MED-WET

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PRIMA PARTNERSHIP FOR RESEARCH AND INNOVATION IN THE MEDITERRANEAN AREA

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Operation and Maintenance Manual

Solar Desalination Greenhouse

March 2024

Project

Improving MEDiterranean irrigation and Water supply for smallholder farmers by providing Efficient, low-cost and nature-based Technologies and practices Project (MED-WET)

Deliverable Leader

EcoGozo Directorate

Ministry for Gozo and Planning

Government of Malta

Authors

Igor Luketina, Joseph Mizzi, Reno Micallef

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1. Introduction

The Operation and Maintenance (O&M) manual serves as a comprehensive guide for the proper operation, maintenance, monitoring, and emergency procedures of the Solar Desalination Greenhouse (SDGH) and its components. This manual is designed to provide clear instructions and guidelines to ensure the efficient and effective functioning of the SDGH, promoting its longevity and optimal performance.

The O&M manual is an essential resource for the individuals responsible for the operation and maintenance of the SDGH, including system operators, technicians, and facility managers. It aims to provide them with the necessary knowledge and procedures to perform their duties effectively, minimizing downtime, maximizing productivity, and addressing potential issues promptly.

The manual is structured to provide detailed information about each component of the SDGH, outlining its description, operational procedures, maintenance procedures, monitoring and control requirements, and emergency procedures. By following the guidelines presented in this manual, users can ensure the safe and reliable operation of the SDGH, as well as the longevity and performance of its components. Additionally, it contains valuable information about the automated components and controlling of devices like the fans, the windows and the pumps for the vertical farms and other parameters.

It is important to note that the O&M manual should be used in conjunction with any specific instructions provided by equipment manufacturers or suppliers. These specific instructions should take precedence if there are any discrepancies or conflicts with the guidelines presented in this manual. Such devices are for example the motors for the roll-up sides, the dehumidifier and the pumps.

Regular training and familiarization with the content of this manual are highly recommended for all personnel involved in the operation and maintenance of the SDGH. By adhering to the procedures outlined in this manual, users can contribute to the overall success and sustainability of the SDGH, promoting the production of high-quality crops, efficient water utilization, effective energy management and scientific value.

The O&M manual is a living document that should be updated periodically to incorporate any changes in equipment, technologies, or best practices. Users are encouraged to provide feedback and suggestions for improvements to ensure that the manual remains up-to-date and relevant. Please contact igor.luketina@alchemia-nova.net for feedback and suggestions.

1.1 Acronyms

O&M Operation and Maintenance

SDGH Solar Desalination GreenHouse.

2. Vertical farming

Vertical Farming refers to the cultivation of plants in vertically stacked layers or structures. It utilizes controlled environments, such as the SDGH, to optimize plant growth and maximize

space efficiency. One vertical farming rack consists of connected pipes that create a cascade flow of water. This water is the irrigation water, which is saline and has enough nutrients to ensure healthy plant development. Here we have split the actual crop from the mechanical and hydroponical setup.

2.1 Operational Procedures

- Vertical farming systems operate without leaks and the pumps connected to a timer based controlling unit.
- The intervals can be set at 15min/45min or 15min/30min depending on the temperature and growth stage of the plants.
- Control water salinity and quality of each tank and take measures if needed.
- Monitor and adjust environmental conditions, such as temperature, humidity, and lighting to meet the requirements of the plants.
- Implement appropriate irrigation and nutrient delivery systems to ensure adequate water and nutrient supply to the plants.
- Regularly inspect and maintain the vertical farming infrastructure, including shelves, grow lights, and irrigation systems.

2.2 Maintenance Procedures

- Check regularly for leaks and structural damages.
- Clean and sanitize the vertical farming equipment and growing areas regularly to prevent the buildup of pests, diseases, and contaminants.
- Check and maintain the functionality of grow lights (if operated), ensuring proper intensity and spectrum for optimal plant growth.
- Inspect and maintain irrigation systems, including pipes, valves, and pumps, to ensure proper water distribution.
- Regularly monitor and adjust nutrient solutions to provide the necessary nutrients for plant growth.
- Conduct periodic inspections for plant health, identifying and addressing any signs of pests, diseases, or nutrient deficiencies.

2.3 Monitoring and Control

- Regularly review plant health and growth patterns to identify any deviations or issues that require attention.

