Desalination and Sustainability

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Definition

Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.

water systems that are managed to satisfy changing demands placed on them (both human and environmental) now and into the future, whilst maintaining ecological and environmental integrity of water systems

Sustainability: non declining utility of representative member of society for millennia into the future.

Sustainable activity is that level of economics activity which leaves the environment quality level intact.

sustainability requires

- The use rate of renewable resources (e.g. groundwater) does not exceed the rate of their regeneration.
- The extraction rate of non-renewable resources (e.g. fossil fuel, mineral ores) does not exceed the development rate of sustainable substitutes.
- The pollutants emission rate does not exceed the capacity of the environment to absorb and render them harmless.

three pillars of human well being:
economic,
socio-political
ecological/environmental.

water scarcity and quality affect

- Human health and welfare,
- Food security,
- Industrial development ,
- The ecosystems

Integrated water resource management requires

- Knowledge and understanding of freshwater resources
- Enhancing the efficiency of water use
- Sustainable water utilization patterns
- Water conservation
- Wastage minimization.

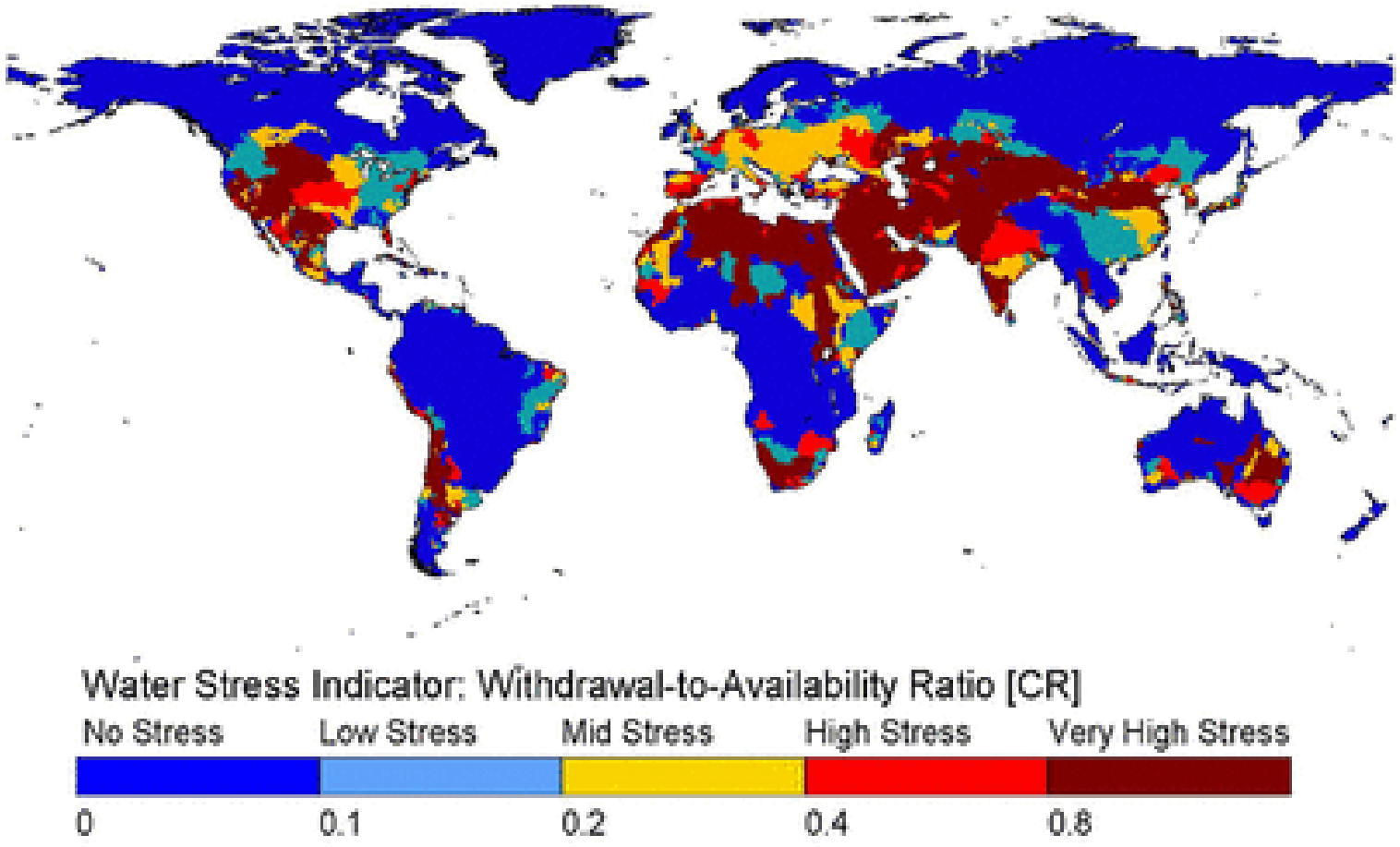
Available Water resources

Al-Weshah, Desalination, Vol. 52, pp. 1, 2002

Continent	Actual water availability, 10^3 m^3/year-capita							%Average reduction /year
	1950	1960	1970	1980	2000	2010	2020	
Europe	5.9	5.4	4.9	4.6	4.1	3.8	3.6	0.6
North and Central America	37.2	30.2	25.2	21.3	17.5	15.6	13.6	1.1
Africa	20.6	16.5	12.7	9.4	5.1	4.3	3.6	1.5
North Africa	2.3	1.6	1.1	0.69	0.21	0.17	0.13	1.8
Asia	9.6	7.9	6.1	5.1	3.3	2.9	2.4	1.3
West Asia	6.3	4.2	3.3	2.3	1.3	1.09	0.88	1.6
South America North	105	80.2	61.7	48.8	28.3	24.0	19.8	1.5
S. America	179	128	94.8	72.9	97.4	81.8	66.2	1.6
Australia and Oceania	112	91.3	74.6	64.0	50	44.5	39.0	1.1

Falkenmark Indicator

Consumption (m^3/capita-year)	Condition
>1700	No stress
1000 – 1700	Stress
500 – 1000	Scarcity
< 500	Absolute Scarcity


Water Stress Indicator: Withdrawal-to-Availability Ratio [CR]
No Stress
Low Stress
Mid Stress
High Stress
Very High Stress
0
0.1
0.2
0.4
0.8

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
Tunisia	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

Total Renewable 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
Tunisia	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

MAIN CAUSES OF WATER SHORTAGE PROBLEMS

- Demographic explosion
- Rising of living standards
- Short-term climatic changes
- Management of water resources

%Installed Desalination Plants

