



## FOG CATCHING: A FOG HARVESTING TOOL DESIGN USING THE THEORY OF INVENTIVE PROBLEM SOLVING (TRIZ)

**Indro Prakoso,<sup>1</sup> Ardi Jumanto<sup>2</sup>, Sugeng Waluto**

<sup>1</sup> Departement of Industrial Engineering, University Jenderal Soedirman, Purwokerto, 532123, Central java, Indonesia

\*Email : prakosoindro@unsoed.ac.id

**Abstract.** The availability of clean water in highland regions is significantly impacted by geographic factors, seasonal rainfall, and distribution system constraints. Mountaineering, agriculture, household necessities, and environmental preservation are all directly impacted by these factors. Clean water is essential for mountain climbing in order to avoid hypothermia and dehydration, but its supply is frequently restricted because of irregular natural springs and decreased discharge during the dry season. However, fog, which is frequently found in mountainous areas, offers a lot of promise as a replacement water source. The goal of this project is to create a novel fog-harvesting tool that will help climbers become self-sufficient and offer a sustainable highland water supply. To come up with innovative and methodical answers to engineering problems, the design process uses the TRIZ (Theory of Inventive Problem Solving) methodology. The study generated a preliminary design concept that prioritized sustainability and functionality using the 40 Inventive Principles and the Contradiction Matrix. The study skips over material selection and production costs in favor of concentrating only on form exploration, visual design, and user interaction. Principles 10 (Preliminary Action), 34 (Discarding and Regeneration), 40 (Composite Materials), and 35 (Parameter Changes) were among the dominant principles found in the resulting TRIZ matrix (7×7). The finished design incorporates large reservoirs for increased capacity without undue complexity, protective side covers, tilted positioning for effective flow, vertical-horizontal nets for optimal fog capture, and filtration for water quality.

**Keywords:** Fog-to-water conversion, inventive principles, mountain , TRIZ method, water scarcity

### 1. Introduction

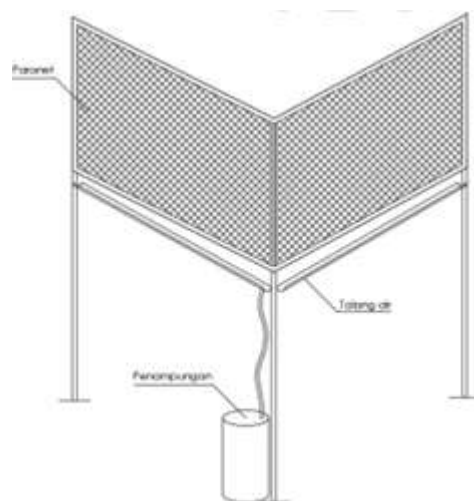
The availability of clean water in highland areas, according to Bumi et al. (2025) is greatly influenced by geographical conditions, including steep terrain, seasonal rainfall, and limited access and distribution infrastructure. These conditions have a direct impact on hiking, agriculture, domestic needs, and environmental conservation. The accessibility of clean water along mountain trails is important to prevent health risks such as dehydration and hypothermia in high-altitude environments (Bumi et al., 2025). As stated by Hadikristanto & Pranoto (2023), the uncertainty surrounding the availability of water sources along mountain climbing trails poses a significant challenge, particularly in cases where trails are characterized by a limited water source, as is the case with Mount Sumbing.

Mountainous regions are known to experience dense fog with relatively high intensity. This phenomenon can be explored as a potential water source through scientific and technological approaches. The utilization of fog as a water source remains underdeveloped, particularly in mountainous regions with constrained access to clean water. Consequently, fog-to-water conversion devices represent an innovative approach to addressing water scarcity in

mountainous regions, offering a sustainable solution (Ambali & Lolo, 2020). Fog is an atmospheric phenomenon formed from the condensation of water vapor into microscopic particles measuring approximately 1–50 microns. These particles float near the ground and remain suspended because they are very light. In the context of meteorological classification, fog is frequently categorized as a low-level cloud, a phenomenon that arises from the cooling of air to its dew point (Morales Vergara et al., 2023).