2.4 Human and Environmental Hazards

- Develop contingency plans for potential environmental emergencies, such as power outages or equipment failures.
- Establish protocols for addressing plant diseases, pests, or other emergencies that may affect the vertical farming operation.

- Train staff on emergency procedures and ensure they have access to necessary tools, equipment, and resources to respond effectively.

3. Halophytes

Halophytes are a unique group of salt-tolerant plants that play a pivotal role in the Solar Desalination Greenhouse (SDGH). These remarkable plants have adapted to thrive in saline environments, making them well-suited for the SDGH's mission of sustainable agriculture and water desalination. Within the greenhouse, halophytes serve a dual purpose: they contribute to the humidification phase of the desalination process, aiding in freshwater production, and they yield edible crops when harvested. This dual functionality underscores the innovative and interdisciplinary nature of the SDGH, highlighting the potential for halophytes to provide both food and freshwater in arid regions while minimizing the environmental impact associated with conventional desalination methods.

Figure 1 Salicornia europea also known as glasswort or sea asparagus at different growth stages.

3.1 Operational Procedures

- Select healthy Salicornia seedlings or seeds, ensuring they are free from diseases and pests.
- Soak seeds in freshwater for about 12 hours to enhance germination.
- Sow seeds about 1 cm deep in the medium
- Ensure the seedlings roots are well-covered with the growing medium.
- Allow adequate spacing between plants for proper air circulation
- The vertical farming system must have a reliable drainage mechanism to prevent waterlogging.
- Prepare a saline water solution with maximum salinity level not more than that of seawater (around 35 ppt).
- Salicornia will need 12-14 hours of light daily, preferably from LED grow lights.
- Apply the essential macro and micronutrients using a hydroponic solution suitable for saline-tolerant plants.
- Once the plants reach a height of 20-30 cm, they are ready for harvest.
- Use sharp scissors to cut the stems, leaving the roots for potential regrowth.
- Wash the Salicornia thoroughly to remove any residual salt or growing medium.

3.2 Maintenance Procedures

- Regularly inspect the pumps and hoses to ensure they are in optimal working condition and free from blockages or leaks.
- Always remove any debris or waste from within the greenhouse.
- Sanitize regularly the tools and equipment used in the cultivation process.

3.3 Monitoring and Control

- Regular inspect for pests or diseases.
- Apply natural pest control methods, such as introducing beneficial insects to manage any outbreaks.
- Continuously monitor Salicornia's health and adjust growing conditions as needed
- Monitor the salinity levels, to ensure they are not showing signs of stress or nutrient deficiencies (optimal salinity levels can vary based on the specific species and growth stage).
- Record the growth of plants to ensure not only their well-being but also to enhance the overall efficiency and productivity of the vertical farming system.
- Measure the evapotranspiration rate of the plant as it is a significant indicator of good growth and well-functioning of the SDGH in general.

3.4 Human and Environmental Hazards

- Training to personnel on the proper handling of these halophyte plants and the associated equipment.
- Workers should have access to protective gear, especially when working directly with the halophytes.
- Check for leakages so as no saline effluent from the desalination process percolates into the surrounding environment.
- Proper waste management, including the disposal of plant debris and unused saline water is also vital to minimize the cultivation's environmental impact.

4. Water Storage and Pumping

Water storage and pumping in the Solar Desalination Greenhouse (SDGH) are critical components of the system's operation. The SDGH relies on a robust water storage system to collect and retain saline water, which serves as the feedstock for the desalination process. A network of pumps ensures the efficient circulation of water throughout the greenhouse, facilitating the humidification-dehumidification process. These pumps are carefully controlled to maintain optimal conditions for plant growth and water desalination. Additionally, the SDGH is equipped with backup systems and emergency protocols to guarantee a constant water supply, mitigating potential disruptions and contributing to the sustainability and resilience of the system in arid regions.

4.1 Operational Procedures

- Regularly assess the availability and quality of the saline water source.
- Ensure the water source meets the requirements for SDGH operation.

- Start and stop the water pumps as needed to maintain a consistent water supply to the SDGH.
- Monitor pump performance and pressure to ensure efficient water delivery.
- Fill the storage tanks with saline water from the source.
- Maintain proper water levels in the storage tanks to meet the greenhouse's demand.

4.2 Maintenance Procedures

- Regularly inspect and maintain water pumps, including cleaning, lubrication, and replacing worn components. Stick to the manufacturer's maintenance procedure.
- Address any pump malfunctions promptly to prevent disruptions in water supply.
- Inspect storage tanks for leaks or damage.
- Clean and sanitize tanks periodically to prevent bacterial growth and contamination, especially algae.
- Implement corrective actions if water quality deteriorates, such as flushing the tanks or replacing the water.

