ZIBELINE INTERNATIONAL™ PUBLISHING

Water Conservation & Management (WCM)

DOI: http://doi.org/10.26480/wcm.04.2025.774.778

ISSN: 2523-5664 (Print)
ISSN: 2523-5672 (Online)
CODEN: WCMABD

CrossMark

RESEARCH ARTICLE

REIMAGINING WASTEWATER: AIR CONDITIONING CONDENSATE AS A VIABLE IRRIGATION SOURCE

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Article History:

Received 11 September 2025
Revised 21 October 2025
Accepted 17 November 2025
Available online 18 December 2025

ABSTRACT

In the face of growing water scarcity, particularly in hot and humid regions, the recovery and reuse of air conditioning condensate is emerging as a promising sustainability strategy. This often-overlooked byproduct of cooling systems, typically discarded as waste, presents opportunities for alternative applications such as landscape irrigation, facility maintenance, and industrial cooling. A longitudinal six-year study explored air conditioning condensate's water resource potential, revealing that a two-ton unit consistently generates in excess of 2 liters of condensate per hour, suggesting significant untapped water harvesting opportunities. Building on these findings, this investigation explored sustainable water management by creating and deploying an innovative system that harvests condensate from residential air condition units and repurposes it for garden irrigation. The project verified condensate collection rates for newly installed 2-ton and 3-ton air conditioning units. Results demonstrate that harnessing air conditioner condensate can significantly contribute to water conservation efforts and promote eco-friendly practices in urban environments. This approach not only addresses water scarcity issues but also prevents the unsightly and potentially damaging effects of condensate dripping onto building exteriors. By reimagining this waste product as a valuable resource, the study highlights a practical method for enhancing sustainability in modern city planning and development.

KEYWORDS

AC Condensate collection, Condensate recovery, sustainability, Collecting condensate for irrigation, smart cities.

1. INTRODUCTION

The Earth's climate system is undergoing significant transformations, leading to erratic weather patterns and extreme events. These shifts are profoundly affecting the hydrological cycle, causing unpredictable fluctuations in water availability and compromising water quality. As a result, many regions worldwide are grappling with unprecedented water scarcity issues, threatening the fundamental human need for clean, accessible water. This crisis is particularly acute in arid regions, such as the Arabian Gulf countries, which are situated in one of the planet's most water-stressed areas. These nations have become heavily dependent on energy-intensive desalination technologies to meet their basic water requirements. As populations grow and economies develop, the demand for water continues to escalate, placing additional pressure on already strained resources. Concurrently, global warming is causing a steady rise in average temperatures. This trend is especially problematic in humid climates, where the combination of heat and moisture creates oppressive living conditions. The need for artificial cooling in these environments is becoming increasingly critical, yet it often conflicts with water conservation efforts. The interplay between water scarcity, rising temperatures, and the growing demand for both water and cooling presents a complex challenge for policymakers and engineers alike. It calls for innovative solutions that can address multiple issues simultaneously, balancing human comfort with environmental sustainability in an era of climate uncertainty (Kushwaha and Kumar, 2025; Ahmed, 2024; Chen et al., 2024). In recent decades, Air conditioning systems have transitioned from luxury items to essential fixtures in buildings worldwide. These devices, which regulate indoor climate by adjusting temperature and moisture levels, have become integral to daily life in many regions. The proliferation of such technology has been remarkable, with global adoption rates surging by 6.3% in just half a decade. However, this rapid expansion of cooling infrastructure comes with significant energy implications. As more households and businesses install Air Conditioning units, power grids face mounting pressure to meet the escalating demand. Projections from energy experts paint a concerning picture for the future, suggesting that electricity consumption related to cooling could potentially triple by mid-century. This trend poses complex challenges for energy policy and infrastructure planning. While cooling technology enhances comfort and productivity in increasingly warm climates, its growing energy footprint raises questions about sustainability and grid resilience. Balancing the need for thermal comfort with environmental concerns will likely be a key issue for policymakers and engineers in the coming decades (Kabeel and El-Said, 2015; Ahmed, 2019; Dhamodharan et al., 2023; Yau and Pean, 2011). In tropical and subtropical zones, where