In certain climatic conditions, fog conversion technology facilitates the collection of water droplets present in fog through polypropylene mesh and directs them into water collection container, producing clean water for utilization. This technology works by capturing fog droplets through vertical mesh or grids (usually made of polypropylene), where the water will flow down and be collected in a container (Qadir et al., 2018). The primary challenges associated with the development of this technology are not exclusively technical in nature; social and institutional factors also play a significant role. A number of studies have revealed that the lack of supporting policies, the technical capacity of the community, and limited funding are the main obstacles to the long-term adoption of this technology (Qadir et al., 2018).

In the context of fog harvesting devices, the design of these systems is crucial in transforming natural phenomena into technological solutions that benefit communities, particularly in areas with limited access to clean water. The efficiency of fog harvesting devices is significantly influenced by their technical design and the environmental conditions in which they are utilized. The utilization of mesh materials, such as polypropylene or nylon coated with a hydrophilic layer, has been demonstrated to enhance the water capture capacity from fog particles. The configuration of the device's structure is also a crucial factor, as evidenced by the L-shaped design that enables the mesh to be perpendicular to receive wind exposure from multiple directions. This configuration also considers the sun's azimuth, facilitating condensation evaporation (Ambali & Lolo, 2020). As illustrated in Figure 2.4, the fog converter design from previous research is presented.



**Figure 1 Fog Converter Design**

Acknowledging this potential, the present study proposes a design for a device that converts fog into water by employing TRIZ methods. TRIZ is an acronym for the Russian term Teoriya Resheniya Izobreatatelskikh Zadatch. Translated into English as Theory of Inventive Problem Solving, it is a systematic approach to innovation developed in the Soviet Union by Genrich Altshuller in 1946. The objective of this initiative is to facilitate the identification of innovative solutions to technical and non-technical challenges through the implementation of proven and structured principles (Yao et al., 2024). The objective of this theory is to facilitate a systematic analysis of problems, the identification of their fundamental issues, and the generation of



innovative solutions with greater speed and efficiency. An analysis of thousands of patents reveals that TRIZ identifies universal inventive principles that can be applied to solve various technical contradictions in the design and engineering process (Xie & Liu, 2023).

The primary objective of this concept is to provide an innovative solution that can reduce the logistical challenges and enhance the independence of climbers in their activities on the climbing route. This research is subject to certain limitations in its design process, particularly with regard to the exclusion of information related to the selection of final materials, technical product structures, and production cost calculations.

Based on the problem formulation, the objectives of this study are as follows: Develop a device capable of converting fog into water through the application of the TRIZ method. The research findings, which include the design of a device capable of converting fog into water, are anticipated to serve as a potential alternative technology to be developed and utilized for activities undertaken at elevated altitudes, such as climbing.

## 2. Methods

This study consists of four stages, starting from the preliminary stage to the conclusion.

### A. Preliminary Stage

At this stage, the researchers searched various sources, such as books, scientific journals, and previous research results, for information relevant to fog-to-water conversion, water harvesting technology, and product design methods. The goal of this literature study was to strengthen the theoretical basis and provide an overview of appropriate design approaches for the research context. The researchers identified the problems that formed the background of the study and formulated the research objectives. The issue was identified as a result of the limited access to clean water on mountain climbing trails, particularly in foggy conditions, which required the development of an innovative solution. This solution took the form of a device capable of harvesting fog into water. The primary objectives of the research initiative is to produce a design with TRIZ approach.

### 3. Data Collection and Processing Stage

The initial step for researchers is to collect data parameters relevant to the TRIZ method. These parameters include the identification of technical contradictions, main functions, and undesirable functions. This data was obtained through a comprehensive literature study on existing fog converter designs. The data can be in the form of design details that have been or have been made, then selected from these details according to the desired design to be made. The existing design functions are utilized as a point of reference because the new design process must still rely on existing references when considering the manufacturing process.

