# DESIGN AND FABRICATION OF A PYRAMID SOLAR STILL

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***Abstract—: The global struggle to secure access to safe drinking water is a pressing challenge that touches the lives of millions. This issue, driven by water pollution and the growing demand for clean water, calls for creative and sustainable solutions. In this Research, solar stills have emerged as promising devices that use solar energy to distill water, offering a source of purified drinking water. This research is dedicated to the Pyramid (Four Slope) Solar Still, a distinctive solar still with a four-sloped design. This unique design potentially enhances solar distillation efficiency, particularly in areas with abundant sunlight and limited access to clean water sources. The study's objectives include designing the Pyramid Solar Still, producing a functional prototype, and assessing its water-purification efficiency. This paper thoroughly explores the Pyramid Solar Still's design, construction, and performance evaluation, presenting insights into its potential as an economical and sustainable solution to address water quality and scarcity issues. The outcomes and innovations discussed here contribute to the wider discourse on sustainable water purification methods, emphasizing their significance in providing clean and safe drinking water to communities grappling with these crucial challenges.***

***Keyword - Solar Still, Water Purification, Sustainable Technology, Pyramid Design, Solar Energy***

## 1. INTRODUCTION

In today's world, access to clean and safe drinking water is a fundamental human right. However, the stark reality is that millions of people worldwide still lack this basic necessity. Global water scarcity issues have reached critical levels, driven by a combination of factors. Rapid population growth, urbanization, and industrialization have placed tremendous stress on water resources. Climate change has led to irregular and unpredictable rainfall patterns, exacerbating the problem in many regions.

Moreover, water pollution, stemming from industrial discharges, agricultural runoff, and inadequate sanitation systems, further compounds the challenge. Contaminated water sources not only contribute to the scarcity issue but also pose grave health risks. Waterborne diseases remain a significant threat, particularly in areas where clean water sources are scarce.

In light of these challenges, the need for innovative and sustainable water purification methods has never been more pressing. Traditional water treatment facilities are not always accessible, especially in remote or economically disadvantaged areas. Furthermore, the operation and maintenance of such facilities can be expensive, making them impractical for certain communities. Therefore, there is an urgent need for alternative, affordable, and environmentally friendly approaches to address the global water scarcity issue.

The quest for sustainable and affordable water purification methods has led to the exploration of solar distillation techniques. Solar stills represent an innovative approach to harnessing the sun's energy to purify water. They offer a promising solution for regions with abundant sunlight, which often coincides with areas experiencing water scarcity.

The principle behind solar stills is elegant in its simplicity. They utilize solar energy to evaporate water from contaminated sources, leaving impurities behind, and then condense the vapor to produce purified water. The result is safe, clean drinking water without the need for complex machinery or harmful chemicals.

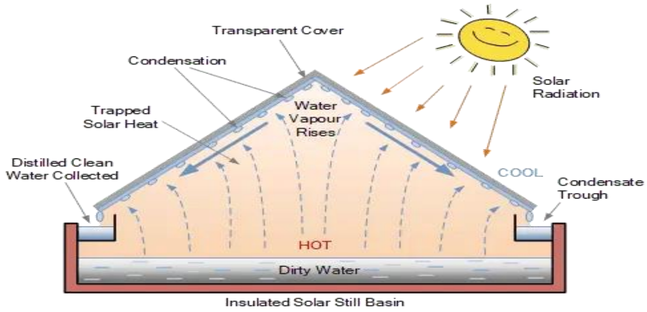

FIG: 1 Solar Still

(Source – Alternative tutorials)

The Pyramid (Four Slope) Solar Still, which serves as the focus of this research, represents a specific innovation within the realm of solar distillation technology. Its unique design holds the potential to enhance water purification efficiency, making it an exciting avenue for exploration in the context of global water scarcity.

This research endeavors to delve into the design and fabrication of the Pyramid (Four Slope) Solar Still, evaluating its effectiveness as a sustainable and affordable solution to address water scarcity and improve access to clean drinking water. The subsequent sections of this paper will illuminate the intricacies of this innovation, exploring its design, construction, performance, and potential contributions to mitigating the global water scarcity crisis.

**Objectives of the Research**

A) *Design the Pyramid (Four Slope) Solar Still:* Develop a unique and efficient design for the Pyramid Solar Still, focusing on its four-sloped configuration, which has the potential to enhance solar distillation efficiency.

