International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 07 Issue: 05 | May 2020 www.irjet.net p-ISSN: 2395-0072

DESALINATION BY SOLAR HEAT AND CONDENSATION

By

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ABSTRACT: *Over the decades, there has been great growth in Global Population and Industrialization. This phenomenon makes the path for increase in demand for water globally. The increased consumption for water is leading the path for Global Water crisis. To overcome the future challenges for water and to surpass this problem which is in its initial stage, we have to search for a proper solution. Though the planet Earth possesses about 1385MKm^3 of water in various forms, but majority of this water of about 97.1% is in the form of Ocean water, which is Saline by nature and is unfit for consumption for any purpose. So, Ocean water can be used, only after removing that salt content from it.*

This study primarily discusses to conduct the process of Desalination using simple resource of Solar Energy. After purifying this ocean water, the water would be subjected to various Physical and Chemical tests and if the test results satisfy the Drinking water standards specified as IS: 10500-2012, then the purified would be fit for consumption, and make a step towards surpassing of the global Water problems.

Key Words*: Desalination; Global Water Crisis; Physical and Chemical tests for water, IS:10500-2012, Solar Energy*

I. INTRODUCTION:

Global water Crisis is an evolving problem globally. According to a recent survey, about 29% of the world population are not having accessibility to fresh drinking water. Even our country India, which holds, 16% of Global population, today has just 4% of fresh water access. By 2025, an estimated 1.8 billion people will live in areas plagued by water scarcity, with two-thirds of the world's population living in water-stressed regions as a result of use, growth, and climate change. And the world is half its way to Water Crisis. There are ample amount of likelihoods that the situation may even worsen, if we still continue depending on sources like rivers, ground water, tanks etc.,

Ocean water covers about 97.1% of Global Water, where the remaining amount of water is occupied by surface and sub-surface sources like rivers, aquifers etc., [13]. Ocean water also consists of 2-4% of salt content and other chemicals which resists its direct consumption any form including domestic, industrial, agricultural and many purposes. If this salt matter could be eliminated from Ocean water, then an extremely huge source for water could be unlocked.

Generally, the treatment for water from the sources like Rivers, Tanks etc., can be done using the treatment process involving Aeration, Sedimentation, Coagulation etc., [14], [16]. Since the salt content from the water, cannot be removed by these processes removed, a special process is required, and the process of removing salt content from Ocean Water may be called "Desalination"[11]. This method is in service across the globe currently. Desalination is usually carried out using a few methods, such as:

- Multi Effect Distillation [2]
- Multi-Stage Electro-dialysis [3]
- Reverse Osmosis [5], [11]
- Multi- Stage Flash Evaporation [9]

and many other processes [1]. These processes generally demand huge scale of resources including Land, Labor, Machinery, Electricity, Investment and other resources [10].

This study focuses on analyzing and then desalinating the Ocean Water sample, without involving such resources but using Solar Energy 's basic resource, and verifying the results using drinking water standards. We are also aiming to very cost-effectively desalinate the Ocean Water.

II. LITERATURE REVIEW:

[1] Ahmed, F. E., Hashaikeh, R., & Hilal, N. (2019) have made a study based on "Solar powered desalination – Technology, energy and future outlook" and made the following conclusions:

Solar-driven desalination is a rapidly increasing field of research, with considerable progress over the last few years. Rising desalination capability and the competing need to de-carbonize and reduce the adverse effects of global warming has resulted in efforts to accelerate renewable energy desalination. In particular, solar energy is an attractive source of energy for desalination, especially because freshwater scarcity and solar irradiation overlap in many regions.

Over the past two years, direct solar desalination has attracted attention as novel photo thermal materials, graphene-based and metal / ceramic nanostructures have allowed evaporation by means of localized heating. Using solar photovoltaic technology, or using collectors that can also be converted to electricity, solar energy can be harnessed as electric power.

[4] Kasaeian, A., Babaei, S., Jahanpanah, M., Sarrafha, H., Sulaiman Alsagri, A., Ghaffarian, S., & Yan, W.-M. (2019) have worked on the concept of *"Solar humidification-dehumidification desalination systems: A critical Review"* and have stated their results as follows:

Crisis in the availability of fresh water is spreading worldwide. Considering the rapid population growth, arid and semi-arid regions must migrate towards safe freshwater sources. Desalination is a capital-intensive and low-efficiency energy operation.

