Original Paper

A systematic literature review of architecture-related dew and fog harvesting

Muhammar Khamdevi

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Abstract. *Dew and fog harvesting have been the topic of numerous studies since the 2000s to address the global water crisis brought on by climate change, as an alternative and sustainable solution. Though this topic has many connections to architectural science, it is nonetheless largely alien to* *academics and practitioners with architectural backgrounds. What research focuses have been done? What research methodologies have been employed? What implications and limitations have been discovered? This study addresses these questions by conducting a systematic literature review. This discovered that the effectiveness and efficiency of planar shape-based fog nets and dew condensers have continued to dominate the research focus, although several studies have begun to consider the forms of three-dimensional and biomimicry. One study also started researching the application of this technology to urban settings apart from rural areas affected by water scarcity. The most employed methodology in this research has been design testing and review. Some models, prototypes, and developments are implicated as best practices, although the limitations of these studies are in the physical local context, material selection, methodologies, scalability, water quality, and water quantity. The results of this review provide directions for further research in Indonesia to consider the use of harvesting combination systems in three dimensions form with passive systems and low tech. Moreover, this discovery also opens opportunities for the use of vernacular or traditional architecture and local natural materials that have not been discussed by previous studies.*

1. Introduction

Water scarcity is defined as an excess of demand for water relative to available supply (Damkjaer and Taylor, 2017). Increased total water demand, as well as increased groundwater use, have contributed to increased stress between the use of freshwater supplies and addressing regional water scarcity (Jimenez-Cisneros et al., 2014). This symptom is distinguished by water stress and water shortage. Water stress is produced by excessive consumption of groundwater whereas water shortage is caused by a lack of available water per person. A considerable loss in the quality and quantity of freshwater causes a water crisis, which harms human health and economic activity (Manungufala, 2021). Water resources are critical in ensuring environmental sustainability and food security by maintaining the natural and agricultural environments. Agriculture is critical to the economies and public health of developing countries (Zhang et al., 2021). The global water consumption is estimated to be over 4 trillion cubic meters. Agriculture consumes the most water in Asian countries (82% of total consumption), whereas industry consumes the most water in Europe (55% of total consumption) (Du et al., 2022).

However, this is currently occurring not only in arid areas but also in overdeveloped areas suffering from environmental degradation (Manungufala, 2021). Water scarcity is becoming more of a worldwide concern. This crisis has had the greatest impact on South Asia, followed by East Asia, Southeast Asia, Sub-Saharan Africa, North Africa, Europe, North America, and South America (Sadoff et al., 2015). More than two billion people globally have experienced it (Chakkaravarthy & Balakrishnan, 2019). Climate change, which affects hydrometeorological conditions, also adds to water scarcity (Assaf & Erian, 2012).

Since 2015, water scarcity has been a worry addressed in the UN Sustainable Development Goal 6 (Van Vliet et al., 2021). This is one effect of global climate change, both in terms of quantity and quality (Ling, 2021). In drought-affected, densely populated, and socioeconomically unstable places, this will have an impact on security and sustainability (Singh et al. 2014). The energy supply, food security, financial, and economic sectors are all at risk due to this water crisis (Chakkaravarthy & Balakrishnan, 2019). Even though the region is generally abundant in water resources, Indonesia is not immune to this (Afrilia, 2022). The Indonesian Meteorological, Climatological and Geophysical Agency (BMKG) has issued the warning and predicted this crisis will occur in Java, Bali, and Nusa Tenggara. This problem will have the greatest impact on low-income households that lack access to clean water, as well as farmers in rural areas (Hapsari, 2022; Ina, 2022).

Numerous researchers have tried to find alternatives to solve this problem. Some of them have studied the collection of water from the sea and the air (Cassauwers, 2022). Some investigations about atmospheric water harvesting, particularly from dew and fog, have been conducted since the year 2000. The technique used to capture dew is dependent on condensation, either passively or actively. Fog harvesting technology uses conventional methods, biomimicry, and bioinspiration. According to Jarimi et al. (2020), both technologies were developed on a small or large scale. Many dew and fog collectors still in use today, particularly those built for large-scale use, have inefficient designs (Suau, 2010; Beysens et al., 2012).

Condensation is the process by which water vapor (moisture or vapor) in the environment changes state from gas to liquid (Schiermeier, 2008). Condensation is crucial in the creation of fog and dew. Condensation happens because of temperature changes that result in cooling (cooling), which is strongly tied to the dew point temperature and a specified degree of relative humidity (RH). Light water droplets or water droplets are usually suspended or suspended in the air and are referred to as fog (Pearce, 2002). Meanwhile, the heavy one is commonly referred to as dew when it comes into touch with liquid or solid surfaces (Khalil & Adamowski, 2016).

Fog and dew can occur at any time of day or night but are most common from late night until early morning (Leopold, 1952). At least two parameters must be met: relative humidity (RH) near to 100% saturation (Francis, 2002; Gleissman, 2007), and temperature variations. Fog forms when the ground surface temperature approaches the dew point temperature, whereas dew forms when the surface temperature approaches the dew point temperature (Di Bitonto, 2020). The temperature at which air must be chilled to become saturated with water vapor (assuming constant air pressure and moisture content) is known as the dew point. The moisture capacity is lowered at that time. Humidity influences the dew point. The dew point rises as the amount of water vapor in the air increases (Wallace & Hobbs, 2006).

This research issue has thus far received little discussion in Architecture. Water conservation has not received as much attention as reducing water use, especially when it comes to the topic of green buildings (Weeks, 2013). A prior study using bibliometric analysis discovered that architecture may step in and take a place in this research where it has opportunities to make contributions independently or collaborate multidisciplinary with other scientific disciplines (Khamdevi & MLT, 2023). This systematic literature review (SRL) has the objective of identifying and analysing the research focuses, methodologies, implications, and limitations used in dew and fog harvesting research related to architecture.

2. Materials and Methods

SLR is the process of locating, evaluating, and understanding all relevant research data to respond to research questions (Kitchenham & Charters, 2007). It uses strategies to collect secondary data, evaluate research critically, and synthesize qualitative or statistical findings (Armstrong et al., 2011). The intention is to provide an exhaustive assessment of the most recent published and unpublished research evidence that is methodical, thorough, transparent, and repeatable

(Siddaway et al., 2019). Furthermore, SLR lessens bias to make data more objective (Egger et al., 2001).

To keep the review narrowly focused, specific research questions were developed. The following research questions are based on the research objectives:

RQ1: What kind of research focuses are selected by researchers in dew and fog harvesting related to architecture?

