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Thermal Comfort In Recreational Facilities: Examining the Effect of Misting Systems

Oladunmoye Oluranti Mobolaji
Department of Architecture
University of Ibadan
Ibadan, Nigeria.
E-mail: bjarchimat23@gmail.com

ABSTRACT

This paper delves into the significance of misting systems in enhancing thermal comfort in indoor and outdoor environments, particularly in recreational facilities. It explores how misting systems regulate temperature and humidity to create optimal thermal conditions for users. The evolution of misting-cooling systems as integrated design solutions for outdoor spaces is also discussed, highlighting their benefits in achieving and maintaining thermal comfort. Thermal comfort plays a crucial role in the overall experience of individuals in recreational facilities. Misting systems have emerged as effective tools for regulating temperature and humidity levels, thereby enhancing the comfort of users. These systems have evolved over time to become integral components of indoor and outdoor design, offering a range of benefits in creating ideal thermal conditions. Misting systems operate by releasing fine water droplets into the air, which evaporate quickly, absorbing heat and lowering the surrounding temperature. This process helps to cool the environment and maintain optimal humidity levels, contributing to a more comfortable experience for individuals in recreational spaces. The use of misting systems in recreational facilities offers several advantages, including improved thermal comfort, energy efficiency, and enhanced user experience. By creating a pleasant microclimate, these systems contribute to increased satisfaction among visitors and can help attract more patrons to the facility. Misting-cooling systems have undergone significant advancements in recent years, with a focus on integrating them seamlessly into outdoor spaces. By considering factors such as site topography, vegetation, and daily shade patterns, designers can optimize the effectiveness of misting systems in controlling microclimatic conditions.

Keywords: Thermal Comfort, Recreational Facilities, Misting Systems, Droplets, Vegetation

1. INTRODUCTION

1.1 Background to the Study

Thermal comfort is crucial, especially in recreational facilities where individuals engage in physical activities and require an optimal atmosphere for performance (Ali et al., 2019). The design and operation of these facilities must consider various environmental factors like temperature, humidity, and air movement, along with personal characteristics of occupants such as clothing and activity levels. One effective strategy to enhance thermal comfort in recreational facilities is the utilization of misting systems, which can help regulate temperature and humidity through evaporative cooling.

Misting-cooling systems have been utilized in architecture and landscape architecture for many years, primarily for aesthetic purposes and achieving localized cooling effects. Recently, there has been a heightened focus on bioclimatic comfort in outdoor spaces, adapting to specific climatic and weather conditions, and redefining the significance of steam produced by misting systems. Advancements in misting system technology have enabled their integration as comprehensive design solutions, blending aesthetic principles with mechanisms to enhance outdoor comfort.

In the 1970s, misting systems began to evolve into sculptural elements under the guidance of artists and architects, incorporating steam as a fundamental aspect of spatial design. Notable examples include the Pepsi Pavilion at the Japan Expo 1970, designed by Japanese sculptor Fujiko Nakaya. Subsequently, misting systems were swiftly embraced in landscape architecture, particularly in public space projects. From the early 1980s to the mid-1990s, steam played a central role in spatial design in various locations, notably in North America and Northern Europe, with projects like the Tanner Fountain at Harvard University, Axeltory in Copenhagen, and Le Miroire d'eau in Bordeaux.

Until the late 20th century, the incorporation of steam in open spaces was primarily for sculptural purposes, lacking considerations for spatial functionality, resource consumption, or urban ecosystem impacts. However, with the increasing focus on bioclimatic comfort in public spaces, misting systems have gained importance in controlling microclimatic conditions to enhance user comfort. Achieving ideal conditions of temperature, humidity, solar radiation, and wind protection is essential for public space comfort, and misting systems play a significant role in this regard.

