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Parameter Optimization of Particle Swarm Optimization Algorithm on Solar Distillation System

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Abstract – As the global population continues to grow, so does the demand for potable water. However, the ever-decreasing reserves of fresh water are under serious threat. Freshwater reserves constitute only 2.5% of the world's total water supply. According to various research reports, by 2050, 75% of the global population will struggle to access potable water and face severe water scarcity. To mitigate this issue, water resources need to be managed intelligently and sustainably. In addition, scientists are working on desalination systems to make non-potable water drinkable. This study focuses on a solar distillation system with a conical shape designed to produce drinkable water by distilling saline water under appropriate conditions. Since the performance of these solar distillation systems depends on multiple parameters, careful optimization is necessary. In this study, the optimization of three key parameters was carried out using Particle Swarm Optimization (PSO): solar radiation, saline water mass, and water inlet temperature. As a result of the optimization, potable water production of 1.81780 kg/m² with 63.51% efficiency was achieved under the conditions of 1000 W/m² solar radiation, 3 kg saline water mass, and 30°C water inlet temperature.

Keywords – Grey Wolf Optimization, Solar Distillation System, Parameter Optimization.

I. INTRODUCTION

Potable water is of vital importance for human life; however, only approximately 2.5% of the world's total water supply is directly drinkable. Over the past two decades, freshwater sources have faced a serious depletion threat due to population growth and industrialization. UN reports indicate that by 2050, three-quarters of the world's population will experience severe shortages of clean water [1]. Desalination wastewater treatment technologies are considered viable solutions to address the challenge of water scarcity [2]. However, due to the high energy requirements of the technologies used in desalination systems, the cost of freshwater production has increased. Renewable energy sources are becoming more accessible and cost-effective for this purpose [3].

Solar desalination techniques are known for their remarkable feasibility, low cost, and eco-friendliness. Solar energy uses thermal energy from sunlight to evaporate saline water and then condenses it into potable water [3]. According to the World Health Organization (WHO), water salinity should not exceed 500ppm, although in some cases, levels up to 1000 ppm are permitted [3]. However, according to a survey conducted by WHO and the United Nations Children's Fund (UNICEF), A significant number of people, estimated to be around 122 million globally, rely on untreated water sources such as rivers, lakes and ponds [4]. This directly obtained water has an approximate salinity of 10,000 ppm, while the salinity of seawater generally falls within the range of 35,000 to 45,000 ppm. In developing countries, unreliable drinking water is a major cause of widespread diseases and deaths, accounting for 50% of child mortality [3]. Many research efforts have been carried out to assess and improve the performance of solar distillers [5]. Vembu et al. developed and tested two types of solar distillation devices: one with a black absorber and charcoal cylinder (CSS-BA) and another with a black absorber and charcoal-coated cylinder (CSS-BA&CC) produced 2.88 kg/day, resulting in a 44.4% increase in efficiency [6].

Attia et al. investigated the performance of a single-slope solar distiller by adding introducing 25 round saline spheres into pools at water levels of 15 mm and 20 mm, discovering that these saline spheres played a significant contribution to improving the performance of solar desalination systems. The first scenario provided 8.06% more efficiency than second and 17.45% more efficiency than the conventional solar distillation device [7]. Kumar et al. optimized the parameters of a solar distillation unit using MCDM-GRA and determined that the best parameters for achieving maximum output include 1000W/m^2 solar radiation, 3kg saltwater, and a water temperature of 40°C. Under these conditions, the system achieved an efficiency of 65.33% along with produced 1.96 kg of drinkable water. Conversely, the ABC algorithm suggested that the best possible settings are 1000 W/m^2 solar intensity, 3kg saline mass, and 30°C water inlet temperature, yielding 64% efficiency and producing 1.92 kg of drinkable water [3].

In this study, optimization was performed using the Particle Swarm Optimization (PSO) algorithm to achieve maximum efficiency at minimum cost in solar distillation systems. Solar radiation, water temperature, and saline water mass are the most critical parameters determining system performance in solar distillation systems. In this work, these three parameters were optimized. Since the PSO algorithm is cost- effective and known for its fast convergence capability in optimization problems, it is a suitable algorithm for solar distillation systems. This study aims to evaluate the applicability of the PSO optimization method for solar distillation systems and propose an alternative solution in addition to the methods presented in the literature.