Quick Response Code	Access this article online	
	Website: www.watconman.org	**DOI:** 10.26480/wcm.04.2025.774.778

Cite The Article: Husham M. Ahmed, Muhammad Aqeel Ashraf, Chan Kah Yoong, Tan Yi Fei (2025). Reimagining Wastewater: Air Conditioning Condensate As A Viable Irrigation Source. Water Conservation & Management, 9(4): 774-778.

high temperatures and humidity prevail, residential energy profiles reveal a striking pattern. Climate air conditioning systems dominate household electricity usage, accounting for an overwhelming majority of power consumption. In these regions, the quest for indoor comfort drives up to 70% of total electricity generation. This heavy reliance on artificial cooling not only strains power grids but also has a less obvious impact on water resources. As these systems work to dehumidify indoor air, they produce substantial volumes of condensate. Ironically, in areas often facing water scarcity, this potentially useful byproduct is typically channeled into wastewater systems, effectively squandering a valuable resource. The dual challenge of managing both energy demand and water resources in these climate zones highlights the need for integrated approaches to building design and urban planning. Addressing these interconnected issues will be crucial for creating sustainable living environments in regions where the desire for comfort intersects with environmental constraints (Algarni et al., 2018; Dino and Akgül, 2019). Atmospheric moisture, a vast untapped resource estimated at 12,800 trillion liters, offers a promising avenue for freshwater production. This innovative approach could be particularly beneficial in regions lacking even brackish water sources, potentially revolutionizing water access in water-scarce areas (Bagheri, 2018). Innovative scientists are investigating the potential of air conditioner condensate as a sustainable water source. This often-overlooked byproduct is gaining attention as a possible solution to water scarcity issues. By repurposing this waste stream, researchers aim to enhance both water and energy efficiency, addressing dual environmental concerns through a single, innovative approach (Al-Abbasi, 2018). A field investigation by Ref. explored condensate recovery from air conditioners (Okeyinka et al., 2021). The research employed analytical techniques to quantify water yield, revealing that a typical unit running for an 8-hour cycle produces around 7.4 liters of condensate daily, highlighting a potentially significant untapped water resource. In a controlled environment. Ref. (Dhamodharan et al., 2024) conducted a study exploring the potential of recycling condensate from a 35-kW ceiling-mounted radiant cooling system in a cabin environment. The research revealed an average condensate production of 8.2 L/h. Exergy analysis demonstrated significant improvements in system performance when utilizing the recovered condensate, with a 31% decrease in exergy consumption and a 5% boost in exergy efficiency. The approach also yielded 35% energy savings, with an economically viable payback period of 6.2 years, highlighting the promising potential of this innovative cooling strategy. (Galindo, 2019) investigated the viability of air conditioner condensate as an alternative water supply. Using a window-type unit, the study yielded 25.9 to 36.7 liters of condensate daily. This significant output suggests that, when properly harvested, Air condition condensate could serve as a valuable non-potable water source. The research included a life cycle assessment to further evaluate the practical implications of this approach. A comparative study evaluated the efficacy of air conditioning condensate and rainwater harvesting systems for non-potable use in U.S. commercial buildings (Ghimire et al., 2019). Focusing on 4-story and 19-story structures in San Francisco, the research revealed striking contrasts. In the taller building, condensate collection surpassed rainwater harvesting by 51-83%, while the shorter building saw rainwater collection outperforming condensate by 45-80%. This disparity was attributed to increased condensate availability in taller structures. The study underscored the critical role of local climate, humidity, collection rates, precipitation patterns, and water needs in optimizing building-scale water reclamation systems analyzed the composition of air conditioner condensate (Matarneh et al., 2024). The research examined physical and chemical attributes, including heavy metal content. Most parameters, such as acidity, conductivity, dissolved solids, turbidity, hardness, and specific ion concentrations, fell within acceptable ranges. While microbial testing was omitted, the findings suggested that the condensate could potentially serve as both drinking water and irrigation source. This research highlights the untapped potential of Air condition condensate in water-scarce regions research explored air conditioner condensate as an alternative water