



Optimising Saltwater Coolants in Peltier-Based Systems for Enhanced Fever Management and Energy Efficiency

Faiza Yuniati^{1*}, Erwin Erwin², Sherli Shobur¹

¹Department of Epidemiology Surveillance, Health Polytechnic of Palembang, Palembang 30126, Indonesia

²Department of Mechanical Engineering, Sultan Ageng Tirtayasa University, Banten 42163, Indonesia

*Corresponding Author's Email: faizayuniati@poltekkespalembang.ac.id

Abstract

Fever management in paediatric care requires efficient and reliable cooling systems; however, traditional methods often fail to meet these demands due to discomfort and maintenance challenges. This study investigates the effectiveness of different saltwater concentrations (5%, 10%, and 20%) as coolants in a Peltier-based cooling system designed to enhance cooling efficiency for paediatric fever management. The research aims to identify the optimal salt concentration that maximises cooling performance and energy efficiency. An experimental setup was used to compare the cooling performance of the three saltwater solutions against pure water, with temperature data collected at one-minute intervals over a 60-minute period. Key parameters measured included temperature reduction and energy consumption. The results demonstrated that the 10% saltwater solution achieved the greatest temperature reduction and energy efficiency, significantly outperforming both the higher (20%) and lower (5%) salt concentrations, as well as pure water. In contrast, the 20% saltwater solution initially exhibited a temperature increase, likely due to its higher viscosity, which hindered heat dissipation. The 5% saltwater solution provided only marginal improvements over pure water, indicating the necessity of an optimal salt concentration for effective cooling. These findings suggest that optimising salt concentration in coolants is critical for enhancing the performance of Peltier-based cooling systems, particularly in medical applications requiring precise temperature control. The study provides valuable insights for developing more efficient and reliable fever management systems, with broader implications for various medical and industrial cooling applications.

Keywords: *Energy Efficiency; Fever Management; Paediatric Healthcare; Peltier-Based Cooling; Saltwater Coolant*

Introduction

The effective management of fever, particularly in paediatric healthcare, is critical for maintaining the well-being of children. While fever management strategies have evolved, traditional methods such as cold compresses and gel ice pads often face limitations, including discomfort and maintenance challenges (Sukarno *et al.*, 2023; Yuniati *et al.*, 2025). Innovative approaches to fever management are increasingly important, especially as current paediatric devices remain limited (Ademola, 2020). As a result, there is an urgent need to develop more efficient and user-friendly cooling systems specifically designed for paediatric use, which could significantly improve care quality (Siahmargoi *et al.*, 2019).

Recent advancements in thermoelectric technologies, particularly Peltier elements, offer promising possibilities for improving cooling systems. Peltier devices, known for their energy efficiency, reliability, and compactness, are now being explored for various medical applications, including fever

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management systems (Balaji & Irons, 2023). However, optimising the cooling performance of these systems remains a significant challenge, particularly in developing a coolant that can effectively enhance heat transfer and maintain the necessary low temperatures (Hijano *et al.*, 2023).

Current cooling systems, while somewhat effective, often fail to meet the demands of rapid and efficient fever management, particularly in paediatric care. Traditional methods are either uncomfortable for patients or require constant maintenance to remain effective. This has led to the need for more advanced systems that can provide consistent and reliable cooling with minimal intervention. The adoption of Peltier elements in cooling systems shows promise; however, these systems still require an optimised cooling medium to enhance their overall performance (Ceviz *et al.*, 2023).

An emerging solution to this problem is the integration of saltwater as a coolant within these systems. Saltwater's high thermal conductivity and specific heat capacity make it a potential candidate for improving the cooling efficiency of systems that utilise the Peltier effect. However, the precise impact of varying salt concentrations on the performance of such cooling systems remains underexplored. Addressing this knowledge gap is crucial for developing more effective fever management systems that can be widely applied in clinical settings (Zhang *et al.*, 2020).

The Peltier effect, which allows for precise temperature control, has been widely applied in various cooling technologies, from consumer electronics to industrial systems. Research has shown that Peltier elements can be highly effective in medical applications, such as temperature control in wearable devices (Sirikasemsuk *et al.*, 2021). These elements work by creating a temperature difference when an electric current is applied, which can be harnessed for cooling in medical settings. However, the performance of Peltier-based systems is highly dependent on the coolant used, necessitating further research into optimising these systems for medical applications (Kondratiev *et al.*, 2022).

One potential approach is the use of saltwater as a cooling medium. Studies have indicated that increasing the salinity of a coolant can enhance its thermal properties, thereby improving the overall cooling performance of systems that rely on the Peltier effect. For instance, higher salt concentrations have been associated with improved heat transfer efficiency in various industrial cooling applications, suggesting similar benefits could be achieved in medical cooling systems (Skovajsa & Zalesak, 2018). However, the relationship between salt concentration and cooling performance in medical Peltier systems remains underexplored, highlighting a significant gap in the current research.

Further studies have explored the use of different salt concentrations in enhancing the cooling efficiency of systems that rely on phase change materials or other advanced cooling technologies. For example, research into the use of saltwater in solar distillation units has shown that optimising salt concentrations can significantly improve system efficiency (Shilpa *et al.*, 2023). This research suggests that a similar approach could be beneficial for improving the cooling performance of Peltier-based medical devices, particularly in the context of fever management (Atta, 2018).

Despite the promising advancements in the use of Peltier elements and saltwater coolants, there is still a lack of comprehensive studies that specifically address their application in paediatric fever management systems. While research has explored the thermal properties of saltwater and its potential as a coolant, few studies have focused on how different salt concentrations affect the cooling performance of Peltier-based systems designed for medical use (dos Santos *et al.*, 2022). This gap in the literature underscores the need for targeted research that can provide clear guidelines for optimising these systems for clinical applications.

Furthermore, while some studies have examined the use of Peltier elements in general cooling systems, there is limited data on their performance when integrated with saltwater coolants, especially at varying concentrations (Zhang *et al.*, 2019). This lack of detailed analysis presents a significant barrier to the development of optimised fever management systems that can meet the specific needs of paediatric care. Addressing these gaps is crucial for advancing the field and improving the effectiveness of cooling systems in clinical settings.

The existing literature also highlights the need for experimental studies that can systematically

investigate the effects of different salt concentrations on the cooling efficiency of Peltier-based systems. Such studies are essential for developing practical solutions that can be implemented in real-world healthcare environments, particularly for managing fever in children, where precise temperature control is critical (Ruiz-Ortega, Olivares-Robles & Badillo-Ruiz, 2021).

