Introduction

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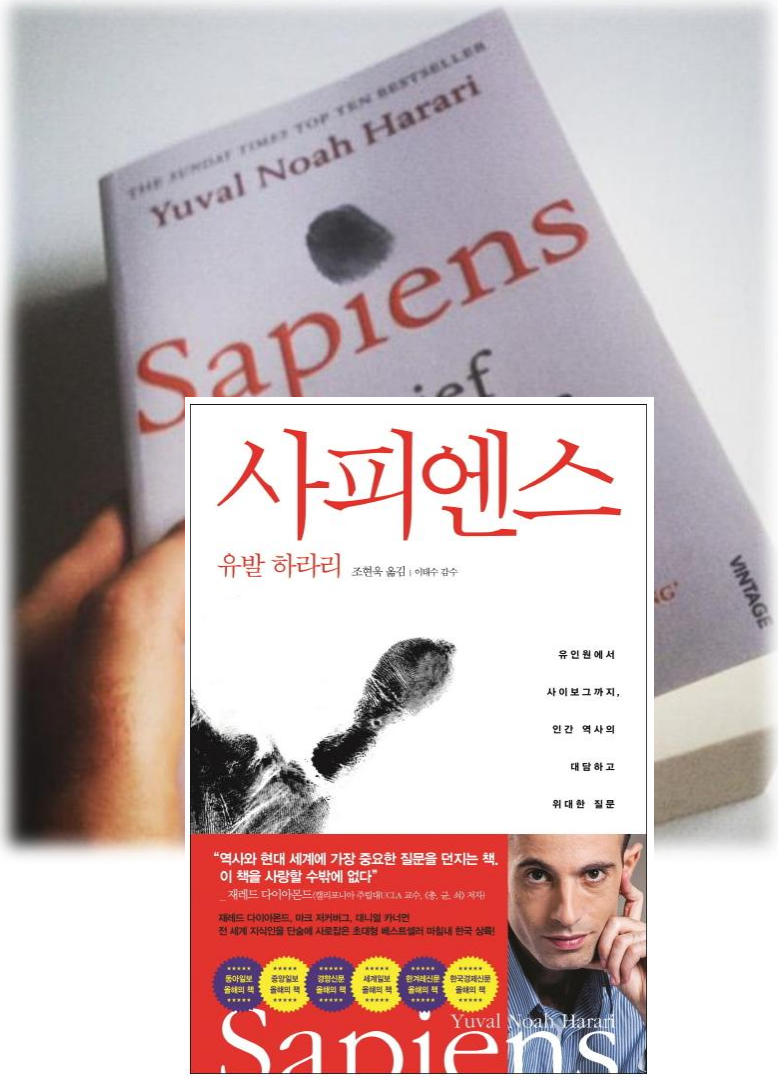
Are We Terrorists?



"HOMO Sapiens transformed itself into the master of the entire planet and the terror of the ecosystem.

…

Unfortunately, the Sapiens regime on earth has so far produced little that we can be proud of."

In "*Sapiens: A Brief History of Humankind*" by Yuval Harari (2011)

