

Review Of Small Solar Water Desalination Units And Their Productivity

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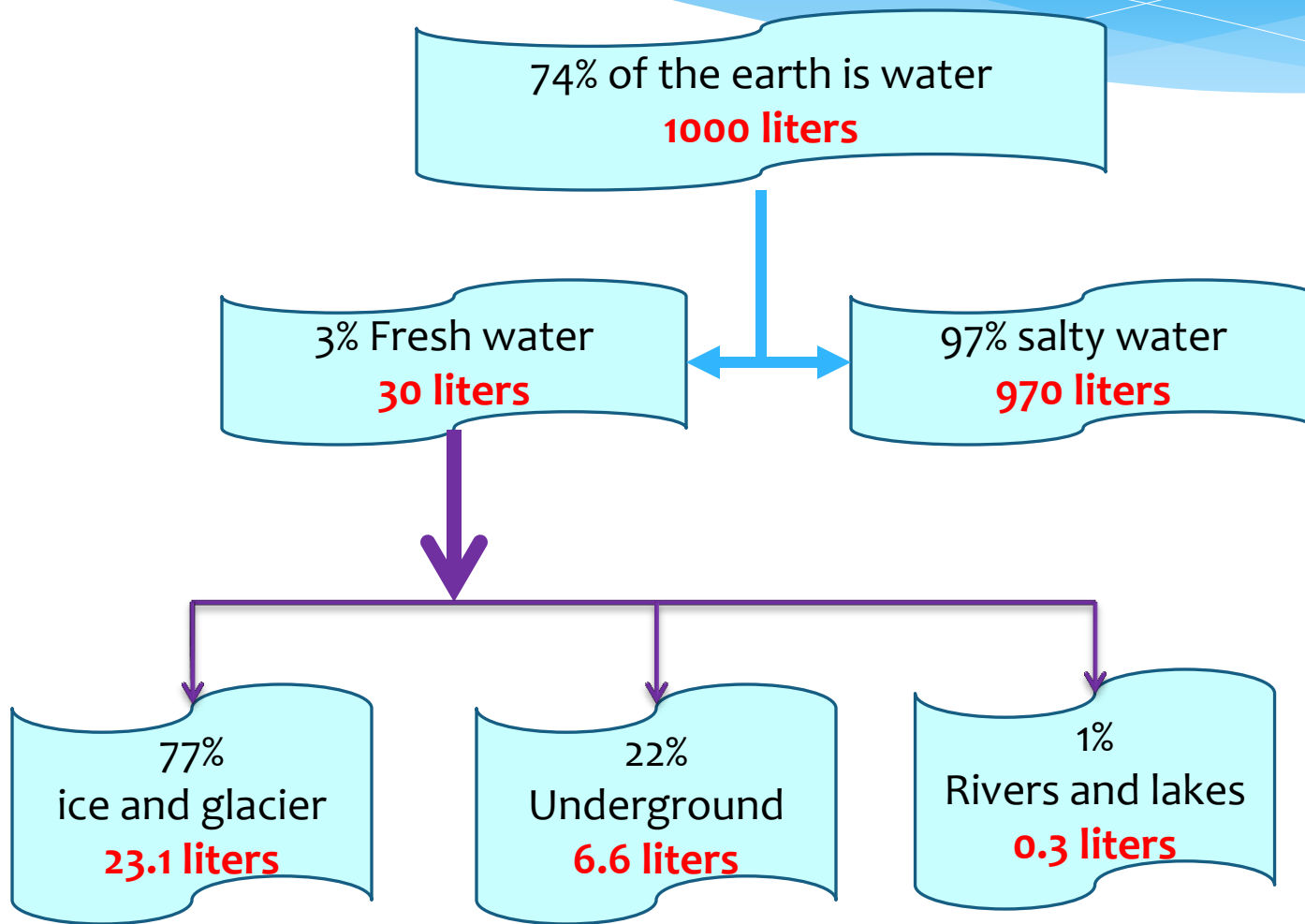
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Workshop on Water and Energy

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Water Chemistry

- It is a great solvent
- It is very stable material
- Compared to similar liquids it, exhibits higher physical properties e.g. boiling point, freezing point, latent heat...
- Density is $\ll$ expected (1.84 g/cm^3)
- $^1\text{H}_2^{16}\text{O}$ (3 isotopes of H exist: H^1 , H^2 , H^3
(6 isotopes of O exist: ^{14}O , ^{15}O , ^{16}O , ^{17}O , ^{18}O , ^{19}O)



CONCERNS

- The available fresh water is not evenly distributed
- Rate of water consumptions is doubled every 20 years. In 2025 the demand for fresh water will exceed the supply by 56%
- It is estimated that 1/6 of the world population (>1 billion) have no access to fresh water.
- Contamination of the fresh water (2×10^6 ton of waste/day is being dumped in rivers, lakes and streams)