This research aims to examine the effect of different salt concentrations (50g, 100g, and 200g) on the performance of a Peltier element cooling system, with the goal of identifying the optimal salt-to-water ratio that maximises cooling performance and energy efficiency. The study also seeks to develop coolants that can function optimally within the temperature range of 30 to 40 degrees Celsius, aligning with the human body's temperature range, which is critical for managing fever in paediatric patients.

Although this study is positioned within the domain of thermal systems, it is contextually situated in paediatric fever management. Paediatric patients present unique physiological and thermal comfort requirements compared to adults, such as a higher surface area-to-body mass ratio and lower tolerance to external temperature changes. Consequently, the proposed cooling system, incorporating Peltier elements and saltwater-based coolants, was specifically designed to deliver controlled, safe, and comfortable cooling suitable for children. This research acknowledges the physiological specificity of paediatric patients and targets an effective, child-appropriate thermoregulation method.

The novelty of this study lies in its focus on optimising the salt concentration in the coolant to enhance the cooling performance of Peltier-based systems, a topic that has not been extensively explored in the literature. By addressing this gap, the research aims to provide new insights that can contribute to the development of more effective and energy-efficient fever management systems in paediatric care.

The scope of the study includes experimental design and product development, focusing on the integration of saltwater coolants with Peltier elements in active fever compress systems. The research will systematically explore the impact of varying salt concentrations on the cooling performance and energy efficiency of these systems, providing valuable data that can inform future innovations in paediatric healthcare technology.

Material and Methods

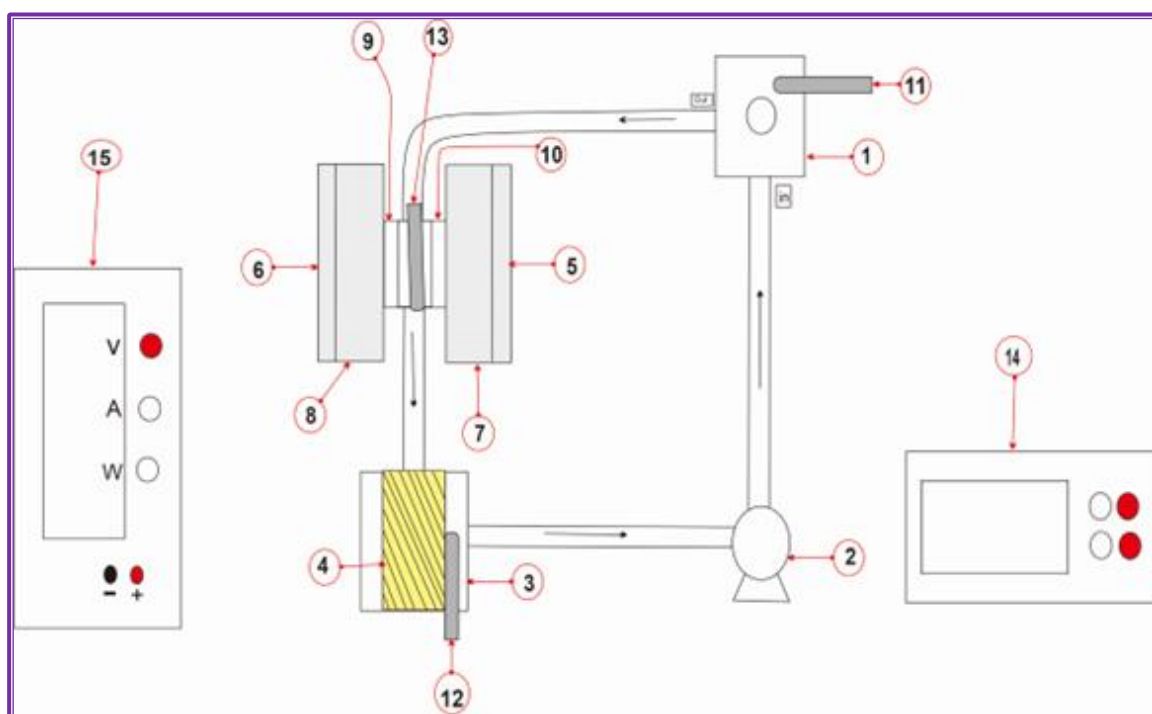
The materials used in this study included the essential components required for constructing and testing the active fever compress system. The primary materials comprised an acrylic reservoir, a liquid pump, a water-cooling block, and a heat source, which together formed the core of the cooling system. Additionally, two Peltier elements were employed to generate the cooling effect, with heatsinks attached to enhance heat dissipation (Sari *et al.*, 2022).

Refrigerator Utilizing the Peltier Effect. Sensors (PT100) (Abdullah *et al.*, 2024) were strategically placed on the reservoir, water cooling block, and heatsink to measure temperature variations. A 6-channel RS485 data acquisition system (Choi *et al.*, 2024) was employed to collect real-time data, and a power supply was used to maintain the operation of the entire system. The coolants tested included freshwater (as the control), and saltwater solutions (Li *et al.*, 2024) with concentrations of 50g/L (Concentration A), 100g/L (Concentration B), and 200g/L (Concentration C). This study has received approval from the Health Research Ethics Committee of the Health Polytechnic of the Ministry of Health in Palembang, with Approval Number: 0817/KEPK/Adm2/2024.

The selection of saltwater concentrations at 50 g/L (Concentration A), 100 g/L (Concentration B), and 200 g/L (Concentration C) was based on thermodynamic principles and the thermal conductivity behaviour of electrolyte solutions. In Peltier-based cooling systems, increasing salt concentration can enhance both specific heat capacity and thermal conductivity, which improves heat transfer performance up to an optimal point. However, excessively high concentrations raise the fluid's viscosity, hindering flow and reducing cooling efficiency. These concentrations were therefore selected to explore this performance threshold. The relevant heat conduction equation used to describe the thermal transfer process is:

where q is the heat transfer rate, k is the thermal conductivity of the coolant, A is the heat exchange area, and dT/dx is the temperature gradient.

The experimental setup, as illustrated in the setup diagram, involved integrating all components of the cooling system. The acrylic reservoir was filled with the prepared coolant, which was then circulated through the system using a liquid pump. The Peltier elements were mounted between heatsinks and positioned to facilitate efficient cooling of the water block. The heat source was applied to the water block, simulating the thermal load. Temperature data was continuously collected by the PT100 sensors placed at strategic points: the reservoir, the water-cooling block, and the Peltier heatsink. The system was initiated, allowing the coolant to circulate and stabilise, with data recorded at one-minute intervals over the course of 60 minutes.