source (Alom et al., 2021). The study analyzed 270 samples from units with 3-4.5 tons/h capacity, focusing on both volume and quality aspects. Results revealed that while the condensate offers potential as a water resource, it requires treatment before being considered potable. This investigation sheds light on the possibilities and limitations of repurposing Air condition condensate, contributing to discussions on sustainable water management strategies. A groundbreaking study examined the condensate recovery potential from the Burj Khalifa's air conditioning system (Frechette et al., 2006). Engineers developed an innovative collection method for water formed on cooling coils throughout the 150-story structure. Results showed a daily yield of 178 cubic meters of condensate. This reclaimed water serves a dual purpose: pre-cooling incoming water supply during summer months and irrigating the expansive surrounding greenery. The system's efficiency is remarkable, producing about 37,079 cubic meters of usable water annually. This sustainable approach not only conserves resources but also enhances the building's environmental footprint, showcasing an ingenious solution to water management in urban skyscrapers. A campus-based study explored air conditioner condensate as a sustainable water source (Scalize et al., 2018). Findings revealed its viability for diverse on-site applications, including restroom facilities, laboratory use, walkway maintenance, and landscape irrigation. This research highlights the potential of repurposing Air condition condensate to meet various non-potable water needs within institutional settings. Studies explored Air condition water generation under varied conditions (Ali et al., 2018). Controlled experiments revealed that condensate production primarily depends on indoor-outdoor humidity and temperature differentials. The study concluded that larger disparities between interior and exterior environments correlate with increased water yield from air conditioning systems. A study found Air condition condensate temperatures ranging from 10-15°C (Nethaji et al., 2019). Utilizing this for wall cooling yielded 6-8% energy savings. Building on these findings, this research investigates the practical implementation and viability of harvesting Air condition condensate in Bahraini homes, aiming to assess its potential for sustainable residential applications. This present research investigated an innovative approach to microalgae cultivation using air conditioner condensate water (Ansari et al., 2024). The study focused on novel method explores the synergy between waste management and sustainable biotechnology, potentially offering a solution to reduce the environmental impact of air conditioning systems while generating valuable algal biomass. The study estimated that this approach could potentially capture 9.5% of total emissions from air conditioning systems. Their results suggest that Aie condition condensate can effectively support microalgal cultivation, reducing freshwater dependency for large-scale production while simultaneously decreasing the carbon footprint of the air conditioning industry. This study examined condensate production from a split air handling unit across 31 Chinese provincial capitals (Deng et al., 2024). The research aimed to assess condensate as a sustainable water source for eco-friendly campus development. Findings showed peak daily condensate yields of 52.99 kg during prime cooling seasons, with highest monthly outputs of 1600 kg and 1100 kg in Hot Summer and Warm Winter periods, respectively. Regression analysis identified outdoor dry-bulb and dew point temperatures as the most significant factors influencing condensate production. A study in Dhahran, Saudi Arabia, examined condensate production from a 1.5-ton split air conditioner during summer months, where temperatures ranged from 25-50°C and relative humidity from 15-90% (Al-Farayedhi et al., 2014). Monthly condensate yields per cooling degree day were June (1.26 kg/ton), July (1.29 kg/ton), August (2.50 kg/ton), and September (2.33 kg/ton). Humidity and temperature were identified as primary factors influencing condensate formation, with extraction patterns closely mirroring relative humidity fluctuations. Chemical analysis suggested the condensate's potability for human consumption. The research developed an analytical model for predicting condensate production, achieving over 90% correlation with experimental data.

This study aims to evaluate the irrigation potential of air conditioner condensate in Bahrain's residential context. It examines climate factors, Air condition system capacities, and condensate yield rates to determine the viability of this alternative water source. The research seeks to uncover opportunities for enhancing local water conservation, decreasing dependence on traditional supplies, and fostering community-level sustainability practices through innovative resource management.