4.3 Monitoring and Control

- Adjust pump operation based on real-time data to maintain optimal water delivery.
- Continuously monitor the salinity and quality of the stored water manually with salinity meters and by visual means.

4.4 Human and Environmental Hazards

- Provide training and guidelines for personnel responsible for operating and maintaining water storage and pumping systems.
- Ensure workers are aware of safety measures, including electrical and mechanical hazards.
- Prevent any accidental spills or contamination of the saline water source.
- Properly manage waste materials and chemicals used in water treatment to minimize environmental impact.
- Provide appropriate protective gear and training to address potential health concerns.
- Develop and communicate emergency response procedures in case of accidents, pump failures, or water supply disruptions.

5. Wet Walls

The wet walls are pivotal elements of the climate control system. These porous, water-absorbent walls are strategically placed within the greenhouse structure. Their primary function is to maintain a controlled microclimate by actively regulating temperature and humidity levels. Water is circulated through these walls, where it evaporates and cools the surrounding air, creating a favorable environment for plant growth. The wet walls play a critical role in achieving the high humidity required for the humidification-dehumidification process, which is central to the SDGH's water desalination capabilities. Their proper

operation is essential for sustaining optimal conditions for both crop cultivation and freshwater production. Regular maintenance and monitoring ensure that the wet walls continue to function effectively, contributing to the SDGH's overall success in arid regions.

5.1 Operational Procedures

- Ensure wet walls are activated when the greenhouse is in operation and temperature is rising over a threshold (typically at 35°C). Use the wet walls to control and maintain optimal humidity levels within the greenhouse.
- Properly shut down the wet walls when not in use to prevent unnecessary water consumption.
- Monitor and maintain a sufficiently full water tank to supply the wet walls.
- Adjust water flow rates as needed based on the wet wall design, environmental conditions and greenhouse requirements.
- Adjust the wetting frequency to achieve the desired humidity range for plant growth.

5.2 Maintenance Procedures

- Regularly clean the wet wall surfaces to prevent algae or mineral buildup that can reduce their effectiveness.
- Periodically clean the wet wall surfaces with mild detergents or antifungal agents to remove contaminants.
- Rinse thoroughly to prevent chemical residues.
- Inspect the wet walls for physical damage or clogs in the water distribution system.
- Check water distribution pipes, nozzles, and valves for clogs or leaks.
- Repair or replace damaged components promptly to maintain even wetting.

5.3 Monitoring and Control

- Install humidity sensors close to the wet walls to monitor and control humidity levels.
- Adjust wetting frequency based on real-time humidity data and temperature to maintain optimal conditions.
- Take readings of the tanks to determine the evaporation losses.

5.4 Human and Environmental Hazards

- Provide training and guidelines for personnel responsible for operating and maintaining wet wall systems.
- Ensure workers are aware of safety measures, including electrical and mechanical hazards.
- Prevent any accidental spills or leaks from the wet wall system.
- Properly manage wastewater from wet walls to minimize environmental impact.

6. Roll-up Sides

The roll-up sides serve as a key component of the SDGH's environmental control system. These sides are designed to be flexible and can be easily rolled up or down as needed. Their primary function is to regulate temperature and ventilation within the greenhouse. During periods of excessive heat, the roll-up sides can be opened to allow hot air to escape and facilitate natural cooling through cross-ventilation. Conversely, they can be closed during cooler nights or in adverse weather conditions to retain heat and protect the crops and equipment inside. Proper operation and maintenance of the roll-up sides are essential to ensure a stable and controlled climate that supports plant growth and the SDGH's overall functionality. Monitoring and control systems may be integrated to automate this process, optimizing environmental conditions for plant health and water desalination.

6.1 Operational Procedures

- Clearly define procedures for opening and closing roll-up sides based on environmental conditions such as temperature (typically 35°C) but also wind speed (shutdown at v>10m/s).
- Use the roll-up sides to regulate internal temperatures and provide proper ventilation within the greenhouse.
- Adjust the height of roll-up sides to achieve the desired airflow and temperature range.
- Train personnel responsible for operating the roll-up sides on the correct techniques.