(1) Reservoir, (2) Pump, (3) Water block, (4) Load (heat sources), (5) Fan 1, (6) Fan 2, (7) Heatsink 1, (8) Heatsink 2, (9) Peltier 1, (10) Peltier 2, (11) Sensor temp 1 Reservoir, (12) Sensor temp 2 Water block, (13) Sensor temp 3 Peltier, (14) Data Acquisition, (15) Power supply.

The key parameters measured during the experiments included temperature, cooling rate, and system efficiency. Temperature readings were taken at the reservoir, the Peltier cooling unit, and the load to assess the coolant's performance at different points in the system. The cooling rate was calculated by analysing the change in temperature over time, while system efficiency was determined by comparing the electrical energy consumed by the Peltier elements to the degree of temperature reduction achieved. These parameters were crucial for understanding how variations in salt concentration influenced the cooling performance.

Statistical Analysis

The statistical analysis involved both descriptive and correlation analyses to explore the relationship between salt concentration and cooling performance. Descriptive statistics provided an initial overview of the temperature data, cooling rates, and system efficiency across different salt concentrations. Correlation analysis was used to determine the strength and nature of the relationship between the salt concentration and cooling performance metrics. The presentation of statistical results should include correlation values along with 95% confidence intervals to demonstrate the tool's effectiveness and efficiency. Additionally, ANOVA tests were conducted to compare the means of the different coolant types, ensuring that the observed differences were statistically significant. This comprehensive analysis allowed for a deeper understanding of how salt concentration affects the cooling efficiency of the system.

Results

The experimental study conducted aimed to assess the cooling performance of an active fever compress system using different saltwater concentrations as coolants. The experiment involved the use of three distinct salt concentrations (50g/L, 100g/L, and 200g/L) along with freshwater control. Temperature data was collected at one-minute intervals over a 60-minute period using PT100 sensors placed on the reservoir, Peltier cooler, and the load. Initial temperatures across all coolant types were stabilised between 24°C to 25°C before the experiment commenced.

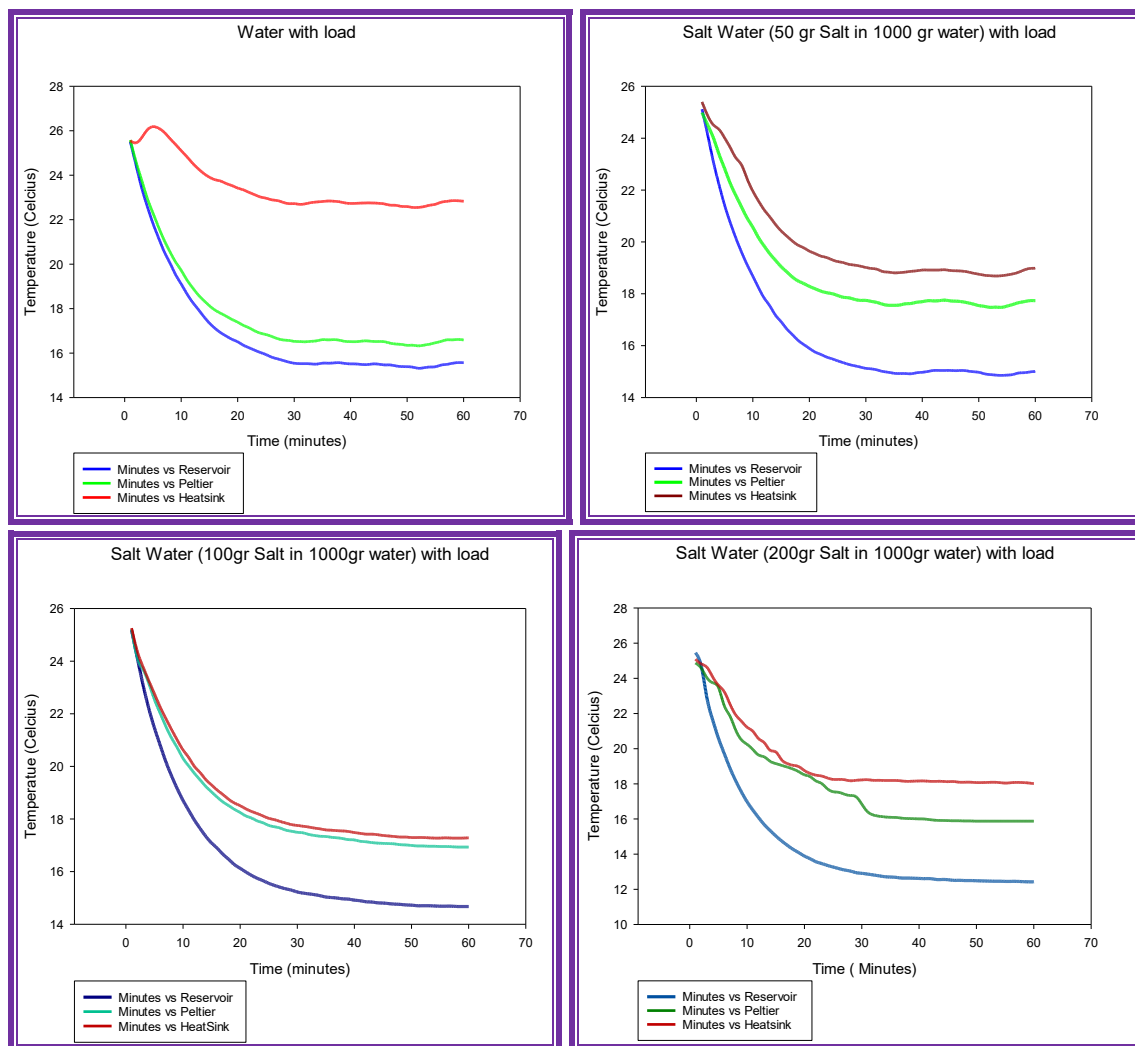


Figure 1: Comparative Temperature Profiles of Four Coolants Over Time

Figure 1 shows the experimental results for varying cooling performance of the system with different coolant concentrations. Temperature measurements at critical points, including the reservoir, Peltier, and load, revealed significant temperature differences between the system using water, and those using concentrations A, B, and C. The system with coolant concentration B exhibited the best performance, with a temperature difference between the water block and reservoir of approximately 2°C (17.4-15.2°C) and an energy consumption of 48.7 Watts. In contrast, the water coolant showed a temperature difference of 7°C (22.5-15.3°C) with an energy consumption of 50.4 Watts, while concentrations A and C displayed temperature differences of 4°C and 6°C, with energy consumptions of 57.3 Watts and 69 Watts, respectively.

