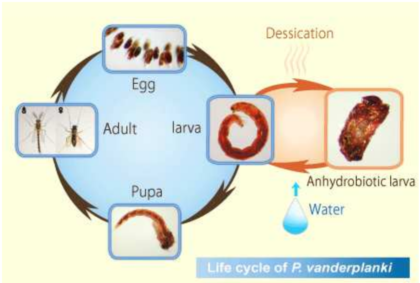
Water and Health

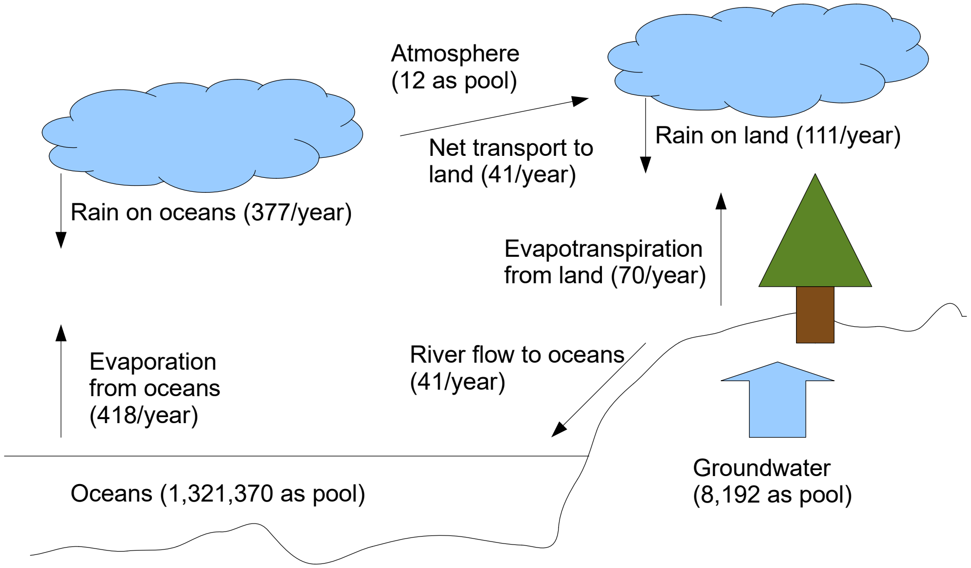
- Frumkin H [Ed.] (2010) Environmental Health: From Global to Local, 2nd Ed. Chap.15 "Water and Health" pp.487-555.(In 3rd Ed., Chap.16)
- KEY CONCEPTS
  - Critical for all forms of life on the earth
  - Human may threaten quality and quantity of water in many ways, then human health and the earth's health
  - Protecting our health needs to conserve water, reduce wastewater production, begin to recycle
  - US regulatory framework ensures the provision of safe drinking water to the public
  - Future risks to water resources and potential mitigation
- Other reference web pages
  - Grafton QR, Wyrwoll P, White C, Allendes D [Eds.] (2014) *Global Water Issues and Insights*. ANU Press. https://doi.org/10.26530/OAPEN_496490.
  - <UN> http://www.un.org/en/sections/issues-depth/water/
  - <World Water Council> http://www.worldwatercouncil.org
  - <WHO/Water> http://www.who.int/topics/water/en/
  - <WHO/Water sanitation and health> http://www.who.int/water_sanitation_health/en/
  - http://www.wssinfo.org/fileadmin/user_upload/resources/JMP-Update-report-2015_English.pdf