Reported Data

- 14 million child die/year from water borne diseases
- 1.1 billion people (15% of the world population) live without clean drinking water
- 2.6 billion (37% of the world population) people lack adequate sanitation
- 85% of the world population lives in the driest half of the planet

Falkenmark Indicator

Consumption (m³/capita-year)	Condition
>1700	No stress
1000 – 1700	Stress
500 – 1000	Scarcity
< 500	Absolute Scarcity

Water Consumption In Some Arab Countries

Country	Water consumption m ³ /capita-year	Situation
Palestine	104	Absolute Scarcity
Jordan	158	Absolute Scarcity
Yemen	160	Absolute Scarcity
Algeria	196	Absolute Scarcity
Tunis	296	Absolute Scarcity
Lebanon	315	Absolute Scarcity
Morocco	427	Absolute Scarcity

Country	Water consumption m ³ /capita-year	Situation
Oman	485	Absolute Scarcity
Qatar	500	Scarcity
Kuwait	500	Scarcity
United Arab Emirates	916	Absolute Scarcity
Egypt	937	Scarcity
Saudi Arabia	959	Scarcity
Sudan	1020	Stress

Water Consumption In Some Foreign Countries

Country	Water consumption m ³ /capita-year	Situation
UK	202	Absolute Scarcity
Brazil	305	Absolute Scarcity
China	415	Absolute Scarcity
Russia	456	Absolute Scarcity
France	513	Scarcity
Turkey	550	Scarcity
Netherlands	642	Scarcity
India	644	Scarcity
Japan	708	Scarcity
Spain	730	Scarcity
Mexico	735	Scarcity
Italy	790	Scarcity
Australia	1150	Stress
Canada	1468	Stress
USA	1550	Stress

Water Consumption To Produce Various Items

Foodstuff	Quantity	Water consumption (liters)
Tea	250ml	27
Egg	1	196
Tomato	1 kg	214
Cabbage	1 kg	237
Milk	250ml	255
Potatoes	1 kg	287
Banana	1 kg	790
Apple	1 kg	822
Wheat	1 kg	1000

Foodstuff	Quantity	Water consumption (liters)
Pizza	1 unit	1,239
Bread	1 kg	1,608
Rice	1 kg	2,497
Olives	1 kg	3,025
Cheese	1 kg	3,178
Chicken meat	1 kg	4,325
Butter	1 kg	5,553
Sheep Meat	1 kg	10,412
Beef	1 kg	15,415
Chocolate	1 kg	17,196

Quantity of Water Needed for Various Industry

Industry	Water consumption (L)
1 bottle of water	3
1 sheet of A4 paper	10
Fertilizer	140
One kg of plastic	200
One can of Coca Cola	200
One kg of steel	237
One kg of Aluminum	410
One kg of copper	440
One car tyre	1960
Cheese	5000
One medium sized car	148,000

Energy Consumption of Sea Water Desalination Methods

Desalination Method	Multi-Stage Flash (MSF)	Multi-Effect Distillation (MED)	Mechanical Vapor Compression (MVC)	Reverse Osmosis (RO)
Electrical energy kWh/m ³	4-6	1.5-2.5	7-12	3-5.5
Thermal energy kWh/m ³	50-110	60-110	None	None

95 L of water is needed to produce 1 kW-hr electricity

Water Consumption for Different Energy Source

Fuel Source	Water required (L/1000 kW-hr)
Natural Gas	38
Coal Gasification	144 - 340
Tar Sand	190-490
Oil Shale	260 – 640
Coal	530 – 2100
Hydrogen	1850 - 3100
Liquefied Natural gas (LNG)	1875
Petroleum / Oil-Electric	15500 – 31200
Fuel Ethanol	32400 – 375900
Biodiesel	180900 - 969000

Total Renewable Fresh Water Supply and Water Withdrawal

Country	Renewable (billion m ³)	Withdrawal (billion m ³)
Kuwait	0.03	0.91
Bahrain	0.1	0.36
Qatar	0.1	0.44
Libya	0.6	4.27
Jordan	0.9	0.94
Oman	1.4	1.32
Yemen	2.1	3.4
Saudi Arabia	2.4	23.7
Tunis	4.6	2.64
Algeria	11.6	6.07
Syria	16.8	16.7
Morocco	29	12.6
Egypt	58.3	68.3
Iraq	75.6	66

Amount of Fresh Water Produced by Desalination

Country	Production (m ³ /day)
Saudi Arabia	5,006,194
United Arab Emirates	2,134,233
Kuwait	1,284,327
Libya	638,377
Qatar	560,764
Iraq	324,476
Bahrain	282,955
Oman	180,621
Algeria	190,837
Egypt	102,051
Tunisia	47,402
Yemen	36,996
Syria	5,488
Sudan	1,450