RQ2: What kind of research methodologies are applied in dew and fog harvesting related to architecture?

RQ3: What kind of implications and limitations are applied in dew and fog harvesting related to architecture?

High levels of methodological detail should be provided when describing systematic reviews (Haddaway et al., 2022). Therefore, the PRISMA (Preferred Reporting Items for Systematic Review and Meta-Analyses) protocol method is employed in this research. This method has three steps: identification, screening, and inclusion (see Figure 1).

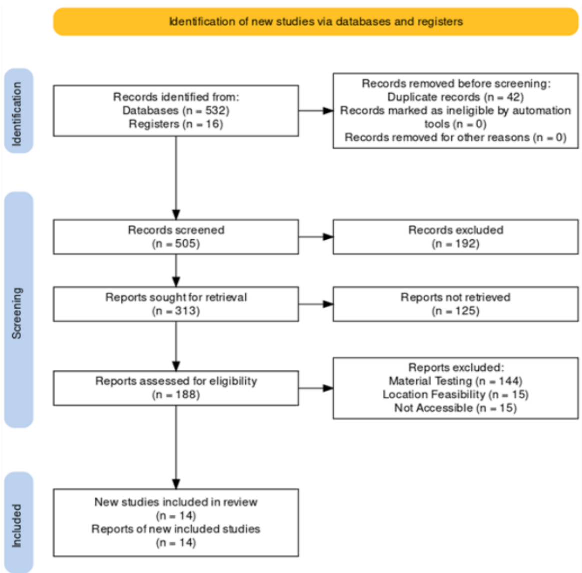

Figure 1. PRISMA Flow diagram of primary study selection and search.

2.1. Search Strategy

In this study, dew and fog harvesting-related scholarly papers from a variety of fields - based on certain keywords related to the study - were gathered from the SCOPUS database using the Publish or Perish (PoP) software. Due to limited access to SCOPUS, PoP is used. The keywords were dew catcher, dew collection, dew collector, dew condensation, dew condenser, dew harvesting, fog catcher, fog collection, fog collector, and fog harvesting.

The search was conducted without regard to the year of publication to gather more comprehensive literature data due to the small amount of data discovered. Furthermore, certain data that is found individually outside of SCOPUS using PoP was manually registered because, despite not being published in a peer-reviewed journal or being indexed in SCOPUS, these publications are very important to this research area and have a significant relation to architecture. The final dataset was then converted into *.xlsx format after being saved in *.csv and *.ris formats. Microsoft 365 Excel version 2212 was used to assist in data identification, evaluation, and descriptive analysis.

2.2. Inclusion and Exclusion

Because the data collected are SCOPUS-indexed scientific publications that are of high quality and are in English, a quality assessment and exclusion of non-English papers was not carried out. From searching using PoP, a dataset of 547 was obtained, of which 531 data came from Scopus and 16 data were outside Scopus. Among them, there were 42 data that were duplicate data that needed to be removed as pre-screening. So that left 505 data to then enter the screening step.

2.3. Data Extraction

192 data were eliminated from the first screening because they had fewer than four citations. Then after reviewing the title and abstract, 125 publication data from the following screening were not collected. Among them, 31 data had no relevance to the topic of dew and fog harvesting design, and as many as 94 data had no discussion related to architectural research. Finally, the dataset was again screened for the last time after reviewing the full text, 174 data were removed. 144 data had a research focus on material testing, 15 data focused on location feasibility, and 15 data were not accessible in Scopus, ResearchGate, Academia, and repositories. So finally, from this screening step, 14 primary data were included in the review (see Table 1).

No.	Publication Titles	Year	Authors
P1	New architectural forms to enhance dew collection	2013	Beysens, D., Broggini, F., Milimouk-Melnytchouk, I., Ouazzani, J., Tixier, N.
P2	Dew water collector for potable water in Ajaccio (Corsica Island, France)	2002	Muselli, M., Beysens, D.A., Marcillat, J., Milimouk, I., Nilsson, T.M., & Louche, A.
P3	A very large dew and rain ridge collector in the Kutch area (Gujarat, India)	2011	Sharan, G., Clus, O., Singh, S., Muselli, M., & Beysens, D. A.
P4	Fog and Dew as Potable Water Resources: Maximizing Harvesting Potential and Water Quality Concerns	2018	Kaseke, K. F., & Wang, L.
P5	Fundamental Limits of the Dew-Harvesting Technology	2020	Dong, M., Zhang, Z., Shi, Y., Zhao, X., Fan, S., & Chen, Z.
P6	Roof-integrated dew water harvesting in Combarbalá, Chile	2018	Carvajal, D., Minonzio, J., Casanga, E., Muñoz, J., Aracena, A., Montecinos, S., & Beysens, D.
P7	An innovative fog catcher system applied in the Andean communities of Ecuador	2017	Carrera-Villacrés, D.V., Robalino, I.C., Rodríguez, F., Sandoval, W., Hidalgo, D.L., & Toulkeridis, T.
P8	Design of water harvesting towers and projections for water collection from fog and condensation	2020	Bhushan, B.
P9	Fog harvesting: An alternative source of water supply on the West Coast of South Africa	2004	Olivier, J.
P10	Harvesting Fresh Water from Fog in Rural Morocco: Research and Impact Dar Si Hmad's Fogwater Project in Aït Baamrane	2015	Dodson, L.L., & Bargach, J.
P11	Simplified modeling and analysis of the fog water harvesting system in the asir region of the kingdom of Saudi Arabia	2018	Gandhidasan, P., Abualhamayel, H.I. and Patel, F.
P12	Water harvesting from fog using building envelopes: part I	2018	Caldas, L., Andaloro, A., Calafiore, G., Munechika, K., & Cabrini, S.
P13	Modelling Environmental Problem-Solving Through STEAM Activities: 4Dframe's Warka Water Workshop	2016	Fenyvesi, K., Park, H., Choi, T., Song, K., & Ahn, S.I.
P14	Warka water promises to harness safe drinking water from the air	2015	Williams, A.

Table 1. Publications included in the review.

2.4. Descriptive and Content Analysis

14 primary papers that have been read in full text, then analysed using descriptive and content analysis approaches. Descriptive analysis tries to reveal research trends presented in figures and tables. While content analysis is used to uncover these papers' research focuses, methodologies, implications, and limitations.