1.2 Problem Statement

The problem addressed in the study is the need to enhance thermal comfort in recreational facilities during hot seasons, where traditional cooling methods may be insufficient or energy-intensive. This necessitates exploring the effectiveness of misting systems as a sustainable and eco-friendly alternative to improve comfort levels in such environments.

1.3 Aim of this Study

The aim of the study is to investigate the impact of misting systems on thermal comfort in recreational facilities. This involves assessing thermal comfort levels with and without misting systems, evaluating the influence of these systems on indoor environmental parameters like temperature and humidity, examining the energy efficiency and cost-effectiveness of implementing misting systems, understanding user perceptions and preferences regarding their use in recreational settings, and proposing design guidelines for integrating misting systems to optimize thermal comfort and energy performance

1.4 Objectives of the Study

I. Assess the thermal comfort levels in recreational facilities with and without misting systems.
II. Evaluate the influence of misting systems on indoor environmental parameters such as temperature and humidity.
III. Examine the energy efficiency and cost-effectiveness of implementing misting systems in recreational facilities.

IV. Identify user perceptions and preferences regarding the use of misting systems in recreational settings.
V. Propose design guidelines for integrating misting systems in recreational facility design to optimize thermal comfort and energy performance.

1.5 Justification of the Study

The study is justified by the increasing importance of providing comfortable recreational spaces, especially during hot weather conditions, to enhance user experience and promote outdoor activities. By exploring the effectiveness of misting systems in improving thermal comfort, the study aims to contribute valuable insights into sustainable cooling solutions for recreational facilities, aligning with the growing emphasis on eco-friendly practices and energy efficiency in architectural and landscape design.

1.6 Significance of the Study

The significance of the study lies in its potential to offer practical solutions for enhancing thermal comfort in recreational facilities through the implementation of misting systems. By evaluating the impact of these systems on indoor environmental conditions and user comfort, the study can inform decision-making processes for architects, landscape designers, and facility managers seeking to create comfortable and sustainable outdoor spaces. Additionally, the study's findings may contribute to the broader discourse on energy-efficient cooling technologies and their application in recreational settings.

1.7 Scope of the Study

The scope of the study encompasses the evaluation of misting systems' effectiveness in improving thermal comfort specifically in recreational facilities. The study will focus on assessing thermal comfort levels, indoor environmental parameters, energy efficiency, user perceptions, and design considerations related to the integration of misting systems in recreational settings. The research will provide insights into the practical implications of using misting systems to enhance comfort and energy performance in outdoor recreational spaces

2. LITERATURE REVIEW

2.1 Introduction

The literature review examines the multifaceted realm of misting systems technology and its impact on thermal comfort in recreational facilities. This section serves as a comprehensive exploration of existing research, theories, and practical applications related to misting systems, highlighting their significance in enhancing outdoor comfort and energy efficiency. Misting systems technology has evolved over the years, finding diverse applications not only in landscape architecture but also in various industries such as iron steel, paper making, electronics, and food conservation. The introduction of misting systems marked a shift towards more sustainable cooling solutions, particularly in outdoor environments where traditional air conditioning may not be feasible or environmentally friendly.

By utilizing the principles of vaporization and evaporation, misting systems offer a unique approach to cooling outdoor spaces while minimizing water consumption and energy usage. The integration of misting systems in landscape architecture and recreational facilities has gained traction in recent years, driven by a growing emphasis on bioclimatic comfort and sustainable design practices.

These systems have transcended their initial aesthetic purposes to become integral components of outdoor comfort strategies, adapting to site-specific climatic conditions and user needs. Notable examples, such as the Pepsi Pavilion designed by Fujiko Nakaya, showcase the artistic and functional potential of misting systems in creating immersive outdoor experiences.

The literature review also delves into the technical aspects of misting systems, distinguishing between high-pressure and low-pressure systems based on their operational mechanisms and cooling efficiency. High-pressure misting systems, powered by specialized water pumps, offer superior cooling capabilities by generating a fine mist that evaporates quickly, resulting in significant temperature reductions in outdoor spaces. In contrast, low-pressure systems are more suitable for specific applications where water conservation and targeted cooling are priorities.