- 7% in the Americas
- 10% in Europe
- 26% in UAE
- 23% Saudi Arabia
- 7% in Kuwait

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

- Desalination may have an impact on five domains:
  1. the use of the land,
  2. the groundwater,
  3. the marine environment,
  4. noise pollution,
  5. the intensified use of energy.
- Installing the plant inland there is a threat that the brine will penetrate to the aquifers

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

Chemicals used in the pretreatment of seawater

- Flocculants: $FeCl_3$, $Fe_2(SO_4)^{3-}$, $Al_2(SO_4)^{3-}$ (aluin), $AlCl_3$
- pH adjustment: H_2SO_4, or HCl
- Algaecides: copper sulphate, iron salts, rosin amine salts and benzalkonium chloride

Antiscalants

- Calcium carbonate ($CaCO_3$),
- calcium sulfate ($CaSO_4$),
- barium sulfate ($BaSO_4$),
- strontium sulfate ($SrSO_4$),
- silica (SiO_2), calcium fluoride (CaF).
- Treatment by: sodium hexa meta
- Phosphate, polyphosphates,

Polymeric Maleic acid,

polymeric carboxylic acids,

polystyrene sulfonate, polyacrylamides,

Scale formation on membrane

Scale formation on pipe

ANTI CORROSION AGENTS

- chromate,
- nitrite and nitrate
- non-oxidizing ions such as phosphate and molybdate

Cleaning of membrane:

EDTA, Citric acid, $NaPO_3$

Anti-Biofoulants

- Organotin biocides
- Chlorine: 200-500 μg/L causes the formation of trihalomethane 9.5 μg/L and as high as 83 μg/L
- $NaHSO_3$ used in order to neutralize any remains of chlorine in the feed water.
- ClO_2 (has chlorite as a by–product)
- Ozone

Heavy metals

- Traces of iron, nickle, chromium, molybednum (below critical level).
- Cu 15 – 100 μg/L

Impact on marine life

- destruction of ecosystems located at the discharge area
- increase in suspended particles concentration and turbidity.
- The risk of saltwater intrusion into nearby fresh groundwater aquifers, in case of subsurface water intakes.
- Needs for more concentration of chemical additives in the pre-treatment phase, due to lower quality of feed water.
- Negative impacts on habitats which are in the vicinity of the intake due to the extraction of large quantities of water.

Impact of brine temperature

The temperature can go as high as 57°C

- Influences the growth and reproduction of marine species
- Affects marine habitat

Conclusions

- Fresh water is a finite and vulnerable resource
- Effective management
- Increase awareness of water among policy makers and the public
- Water has an economic value
- Saving and multiple use of water have an enormous impact on future sustainability

- Effects on water quality due to potential chemical pollution
- Impacts on fish fauna.
- Effects on coral reefs, which are very sensitive to changes in environmental conditions
- Impacts on sea grasses and algae due to turbidity and salinity of the brine presence.