2. METHODOLOGY

Over a six-year research period, the investigator systematically quantified the freshwater generation potential from a two-ton refrigeration air conditioning unit. During the peak cooling season (April to October) in Bahrain's hot, humid climate, a two-ton unit yielded over 2 liters of condensate hourly. During the sweltering months of April to October in Bahrain, when cooling demands are highest, a two-ton Air condition unit yielded more than 2 liters of condensate each hour. The research highlighted that air conditioning processes simultaneously manage both temperature and humidity, effectively extracting moisture from the air alongside heat removal, underscoring the untapped water resource inherent in HVAC operations. This study uncovered a promising avenue for alleviating water scarcity in certain global areas by harnessing condensate from air conditioning systems. Implementing condensate collection technology could significantly supplement existing water supplies, offering a sustainable solution to water stress in regions with appropriate climatic and infrastructural conditions. In hot, humid climates like Bahrain, Gulf nations, and the Middle East, where air conditioning is ubiquitous, this study proposes repurposing the often-wasted condensate for irrigation. The approach involves rerouting Air condition drainage pipes from sewage systems to garden areas, potentially alleviating water scarcity issues and impacting water conservation efforts in regions struggling with limited freshwater supplies.

Seizing the opportunity of the construction of a new residence, the investigator implemented an innovative water management system. This design incorporated specialized piping to channel condensate from the property's air conditioning units directly to the landscaped areas. The residence features six bedrooms, dual living areas, and a kitchen, with climate control managed by 15 air conditioning systems (five 3-ton units and ten 2-ton units). A custom-designed condensate recovery network channels water to eight strategically placed garden outlets. A detailed schematic illustration of the water reclamation system is presented in Figure 1, showcasing the architectural design of the condensate piping connections from the air conditioning units. This visual representation offers a comprehensive overview of how the system is integrated within the building's structure, demonstrating the efficient routing of condensate from its source to its point of use. The piping system concludes with eight outlets in the garden, as illustrated in Figure 2, which shows the drainage pipe outlets leading to the garden.

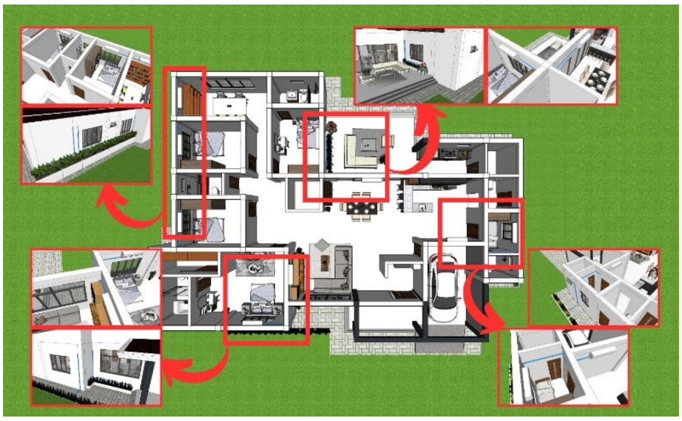

Figure 1: The architectural design of the condensate piping network

Figure 2: The AC drainage piping outlets

This research project evaluates the potential of repurposing air conditioning condensate as an irrigation resource in home environments. By analyzing real-world applications, the investigation seeks to determine whether this approach offers a viable solution for sustainable residential water management, potentially addressing water scarcity issues while maximizing resource efficiency in household settings.

