ENERGY REQUIREMENTS IN THE PRODUCTION OF PURE WATER

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Importance of water quality

- Health and disease (large scale)
- Industrial use (for example, boiler needs ultra-pure water)
- Waste heat management
- Cooling towers
Hydrological cycle
Sources of water

- Rain water; ground water
- Storage in aquifers, lakes, reservoirs
- Dams
- Glacial flows

Flow of Ganga in the Himalayas

Ganga barrage, Kanpur
Scarcity of fresh water

- Population pressure
- Diminishing and non-uniform rainfall (climate change?)
- Limited storage options (lakes, barrage, groundwater; amount to 1% of total water quantity)
- Increasing power consumption using (pure water guzzling) thermal and nuclear power plants
From the literature...

- **Water, water everywhere, Nor any drop to drink.**
  from “The Rime of the Ancient Mariner,” by Samuel Taylor Coleridge, 1834. [The speaker, a sailor on a becalmed ship, is surrounded by salt water that he cannot drink.]

Water stress: International Scenario

http://www.worldwatercouncil.org/
Water pollution

- Deliberate contamination of water bodies
- Thermal, chemical and particulate matter
- Industrial waste
- Regulation is the key.
Naturally impure water

- Groundwater with dissolved minerals
- Groundwater contaminated by arsenic
- Muddy water in shallow reservoirs
- Water in seas and oceans
Water purification

- Existing methods include
  - Filtration
  - Flash evaporation
  - UV treatment
  - Chemical treatment (sedimentation)

- **Distillation:**
  - Technologically simple process
  - Removes most of the impurities
  - Intrinsically slow; energy intensive if accelerated
Reverse Osmosis of sea water

5-10% water recovery
50-100 bar external pressure
Energy recovery systems essential
Power consumption, 3-5 kWh/m³ [operating cost]
(3—5 kW per m³/h)
Under Indian coastal conditions, a total of 20°C temperature differential is available. Water production is expected to be per 2000 m³/day per MW. Power is required for flow of water in tubes, up to $10^4$ lit/s (10 tons per sec per MW power) and for creating vacuum conditions.

Source: Indian OTEC ship Sagar Shakti (NIOT Chennai)
Simple solar still

Condensed droplets flow along the inside of the glass cover and collect in the gutter.

Heated by the sun, water evaporates and condenses.

Distilled water gutter

Glass cover

Outlet

Overflow

Inlet

Black heat-absorbent surface
Simple solar still
Thermal distillation technique

These designs exploit increased productivity of pre-heated thin layers of water
Solar still developed as a part of a B.Tech. project
Device features

- a central chamber containing water which absorbs heat,
- two reservoirs of dirty water connected to it to ensure continuous supply of dirty water,
- two chambers to collect the condensate which is fed through the air pumps.
- Fresnel lens on top to concentrate the solar radiation over a smaller area thus increasing the amount of solar energy input.
- membrane distillation through a porous hydrophobic membrane is the key process which affects the rate of mass transfer across the membrane.
- membrane allows selective evaporation of water vapor through it at a lower temperature.
- An additional solar photo voltaic panel can be installed to provide heat through a heating element during night time, thus ensuring 24 hours working of the device.
Research areas

- Evaporation characteristics of a hydrophobic membranes
- Making textured membranes
- Dropwise condensation on coated surfaces
- Dropwise condensation on mesh screens
With Fresnel lens array

38 Fresnel Lens
Floating Desalination
Chambers per Petal

304 Floating Passive
Solar Desalination
Chambers on
each Cosmos
Advantages of using solar energy are self-evident.

Integration of multiple means to enhance water productivity:
- Typical solar still productivity: 2-3 L/m²/day
- Aims for a productivity of 25 L/m²/day

Steps to improve the nocturnal output of a solar still.
A Proposal

Diagram showing:
- Overhead Tank
- Diffusion Still
- Membrane
- Double Basin
- Composite Solar Collector
- Clean Water Tank
- PCM
- Reservoir

Dimensions:
- 500 mm
Multi-effect solar still

Fig. 1. Schematic of the multi-effect solar still. (1) holder; (2) sunlight; (3) vacuum tube collector; (4) water tank; (5) glass cover; (6) seawater valve; (7) stacked tray; (8) V-shape troughs; (9) connecting tube; (10) freshwater valve; (11) overflow valve; and (12) freshwater tank.
Evaporation through a hydrophobic membrane

Water distillation
Replaces RO
Includes thermal effects
Nanopores in the membrane
Selectivity improved because of vapor phase transport
Dew formation and water harvesting from moist air
Commercial designs of Solar Stills
A matrix of floating solar stills could cover great extensions in a tailings dam to generate a considerable flow of distilled water.
Example from Chile

- Mantos Blancos current tailings dam has a lagoon of 69,475 m²
- At Mantos Blancos the water evaporation rate reaches 10.1 l/m² per day.
- Under this conditions, the distilled water production potential of MB’s tailings dam is 8 l/s (liters per second).
Peltier cooling
Methods based on conservation

- Rainwater harvesting
Singapore example (no natural resources)

Desalinated seawater,
Recycling wastewater
Rain harvesting
Imported supply from Malaysia (80% being reduced to 60%)
Education begins in schools!
Agriculture (green revolution: 1984)

- Energy required for making fertilizers and pesticides, and electricity for irrigation
- The 1984 green revolution was possible because of increase in the availability of hydrocarbon-based electricity at around the same time.
- Energy shortages in the present (peaking oil and reduced natural gas supply) will affect agriculture and lead to food scarcity and inflation (2020-2050; Hubbert’s analysis).
- Experts recommend massive control in population.
Initiatives

- Superior technologies that consume less water
- Targeted consumption (drip irrigation)
- Conservation
- Volunteerism

2013-2015, Ukkadam lake, Coimbatore
Closure

- Availability of water is becoming critical.
- Water purification is energy intensive.
- Heating water for distillation using solar means and waste heat are possible alternatives.
- Water conservation is an important alternative.
THANK YOU!