Based on these parameters, the researchers then developed a design for a device that converts fog into water using the TRIZ method. The TRIZ method utilizes technical contradictions, defined as the utilization of parameters that undergo increase and decrease or deterioration. The data, in the form of features in the design, are entered into one of the 39 existing parameters. The parameters were then adjusted to the design to be created, resulting in an assessment of whether the design would fall into the improved or degraded category. The results that were desired were also entered into the data to determine the purpose of using the design features. The improved and degraded parameters were then compiled into a matrix, such as the TRIZ Contradiction Matrix Table. The resulting matrix generated TRIZ inventive principal recommendations that could be used as solutions or attributes in the design. This approach is adopted by researchers as it facilitates the formulation of innovative technical solutions by eliminating contradictions between design elements, eliminating the need for prior consideration of user preferences. The result of this stage is a design visualization in the form



of a conceptual (non-physical) prototype, which is then used as a basis for obtaining user input in the subsequent stage.

### 3.1. Analysis Stage

An analysis was conducted to evaluate the effectiveness of the design developed using the TRIZ approach, focusing on how the resulting technical solutions were able to address the main challenges in the process of converting fog into water. This assessment evaluated the extent to which the design features aligned with the TRIZ innovation principles and the functionality of the technical elements implemented.

### 3.2. Conclusion Stage

In the final stage, researchers formulate conclusions from the overall research results. The conclusions are derived from the design using TRIZ method. Furthermore, researchers have provided recommendations for future development, physical testing of the actual design, or the potential application of similar technology in other locations with high fog characteristics.

## 4. Results And Discussion

The problem-solving process in this study involved the implementation of the TRIZ method. The process was initiated with the identification of issues in the fog-to-water conversion device. The subsequent step entailed the delineation of the problem model, which was followed by the formulation of a solution model through the application of contradiction analysis, the identification of improving and worsening features, and the refinement of these features until a particular solution was obtained based on the inventive principles of TRIZ (Erlangga, 2018).

### 4.1. Identification of Problems in Fog-to-Water Converters

Data collection is conducted for data parameters relevant to the TRIZ method. This data set comprises the technical specifications of the components to be designed. This data was obtained from literature references related to existing fog conversion device designs. As illustrated in Table 4.1, the following section presents a comprehensive overview of the device components, drawing upon existing research and literature.

Tabel 4. 1 Detailed Specifications of Components for Fog-to-Water Conversion Device

| No. | Component Specifications    |   | Reference                                  |
|-----|-----------------------------|---|--|
| 1.  | Mesh                        | Area 4m <sup>2</sup>                      | (Ambali & Lolo, 2020)                      |
|     |                             | Height 2m from the ground                 |  |
|     |                             | Position perpendicular to azimuth 90      |  |
|     |                             | Type of polypropylene shape plus          |  |
|     |                             | Vertical mesh                             | (Shi et al., 2018)                         |
|     | Mesh position inclined      | (Erwanto, Rizalul Ilmi, & Husamadi, 2021) |  |
| 2.  | Water gutter                | Size 1x0,15x0,15                          | (Arbaningrum, 2019)                        |
|     | Hose connected to jerry can |   |  |
| 3.  | Water collector             | Water collection jerry can                |  |
| 4.  | Foundation                  | Depth 35cm                                |  |
|     |                             | Width/length 50cm                         |  |
| 5.  | Recommendations             | Water filter                              | (Menéndez, 2025)                           |
|     |                             | Side and top covers                       |  |
| 6.  | Results                     | 87 ml/day                                 | (Ambali & Lolo, 2020)                      |
|     |                             | 8 liters/m <sup>2</sup> /8 hours          | (Taufani, Utomo, Maulana, & Maulana, 2013) |

The above specifications are used as a reference in processing TRIZ method parameter data because the design of this fog converter does not take consumers into consideration.