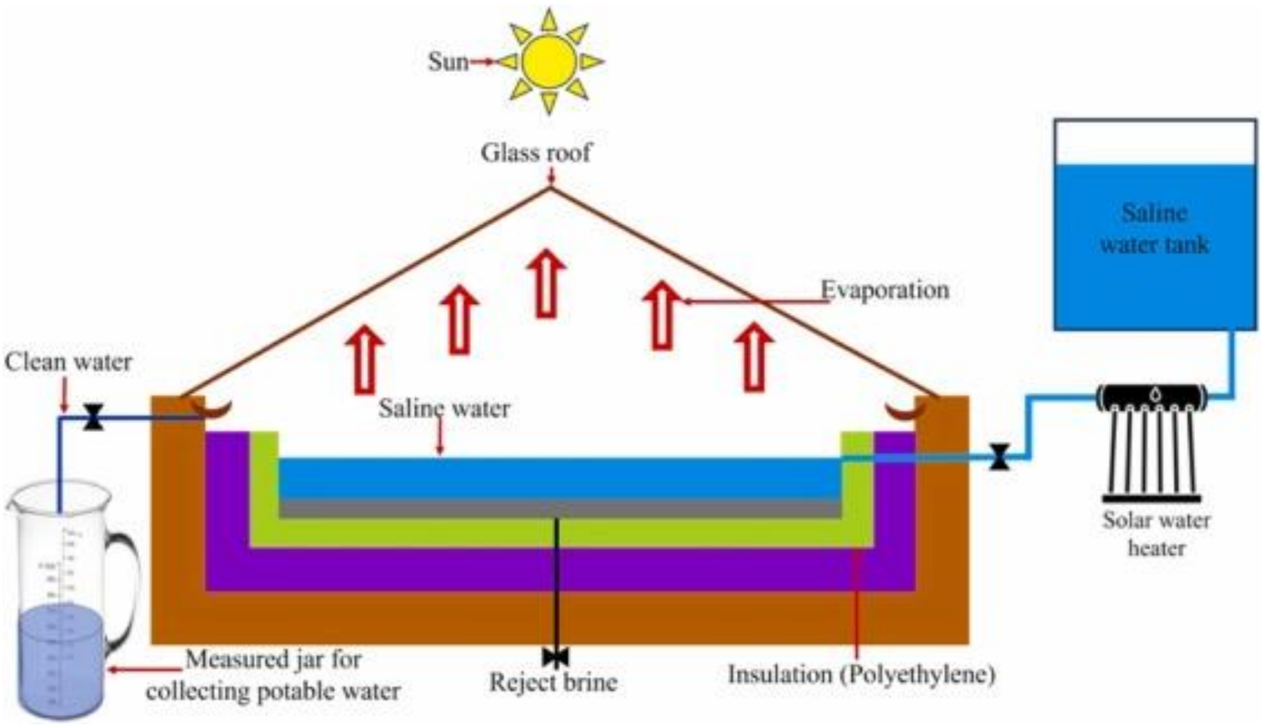

Fig.1 Pyramid solar still with water heater [3]

II. MATERIALS AND METHOD

A. Particle Swarm Optimization (PSO)

Particle Swarm Optimization (PSO) is a metaheuristic technique influenced by the collective movement of animals, such as fish schools and bird flocks. First presented by [8] PSO is widely used algorithm. PSO is a global optimization algorithm that does not require algebraic operations to compute changes in the objective function. Initially, the method was capable of solving only nonlinear continuous functions, but over time, it was developed further to be applied to more complex engineering problems for finding optimal solutions.

The PSO algorithm is based on the movement patterns of bird and fish swarms. The behavior of animal groups searching for an unknown object or target in their search space is likened to solving an optimization problem. While searching, animals tend to follow the ones closest to the target. The fundamental principle of PSO is to improve information sharing among individuals in the group. In this method, each individual in the swarm is referred to as particle, and the entire group of particles is called a swarm [8].