Country	Production (m ³ /day)
United States	2,799,000
Japan	637,900
Spain	492,824
Italy	483,668
India	115,509
UK	101,397
Australia	82,129
Canada	35,629
Greece	35,620
Pakistan	4,560
Ecuador	4,433
Belgium	3,900
Ireland	2,725
Russia	116,140

METHODS OF WATER DESALINATION

➤ Thermal

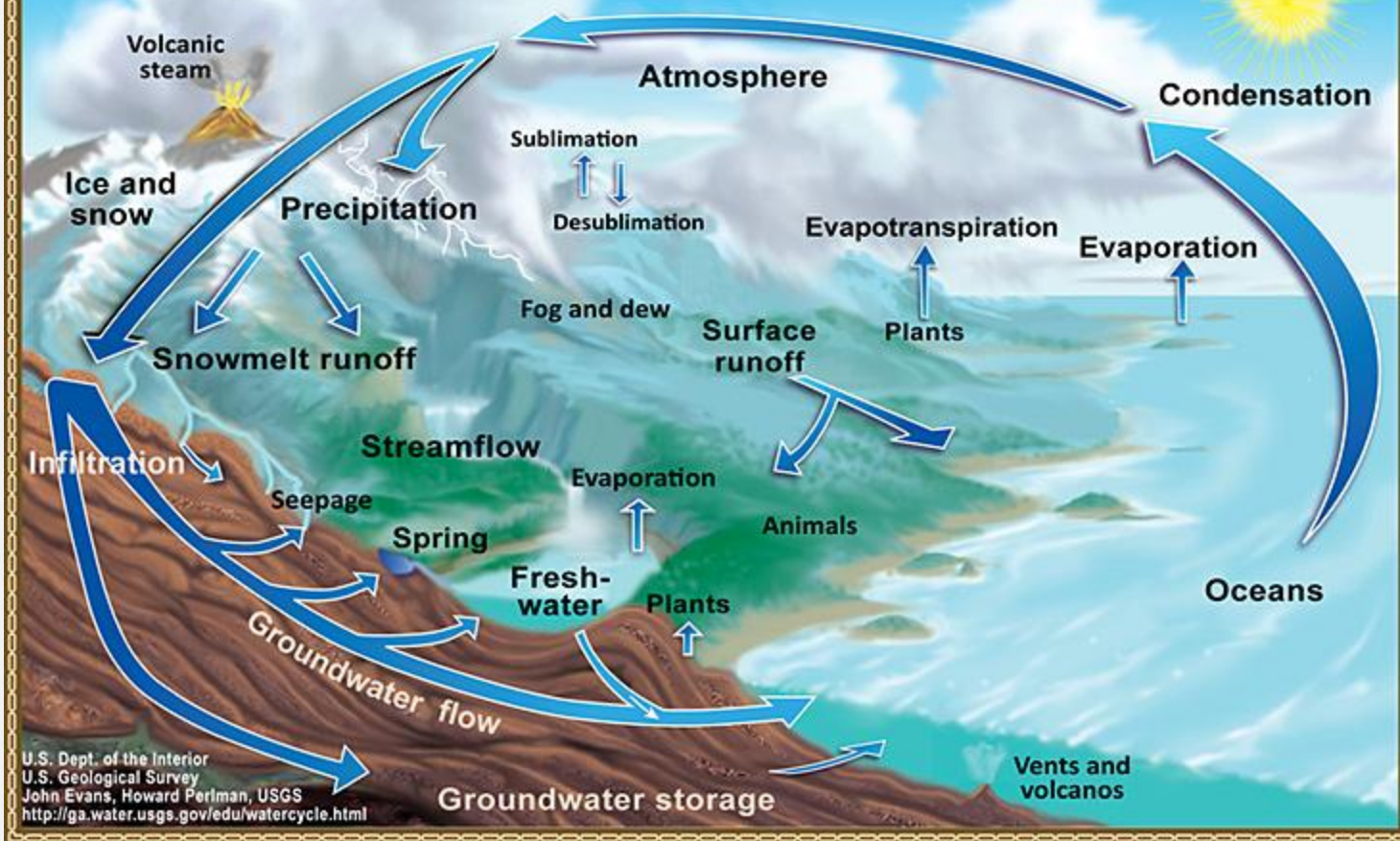
- Based on fuel: Multi-Stage Flash (MSF)
- Solar