3. Results and Discussion

Of the many publications collected, data analysis shows that research on dew and fog harvesting systems has grown optimistically in various parts of the world to solve the problem of water scarcity. This section will provide an overview of the global progress of research on dew and fog harvesting systems related to architecture. Then, we will examine both newly planned and already implemented systems and techniques to determine their potential as alternative solutions to meet the water needs of households and other essential sectors. Aside from that, we focus on what we may learn about its role in achieving security and sustainability.

3.1. Descriptive Analysis

The first search on the SCOPUS database revealed that there were still not many studies overall on the topic. There was also not much research on this subject specifically tied to architecture. Therefore, it was entirely understandable that the articles under review for this study had very few outcomes. According to everything that had been published, this research only recently began to gain traction in 2015. The year 2018 saw the most studies produced, with 4 papers (see Figure 2).

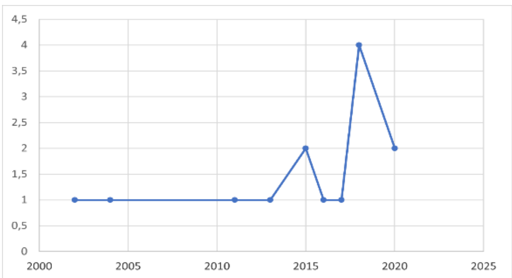

Figure 2. Publication Year on Dew and Fog Harvesting Related to Architecture.

Four of the 14 published papers came from studies in the United States, accounting for most of the publications, followed by two papers from France. In addition, one paper was generated by Chile, China, Ecuador, Finland, India, Saudi Arabia, and the United Kingdom (see Figure 3). This demonstrated how extensively the subject of this research is being explored around the globe. This also showed the attention and significance of this subject and the possibility of highly major future development.

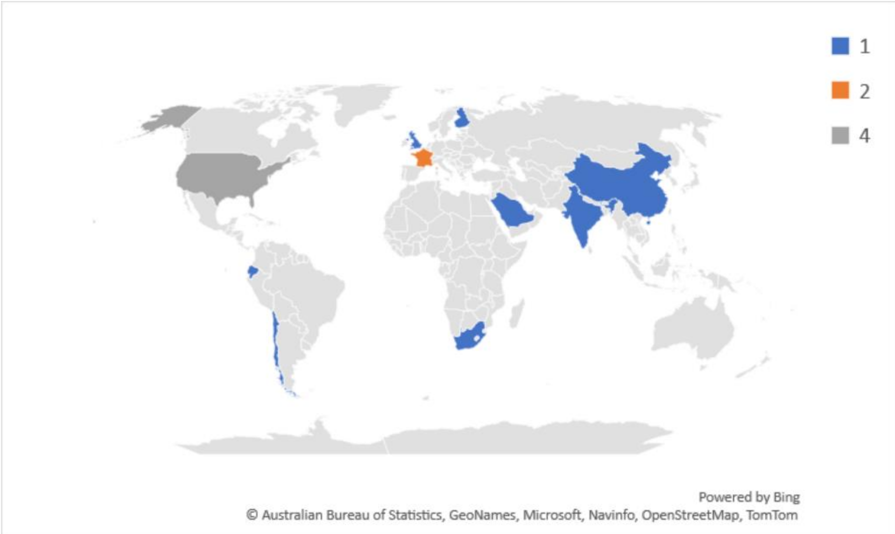

Figure 3. Countries origin of publications on dew and fog harvesting related to architecture.

These publications have been widely disseminated, particularly in the engineering, hydrology, and geography fields. However, research on the topic of dew and fog collecting have not been published in any architectural scientific journals (see Table 2). This demonstrated that the study on this subject is still unfamiliar to architecture. The more diverse points of view are used to solve the problems in this research because there are many of these concerns in architectural studies. In addition, architecture integrates engineering, design, social sciences, and natural sciences to create a more holistic science.

No.	Sources	Papers
P1	Aerosol and Air Quality Research	1
P2	Atmospheric Research	1
P3	Bridges Finland Conference	1
P4	Chemical Engineering Transactions	1
P5	GeoHealth	1
P6	GeoJournal	1
P7	Journal of Hydrology	1
P8	Journal of Water Supply: Research and Technology - AQUA	1
P9	Nanoscale and Microscale Thermophysical Engineering	1
P10	New Atlas	1
P11	Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences	1
P12	Procedia Engineering	1
P13	Transactions of the ASABE	1
P14	Water and Environment Journal	1

Table 2. Publication sources on dew and fog harvesting related to architecture.

Most of the publications in this study - a total of 10 papers - were journal articles. The remaining 3 studies were presented as conference papers. One more article was found on the Web News (see Figure 4). It indicated that many of the study papers have been published in a variety of sources. At least it attracts the attention of many academics from different fields to participate in this research with the numerous appearances of these publications.

Three of the 53 authors were active in creating publications. With four papers, Beysens is the author who has produced the most publications. Then Muselli and Milimouk-Melnytchouk have each produced two papers. The rest only have produced 1 paper. The same research on dew harvesting has been the topic of discussion among the three of them. They have also worked together to write several papers. Such research relationships are crucial for the development of a robust and extensive research network.

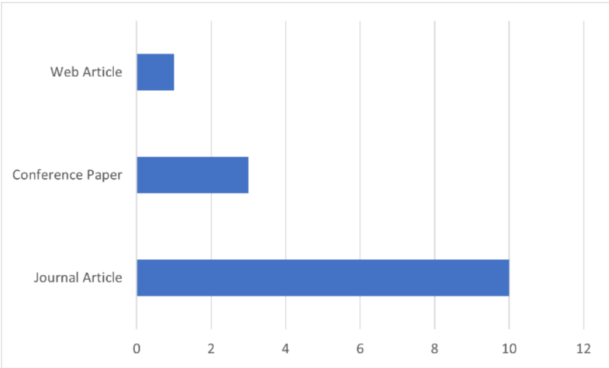

Figure 4. Publication types on dew and fog harvesting related to architecture.

In as many as five publications, the system regarding fog harvesting has frequently been explored. The dew harvesting system was present in three works below the fog harvesting system (see Figure 5). The remaining systems combined rain harvesting, dew harvesting, and fog harvesting to obtain the necessary amount of water for everyday needs. Dew harvesting has been a highly popular motif since the 2000s, but it has ultimately fallen out of favour. Many limitations exist on this technology, especially if it is intended to be scaled up. In this study, the problem of maximum height and surface area posed a hurdle.