The initial step in the TRIZ method is the identification of problems in fog-to-water converters. The identified problems are obtained from existing research. Several existing

problems are then categorized into attributes. Attributes are determined based on existing problems, and the function of attributes is the primary objective of the design. Table 4.2 below presents the details of the problems, attribute categories, and codes to facilitate writing in the subsequent stage.

Tabel 4. 2 Problem Details and Attribute Categories

| No. | Problem Details  | Kategori Atribut                 | Kode |
|-----|--|----------------------------------|------|
| 1.  | The device must be able to maximize the fog captured through the capture mesh  | Output efficiency (productivity) | M1   |
| 2.  | The perpendicular position of the mesh affects the amount of mesh available.   | Output efficiency (productivity) | M2   |
| 3.  | The water obtained is difficult to flow down because a certain type of mesh traps the water but makes it difficult to drain. | Water flow & storage             | M3   |
| 4.  | The water container must be able to collect water from all sides.  | Water flow & storage             | M4   |
| 5.  | Other particles from above can enter the device.   | Water quality & cleanliness      | M5   |
| 6.  | Ensuring the cleanliness of the collected water.   | Water quality & cleanliness      | M6   |
| 7.  | The size of the device is suitable for climbers.   | Portability & ease of use        | M7   |

#### 4.2. Contradiction Analysis

The objective of contradiction analysis is to identify solutions for enhancing functionality and the impact of such improvements. The enhancements and their impacts are derived from an analysis of the problems and their relationship to the design components of the fog-to-water conversion device. This analysis reveals contradictions in the technical aspects of the device. As illustrated in Table 4.4, a contradiction analysis of the design of the fog-to-water conversion device is presented

Tabel 4. 3 Contradiction Analysis

| Code | Improvements  | Impact  |
|------|---|---|
| M1   | Use of polypropylene mesh (increased fog capture efficiency)                    | The mesh is more easily damaged by UV rays (short service life) |
| M2   | Mesh positioned at an angle to accommodate multiple layers                      | Requires more space, impractical for climbers                   |
| M3   | Use of vertical mesh to accelerate water flow                                   | Flow is too fast, water spills/is carried away by the wind      |
| M4   | All water enters the water collection container (no waste)                      | Large container, difficult for climbers to carry                |
| M5   | Covers on the sides and top (cleaner water)                                     | More equipment, more complicated installation                   |
| M6   | Filter before water enters the water collection container (more clean water)    | Water flow is slower because the filter can become clogged      |
| M7   | Filter before water enters the water collection container (more hygienic water) | Smaller mesh area, reduced water collection                     |

The following step is to determine the TRIZ parameters for each solution to improve functionality based on the existing contradiction analysis. As illustrated in Table 4.5, the analysis of improving features is presented.



Tabel 4. 4 *Improving Feature*

| Code | Improvements  | Improving Feature                                    |
|------|---|--|
| M1   | Use of polypropylene mesh (increased fog capture efficiency)                    | 39 - Productivity (efficiency/productivity)          |
| M2   | Mesh positioned at an angle to accommodate multiple layers                      | 39 - Productivity (efficiency/increased work output) |
| M3   | Use of vertical mesh to accelerate water flow                                   | 9 - Speed (process/object speed)                     |
| M4   | All water enters the water collection container (no waste)                      | 39 - Productivity (efficiency/productivity)          |
| M5   | Covers on the sides and top (cleaner water)                                     | 27 - Reliability / Quality (improved water quality)  |
| M6   | Filter before water enters the water collection container (more hygienic water) | 27 - Reliability / Quality (improved quality)        |
| M7   | Simpler design and easier to install  | 33 - Ease of operation (ease of use).                |

The following step is to determine the TRIZ parameters for each impact based on the contradiction analysis. As illustrated in Table 4.6, the resulting impacts (worsening features) were analyzed.

