in that study, the correlation that gives the water evaporation flux are obtained as follows:

$$J = 1 \times 10^{-9}(64.58 + 28.06V)(P_w - \emptyset P_\infty) \quad (3)$$

In an experimental method similar to that used by Himus and Hinchley [6], with a container having a much higher water evaporation surface area, of 0.84 $m^2$, Rowher [7] derived the following expression,

$$J = 1 \times 10^{-9}(64.58 + 28.06V)(P_w - \emptyset P_a) \quad (4)$$

Experimental studies and theoretical expressions about water evaporation from water bodies used large and small surface areas have compiled by Sartori [9]. He developed evaporation equations for turbulent flow regimes based on Reynolds, Schmidt and Sherwood dimensionless numbers.

Raimundo et al. [10] investigated the connection between evaporation from heated water surfaces and thermophysical properties of the forced air flow where Reynolds numbers between 2475 and 49503 were varied. Experimental tests have been carried out four partial vapor pressure difference (in the range of 1850-8751 Pa) and seven air flow velocities (in the range of 0.101-0.697 m/s) of 28 different conditions where Reynolds numbers between 2475 and 17326. Using a regression analysis, experimental measurements of the mass of evaporated water for different environmental conditions and airflow velocities obtain from the following correlation:

$$J = 1 \times 10^{-9}(37.17 + 32.19V)(P_w - P_\infty) \quad (5)$$

They have indicated that evaporation rate as multi-interactive function of air flow velocity, relative humidity and water-air temperature difference also can be expressed as in Eq. (6):

$$J_w = 1 \times 10^{-6}(22.77 + 215.85V - 23.59RH - 219.05V * RH + 13.95V * RH * T) \quad (6)$$

Experimental studies using a heated pool into a low speed wind tunnel were carried out by Pauken [8]. He made comprehensive experimental analysis using a wind tunnel with axial fan where average inlet air flow velocities varying between 0.33 and 1.45 m/s. Using a last squares fit on his experimental data, he has been indicated the following equation:

$$J = a(P_w - \emptyset P_\infty)^b$$
$$a = 74 + 97.97V + 24.91V^2, \qquad b = 1.22 - 0.19V + 0.038V^2 \quad (7)$$

Marek and Straub [11] pointed out that water evaporation rate increased with the increasing of water surface temperature, but the rate of this increase by stages slow down with the surface temperature increase. It means that the water evaporation rate is not proportional to water vapor pressure difference, and may relate to its exponent i.e. $(P_w - \emptyset P_a)^n$, $(n < 1)$. As stated by Marek and Straub [11], Tang and Etzion [2] and Pauken [8] also achieved experimental correlation which is an exponential function of water vapor partial pressure difference. The correlation proposed by Tang Etzion [2] can be seen in Eq. (8):

$$J = (0.2253 + 0.24644V)\,(P_w - \emptyset P_\infty)^{0,82}/h_{fg} \quad (8)$$

According to Pauken [8], Himus and Hinchley' s [6] correlation has a trends to excessive water evaporation when their results compared with the others at the similar air temperature, water temperature, relative humidity and air flow velocity. He defined as the most accurate expressions based on wind tunnel measurements those of Carrier [3].

The main objectives of the present study include the determination of the water evaporation rate from a horizontal free surface and to create new empirical correlation depending on air flow velocity and partial vapor pressure difference for this issue. The parameters such as air velocity, moving air temperature and relative humidity were performed in the experimental tests under different environmental conditions in a climatic test chamber which can be maintained at a durable required values.

## 2. EXPERIMENTAL SETUP

The experiments were performed in the climatic test chamber in order to provide the required temperature and relative humidity of ambient air. In the chamber, with the dimensions of 3500 mm × 2800 mm × 1600 mm the environment temperature between 5 and 50 °C and the relative humidity between 20% and 95% can be adjusted to the desired values. The experimental apparatus installed for this study which is shown in schematic diagram in Fig. 1, are consists of four major units namely the conditioned room, wind tunnel with flow straighteners, measurement and data acquisition unit, power and control system of fifteen parts.