The initial temperatures of the four coolants—water, 5% salt water, 10% salt water, and 20% salt water—were measured at the beginning of the experiment, with values ranging between 24.9°C and 26.1°C. The lowest baseline temperature was observed in 5% salt water (24.9°C), while the highest was recorded in 20% salt water (26.1°C). Each coolant was tested three times, and the average baseline temperatures were as follows: 25.57°C for water, 25.4°C for 5% salt water, 25.23°C for 10% salt water, and 25.73°C for 20% salt water. Notably, the highest average baseline temperature was found in 20% salt water, while the lowest was in 10% salt water.

Table 1: Baseline Temperature Comparison of Four Coolant Types

Types of Coolant		Temperature (°C)			
		Time (0)	Mean	SD	p-value
Water (N=3)	Water 1	25.30			0.478*
	Water 2	25.70	25.57	0.23	
	Water 3	25.70			
Salt water 5% (N=3)	Salt water 5% 1	25.60			
	Salt water 5% 2	24.90	25.4	25.4	
	Salt water 5% 3	25.70			
Salt water 10% (N=3)	Salt water 10% 1	25.00			
	Salt water 10% 2	25.20	25.23	25.23	
	Salt water 10% 3	25.50			
Salt water 20% (N=3)	Salt water 20% 1	25.10			
	Salt water 20% 2	26.10	25.73	25.73	
	Salt water 20% 3	26.00			

Note: * ANOVA test, significant at $P < 0.05$ (CI 95%)

Abbreviation: SD Standard Deviation

The Kolmogorov-Smirnov test was applied to assess the normality of the temperature data across the four coolant types. The results indicated that the temperatures at each observation time followed a normal distribution, as the p -values were greater than 0.05. This suggests that the temperature data for all coolant types did not significantly deviate from a normal distribution, validating the assumption of normality required for subsequent statistical analyses.

An ANOVA test was conducted to determine if there were any statistically significant differences in the baseline temperatures among the four coolants. The results showed no significant difference in the baseline temperatures (p -value = 0.478), confirming that the initial temperatures across all coolant types were homogeneous. This homogeneity in baseline temperatures suggests that any differences observed in cooling performance during the experiment were not influenced by initial temperature disparities.

Table 2 shows in the first 10 minutes after the system was activated, a noticeable decrease in temperature was observed in three of the coolants: water, 5% salt water, and 10% salt water. During this initial period, the most significant temperature drop occurred in 10% salt water, which decreased by 4.8°C, followed by a 2.5°C drop in 5% salt water, and a minor decrease of 0.47°C in water. In contrast, 20% salt water experienced an initial increase in temperature from 25.73°C to 26.27°C, followed by a gradual temperature decrease beginning at the 20-minute mark. By the end of the 60-minute observation period, 10% salt water demonstrated the greatest overall temperature reduction of 7.96°C, followed by 5% salt water with a reduction of 6.43°C. The temperature reductions for water and

20% salt water were nearly identical, at 2.74°C and 2.73°C, respectively. The within-group analysis revealed a significant difference between the average initial temperature and the temperatures recorded from the 10-minute to the 60-minute measurements for each coolant type (p -value = 0.000). Additionally, the between-group analysis confirmed significant differences in temperature reductions across the different coolant types (p -value = 0.000).

Table 2: Temperature Changes for Four Coolant Types at Six Specific Time Measurement

Coolant Types	Mean Temperature (0C)							Change within-coolant		Coolants Effects (Between group x time)		
	Baseline	101	201	301	401	501	601	F	p-value	F	P-value	PES
Water	25.57	25.10	23.40	22.73	22.57	22.57	22.83	2.74	0.00	27.62	0.00	0.91
Salt water 5%	25.4	22.90	19.57	19.00	18.93	18.77	18.97	6.43				
Salt water 10%	25.23	20.43	18.50	17.73	17.47	17.27	17.27	7.96				
Salt water 20%	25.73	26.27	24.07	23.27	23.13	23.00	23.00	2.73				

F: Estimated mean differences obtained using repeated measures ANOVA, significance at $p < 0.05$

^a Test of within trial effect, significance at $p < 0.05$

^b Test of between trial effect, significance at $p < 0.05$

Abbreviation; SD: Standar Deviation, PES: Partial eta squared

The Figure 2 illustrates the average temperature reduction over six observation times for four different coolant types. The 10% salt water demonstrated the most significant and consistent temperature drop across all time points, followed by 5% salt water. The water coolant exhibited a moderate decrease, while the 20% salt water showed the least reduction in temperature, with some fluctuations observed throughout the measurement period. This pattern indicates varying cooling efficiencies among the tested coolants, with 10% salt water consistently outperforming the others.

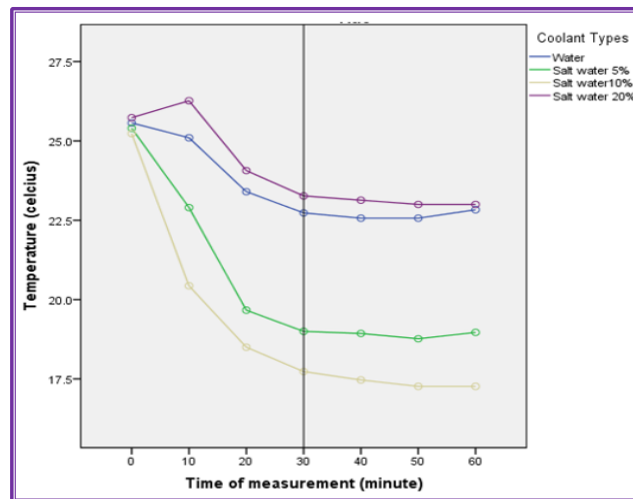


Figure 2: Average Temperature Reduction Across Six Observation Times for Four Coolant Types

The Post Hoc comparison revealed significant differences in the average temperature changes between several coolant types. The largest mean difference (MD) was observed between 10% salt water and 20% salt water (MD = 4.938, $p < 0.001$), followed by the difference between 10% salt water and regular water (MD = 4.410, $p < 0.001$). In contrast, the smallest mean difference was observed between 20% salt water and regular water (MD = 0.529, $p = 1.000$), indicating no significant difference between these two coolants. Additionally, significant differences were found between water and 5% salt water (MD = 3.019, $p = 0.009$), and between 5% salt water and 20% salt water (MD = 3.548, $p = 0.003$). However, there was no significant difference between 5% salt water and 10% salt water (MD = 1.39, $p = 0.368$), or between water and 20% salt water (MD = 0.529, $p = 1.000$) (Table. 3).