6.2 Maintenance Procedures

- Regularly inspect the roll-up mechanisms, including rollers, tracks, and drive systems, for wear and tear.
- Lubricate moving parts as needed and replace damaged components promptly.
- Periodically clean the roll-up side material to remove dust, debris, and organic matter.
- Ensure the material's transparency is maintained for optimal sunlight penetration.
- Check the condition of the winch, pulleys, and cables used in the roll-up mechanism.
- Grease and maintain these components to prevent corrosion and ensure smooth operation.
- Replace sections of the material or the entire roll-up sides as necessary to maintain integrity.

6.3 Monitoring and Control

- Use sensor data to make informed decisions regarding roll-up side adjustments.
- Consider the automated control systems that can adjust roll-up sides based on preset temperature and humidity thresholds.
- Regularly calibrate and maintain these systems to ensure accurate operation according to manual observations and experience.

6.4 Human and Environmental Hazards

- Establish safety procedures for personnel involved in opening, closing, or maintaining roll-up sides.
- Highlight potential risks, such as falling objects or entanglement, and provide appropriate training.
- Ensure that individuals handling roll-up side materials are aware of proper lifting and safety techniques.
- Prevent accidents related to the manipulation of large and heavy materials.
- Prevent any accidental damage to the roll-up side material that could impact climate control.

7. Dehumidifier

The dehumidifier plays a critical role in the water desalination process and maintaining an optimal climate for plant growth. It functions by removing excess moisture from the air inside the greenhouse, which is essential for the humidification-dehumidification desalination process. By reducing humidity levels, the dehumidifier enables efficient evapotranspiration. Proper operation and maintenance of the dehumidifier are essential to ensure its efficiency and longevity. Regular checks should be performed to clean and replace components such as filters or desiccant materials. Monitoring and control systems may be utilized to maintain humidity levels within the desired range, ensuring that the SDGH operates effectively for both water condensation and crop cultivation.

7.1 Operational Procedures

- Train personnel responsible for operating the dehumidifier on these procedures. Stick to manufacturers' manuals.
- Set and adjust the dehumidifier's settings to maintain the desired humidity levels within the greenhouse (typically run at RH>60%).
- Establish a routine for checking the dehumidifier's performance and settings to ensure it operates optimally according to the manufacturer's instructions.

7.2 Maintenance Procedures

- Stick to manufacturers manuals.
- Inspect and replace air filters regularly to ensure proper airflow and maintain the unit's efficiency.
- Cleaning or replacing filters prevents dust buildup and reduces strain on the equipment.
- Keep the condensate collection tray or drain system clear of debris and blockages.
- Regularly empty and clean the collection tray to prevent mold or bacterial growth.
- Regularly assess and improve the unit's energy efficiency to reduce operational costs.

7.3 Monitoring and Control

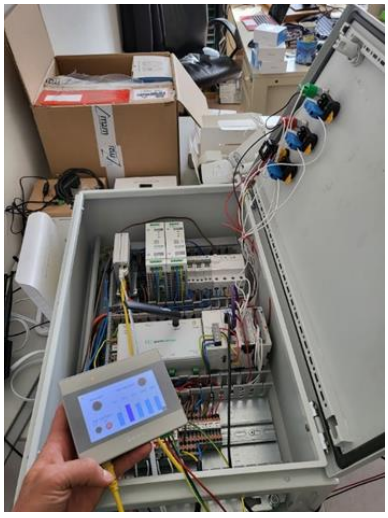
- Stick to manufacturers manuals.
- Implement alarm systems that notify personnel in case of dehumidifier malfunctions or extreme humidity conditions.

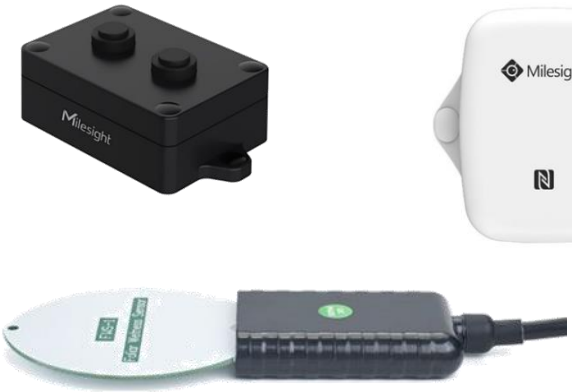
7.4 Human and Environmental Hazards

- Emphasize the importance of turning off the unit before performing maintenance or repairs.
- If the dehumidifier uses any chemicals or desiccants, provide guidelines for their safe handling, storage, and disposal.
- Educate staff on potential hazards and appropriate personal protective equipment (PPE).
- Encourage responsible use of the dehumidifier to minimize energy consumption and environmental impact.

