Water Tech
Past and Future

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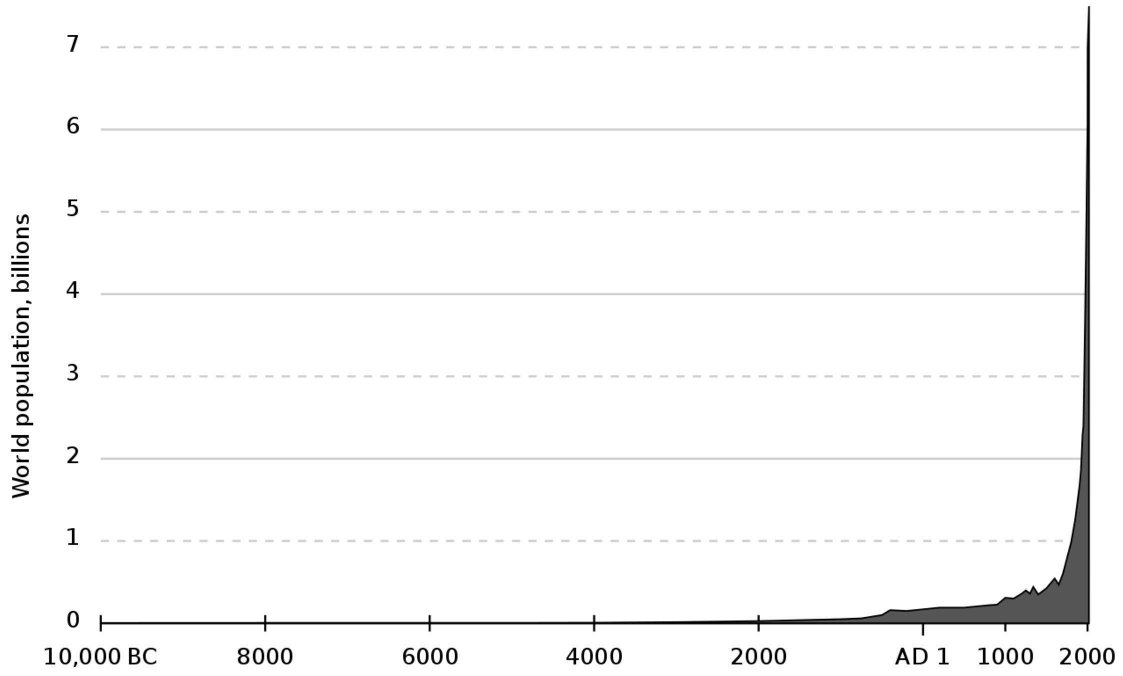
A Short History Lesson

World Population Timeline

- Last ice age (10,000 BC marks the beginning of the Neolithic* period)
  - The last ice age began about 30,000 years ago, reached its greatest advance 21,000 years ago, and ended **about 10,000 years ago**.
- World population 10,000 BC
  - ~2-4 million (~7.9 billion today)
- First large human settlements
  - begins transition from hunter/ gatherer to agriculture and settlement
  - earliest permanent settlement established in Sumer in southern Mesopotamia (c. 6,500 BC)



*Neolithic = 'New Stone Age'

History of water supply and sanitation

- Hunter-gatherers use rivers for drinking and bathing. Permanent settlements were usually established near a river or lake. When there are no rivers or lakes in an area, people use groundwater for drinking.
- Early in the Neolithic period, humans dug the first permanent water wells, from where vessels could be filled and carried by hand. Wells dug around 6500 BC have been found in the Jezreel Valley. The size of human settlements was largely dependent on nearby available water.

Innovations arising from permanent human settlements – a short list

- Language
- Religion
- Social classes
- Slavery
- Trade
- Money
- Leaders
- Armies
- Laws
- Domesticated crops and animals
- Food storage
- Social services
- Specialized tools and skills
- Permanent structures…

And, of course, water and waste management!

Early Water Management Timeline (source)