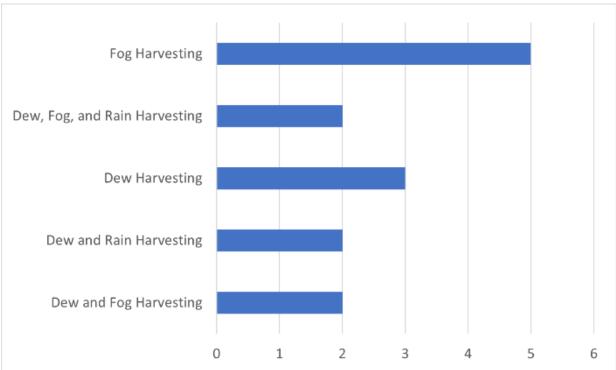

Figure 5. Dew and Fog Harvesting Systems Related to Architecture.

Even though there was little activity at first, the concept of fog harvesting has been becoming more and more prevalent. When this theme emerged as an alternative, it didn't mean that dew harvesting research would cease altogether. A lot more attention is now being paid to the specific research themes of the two combined, moreover with rain harvesting technology. To achieve the intended effectiveness and efficiency, these technologies could complement one another. In the future, this combination is an option.

3.2. Research Focuses

3.2.1. Planar Shape Dew Condenser and Fog Net

Muselli et al. (2002) attempted to test and construct a dew water collector for drinkable water at Ajaccio on the island of Corsica, France. The design of the collector, its performance in terms of water yield, and the analysis of the collected water to evaluate its acceptability for drinking were all covered in the paper. According to them, there was a lack of information on the design and performance of dew water collectors, particularly in the Ajaccio district. While earlier studies had investigated dew collection in a variety of places and climates, there had been little focus on the Ajaccio Gulf area. This research intended to fill that gap by detailing the development and testing of a dew water collector in this location.

Meanwhile, Olivier (2004) investigated the viability and execution of fog water collecting as a supplementary water supply in a water-stressed settlement on South Africa's West Coast. The paper examined the process of choosing an experimental site, designing the fog water collection equipment, and analysing water yields, fog occurrence, and water quality. The purpose of this article was to address the scarcity of comprehensive research on the viability and implementation of fog water harvesting as a supplementary water source in water-stressed areas on South Africa's West Coast. While there had been past experiments and studies on fog water collecting in other places, such as Namibia and Chile, there was a need for research focused exclusively on South Africa's West Coast. This work intended to fill a research gap by offering insights into the design, installation, and performance of a fog water collection system in this region.

Sharan et al. (2011) concentrated on evaluating the yield of ridge-and-trough modules for dew water collection, determining whether results from small condensers could be extrapolated to larger dew condensers, and designing a more efficient condenser setup using computational fluid dynamics (CFD) simulation.

This study was conducted due to a lack of quantitative data on the frequency and amount of dew occurrence in the study area. This information was critical for estimating the potential yield of large-scale dew condensers and developing effective condenser configurations.

Dodson et al. (2015) attempted to put the fog water collection idea into action in Morocco, focusing on rural Berber villages. The study's goal was to solve water scarcity in these regions by investigating the use of fog as a possible supply of potable water. It also entailed the development and deployment of sustainable solutions to improve water management and sanitation, such as fog-collecting nets and ecological filtering systems. The research gap was not specifically highlighted in this study. Based on the information presented, one potential study gap could be the need for additional research on the long-term durability and scalability of fog water harvesting systems in rural Berber villages. While the report detailed the successful implementation of fog-collecting nets and biological filtering systems, it did not go into detail about their long-term usefulness and maintenance. Future research on fog yield models, a correlation between fog yield and wind direction/speed, and water quality monitoring were all mentioned. These research topics indicated a need for additional exploration and knowledge of the technological components and environmental factors associated with fog water collection in rural Berber villages.

Carrera-Villacrés et al. (2017) installed a fog catcher system in the Ecuadorian towns of Yaguachi and Galte to alleviate the region's water deficit and boost agricultural production. The study was done to estimate the demand for irrigation water, collect weather data to evaluate the ability of a fog catcher to trap condensation and assess the water demands of residents and crops. Given the availability of fog conditions that might potentially give a water supply, they sought a solution to the lack of fog catcher systems in the Ecuadorian settlements of Yaguachi and Galte. The purpose of this article was to close this gap by building a fog catcher system and evaluating its effectiveness in satisfying the communities' water needs.

Caldas et al. (2018) explored the technical elements of fog collection mechanisms, specifically the development and deployment of fog harvesting devices in urban contexts as a sustainable water supply option. While fog harvesting systems had been extensively researched and used in rural settings, this work attempted to address the gap in research on their application and viability in urban settings. The report presented a novel adaptation of fog harvesting technology utilized in rural regions for use in cities as a sustainable alternative to water delivery. There was, however, little research on the technical elements and implementation of fog collection methods in urban contexts.

Gandhidasan et al. (2018) attempted to focus on fog water collection and the factors influencing its efficiency. The paper examined various models and methodologies for estimating fog water collection potential, as well as the impact of impaction surface properties and mesh design variables on collection efficiency. The scientists also investigated advanced strategies inspired by biological species for developing and modifying fog collector impaction surfaces. Overall, the research sought to provide insights into optimizing fog water collection efficiency based on local climatic conditions and fog collector design characteristics. This study was conducted to address the scarcity of large-scale field testing of impaction surfaces for fog water collecting under uncontrolled natural fog circumstances. While several surfaces have been evaluated in laboratories under controlled artificial fog circumstances, their performance in the field has received less attention.

Carvajal et al. (2018) investigated the chemical composition of dew water collected from rooftops in Chile's semi-arid region. The authors wanted to know if dew water might be used as an alternate water source in locations with limited freshwater supplies. They attempted to address the lack of long-term research into potential water losses owing to stagnation and evaporation. The authors stated that some water remains stagnant in the gutter after dew events and evaporates during the day, but this water loss was not measured. They believed that water losses due to stagnation might be significant, particularly in semi-arid areas with dust and debris deposition on rooftops, although this issue had not been thoroughly addressed and requires additional research.

Dong et al. (2020) investigated and optimized dew-harvesting technology. The authors provided a comprehensive framework for analysing dew harvesting elements such as ambient temperature and relative humidity. In addition, they offered a photonic design for a selective emitter to increase the condensation mass flux. The purpose was to improve dew collecting efficiency for water collection. This study attempted to address the absence of comprehensive dew-harvesting technology analysis and optimization by considering aspects such as ambient temperature, relative humidity, and the design of a selective emitter. While earlier research had concentrated on individual features of dew harvesting, this paper provided a broad framework for analysing and optimizing the technology. In addition, the authors offered a photonic design for a selective emitter to increase condensation mass flux.

