Safe and Sustainable Wastewater Treatment and Reuse: In Theory and Reality

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Subject matter for the day…

Brief introduction of my history with water

- What is ‘wastewater’ (WW)?, and is it safe to reuse??
- Who is reusing WW *in the United States*, and for what?
- Who is re-using WW around *the world*, and for what?
- The future of reusing WW: Challenges and opportunities

B.S. Environmental Biology

Ohio University (2000-2005)

Ohio EPA (2004-2005)

Division of Surface Water

- Assessment of state water conditions/trends
- Information used for TMDL modeling

- Physical (turbidity, flow, sediments)
- Chemical (pH, conductivity, nutrients)

M.S. Environmental Science

Univ. of Cincinnati (2005-2007)

- Water Quality Specialization

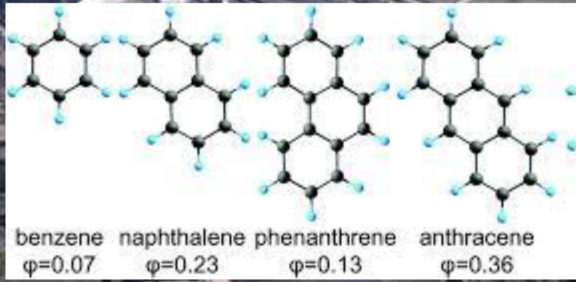
- Studied physical, chemical, and biological methods for the remediation for heavily contaminated sediments

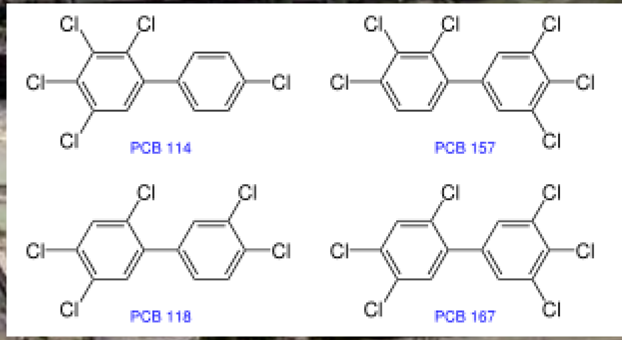
<u>Thesis</u>: Steam extraction of polycyclic aromatic hydrocarbons and lead from contaminated sediment using surfactant, salt and alkaline conditions

Remediation Journal, 20(3), 121-132 (*2010*)

Indiana Harbor Canal Superfund Site

- Contaminated sediments polluting Lake Michigan
- Containing PAHs, PCBs, heavy metals (Pb, Cd)

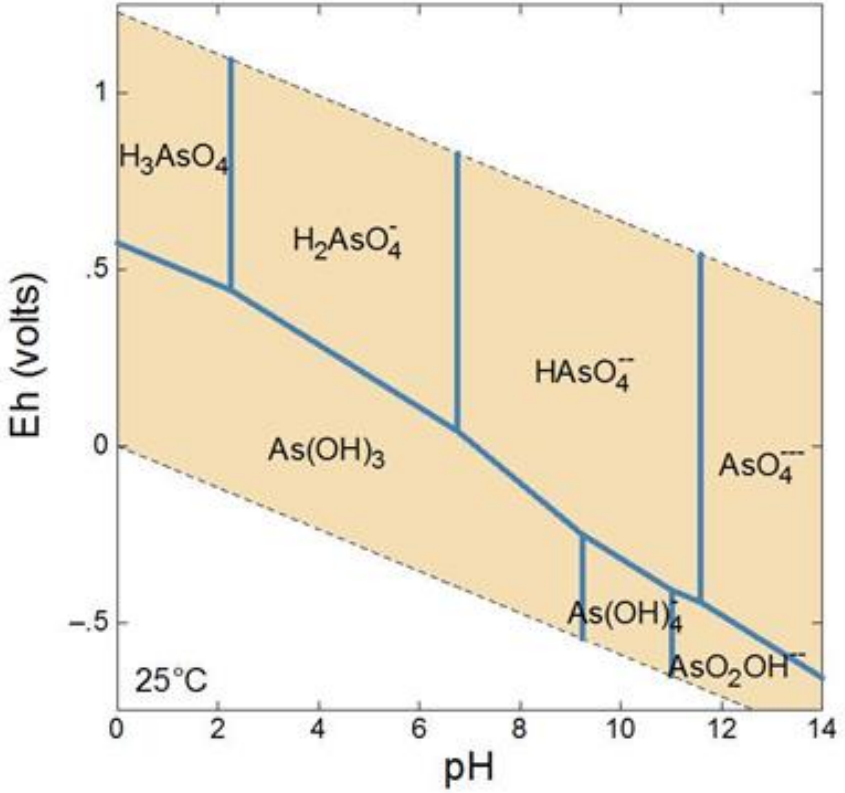




U.S. EPA Contractor (Cincinnati, OH) (2007-2011)

Formation, fate, and transport of contaminants in aquatic and terrestrial systems:

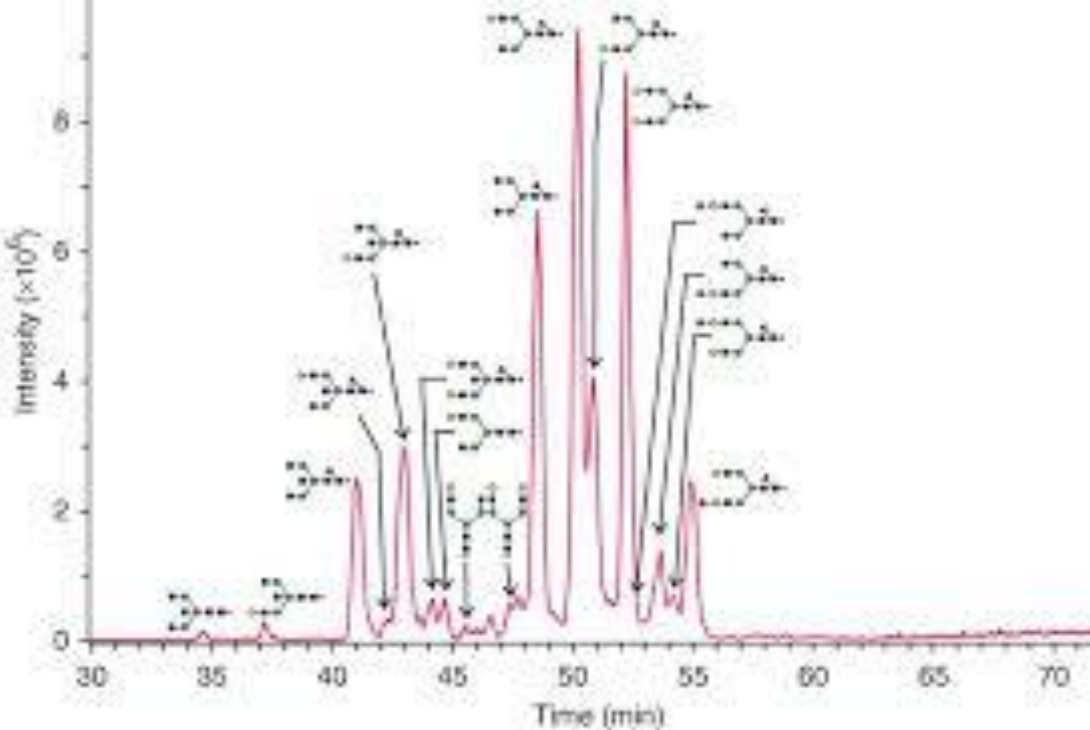
- Drinking water distribution systems and source waters
  - Precipitation and dissolution of metals
  - Disinfection byproduct (DBP) formation



Wastewater: Liquids and Solids

Method development and analysis of:

- Pharmaceuticals, industrial byproducts
- Microbial contaminants



Surface Water ⇔ Groundwater

Green Infrastructure

- Rain barrels, rain gardens, bioswales
- Influence on sediment and nutrients loads

Watershed Restoration

Wetland and Stream Restoration Institute (KY)

- Ecological restoration
- Stormwater management

Eastern Coal Regional Roundtable (WV)

- Addressing mining impacted waters

Ph.D. Environmental Engineering Sciences
Univ. of Florida (2011-2015)

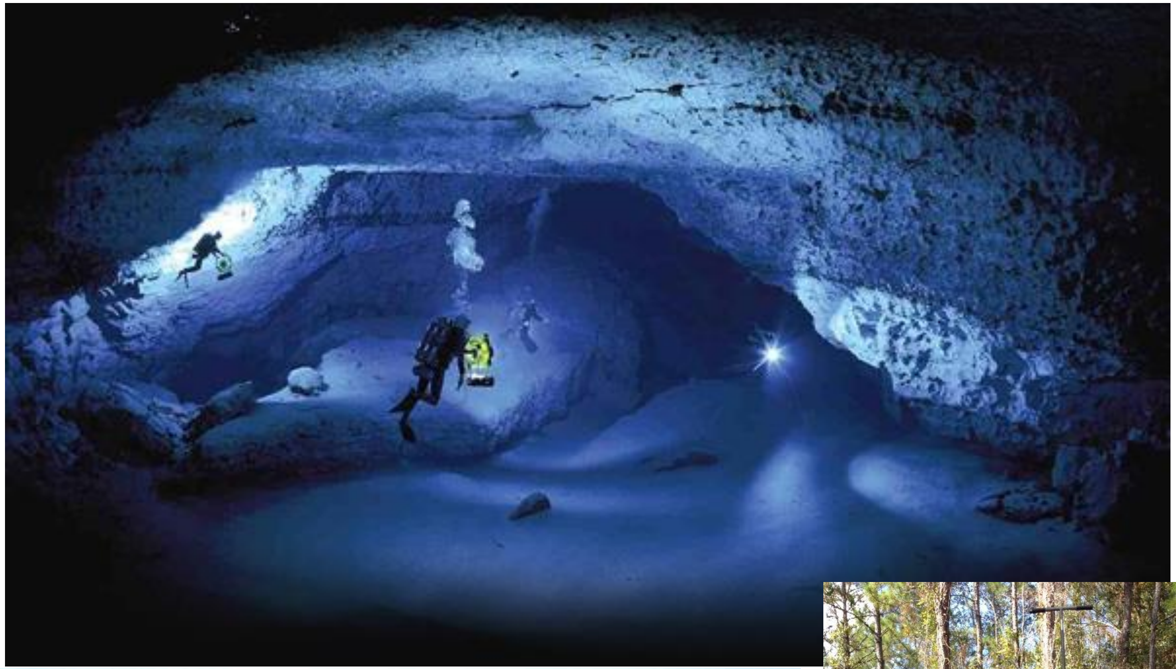
Interdisciplinary program applying ecological, hydrological, and sociological principles to solve complex water quality/quantity issues