Tabel 4. 5 *Worsening Feature*

| Code | Impact  | Worsening Feature                                 |
|------|---|---|
| M1   | The mesh is more easily damaged by UV rays (short lifespan) | 27 - Reliability (reliability/durability)         |
| M2   | Requires more space, not practical for climbers             | 8 - Volume of stationary (volume of equipment)    |
| M3   | Flow is too fast, water spills/is carried away by the wind  | 23 - Loss of substance (loss of mass/water waste) |
| M4   | Large container, difficult for climbers to carry            | 8 - Volume of stationary (volume of equipment)    |
| M5   | More equipment, more complicated installation               | 36 - Device complexity (complexity of equipment)  |
| M6   | Water flow is slower because the filter can become clogged  | 9 - Speed (flow rate)                             |
| M7   | Smaller mesh area, reduced water catchment                  | 39 - Productivity (efficiency/reduced yield)      |

#### 4.3. A. Contradiction Matrix

At this stage, the TRIZ contradiction between improving features and worsening features is established. Utilizing the contradiction matrix, a series of inventive principles are generated, which offer alternative solutions to design problems.

As illustrated in Table 4.7, the TRIZ contradiction matrix discloses a duality between enhancing and worsening features.

Tabel 4. 6 D. Contradiction TRIZ Matrix

| Contradiction Matrix |    | Worsening Feature |                |                |    |               |           |
|----------------------|----|-------------------|----------------|----------------|----|---------------|-----------|
|                      |    | 8                 | 9              | 23             | 27 | 36            | 39        |
| Improving Feature    | 9  | -                 |                | 10, 13, 28, 38 |    |               |           |
|                      | 27 |                   | 21, 35, 11, 28 |                |    | 13, 35, 1     |           |
|                      | 33 |                   |                | -              |    |               | 15, 1, 28 |
|                      | 39 | 35, 37, 10, 2     |                |                |    | 1, 35, 10, 38 |           |

As illustrated in Table 4.8, alternative TRIZ inventive principles have been generated from the contradictions of improving features and worsening features.



Tabel 4. 7 *Inventive Principles TRIZ*

| Code | Improving Feature                                    | Worsening Feature                                 | Inventive Principles   |
|------|--|---|--|
| M1   | 39 - Productivity (efficiency/productivity)          | 27 - Reliability (reliability/durability)         | (1) Segmentation (35) Parameter Changes (10) Preliminary Action (38) Strong Oxidants             |
| M2   | 39 - Productivity (efficiency/increased work output) | 8 - Volume of stationary (volume of equipment)    | (35) Parameter Changes (37) Thermal Expansion (10) Preliminary Action (2) Taking Out             |
| M3   | 9 - Speed (process/object speed)                     | 23 - Loss of substance (loss of mass/water waste) | (10) Preliminary Action (13) The Other Way Round (28) Mechanics Subtitution (38) Strong Oxidants |
| M4   | 39 - Productivity (efficiency/productivity)          | 8 - Volume of stationary (volume of equipment)    | (35) Parameter Changes (37) Thermal Expansion (10) Preliminary Action (2) Taking Out             |
| M5   | 27 - Reliability / Quality (improved water quality)  | 36 - Device complexity (complexity of equipment)  | (13) The Other Way Round (35) Parameter Changes (1) Segmentation                                 |
| M6   | 27 - Reliability / Quality (improved quality)        | 9 - Speed (flow rate)                             | (21) Skipping (35) Parameter Changes (11) Beforehand Cushioning (28) Mechanics Subtitution       |
| M7   | 33 - Ease of operation (ease of use).                | 39 - Productivity (efficiency/reduced yield)      | (15) Dynamics (1) Segmentation (28) Mechanics Subtitution  |

#### 4.4. Specific Solutions

The objective of this stage is to formulate specific solutions to the contradictions between improvement parameters (improving features) and impact (worsening fea Following the generation of alternatives through the application of inventive principles, the next step is to select and apply specific principles to the tool design. to the tool design. As illustrated in Table 4.9, these solutions are derived from the underlying TRIZ inventive principles.