3.2.2. 3D Form Dew Condenser and Fog Net

Beysens et al. (2013) presented research on the effectiveness of different designs of dew condensers in collecting water from the atmosphere. This study was carried out since there had been little research on the usefulness of various designs of dew condensers in collecting water from the atmosphere. The purpose of this work was to close this gap by comparing the water yields of various forms, such as conical, egg-box, and origami, with a standard planar condenser.

Williams (2015) attempted to reveal the development and implementation of Arturo Vittorio's Warka Water building, which was built in 2015 and aimed to capture clean drinking water from the air in locations where traditional water delivery infrastructure was unavailable. The article covered the Warka Water building's concepts and design using a biomimetic approach, as well as the problems and potential benefits of its application in specific places. This initiative attempted to address the demand for a long-term and easily accessible solution to deliver safe drinking water in locations where traditional water supply infrastructure did not exist. The Warka Water facility was designed and built to address this issue by capturing safe drinking water from the air. Meanwhile, Fenyvesi et al. (2016) used this blueprint as a tool for environmental education and problem-solving in the 4Dframe Warka Water workshop, notably in the areas of mathematics, architecture, and natural science. The research investigated the linked nature of these disciplines and how they could be integrated into educational settings to create environmental consciousness and develop the abilities needed for long-term problem-solving. This study attempted to address the lack of understanding of mathematics and natural sciences in answering design difficulties in the absence of architectural knowledge.

Bhushan (2020) studied bioinspired techniques for water harvesting, focusing on the water collection and transport strategies utilized by plants and animals in arid desert settings. The paper also explored the possible uses of these bioinspired techniques in a variety of domains, including consumer, emergency, and defence. The goal of this study was to address the lack of thorough understanding and use of bioinspired approaches to water collection. While studies on the tactics employed by plants and animals in arid desert circumstances to gather and carry water have been conducted, there is a need for additional research to investigate the possible uses of these bioinspired approaches in many domains such as consumer, emergency, and military. This work emphasized the need for additional research in this area and serves as a jumping-off point for future investigations.

3.2.3. Fog and Dew Potential

Kaseke et al. (2018) investigated fog and dew collection as potential sources of potable water in water-stressed areas. The report covered the variations between fog and dew, their potential water yields, and the need for material science and collector design innovations to increase efficiency. It also emphasized the absence of worldwide coordination and information on fog and dew harvesting programs, as well as the necessity for greater research on the potability of fog and dew water. The problems identified in this study were a lack of cooperation and information on fog and dew harvesting operations around the world. The authors emphasized the need for additional research on the potability of fog and dew water and developments in material science and collector designs to improve efficiency. They also underlined the potential of fog and dew as sources of potable water in water-stressed areas but acknowledge the lack of study and expertise in this area.

3.3. Research Methodologies

3.3.1. Design Testing: Model, Prototype, and Implementation

Muselli et al. (2002) used a research methodology that entailed building and testing a dew water collection at Ajaccio on the island of Corsica, France. The collector was a rectangular foil with a 30-degree angle to the horizontal consisting of TiO2 and BaSO4 microspheres embedded in polyethylene. The collector's performance was assessed by monitoring the amount of dew collected over a 478-day period and comparing it to a reference plate. Temperature, humidity, wind velocity, and cloud cover were also gathered and analysed to determine dew generation. Chemical tests of collected water were also performed to assess characteristics such as suspended particles, pH, and ion concentrations.

Meanwhile, Olivier (2004)'s research methodology included several steps. First, an appropriate trial site for a fog water collection system was chosen based on considerations such as water availability, cost, geographical features, and accessibility. A questionnaire survey was used to collect data on home water use in the areas. Then, at the chosen location, a prototype fog water collection system was designed, built, and tested. Water yields, the contribution of fog and rainfall, wet event features, parameters related to water collecting, and water quality were all investigated. An automatic weather station and data recorder were used to collect data on fog occurrence, wind speed, wind direction, and rainfall. A tipping bucket rain gauge was used to capture hourly water collection values, and daily and monthly water collection rates were determined. The study also included training local community members in the operation and maintenance of the system, with the goal of informing a broad audience about the feasibility and benefits of fog harvesting.

Sharan et al. (2011) used a combination of field tests, data analysis, and computational fluid dynamics (CFD) simulation in their work. Field tests were carried out to assess the yield of ridge-and-trough modules for dew water collecting in several models of large-scale dew condensers. Data were analysed to see if the results from small condensers could be generalized to bigger dew condensers. CFD simulation was also used to build a more efficient condenser configuration.

The Beysens et al. (2013) paper's research methodology included conducting trials and measurements in the field to examine the water yields of different forms of dew condensers. The trials were carried out in the summer and fall of 2009 at Pessac, France. The researchers looked at conical shapes as well as two new families of forms: egg-box and origami. The yields of these designs were compared to those of a conventional planar condenser positioned at a 30° angle from the horizontal. Over a 51-day period, data on air relative humidity, air and dew point temperature, wind direction, and wind speed were continually recorded using an autonomous meteorological station. The findings were explained in terms of radiative impacts, heat losses, and gravity water flow.

The research methodology was not specifically specified in Dodson et al. (2015) paper. However, based on the information supplied, it is possible to deduce that the research methodology included a mix of qualitative and quantitative approaches. The use of household surveys to collect data on water use behaviours and consumption trends was mentioned in the paper. It also included climate scientists and meteorologists collecting and analysing micrometeorological data and climate trends. The report also explored the design and implementation of fog-collecting nets and ecological filtering systems, which proposed a practical and experimental way to study fog water harvesting.

Carrera-Villacrés et al. (2017) used a multi-step research methodology. To begin, weather parameters such as precipitation, temperature, sunlight hours, relative humidity, and wind speed were gathered from Ecuador's National Institute of Meteorology and Hydrology (INAMHI) using two weather stations. To calculate the water deficit and evaporation, monthly precipitation data from the previous ten years were utilized, as well as the Wilson nomogram, Thornthwaite method, and Blaney-Criddle method. A community survey was conducted to collect data on socioeconomic characteristics, water sources, agricultural and animal production, crop yields, and water requirements. In 2014 and 2015, fog catcher prototypes were placed, and their performance was tracked. Finally, the collected data and information were utilized to compute the required size of the fog catcher system and determine the community's water requirements.