3. Results And Discussions

Building on prior research, the author's findings indicated that a standard 2-ton air conditioning unit produces roughly 2 liters of condensate hourly (Ahmed, 2019; Ahmed and Calucag, 2023). The monthly mean condensate collection volumes are depicted in Figure 3. An extensive three years dataset that elucidates the complex interplay between indoor and outdoor relative humidity and the quantity of condensate water recovered is presented in Figure 4. This visual representation offers valuable insights into the factors influencing condensate production, potentially informing more efficient water recovery strategies in air conditioning systems. To validate the consistency between previous research and current condensate production in the newly built residence, a novel experiment was conducted. This study focused on two distinct air conditioning units: a 2-ton and a 3-ton refrigeration capacity system. The investigation spanned a three-month period during the summer of 2023, encompassing June, July, and August. This targeted approach aimed to provide contemporary data on condensate generation, allowing for a direct comparison with earlier findings and potentially revealing any variations in production rates or patterns. The experiment yielded conclusive results, affirming that the 2-ton refrigeration AC unit generated 1.963 liters of condensate hourly, while the 3-ton unit produced 2.54 liters per hour. These outcomes are visually represented in Figures 5 and 6. Environmental data analysis revealed significant fluctuations in outdoor relative humidity, peaking at 100% and occasionally dipping to a mere 9%. The mean outdoor relative humidity was calculated at 54.1%. Interestingly, the indoor environment maintained a notably lower average relative humidity of 32.4%, highlighting the substantial moisture-removal capacity of the air conditioning systems under study. To assess the viability of using AC-generated condensate for garden irrigation, a targeted experiment was devised. The existing condensate drainage system was modified, extending pipe outlets to directly feed trees and plants. This custom network strategically extended the condensate irrigation system to support a comprehensive garden landscape. The design incorporated a linear watering pathway for general plant maintenance, seamlessly integrated with a dedicated vegetable cultivation area. By redirecting air conditioning condensate, the system transformed previously wasted water into a sustainable irrigation solution, enabling green space development while maximizing water resource efficiency. Figure 7 provides a visual representation of this innovative irrigation setup, demonstrating the practical application of repurposed condensate water in sustaining both ornamental and edible plants within the residential landscape. The residence's occupants employ climate control as needed, benefiting from the structure's effective thermal insulation. Daily usage patterns reveal 8-10 AC units operating during daylight hours, with 3-4 units running overnight, ensuring round-the-clock cooling. This consistent operation yields approximately 8 to 20 liters of hourly condensate, redirected for landscape irrigation. In the context of global water scarcity, smart urban planning must prioritize sustainable water management. Harnessing Air condition condensate emerges as a promising strategy, offering a soft water source with particular potential for irrigation. This innovative approach aligns with the broader goal of ensuring adequate water access for urban communities and meets smart cities requirements, demonstrating how repurposing what was once considered waste can contribute to resource-efficient city designs.

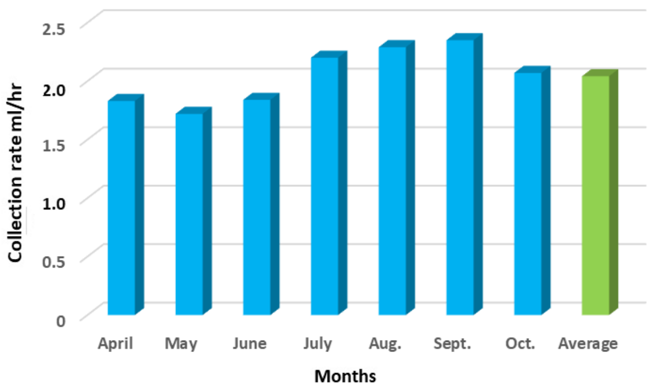

Figure 3: Average monthly collection rate

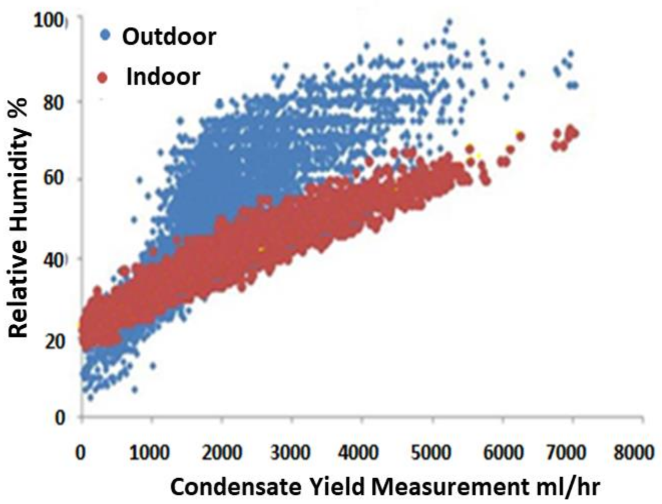

Figure 4: Three-Year Analysis of Relative Humidity's Impact on Condensate Collection