The area of study was classified into three chapters based on the methods conducted, namely experimental, numerical, and optimization, exergy, economic studies. In addition, the first two chapters are categorized based on the form of collector including flat plate, bubble board, evacuated tube, condensed and PV collectors, and hybrid modules. Every section contains a table that summarizes important relevant research attempts along with major findings.

[6] Mohammadi, K., Saghafifar, M., Ellingwood, K., & Powell, K. (2019) have published a paper entitled *"Hybrid concentrated solar power(CSP)-desalination systems: A Review"* and have got these results:

This paper hass presented as a commentary on the status of state-of-the-art CSP-desalination hybrid systems and based research on these systems. The study offers an overview of the latest CSP and desalination technologies and focuses on two forms of hybrid systems: plants that only produce freshwater and plants that co-generate powered freshwater.

[7] **Chiavazzo, E., Morciano, M., Viglino, F., Fasano, M., & Asinari, P. (2018),** have worked on the concept of *"Passive solar high-yield seawater desalination by modular and low-cost distillation*" and have got these results:

Comparison of the output of active and passive solar desalination technologies (i.e., liters of distilled water generated per kWh of solar energy input) from the literature. Unlike active devices that require mechanical moving parts, passive technology's operating theory relies only on combinations of solar-absorbing hydrophilic layers and thermally insulating material. Full distillation, membrane distillation (MD), and reverse osmosis (RO) technologies coupled with photovoltaic (PV) processes are seen.

III. OBJECTIVES:

- Extrapolating optimization of the desalination techniques for better use.
- Analysis of Ocean Water and study of its characteristics and behavior.
- To desalinate the Ocean Water using Solar Energy.
- Analysis of water extracted after Desalinating using various methods and compare the results with IS: 10500-2012 and zero the best method which gives best results and overall economy.

IV. MATERIALS USED:

1) Ocean Water:

Ocean water basically occurs across the globe. This water generally has the presence of Salt of about 2.5-4% [1]. It also has various chemicals including Magnesium, Calcium, Potassium, Iron, Zinc and iodine at varying percentages. Ocean Water also acts as a medium for the survival of Millions of species of Aquatic creatures.

For this study, we have collected the Ocean Water from RK Beach in Bay of Bengal from Visakhapatnam, as shown in **Fig:1** and **Fig:2** respectively. The sample is properly sealed in water cans as shown in **Fig:3** and transported properly to our laboratory and proceeded to further experimentations.