- Soil and Water Science
- Ag and Bio Engineering
- Forestry/Eco-hydrology
- Hydro-geology
- Law/Policy

Courses Taught:

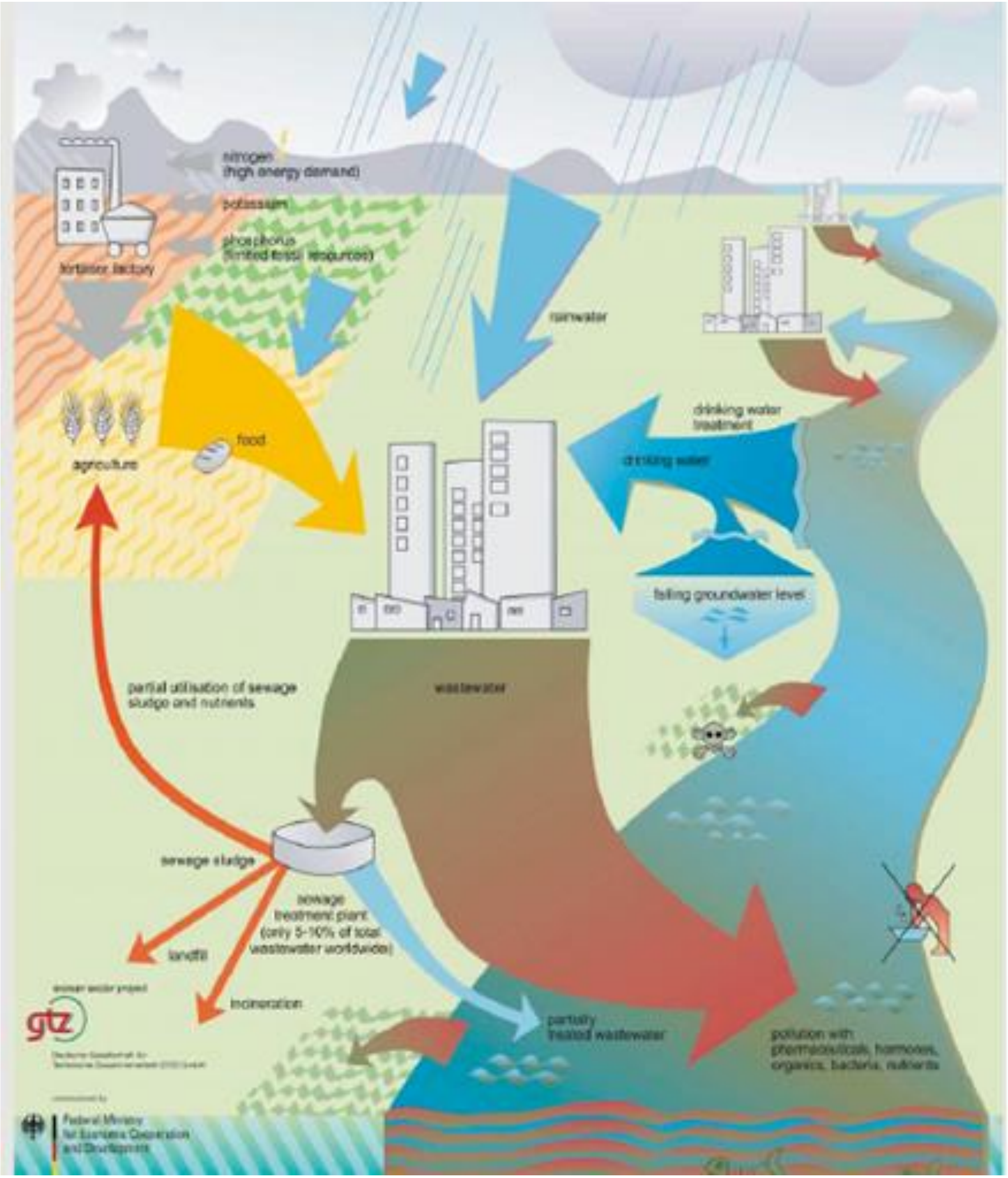
- ✓Issues in Water Resources
- ✓Green Engineering Design
- ✓Environmental Analysis

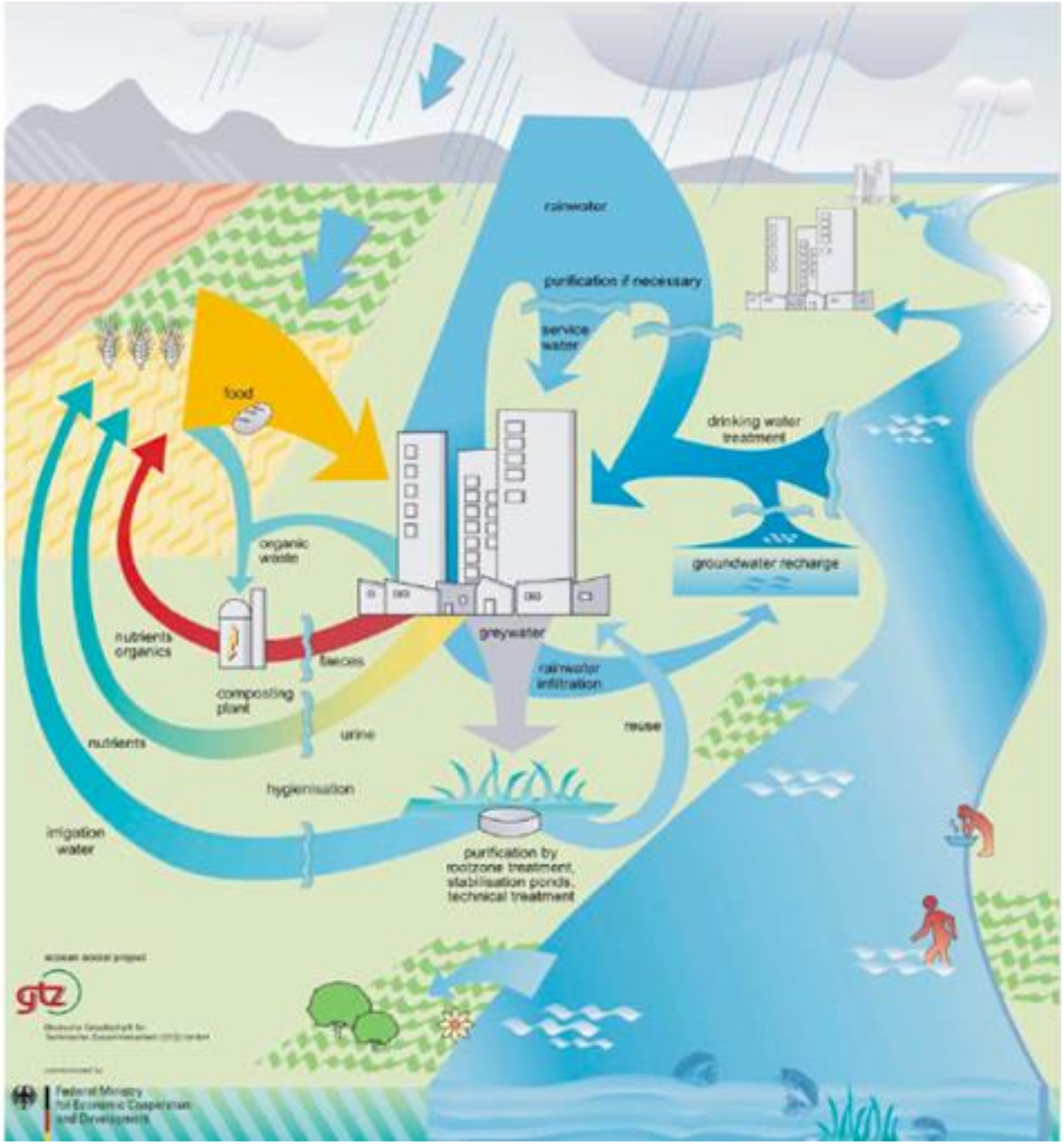
Univ. of Arizona – Water Resources Research Center



Water RAPIDS

Water Research And Planning
Innovations for Dryland Systems


nitrogen
(high energy demand)
potassium
phosphorus
(limited fossil resources)
fertilizer factory
agriculture
food
rainwater
drinking water treatment
drinking water
falling groundwater level
wastewater
partial utilisation of sewage sludge and nutrients
sewage sludge
sewage treatment plant
(only 5-10% of total wastewater worldwide)
landfill
incineration
partially treated wastewater
pollution with pharmaceuticals, hormones, organics, bacteria, nutrients
gtz
Federal Ministry for Economic Cooperation and Development


rainwater
purification if necessary
service water
food
drinking water treatment
groundwater recharge
organic waste
nutrients organics
faeces
composting plant
greywater
rainwater infiltration
urine
nutrients
reuse
hygienisation
irrigation water
purification by rootzone treatment, stabilisation ponds, technical treatment
gtz
Federal Ministry for Economic Cooperation and Development

(Werner, 2006)

“wastewater”

- **Greywater** - the relatively clean wastewater from baths, sinks, washing machines, and other kitchen appliances.