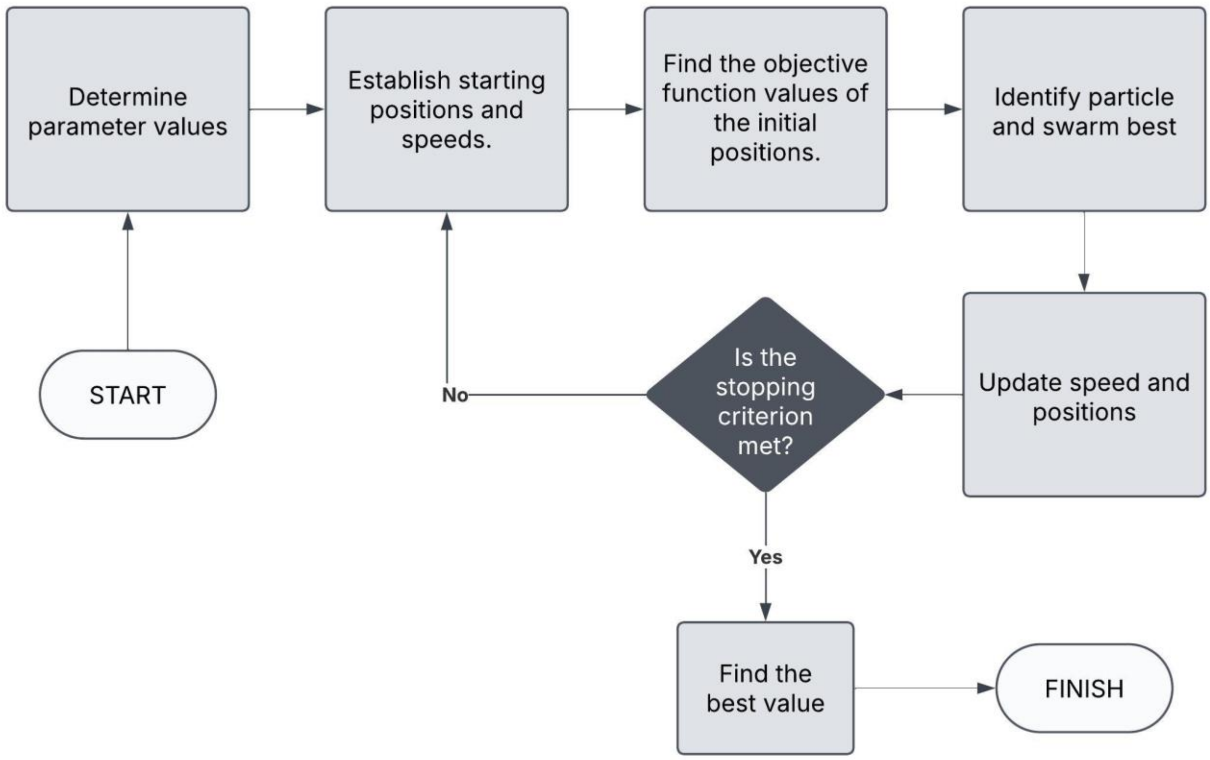

Fig. 2 PSO flow chart

The PSO algorithm begins the process by randomly initializing parameters such as problem dimension, population size, inertia weight, and the initial number of iterations. During this process, the position and velocity vectors are assigned values within specified boundaries. The objective function values of the randomly generated position vectors are then calculated, and the best solution for each particle along with the globally optimal solution for the swarm is determined. Afterward, the velocity vector is updated according to the equation shown in Equation (1).

$$V_i^{k+1} = \left(w^{k+1} * V_{i\,j}^{k}\right) + c_1.r_1\left(p_{i\,j}^{k} - x_{i\,j}^{k}\right) + c_2.r_2\left(g_{ij} - x_{i\,j}^{k}\right) \quad (1)$$

In the equation, r_1 and r_2 are random values uniformly values spread within the interval [0,1], while c_1 and c_2 coefficients representing cognitive learning (individual particle learning) and social learning (swarm learning), respectively. In the next step, the new position vector is obtained through incorporating the adjusted velocity vector to the earlier position vector.

$$x_{i\,j}^{k+1} = x_{i\,j}^{k} + v_{i\,j}^{k+1} \tag{2}$$

If some particles exceed the flower or upper boundaries during the position update, their positions are adjusted to remain within the specified limits. The objective function values for the newly updated positions are recalculated, and the best solutions for each particle and swarm are updated accordingly. The algorithm proceeds until in it hits the set iteration threshold.