Role of water in life

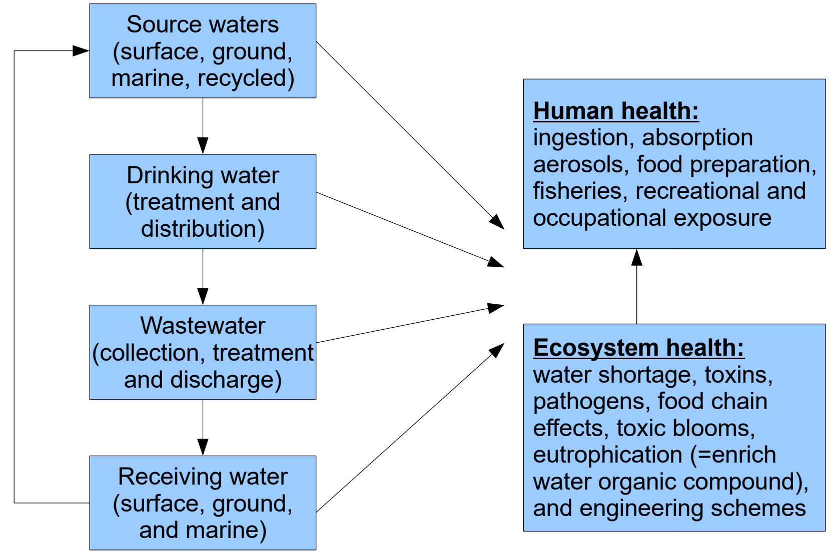
- No water, no life
  - Human, animal, avian, reptile, amphibian, plant, microbe
    - (cf.) sleeping chironimid can survive for several months without water (cryptobiosis = suspending metabolism, losing 97% of its body water) (http://www.nias.affrc.go.jp/anhydrobiosis/Sleeping%20Chironimid/e-index.html, see below)
  - Searching for life on other planets begins from searching water
  - Humans are 60% water
    - cannot survive for more than a few days without water
  - Human culture has been restricted to the area with rich water supply by big rivers: Egypt, Indus, China, Mesopotamia



Hydrologic cycle (unit: Tt)



Interconnections between water and health

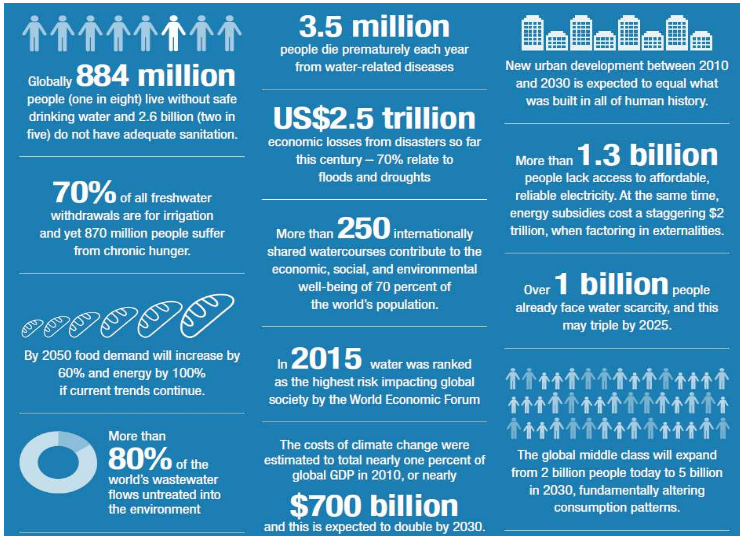


Surface water vs groundwater

- Freshwater supplies (EPA, 2007)
  - Surface water: all waters naturally open to the atmosphere (rivers, lakes, reservoirs, ponds, streams, impoundments, seas, estuaries, ...)
  - Groundwater: the supply of fresh water found beneath the Earth's surface, usually in aquifers, which supplies wells and springs
  - Groundwater under the direct influence of surface water (significant occurrence of insects or other microorganisms, rapid shift of water characteristics)
- Humans can manage the water resource
  - Source water: highest quality for drinking water can reduce treatment cost, avoid contamination
  - Groundwater: traditionally considered as high quality because of percolation through soil, but not always due to human activities
    - In Bangladesh, part of India, China, Argentina, Chile, Mexico, and western USA, naturally contaminated by As.
    - Especially in Bangladesh, some water resources were developed by overseas aid as deep wells, which saved children from diarrhea, but caused skin discoloration and skin cancer by long-term exposure.