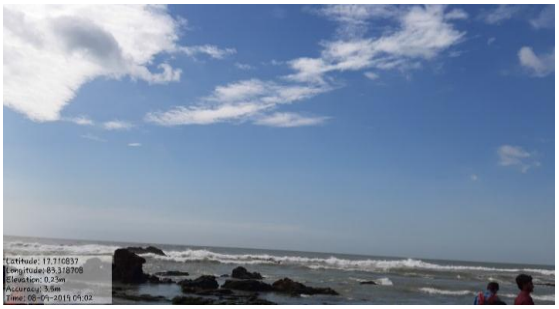


Fig.1: RK Beach Visakhapatnam

Fig.2: Collection of Ocean Water

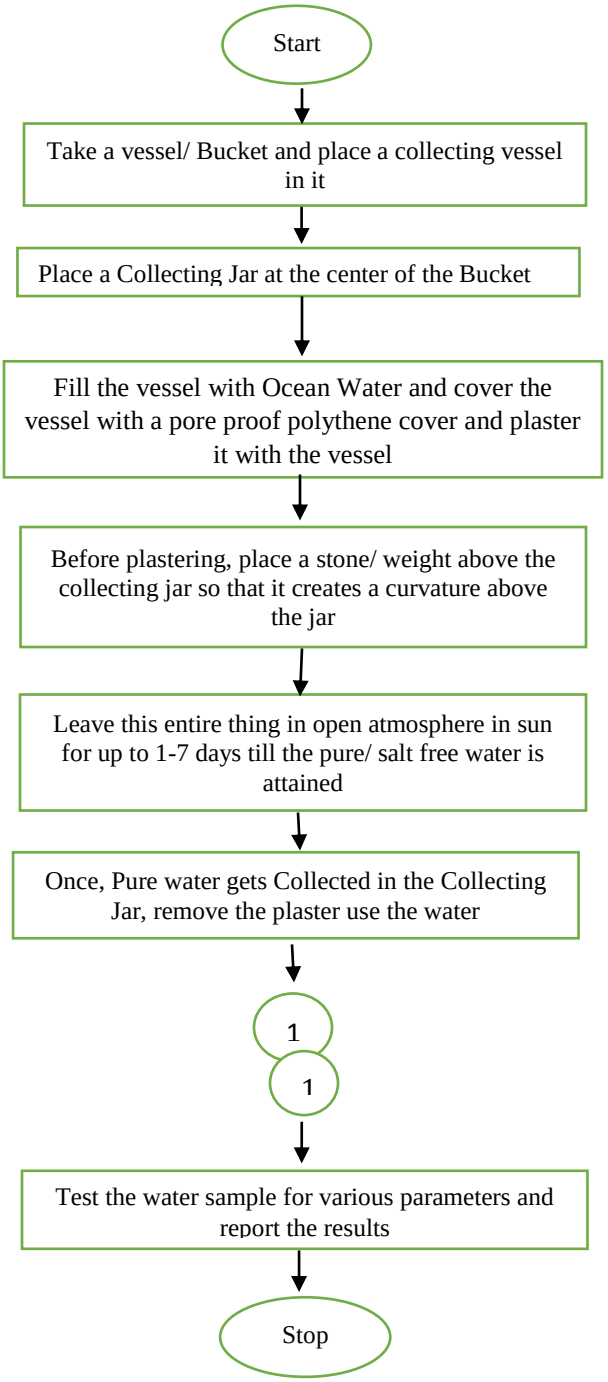
Fig.3: Collected Ocean Water

V. METHODOLOGY:

Before carrying out the process the ocean water is tested for various observations such as pH, turbidity, TDS, conductivity, acidity, alkalinity and salt content and others. Then the Ocean water is purified by Desalination and tests are carried out on the purified Samples. Then a comparative analysis is done with respect to standards of IS: 10500-2012 [12].

Process of Desalination using Direct Solar Energy and Condensation:

This method is very simple and the agent for Desalination is Solar Energy. The process for desalination goes as shown in **Flow Chart:1** below.



Flow Chart:1: Methodology of Desalination using Solar Energy and Condensation

Elucidation of Methodology:

- Initially, a Plastic/Steel bucket/tub is taken and is filled it with 4 Liters of Ocean Water as shown in **Fig:4**.
- A Collecting Vessel is placed at the center of the tub, as show in **Fig:5.**

- The tub is now covered with a Plastic/ Tarpaulin Cover, and just above the top of the collecting vessel, a small weight is placed, like as stone pebble. Now, the Plastic cover is banded with the tub using a plaster, as shown in **Fig:6.**
- Now, this entire setup is placed in the sun for a certain period of time for about 2-7 days. Now the heat from solar energy starts heating the Ocean Water as shown in **Fig:7.**
- Then the vapor collected on the lower side of the cover gets condensed and starts getting collected in the collecting vessel as shown in **Fig:8.**
- Because the Salt Water is denser that Normal in **Fig:9.**
- In this case, this process is independent on resources like Electricity, Thermal Heat etc., but only on Atmospheric Solar Heat. Therefore, the amount of yield is directly proportional to External temperature.
- This process of Desalination was conducted in the month of November 2019 in Hyderabad, where the Temperature was around 20°C to 29°C, therefore 1liter of Salt Free water is attained in 6 days of time.