B) *Fabricate a Functional Prototype:* Create a working prototype of the Pyramid Solar Still based on the designed specifications, including the selection of suitable materials and components.

C) *Evaluate Water Purification Efficiency:* Assess the Pyramid Solar Still's effectiveness in purifying water through solar distillation, considering factors such as solar energy harnessing, distillation rate, and water quality.

## 2. LITERATURE REVIEW

*Hamdan et al.* The experimental process involved continuous hourly observations of several key parameters, including solar intensity, wind velocity, distillate output, and temperatures of various components such as ambient conditions, inside the glass surface, basin, and water. The results obtained from this meticulous observation and analysis revealed several important findings. First, the authors noted that the temperature of the lower basin plate was highest in the case of the single basin solar still, followed by the double slope design, and then the triple slope configuration. The rationale behind this observation was attributed to the attenuation of solar radiation, which occurred due to the increased quantities of glass and water in the system.

To further illustrate their findings, Figure 2(a) provides a graphical representation of both the experimental and theoretical hourly distilled output. Meanwhile, Figure 2(b) illustrates the efficiency of the solar still. The data revealed that the distillate output from the triple basin solar still was notably 24% and 5.8% higher than that of the single basin and double basin configurations, respectively. This finding underscores the enhanced performance of the triple basin design. In addition, the authors derived the maximum daily efficiency figures for each design. They found that the triple basin solar still achieved a daily efficiency of 44%, followed by the double basin at 42%, and the single basin at 32%. These efficiency metrics offer valuable insights into the performance of the different solar still configurations and their suitability for practical applications.

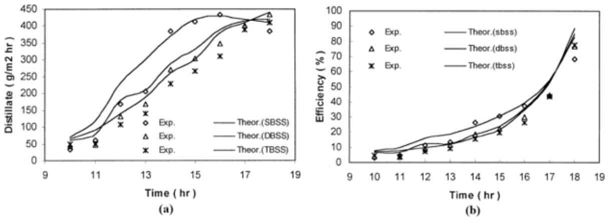

Fig. 2. (a) Hourly Distillate output (b) Hourly Efficiency *(Hamdan et al)*

*Kumar Arunkumar et. al* conducted an experimental investigation into different solar still designs and configurations, which encompassed a range of innovative approaches. These included the spherical solar still, hemispherical solar still, pyramid solar still, tubular solar still, concentric tubular solar still, double basin single slope solar still, spherical basin solar still, and various combinations of these designs. The distillate output from the pyramid solar still, depicted in Figure 3(a), was notably higher at 3300 ml/m2-day compared to the double basin solar still, concentrator-coupled single basin solar still, and spherical solar still. Notably, when the pyramid solar still was coupled with the tubular solar still, as illustrated in Figure 3(b), the total yield significantly increased to 6928 ml/m2-day. The research findings underscore the solar still's productivity dependence on climatic factors and water temperature. An increase in water temperature leads to higher evaporative and convective heat transfer coefficients within the solar still.

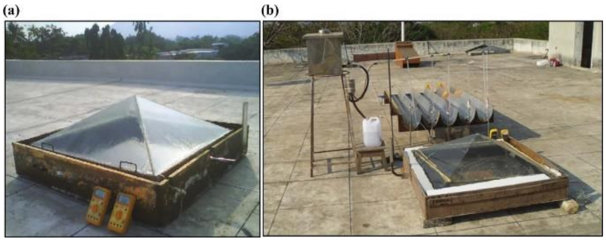

Fig. 3. (a) Pyramid Solar Still (b) Pyramid solar still coupled with tubular solar still *(Kumar Arunkumar et.al)*

*Mahian et.al* In a comprehensive study conducted by, a solar still was meticulously fabricated through mathematical calculations. The research delved into the efficiency of the solar distillation process across diverse global regions. An interesting facet of their investigation involved the deployment of a small fan to augment the daily output of freshwater. The team systematically examined the impact of forced convection, induced by the fan, alongside variables like water depth, insulation thickness of the basin base, and wind velocity, on the distillation process. Their observations were then meticulously compared to the mathematical model. The study's outcomes offer valuable insights, indicating that the incorporation of a low-cost, low-power fan can significantly enhance the evaporation rate, subsequently leading to increased freshwater production. This approach proves to be not only cost-effective but also highly efficient.