A wind tunnel (2) was formed transparent plexiglas plates which thickness is 10 mm, it has 0.4 x 0.4 $m^2$ of cross-sectional area and total length of 1.80 m. To minimize air flow disturbances over the free water surface, evaporation tank was placed to the symmetry axis in the width and depth directions of the tunnel. The dimensionless Reynolds number above the surface is range 6274-12667 based on different air flow velocities and kinematic viscosity values at film temperature. Consequently, Re numbers is smaller than 5 x $10^5$, laminar flow conditions applies for external flow on the surface. Evaporation tank (6) with a water of 5.145 liters are made from sheet material, so it can quickly come into balance with ambient temperature. The photograph of the experimental setup is shown in Fig 2.

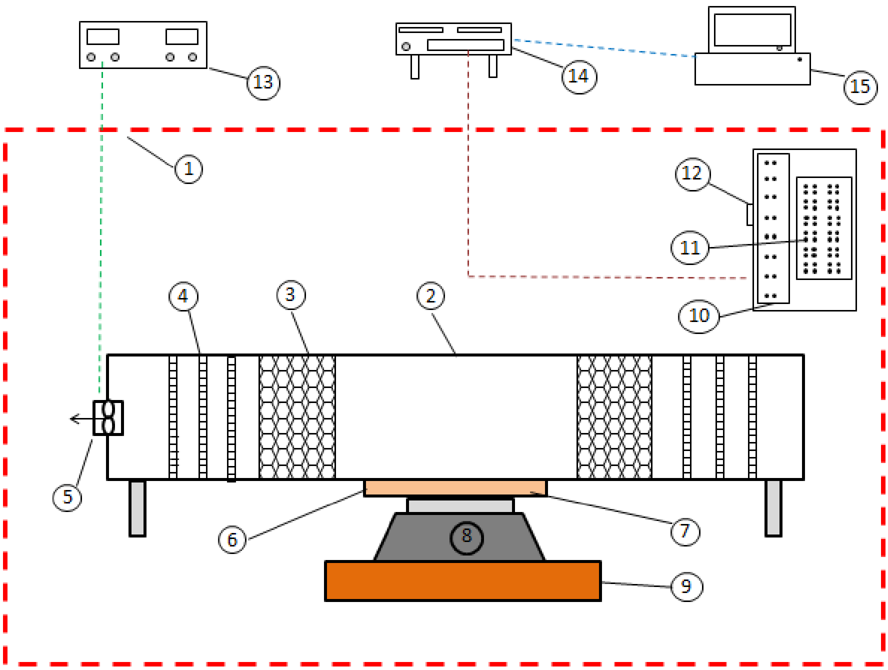


**Figure 1.** Schematic illustration of the experimental apparatus. (1) Climatic test chamber, (2) Wind tunnel, (3) Honey comp type flow straightener, (4) Cell type flow straightener, (5) DC Axial fan, (6) Evaporation tank, (7) Water, (8) Weighing scale, (9) Scale support, (10) Signal panel (for relative humidity sensors), (11) Thermocouples panel (12) AC Electrical panel, (13) DC power supply, (14) Data logger unit, (15) PC

In this system, different type flow straightener equipments were used for smooth flow profiles along the cross-sectional area. These are referred to as cell type flow straightener and honey comb type flow straightener. They were positioned at the air inlet section before the evaporation tank and the air outlet section after the evaporation tank.