Table 3: Post Hoc Comparison of Temperature Differences Among Four Coolant Types

Coolant Types		Mean Difference	P-value (95% CI)
Water	salt water 5%	3.019*	0.009 (0.7995 - 5.243)
	salt water 10%	4.41*	0.001 (2.185 - 6.634)
	salt water 20%	-0.529	1.000 (-2.753 - 1.696)
Salt water 5%	water	-3.019*	0.009 (-5.243 - (-0.795))
	salt water 10%	1.39	0.368 (-0.834 - 3.615)
	salt water 20%	-3.548*	0.003 (-5.772 - (-1.323))
Salt Water 10%	water	-4.41*	0.001 (-6.634 - (-2.185))
	salt water 5%	-1.39	0.368 (-3.615 - 0.8354)
	salt water 20%	-4.938*	0.000 (-7.162 - (-2.714))
Salt Water 20%	water	0.529	1.000 (-1.696 - 2.753)
	salt water 5%	3.548*	0.003 (1.323 - 5.772)
	salt water 10%	4.938*	0.000 (2.714 - 7.162)

*The mean difference is significant at the 0.05 level
Abbreviation; CI: Confidence Interval

Discussion

The present study explored the cooling performance of a Peltier-based system using different saltwater concentrations (5%, 10%, and 20%) as coolants, compared to pure water. The findings revealed significant variations in cooling efficiency depending on the salt concentration, emphasising the importance of optimising coolant composition for enhanced thermoelectric performance.

The results showed that the 10% saltwater solution demonstrated the highest cooling efficiency, with the most significant temperature reduction over the 60-minute period. This finding aligns with studies indicating that optimal salt concentrations can enhance the thermal conductivity of coolants, thereby improving the overall performance of cooling systems (Poojeera *et al.*, 2022). The 10% concentration likely represents a balance, where the salt ions enhance heat transfer without excessively increasing the solution's viscosity, which can impede flow and reduce cooling effectiveness (Şener *et al.*, 2022). In contrast, the 20% saltwater solution initially exhibited a rise in temperature before stabilising and eventually cooling. This initial temperature increase could be attributed to the higher viscosity of the solution, which may reduce the flow rate and heat dissipation efficiency. Previous studies have noted similar effects in other cooling systems, where higher solute concentrations led to diminished cooling performance due to increased resistance to flow (Hommalee, Wiriyasart & Naphon, 2019; Kim *et al.*, 2022).

The superior performance of the 10% saltwater solution highlights the potential for optimising thermoelectric cooling systems for medical and industrial applications. The Peltier effect relies heavily on efficient heat transfer away from the cooling unit, and the choice of coolant plays a critical role in this process. As demonstrated in this study, selecting the appropriate salt concentration can significantly impact the system's overall performance, with direct implications for the design of more effective cooling systems (Belarbi *et al.*, 2020; Yuan *et al.*, 2021).

Moreover, the energy efficiency of the system, as evidenced by the lower energy consumption associated with the 10% saltwater coolant, suggests that such systems could be developed to operate more sustainably. Energy efficiency is a crucial consideration, particularly in medical applications where continuous operation is required. The findings align with the literature suggesting that optimised coolant compositions can reduce energy demands without compromising cooling performance (Ahamat *et al.*, 2019; Hong *et al.*, 2019).

The performance of the 20% saltwater solution highlights a critical limitation in using high-concentration salt solutions as coolants. The increased viscosity not only hinders effective heat transfer but also places additional strain on the system's pumps and circulation mechanisms, potentially leading to higher operational costs and reduced system longevity (Liu *et al.*, 2019; Shittu *et al.*, 2019). This finding is crucial for applications where long-term reliability is essential, as it suggests that there is a threshold concentration above which the disadvantages outweigh the benefits (Rambabu *et al.*, 2023).

Furthermore, the post-hoc analysis revealed statistically significant differences between the 10% saltwater solution and both the 5% and 20% solutions, reinforcing the notion that there is an optimal concentration for maximising cooling efficiency. The performance of the 5% solution, which was only marginally better than pure water, suggests that lower salt concentrations may not significantly enhance the coolant's thermal properties (Lee & Loh, 2021; Zhou *et al.*, 2020). This finding is consistent with previous studies in other cooling applications where low-concentration solutions provided minimal improvement over the baseline (Sari *et al.*, 2022; Sirikasemsuk *et al.*, 2021).

The study's findings have significant implications for the development of cooling systems in medical devices, particularly those designed for paediatric care. The need for efficient, reliable, and energy-efficient cooling is critical in medical settings, where the maintenance of stable temperatures can directly impact patient outcomes (Ajiwiguna, Azizah & Suhendi, 2023; Dehra, 2018). The 10% saltwater solution's superior performance suggests that it could be particularly well-suited for use in devices such as cooling vests or fever management systems, where precise temperature control is paramount (Di & Jahn, 2021; Zhao *et al.*, 2020). Additionally, the insights gained from this study could inform the design of next-generation thermoelectric cooling systems for broader medical applications, including organ preservation and patient cooling during surgical procedures. The ability to fine-tune the coolant composition to maximise efficiency while minimising energy consumption is a significant advantage in these contexts, where system reliability and performance are critical (Moazzez *et al.*, 2020; Parametpisit *et al.*, 2023).

While this study provides valuable insights into the effects of salt concentration on cooling performance, several areas warrant further investigation. Future research should explore the molecular dynamics of saltwater at different concentrations, particularly how salt ions interact with the coolant's thermal properties under varying operational conditions (Ali *et al.*, 2023; Salim, Isalam & Al Rifaie, 2023). Advanced simulation techniques could provide deeper insights into these interactions, helping to identify the precise mechanisms through which salt concentration influences cooling efficiency (Fan *et al.*, 2022; Zhou *et al.*, 2018).