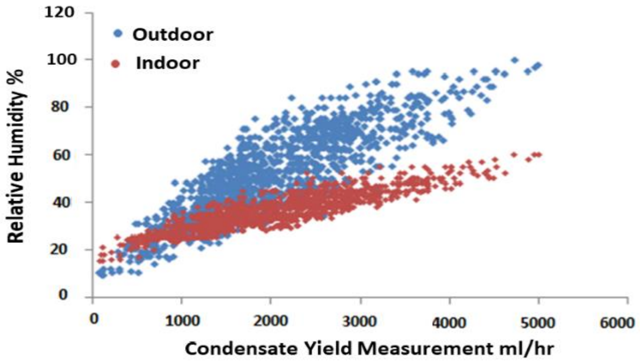

Figure 5: Relationship Between Relative Humidity and Condensate Collection for a 2-Ton Unit

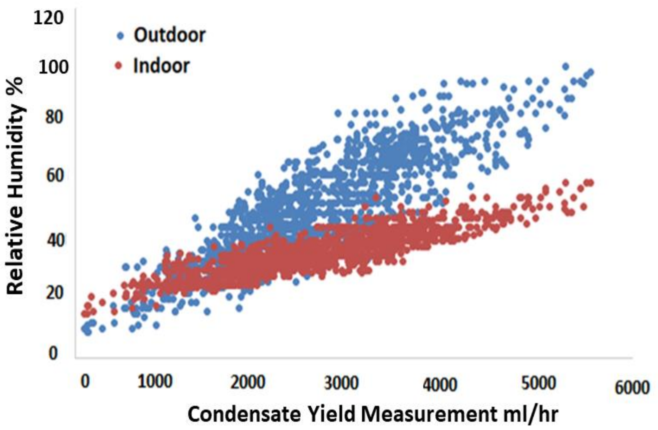

Figure 6: Relationship Between Relative Humidity and Condensate Collection for a 3-Ton Unit

Figure 7: The outlets of the AC drainage piping extend out to the garden.

4. Conclusions

This comprehensive study on air conditioning condensate recovery and utilization presents a compelling case for integrating this innovative approach into smart city designs and sustainable urban water management strategies. Key findings include:

- Consistent condensate production rates: The study confirms that modern 2-ton and 3-ton AC units produce approximately 1.963 and 2.54 liters of condensate per hour, respectively, aligning closely with previous research.
- Environmental impact: The significant difference between outdoor (mean 54.1%) and indoor (mean 32.4%) relative humidity levels demonstrates the substantial moisture-removal capacity of AC systems, highlighting the potential for water recovery.
- Practical application: The successful implementation of a condensate irrigation system showcases the viability of repurposing this water source for residential landscaping.
- Resource efficiency: With daily condensate production ranging from 8 to 20 liters per hour, depending on AC usage patterns, this approach offers a significant and consistent alternative water source for irrigation.
- Smart city integration: The project aligns with smart city requirements by demonstrating how waste can be repurposed to address water scarcity issues and contribute to resource-efficient urban designs.

This research underscores the potential of Air Condition condensate recovery as a sustainable water management solution in urban environments. This approach conserves potable water, promotes green spaces, and enhances urban livability. As cities face water scarcity, integrating condensate recovery systems into urban planning represents a promising step towards sustainable and resilient water management practices.

References

Ahmed, H. M., 2019. Effect of Humidity on the Amount of Water Collected from Air-Condition Systems: Experimental Approach, Journal of Energy Technologies and Policy, Vol.9, No.7, 2019, Pp. 35-38.