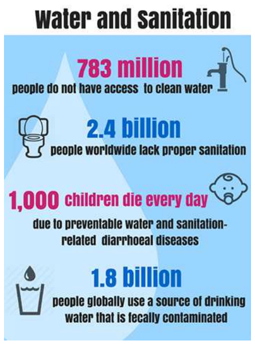
Facts shown in World Water Council strategies 2016-18

- http://www.worldwatercouncil.org/fileadmin/world_water_council/documents/official_documents/20151201_WWC-Strategy-2016-18.pdf



United Nations have addressed water issues

- Global population growth and economic growth increased water demand: basic human needs of safe drinking water, industrial and agricultural use.
- The United Nations Water Conference (1977), the International Drinking Water Supply and Sanitation Decade (1981-1990), the International Conference on Water and the Environment (1992) and the Earth Summit (1992) — all focused on water.
- In 2003, UN declared "International Year of Freshwater" and established UN Water (http://www.unwater.org/).
- In 2005, UN General Assembly agreed on "International Decade for Action "WATER FOR LIFE" 2005-2015 (http://www.un.org/waterforlifedecade/)
- MDGs: Goal 7 [Target 7.C] "Halve, by 2015, the proportion of the population without sustainable access to safe drinking water and basic sanitation" was achieved in 2010
  - 91 per cent of the global population now uses an improved drinking water source
  - 2.6 billion people have gained access to an improved drinking water source since 1990
  - 96 per cent of the global urban population uses improved drinking water sources
  - 84 per cent of the rural population uses improved drinking water sources
  - 8 of 10 people still without improved drinking water sources live in rural areas
  - 42 per cent of the population of least developed countries gained access to improved drinking water sources since 1990
  - In 2015, 663 million people still lack improved drinking water sources
- SDGs: Goal 6 "Ensure access to **water and sanitation** for all" (http://www.un.org/sustainabledevelopment/water-and-sanitation/)
  WHO/UNICEF JMP's global data (https://washdata.org/)
- In 2011, the UN Security Council recognized climate change for its security implications, with water being the medium through which climate change will have the most effects.



<u>Water scarcity</u> as one of the most critical health threats

- Water use may cause water scarcity
  - Long term view: the use of nonrenewable resource is finite; if resource extraction is faster than renewal, any resource supplies eventually cannot meet the demand -> both non-sustainable, like fossil fuels
  - If the water use increase faster than its renewal, the same situation as fossil fuels may happen → "Water Crisis" will occur
    - In arid regions: <u>aquifer recharge</u> are low ("aquifer" refers the soil zones containing rich water). Ogallala Aquifer in USA (ranging SD to TX): 448,000 km^2, provided 30% of all groundwater for irrigation in the USA, changed central plains of North America to rich farm, but it was <u>fossil water</u>, may deplete in the next 20-30 years.
    - Estimating reserved water in aquifer is needed. (cf. R package "reservoir")
- Population increase may cause water scarcity
  - Balance among <u>water availability</u>, population, the ways of water use
  - 27% of nations face <u>water stress</u> (available water per person < 1,700 t/year) by 2025 + 11% of nations face <u>water scarcity</u> (<1,000 t/year)
  - Zero available water in West Bank of Jordan, Seychelles -> import
  - Renewable freshwater supply per person: 10,527 t/year in USA, 1,787 t/year in Somalia
  - Annual withdrawal in USA: 1,654 t (46% industry, 41% agriculture, 13% home); Among home use (0.59t/day/person), only 0.2% for drinking
- Agricultural use may be a primal cause of water scarcity
- <GEOSS (in EU)'s movie> https://www.youtube.com/watch?v=-4MXeePC-d4
- https://www.youtube.com/watch?v=fLMn2P5q1ho
- https://www.youtube.com/watch?v=Fvkzjt3b-dU

Political implications

- Food production depends on irrigation
  - freshwater use is linked with food security, human nutrition, then well-being
  - enormous political implications of water scarcity
    - Major rivers / aquifers cross international / state borders → use by a nation/state affects downstream
      - Dams damage to downstream users
      - Political hot spots (See the next slide): Nile, Tigris/Euphrates, Indus/Beas/Sutlej/Ravi, Ganges/Brahmaputra, Jordan, Parana/Paraguay, Rio Grande, Colorado
    - "Resource Wars" may occur
- Global burden of waterborne diseases
- Safe drinking water needs -> treatment technologies , including chlorination (by-products should be paid attention)