Fig: 4: Filling Bucket with Ocean Water

Fig: 5: Placing a collecting vessel in Bucket

Fig: 6: Covering Bucket and placing a stone

Fig: 7: Moisture accumulating on cover

Fig:8: Water collecting in the vessel

Fig: 9: Salt free water collected in the vessel

VI. RESULTS AND DISCUSSIONS:

As stated above, initially the Ocean Water is subjected to few physical and chemical tests, later the same tests are done on the purified water sample and the results are compared with the drinking water standards specified in IS:10500-2012 [12]. All the results for the tests on water, and drinking water standards are represented in **Table:1** below.

S. No	Parameter	Ocean Water	Solar Energy	IS Standards
1	**pH**	8.9	8.4	6.5- 8.5
2	**Turbidity**	19 NTU	1 NTU	1-5NTU
3	**TDS**	1521 ppm	4 ppm	Up to 500ppm
4	**Conductivity**	2889.97 µs/cm	8 µs/cm	5-50 µs/cm
5	**Acidity**	50 ppm	5 ppm	NA
6	**Alkalinity**	28 ppm	30 ppm	20-200 ppm
7	**Hardness**	5000 ppm	136 ppm	120- 180 ppm
8	**Chloride Content**	1635.495 ppm	28.99 ppm	Up to 250 ppm
9	**Salt Content**	2954.603 ppm	52.370 ppm	Up to 200 ppm

Table:1: Over-all test results and drinking water standards

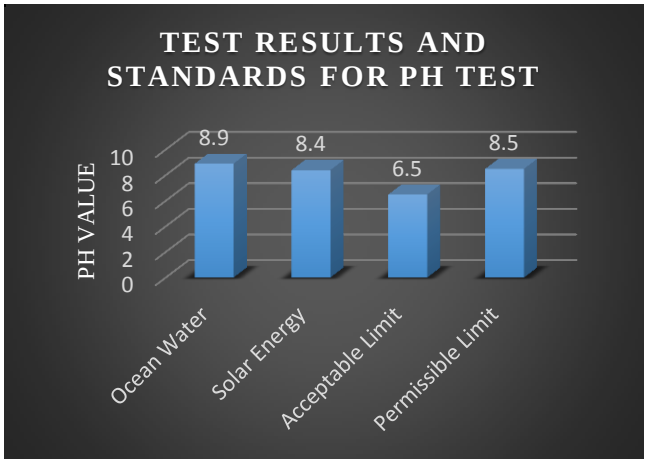
Let us also look into the analysis of each and every parameter.

1) Analysis of pH Test:

The Test results for pH factor for Ocean Water and Purified Ocean Water using Solar Energy, along with IS Acceptable and Permissible Limits are tabulated in **Table: 2** and their variations are presented in **Graph:1.**

Parameter	Ocean Water	Solar Energy	IS Standards	
			Acceptable Limit	Permissible Limit
pH	8.9	8.4	6.5	8.5

Table: 2: Results for pH Test



Graph:1: pH parameter test results and Standards

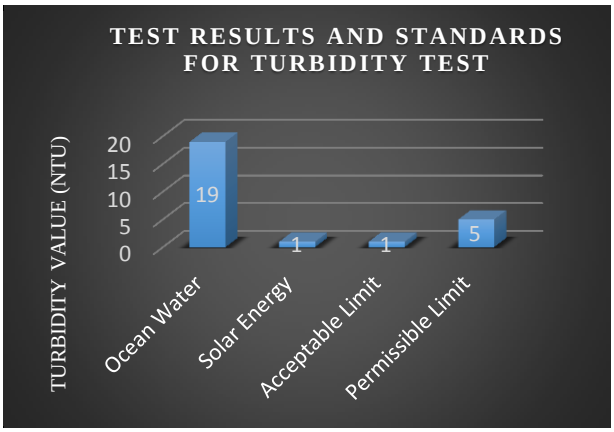
From the **Graph: 1**, it is evident that the Ocean Water is beyond the permissible limit for consumption, whereas the purified sample have arrived in within the consumable range as per IS Standards with 8.4, which is satisfactory.

2) Analysis of Turbidity Test:

The Test results for Turbidity factor for Ocean Water and Purified Ocean Water using Solar Energy, along with IS Acceptable and Permissible Limits are demonstrated in **Table: 3** and **Graph:2** respectively.