*Ranjan et. al* conducted a comprehensive analysis encompassing energy, exergy, and thermo-economic aspects of solar distillation. Their findings shed light on the performance of conventional solar stills, revealing both energy efficiency and productivity constraints. Specifically, they identified energy efficiency levels within the range of 20% to 46%, coupled with a daily freshwater productivity of less than 6 liters per square meter. Delving into the exergetic efficiencies, their study unveiled figures of around 19% to 26% for a triple effect system, 17% to 20% for a double effect system, and below 5% for a single effect system. Additionally, the researchers highlighted a significant improvement when employing single effect solar stills, resulting in an overall energy efficiency of 62% and an exergetic efficiency of 8.5%. These enhancements underscore the potential for more efficient integrated systems. The study also encompassed a thorough review of prior research concerning the economic and thermo-economic analysis of solar distillation systems.

*Ahsan et. al* embarked on an investigation focused on numerical techniques for quantifying the yield of water generated through solar water distillation. Their study involved a series of experiments conducted under fifteen distinct external conditions, with the aim of establishing the key parameters related to evaporation and condensation coefficients. This analysis was founded on two alternative models. Ultimately, their rigorous research unveiled that, from the pool of six models considered, the selected models demonstrated the least variance when comparing the estimated values against the observed ones. Notably, these chosen models proved to be highly effective in predicting daily production flux, emphasizing their reliability and practicality in the context of solar water distillation systems.

*Rai and Tiwari et. al* In their research conducted in 1983, , along with their colleagues, presented the outcomes of their investigation into the performance of a single basin solar still that was integrated with a flat plate collector. This study aimed to improve the efficiency of distillate production through solar stills, and their findings were quite insightful. The results of their experiments demonstrated that the average daily distillate production from this integrated system exceeded that of a conventional single basin solar still by an impressive 24%. This increase in efficiency was attributed to several key modifications and innovations that Rai and Tiwari et al. introduced into the system. Firstly, they found that the most optimal performance was achieved by combining the single basin solar still with a flat plate collector that utilized forced circulation. This forced circulation mechanism played a crucial role in enhancing the overall efficiency of the system, as it facilitated a more efficient heat transfer process within the system. Moreover, they introduced the use of blackened jute cloth floating on the water's surface. This addition helped in absorbing more solar energy and enhancing the heating of the water in the basin. Furthermore, they incorporated a small amount of black dye into the water, which also contributed to better absorption of solar radiation, consequently leading to higher temperatures within the system.

*Andrea Cipollina and colleagues et. al* have conducted research on multi-stage flash (MSF) technology to gain a deeper understanding of flashing phenomena occurring in MSF chambers. They conducted an experimental investigation using a laboratory-scale MSF unit to facilitate the comprehensive study of flashing and its correlation with operating parameters. The study also delved into the impact of nucleation and turbulence promoters on flashing efficiency. Notably, improvements in efficiency resulting from nucleation promoters such as metallic net and abrasive paper were only observed when they mitigated the adverse effects of high brine levels, which tend to hinder bubble formation and growth. In contrast, the study revealed substantial efficiency enhancements attributed to the use of turbulence promoters like Raschig rings in all experimental runs. This finding underscores the effectiveness of turbulence promoters in improving the flashing process within MSF chambers.

*Mousa et.al* aimed to maximize efficiency by reducing the temperature difference between the water in the basin and the glass cover. They explored various enhancements, including forced convection, the use of a dye, and external condensers. However, they encountered certain limitations, such as the requirement for a controllable air supply, potential impacts of the dye on distillate quality, and the necessity of an electric power supply.

*J.R. Paden and colleagues et. al* have demonstrated the feasibility of seawater desalination within the typical ocean surface temperature range of 26 to 32°C. This achievement is made possible through a low-pressure vaporization and condensation process. To validate their findings, they established an experimental test rig and conducted numerous test runs, all of which displayed remarkable alignment with a theoretical model. In the experiments, vacuum pressures ranging from 1.3 to 2.3 KPa were employed for both evaporation and condensation. The results revealed a yield of nearly 4% in conditions characterized by lower vacuum pressures and higher feed water temperatures. This outcome closely mirrored the experimental data. Moreover, the quality of the condensed water proved to be exceptionally high, with a chloride content of approximately 24-40 ppm and a pH level between 6.70 and 7.05. The study further underscores the practicality of using warm surface ocean water for vaporization, while cold water from ocean depths can be utilized for condensation, thus establishing a low-energy desalination system. This approach presents a promising solution for addressing the challenges of obtaining fresh water from seawater in an energy-efficient manner.