Conflicts (“hot spots”) due to water scarcity

(Frumkin’s text 3rd Ed. Table 16.1; and WWF’s website https://wwf.panda.org/our_work/water/rivers/)

River basin	Length (km)	Countries	Sources of conflict
Nile	6,693	Tanzania, Kenya, Zaire, Burundi, Rwanda, Ethiopia, Uganda, Sudan, and Egypt	Irrigation
Tigris/Euphrates	1,840/ 2,700	Turkey, Syria, Iraq, and Iran	Hydroelectric projects, irrigation
Indus/Beas/Sutlej/ Ravi	2,896 (Indus)	India, Pakistan, and Tibet	Diversions, Sikh vs Hundu
Ganges/ Brahmaputra	2,507/ 2,900	India, Bangladesh, Nepal, and Bhutan	Deforestation and siltation, diversions
Jordan	93	Israel, Jordan, Lebanon, and Syria	Diversions – arguably an underlying cause of Arab-Israeli conflicts
Paraná/ Paraguay	3,998 (Paraná)	Brazil, Paraguay, Bolivia, Argentina, and Uruguay	Dams – hydroelectric
Rio Grande	3,057	United States and Mexico	Development, irrigation
Colorado	2,336	United States and Mexico	Development, irrigation

Climate change and water

- Global climate change affects water
- Global warming cause the increase of evaporation from the oceans -> increase of water vapor in the atmosphere -> increase of precipitation -> more severe weather events
- Positive feedback loop (cf. hydrologic cycle)
- The burden of water scarcity may shift
  - Arid regions may benefit
  - Mountainous regions (depending on snowpack) may short
- Gosling SN, Arnell NW (2016) A global assessment of the impact of climate change on water scarcity. *Climatic Change*, 134: 371-385. doi 10.1007/s10584-013-0853-x
  - Based on 4 scenarios and 21 Global Climate Models (GCMs), Water Crowding Index (WCI) and Water Stress Index (WSI) were calculated.
  - The models estimated that 1.6 (WCI) and 2.4 (WSI) billion people live in watersheds exposed to water scarcity now.
  - Using WCI, A1B scenario, 0.5 to 3.1 billion people will be exposed to an increase in water scarcity by 2050.

Long-term water resource projection by Hejazi et al. (2014)

- Hejazi M, Edmonds J, Clarke L, Kyle P, Davies E, Chaturvedi V, Wise M, Patel P, Eom J, Calvin K, Moss R, Kim S (2014) Long-term global water projections using six socioeconomic scenarios in an integrated assessment modeling framework. *Technological Forecasting & Social Change*, 81: 205-226.

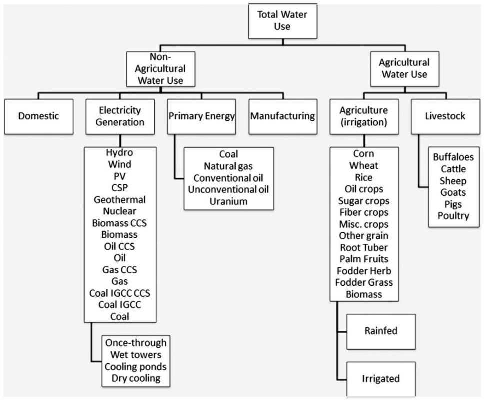


Fig. 2. Representation of all components of the water demand sectors in GCAM.

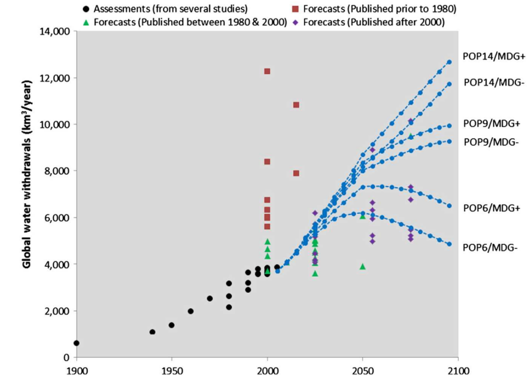


Fig. 10. Global water withdrawals for each of the socioeconomic scenarios in comparison to literature estimates of historical water use and other studies; sources: Gleick [18] (and references therein), Falkenmark & Rockström (cited in [16]), Alcamo et al. [38], Shiklomanov & Rodda [100], Alcamo et al. [15], Shen et al. [16] Wada et al. [52], and AQUASTAT [58].