Moreover, the review discusses the implications of misting systems on thermal comfort, emphasizing the importance of considering environmental factors such as temperature, humidity, and air movement in recreational facility design. By evaluating the impact of misting systems on indoor environmental parameters and user perceptions, researchers aim to provide valuable insights for optimizing comfort levels and energy performance in outdoor settings.

Overall, the literature review sets the stage for a comprehensive analysis of misting systems' role in enhancing thermal comfort in recreational facilities. By synthesizing existing knowledge and identifying gaps in research, this section lays the foundation for the study's objectives, and potential contributions to the field of architectural and environmental design.

2.2 Recreational Facilities

Recreational facilities play a vital role in providing essential amenities and services to communities through public or private organizations. These facilities include public spaces, parks, green areas, playgrounds, sports facilities, and community spaces for social interaction, forming a crucial part of individuals' daily lives. Recreation encompasses a diverse range of activities valued during leisure time, incorporating physical, cognitive, emotional, and social elements. It involves visiting parks, green areas, lakes, rivers, forests, as well as engaging in activities like trekking, fishing, hunting, and camping. Recreational pursuits are intrinsic to human life, tailored to individual interests and societal norms, and can be communal or individual, active or passive, indoor or outdoor, beneficial to health, and essential for societal well-being [Broadhurst, 2001; Hurd & Anderson, 2010; Kara & Demirci, 2010; Ezeamaka & Oluwole, 2016].

The twenty-first century presents new challenges in adapting and planning sports and recreation facilities to meet evolving community needs. Ensuring accessibility, quality, and strategic placement of these facilities is crucial to promoting diverse activity choices and enhancing community participation. This paper emphasizes the integration of inclusive and sustainable practices in city planning to create livable environments. Proper placement of recreational facilities within society contributes to fostering a livable city by catering to diverse recreational needs. Outdoor recreation, a fundamental aspect of human life, manifests in various forms and is influenced by individual preferences and societal dynamics [Ezeamaka & Oluwole, 2016].

2.3 Hierarchy and Types of Recreational Facilities

Different countries have distinct hierarchies and types of recreational facilities. As exemplified by the City of Los Angeles, common categories include:

- **Mini Parks:** Small parks under one acre in size, serving immediate neighborhoods.
- **Neighborhood Parks:** Providing space and facilities for a range of outdoor and indoor recreational activities for all age groups within the local community.
- **Community Parks:** Designed to cater to diverse age groups across multiple neighborhoods, offering amenities like community halls, multi-purpose fields, playgrounds, and parking areas. Ideally, community parks span 15 to 20 acres, with a service radius of 3km, ensuring accessibility to the surrounding areas

2.4 Thermal Comfort

Thermal comfort is a subjective evaluation of an individual's satisfaction with the thermal environment, reflecting their neutral feeling in a given thermal setting without sweating. In tropical regions with high temperatures and humidity levels, human thermal discomfort is a significant concern. Factors such as location, climatic conditions inside and outside buildings, and exposure to sunlight influence thermal comfort standards. The tropics experience elevated humidity levels due to temperature-induced perspiration, leading to discomfort. Climate change poses challenges to traditional cooling methods in hot and humid regions, necessitating innovative approaches to mitigate thermal discomfort. Strategies like natural ventilation, shading devices, and landscaping elements play a crucial role in enhancing thermal comfort and protecting against excessive heat exposure. While achieving 100% thermal comfort may be unattainable in all climatic conditions, maintaining a satisfactory thermal environment is essential for overall well-being, productivity, and health [Balbis-Morejón et al., 2020].