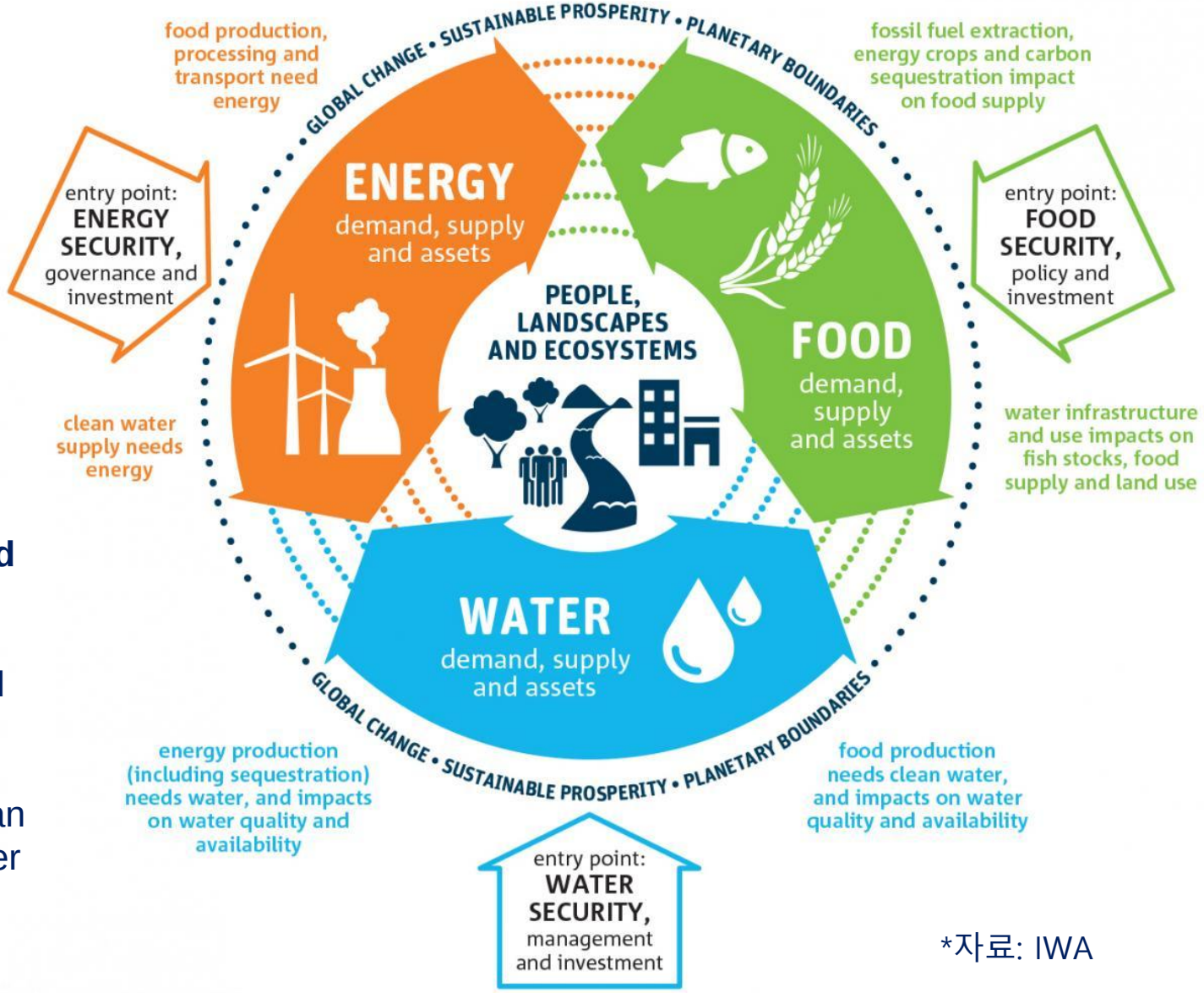
Top 10 Problems for the Next 50 Years

Professor R. E. Smalley,
Energy & Nanotechnology Conference, Rice University, May 3, 2003.

1. Energy
2. Water
3. Food
4. Environment
5. Poverty
6. Terrorism & war
7. Disease
8. Education
9. Democracy
10. Population

Water–Energy–Food Nexus

The water, energy and food nexus:
The securities of these three are closely linked to one another, so that the actions in any one particular area often can have effects in the other areas



*자료: IWA

Environmental Engineering

√ What is Environmental Engineering?

Environmental engineering is the solution of problems of environmental sanitation, notably in the provision of:

- Safe, palatable, and ample public water supplies
- The proper disposal or recycle of wastewater and solid wastes
- The adequate drainage of urban and rural areas for proper sanitation
- Control of water, soil, and atmospheric pollution

Environmental Engineering

√ Mission of Environmental Engineering

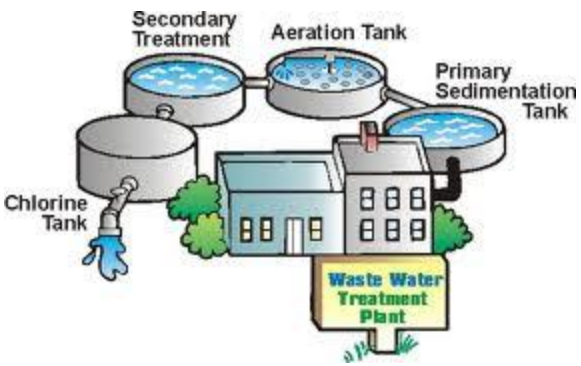
To improve or sustain the quality of life by protecting or restoring environmental quality.