BEGIN
Assign random velocity and position values to ***P particles****.*
REPEAT
    FOR i=1 TO p
        Compute the fitness value.
        Update the ***Pbest*** *(personal best position).*
        Update the ***Gbest*** *(globally optimal position).*
        Revise the velocity and position values.
    END FOR
UNTIL termination criterion is met.
END

Fig. 3 PSO pseudocode

III. RESULTS

Rin this study, the Particle Swarm Optimization (PSO) algorithm was applied to optimize the efficiency of a pyramid-shaped solar distillation system. The optimization aimed increase the system's productivity and efficiency by focusing on three key parameters: solar radiations (S) ranging from 600-1000 W/m^2, saline water mass (M) ranging from 1-3 kg and inflow water temperature (T) ranging from 30-50°C. The initial values for the algorithm were set as follows: particle count 30, iteration count 100, learning coefficients c_1=2 and c_2 = 2, and inertia weight w = 0.7.

The objective function used in this study was derived from the equations presented in the work of Mathan Kumar et al. The productivity and efficiency calculations are given in Equations (3) and Equation (4), respectively:

$$Productivity = -0.999 + 0.001717 * solar\ radiation + 0.4583 * saline\ water\ mass - 0.00917 * water\ temperature \tag{3}$$

$$Efficiency = -17.94 + 0.08388 * solar\ radiation - 0.17 * saline\ water\ mass - 0.064 * water\ temperature \tag{4}$$

These equations and their coefficients were determined based on the physical characteristics of the system. [3] The results obtained from the optimization process using the PSO algorithm are presented in the table below:

Table 1. Optimization Results Table

Algorithms	Solar radiation (S)	Saline water mass (M)	Water Temperature(T)	Productivity (P) (kg/m^2)	Efficiency(E) (%)	Objective Function
PSO	1000	3	30	1.818	63.51	-32.664
ABC	1000	3	40	1.960	65.33	-31.868

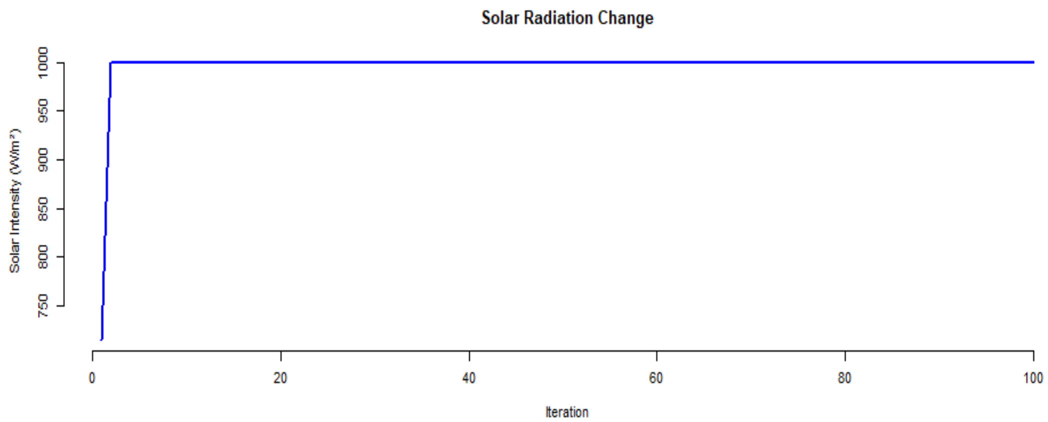

Fig. 4 Solar radiation change

In the first iteration, solar radiation was 715 W/m^2, but it quickly converged, reaching 1000 W/m^2 in the second iteration, achieving the maximum level early in the process.

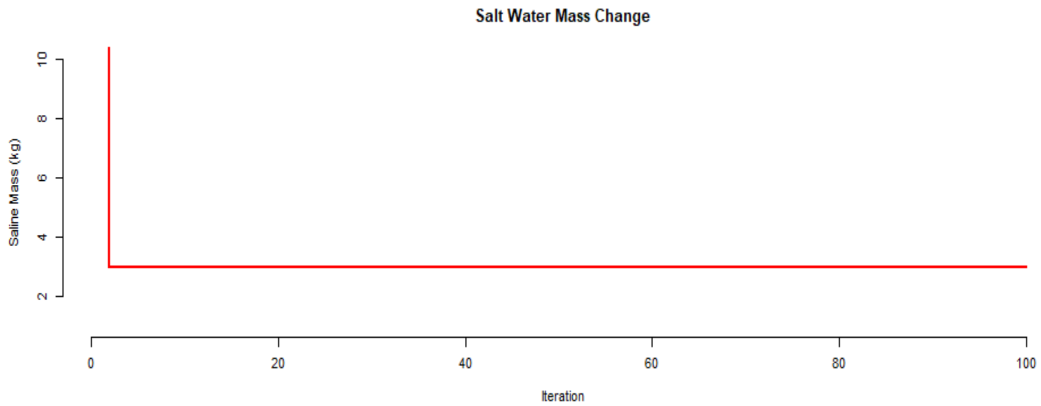

Fig. 5 Salt water mass change

Due to the random initialization of particles, the saline water mass was initially measured at 985.21 kg in the first iteration. However, by the second iteration, it successfully converged to 3.00 kg.