Carvajal et al. (2018) employed dew water measurements collected from a rooftop in a semi-arid region of Chile as their methodology in their paper. To quantify the volume of dew water collected, a graduated bottle with a capacity of 20 L was installed. The measurements were taken at 08:00 local time every day, and the cumulative volume in the container was recorded without scraping the collecting surface. A nearby meteorological station provided data such as air temperature, relative humidity, wind direction and speed, and rainfall. Dew readings were taken from 3 September 2014 to 31 August 2015.

Gandhidasan et al. (2018)'s research methodology implied a combination of literature evaluation, theoretical analysis, and field testing. Previous research on fog water collecting, impaction surfaces, and collection efficiency aerodynamic models were reviewed. They examined the existing models and methodologies for estimating the potential for fog water collecting and highlight research needs in the field. In addition, the authors undertook field testing in the Kingdom of Saudi Arabia's Asir region to collect data on fog water collection potential and atmospheric conditions. The data gathered was then utilized to validate and improve the existing models.

A study by Dong et al. (2020) did not go into specifics about the methodology. This paper, on the other hand, appeared to employ a combination of theoretical analysis and numerical simulations. The scientists created a theoretical framework to study the dew-harvesting process, considering variables like ambient temperature, relative humidity, and the design of a selective emitter. In addition, they presented a photonic design for a selective emitter to increase condensation mass flux. To validate the suggested framework and design, the theoretical study was supplemented with numerical simulations.

The research methodology was not specifically specified in Bhushan's (2020) paper. However, based on the paper's content and structure, it appeared to be a review article synthesizing existing literature and research on bioinspired approaches to water collection. The authors offered an overview of arid desert environments, water supplies, and water collection mechanisms employed by plants and animals. They also talked about natural teachings, water harvesting data from fog and condensation, and several designs for water harvesting towers and predictions. There were no experiments or data collection methods described in the publication.

3.3.2. Design Reviews: Process, Concept, and Potential

Williams (2015) paper described the research process of Arturo Vittori's Warka Water building. The Warka Water building was field tested and implemented using a combination of biomimetic design and engineering approaches. The article covered the building system's architecture and principles, as well as the problems and potential benefits of using it in specific places. It also mentioned the creation of a modest functional prototype as well as plans for a large-scale field test.

Fenyvesi et al. (2016) did not specify their research approach directly. However, the research appeared to use a combination of literature assessment, theoretical analysis, and description of the 4Dframe Warka Water workshop and its teaching activities. The article was based on existing literature and principles in environmental education, problem-solving, and the integration of mathematics, architecture, and environmental science. It also described the workshop format, activities, and learning objectives in depth.

Kaseke et al. (2018)'s research methodology was not specifically disclosed in their paper. However, the publication appeared to be a review article that synthesised previous fog and dew-collecting research and studies. It explored the distinctions between fog and dew, their prospective water yields, the need for breakthroughs in material science and collection designs, and the possible public health risks associated with heavy metals and biological pollution in fog and dew water. In addition, the report gave examples and estimations of probable fog and dew yields in various locales.

The research methodology of the paper, used by Caldas et al. (2018), involved a literature review and analysis of existing fog harvesting technologies and their application in urban environments. The authors reviewed various fog collection mechanisms, such as drop coalescence on vertically placed meshes, chemical absorption, and desorption processes, and condensation on cold surfaces during the night. They also discussed the different types of fog collectors, including standard fog collectors (SFC) and large fog collectors (LFC), and the materials used for fog collection meshes. The paper also presented the author's own experimental campaign on radiative surfaces, which was discussed in a separate paper. Overall, the research methodology of this paper was based on a comprehensive review of existing literature and the author's own experimental work.

The research methodology was not specifically specified in Bhushan's (2020) paper. However, based on the paper's content and structure, it appeared to be a review article synthesizing existing literature and research on bioinspired approaches to water collection. The authors offered an overview of arid desert environments, water supplies, and water collection mechanisms employed by plants and animals. They also talked about natural teachings, water harvesting data from fog and condensation, and several designs for water harvesting towers and predictions. There were no experiments or data collection methods described in the publication.

3.4. *Implications and Limitations*

3.4.1. Dew Harvesting

The research paper of Muselli et al. (2002) had the implications that well-designed dew water collectors, such as the one constructed and tested in Ajaccio on the island of Corsica in France could be a vital source of water in locations where fog or rainfall is limited. The study found that during a 16-month period, the collector captured a large amount of water, demonstrating its potential as an alternate water source. The chemical examination of the collected water revealed that it is potable, at least in terms of the studied ions, and does not require further filtration. This discovery emphasized the possibility of using dew water as a drinking water source in water-stressed areas. However, there were certain limitations to this study. Firstly, the study was limited to a single area and may not be immediately applicable to other locations with varying climatic circumstances. Furthermore, bacteriological studies of the dew water were not included in the study, which was a crucial factor to consider for its safety as a drinking water source. More research was needed to determine the presence of bacteria and other compounds in dew water, as well as to evaluate the concentration of suspended particles, which was found to be relatively high in this study. Overall, while the study gave useful insights into the design and performance of dew water collectors in a specific region, more research is needed to overcome the constraints and investigate the broader applicability and safety implications of dew water as a drinkable water source.

Beysens et al. (2013) findings had implications for developing and optimizing dew collection systems, particularly in areas where water scarcity is an issue. The findings suggested that employing precise shapes and angles can improve dew water collecting, potentially offering a supplemental source of drinking water. However, some limitations of this study should be noted. To begin, the trials were done in a specific place (Pessac, France) and time (summer and fall of 2009), which may restrict the findings' generalizability to other regions and seasons. Furthermore, the study only looked at a few designs (conical, egg-box, and origami), and there could be other shapes that might harvest even more water. More research was required to investigate a broader range of forms and their usefulness in various environmental situations.

Dong et al. (2020) offered a general framework for studying and optimizing dew-harvesting technologies in their research. The authors attempted to increase the effectiveness of dew harvesting for water collection by considering elements such as ambient temperature, relative humidity, and the design of a selective emitter. This study held the potential to help develop more effective and sustainable water-gathering systems. However, the limitations of this study should not be overlooked. The paper did not include specifics about the research methods, such as numerical simulations and experimental validation. Furthermore, the research did not address the proposed framework and design's actual implementation or scalability. More study and testing were required to evaluate and optimize the proposed technique in real-world settings.