Human impacts on water

- Hydrodynamics (the way water moves) is dramatically altered by human activity (construction of dams, levies, canals, ...) → completely change the biology and chemistry of an ecosystem, sometimes eutrophication, oxygen depletion, massive fish die-out, cyanobacteria-derived toxins (microcystins: WHO's criteria, 1 μg/L) in drinking water (occurred in Lake Erie, USA; Caruaru city, Brazil: https://www.ncbi.nlm.nih.gov/pubmed/12505349)
- Engineering schemes resulted in large health effect
  - Dam and irrigation -> snails -> schistosomiasis
  - Hydroelectric -> methylation of Hg -> Hg overintake
  - Channelization -> extreme flood -> Huge economic loss
  - Draining -> loss of wildfowl and fish -> economic loss, long term effects on human may occur (unknown)
- Water contaminants
  - Chemical: (eg. As, Hg, Cd, Pb, PCB, oils, chloroform, salt) naturally (esp. N, F, As, salt) or artificially (esp. POPs, radionuclides – Pt, ^{137}Cs, ^{90}Sr) comes
  - Biological: (eg. bacteria, virus, protozoa) comes from many sources including human and animal wastes -> waterborne disease outbreaks (eg. cryptosporidiosis, *E. coli* O157)
  - Deposition, storage, bioconcentration should be paid attention for both.

Sanitation systems (Frumkin's text 3rd Ed. Fig. 16.4)

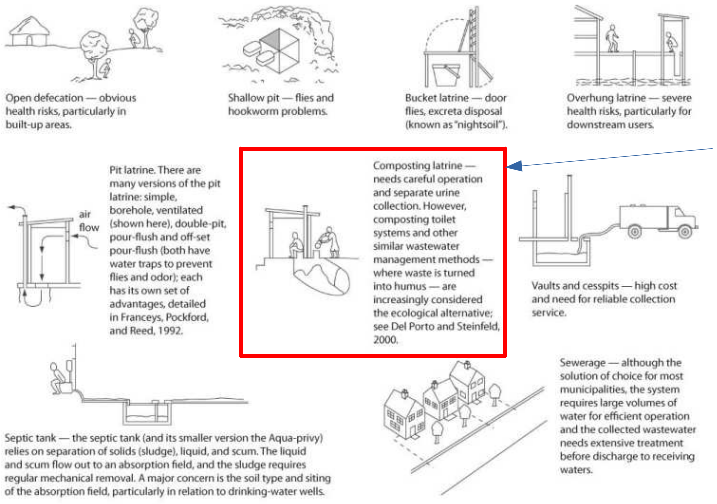


Figure 16.4 Sanitation Options

Source: Diagrams reproduced from Franceys, Pickford, & Reed, 1992. © World Health Organization.

Composting latrine is a kind of eco-toilets.

See, https://www.youtube.com/watch?v=eroG02bTk3Q

or

https://capecodecotoiletcenter.com/

Idealized sanitation system (Frumkin's text 3rd Ed. Fig. 16.5 and 16.8)