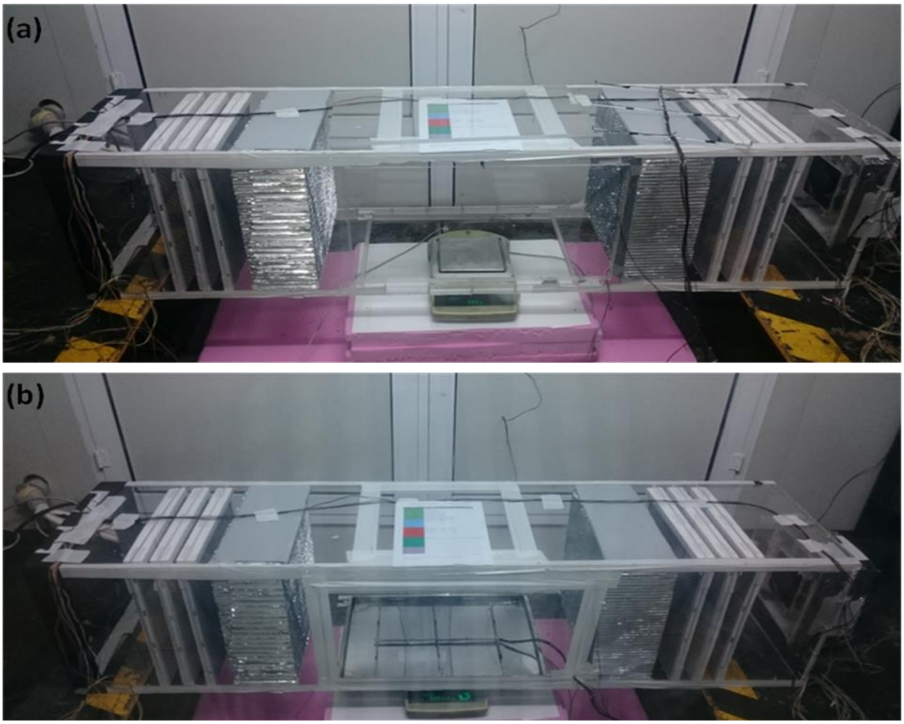


**Figure 2.** Photograph of the experimental setup, (a) Without the evaporation tank, (b) With the evaporation tank and thermocouple grid on water surface

During the experiments, four T type thermocouples (with ±0.2 °C sensitivity) are placed both on the inlets and outlets of the wind tunnel. The humidity sensors (with ±3% accuracy) have the same number are located in the same points. Thermocouple grid was made on the free water surface to get the most accurate temperature distribution. Additionally, Mettler Toledo 6002-SDR model, digital screen, range from 0 to 6100 g, accuracy ±0.05 g, used to value evaporated water mass depending on the time.

Once the temperature difference between air and water is approximately fixed, experiment begins and ends after three hours.

The calibration of thermocouples, relative humidity sensors and weighing balance were completed before the measurements. All the uncertainties of the measurements are listed in Table 1.

**Table 1.** Uncertainties of the measurements

| Measured parameters | Uncertainty values |
|---|---|
| Relative humidity | ± 3% |
| Temperature | ± 0.2 °C |
| Weighing scale | ± 0.05 g |

Several error analysis methods have been developed in order to identify experimental uncertainties. Among them, the proposed method Kline and McClintock [12] is most commonly used one for experimental studies.

In this experimental study, the uncertainty analysis method which is more susceptible compared the others is applied. If the independent variables that cause errors in experiments are chosen as weighing scale, relative humidity of the ambient air, nine local free water surface temperatures and the surrounding air temperatures that measured from four points. The uncertainty of mass transfer coefficient of evaporation process and dimensionless Sherwood number can be defined as follows. The uncertainty analysis results are given in Table 2 for the evaporation rate, mass transfer coefficient and Sherwood number.

$$h_m = \frac{\dot{m}}{A(\rho_s - \rho_\infty)} \tag{9}$$

$$\rho_s = \frac{P_s}{R_v T_s} = \frac{P_s}{\frac{8,314}{18} T_s} \tag{10}$$

$$\rho_\infty = \frac{P_\infty}{R_v T_\infty} = \frac{\phi P_\infty}{\frac{8,314}{18} T_\infty} \tag{11}$$

$$w_{h_m} = \pm \left[ \left( \frac{\partial h_m}{\partial \dot{m}} w_{\dot{m}} \right)^2 + \left( \frac{\partial h_m}{\partial \phi} w_\phi \right)^2 + \left( \frac{\partial h_m}{\partial T_s} w_{T_s} \right)^2 + \left( \frac{\partial h_m}{\partial T_\infty} w_{T_\infty} \right)^2 \right]^{1/2} \tag{12}$$

$$Sh = \frac{h_m L}{D_{AB}} \tag{13}$$

$$w_{Sh} = \pm \left[ \left( \frac{\partial Sh}{\partial h_m} w_{h_m} \right)^2 \right]^{1/2} \tag{14}$$

**Table 2.** Uncertainty analysis results

| | **m (g/h)** | **$h_m$ (m/s)** | **Sh (-)** |
|---|---|---|---|
| **±w** | 0.050 | 0.000203 | 4.011 |
| **%w** | 0.330 | 4.814 | 4.815 |

## 3. EXPERIMENTAL RESULTS

### 3.1. Analysis of the experimental data

In this study, the effects of three factors on the evaporation from a horizontal free water surface are investigated. The values for these process parameters that are examined in the experiments are given in Table 3.