Table: 3: Results for Turbidity Test

Parameter	Ocean Water	Solar Energy	IS Standards	
			Acceptable Limit	Permissible Limit
Turbidity	19 NTU	1 NTU	1 NTU	5 NTU



Graph:2: Turbidity parameter Test results and Standards

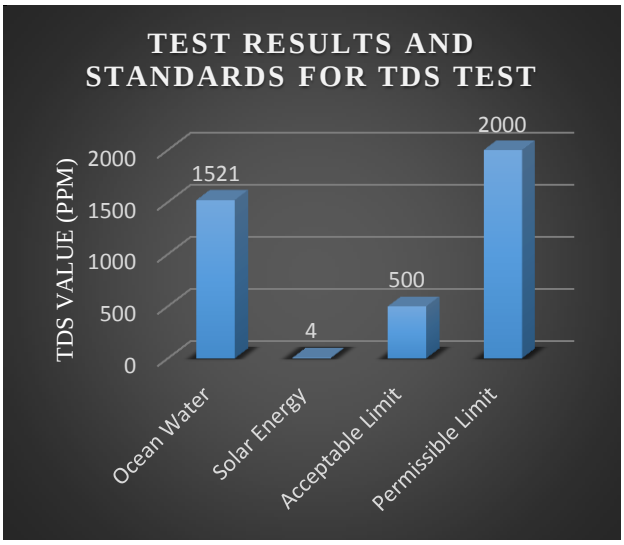
From the **Graph: 2,** it is evident that the Ocean Water is extremely beyond the permissible limit for consumption for Turbidity with 19 NTU, whereas the purified samples Solar Energy have lost the Turbidity drastically and have arrived within the consumable range as per IS Standards with 1 NTU.

3) Analysis for TDS Test:

TDS stands for "Total Dissolved Solids". The Test results for TDS factor for Ocean Water and Purified Ocean Water using Solar Energy, along with IS Acceptable and Permissible Limits are tabulated in **Table: 4** and their variations are presented in **Graph:3**.

Table: 4: Results for TDS Test

Parameter	Ocean Water	Solar Energy	IS Standards	
			Acceptable Limit	Permissible Limit
TDS	1521 ppm	4 ppm	500 ppm	2000 ppm



Graph:3: TDS parameter Test results and Standards

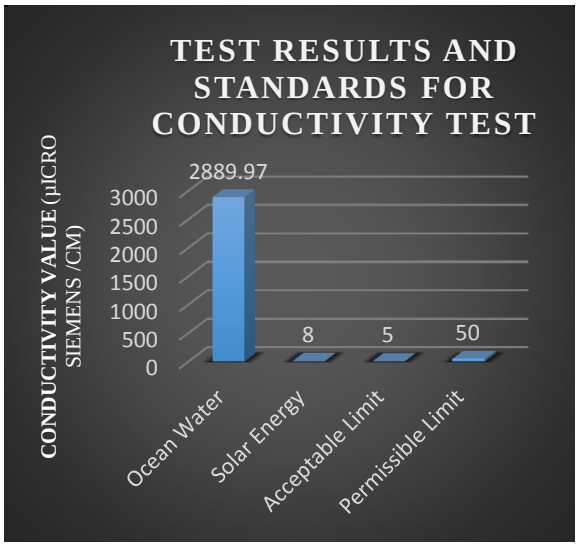
From the **Graph: 3,** it is evident that the Ocean Water sample is within the permissible limit for consumption with 1521 ppm, whereas the purified sample Solar Energy have lost its TDS drastically and have arrived within the extremely friendly consumable range as per IS Standards with 4ppm respectively.

4) Analysis for Conductivity Test:

The Test results for Conductivity factor for Ocean Water and Purified Ocean Water using Solar Energy, along with IS Acceptable and Permissible Limits are tabulated in **Table: 5** and their variations are presented in **Graph:4**.

Table: 5: Results for Conductivity Test

Parameter	Ocean Water	Solar Energy	IS Standards	
			Acceptable Limit	Permissible Limit
Conductivity	2889.97 µs/cm	8 µs/cm	5 µs/cm	50 µs/cm



Graph:4: Conductivity parameter Test results and Standards

From the **Graph:4**, it is evident that the Ocean Water is extremely beyond the permissible limit for consumption with 2889.97 µs/cm, whereas the purified sample with Solar Energy have lost the Conductivity drastically and have arrived within the consumable range as per IS Standards with 8 µs/cm.