2.4.1 Impact of Local Climate Change on Indoor and Outdoor Comfort Conditions

The indoor and outdoor thermal comfort is significantly influenced by ambient temperature (ANSI/ASHRAE, 2013), with levels above a certain threshold leading to discomfort and impacting human physiology. Urban warming's specific impact on thermal comfort has been extensively studied (Wright et al., 2005; Summerfield et al., 2007; Sakka et al., 2012; Lomas and Kane, 2013), particularly in low-income households during heat waves where achieving thermal comfort can be challenging. Studies have shown that indoor temperatures can exceed health thresholds during heat waves, with measurements in various cities like London, Manchester, and Athens revealing severe overheating in homes, the average indoor temperature was almost 4.2K higher than the temperature recorded during the rest of the summer. Spells of more than 216 hours above 30°C were recorded in many of the houses (Fig.2.1).

Regarding outdoor thermal comfort, research has identified four main clusters of studies focusing on spatial distribution differences (Krüger et al., 2012; Hedquist and Braze, 2014), temporal evolution (Bartzokas et al., 2013), heat wave impacts, and potential changes due to global climate change (Papanastasiou et al., 2015). Studies in Glasgow (Krüger et al., 2012) and Athens (Giannopoulou et al. 2013, Katavoutas et al. 2015) have highlighted the role of Urban Heat Island (UHI) in reducing thermal comfort levels during summer, with urban areas experiencing lower comfort levels compared to suburban areas. The temporal variability of thermal discomfort conditions in Athens has shown a significant increase in discomfort levels after 1980, with more frequent high discomfort days occurring between mid-June to mid-September (Bartzokas et al. 2013). Fig.2.2 shows the temporal variation of the number of summer days presenting a PMV >2 (very warm conditions) under calm and windy conditions.