Ahmed, H. M., and Calucag, L. S., 2023. Exploring the Outdoor Relative Humidity Correlates of Collected Water Condensation: A Statistical Analysis in the Kingdom of Bahrain Environment, 2023 IEEE 8th International Conference on Engineering Technologies and Applied Sciences (ICETAS), Bahrain, 2023, Pp. 1-5, doi: 10.1109/ICETAS59148.20 23.103 46436.

Ahmed. H. M., 2019. The Amount of Fresh Water Wasted as by Product of Air Conditioning systems: Case study in the Kingdom of Bahrain, International Conference on Fourth Industrial Revolution, ICFIR 2019, Session code: S20, Paper sequence within session : 1, Kingdom of Bahrain, 19-21 Feb 2019. IEEE Explore DOI: 10.1109/ICFIR.2019.8894782.

Ahmed. H. M., 2024. Air Conditioning Condensate: A Potential Water Source for Irrigation, Business Sustainability with Artificial Intelligence (AI): Challenges and Opportunities: Springer Nature Switzerland, Volume 1, Pp. 1213-1223

Al-Abbasi, O., 2018. Water Desalination Using Renewable Energy in a Humidification-Dehumidification Cycle for Bahrain Climate Conditions, Sustainability and Resilience Conference, University of Bahrain, October 16-17. DOI:10.18502/keg.v3i7.3084

Al-Farayedhi, A. A., Ibrahim, N. I., Gandhidasan, P., 2014.Condensate as a water source from vapor compression systems in hot and humid regions, Desalination, Volume 349, Pp. 60-67, ISSN 0011-9164, https://doi.org/10.1016/j.desal.2014.05.002.

Algarni, S., Saleel, C. A., and Abdul Mujeeb, M., 2018. Air-Conditioning condensate recovery and applications: Current developments and challenges ahead, Sustainable Cities and Society, Volume 37, Pages 263-274. https://doi.org/10.1016/j.scs.2017.11.032.

Ali , M. A., Saifur, S., Ali, M. A., 2018. Quantification of Condensate Water Generated from Air Conditioning System, Global Science and Technology Journal Vol. 6. No. 3. Issue. Pp.44-56. https://www.scirp.org/reference/referencespapers?referenceid=2671829.

Alom, M. M., Ahsan, A., Imteaz, M., 2021. Quantity and quality of condensate air conditioner water for potential use in drinking purpose, Desalination and Water Treatment , 210, Pp. 164–169, 2021. https://doi.org/10.5004/dwt.2021.26571

Ansari, F. A., Hassan, H., Ramanna, L., Gani, K. M., Singh, K., Rawat, I., Gupta, S. K., Kumari, S., Bux, F., 2024.Recycling air conditioner-generated condensate water for microalgal biomass production and carbon dioxide sequestration, Journal of Environmental Management, Volume 351, 2024, 119917, ISSN 0301-4797, https://doi.org/10.1016/j.jenvman.2023.119917.

Bagheri, F., 2018. Performance investigation of atmospheric water harvesting systems, Water Resources and Industry 20, Pp. 23–28. https://doi.org/10.1016/j.wri.2018.08.001.

Chen, X., Liang, Y., Yin, L., Cheng, H., 2024. Experimental study on heat recovery and utilization of air conditioning condensate, Energy Reports, Volume 12, Pp. 4004-4015, ISSN 2352-4847, https://doi.org/10.1016/j.egyr.2024.10.007.

Deng, X., Shen, Y., Yang, S., Feng, J., Wang, S., Li, D., Li, Y., 2024. Feasibility of condensate water recycle of split air handling unit in Chinese University buildings, Energy and Built Environment, Volume 5, Issue 2, Pp. 309-315. https://doi.org/10.1016/ j.enbenv.2022.10.006.

Dhamodharan, P., Ayalur, B K., Judefelix, J., Prabakaran, R., Kim, S. C., 2024. Energy saving potential in radiant cooling system by utilizing air-conditioning condensate: A strategy for green building rating, Applied Thermal Engineering, Volume 236, Part A, 5, 121492, January 2024. https://doi.org/10.1016/j.applthermaleng.2023.121492.