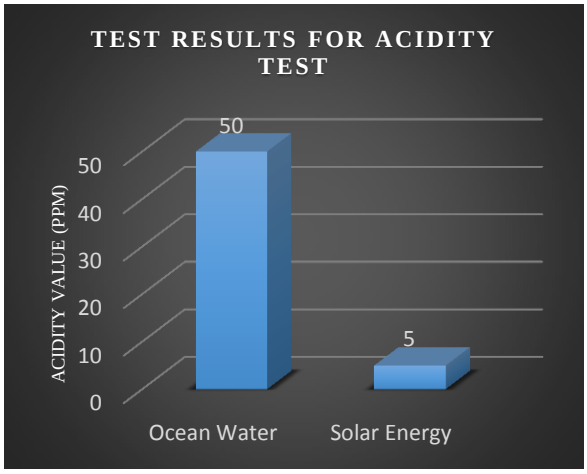
5) Analysis for Acidity Test:

The Test results for Acidity factor for Ocean Water and Purified Ocean Water using Solar Energy are tabulated in **Table: 6** and their variations are presented in **Graph:5.**

Table: 6: Results for Acidity Test

Parameter	Ocean Water	Solar Energy	IS Standards	
			Acceptable Limit	Permissible Limit
Acidity	50 ppm	5 ppm	NA	NA

Note: The Permissible and Acceptable limits for acidity for drinking water are not specified in IS: 10500- 2012 code



Graph:5: Acidity parameter Test results and Standards

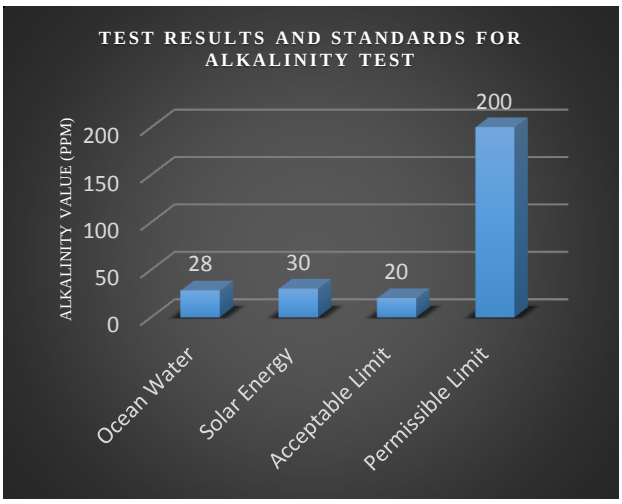
From the **Graph: 5,** it is clear that the Ocean Water possesses the Acidity of about 50ppm, whereas the purified sample with Solar Energy have lost the its Acidity property radically and both have arrived at 5ppm.

6) Analysis for Alkalinity Test:

The Test results for Alkalinity factor for Ocean Water and Purified Ocean Water using Solar Energy, along with IS Acceptable and Permissible Limits are tabulated in **Table: 7** and their variations are presented in **Graph:6.**

Table: 7: Results for Alkalinity Test

Parameter	Ocean Water	Solar Energy	IS Standards	
			Acceptable Limit	Permissible Limit
Alkalinity	28 ppm	30 ppm	20 ppm	200 ppm