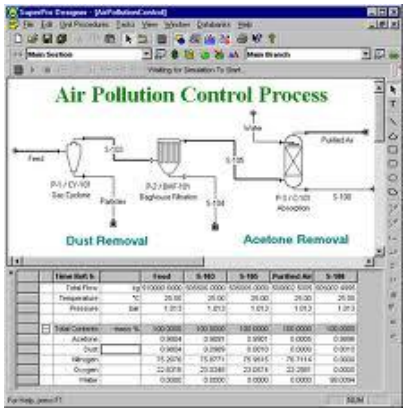
- Driven mainly by public health concerns
- Also by aesthetics and environmental protection.

Environmental Engineering

√ What do Environmental Engineers do?

- Water and wastewater treatment plants/processes
- Air pollution control
- Solid/Hazardous waste management
  - design of treatment and disposal facilities
- Industrial ecology and safety compliance
  - materials and energy flow





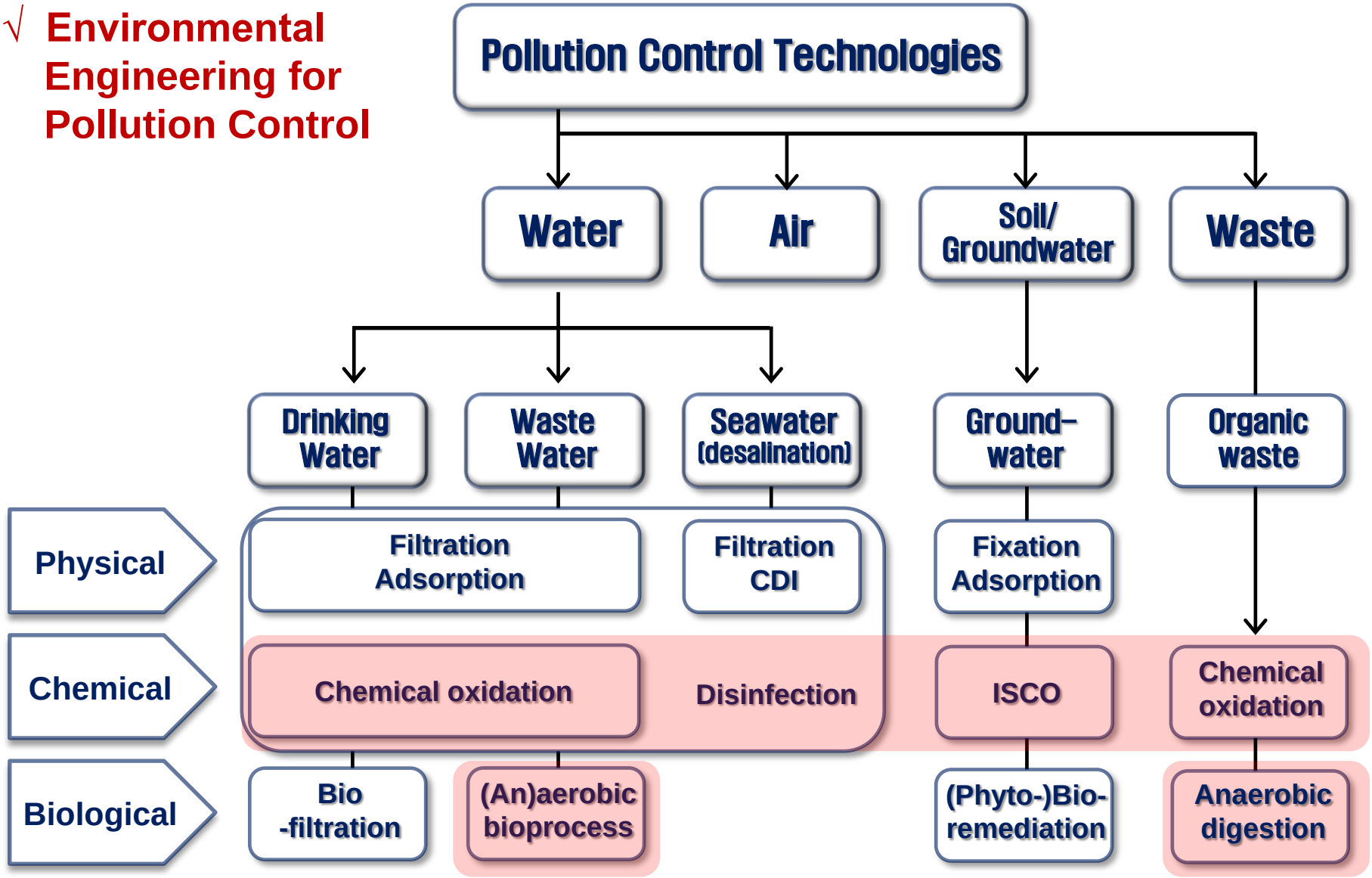
Environmental Engineering

√ What do Environmental Engineers do? (Cont'd)