**Table 3.** Experimental design parameters

| V (m/s) | 0.20 | 0.29 | 0.38 |
|---|---|---|---|
| $T_\infty$ (°C) | 16 | 21 | 26 |
| ∅ (%) | 50 | 61 | 72 |

The process parameters applied in these experiments mentioned above was used to evaluate the evaporation rate of water from a horizontal free surface. Using the full factorial design which is a kind of DOE, each of tests were formed by the crossing of low and high level for each parameter. Finally, one experiment was conducted using the middle value of the midpoint of each level to create a curve through three points such as Fig. 3. In this context, the generated experiment steps and experimental measurement results were presented in Table 4. Water surface temperatures and water loss values was recorded depending on the time and evaporation rate results were evaluated for mass transfer surface area of 0.1715 $m^2$.

**Table 4.** Experimental measurement results

| **Test No** | **V (m/s)** | **$T_s$ (°C)** | **$T_\infty$ (°C)** | **∅ (%)** | **$\dot{m}$ (g/h)** | **E ($g/m^2h$)** |
|---|---|---|---|---|---|---|
| 1 | 0.20 | 14 | 16 | 50 | 10.061 | 58.665 |
| 2 | 0.38 | 14 | 16 | 50 | 12.480 | 72,770 |
| 3 | 0.20 | 23 | 26 | 50 | 15.167 | 88.437 |
| 4 | 0.38 | 23 | 26 | 50 | 20.130 | 117.376 |
| 5 | 0.20 | 15 | 16 | 72 | 7.110 | 41.458 |
| 6 | 0.38 | 15 | 16 | 72 | 10.893 | 63.516 |
| 7 | 0.20 | 24 | 26 | 72 | 9.213 | 53.720 |
| 8 | 0.38 | 24 | 26 | 72 | 11.603 | 67.656 |
| 9 | 0.29 | 19 | 21 | 61 | 11.221 | 60.426 |

As a result of tests, the maximum water evaporation rate was measured as 117.376 $g/m^2h$ when air temperature was 26 °C, water surface temperature was 23 °C, relative humidity was 50 % and air flow velocity above free surface was 0.38 m/s. The minimum evaporation rate was measured as 41.458 $g/m^2h$ when air temperature was 16 °C, water surface temperature was 15 °C, relative humidity was 72 % and air flow velocity above free surface was 0.20 m/s.

Using the full factorial design; the main effects of these factors has been identified on the water evaporation rate. Analysis of the experimental data has been done by using Minitab 17.0 statistical software program. Fig. 3 presents the main effects of the parameters on the mean water evaporation rate. The results show that when the air flow velocity above the water surface and temperature of the moving air increase, rate of evaporation increase. For same experimental conditions, when relative humidity of the moving air is high, this situation is reversed. The reason for this, high RH condition has reduced the partial vapor pressure difference at air-water interface. Besides, air temperature has increased this difference. Forced evaporation tends to increase with increasing air flow velocity.