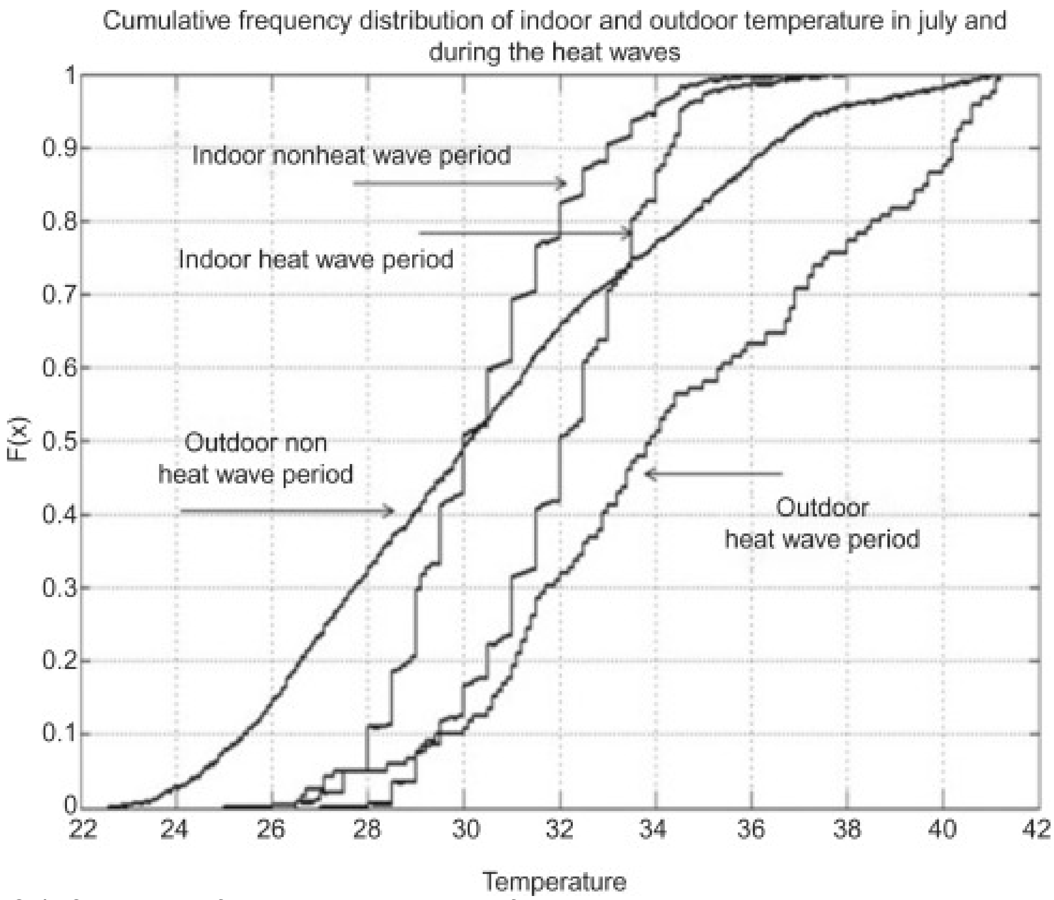

Figure 2.1. Cumulative frequency distribution of indoor and outdoor temperatures during the heat wave period and the rest of July.
Source: Sakka et al. (2012).

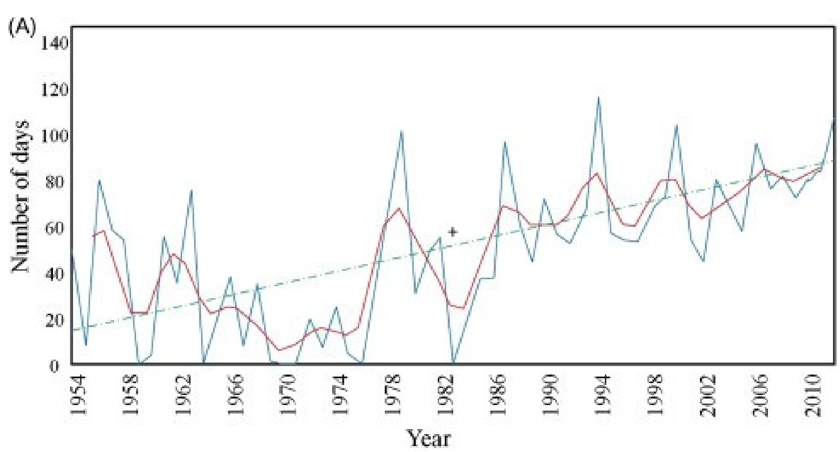

Figure 2.2a. Inter-annual variation of duration of PMV ≥2 summer discomfort in Athens at 14:00 for (A) calm and (B) light wind conditions for the period 1954–2012.
Source: Bartzokas et al. (2013).

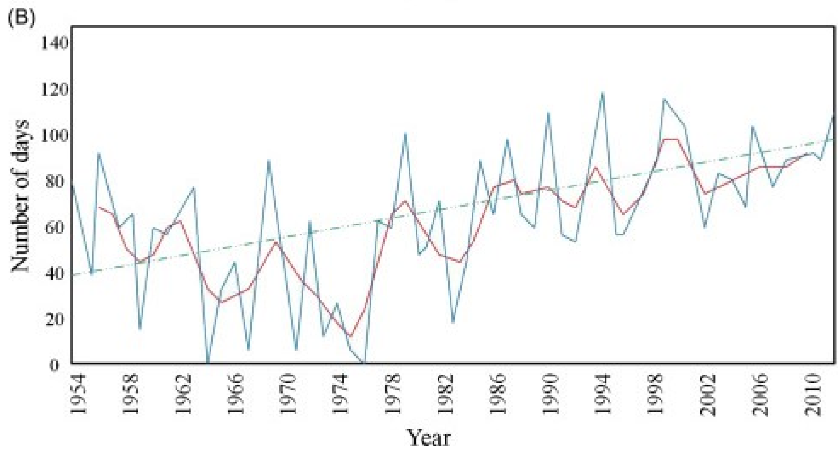

Figure 2.2b. Inter-annual variation of duration of PMV ≥2 summer discomfort in Athens at 14:00 for (A) calm and (B) light wind conditions for the period 1954–2012.
Source: Bartzokas et al. (2013).