Thank You

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

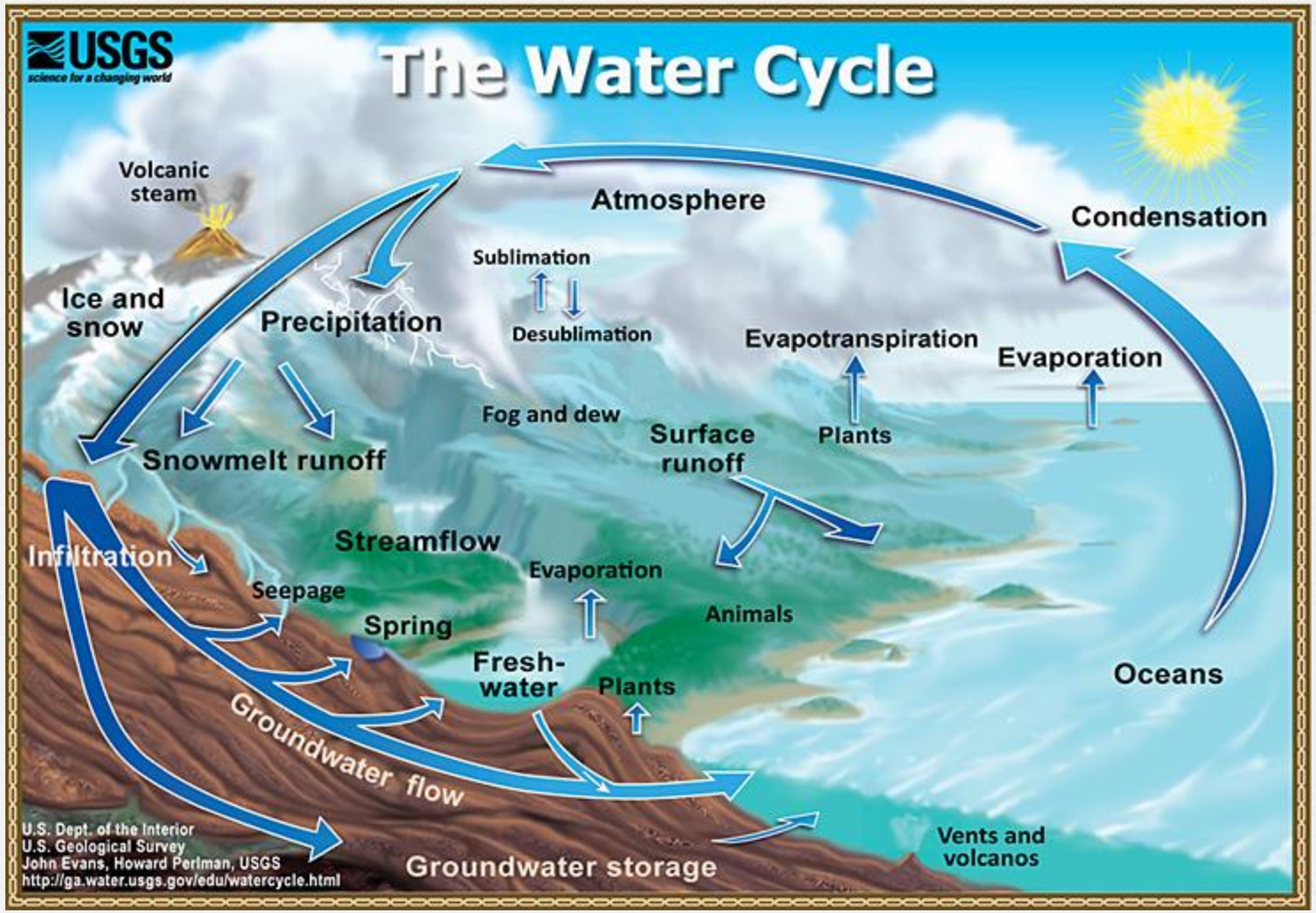
Foodstuff	Quantity	Water consumption (liters)
Pizza	1 unit	1,239
Bread	1 kg	1,608
Rice	1 kg	2,497
Olives	1 kg	3,025
Cheese	1 kg	3,178
Chicken meat	1 kg	4,325
Butter	1 kg	5,553
Sheep Meat	1 kg	10,412
Beef	1 kg	15,415
Chocolate	1 kg	17,196