Tabel 4. 8 Specific Solutions TRIZ Inventive Principles

| Code | Specific Inventive Principles | Description  | Specific Solutions   |
|------|-------------------------------|--|--|
| M1   | (1) Segmentation              | <ul style="list-style-type: none"> <li>• Divide objects into independent parts.</li> <li>• Make objects easy to disassemble.</li> <li>• Increase the level of fragmentation or segmentation.</li> </ul>  | Using polypropylene mesh with a high density to capture as much fog as possible passing through the mesh.  |
| M2   | (10) Preliminary Action       | <ul style="list-style-type: none"> <li>• Make any necessary changes to the object (either in whole or in part) before they are needed)</li> <li>• Arrange the object so that it can be used from the most convenient location and without wasting time on delivery.</li> </ul> | Adjust the position of the mesh from vertical to slanted so that they can hold more mesh and catch more fog.   |
| M3   | (10) Preliminary Action       | <ul style="list-style-type: none"> <li>• Make any necessary changes to the object (either in whole or in part) before they are needed.</li> <li>• Arrange the object so that it can be used from the most convenient location and without wasting time on delivery.</li> </ul> | A single-sided vertical mesh is used in the center of the device to maximize the water flow obtained from the fog collection mesh.                                   |
| M4   | (10) Preliminary Action       | <ul style="list-style-type: none"> <li>• Make any necessary changes to the object (either in whole or in part) before they are needed)</li> <li>• Arrange the object so that it can be used from the most convenient location and without wasting time on delivery.</li> </ul> | Placement of water containers at the bottom to maximize water collected from the fog mesh  |
|      | (2) Taking Out                | Separate distracting parts or properties from an object, or select the only necessary part (or property) of an object.   | Separation of the container from the device with a modular concept to facilitate water collection  |
| M5   | (1) Segmentation              | <ul style="list-style-type: none"> <li>• Divide objects into independent parts.</li> <li>• Make objects easy to disassemble.</li> <li>• Increase the level of fragmentation or segmentation.</li> </ul>  | Use waterproof material to cover the top to prevent water from entering the device, and use a mesh on the sides to prevent other particles from entering the device. |
| M6   | (11) Beforehand Cushioning    | Prepare emergency measures in advance to compensate for the relatively low reliability of an object.   | Using water filters to improve the quality of the water produced   |
| M7   | (1) Segmentation              | <ul style="list-style-type: none"> <li>• Divide objects into independent parts.</li> <li>• Make objects easy to disassemble.</li> <li>• Increase the level of fragmentation or segmentation.</li> </ul>  | Making parts of the device removable or modular so that users can easily carry them  |

#### 4.5. Modeling Designs with the TRIZ Method

Utilizing TRIZ parameters and employing specific solutions, the researcher then proceeded to model the design of a device capable of converting fog into water. The TRIZ method and Solidworks modeling were employed as the primary tools for the development of the device design.

Once each component has been created, they are assembled into a single device capable of capturing fog and converting it into water for users. As illustrated in Figure 4.12, the design of the fog-to-water converter is shown after the assembly of all components.

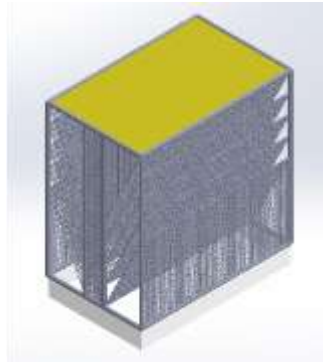


Figure 4. 1 Design of a device that converts fog into water

As illustrated in Figure 4.13, the device's design is shown alongside its component details. The water filter utilizes polypropylene mesh, a material that is not visible in the design due to its coverage of the water container.