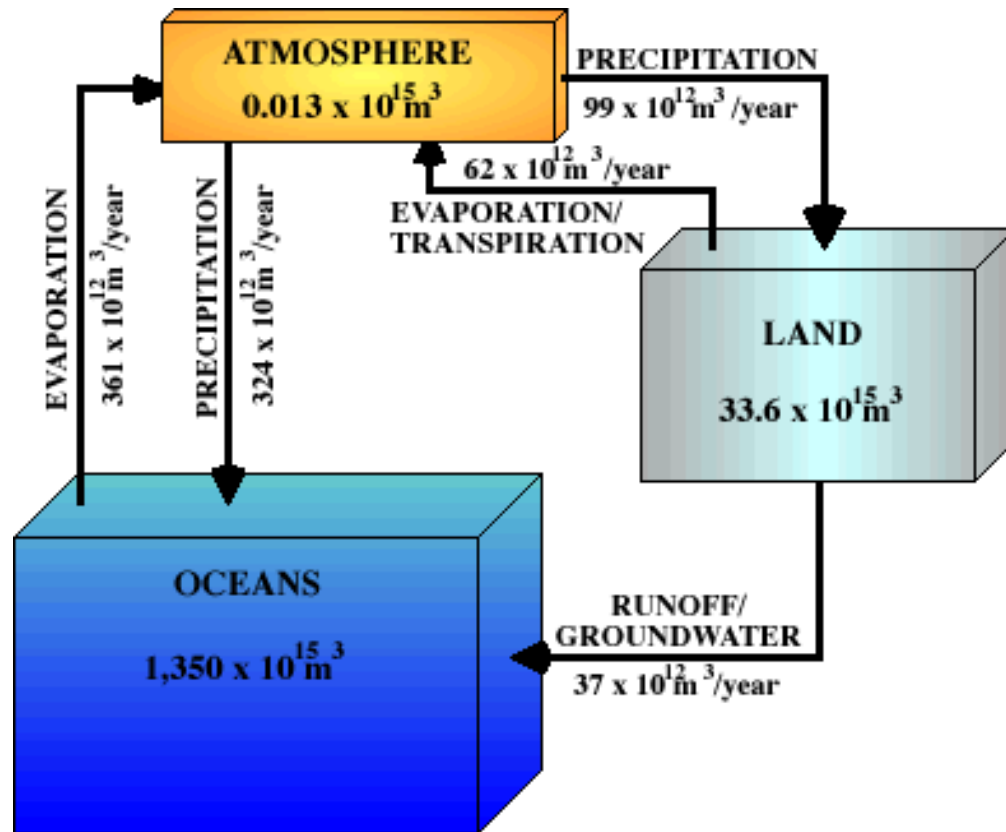
➤ Membrane

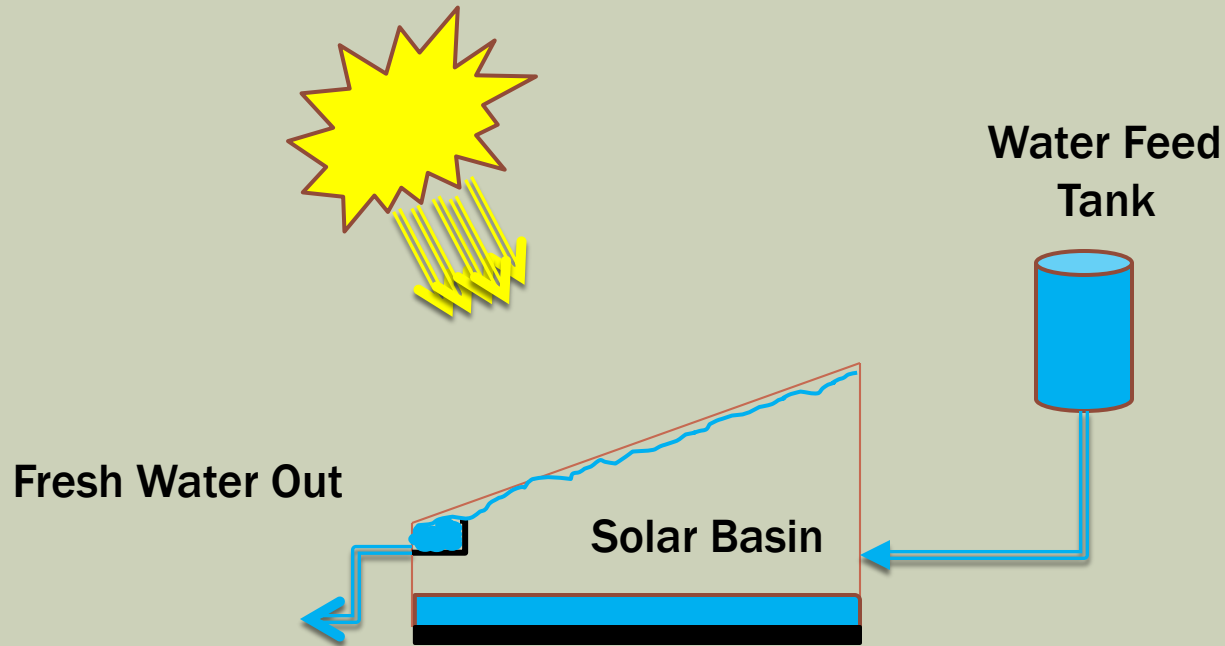
- ❖ Reverse Osmosis (RO)
- ❖ Electro dialysis (ED)
- ❖ Mechanical Vapor Compression: (MVC)
- ❖ Multi Effect Distillation: (MED)