8. Monitoring and Control

The monitoring and control system is a crucial component for overseeing and optimizing its operations. This system is designed to continuously collect data on various parameters within the greenhouse, including temperature, humidity, water quality, plant growth, and energy consumption. It provides real-time insights into the performance of the SDGH, allowing operators to make informed decisions and adjustments. Operational procedures involve configuring and calibrating the monitoring and control system to ensure accurate data collection. Regular maintenance procedures include cleaning sensors, calibrating instruments, and replacing faulty components to maintain system reliability. The system's data is continuously analyzed to ensure that environmental conditions remain within specified ranges for optimal plant growth and water desalination. It serves as a safety feature, as it can trigger alarms or shutdown processes in response to critical deviations, thus preventing potential hazards.





8.1 Operational Procedures

- Follow instructions for starting up and shutting down the monitoring and control systems within the SDGH.
- Define who is responsible for these tasks and under what conditions they should be performed.
- Establish a schedule for routine checks of the monitoring and control systems. Stick to the attached monitoring plan.
- Procedures for calibrating sensors and monitoring equipment are to be followed by the manufacturer.
- Change the frequency of calibration checks if needed.

8.2 Maintenance Procedures

- Provide guidance on cleaning, maintaining, and calibrating sensors used for data collection according to the manufacturer.
- Ensure that damaged or malfunctioning sensors are promptly replaced.
- Conduct procedures for data logging and storage to maintain historical records of environmental conditions.
- Establish protocols for data backup and secure storage.

8.3 Monitoring and Control

- Define specific thresholds for environmental parameters (e.g., temperature, humidity) that trigger alarms.
- Explain to the personnel how to respond to alarms and when to take corrective actions.
- If applicable, describe procedures for remote monitoring of SDGH conditions, allowing real-time adjustments.
- Ensure that remote access is secure and limited to authorized personnel.
- Explain how collected data is analysed and interpreted to make informed decisions.
- Define who is responsible for data analysis and how results are communicated to the SDGH team.

8.4 Human and Environmental Hazards

- Include safety protocols for personnel working with monitoring and control systems, emphasizing safe practices.
- Address any potential electrical hazards or risks associated with data cables.
- Highlight environmental considerations, such as responsible disposal of electronic components and batteries.
- Promote energy-efficient practices to minimize the environmental footprint of monitoring and control systems.
- Stress the importance of data security and privacy, especially if the SDGH collects sensitive information.

- Ensure that there are backup plans in place to maintain critical functions during emergencies.

9. Power Supply

The Solar Desalination Greenhouse (SDGH) relies on a grid-connected power supply system to ensure a consistent and reliable source of electricity. This grid connection powers various essential components within the SDGH, including fans, pumps, lighting, and the monitoring and control systems. Maintenance procedures involve regular checks of electrical connections and voltage stability to optimize energy efficiency and minimize operational costs. Safety features are incorporated to mitigate potential electrical hazards.

9.1 Operational Procedures

- Provide instructions for starting up and shutting down the power supply systems connected to the grid.
- Define who is responsible for these tasks and under what conditions they should be performed.
- Outline the specific parameters to be monitored, such as voltage levels and grid frequency.
- Describe actions to be taken in case of power grid failures or disruptions.
- Explain how to initiate backup systems or emergency power sources if available.

9.2 Maintenance Procedures

- Perform checks of the power supply systems, including electrical connections and grid stability according to local law.
- Provide guidance on maintaining and inspecting electrical connections between the SDGH and the power grid.
- Report grid-related issues to the relevant authorities.

9.3 Monitoring and Control

- Provide guidance on tracking energy consumption within the SDGH to optimize power usage.
- Encourage energy-efficient practices to reduce electricity consumption.

9.4 Human and Environmental Hazards

- Include safety protocols for personnel working with electrical components and grid-connected systems.
- Address potential electrical hazards and promote safe practices.
- Develop procedures for responding to power grid-related emergencies, such as extended power outages.

- Ensure that backup plans are in place to maintain critical functions during grid disruptions.
- Ensure responsible disposal of electronic components and batteries if applicable.
- Promote eco-friendly practices to minimize the environmental impact of power supply systems.