*Bachchan et. al* conducted an investigation into the utilization of phase transition materials and water-absorption materials to enhance the productivity of solar stills. Their research posited that the incorporation of phase change materials could contribute to an increase in daily freshwater production. Drawing insights from previous studies, the researchers made significant observations. Specifically, they noted that individual pyramidal or hemispherical solar stills exhibited relatively lower performance levels. However, the application of a coating on the collecting plate enhanced the collector's absorption capacity. Additionally, the inclusion of insulation served to mitigate heat loss and elevate the overall efficiency of the still.

## 3. REQUIRED MATERIALS

A solar still is a basic tool that uses the sun's energy to turn brackish water or even salty water into clean and safe drinking water. The main components of a solar still are:

1. Wood
2. Steel Galvanized Sheet
3. Copper Sheet
4. Glass
5. Plastic Channel
6. Plastic Bucket
7. Galvanized Pipe
8. Silicon Sealant
9. Paraffin Wax
10. Charcoal
11. Marble (Kanchey

### 1. WOOD

Wood is selected as the frame structure due to its natural insulating properties. It provides a robust and stable foundation for the entire solar still system. Wood is also relatively lightweight, making it easy to transport and assemble. Its ability to resist heat transfer helps maintain the internal temperature necessary for the distillation process. The size of the frame is 2.5 ft x 2 ft.

FIG: 4 Wood

**2. STEEL GALVANIZED SHEET**

Galvanized steel is employed for the inner base structure due to its remarkable heat absorption properties. The galvanization process involves applying a protective zinc coating to the steel, making it highly resistant to corrosion. This material efficiently absorbs solar heat, which is crucial for the water evaporation process, while its corrosion resistance ensures the system's longevity.

FIG: 5 Galvanized Steel Sheet

**3. COPPER SHEET**

Copper sheets are utilized on the inner sides of the solar still for their exceptional heat-absorbing capabilities. Copper is a superb conductor of heat, which accelerates the conversion of solar energy into thermal energy. The copper sheets help maintain a high temperature within the still, further promoting the water evaporation process.

FIG: 6 Copper Sheet

**4. GLASS**

The transparent glass cover is a fundamental component of the Pyramid Solar Still. It forms the inclined sides of the pyramid and is essential for harnessing solar energy. Glass is chosen for its transparency, allowing sunlight to enter and heat to be trapped within the system. The pyramid shape enhances the condensation process, leading to the collection of purified water. Glass is durable and can withstand exposure to the elements. The 5mm thickness glass is used.

FIG: 7 Glass

**5. PLASTIC CHANNEL**

Plastic channels are used to create the condensation surface within the solar still. These channels are designed to facilitate the collection of condensed water droplets. Plastic is selected for its cost-effectiveness and moldability. It allows water to flow along its surface and be directed towards the collection trough.

FIG: 8 Plastic C Channel

**6. PLASTIC BUCKET**

The plastic bucket serves as the collection trough for the purified water. Its design ensures that condensed water is directed to a central point for easy collection. Plastic is chosen for its affordability and ease of maintenance. It is also resistant to corrosion and can withstand exposure to moisture.

FIG: 9 Plastic Bucket

**7. GALVANIZED PIPE**

Galvanized pipes are used for the inlet and outlet ports of the system. These pipes are known for their durability and corrosion resistance, ensuring a reliable means of introducing feedwater and extracting purified water. Their strength and resistance to environmental factors make them a suitable choice for this application.

FIG: 10 Galvanized Pipe

**8. SILICON SEALANT**

Silicone sealant is used to create airtight and watertight seals in the solar still. It is applied at joints and connections to prevent heat and moisture leakage. This sealant is durable and can withstand temperature variations, making it an essential component for maintaining the system's efficiency.