Solar Desalination

The Water Cycle







Production is a function of

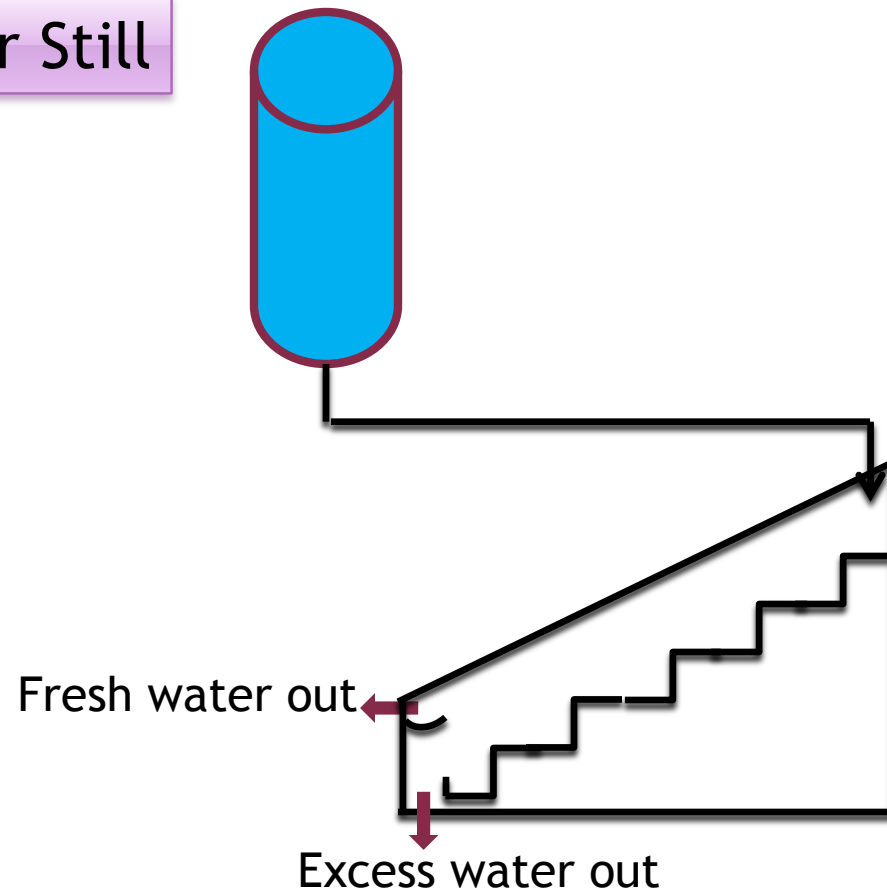
- Solar irradiation,
- Water depth in the basin
- Ambient temperature
- Wind speed
- Feed water temperature

Production ranges between 2-4 L/day-m²

BASIN TYPE SOLAR STILL

Modification	% Improvement on the Productivity
Decrease the water depth	1-2 cm optimum Stepped Solar Still
Improve the area by adding fins	Up to 49%
Floating perforated plates	15% - 40%
Dye the water (naphthalamine, ink, ...)	Up to 60%
Adding surfactant (SLS)	Up to 7%
Coating the basin with various black material (sponge, wick, rubber, gravel...)	Up to 273%
Apply vacuum	100- 303% improvement