- Contaminated site assessment and remediation
- Mathematical modeling
  - Risk analysis
  - Fate and transport of priority pollutants
- Environmental law and regulations
- Water resources management
- Research

Environmental Engineering

√ **Environmental Engineering for Pollution Control**



What Environmental Engineering Has Brought Us

√ Environmental Engineering for the extension of human lifespan

- **Medical Milestones**

  From 5-14 January 2007, the British Medical Journal conducted an online poll to decide the most important medical advance since 1840.
  From a list initially suggested by our readers, an expert panel chose the top 15, which formed the basis for the vote.

  Sanitation (clean water and sewage disposal) emerged as the winner.

  1. Sanitation (clean water and sewage disposal)
  2. Antibiotics
  3. Anaesthesia
  4. Vaccines
  5. Discovery of DNA structure

  …

What Environmental Engineering Has Brought Us

√ **We have made considerable progress in the last few decades (Really?)**

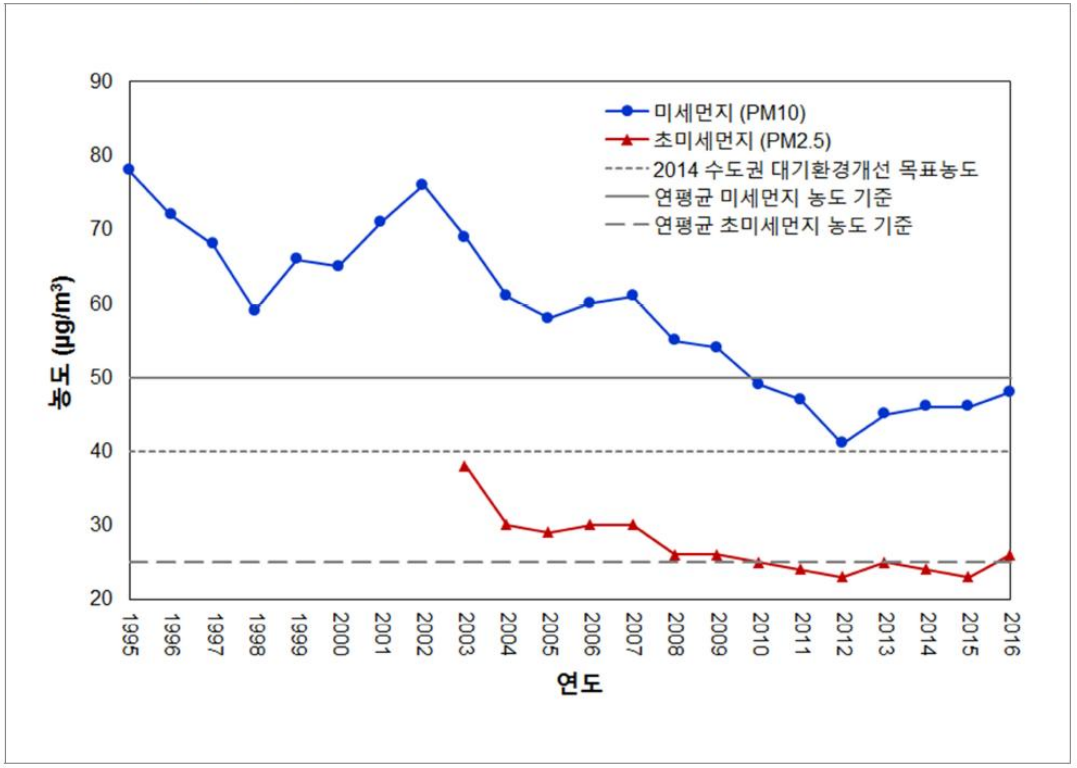
- Less emissions per capita/economic activity
- Most cities have cleaner air
- Most lakes and rivers are more “fishable and swimmable”

What Environmental Engineering Has Brought Us

√ Some problems were solved. Particles?

- The situation of particle pollution is now better than the past?
- The levels of PM10 and PM2.5 in Seoul tend to decrease.