- **Wastewater** - Spent or used water with dissolved or suspended solids, discharged from homes, commercial establishments, farms, and industries.

- **Reclaimed water** – or recycled water, is defined as “municipal wastewater that has been treated to meet specific water quality criteria with the intent of being used for a range of purposes”.

Some of the (biological & chemical) factors in wastewater that could degrade a receiving waterbody?

- Physical materials
  - sediment, organic matter, food scraps
- Chemicals
  - (dissolved) and (solid)-bound phases
  - pH, metals, nutrients (N and P)
- Pathogens
  - bacteria = not all are pathogenic
  - viruses
  - protozoa
    - Giardia, *Naegleria fowleri,* cryptosporidium
  - helminths

<u>EPA 2° *Effluent Standards*</u>

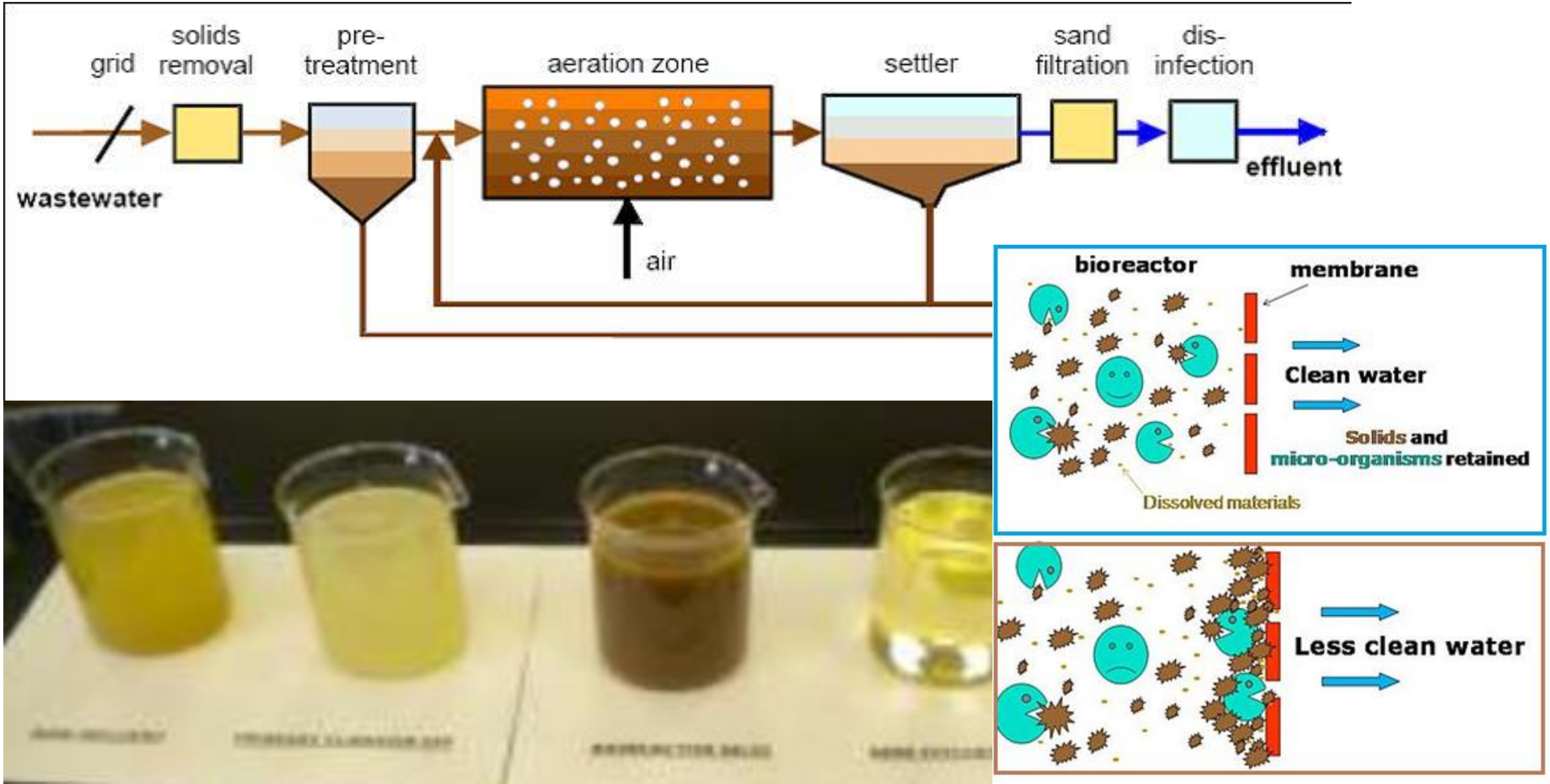
< 200 **FC** / 100 mL

6 < **pH** < 9

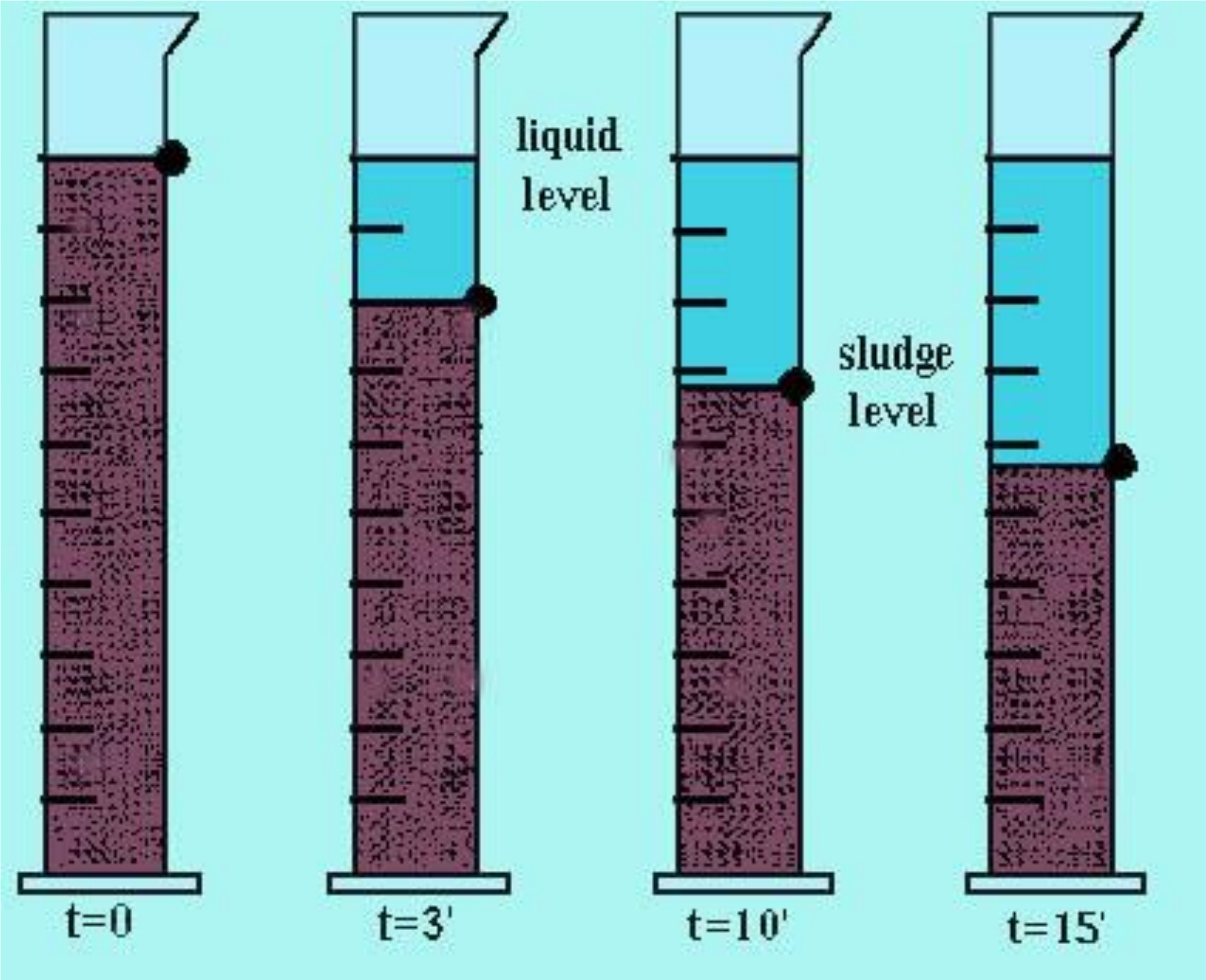
BOD_5 < 20 mg/L

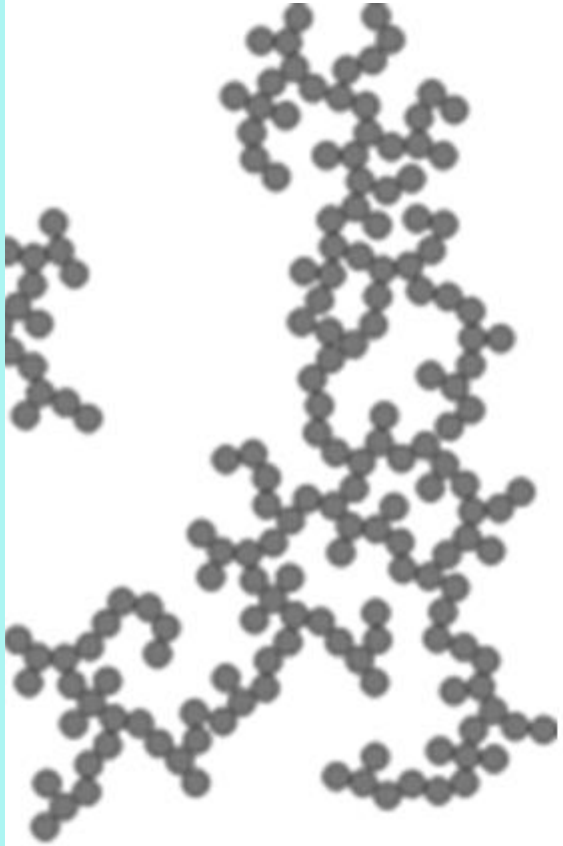
TSS < 20 mg/L

Common Wastewater Treatment Process



Primary (Physical) Treatment:
Coagulation and Precipitation of Denser Material

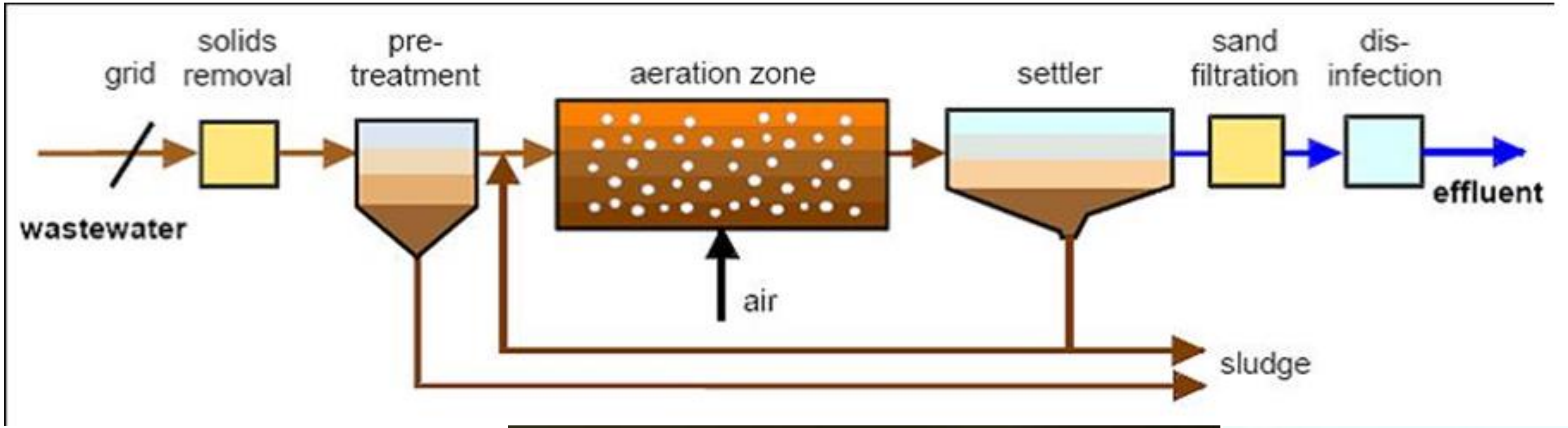




Secondary (Biological) Treatment: Activated Sludge Process

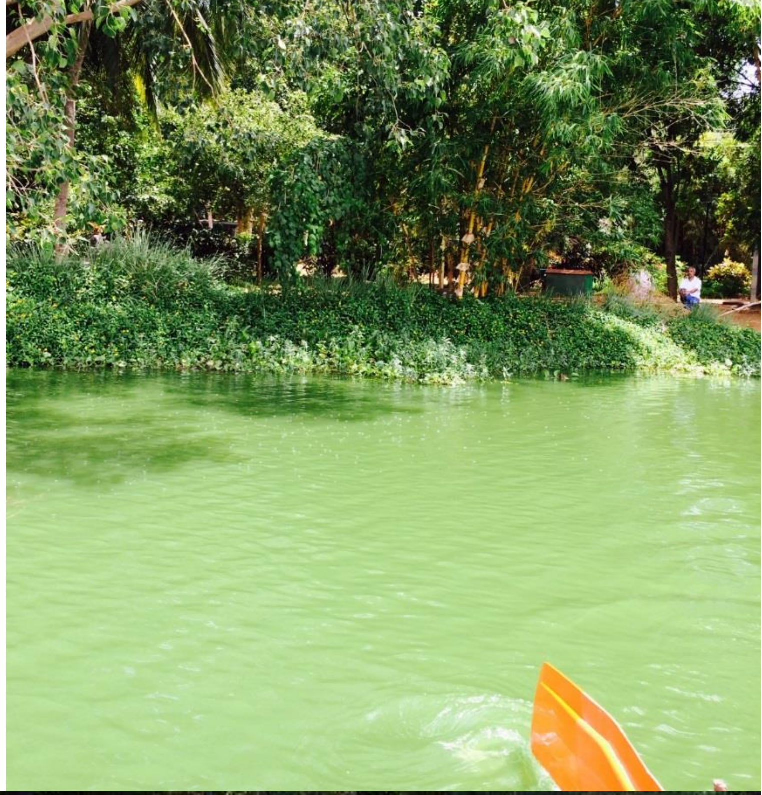
- The liquid portion of the settled sewage then flows to an aerobic biological treatment stage for several hours where it comes into contact with micro-organisms which remove and oxidize most of the remaining organic pollutants

Settling of aeration zone microbes



Tertiary (Advanced) Treatment

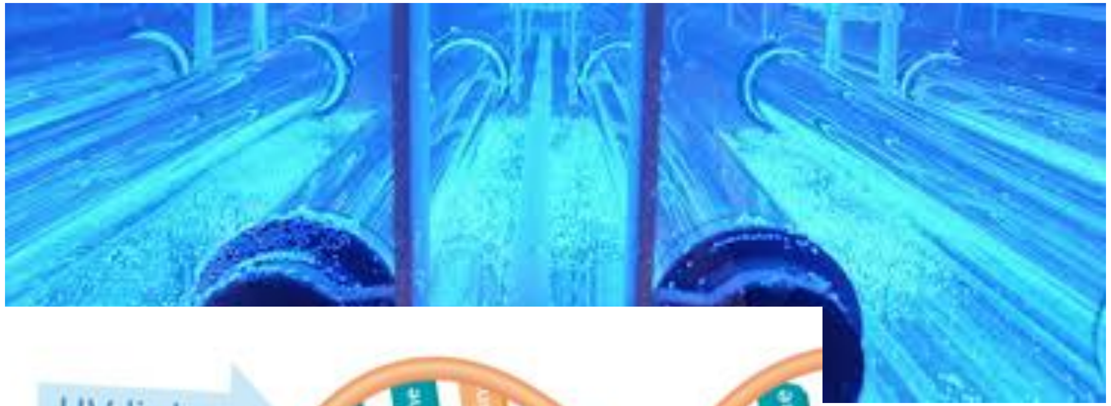
- Not required by law for most facilities, except when the receiving water body is in need of pollutant reduction
  - Nitrogen removal
    - Convert the dissolved nitrogen to a gas
      (NH_4 => NO_3 => N_2)
  - Phosphorus reduction
    - Biological or chemical removal
  - Additional contaminant reduction
    - Pharmaceuticals, endocrine disruptors, nanoparticles…



Disinfection

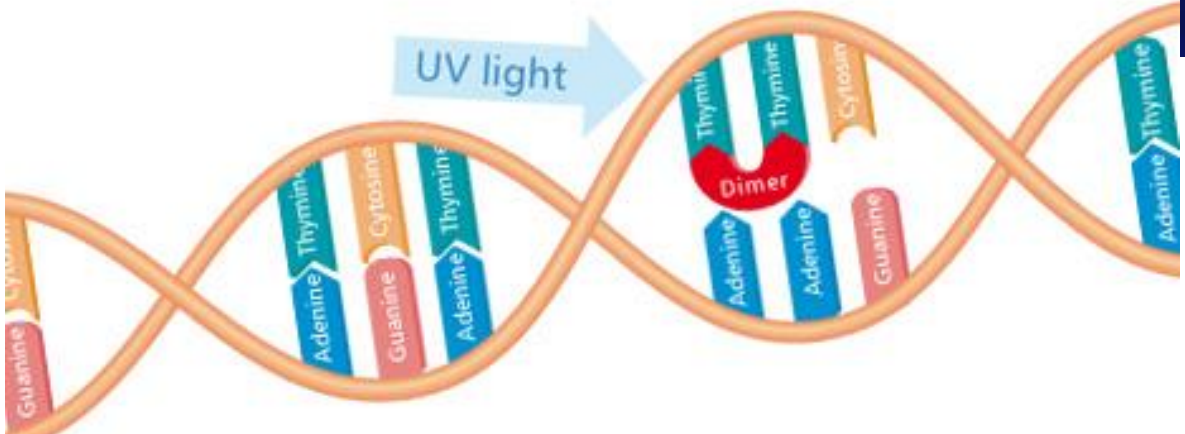
To meet the EPA standard for domestic water discharges:

- in FL < 200 fecal coliforms (FC) per 100 mL of water
- in AZ < 23 FC (max) per 100 mL for reuse purposes

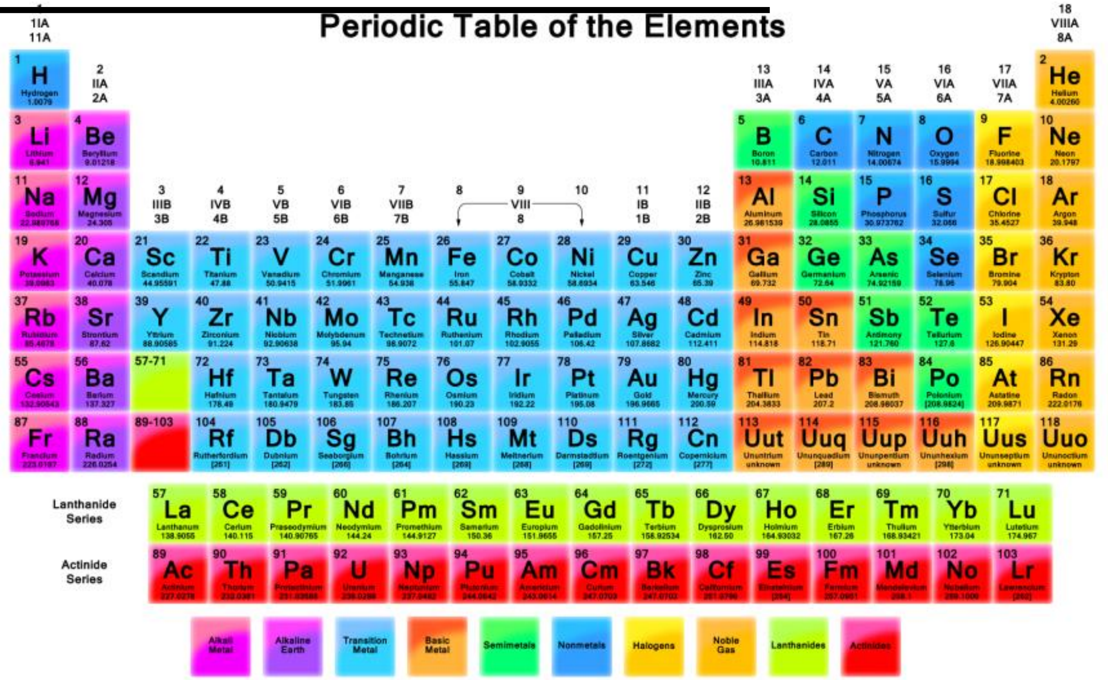


99.99% reduction of pathogens can be achieved with:

- Chlorine/chloramine
- Ozone (O_3), Peroxides (H_2O_2)
- Ultraviolet (UV) radiation



Additional compounds in treated wastewaters

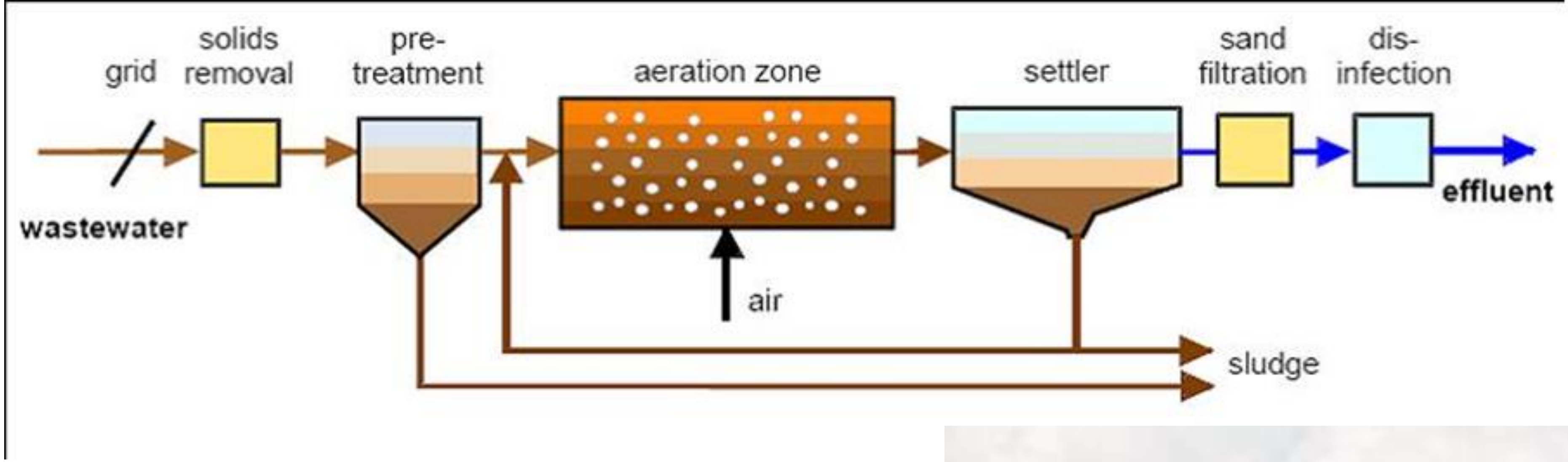


- **Disinfection By-Products (DBPs)**
  - Tri-halo-methanes (THMs)
  - Halo-acetic acids (HAAs)
  - Nitrosamines

- **Contaminants of emerging concern**
  - Endocrine disrupting compounds (EDCs)
  - Nanoparticles
  - Pharmaceuticals and personal care products
    - Some contaminants can negatively impact aquatic organisms at:

    < 1 ng/L = 1 part per trillion = 1×10^{-9} g/L

Dealing with the Sludge turned "Biosolids"



These "digestion" systems are *anaerobic*.

What potentially *beneficial gas is produced*?

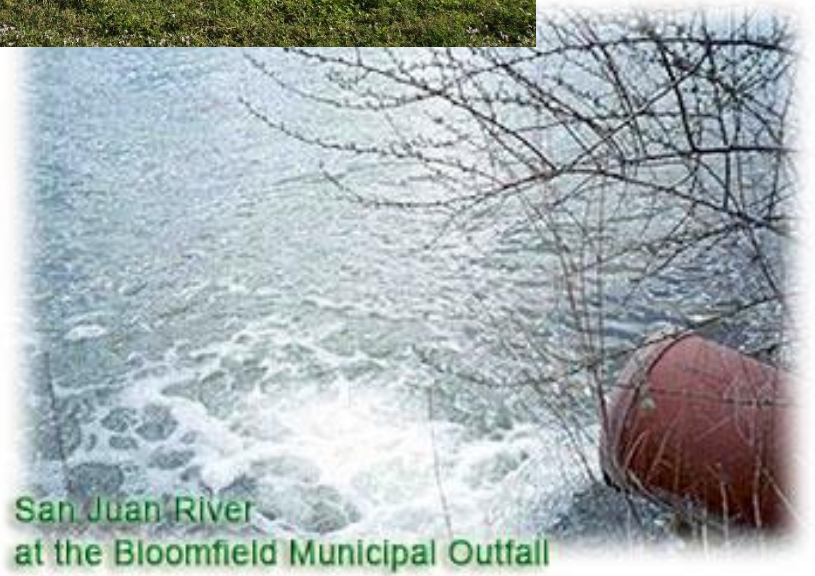
Methane produced by digestion is fed to a generator, **producing electricity.**