Stepped Solar Still

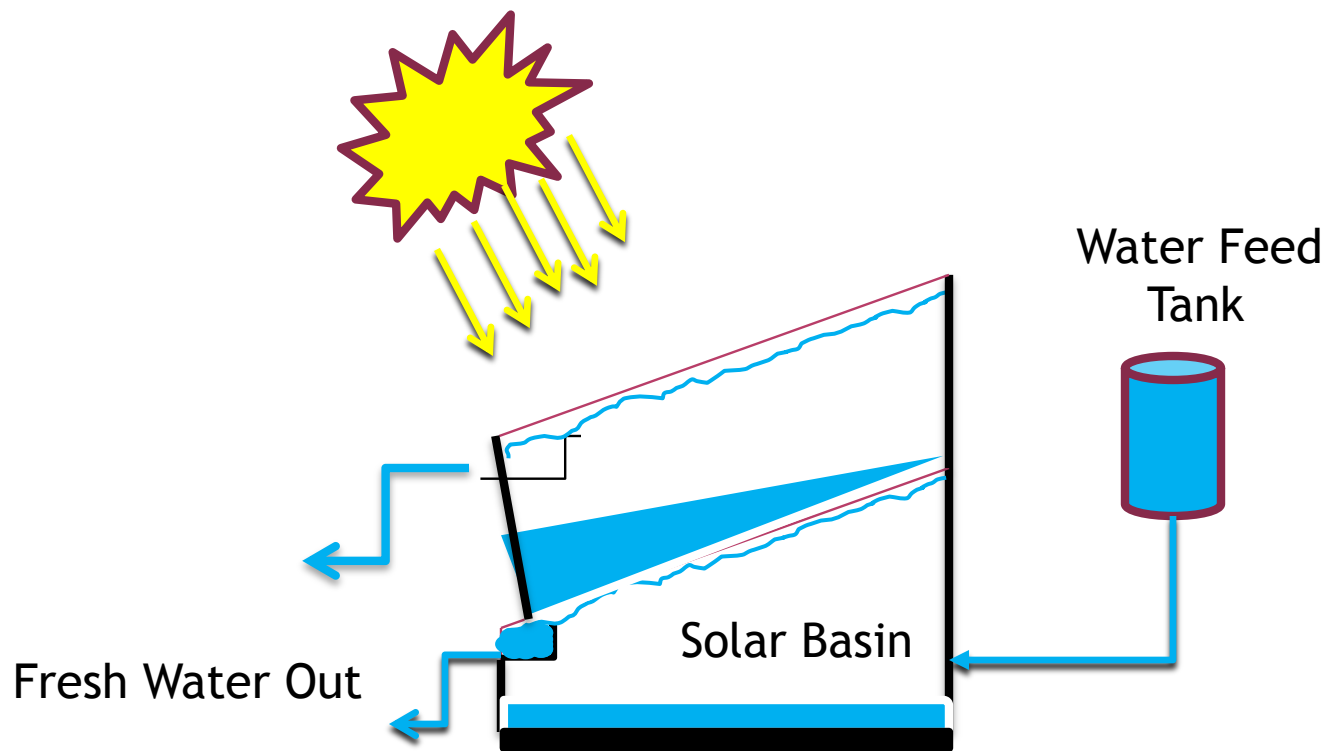


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Apply vacuum	100- 303% improvement

BASIN TYPE SOLAR STILL (CONTINUES)

Modification	% Improvement on the Productivity
Cooling the glass cover	20% improve
Evenly distributing the cooling water	30%
Single effect & Double effect	40% - 55%
Adding Condenser	30%
Tracking the Sun	22%
Humidification-Dehumidification	37 l/m ² -day
Energy storage material (PCM)	20% - 85%



Production is improved by 40 - 55%

BASIN TYPE SOLAR STILL(CONTINUES)

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Single effect & Double effect	40% - 55%
Adding Condenser	30%
Tracking the Sun	22%
Humidification-Dehumidification	37 l/m ² -day
Energy storage material (PCM)	20% - 85%

Basin Type Solar Still

27

Modification	Productivity
Falling Film	Single with cloth strips, fleece wick 70%-80%
	Directing the unit towards the maximum irradiation intensity Up to 80%
Still Basin Enhanced by an external collector	50% - 230%
Parabolic trough	2.3 l/day
Dish type solar concentrator	0.3 l/day-m ² dish
Mini solar pond	Productivity increase by 28%