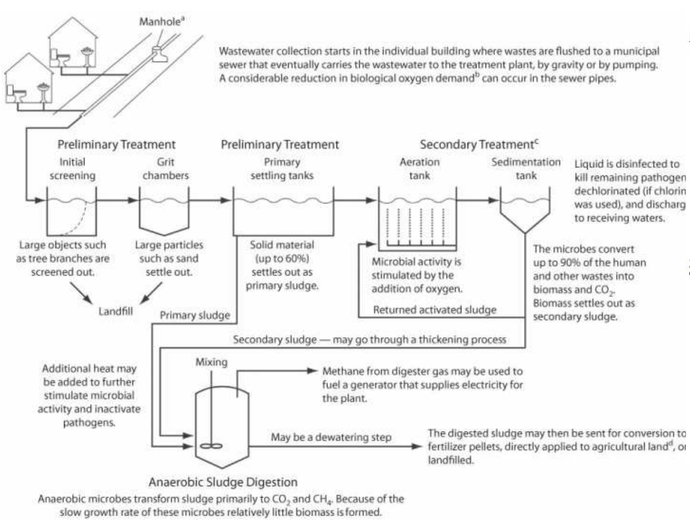


Figure 16.5 An Idealized Wastewater Treatment System, Based on Boston's Deer Island System

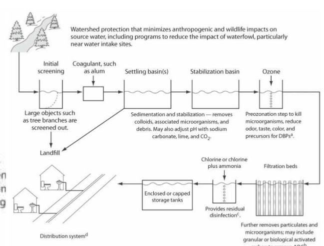


Figure 16.8 A Multibarrier Approach to Maximize Microbiological Water Quality

Note: This presumes a treatment system that has sufficient capacity to maintain adequate pressure throughout the distribution system for twenty-four hours per day and that minimizes opportunities for microbial colonization of the pipelines.

[a] Disinfection by-products, including aldehydes and brominated by-products, are formed by ozonation of source waters (discussed in Krasner, 2009; see also Tox Box 16.2). UV disinfection, used extensively in wastewater treatment, is rapidly gaining acceptance as an alternative to ozonation.

[b] AOC = Assimilable organic carbon, carbon that can be readily utilized by microorganisms and therefore stimulates their growth.

[c] Residual disinfection requires a chemical that will not be rapidly broken down in the distribution system so that it retains some disinfecting activity at point of use (the tap). To date the only practical chemicals appear to be chlorine or chloramines. Chloramination may be preferable to chlorination, as chloramines may penetrate biofilms more effectively than chlorine alone. They also reduce formation of disinfection by-products and are more effective at a high pH (a high pH is often necessary for corrosion control). Where chloramination is used, intermittent chlorination and system flushing is recommended, as chlorine is the more powerful oxidizing agent.

[d] A rigorous program is necessary to upgrade distribution system networks and to prevent interconnections through leakage, backflushing, improper hydrant use, and so forth.

Water treatments

- Simple, low-cost treatments
  - [Safe water system] Bleach, storage vessel, and behavior change; pathogen removal by NaOCl (sodium hypochlorite)
  - [Flocculant / disinfectant] P&G Purifier of Water: $Ca(OCl)_2$
  - [Ceramic water filters] Variety of types, colloidal silver and also copper
  - [Biosand filter] Absorption / competition
  - [Boiling] Sterilizing (inactivating microorganisms) by high temperature
  - [Solar water disinfection] UV and temperature
  - [Llaveoz] UV
  - [LifeStraw] Iodine and silver
  - [Sari cloth] Prefilter for particles and pathogen hosts (eg. copepods)
  - [The drinkable book] Filtration (each page is a readable filter)
  - [C-L γ-PGA from Natto] Flocculation and precipitation (https://doi.org/10.1263/jbb.99.245; http://japan-product.com/ads/nippon-poly-glu-co-ltd/)
- Approaches to disinfection / Issues like by-products (eg. chloroform, bromate, chlorite, ...)
  - [Cl] Retains a residual; strong disinfectant / Taste, odor, toxicity
  - [Chloramine] Retains a residual; penetrate biofilms more effectively than free chlorine / Weaker disinfectant, by-products
  - [Chlorine dioxide] Powerful disinfectant; no by-products / Toxic, cannot be stored, no residual, expensive
  - [Ozone] Powerful disinfectant; kill Cl-resistant microbes (eg. Cryptosporidium) / Expensive
  - [UV (pulsed)] Short contact time; no toxic by-products / No residual; not effective with high turbidity water
  - [Solar] Simple and readily available supplies / Small scale; slow; potential chemical leaching from PET bottles; low cost