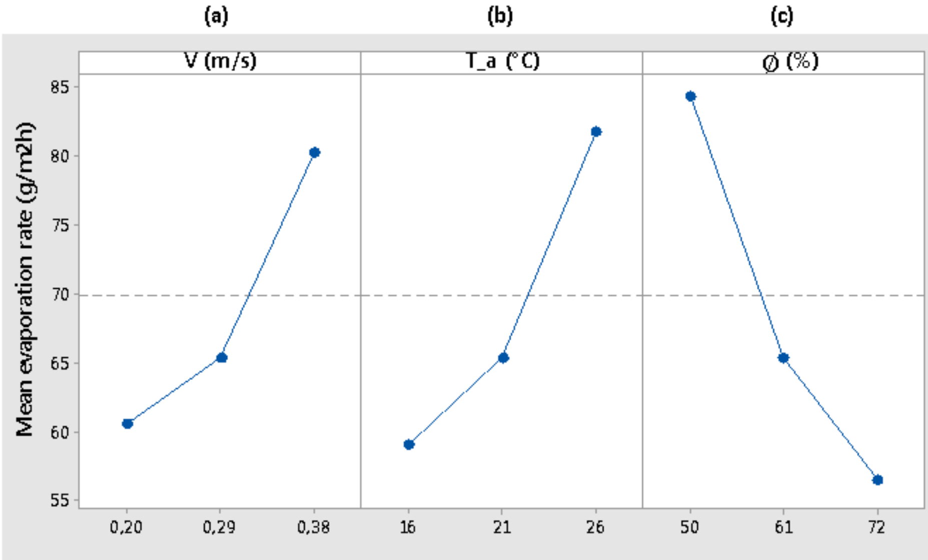


**Figure 3.** The main effects of the parameters on the evaporation rate
(a) Air velocity, (b) Air temperature, (c) Relative humidity

### 3.2. Comparison of proposed empirical correlation with available correlations

Empirical correlation structure for the evaporation rate from free water surface is usually below in Eq (15). The researchers who study about this subject were obtained A and B constants and proposed different correlations according to the conditions of their experiment. However, recent studies show that the difference in partial vapor pressure requires that should be corrected with exponential coefficient.

$$E = (A + BV)\frac{(P_s - \emptyset P_\infty)^n}{h_{fg}} \quad (15)$$

To achieve nonlinear regression analysis, experimental results such as air flow velocity and partial vapor pressure difference were collected in Table 5. To find the coefficient of n with constants A and B, must create the regression model with the known measurement results as follows are Eq. (16) and Eq. (17).

$$E \times h_{fg} = (A + BV)(P_s - \emptyset P_\infty)^n \quad (16)$$

$$E \times h_{fg} = (A + BV) \times (\Delta P \,\hat{}\, n) \quad (17)$$

In the database located in various statistical calculations, nonlinear regression analysis was carried out using Gauss-Newton algorithm with a maximum of 200 iterations, convergence tolerance of 0.00001 and 95% confidence interval in the Minitab 17.0. Empirical correlation for the evaporation rate from free water surface given below in Eq. (18) was derived by nonlinear regression analysis, including all statistically important effects with standard error value (S) 4.57. This experimental correlation is valid under the following conditions.

$16\ °C \le T_\infty \le 26\ °C$
$\%50 \le RH \le \%70$
$0.20\ m/s \le V \le 0.38\ m/s$

$$E = (0{,}280 + 0{,}784V)\frac{(P_s - \emptyset P_\infty)^{0.695}}{h_{fg}} \quad (18)$$

where V is the air flow velocity above water surface (m/s), $P_s$ and $P_\infty$ are saturated vapor pressure at water temperature and air temperature (Pa), respectively. The latent heat of vaporization is shown with $h_{fg}$ (kJ/kg).

**Table 5.** Percentage deviation values (δ) between measured and calculated water evaporation rates

| Test no | V (m/s) | $T_s$ (°C) | $T_\infty$ (°C) | Ø (%) | $P_s - Ø^*P_\infty$ (Pa) | $E_{exp.}$ (g/m$^2$h) | $E_{corr.}$ (g/m$^2$h) | δ (%) |
|---|---|---|---|---|---|---|---|---|
| 1 | 0.20 | 14 | 16 | 50 | 693.98 | 58.665 | 60.014 | -2.30 |
| 2 | 0.38 | 14 | 16 | 50 | 693.98 | 72.770 | 79.381 | -9.09 |
| 3 | 0.20 | 23 | 26 | 50 | 1144.95 | 88.437 | 85.711 | 3.08 |
| 4 | 0.38 | 23 | 26 | 50 | 1144.95 | 117.376 | 113.372 | 3.41 |
| 5 | 0.20 | 15 | 16 | 72 | 386.37 | 41.458 | 39.996 | 3.53 |
| 6 | 0.38 | 15 | 16 | 72 | 386.37 | 63.516 | 52.904 | 16.71 |
| 7 | 0.20 | 24 | 26 | 72 | 566.32 | 53.720 | 52.617 | 2.05 |
| 8 | 0.38 | 24 | 26 | 72 | 566.32 | 67.656 | 69.597 | -2.87 |
| 9 | 0.29 | 19 | 21 | 61 | 684.25 | 60.426 | 69.351 | -14.77 |

The water evaporation rate is not linear tendency with water vapor pressure difference (ΔP) at low air flow velocities and under natural convection conditions. This non-linearity of the water evaporation rate from the vapor pressure difference has been observed by other investigators for small airflow velocities and for free convection evaporation [2, 5, 8].