Specifically in Athens, during heat waves, conditions of discomfort persist throughout the period, with severe heat stress conditions occurring for a significant portion of the time, leading to medical emergency situations in about 13% of the heat wave period (Papanastasiou et al. 2015). The potential impact of global climate change on future thermal comfort conditions has been investigated by Orosa et al. (2014), Thorsson et al. (2011), and Cheung and Hart (2014). In the city of Gothenburg, Sweden, it is projected that the ambient temperature may increase by 3.2°C by the end of the century, potentially tripling the hours of extreme heat stress in the city (Thorsson et al., 2011). Orosa et al. (2014) estimated that the expected rise in ambient temperature over the next 20 years could elevate the humidex thermal comfort index in Galicia, Spain from 18 to 21. Similarly, Cheung and Hart (2014) noted that in Hong Kong, the anticipated temperature increase due to global climate change might shift thermal conditions from "no thermal stress" to "moderate heat stress" by 2065.

2.4.2 Factors Affecting Thermal Comfort

Air temperature is a commonly used indicator of thermal comfort but should be considered alongside other environmental and personal factors.
Environmental factors such as;

- Air temperature
- Radiant temperature
- Air velocity
- Humidity

And personal factors like;

- Clothing insulation
- Metabolic heat

All contribute to overall thermal comfort.

2.5. The Misting system

2.5.1. Classification and Types of Misting Systems

Misting systems, often seen as affordable luxuries, play a significant role in enhancing comfort during hot seasons when simply enjoying the weather can lead to overheating and discomfort, prompting individuals to retreat indoors. These systems disperse cool mist into the air, creating a refreshing environment and making even the hottest days more bearable.
However, not all misting systems are created equal. There are two primary types of misting systems high-pressure and low-pressure systems that can greatly influence the overall experience (Aermist, 2022).

Low-Pressure Misting Systems

Akin to the sprinklers discussed earlier but with enhanced performance, typically consist of PVC tubing, nozzles, and an adapter point. Unlike high-pressure systems, low-pressure systems rely solely on the pressure from a hose or water line, without additional pressurization mechanisms. The finer nozzles of low-pressure systems facilitate the separation of water into smaller droplets, improving their cooling efficiency compared to greenhouse sprinklers. One of the advantages of low-pressure misting systems is their cost-effectiveness, as they essentially function as hose accessories with minimal additional components. These systems provide effective cooling by enveloping the skin with cold water droplets while simultaneously lowering the surrounding air temperature, offering a comfortable cooling experience (Aermist, 2022).

High-Pressure Misting Systems

High-pressure misting systems share similarities with low-pressure systems but with a key distinction they do not rely on a hose for operation. Instead, these systems incorporate a high-pressure water pump as part of their kit to propel water through tubing at approximately 1000 PSI. This high pressure allows for the efficient use of minimal water, which is dispersed over a wide area, creating a mist akin to a cloud rather than individual droplets. The mist produced by high-pressure systems can significantly cool a patio by 20 degrees or more during hot days. Moreover, these systems are cost-effective to operate as they consume less water to achieve effective cooling, resulting in a dry environment post-misting. The fine separation of water droplets due to pressure and specialized nozzles facilitates rapid evaporation, enabling users to fully enjoy their outdoor spaces without concerns about water accumulation (Aermist, 2022).