Year	Event Type	Details	Present Location
8500 BC – 7000 BC	Storage	Some of the world's oldest known wells, located in Cyprus, date from this period.[8]	Cyprus
6500 BC	Storage	Wells dug around this time are found in the Jezreel Valley.[3] Petra was first inhabited in this timeframe.	Israel
5000 BC	Storage	Jericho stores water in water wells that are used as sources.[1]	
3200 BC – 1100 BC	Piping	The Minoan civilization in Crete is the first to use underground clay pipes for sanitation and water supply. Knossos, the capital, has a well-organized water system for bringing in clean water.[11]	Greece
3000 BC	System	The city of Mohenjo-Daro in Pakistan uses a very extensive water supply. The city boasts public bathing facilities with water boiler installations and bathrooms.[1]	Pakistan
2090 BC	Storage	Wood-lined wells are known from the early Neolithic Linear Pottery culture, for example in Kückhoven, Germany.[10]	Germany
700 BC – 681 BC	Canal	Assyrian king Sennacherib builds a 80km stone-lined canal 20 metres wide to bring fresh water from Bavian to Nineveh, including a stone aqueduct 330 metres long.[12]	Iraq, Iran
700 BC–400 AD	Aqueduct	The Romans build a system of aqueducts providing inhabitants with fresh running water, which is piped directly to homes of the wealthy, and to public fountains and baths. This system greatly improves domestic sanitation and adequate disposal of sewage.[13]	Italy
40 – 60 AD?	Aqueduct	Ancient Roman aqueduct Pont du Gard is finished.[15]	France
52 AD	System	Rome has 220 miles of aqueducts, which bring in fresh water to the city, and is used for public bathing, fountains, and latrines. The waste water is then removed by the city's sewage system, some of which, like the Cloaca Maxima, is still in use today.[16]	Italy
100 AD	Publication	Roman senator Frontinus writes a handbook on the Roman aqueduct system.[15][17]	Italy
100 BC – 800 AD	System	Nazca people in ancient Peru employ a system of interconnected wells and an underground watercourse known as puquios.[14]	Peru
200 AD – 400 AD	Storage	The first rock-cut stepwells are built in India.[18]	India
532 AD	Storage	The Basilica Cistern is built in Istanbul to store fresh water for the Byzantine Emperor Justinian I's palace and nearby buildings.[19][2]	Turkey
550 AD – 625 AD	Storage	The stepwells at Dhank in Rajkot district in India are built.[18]	India
1500	System	In Hama, Syria, there are a series of water driven wheels of various diameters, that lifts the river water to an aqueduct at a higher level for drinking and irrigation purposes.[2]	Syria
1579	Technology	Dutchman Peter Maurice acquires a 500 year lease to construct a water wheel under the first arch of London Bridge on the River Thames, supplying water to individual local houses through lead pipes.[2]	United Kingdom
1723	Technology	Chelsea Waterworks Company becomes one of the first water companies to use steam driven Newcomen engine.[2]	United Kingdom
1775	Piping	Scottish watchmaker Alexander Cummings invents the S-bend pipe.[20]	United Kingdom
1802	Canal	Napoleon Bonaparte builds the Ourcq canal which would bring 70,000 cubic meters of water a day to Paris.[20][21]	France
1804	System	The first drinking water supply covering an entire city is built in Paisley, Scotland by Scottish civil engineer John Gibb, in order to supply his bleachery and the entire city with water.[1][7]	United Kingdom
1807	Transportation	Filtered water is transported to Glasgow.[1]	United Kingdom
1845	Technology	The first screw-down water tap is patented by Guest and Chrimes, a brass foundry in Rotherham, England.[20]	United Kingdom

What’s the Problem?

What’s Changed?

- Population growth increases in places without adequate water resources or sufficient infrastructure for water and waste management
- Inefficient water use practices (in the US, 50% or 4.5 billion gallons/day wasted)
- Regional issues resulting from climate change (link)
- High cost of technology to mitigate water shortages
  - Long distance pipeline transport (link)
  - Desalination*
  - Cheap energy…

What is ‘Water Scarcity’?

Water Scarcity

- Water scarcity means scarcity in availability due to physical shortage, or scarcity in access due to the failure of institutions to ensure a regular supply or due to a lack of adequate infrastructure.
- Water scarcity already affects every continent. Water use has been growing globally at more than twice the rate of population increase in the last century, and an increasing number of regions are reaching the limit at which water services can be sustainably delivered, especially in arid regions.

Water Scarcity

Challenges

- Water scarcity will be exacerbated as rapidly growing urban areas place heavy pressure on neighboring water resources. Climate change and bio-energy demands are also expected to amplify the already complex relationship between world development and water demand.

Water Scarcity

Opportunities

- There is not a global water shortage as such, but individual countries and regions need to urgently tackle the critical problems presented by water stress. Water has to be treated as a scarce resource, with a far stronger focus on managing demand. Integrated water resources management provides a broad framework for governments to align water use patterns with the needs and demands of different users, including the environment.

Water Scarcity

Links

- FAO: Aquastat
- FAO (2020): The State of Food and Agriculture 2020
- FAO (2016): Coping with water scarcity in agriculture: a global framework for action in a changing climate
- FAO (2008): Coping with water scarcity: An action framework for agriculture and food security
- UN (2006): UN World Water Development Report 2006: 'Water: a shared responsibility'
- UNDP (2006): Human Development Report 2006: 'Beyond scarcity: Power, poverty and the global water crisis'
- UNICEF (2021): Water Security for All
- UNICEF (2017): Thirsting for a Future: Water and children in a changing climate
- UN-Water Activity Information System: National Drought Management Policies Initiative
- UN-Water (2021): Summary Progress Update 2021: SDG 6 — water and sanitation for all
- UN 2018: SDG 6 Synthesis Report
- World Resources Institute: Blog: What we know about water scarcity

Is Desalination the Solution?