[그림 11] 서울시 연평균 미세먼지와 초미세먼지 농도 변화



* 자료: 서울연구원

What Environmental Engineering Has Brought Us

√ Some problems were solved? Point Source Discharge:

- The development and widespread supply of wastewater treatment facilities have cleaned the point source discharge.

- **Miracle of the Taehwa River**
  "태화강의 기적**"**

*자료: 연합뉴스(태화강 수영대회)

Pollution Sources

- **Point Source**

- **Nonpoint Source**

What Environmental Engineering Has Brought Us

√ Some problems were solved? Lake Erie:

- Lake Erie (one of the five great lakes in North America) was “dead” but we modeled the problem, working with the IJC (International Joint Commission), passed the Clean Water Act, and removed P from detergents.

- Now, POPs, invasive species and climate change hypoxia threaten again.

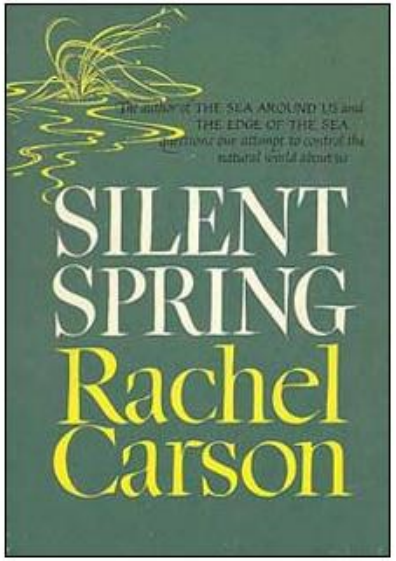
What Environmental Engineering Has Brought Us

√ **Some problems were solved? DDT, PCBs…:**

- DDT provided great benefits for malaria control but it was killing eagles and other birds.

  Silent Spring galvanized people and EPA passed FIFRA & banned many POPs.

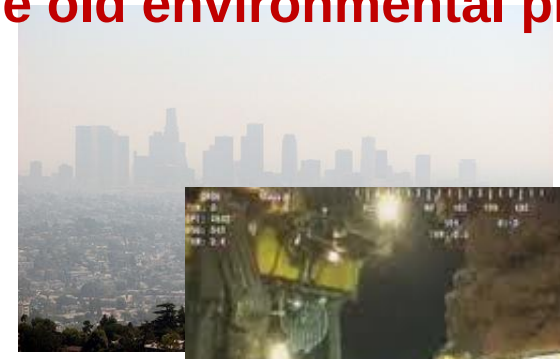
- Now, new chemicals cause other problems (e.g., endocrine disruption).

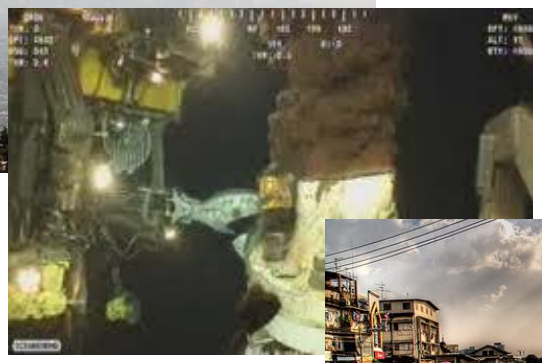


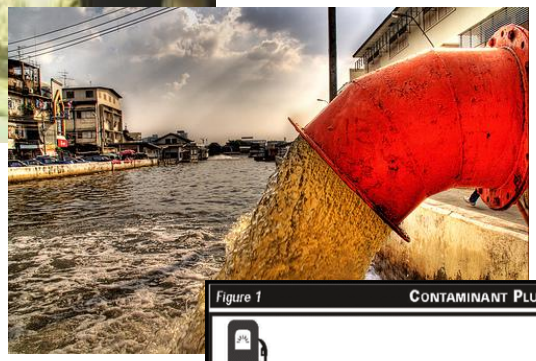
Remaining Problems

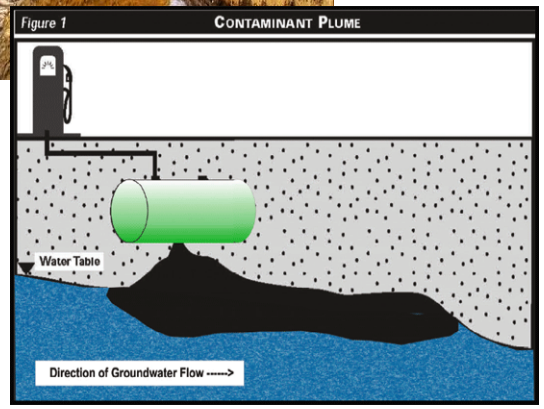
√ **But, we still face some old environmental problems**