The **sludge** can be dried and **processed into fertilizer pellets.**

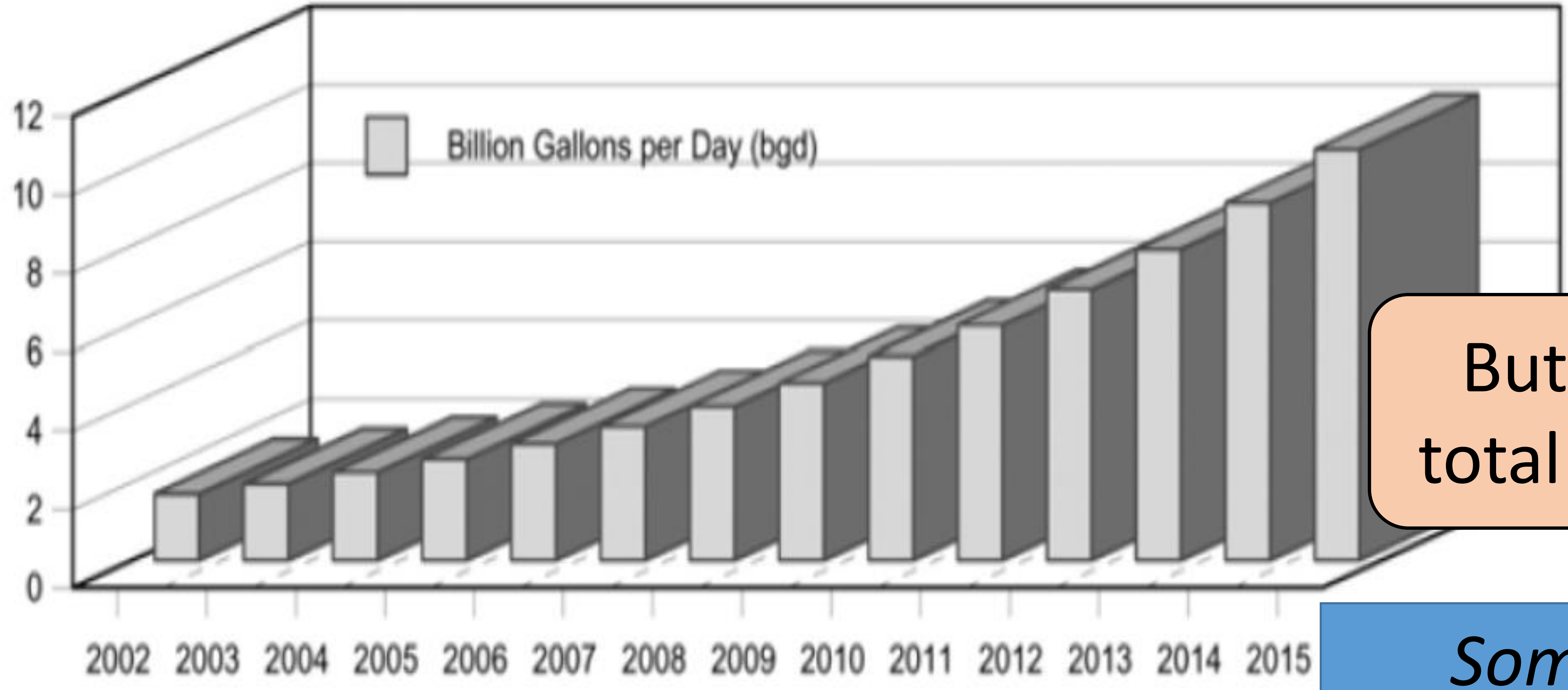
Effluent Disposal/Usage Methods

Surface water discharge

i. Land application
ii. Ground water recharge
iii. Wetland augmentation
iv. Industrial
v. other uses?
vi. Potable reuse



Reuse rates are increasing in the United States



Projected water reuse. Estimated growth of water reuse in the US, 2

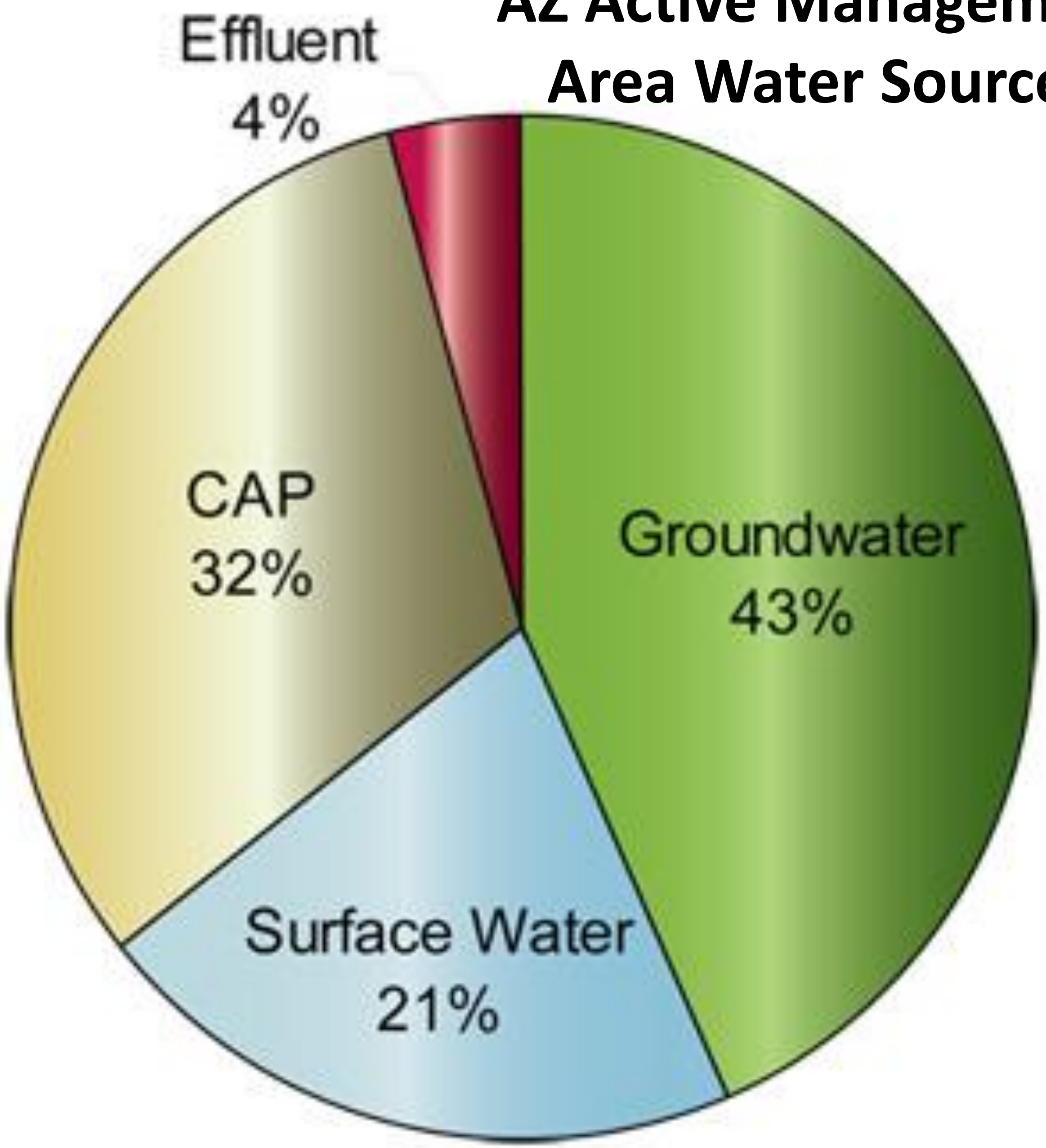
But < 10% of total WW flows

Some cities & countries around the world reusing > 90%

Reuse Flow Per Capita for the Nine States that Reported Having Reuse in 2006

State	Population (2006 est)	Reported Reuse1 in Millions of Gallons per Day
Florida	18,019,093	663.0
California	36,121,296	580.02
Virginia	7,628,347	11.2
Texas	23,367,534	31.4
Arizona	6,178,251	8.2
Colorado	4,751,474	5.2
Nevada	2,484,196	2.6
Idaho	1,461,183	0.7
Washington[3]	6,360,529	0

AZ Active Management Area Water Sources



	California
	— % —
Agriculture	48
Landscape irrigation	20
Groundwater recharge	15
Industry	5
Environment & other	12

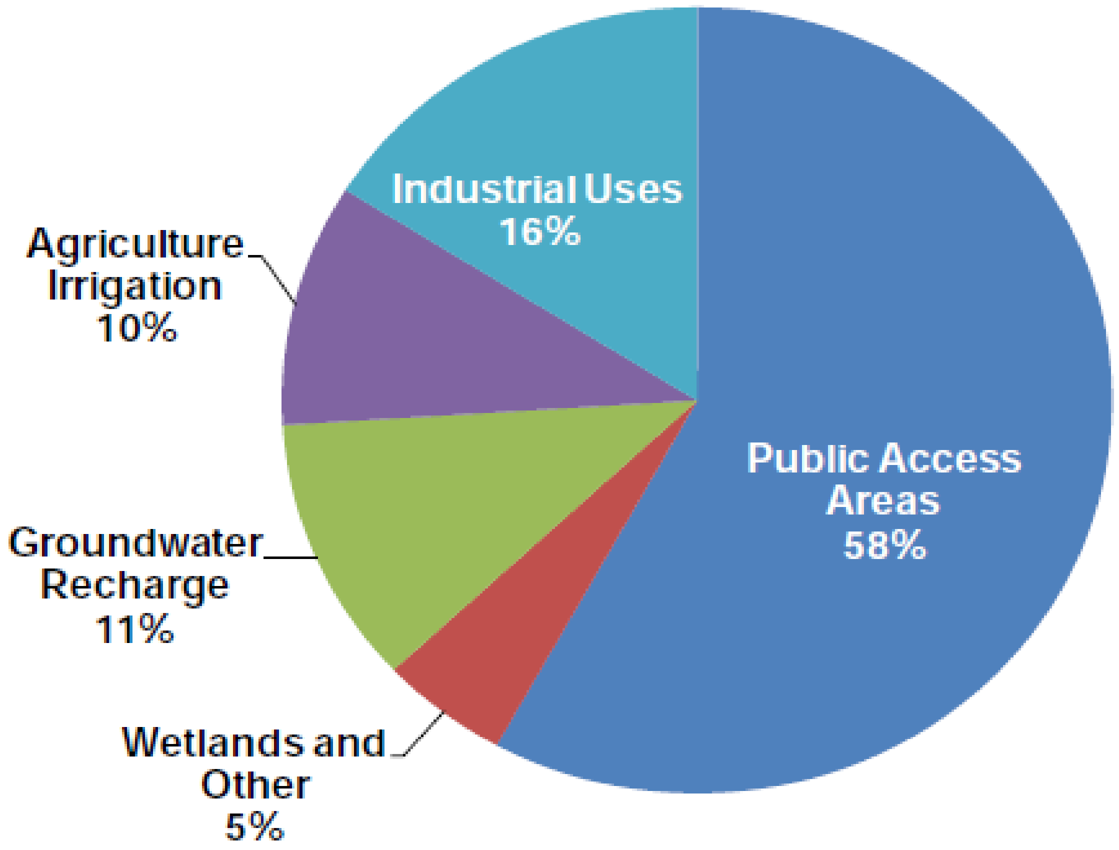


Figure 5-12
Water reuse in Florida by type (FDEP, 2012)