Can Sea Water Desalination Save The World? (13.5 min)

- Today, one out of three people don't have access to safe drinking water.
- Most of the freshwater is locked away in glaciers or deep underground. Less than one percent of it is available to us.
- The ultimate question: So why can't we just take all that seawater, filter out the salt, and have a nearly unlimited supply of clean, drinkable water?

What’s desalination?

- Desalination is **a process that takes away mineral components from saline water**. More generally, desalination refers to the removal of salts and minerals from a target substance, as in soil

And why is it so hard to do?

- It’s all about entropy*. It will always take approximately 1 kWh** of energy to desalinate a cubic meter of seawater. Add to this facilities maintenance and waste management and this is an expensive proposition.

***Entropy is is the measure of disorder, uncertainty, and randomness in a closed atomic or molecular system. (intro to entropy)**

****A kWh equals the amount of energy you would use by keeping a 1,000 watt appliance running for one hour.**

Why is desalination not the answer to all the world's water problems, considering that two-thirds of the earth's surface is ocean?

Richard Muller, CoFounder, Berkeley Earth, Prof Physics UCBerkeley

- “The world doesn’t have a shortage of water; it has a shortage of cheap water. And the cost of desalination has a physics limit: it will always take 1 kWh or more of energy to desalinate a cubic meter of seawater.”

Why is desalination not the answer…

- It is based on the Second Law of Thermodynamics, a fundamental law of physics. Desalination decreases the entropy of the water and salt (by separating them, that is, by making them less disordered). Any process that does that must be accompanied by an entropy increase elsewhere. From that we can show that energy must be "expended", that is, turned from a useful organized form (such as electricity) into a less useful disorganized higher-entropy form (such as heat). The calculation shows that the energy needed is (roughly):
  - 1 kilowatt-hour to desalinate 1 cubic meter of seawater
  - 1 Megawatt-hour to desalinate 1 acre-foot of seawater
  - 1 Megawatt-hour to desalinate 1 hectare-cm of seawater

Why is desalination not the answer…

In the US, the cost of electricity is about 15¢ per kWh retail, 5¢ wholesale. Farmers in California can currently buy fresh water at $4 per acre foot, if they are near the aqueduct. Putting this into a list, we get the costs of fresh water today for an acre-foot of fresh water in California:

- $4 (river water from aqueduct)
- $50 (desalinated water, physics limit, wholesale electricity, not yet achieved)
- $150 (desalinated water, at physics limit, retail electricity, not yet achieved)
- $1100 (desalinated water at Santa Barbara California, using best desalination technology available when it was built in the 1980s) – yikes!

Why is desalination not the answer…

Desalinated water is cheaper than bottled water, but 275x more expensive than currently available farm water in the central valley of California. It is affordable if you need water to drink and to take showers, but not if you are using it for agriculture in a world market. Santa Barbara installed their desalination plant during a severe drought (see link: Meyer Desalination Plant). The drought ended in the late 1980s, so they turned it off (the water was too expensive), and they have not operated it since. But they will use it if a severe drought returns.

Why is desalination not the answer…

The high costs and the physics limit make it look as if desalination will never be cheap enough for agriculture. But there is a potential loophole: there are cheaper forms of energy than electricity. If you have big ponds of saltwater, you can use solar heating directly. The cost of this approach is not clear, but there are regions in the Middle East where it is being tried with brackish water. They have substituted the cost of maintaining large salt-water pools for the cost of electricity, and it isn't clear if it can truly be done cheaply enough. Salt water pools have their own problems, including their size, the corrosive power of salt water, and the growth of algae and other plants in the pools.

So, what is the Solution?

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Read also: **The Future of Water is Digital**

Summary: Digital technologies are leading the transformation through the emergence of technologies such as remote sensing, inexpensive sensors, smart devices (e.g., internet of things), machine learning, artificial intelligence, virtual reality, augmented reality and blockchain. This digital transformation of water is currently enabling real time water quantity and quality monitoring, vastly improved management of infrastructure assets, direct consumer engagement and facilitating the adoption of off-grid and localized infrastructure technologies… efforts on these fronts will power continued innovation that will in turn drive modern regulation. Ultimately, this means reinventing how water is shared and delivered, without losing sight of the overarching goal—a safe, reliable water supply accessible by all.