2.5.2. Comparison of Types: High-Pressure vs. Low-Pressure Systems

For most consumers, high-pressure misting systems are often preferred over low-pressure alternatives. The primary advantage lies in the dryness of the cooled area, along with long-term cost savings. While the initial investment in a high-pressure pump may be higher than attaching a hose to an adaptor for a low-pressure system, the reduced water consumption of high-pressure systems leads to lower monthly water bills. Additionally, maintaining high-pressure nozzles is straightforward, requiring occasional submersion in white vinegar. However, low-pressure systems can still be beneficial for specific applications, such as watering plants without excessive soaking or providing quick cooling in temporary settings. Business owners may find low-pressure systems more suitable for practical purposes, while residential consumers seeking enhanced patio enjoyment typically opt for high-pressure misting systems (Aermist, 2022).

3. METHODOLOGY

3.1. Misting Systems Technology

The technology of misting systems finds diverse applications not only in landscape architecture but also in various professional fields such as iron and steel, papermaking, electronics, oil burners, fire suppression, and food preservation (Kyoritsu Gokin Company, 1938). When designing an outdoor misting system, factors such as climatic conditions (wind, humidity, temperature, precipitation) play a crucial role in determining the effectiveness of vaporization mechanisms and the timing of water release. To ensure the sustainable use of misting systems for cooling purposes, it is essential to consider climate influences through systematic data analysis and coherent measurement techniques. Additionally, the type and arrangement of nozzles used are vital in understanding the behavior and applications of water droplets.

In instances of strong winds, the intensity and direction of the wind can lead to unnecessary water losses and dispersion into surrounding areas. Conversely, on rainy days, mechanisms should be in place to halt misting operations. Temperature considerations are also important for misting systems to operate within an optimal temperature range and avoid energy wastage. Air humidity plays a significant role in misting-cooling systems, particularly in hot-humid climates where water spraying and evaporation are more challenging due to the atmospheric water content. Different nozzle pressures can be applied to generate varying sizes of water droplets, with higher pressures producing smaller droplets that enhance evaporation. Studies have shown that the size of water droplets emitted from nozzles does not significantly impact temperature reduction (Gyuyoung Yoon, 2008) and (Hideki Yamada, 2008).

In order to understand and measure important parameters such as mist evaporation and effective temperature, systematized calculations suggest that on warm humid conditions, fine cooling mists will increase thermal comfort, even with small cooling effect. They also indicate that, without air movement, wetting conditions will still occur (Craig Farnhama, 2011). Efforts to enhance the effectiveness of misting systems involve the utilization of advanced technologies with more efficient components, robust construction methods, and improved management practices. To optimize the cooling effect range, precise measurements and assessments are necessary. Various types of nozzles, including water expelling, air expelling, and mixed expelling nozzles, are available, each capable of producing different water distribution patterns (Kyoritsu Gokin Company, 1938). By controlling the water release periods accurately, the system's efficiency can be further regulated and optimized.

3.2. Role of Misting Systems in achieving thermal comfort.

When temperatures rise, it is crucial to find effective cooling solutions. While traditional methods of cooling can be expensive and energy-intensive, misting systems offer a refreshing and environmentally friendly alternative for immediate relief. These systems utilize small water droplets to reduce the ambient temperature by producing a fine mist through high-pressure pumps or fans that propel water through specialized nozzles. As the mist evaporates, it absorbs heat from the surrounding air, delivering a noticeable cooling effect. Misting technology can be applied in various settings, including patios, gardens, outdoor events, and indoor spaces. Misting systems operate as a temperature-based control solution, generating rapidly evaporating, ultra-fine water droplets that cool the air without leaving a damp sensation on the skin.

The use of misting systems dates back to their application in vernacular architecture during the Islamic era over a millennium ago, leveraging water's natural cooling properties to enhance thermal comfort and stability in landscaping. To harness the full potential of misting systems while minimizing environmental impact, it is essential to integrate them sustainably into landscape design to optimize energy efficiency and water usage without exacerbating global warming (Dr. Oluranti, 2024).

3.3 Benefits of Misting Cooling Systems

I. Immediate and Refreshing Cooling: Misting systems provide a quick and invigorating cooling experience. The tiny droplets generated by misting systems evaporate rapidly, extracting heat from the air and lowering the surrounding temperature. Enjoy the sensation of a cool breeze even on sweltering summer days.