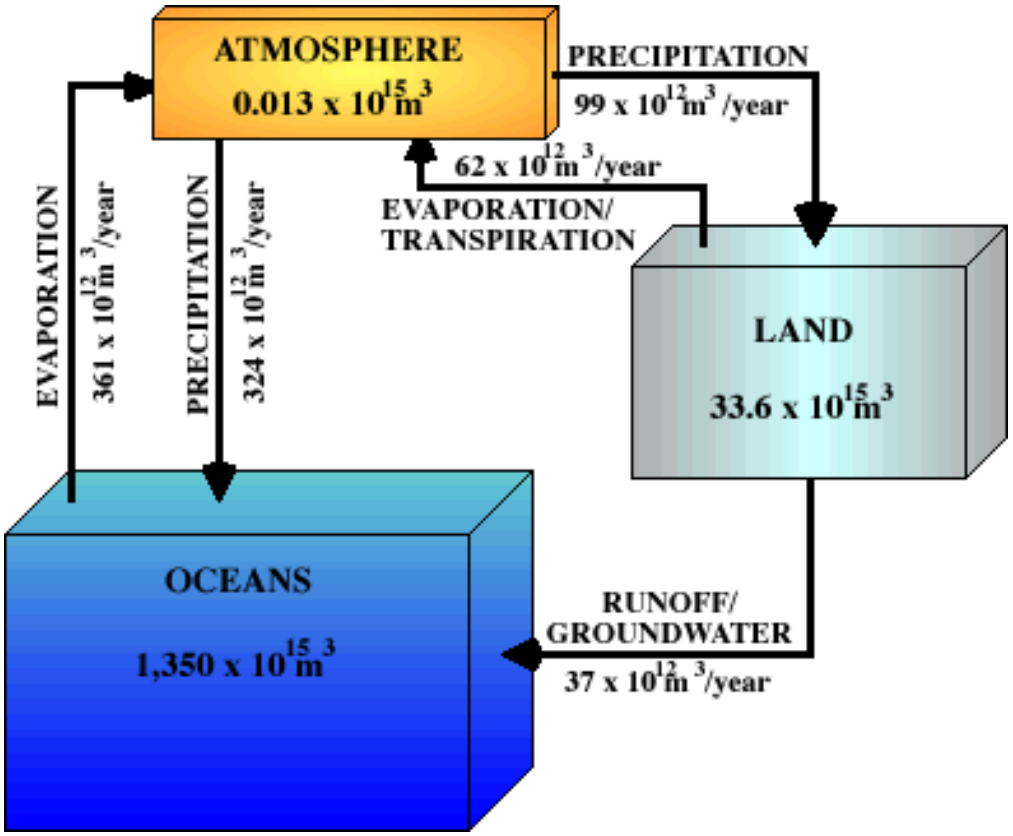
Quantity of Water Needed for Various Industry

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

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


USGS
science for a changing world
The Water Cycle
Volcanic steam
Atmosphere
Condensation
Sublimation
Desublimation
Ice and snow
Precipitation
Evapotranspiration
Evaporation
Fog and dew
Surface runoff
Plants
Snowmelt runoff
Streamflow
Infiltration
Evaporation
Seepage
Animals
Spring
Fresh-water
Plants
Oceans
Groundwater flow
U.S. Dept. of the Interior
U.S. Geological Survey
John Evans, Howard Perlman, USGS
http://ga.water.usgs.gov/edu/watercycle.html
Groundwater storage
Vents and volcanos


ATMOSPHERE
0.013 x 10^15 m^3
PRECIPITATION
99 x 10^12 m^3 /year
62 x 10^12 m^3 /year
EVAPORATION/
TRANSPIRATION
EVAPORATION
361 x 10^12 m^3 /year
PRECIPITATION
324 x 10^12 m^3 /year
LAND
33.6 x 10^15 m^3
OCEANS
1,350 x 10^15 m^3
RUNOFF/
GROUNDWATER
37 x 10^12 m^3 /year

فقلت استغفروا ربكم انه كان غفارا ● يرسل السماء عليكم مدرارا ● ويمددكم بأموال وبنين ويجعل لكم جنات ويجعل لكم أنهارا ● نوح 10 – 12

صدق الله العظيم

As a consequence of climate change: shortage of fresh water resources, changes in the pattern of rainfall

- In Saudi arabia Some 95% of water comes from aquifers, 4% from desalination, and 1% from reclamation.
- more 50% of the world's desalination capacity exists in the gulf, 26% in Saudi Arabia. USA 19%, 13% Europe, 12% Asia and 6% Africa.
- 13600 desalination units in 120 countreis

- Electrical energy requirement: 3.5-4.5 kWh/m3.
- Coal needed is 353.8 kWh/g.
- Crude oil:234.9 g/kWh
- 12 kWh/m3 thermal energy for MSF) and
- For MED 6 kWh/m3 thermal energy and 1.5 kWh electrical