In Fig. 4, in the range of mean velocities above free surface between 0.20 and 0.38 m/s the experimental and obtained by proposed correlation (17) results are very close to the values obtained by Pauken [8] for the water vapor pressure difference. In addition, considering the correlation proposed by Tang [2] a large difference is observed. Overestimate discrepancies have been occurred between experimental and correlations from the literature results for the upper vapor pressure difference due to the exponential factor (n). The evaporation tank sizes may be one of the reasons for the large evaporation rates. Another reason may be the wind velocity above the water surface in their experiments [8].

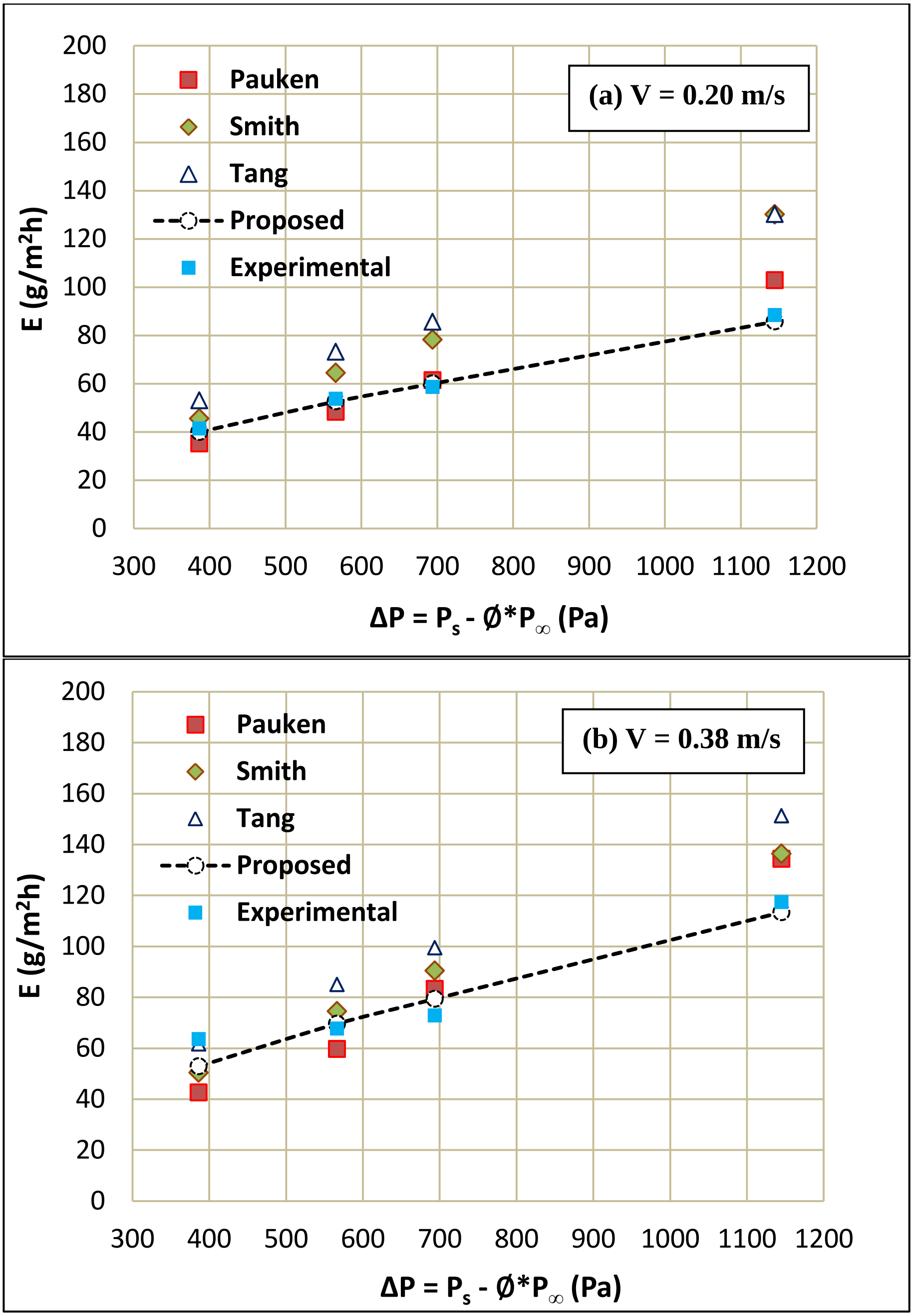


**Figure 4.** Depending on the partial vapor pressure difference, evaporation rate comparison of experimental results, proposed correlation and correlations from the literature