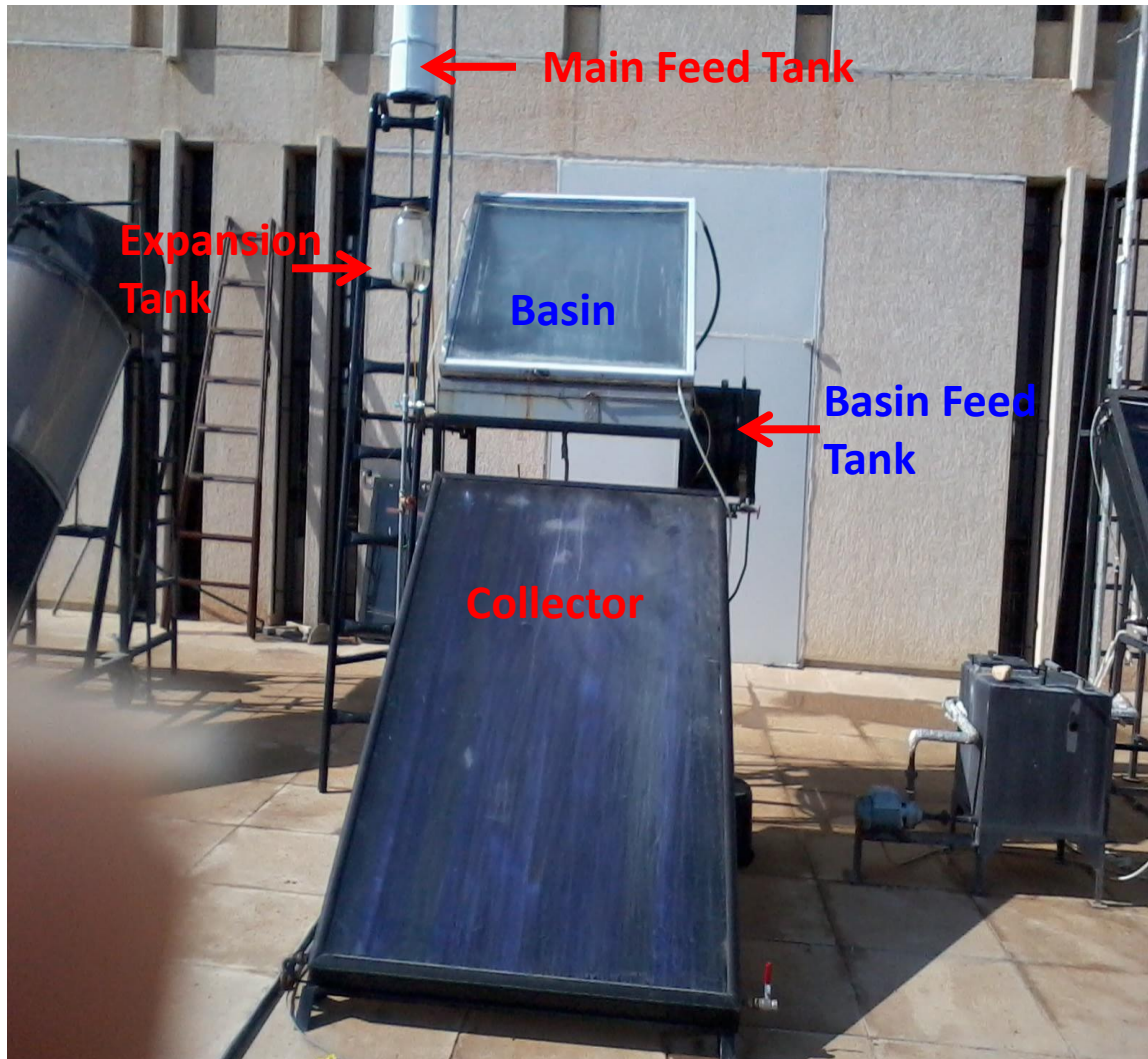
Falling Film desalination Unit

Improvement
by 80%



Modification	Productivity
Falling Film	Single with cloth strips, fleece wick 70%-80%
	Directing the unit towards the maximum irradiation intensity Up to 80%
Still Basin Enhanced by an external collector	50% - 230%
Parabolic trough	2.3 l/day
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Basin Enhanced by Solar Collector