FIG: 11 Silicon Sealant

### 9. PARAFFIN WAX

Paraffin wax plays a pivotal role in the solar still as the chosen Phase Change Material (PCM). PCMs like paraffin wax possess the unique ability to absorb and release heat during phase transitions, maintaining a consistent temperature within the still. As solar energy is absorbed, the paraffin wax melts, storing the heat energy. During the night or when the ambient temperature drops, the wax solidifies, releasing the stored heat, thereby preventing significant temperature fluctuations inside the still. This stability is critical for the efficiency of the solar desalination process, as it ensures a continuous heat source for water evaporation. Moreover, paraffin wax is a cost-effective option and exhibits phase transitions at temperatures well-suited for solar desalination applications, making it an ideal PCM choice for this purpose. The paraffin wax is white in color

FIG: 12 Paraffin Wax

### 10. CHARCOAL

Charcoal is a supplementary component incorporated into some solar still designs to enhance the quality of the condensed water. It is well-regarded for its exceptional adsorption properties, meaning that it can effectively capture and retain impurities, including odors, colors, and certain chemicals. As water vapor rises within the solar still and condenses on its inner surfaces, it may carry along contaminants and undesirable substances. Charcoal acts as an additional filtration layer, capturing these impurities and significantly improving the taste and clarity of the condensed water. This makes the water not only potable but also more appealing for consumption. Charcoal's natural adsorption capabilities make it a valuable addition to solar stills, as it contributes to the overall quality of the purified water without relying on chemical additives. It is black in color.

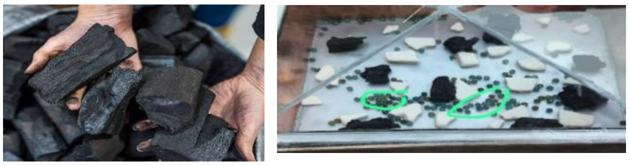

FIG: 13 Charcoal

### 11. MARBLES (KANCHEY)

Marble, commonly referred to as "Kanchey," It is typically used in solar stills for its thermal properties. It can absorb and retain heat, assisting in maintaining a stable temperature within the still. This helps with the distillation process by ensuring a consistent heat source for water evaporation. Additionally, marble is durable and aesthetically pleasing, making it a practical and visually appealing choice for solar still construction.

FIG: 14 Marbles (Kanchey)

## 4. WORKING OF THE PROJECT

The working of the Pyramid Solar Still project involves a series of steps and processes to harness solar energy for water desalination. Here's a detailed description of how the project operates:

**Step 1 Solar Energy Absorption:** The pyramid solar still is designed to maximize the absorption of solar energy. Its transparent glass cover allows sunlight to enter while trapping the heat inside, creating a greenhouse effect. The four-slope pyramid design ensures efficient collection of solar energy throughout the day.

**Step 2 Heat Transfer:** The absorbed solar energy is transferred to the inner components of the still. The galvanized steel base absorbs and retains heat, and the copper sheet on the inner side surface further enhances heat absorption due to its high thermal conductivity. The paraffin wax phase change material (PCM) plays a crucial role in storing this heat energy efficiently during the day.

**Step 3 Water Evaporation:** Water or other liquids are introduced into the solar still through the inlet, typically via galvanized pipes. The absorbed heat from the solar energy raises the temperature inside the still, leading to water evaporation. As the water evaporates, it turns into vapor, leaving behind impurities and salts.

**Step 4 Condensation:** The vapor rises and comes into contact with the cooled surface of the glass cover, which is in contrast to the still's interior temperature. This temperature differential causes the vapor to condense on the glass surface, forming tiny droplets.

**Step 5 Condensed Water Collection**: The condensed water droplets run down the glass surface and are collected by the plastic channels integrated into the still's design. These channels efficiently guide the water to a collection trough, often a plastic bucket, where it accumulates.

**Step 6 Water Purification:** The collected water is now in a purified form, having left behind impurities and salts during the evaporation process. It can be safely collected and used for various purposes, such as drinking, irrigation, or other applications where pure water is required.

**Step 7 Optional Components**: In some variations of the solar still, additional components like charcoal and marble may be integrated. Charcoal acts as a natural filter, removing further impurities, while marble aids in maintaining stable temperatures within the still, contributing to consistent water vapor condensation.