10. Water Sources

In this SDGH configuration, the rejected stream of a Reverse Osmosis (RO) unit provides the saline water feedstock. The maintenance procedures encompass regular inspections of the water source connection to the RO, checking for any leaks, blockages, or contamination risks. Monitoring and control systems are in place to regulate the water intake, ensuring the correct salinity levels for the SDGH operation. Additionally, measures are taken to prevent any potential environmental hazards associated with the water source, including backflow prevention to safeguard against contamination.

10.1 Operational Procedures

- Check the Reverse Osmosis Unit effluent on proper function.
- Measure the salinity of the effluent of the RO.
- Ensure enough water in the feed tanks of wet walls and vertical farming setups.

10.2 Maintenance Procedures

- Check filtration system, including filter replacement or cleaning if applicable.

10.3 Monitoring and Control

- Check parameters of salinity with handheld device and check visually for any impurities and anomalies.

10.4 Human and Environmental Hazards

- Address potential water quality risks associated with the chosen water source.
- Include safety protocols for personnel working with water source systems.
- Cover safety measures related to chemical handling or other water treatment processes if applicable.
- Promote responsible water usage and ensure compliance with environmental regulations.
- Adopt practices to minimize the environmental impact of water sourcing.
- Develop procedures for responding to water source-related emergencies, such as pump failures or water quality issues.

11. Passive Condensation

Passive condensation harnesses the principles of dew formation to recover freshwater efficiently. This process takes advantage of temperature differentials, primarily at night when the greenhouse interior cools down. As warm, moist air contacts cooler surfaces within the SDGH, water vapor condenses into liquid form, which is then collected and stored. Passive condensation is a sustainable and energy-efficient method for augmenting the SDGH's freshwater production, contributing to its overall efficiency and resource conservation.

11.1 Operational Procedures

- Perform regular inspections to ensure the greenhouse remains well-sealed for maximizing passive condensation.
- Continuously monitor temperature differences between the greenhouse interior and the external environment, especially during the night.
- Inspect and clean condensation surfaces regularly to maintain their efficiency.
- Ensure correct alignment and orientation of condensation surfaces for optimal dew formation.
- Stay updated on weather forecasts, focusing on clear nights with low wind and high humidity.
- Set up and maintain channels or gutters for collecting water droplets formed through passive condensation.
- Regularly test and assess the quality of water collected through passive condensation.
- Keep records of system performance, including temperature differences, dew formation, and water collection rates.

11.2 Maintenance Procedures

- Establish a routine maintenance schedule for inspecting and cleaning condensation surfaces, considering factors like climate and usage intensity.
- Select appropriate tools and cleaning agents, such as soft brushes and mild detergents, for cleaning condensation surfaces effectively.
- Implement procedures for thorough inspections, including checking for wear, corrosion, or damage to both condensation surfaces and their support systems.
- Schedule periodic maintenance tasks to address any structural issues promptly, ensuring the reliability of the passive condensation system.

11.3 Monitoring and Control

- Regularly check and record condensation rates using designated sensors and measurement equipment.
- Establish a routine schedule for monitoring passive condensation system performance, ensuring consistent data collection.
- Analyse condensation rate data to identify any significant deviations from expected levels.

- Investigate and troubleshoot issues promptly if abnormal condensation rates are detected.
- Maintain a log of all monitoring activities and results for future reference and analysis.
- Periodically calibrate sensors and measurement equipment to ensure accuracy.
- Train personnel responsible for monitoring procedures and equipment operation.
- Implement corrective actions based on monitoring data to optimize passive condensation system performance.
- Continuously evaluate and improve monitoring procedures in response to system performance trends and developments.

11.4 Human and Environmental Hazards

- Include safety protocols for personnel working with passive condensation components.
- Address any risks associated with accessing condensation surfaces.
- Identify potential risks during maintenance activities, such as slipping on wet surfaces or damaging condensation materials.
- Provide guidance on mitigating these risks.
- Ensure that collected water meets quality standards.
- Develop procedures for responding to passive condensation system malfunctions or unexpected issues.

https://www.medwet-eu.com/

med-wet@hs-wismar.de

0049 3841 753-7649

Hochschule Wismar
University of Applied Sciences
Technology, Business and Design
Philipp-Müller-Straße 14
Haus 21 · Raum 202b
23966 Wismar, Germany

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PRIMA
PARTNERSHIP FOR RESEARCH AND INNOVATION
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