3.4.2. Dew and Rain Harvesting

Sharan et al. (2011) proposed in their research study that large-scale dew condensers, specifically ridge-and-trough modules, could be useful in collecting dew and rainwater for various uses such as irrigation and drinking water supply. The study also highlighted the possibility of employing computational fluid dynamics (CFD) simulation to optimize the design and efficiency of condenser arrangements. This study offered useful information for the design and implementation of dew water collection devices in water-stressed areas. However, there are certain limitations to this study. The absence of quantitative data on the frequency and amount of dew occurrence in the study area was one constraint, which could impair the accuracy of yield estimates for large-scale condensers. Furthermore, the study was limited to a single area and might not be immediately transferable to other regions with different climatic circumstances. More research is needed to validate the findings and investigate the possibility of collecting dew water in different geographical locations.

Carvajal et al. (2018) presented evidence that dew water collected from rooftops in a semi-arid region of Chile has a chemical composition suited for a variety of uses, including irrigation and cattle watering. This revealed that dew water plus rainwater could be a viable alternative water supply in locations where freshwater supplies are scarce. The research gave important insights into the viability of using dew water as a sustainable water supply source. This study did, however, have several shortcomings. To begin with, the study merely looked at the chemical makeup of dew water and did not look at its microbial quality. More research is needed to examine the dangers of microbial contamination related to dew water. Furthermore, the study did not account for long-term water losses owing to stagnation and evaporation, which could impair the overall availability and utilization of dew water. More research is needed to address these constraints and gain a better understanding of the possibilities of dew water as an alternate water source.

3.4.3. Fog Harvesting

Olivier et al. (2004) gave implications that fog water harvesting can be a realistic and effective additional water supply in water-stressed settlements on South Africa's West Coast. The research shed light on the design, implementation, and water yields of a fog water collection system, which can be utilized as a model for similar initiatives in other parts of the country. This study held the potential to address the challenges of water scarcity and improve the quality of life in these communities. However, there were certain limitations to this study. The study has one disadvantage in that it focuses on a specific region and may not be immediately relevant to other geographical areas with various meteorological conditions.

The study by Dodson et al. (2015) did not directly discuss the research's implications and limitations. However, some potential implications and limitations might be deduced from the information supplied. The study emphasized the possibility of fog water collection as a long-term solution to water scarcity in rural Berber villages in Morocco. The study found that fog water collecting had a favourable influence on a variety of factors, including public health, community stability, women empowerment, education, employment, and agriculture. In addition, the paper highlighted the integration of information and communication technologies (ICTs) for water management, bridging the development and digital divides. The research shed light on the collaborative relationships and participatory techniques required for the successful execution of sustainable development initiatives in arid and semi-arid regions. The paper, however, did not go into detail about the long-term durability and scalability of fog water harvesting systems in rural Berber settlements. The study's generalizability may be limited because it focuses exclusively on the context of rural Berber villages in Morocco and their unique water scarcity concerns. The study's research methodology and data-gathering methodologies were not properly defined, making it difficult to assess the findings' reliability and validity. The paper did not address potential obstacles or disadvantages of fog water harvesting, such as changes in fog yield, maintenance requirements, or potential environmental implications. Overall, while the research paper highlighted the potential benefits of fog water harvesting in solving water scarcity, more research and exploration of the long-term sustainability, scalability, and potential limitations of this strategy would be beneficial.

Carrera-Villacrés et al. (2017) showed that installing fog catcher systems might provide a consistent water supply in locations with water scarcity, such as the Ecuadorian communities of Yaguachi and Galte. During the rainy season, the fog catcher system collected up to 20 litres of water per day, with daily water collection ranging from 5 to 10 litres per fog catcher. This technology could help communities achieve their water needs, particularly for agricultural output, and compensate for water shortages. However, there were certain limitations to this study. The absence of complete and trustworthy meteorological data for the study area was one limitation, which necessitated the employment of strategies to compensate for missing data. Another limitation was that the fog catcher system might not be able to meet the research area's overall water requirement since the water needs are disproportionately high. Furthermore, because the study concentrated on two unique villages in Ecuador, the findings may not be immediately transferable to other places with different meteorological conditions or water demands.

Caldas et al. (2018) proposed fog harvesting technology as a sustainable alternative for water supply in metropolitan contexts. This study found that by modifying and executing fog collection technologies utilized in rural areas, fog harvesting might meet water needs in office, institutional, and commercial buildings, providing a local and ecologically friendly water production system. However, the limitations of this study should not be overlooked. The research concentrated on the technical aspects of fog collection systems and did not discuss the potential health risks involved with utilizing atmospheric water. Furthermore, while the report provided a thorough analysis of existing fog harvesting devices, there was little research on the technical elements and implementation of fog collection techniques in urban environments. Overall, this study gave useful insights into the potential of fog harvesting devices in urban contexts; however, more research is required to address health issues and investigate the feasibility and effectiveness of adopting these systems in urban regions.

The implication of the study by Gandhidasan et al. (2018) was that it provided insights into optimizing fog water collection efficiency based on local atmospheric conditions and fog collector design characteristics. The research discussed various models and methodologies for assessing fog water collection potential and investigates the impact of impaction surface characteristics and mesh design variables on collection efficiency. The authors also developed new strategies for modifying the impaction surface of fog collectors inspired by biological species. These findings could help design and improve fog water collection systems in areas where fog water is a potential water resource. However, there were certain limitations to this study. One constraint was that the field testing of impaction surfaces for fog water collection was limited to a certain region (the Asiar region of the Kingdom of Saudi Arabia) and set of atmospheric conditions. The performance of impaction surfaces might differ in other places and under different climate conditions. Furthermore, while the research explored the impact of impaction surface features and mesh design variables on collection efficiency, it did not thoroughly examine all conceivable design variables and their consequences. Further investigation is required to investigate and improve other design variables for fog water collection devices.

3.4.4. Dew and Fog Harvesting

Kaseke et al. (2018) stated that fog and dew harvesting could potentially serve as additional sources of potable water in water-stressed areas. The report emphasized the importance of advances in material science and collector designs to improve the effectiveness of fog and dew harvesting devices. It also stressed the significance of performing additional research on the potability of fog and dew water, as well as addressing potential public health issues about heavy metals and biological contaminants. The absence of detailed facts about the research methods used was one disadvantage of this research paper. The work appeared to be a review article that consolidated existing knowledge, but no precise methodologies were mentioned for selecting and analysing the literature. Furthermore, the paper acknowledged the scarcity of data and analysis on fog and dew harvesting, which made it difficult to make solid conclusions about their potability and usefulness as water sources.