i. Land Application

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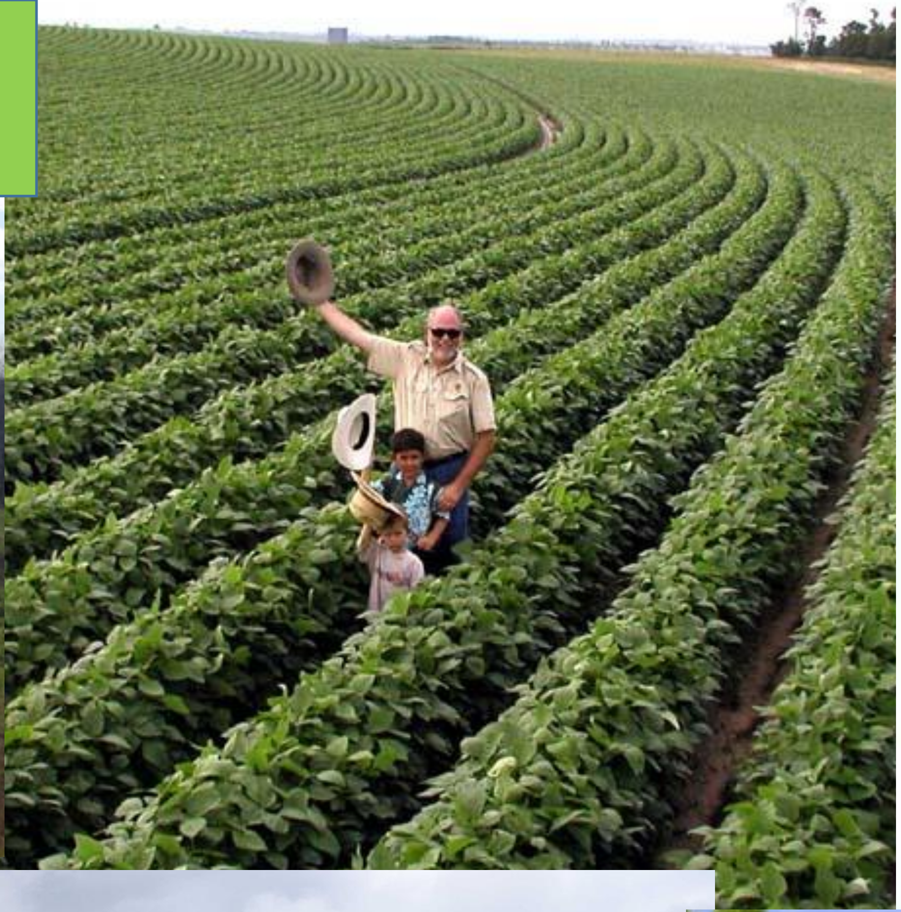
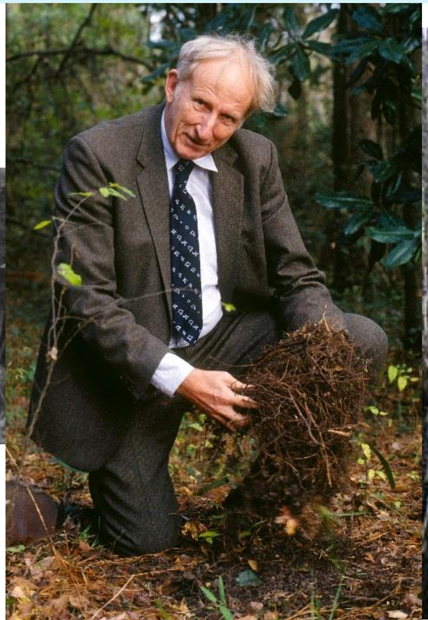




ii. Ground water recharge

- Aquifer storage and recovery (ASR)
- Maintaining ‘Minimum Flows and Levels’ of surface waters
- Salt water intrusion barriers

iii. Wetland / Riparian Zone Augmentation



iii. Wetland / Riparian Zone Augmentation

- Ecological engineering alternative to typical tertiary treatment methods

- Benefit to natural and economic systems

iii. Wetland / Riparian Zone Augmentation

Functional and Educational Wetland Systems

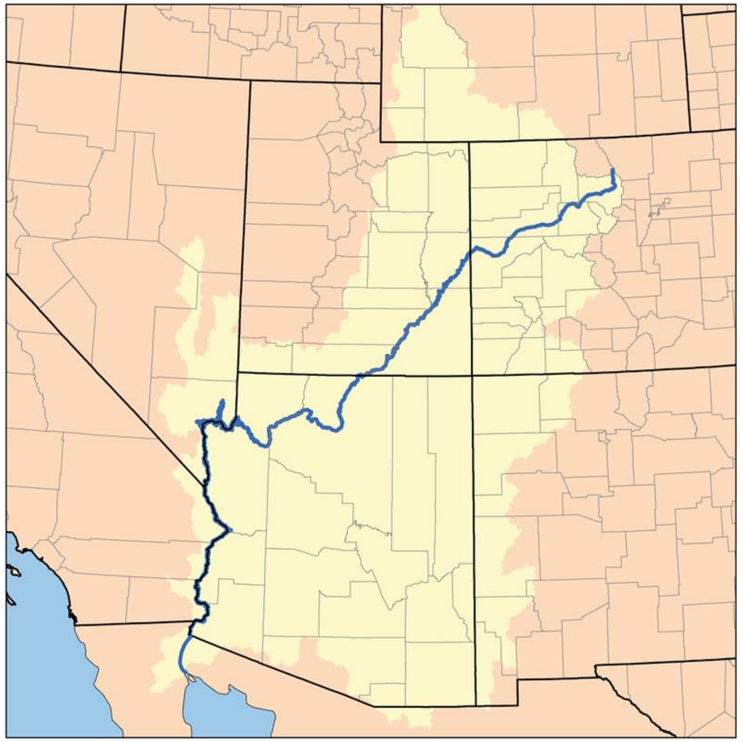
iv. Industrial Uses

v. Other uses??

vi. Potable Reuse – (Indirect and Direct)

Indirect Potable Reuse (IPR) of WW

Has always been occurring… since downstream of every WW effluent outfall is (nearly) always a drinking water intake



"Direct" Potable Reuse (DPR) of WW

Country	City	Project Capacity (mgd)	Description of Advanced System for Potable Reuse	Case Study
Belgium	Wulpen	1.9	Reclaimed water is returned to the aquifer before being reused as a potable water source	[Belgium-Recharge]
India	Bangalore (planned)	36	Reclaimed water will be blended in the reservoir, which is a major drinking water source	[India-Bangalore]
Namibia	Windhoek	5.5	Reclaimed water is blended with conventionally-treated surface water for potable reuse	(NAS, 2012)
United States	Big Spring, Texas	3	Reclaimed water is blended with raw surface water for potable reuse	[US-TX-Big Spring]
United States	Upper Occoquan, Virginia	54	Reclaimed water is blended in the reservoir, which is a major drinking water source	[US-VA-Occoquan]
United States	Orange County, California	40	Reclaimed water is returned to the aquifer before being reused as a potable water source	[US-CA-Orange County]
United Kingdom	Langford	10.5	Reclaimed water is returned upstream to a river, which is the potable water source	[United Kingdom-Langford]
Singapore	Singapore	122	Reclaimed water is blended in the reservoir, which is a major drinking water source	[Singapore-NEWater]
South Africa	Malahleni	4.2	Reclaimed water from a mine is supplied as drinking water to the municipality	[South Africa-eMalahleni Mine]

Source: Adapted from Von Sperling and Chernicharo (2002)

Human pathogens, real issues…

- **Poor water quality and sanitation account for 1.7 million deaths a year, mainly through infections and diarrhea.**
  - **9 out 10 are children**
  - **Virtually all from developing countries**

- **Disease outbreaks attributed to:**
  - **Use of untreated water**
  - **Inadequate or faulty treatment**
  - **Contamination after treatment**

Around the World (2004)

- **Mexico City** – The Atotonilco project will hygienise 60% of wastewater from the metropolitan areas (compared to 8% before)
- **India** – 73% of urban WW untreated
- **China** - 27% of surface waters > 10,000 FC / 100 mL
- **Pakistan** – "much value attributed to the elevated nutrient loads associated with irrigating with wastewater"

$940/ha if access to WW
vs.
$170/ha with only fresh water

…but, 5x greater risk for hookworm infection!

Africa

- Nairobi – 34% of irrigators diverted untreated sewage from trunk sewers directly onto land

- Ghana – 25% no toilet facilities in household
  - 4% use bucket latrines, and dump directly into waterways
  - 10^6 – 10^8 fecal coliforms (FC) / 100 mL