Graph:6: Alkalinity parameter Test results and Standards

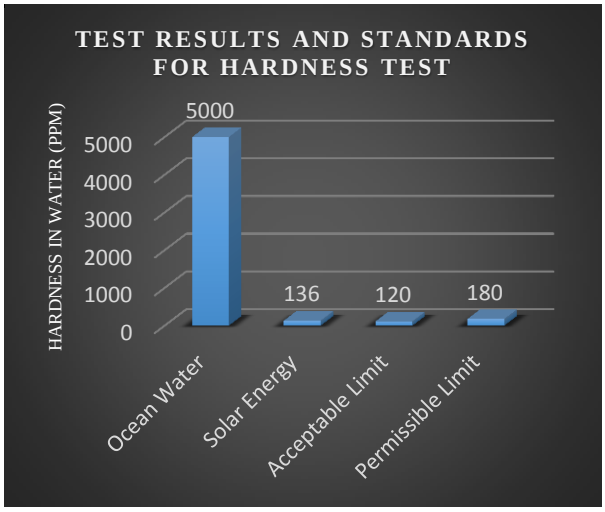
From the **Graph: 6,** it is evident that the Ocean Water and purified samples using both Solar Energy are within permissible limit for consumption with a concentration of 28ppm, 30ppm respectively.

7) Analysis for Hardness Test:

The Test results for Hardness content factor for Ocean Water and Purified Ocean Water using Solar Energy, along with IS Acceptable and Permissible Limits are tabulated in **Table: 8** and their variations are presented in **Graph:7**.

Table: 8: Results for Hardness Test

Parameter	Ocean Water	Solar Energy	IS Standards	
			Acceptable Limit	Permissible Limit
Hardness	5000 ppm	136 ppm	120 ppm	180 ppm
Hardness Rating	Very Hard	Hard	Moderately Hard	Hard



Graph:7: Hardness Parameter Test results and Standards

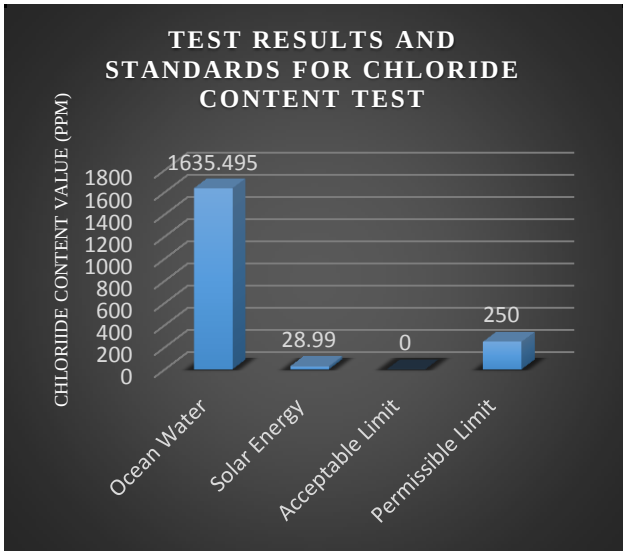
Observing the **Graph:7**, The Ocean Water has got its Hardness as 5000ppm, very undesirable for consumption. The purified samples with Solar Energy have got this property minimized after purification, and have reached within the consumable range as per IS Standards as 136ppm respectively, which is desirable.

8) Analysis for Chloride Content Test:

The Test results for Chloride Content factor for Ocean Water and Purified Ocean Water using Solar Energy, along with IS Acceptable and Permissible Limits are tabulated in **Table: 9** and their variations are presented in **Graph:8**.

Table:9: Results for Chloride Content Test

Parameter	Ocean Water	Solar Energy	IS Standards	
			Acceptable Limit	Permissible Limit
Chloride Content	1635.495 ppm	28.99 ppm	0 ppm	250 ppm



Graph:8: Chloride Content Parameter Test results and Standards

Taking the case of Chloride Content in water, which is an interesting topic to talk about. The Ocean Water sample has got its Chloride Content as 1635.495ppm, which is extremely undesirable, and Chloride content one of those prominent factors that can resist water from consumption, even if the same water has got qualified in all other parameters. Therefore, Ocean Water is unfit for consumption.