Dhamodharan, P., Kannappan, B., Prabakaran, R., Kumar, A. S., Choi, G.S., Kim, S.C., 2023. Current state of research in air-conditioning condensate utilization and challenges: A review approach, Applied Thermal Engineering, Volume 233, 121171, https://doi.org/10.1016/ j.applthermaleng.2023.121171.

Dino, I. G., and Akgül, C. M., 2019. Impact of climate change on the existing residential building stock in Turkey: An analysis on energy use, greenhouse gas emissions and occupant comfort". Renewable Energy, 141, 828e846. https://doi.org/10.1016/ j.renene. 2019. 03. 150.

Frechette, R., Leung, L., and Boyer, J., 2006. Mechanical and Electrical Systems for the Tallest Building/Man- Made structure in the world: A Burj Dubai Case Study, Sustainable Cities and Society 37, Pp. 263–274. https://hdl.handle.net/1969.1/4529

Galindo, R. M., 2019. Air Conditioning Condensate: A Potential Water Source and a Creeping Destroyer, College of Engineering, Cebu Technological University Cebu City, Philippines. Corpus ID: 235194740

Ghimire, S. R., Johnston, J. M., Garland, J., Edelen, A., and Jahne, M., 2019. Life cycle assessment of a rainwater harvesting system compared with an AC condensate harvesting system, Resources, Conservation and Recycling, Volume 146, Pp. 536-548. https://doi.org/ 10.1016/ j.resconrec.2019.01.043.

Hossein, O., and Kargari, A., 2022. Production of high-quality drinking water from chillers and air conditioning units, condensates using UV/GAC/MF/NF hybrid system, Journal of Cleaner Production, Volume 368, 133177, 25 September 2022. https://doi.org/10.1016/ j.jclepro.2022.133177.

Kabeel, A. E., El-Said, E. M. S., 2015. Water production for irrigation and drinking needs in remote arid communities using closed-system greenhouse: A review, Engineering Science and Technology, an International Journal, Volume 18, Issue 2, 2015, Pages 294-301, ISSN 2215-0986, https://doi.org/10.1016/j.jestch.2014.12.003.

Kushwaha, K. P., Kumar, A., 2025 Effect of ambient conditions on the performance of solar-powered atmospheric water harvesting system based on desiccant wheel: An experimental investigation, Solar Energy Materials and Solar Cells, Volume 279,113288, ISSN 0927-0248. https://doi.org/10.1016/j.solmat.2024.113288.

Matarneh, S., AlQaraleh, L., Alkhrissat, T., Abdel-Jaber, M., 2024. Assessing water production from air conditioning systems as an unconventional supply source: A focus on water quality and social acceptance perspectives, Case Studies in Chemical and Environmental Engineering, Volume 9, 100585. https://doi.org/ 10.1016/j.cscee.2023.100585.

Nethaji, N., Mohideen, T.,Nethaji M., 2019. Energy conservation in room air conditioner unit by recovering cold energy from condensate. International Journal of Refrigeration. Volume 104, Pp. 95-102. https://doi.org/10.1016/j.ijrefrig.2019.05.005

Okeyinka, O. M., Ogundipe, O. O., Oloke, D. A., Adesogan, S., 2021. Reclaimed Air Conditioner Condensate as Alternative Source of Water in Hot Humid Region, IOSR Journal of Mechanical and Civil Engineering 18(6):Pp.25-30. DOI: 10.9790/1684-1806012530.

Scalize, P. S., Soares, S., Cristina, A., Alves, F., Albuquerque, A., 2018. Use of condensed water from air conditioning systems, Open Engineering 8(1): Pp. 284-292. https://doi.org/ 10.1515/eng-2018-0031.

Yau, Y. H., Pean, H. L., 2011. The climate change impact on air conditioner system and reliability in Malaysia :A review, Renewable and Sustainable Energy Reviews 15, Pp. 4939– 4949. https://doi.org/ 10.1016/j.rser.2011.07.059.