  = 1,000,000 – 100,000,000 FC / 100 mL

- WHO goal < 1000 FC / 100 mL
- USEPA goal < 100 FC / 100 mL

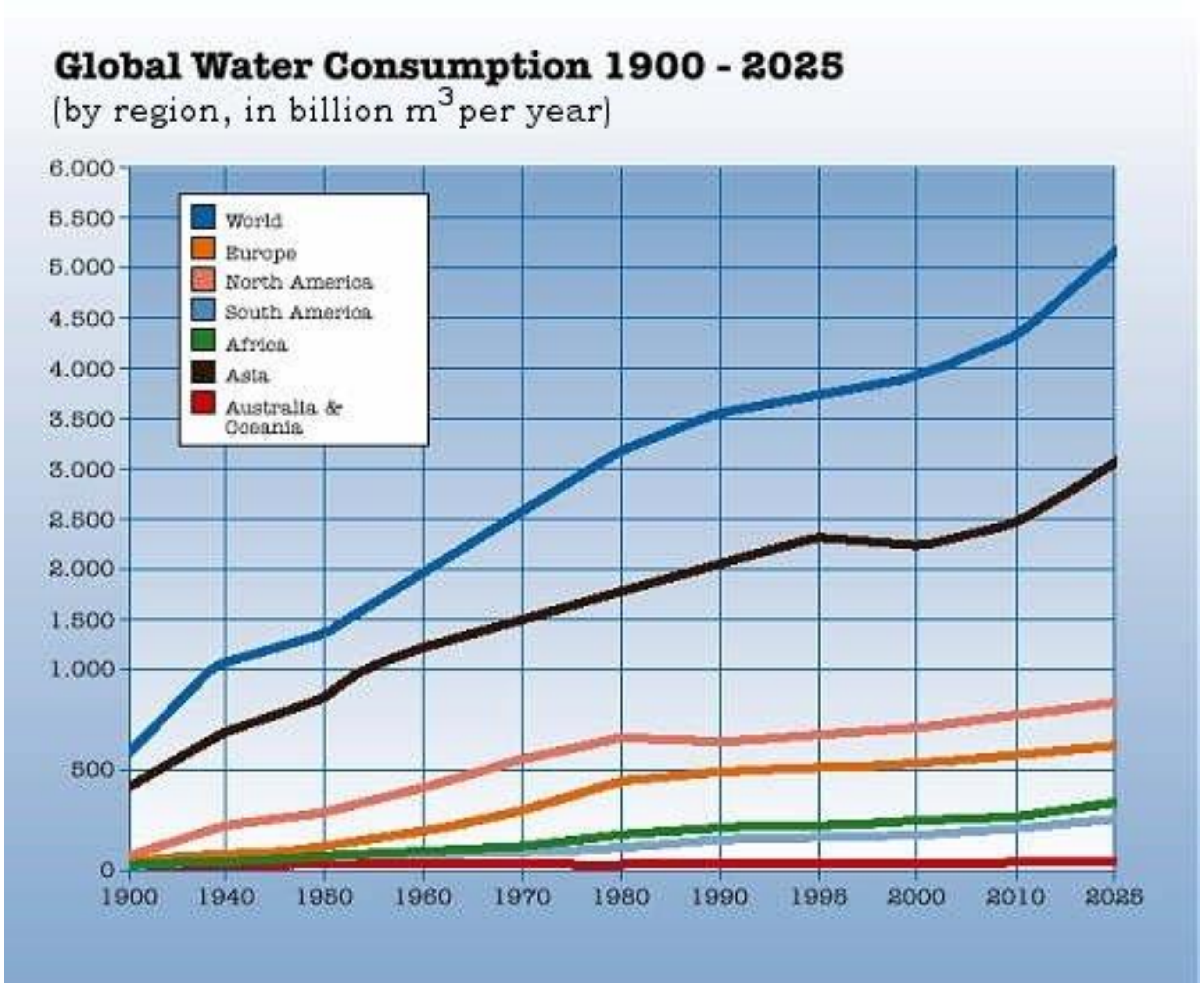
Issues Related to Untreated WW Usage

"If I could have a permanent supply of raw WW for irrigation… without being bothered by the health authorities, I could feed (support) more than 30 people" – farmer in Senegal

Ecological Sanitation

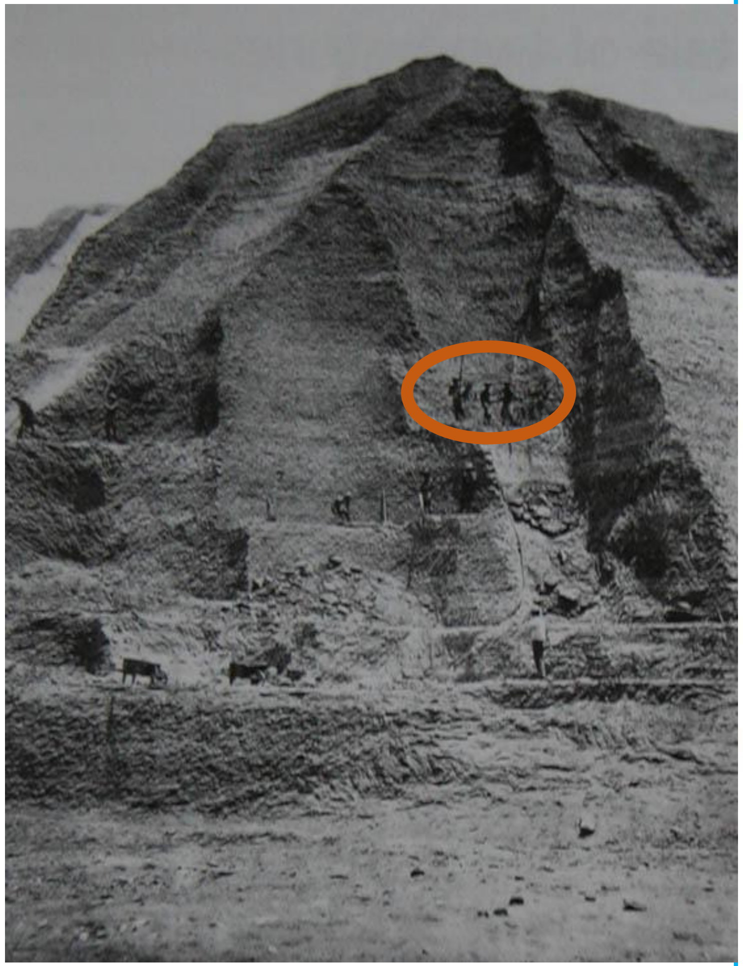
Major Benefits of Reusing Wastewater?

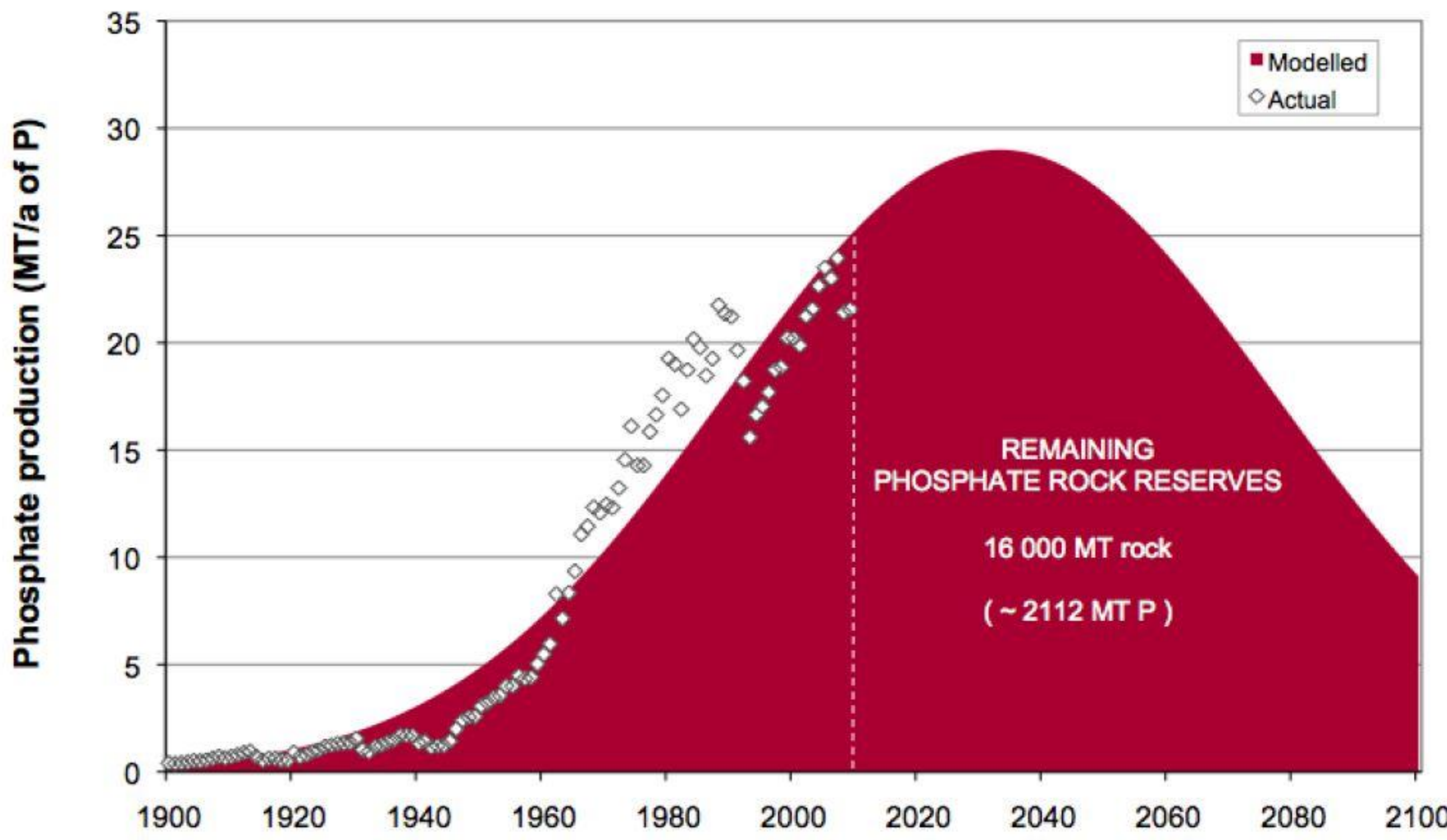
1. Water Conservation



2. Reduced Nutrient Loading to Surface Waters

3. **Phosphorus Conservation**





Reducing soil erosion and <u>recycling phosphorus from</u> farm and <u>human waste could help make food production sustainable</u> and prevent algal blooms.

– Scientific American; Vacarri 2009

Bottoms up!

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