Moreover, the long-term stability of saltwater solutions in Peltier-based systems should be assessed, particularly in terms of potential corrosion or scaling issues that could arise with prolonged use (De Meneck *et al.*, 2023; Niforatos & Pescatore, 2019). Understanding these factors is essential for developing coolants that not only perform well in the short term but also maintain their efficiency and safety over extended periods (Elseady *et al.*, 2021; Shapiro & Fine, 2019).

Finally, the potential for scaling these findings to larger systems or different applications should be considered. While this study focused on a specific type of thermoelectric cooling system, the principles observed may apply to other cooling technologies or different scales of operation (Bertille *et al.*, 2018; Chok *et al.*, 2022). Research in this direction could lead to broader applications of optimised saltwater coolants in various industrial and medical contexts (Talebi *et al.*, 2016; Sunil & Nagesh, 2019).

Limitations of the Study

While this study provides valuable insights into optimising saltwater concentrations in Peltier-based cooling systems, there are several limitations to consider. First, the research was conducted within a controlled experimental setup, which may not fully replicate real-world conditions in clinical or industrial applications. The cooling system's performance, when applied to larger-scale or prolonged use scenarios, may differ due to factors such as environmental fluctuations, system degradation over time, and variations in heat load. Additionally, the study focused on a limited set of saltwater concentrations (5%, 10%, and 20%), and other potential variables such as different types of salt, water purity, and the presence of other additives were not explored. Moreover, the long-term stability and potential issues related to corrosion or scaling in Peltier-based systems using saltwater remain unresolved. These factors may affect the applicability and durability of the systems in actual healthcare settings.

Future Scope of the Study

Future research could extend the findings of this study by exploring a wider range of salt concentrations and other types of salt solutions to further optimise cooling performance. Investigating the molecular

dynamics of saltwater in Peltier systems, particularly under varying operational conditions, could provide deeper insights into how salt ions interact with the coolant's thermal properties and affect the system's efficiency. Additionally, long-term studies focusing on the stability of saltwater coolants in real-world applications, such as in medical devices for paediatric fever management, are needed. Furthermore, future studies should consider the development of advanced simulation models to predict the system's behaviour under different environmental conditions and scales. Finally, the potential for scaling up the cooling system for use in larger industrial or medical applications, beyond fever management, should also be explored, as this could offer significant improvements in various cooling technologies.

Conclusion

This study aimed to enhance the efficiency of Peltier-based cooling systems, particularly for paediatric fever management, by optimising the concentration of saltwater coolants. The research highlights the critical role of coolant composition in maximising cooling performance and energy efficiency, demonstrating that a 10% saltwater solution provides superior results compared to lower and higher concentrations, as well as pure water. The significance of these findings lies in their potential to improve the design of more effective and reliable cooling systems, which are essential for maintaining precise temperature control in medical applications. The broader implications of this study extend beyond paediatric fever management. The optimised cooling method developed here can be applied to a range of thermoelectric cooling systems across various industries, where energy efficiency and reliable temperature regulation are paramount. By establishing an optimal salt concentration, this research provides a foundation for future innovations in cooling technology, offering a scalable solution that could be adapted to other applications requiring efficient thermal management.

This article serves as a basis for further investigation into the molecular dynamics of saltwater coolants in Peltier systems, the long-term stability of such solutions, and their applicability in different contexts. Future research should explore these areas to refine and expand upon the findings presented here, ultimately contributing to the development of advanced cooling systems that can meet diverse and evolving needs across both medical and industrial fields.

Conflict of Interest

The authors declare that they have no competing interests.

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References

- Abdullah; Putri, M., Syahrudin, M., Silitonga, A. S., Dharma, S., Jumaat, A. K., Ridzuan, A. R., & Aritonang, G. (2024). The utilization of a combination of heatsink material and a water cooler block as an effort to reduce heat from solar panels. *International Journal of Applied Research and Sustainable Sciences*, 2(5), 339–352. <https://doi.org/10.59890/ijarss.v2i5.1806>
- Ademola, A. A. (2020). Theoretical and Experimental Analysis of a Thermoelectric. Low-temperature *Technologies*, 59. <https://doi.org/10.5772/intechopen.88664>
- Ahamat, M. A., Abidin, R., Roslin, E. N., & Chieh, O. Y. (2019). Thermoelectric water cooler and heater with intermediate water tank. *International Journal of Engineering and Advanced Technology*, 8(6), 3424–3427. <https://doi.org/10.35940/ijeat.f9513.088619>
- Ajiwiguna, T. A., Azizah, A. N., & Suhendi, A. (2023, December). Investigation of Performance Estimation Methods Validity of Thermoelectric Module. In *Journal of Physics: Conference Series* (Vol. 2673, No. 1, p. 012018). *IOP Publishing*. <https://doi.org/10.1088/1742-6596/2673/1/012018>