Percentage deviation values has remained in the range (-14.77 %) – (16.71 %) between measured and calculated water evaporation rates (Table 5). The measured and calculated water evaporation rates depending on air flow velocity above free surface, ambient air temperature and relative humidity are given in Fig. 5a. As the result of the comparison between the empirical model results and the experimental results, the experimental results are within an error band of ± 20%.

Experimental studies and theoretical expressions about water evaporation rate from free surface has been intensively carried out from past to present. Many researchers proposed empirical correlations in order to predict evaporation rate from free water surface [1,11]. However, they have been found large deviations among themselves.

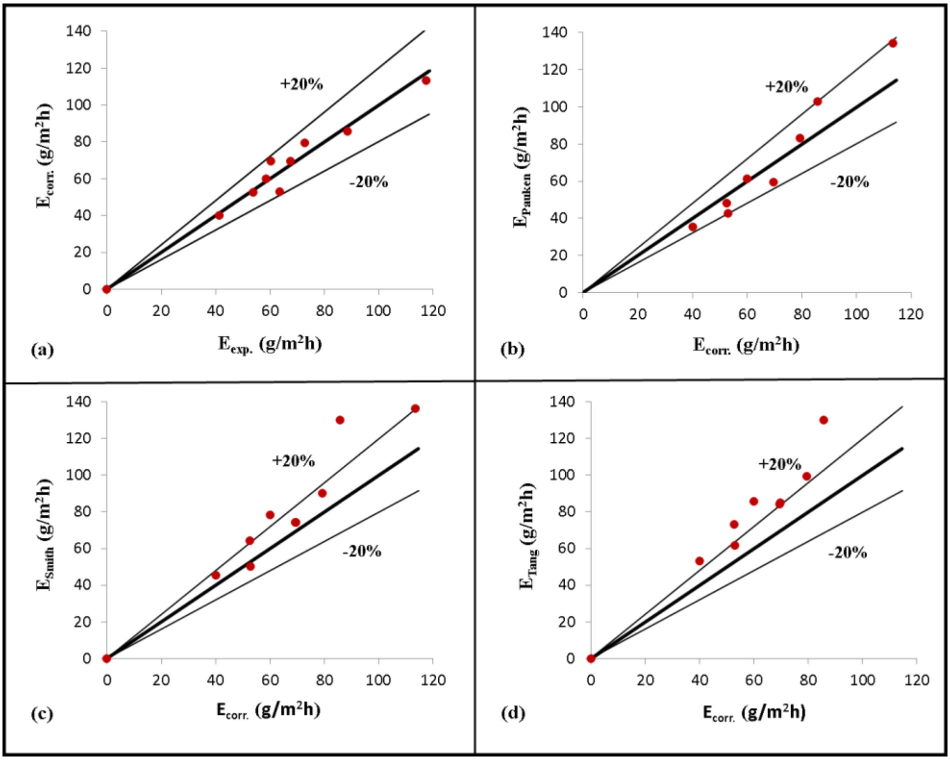


**Figure 5.** Comparison of the proposed correlation results with experimental measurements and available correlations results

In Fig. 5, proposed empirical correlation results of this study were compared with available correlations in the literature which was proposed for similar experimental conditions within an error band of ±20 %. The empirical correlation derived in this study, a better level of agreement was achieved in comparison with Pauken' s correlation. As it can be observed in Fig. 5c and in Fig. 5d, the values obtained by Smith [5] and Tang [2] overestimate the proposed empirical correlation results, but there have been no great differences. Finally, a good agreement was obtained between the experimental values and with those obtained with correlations available in the literature.

## 4. CONCLUSIONS

In this study, the effects of different air flow velocities above the water surface, relative humidity and temperature values of the ambient air on the evaporation rate from a horizontal free water surface are investigated and analyzed by using full factorial experimental design. As a result of the experiments; it is observed that, when either the air flow velocity or air temperature increases, water evaporation rate from free surface has also increased. However, this situation is reversed, when relative humidity of air is high.