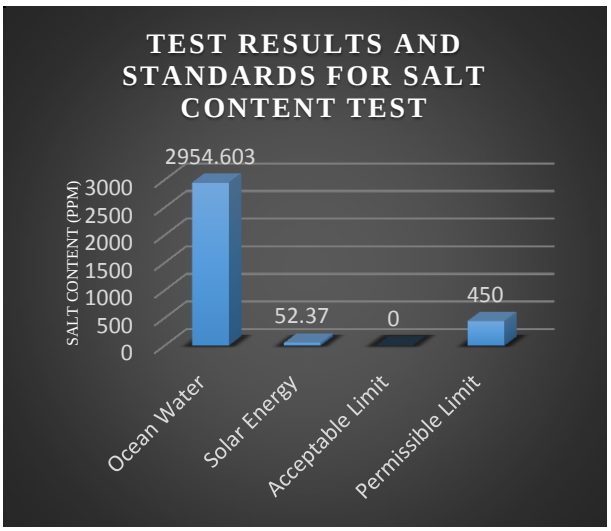
Observing the **Graph: 8**, it is evident that the purified samples with Solar Energy have got this property minimized after purification, and have reached within the consumable range as per IS Standards with 28.99 ppm respectively, which is desirable. Simply, we have removed about 98.5% of Chlorine from Water using Solar Energy method.

9) Analysis for Salt Content Test:

The Test results for Salt Content factor for Ocean Water and Purified Ocean Water using Solar Energy, along with IS Acceptable and Permissible Limits are tabulated in **Table: 10** and their variations are presented in **Graph:9** respectively.

Table: 10: Results for Salt Content Test

Parameter	Ocean Water	Solar Energy	IS Standards	
			Acceptable Limit	Permissible Limit
Salt Content	2954.603 ppm	52.370 ppm	0 ppm	250 ppm



Graph:9: Salt Content Parameter Test results and Standards

Observing the **Graph: 9,** The Ocean Water has got its Salt Content as 2954.603ppm, which is simply common in Ocean Water, but which is extremely undesirable for consumption. It is clear from Graph: 11, that the purified samples with Solar Energy have got this property minimized after purification, and have reached within the consumable range as per IS Standards with 52.37 ppm, which is desirable.

In simple words, we have removed about 98.5% of Salt Content from Water using Solar Energy.

VII. CONCLUSIONS AND RECOMMENDATIONS:

Achievements of Objectives:

- Ocean Water is analyzed in all the possible parameters, and the results are presented the Results and Discussions segment.
- The Ocean Water is subjected to desalination using Solar Energy and Condensation.
- The purified water is also subjected to the same tests, and the results are presented with a comparison with IS: 10500-2012 [12] is presented in the Results segment.

Conclusions of the Study:

- It is found that Ocean Water do not have any factors that support for consumption in any manner.
- All the physical and chemical properties of Ocean Water are beyond the permissible limits for Ocean Water
- 1 liter of Salt free water with 98.5% purity from 4liters of Ocean Water introduced in the bucket, without involvement of any high scale of resources, in 6 days of time, was achieved.
- The overall process of Desalination is conducted in extremely cost effective with us, using extremely basic resources.
- The only undesirable aspect in this process is, the rate of desalination is time taking. It is also depended on Atmospheric Temperature.
- The amount of yield could be higher in Summers and insignificant in Winters.
- Despite of using Electrical Energy to desalinate the Ocean Water, fresh water was yielded with similar properties to distilled water, using basic sources of energy that is Solar Energy.
- Despite of having many unfavorable factors that resists for consumption of Ocean Water, still we are able remove almost all of them and make that water perfect for consumption using basic resources.

Recommendations and Scope for Further Studies:

Since, this study is made as a part of our academic internal project, so we are also aiming to take this study to the next level by:

- Since, it is observed that, this model doesn't demand any resources but only time depending on the atmospheric temperature. Therefore, further developments could be made on both of this model to purify the Ocean Water for greater quantity and quality of purified water within less period of time.
- Further testing could also be done on the purified samples for more detailed picture about the Water Sample.
- By developing this model, surely we can confine the word "Global Water Crisis" only to Dictionary and History, but in reality it could totally be surpassed.

VIII. ACKNOWLEDGEMENT:

We Challa. Datta Karthik, Ch. Abhinav, S. Swetha Sri and D. Venkatesh would take a privilege to thank our Head of the Department Mr. T. Sai Krishna Teja for helping us to carry out this research. We would also like to thank Mrs. K. Sneha Latha, our EE lab in charge for her extended support. We are grateful to the authorities of St. Martin's

Engineering College for their encouragement. Last but not least we are ever thankful to our parents for imposing so much of encouragement and love on us.

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