- Ali, F.A.M.A., Reda, S.M.A.M., Hussein, M.A.M., Ayed, S.K., Jassim, L., Majdi, H.S. (2023). Thermoelectric-Driven room air cooling via a multi-u shaped heat sink system. *International Journal of Heat and Technology*, 41(4), 1000-1006. <https://doi.org/10.18280/ijht.410421>
- Atta, R. M. (2018). Thermoelectric cooling. *Bringing Thermoelectricity into Reality*, 247-267. <https://doi.org/10.5772/intechopen.75791>
- Balaji, P. S., & Irons, M. A. Thermoelectric cooling in greenhouses: Implications for small-holder production. <https://doi.org/10.59720/22-055>
- Belarbi, A. A., Beriache, M. H., Che Sidik, N. A., & Mamat, R. (2021). Experimental investigation on controlled cooling by coupling of thermoelectric and an air impinging jet for CPU. *Heat Transfer*, 50(3), 2242-2258. <https://doi.org/10.1002/htj.21976>
- Bertille, N., Pursell, E., Hjelm, N., Bilenko, N., Chiappini, E., De Bont, E. G., ... & Chalumeau, M. (2018). Symptomatic management of febrile illnesses in children: a systematic review and meta-analysis of parents' knowledge and behaviors and their evolution over time. *Frontiers in Paediatrics*, 6, 279. <https://doi.org/10.3389/fped.2018.00279>
- Ceviz, M. A., Afshari, F., Muratçobanoğlu, B., Ceylan, M., & Manay, E. (2023). Computational fluid dynamics simulation and experimental investigation of a thermoelectric system for predicting influence of applied voltage and cooling water on cooling performance. *International Journal of Numerical Methods for Heat & Fluid Flow*, 33(1), 241-262. <https://doi.org/10.1108/hff-03-2022-0160>
- Choi, S., Yang, H., Noh, Y., Kim, G., Kwon, E., & Yoo, H. (2024). Fpga-based multi-channel real-time data acquisition system. *Electronics*, 13(15), 2950. <https://doi.org/10.3390/electronics13152950>
- Chok, R., Price, V., Steele, M., Corriveau-Bourque, C., & Bruce, A. (2022). Paediatric benign neutropenia: assessing practice preferences in Canada. *Journal of Paediatric Hematology/Oncology*, 44(6), 318-322. <https://doi.org/10.1097/mps.0000000000002427>
- De Meneck, F., Santana, V., Brioschi, G. C., Haddad, D. S., Neves, E. B., Franco, M. D. C., & Brioschi, M. L. (2023). Infrared imaging of the brain-eyelid thermal tunnel: A promising method for measuring body temperature in afebrile children. *International Journal of Environmental Research and Public Health*, 20(19). <https://doi.org/10.3390/ijerph20196867>
- Dehra, H. (2018). Building-integrated thermoelectric cooling-photovoltaic (TEC-PV) devices. *Bringing Thermoelectricity into Reality*. <https://doi.org/10.5772/intechopen.75472>
- Di, C. H., & Jahn, W. (2021). Performance Assessment of Thermoelectric Self-Cooling Systems for Electronic Devices. *Applied Thermal Engineering*, 193, 117020. <https://doi.org/10.1016/j.applthermaleng.2021.117020>
- dos Santos, F. N. Q., Colmanetti, A. R. A., Cabezas-Gómez, L., & Tibiriçá, C. B. (2022). Concept, modeling and experimental evaluation of an integrated cooling, heating and thermoelectric generation system. *Journal of the Brazilian Society of Mechanical Sciences and Engineering*, 44(10), 481. <https://doi.org/10.1007/s40430-022-03791-6>
- Elseady, G., Khalifa, M. I., Okby, O. M., & Fayed, N. M. (2021). Quality of Care Provided by Paediatric Nurses for the Management of Fever in Children. *Menoufia Nursing Journal*, 6(1), 157-166. <https://doi.org/10.21608/menj.2021.187193>
- Fan, K., Xiao, J., Wang, R., & Gao, R. (2022). Thermoelectric-based cooling system for high-speed motorized spindle I: Design and control mechanism. *The International Journal of Advanced Manufacturing Technology*, 121(5), 3787-3800. <https://doi.org/10.1007/s00170-022-09568-4>
- Hijano, A., Bergeret, F. S., Giazotto, F., & Braggio, A. (2023). Microwave-Assisted Thermoelectricity in S-I-S' Tunnel Junctions. *Physical Review Applied*, 19(4), 044024. <https://doi.org/10.1103/physrevapplied.19.044024>
- Hommalee, C., Wiriyasart, S., & Naphon, P. (2019). Development of cold-hot water dispenser with thermoelectric module systems. *Heat Transfer—Asian Research*, 48(3), 854-863. <https://doi.org/10.1002/htj.21409>
- Hong, S., Gu, Y., Seo, J. K., Wang, J., Liu, P., Meng, Y. S., ... & Chen, R. (2019). Wearable thermoelectrics for personalized thermoregulation. *Science Advances*, 5(5), eaaw0536. <https://doi.org/10.1126/sciadv.aaw0536>
- Kim, M., Kang, Y. K., Joung, J., & Jeong, J. W. (2022). Cooling performance prediction for hydraulic thermoelectric radiant cooling panels with experimental validation. *Sustainability*, 14(23), 16214. <https://doi.org/10.3390/su142316214>
- Kondratiev, V. V., Sysoev, I. A., Kolosov, A. D., Galishnikova, V. V., Gladkikh, V. A., Karlina, A. I., & Karlina, Y. I. (2022). Development and Testing of the Thermoelectric Thermal Energy Conversion Device in the Conditions of Existing Aluminum Production. *Materials*, 15(23), 8526. <https://doi.org/10.3390/ma15238526>
- Lee, H. J., & Loh, K. J. (2021). Liquid vaporization actuated soft structures with active cooling and heat loss control. *Smart Materials and Structures*, 30(5), 055007. <https://doi.org/10.1088/1361-665x/abeefb>