An empirical correlation was derived by using the experimental results. When the water evaporation rates calculated with this correlation were compared with the values obtained by experimental results, it was observed that the calculated evaporation rates are within an error band of ±20%. When the experimental results compared to the available correlations individually, a better level of agreement was achieved.

Experimental studies on water evaporation rate at different process parameters must be improved using a high speed wind tunnel. Because, a low speed wind tunnel has been applied in this study. Additionally, experimental and numerical analysis can be examined for various air-water interface temperature difference.

**Nomenclature**

| | |
|---|---|
| A | Surface of evaporation area ($m^2$) |
| $D_{AB}$ | Diffusivity coefficient ($m^2/s$) |
| L | Characteristic length (m) |
| $h_m$ | Mass transfer coefficient (m/s) |
| $h_{fg}$ | Water latent heat of evaporation (kJ/kg) |
| J, E | Evaporation rate ($g/m^2h$) |
| $\dot{m}$ | Mass flow rate (g/h) |
| P | Pressure (Pa) |
| PIV | Particle image velocimetry |
| R | Gas constant (For water vapor = 0.4615 kPa.$m^3$/kg.K) |
| RH | Relative humidity of ambient air (%) |
| Sh | Sherwood number (-) |
| T | Temperature (°C) |
| V | Air flow velocity (m/s) |
| A, B | Correlation constants (-) |
| $\delta$ | Deviation (%) |

**Subscripts**

| | |
|---|---|
| n | Exponential factor |
| s | Surface |
| v | Vapor |
| w | Water |
| $\infty$ | Environment |
| exp | Experimental |
| corr | Correlation |

**Greek letters**

| | |
|---|---|
| $\rho$ | Air density ($kg/m^3$) |
| $\phi$ | Relative humidity of ambient air (%) |

**Acknowledgements / Teşekkür**

This authors are appreciative to Arçelik A.Ş the leading firm of durable consumer sector of Turkey for the usage laboratory, climate chamber and measurement devices.

**REFERENCES / KAYNAKLAR**

[1] Asdrubali, F., (2009). A scale model to evaluate water evaporation from indoor swimming pools, Energy and Buildings 41, 311-319.
[2] R. Tang, Y. Etzion, Comparative studies on the water evaporation rate from a wetted surface and that from a free water surface, Building and Environment 39 (2004) 77-86.
[3] W. H. Carrier, The temperature of evaporation, ASHVE Transactions 24 (1918) 25-50.
[4] ASHRAE. ASHRAE Handbook - HVAC Applications, Atlanta, GA, 2007.
[5] Smith, C. C., Lof G., Jones, R., (1994). Measurement and analysis of evaporation from an inactive outdoor swmming pool, Solar Energy 53-1, 3-7.
[6] Himus, G. W., Hincley, J. W., (1924). The effect of a current air on the rate of evaporation of water below the boiling point, Journal of the Society of Chemical Industry 43-34, 840-845.
[7] Rowher, C., (1931). Evaporation from free water surface, US Department of Agriculture in Cooperation with Colorado Agricultural Experiment Station, Technical Bulletin 271.
[8] Pauken, M. T., (1999). An experimental investigation of combined turbulent free and forced evaporation, Experimental Thermal and Fluid Science 18, 334-340.
[9] Sartori, E., (2000). A critical review on equations employed for the calculation of the evaporation rate from free water surfaces, Solar Energy 68, 77-89.
[10] Raimundo, M. A., Gaspar, R. A., Oliviera, A. V., Quintela, A. D., (2014). Wind tunnel measurements and numerical simulations of water evaporation in forced convection airflow, International Journal of Thermal Sciences 86, 28-40.
[11] Marek, R., Straub, J., (2001). Analysis of the evaporation coefficient and the condensation coefficient of water, International Journal of Heat and Mass Transfer 44, 39–53.
[12] Kline, S. J., and F. A. McClintock, (1953). Describing Uncertainties in Single-Sample Experiments, Mechanical Engineering, Vol. 75, No. 1, 3-8.
[13] Minitab Statistical Software User Guide for Release 17.3.0..