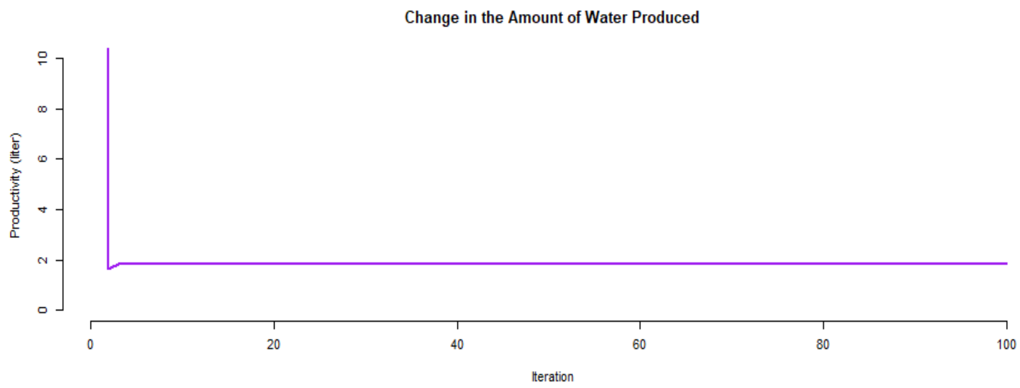

Fig. 6 Change in the amount of water produced

The change in the amount of produced water, driven by the fast convergence of the PSO algorithm, shows that 444 liters of water was produced in the first iteration. 1.63 liters in the second iteration, and 1.82 liters from the third iteration onward.

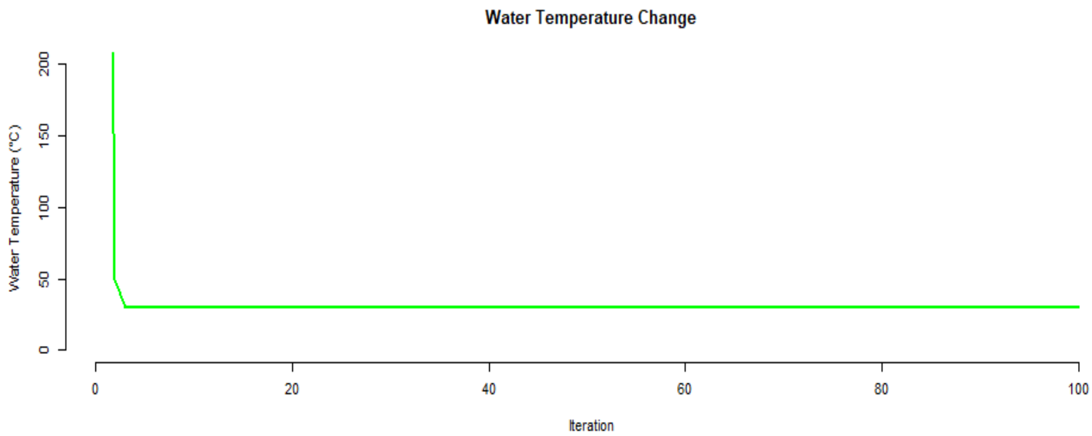

Fig. 7 Water temperature change

The water temperature quickly converged to 30°C, achieving maximum water production at this temperature.