- Li, R., Wang, W., Shi, Y., Wang, C. T., & Wang, P. (2024). Advanced material design and engineering for water-based evaporative cooling. *Advanced Materials*, 36(12), 2209460. <https://doi.org/10.1002/adma.202209460>
- Liu, Z., Li, W., Zhang, L., Wu, Z., & Luo, Y. (2019). Experimental study and performance analysis of solar-driven exhaust air thermoelectric heat pump recovery system. *Energy and Buildings*, 186, 46-55. <https://doi.org/10.1016/j.enbuild.2019.01.017>
- Moazzez, A. F., Najafi, G., Ghobadian, B., & Hoseini, S. S. (2020). Numerical simulation and experimental investigation of air cooling system using thermoelectric cooling system. *Journal of Thermal Analysis and Calorimetry*, 139, 2553-2563. <https://doi.org/10.1007/s10973-019-08899-x>
- Niforatos, J. D., & Pescatore, R. (2019). Search Engine Queries for Paediatric Fever During "Cold and Flu" Season. *Cureus*, 11(4), e4464 <https://doi.org/10.7759/cureus.4464>
- Parametpisit, P., Panmuang, P., Sonsilphong, A., & Soemphol, C. (2023). Experimental investigation of hybrid thermoelectric evaporative air-cooling system for crickets rearing process. *Indonesian Journal of Electrical Engineering and Computer Science*, 29(3), 1374-1381. <https://doi.org/10.11591/ijeecs.v29.i3.pp1374-1381>
- Poojeera, S., Srichat, A., Naphon, N., & Naphon, P. (2022). Study on Thermal Performance of the Small-Scale Air Conditioning with Thermoelectric Cooling Module. *Mathematical Modelling of Engineering Problems*, 9(4), 1143–1151. <https://doi.org/10.18280/mmep.090434>
- Rambabu, V. R., Kuppina, A. V. C., Gowravaram, Kaviti, P. K., Gurugu, N. K., & Lanka, C. V. R. (2023). Design and Fabrication of Solar Powered Portable Thermoelectric Refrigerator. *International Research Journal of Modernization in Engineering Technology and Science*, 05(03), 1401-1403. <https://doi.org/10.56726/irjmets34361>
- Ruiz-Ortega, P. E., Olivares-Robles, M. A., & Badillo-Ruiz, C. A. (2021). Transient thermal behavior of a segmented thermoelectric cooler with variable cross-sectional areas. *International Journal of Energy Research*, 45(13), 19215-19225. <https://doi.org/10.1002/er.7123>
- Salim, B., Alsalam, B., & Al Rifaie, M. (2023). An Experimental Investigation of a Portable Solar Thermoelectric Fridge For Storing Some Vaccines. *Authorea Preprints*. <http://dx.doi.org/10.22541/au.168717639.93235175/v1>
- Sari, H. N., B. I. M. A., Bramantyo, K. U., & Cholikh, M. (2022). Performance Analysis of Electric Coolers TEC1-12706 and TEC1-12715 with Heatsinks at Semi-conductor Cooler Boxes. Proceedings of the International Joint Conference on Science and Engineering 2022 (IJCSE 2022). Atlantis Press International BV. https://doi.org/10.2991/978-94-6463-100-5_29
- Şener, M., Arslan, F., Gürses, O., & GÜRLEK, G. (2022). Experimental investigation of thermoelectric self-cooling system for the cooling of ultrasonic transducer drivers. *Politeknik Dergisi*, 25(1), 169–175. <https://doi.org/10.2339/politeknik.675379>
- Shapiro, D. J., & Fine, A. M. (2021). Patient ethnicity and paediatric visits to the emergency department for fever. *Paediatric Emergency Care*, 37(11), 555-559. <https://doi.org/10.1097/pec.0000000000001945>
- Shilpa, M. K., Raheman, M. A., Aabid, A., Baig, M., Veerasha, R. K., & Kudva, N. (2023). A systematic review of thermoelectric peltier devices: Applications and limitations. *FDMP-Fluid Dynamics & Materials Processing*, 19(1), 187-206. <https://doi.org/10.32604/fdmp.2022.020351>
- Shittu, S., Li, G., Zhao, X., Akhlaghi, Y. G., Ma, X., & Yu, M. (2019). Comparative study of a concentrated photovoltaic-thermoelectric system with and without flat plate heat pipe. *Energy Conversion and Management*, 193, 1-14. <https://doi.org/10.1016/j.enconman.2019.04.055>
- Siahmargoi, M., Rahbar, N., Kargarsharifabad, H., Sadati, S. E., & Asadi, A. (2019). An experimental study on the performance evaluation and thermodynamic modeling of a thermoelectric cooler combined with two heatsinks. *Scientific Reports*, 9(1), 20336. <https://doi.org/10.1038/s41598-019-56672-9>
- Sirikasemsuk, S., Wiriyasart, S., Naphon, P., & Naphon, N. (2021). Thermal cooling characteristics of Li-ion battery pack with thermoelectric ferrofluid cooling module. *International Journal of Energy Research*, 45(6), 8824-8836. <https://doi.org/10.1002/er.6417>
- Sirikasemsuk, S., Wiriyasart, S., Prurapark, R., Naphon, N., & Naphon, P. (2021). Water/Nanofluid Pulsating flow in thermoelectric module for cooling electric vehicle battery systems. *International Journal of Heat & Technology*, 39(5), 1618-1626. <https://doi.org/10.18280/ijht.390525>
- Skovajsa, J., & Zalesak, M. (2018). The use of the photovoltaic system in combination with a thermal energy storage for heating and thermoelectric cooling. *Applied Sciences*, 8(10), 1750. <https://doi.org/10.3390/app8101750>
- Sukarno, R., Premono, A., Gunawan, Y., & Wiyono, A. (2023, September). Experimental study of thermoelectric cooling system for a parked car with solar energy. In *Journal of Physics: Conference Series* (Vol. 2596, No. 1, p. 012052). IOP Publishing. <https://doi.org/10.1088/1742-6596/2596/1/012052>
- Sunil, S. & Nagesh, S. (2019). Trends in Fever Management Prescriptions for Paediatric Patients in India. *International Journal of Paediatrics and Geriatrics*, 2(1), 58–64. <https://doi.org/10.33545/26643685.2019.v2.i1a.231>

- Talebi, S., Shahrabadi, H., VAHIDI, S. A., Talebi, S., & Siyavoshi, M. (2016). Mothers' management Of Fever of Children in Sabzevar. *Journal of Nursing and Midwifery Sciences*, 3(2), 32-39. <https://doi.org/10.18869/acadpub.jnms.3.2.32>
- Yuan, X. H., Qin, C. H., Wang, Y. P., & Liu, X. (2021). Characteristics analysis of small insulated vans based on thermoelectric cooling. *Frontiers in Energy Research*, 9, 740748. <https://doi.org/10.3389/fenrg.2021.740748>
- Yuniati, F., Erwin, E., Shobur, S., Ardianty, S., & Sutrisno, S. (2025). Home fever management in children: a systematic review. *International Journal of Public Health Science (IJPHS)*, 14(1), 529. <https://doi.org/10.11591/ijphs.v14i1.24554>
- Zhang, F., Xu, X., Cheng, L., Wang, L., Liu, Z., & Zhang, L. (2019). Global moment-independent sensitivity analysis of single-stage thermoelectric refrigeration system. *International Journal of Energy Research*, 43(15), 9055-9064. <https://doi.org/10.1002/er.4811>
- Zhang, Z., Zhang, Y., Sui, X., Li, W., & Xu, D. (2020). Performance of thermoelectric power-generation system for sufficient recovery and reuse of heat accumulated at cold side of TEG with water-cooling energy exchange circuit. *Energies*, 13(21), 5542. <https://doi.org/10.3390/en13215542>
- Zhao, D., Yin, X., Xu, J., Tan, G., & Yang, R. (2020). Radiative sky cooling-assisted thermoelectric cooling system for building applications. *Energy*, 190, 5542. <https://doi.org/10.1016/j.energy.2019.116322>
- Zhou, Y., Zhang, T., Wang, F., & Yu, Y. (2018). Performance analysis of a novel thermoelectric assisted indirect evaporative cooling system. *Energy*, 162, 299-308. <https://doi.org/10.1016/j.energy.2018.08.013>
- Zhou, Y., Zhang, T., Wang, F., & Yu, Y. (2020). Numerical study and optimization of a combined thermoelectric assisted indirect evaporative cooling system. *Journal of Thermal Science*, 29, 1345-1354. <https://doi.org/10.1007/s11630-020-1362-7>