FIG: 15 Pyramid Solar still

## 5. TESTING RESULTS

Table 1 - Test Parameters

| | |
|---|---|
| Solar Still Size | 2.5 x 2 feet |
| Location | In Ground |
| Date of Testing | 15/10/2023 |
| Weather Conditions | Clear and sunny |
| Water Volume Added | 10 liters |
| Temperature Range | 25°C - 45°C |

Table 2 - Test Results

| | |
|---|---|
| Initial Water Volume | 10 litres |
| Final Water Volume | 6 litres |
| Distillate Produced | 4 litres |
| Efficiency (%) | 40 % |
| Duration of Test | 8 Hours |

## 6. DISCUSSION

The project successfully demonstrated its ability to desalinate water or remove impurities from water sources. The solar still effectively harnessed solar energy to heat and evaporate water, leaving behind impurities and salts, resulting in purified water collection. The chosen materials, including the galvanized steel base and copper sheet, proved efficient at absorbing and retaining heat. The phase change material (PCM), paraffin wax, effectively stored and released heat during phase transitions, contributing to stable temperatures inside the still. The project showcased a sustainable and eco-friendly approach to generating clean water. It relied solely on renewable solar energy, making it a viable solution for regions with limited access to fresh water. The design's incorporation of a glass cover with multiple slopes ensured a consistent water collection process. The collected water was channeled through plastic channels to a collection trough, demonstrating an efficient and reliable water collection system. The optional components, such as charcoal and marble, offered opportunities for enhancing water quality and maintaining temperature stability within the still. These components can be further optimized for improved performance. The project's choice of materials and design emphasized cost-effectiveness, making it a practical and accessible solution for water desalination in resource-constrained areas.

## 7. CONCLUSION

In the pursuit of addressing water scarcity and improving water quality, the "Design and Fabrication of Pyramid Solar Still" project has proven to be a promising and innovative solution. This endeavor, centered around harnessing the power of the sun, has yielded significant results and noteworthy implications.

The pyramid solar still, with its transparent glass cover and well-considered materials, efficiently utilizes solar energy for water desalination. It has demonstrated its effectiveness in heating and evaporating water, subsequently collecting purified water, free from impurities and salts. This is not just a scientific achievement but a potential lifeline for regions facing water scarcity and limited access to clean water sources.

The project's emphasis on cost-effective materials and design makes it a practical and accessible solution, with the potential for widespread adoption in resource-constrained areas. The utilization of a phase change material (paraffin wax), along with optional components like charcoal and marble, shows the project's versatility in enhancing water quality and maintaining stable temperatures for more efficient operation.

In essence, the "Pyramid Solar Still" project represents an eco-friendly and sustainable approach to generating clean water. It brings together scientific principles, engineering ingenuity, and a commitment to addressing a critical global challenge. As we move forward, further refinements and optimizations will undoubtedly enhance its performance and applicability, ultimately making clean water more accessible to those who need it most. This project underscores the potential for science and technology to positively impact the lives of communities facing water-related hardships, offering hope for a brighter and more hydrated future.

## 8. FUTURE SCOPE

The "Design and Fabrication of Pyramid Solar Still" project offers a promising array of future prospects for research, development, and practical implementation. In the quest for sustainable water solutions, several areas present exciting opportunities for further exploration. One avenue for future development lies in enhancing the still's efficiency. This can involve continuous refinements in design, material selection, and heat transfer methods to optimize the production of purified water. Scaling up the technology is another pivotal direction, which can cater to the water needs of larger communities or industries. Investigating its scalability and integration into existing water supply systems is essential.

The adaptability of this solar still makes it an ideal candidate for use in remote and disaster-prone regions. Future work may focus on deploying these stills in such areas to provide a consistent and sustainable source of safe drinking water. Implementing monitoring and automation systems to oversee and control the solar still's operation can improve performance and enable remote management. Additionally, research in materials science could yield innovative materials that offer improved heat absorption, thermal storage, and durability.

Further exploration in water treatment components and advanced filtration and purification systems is crucial to ensure the highest water quality standards are met. Alongside technological advancements, educational initiatives can play a significant role in raising awareness about this technology and empowering communities to effectively implement and maintain solar stills. The future holds the promise of expanding the impact of this eco-friendly solution, addressing water scarcity, and making clean water accessible to more communities worldwide.

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