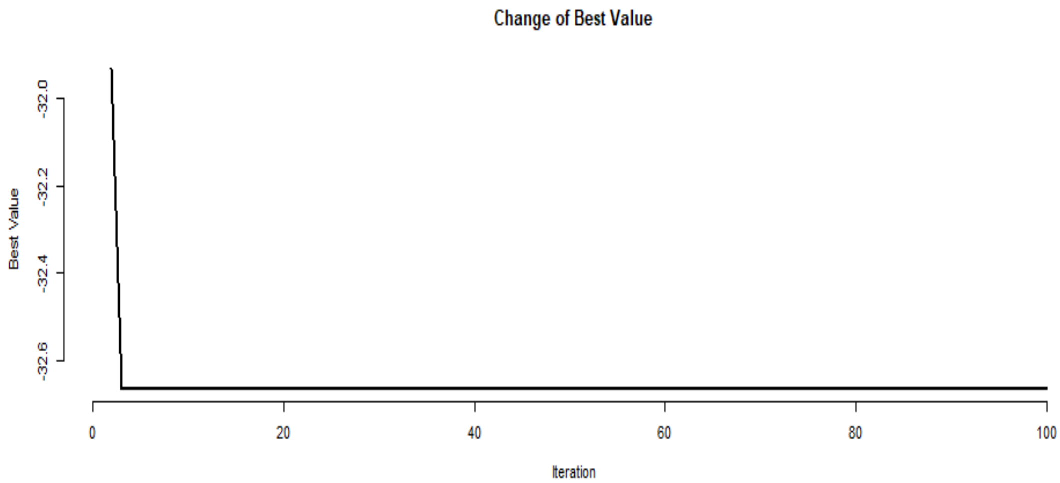

Fig. 8 Change of best value

When examining the best value change graph, the optimized process quickly adjusts the variables in the initial iterations and stabilizes them. As a result of our optimization study on the system, optimal water production was achieved at 30°C water inlet temperature, 3 kg saline water mass, and 1000 W/m^2 solar radiation.

IV. DISCUSSION AND CONCLUSION

According to the experimental results of this study, the PSO algorithm reached the global maximum under conditions of 1000 W/m^2 solar radiation, 3kg saline water mass, and 30°C water inlet temperature, achieving 63.51% efficiency and producing 1.818 kg/m^2 of drinkable water. According to the research conducted by [3], the ABC algorithm produced 1.96 kg/m^2 of drinkable water with 65.33% efficiency under conditions of 1000 W/m^2 solar radiation, 3 kg saltwater, and 40°C water inlet temperature. The PSO algorithm demonstrated a performance close to that of the ABC algorithm used in [3] work.

While the PSO algorithm is recognized for its rapid convergence to the global maximum, the ABC algorithm demonstrated greater accuracy owing to its extensive search capability.

In future studies, other parameters affecting solar distillation systems can be taken into consideration for further optimization. Additionally, hybrid approaches combining different metaheuristic methods could be explored to mitigate the weakness of individual optimization algorithms and achieve more robust optimization results.

REFERENCES

[1] Shaikh, J. S., Aswalekar, U., Ismail, S., & Akhade, A. (2024). The potential of integrating solar-powered membrane distillation with a humidification–dehumidification system to recover potable water from textile wastewater. *Chemical Engineering and Processing-Process Intensification*, *205*, 110036.

[2] Jawed, A. S., Nassar, L., Hegab, H. M., van der Merwe, R., Al Marzooqi, F., Banat, F., & Hasan, S. W. (2024). Recent developments in solar-powered membrane distillation for sustainable desalination. *Heliyon*.

[3] Paulsingarayar, S., Kumar, R. S., Vijayakumar, S. J. D., & Kumar, N. M. (2024). Multi-criteria decision-making and Artificial Bee Colony Algorithm for optimization of process parameters in Pyramid Solar still. *Desalination and Water Treatment*, 100543.

[4] Qin, Q., Lu, H., Zhu, Z., Qiu, Y., Liu, X., & Yin, D. (2025). Safety and security of household water purifiers against pathogenic microbial contamination and bio-risk evaluation of their microbial community structures. *Separation and Purification Technology*, *357*, 130012.

[5] Attia, M. E. H., & Elazab, M. A. (2024). Enhancing drinkable water production in conical solar distillers: Comparative analysis of magnet fin heights. *Solar Energy*, *272*, 112476.

[6] Abdelgaied, M., Attia, M. E. H., Arıcı, M., & Abdel-Aziz, M. M. (2022). Enhancing the productivity of hemispherical solar distillers using dyed flax fibers as natural inexpensive porous materials. *Journal of Cleaner Production*, *379*, 134674.

[7] Vembu, S., Attia, M. E. H., Thangamuthu, M., & Thangamuthu, G. (2023). Energy, exergy, and economic analysis of solar still using coal cylinder fins: an experimental study. *Environmental Science and Pollution Research*, *30*(2), 2597-2606.

[8] Clerc, M., & Kennedy, J. (2002). The particle swarm-explosion, stability, and convergence in a multidimensional complex space. *IEEE transactions on Evolutionary Computation*, *6*(1), 58-73.