Bhushan's (2020) research proposed water harvesting systems based on the strategies used by plants and animals in arid desert settings (bioinspired), which had the potential to be implemented in a variety of domains such as consumer, emergency, and military. Innovative water harvesting technologies could be developed to address water scarcity challenges by researching and reproducing these natural phenomena. However, the limitations of this research work should not be overlooked. To begin with, the paper mostly reviewed current literature and did not present any new experimental data or discoveries. Second, while the report highlighted the possible uses of bioinspired techniques, it did not go into great length on their practical implementation or viability. Additional study and testing were required to confirm and optimize these bioinspired designs for real-world applications.

3.4.5. Dew, Fog, and Rain Harvesting

Williams (2015) paper did not directly highlight the implications and limits of Arturo Vittori's Warka Water. However, some potential consequences and restrictions might be concluded from the information inferred. The design and construction of the Warka Water facility could provide a long-term and accessible alternative for obtaining safe drinking water from (dew, fog, and rain) in locations where conventional water delivery infrastructure does not exist. The structure had the ability to alleviate water scarcity issues in hilly areas where traditional pipelines and wells are impractical. However, the paper did not go into detail about the Warka Water building's performance and efficiency. It remained to be seen whether a full-size device would draw the projected amount of water. The structure might not be ideal for all areas and should be viewed as a tool for providing clean water in specific areas, particularly in hilly terrain. The article also did not address the potential environmental consequences or obstacles of extracting water from the air, such as air drying or the effects on local ecosystems. While the Warka Water building demonstrated promise in alleviating water scarcity, more research and testing are required to assess its effectiveness, efficiency, and potential environmental implications.

The paper of Fenyvesi et al. (2016) implied that the integration of mathematics, architecture, and environmental science through the 4Dframe Warka Water workshop could be an effective tool for environmental education and problem-solving. It emphasized the linked nature of these disciplines and how they may be utilized in real-world circumstances to create environmental consciousness and develop the skills needed for long-term problem-solving. However, the report did not give empirical evidence or a review of the workshop's effectiveness in meeting its teaching objectives. This was a weakness of the study because data on the outcomes and influence of the workshop on participants' learning and environmental consciousness would be useful. More studies might be conducted to assess the workshop's success in reaching its desired educational results.

4. Conclusions and Future Research

Research on dew and fog harvesting related to architecture in SCOPUS-indexed publications is still small. Thus, there are not many publications that can be discussed in this systematic literature review. However, the number of these studies has recently shown a significant and optimistic increase.

The publications reviewed revealed that research focuses on the effectiveness and efficiency of planar shape-based technologies dominated research on dew and fog harvesting concerning architecture. Moreover, the research might start to shift to thinking about three-dimensional forms and their application in the future not only in rural areas but also in urban settings. The conventional engineering approach somehow is the design strategy that was most frequently adopted in this study. Even so, several researchers have been experimenting with alternative strategies, particularly methods that mimic nature's system for collecting water from the atmosphere (bioinspiration and biomimetics).

Most of these studies chose research methodologies in the form of design testing and review of models, prototypes, and developments. Even so, many papers do not provide clear information regarding the research methodology they use, and several papers use research methodologies that are not precise and not holistic enough. So, most of the results are still not optimal.

The research between dew harvesting and fog harvesting technology was relatively balanced in numbers. Nevertheless, several studies were beginning to consider combining both, even with rain harvesting to optimize water quantity and to provide solutions due to changing weather conditions. Thus, research focuses on this system should be seriously discussed in the future.

Many of the design products produced were still in the form of small-scale designs. However, the main goal of dew and fog harvesting research is that this technology can be realized on a large scale. Only a few have been implemented into real developments and become best practices and demonstrate their potential. They need to be further optimised in the future.

The physical local context, material selection, research methodologies, scalability, water quality, and water quantity, continued to be the limitations of this research. Even though all of this can be improved by creating a design that is adaptable to the site, adaptable to the available materials, and an effective and efficient design in collecting the anticipated water amount and quality. Most researchers seem to make the design first and then look for the appropriate context. Though the design should follow the context. Contextual issues such as the physical and cultural environment are sometimes overlooked by some researchers.

Cultural factors and people's daily habits are just as important as technicalities, as they influence how people interact with new technologies. In fact, a well-designed product aims to fulfil the needs of its users, both physically and non-physically. So, in the future, researchers and practitioners in architecture need to step into this research to join forces with researchers from other disciplines to create a feasible, sustainable, and well design. Arturo Vittori's Warka Water is one design work that has considered these issues. He is not a researcher but rather a practitioner and has never published his work in any scientific papers, but his work has been used by many people in Africa. It seems that he has succeeded in adopting and implementing some of the results of existing research and technology, transferring them with his knowledge and skills as an architect into designs that are adaptive to the local physical and cultural environment. He also used nature and culture as a basis for his designs.

In general, it is possible to say that the dew and fog harvesting system can cover some of the daily water needs. On a small scale, this system can offer supplementary water for household and neighbourhood needs. On a big scale, this system can also offer self-sufficient additional water for urban building needs as well as agricultural irrigation needs. As a result, it can reduce overconsumption of groundwater while alleviating water stress and shortage. Of course, this method can be also integrated with a water storage, recycling, and reuse system to ensure that the leftover water is not wasted. Its role will have a favourable influence on security and sustainability, especially on water conservation.

Based on this systematic literature review, we may conclude various findings that are required for our future research, particularly in architecture science. This also pertains to the possibility of its application in Indonesia, particularly in areas impacted by the water crisis. The design of a building with a combination harvesting system (dew, fog, and rain), that is following the site conditions to be identified later in Indonesia, is our next study focuses on the topic of dew and fog harvesting. The anticipated technology will be in the form of a passive system with low-tech, making it affordable to communities with low incomes. However, the planning must consider not only technical concerns but also environmental (natural and cultural) context issues, employing a qualitative and quantitative feasibility study technique. Furthermore, there may be opportunities to use vernacular or traditional architecture that are tied to existing local community knowledge and easily accessible local natural materials, which have not been discussed in previous studies. As a result, a review and testing strategy is required to examine these local designs and materials. This gives originality to our research. A design method is used during the design stage to create models, prototypes, and design implementation. These outcomes are then tested to determine effectiveness and efficiency to get an optimal building design.

Furthermore, the building design is planned to include a communal space function that can satisfy the needs of the community.

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Authors

Muhammar Khamdevi

Universitas Matana - Department of Architecture, Faculty of Arts Design and Humanities, Jl. CBD Barat Kav.1, 15810 Tangerang, Indonesia.

ORCID author: http://orcid.org/0000-0003-2945-800X

E-mail: muhammar.khamdevi@matanauniversity.ac.id

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