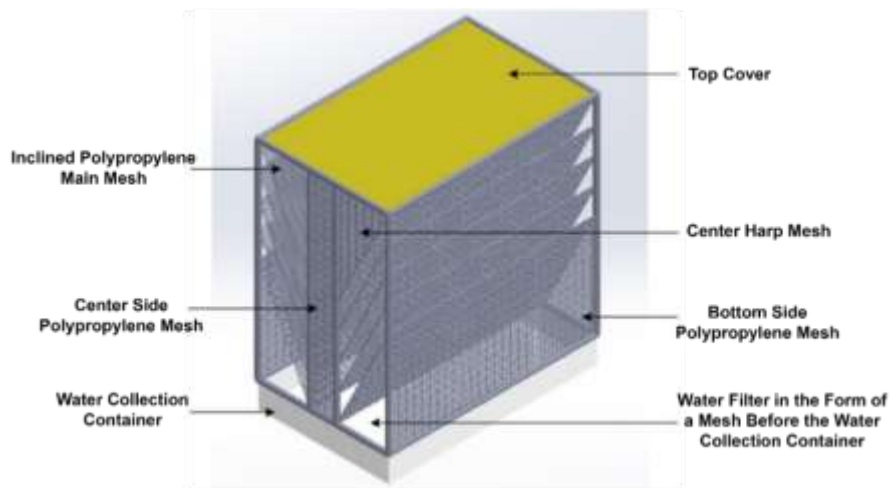


Figure 4. 2 Device design with component details

Figure 4.14 illustrates the design of a device that converts fog into water and its relationship to the TRIZ principles employed. M1 (1) designates the code and principle employed. It should be noted that several TRIZ principles are not included in Figure 4.14 due to the fact that they cannot be visually represented.

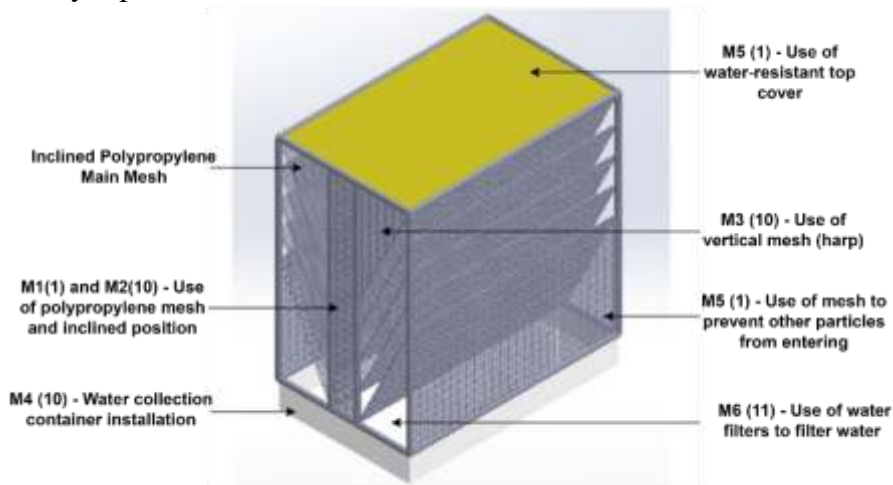


Figure 4. 3 Device design and its relationship to TRIZ principles



The following principles, which are not included in Figure 4.14 of the device design, are as follows:

- 1) M4 (2) - Separation of the container from the device with a modular concept to facilitate water collection.
- 2) M7 (1) - Make parts of the tool removable or modular so that users can easily carry them.

Principles M4 (2) and M7 (1) were excluded due to the fact that the modular concept of the device can be adequately explained verbally, but is not evident in the design

## 5. Conclusion

This study successfully developed a conceptual design of a fog-to-water conversion device using the TRIZ method. The contradiction matrix and inventive principles provided structured solutions to technical conflicts, resulting in a design that directly addresses the challenge of clean water scarcity in high-altitude environments. The integration of TRIZ principles (such as segmentation, preliminary action, and parameter changes) ensured that the proposed solution is both innovative and practical. The final design is adaptable to real-world conditions and suitable for deployment in mountainous regions with high fog intensity. Future research is recommended to validate the design through physical prototyping and explore its applicability in other fog-prone locations.

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