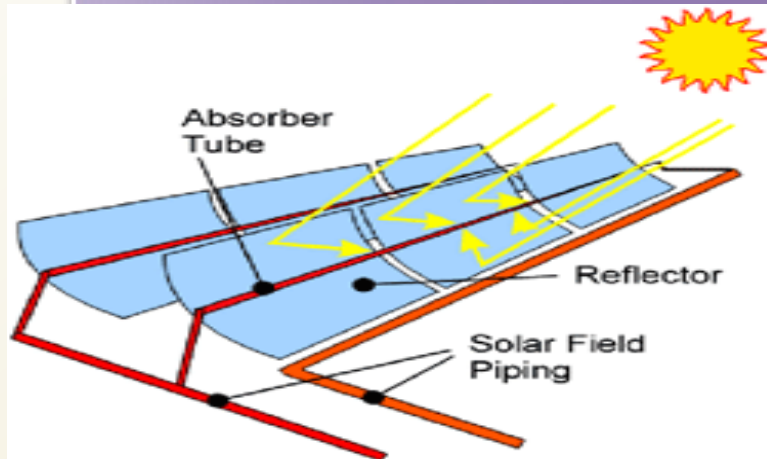
**Enhancement
by 230%**

Basin Type Solar Still

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parabolic trough

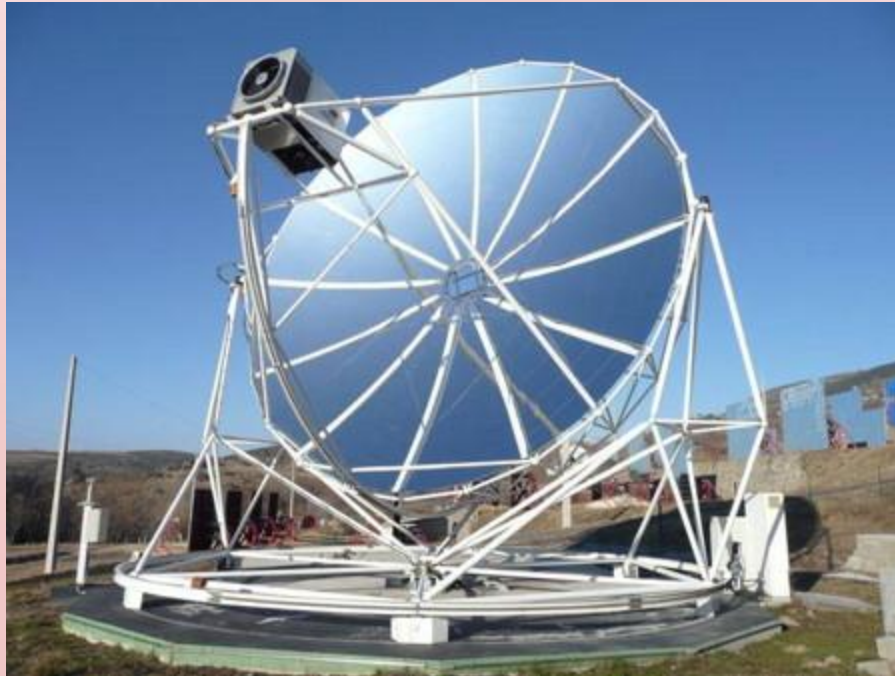
productivity $\sim 50 \text{ l/d-m}^2$



Basin Type Solar Still

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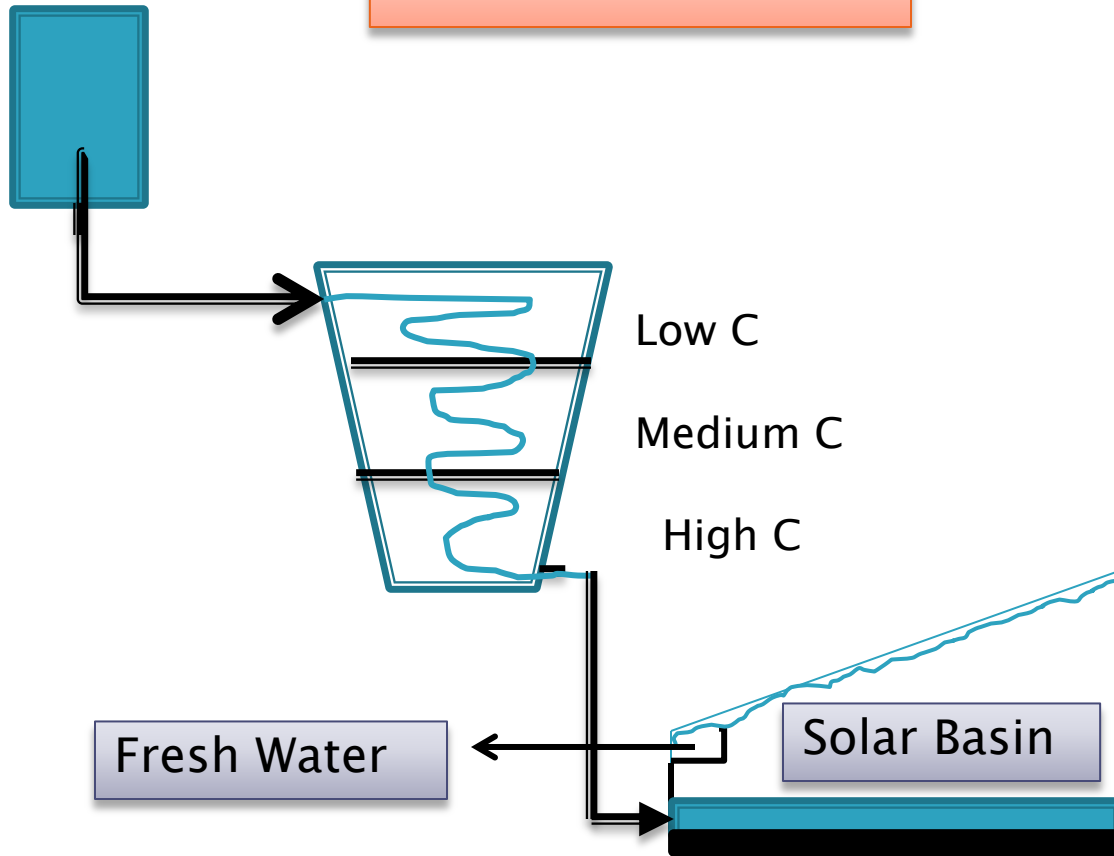
Dish Type Solar Concentrator



Basin Type Solar Still

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Dish type solar concentrator	0.3 l/day-m ² dish
Mini solar pond	Productivity increase by 28%

Mini Solar Bond



Productivity increase by 28%

Conclusions

To maximize the productivity of a simple solar still

- **Decrease the amount of the water in the basin**
- **Increase the heating area/design area by adding baffles, fins...**
- **Change the lining of the basin base (charcoal, rubber, sponge...)**
- **Use phase change material or energy storing material**
- **Cool the glass cover and recycle the cooling water as a feed utilizing the latent heat**
- **Apply vacuum**
- **Apply force convection**

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صدق الله العظيم