II. Energy Efficiency: Misting systems consume notably less energy in comparison to traditional air conditioning units. By harnessing the natural process of evaporation, misting systems achieve efficient cooling without the necessity of compressors or refrigerants. This results in decreased energy expenses and a more sustainable cooling solution.

III. Versatile Cooling Solutions: Misting systems offer adaptable cooling options for both indoor and outdoor settings. Whether you seek to cool your patio, establish a cozy outdoor dining area, or introduce a refreshing ambiance to a greenhouse, misting systems can be customized to meet diverse spatial requirements and preferences.

IV. Enhanced Outdoor Enjoyment: With misting systems, you can elevate your outdoor space into a delightful sanctuary during hot summer periods. Whether you are hosting a backyard barbecue, relaxing by the pool, or hosting a garden gathering, the cooling mist fosters a pleasant environment, enabling you and your guests to remain outdoors and escape the heat.

4. CONCLUSION

In conclusion, the exploration of misting systems technology and its impact on thermal comfort in recreational facilities underscores the significance of sustainable cooling solutions in outdoor environments. Through a detailed literature review and analysis of misting systems' applications, benefits, and challenges, several key insights have emerged regarding the potential of these systems to enhance user experience, energy efficiency, and environmental sustainability. The study's focus on investigating the effectiveness of misting systems in improving thermal comfort has shed light on the importance of considering climatic conditions, system design, and user preferences in recreational facility planning. By evaluating thermal comfort levels, indoor environmental parameters, and user perceptions, the research has provided valuable data for architects, landscape designers, and facility managers seeking to create comfortable and eco-friendly outdoor spaces.

Furthermore, the study's emphasis on energy efficiency and cost-effectiveness in implementing misting systems highlights the practical implications of integrating these technologies into recreational facilities. By proposing design guidelines for optimizing thermal comfort and energy performance, the research offers actionable recommendations for enhancing user comfort while minimizing environmental impact. Overall, the findings presented underscore the potential of misting systems as versatile and sustainable cooling solutions for recreational facilities, paving the way for future research and practical applications in the field of architectural and environmental design.

5. RECOMMENDATIONS

Based on the insights gleaned from the study on misting systems and thermal comfort in recreational facilities, several recommendations can be made to enhance the effectiveness and sustainability of these systems:

1. Climate-Specific Design: Tailor misting system designs to suit the climatic conditions of the site, considering factors such as temperature, humidity, wind speed, and precipitation. By aligning system parameters with local climate data, designers can optimize cooling efficiency and minimize water wastage.
2. User-Centric Approach: Incorporate user feedback and preferences into the design and operation of misting systems to ensure optimal comfort and satisfaction. Conduct surveys and user studies to gather insights on user experiences and adjust system settings accordingly.
3. Regular Maintenance: Implement a routine maintenance schedule for misting systems to ensure optimal performance and longevity. Regularly inspect and clean nozzles, pumps, and tubing to prevent clogs and malfunctions that could affect cooling efficiency.
4. Energy Monitoring: Install energy monitoring systems to track the energy consumption of misting systems and identify opportunities for optimization. By analyzing energy usage patterns, facility managers can implement strategies to reduce operational costs and environmental impact.
5. Continued Research: Encourage further research and innovation in misting system technology to enhance cooling efficiency, sustainability, and user comfort. Collaborate with researchers, industry experts, and technology providers to explore new advancements in misting system design and operation.

By implementing these recommendations, stakeholders in the design and operation of recreational facilities can maximize the benefits of misting systems in enhancing thermal comfort, energy efficiency, and user satisfaction. Embracing a holistic approach that integrates user needs, environmental considerations, and technological advancements will pave the way for sustainable and enjoyable outdoor spaces for years to come.

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