- Smog (& particles)
- Oil spills
- Sewage contamination
- Soil & groundwater contamination
- Waste disposal









New Problems

√ **And, we have new problems of a different nature**

- More intractable and less visible pollutants
  - CO_2
  - CFCs
  - Rn
  - Micropollutants

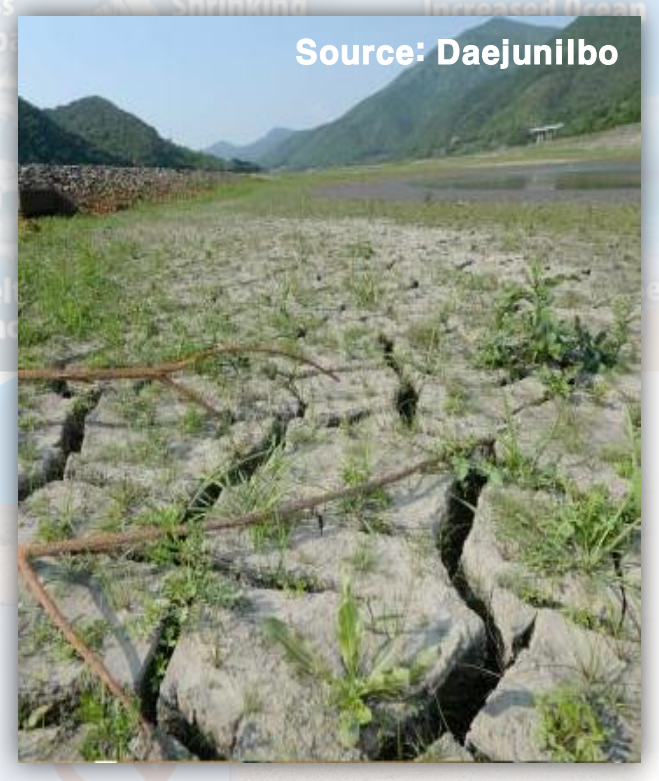
- More global; transcending international boundaries
  - Acid rain
  - Ozone depletion
  - Greenhouse gases
  - Micro- & nano-plastics

- Longer response times
  - Surface water vs. groundwater contamination

Climate Change and Water Problems

- Climate change increases the frequency of extreme weather events.
- Frequent droughts and floods make water quality management difficult and complicated.

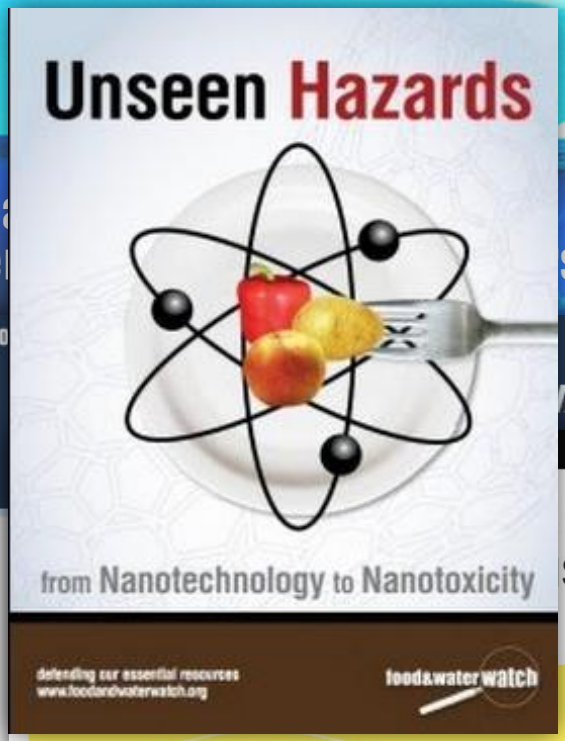
October 15, 2016 (Ulsan)



May 15, 2017 (Boryeong)

Emerging Contaminants

Engineered Nanoparticles



- 60 Items are being regulated in drinking water (Korea).

- The CAS (Chemical Abstracts Service) registered 55 million chemicals.

- More than 100,000 chemicals are mass-produced & commercially used worldwide.

Occurrence and Fate of Water Contaminants

Household

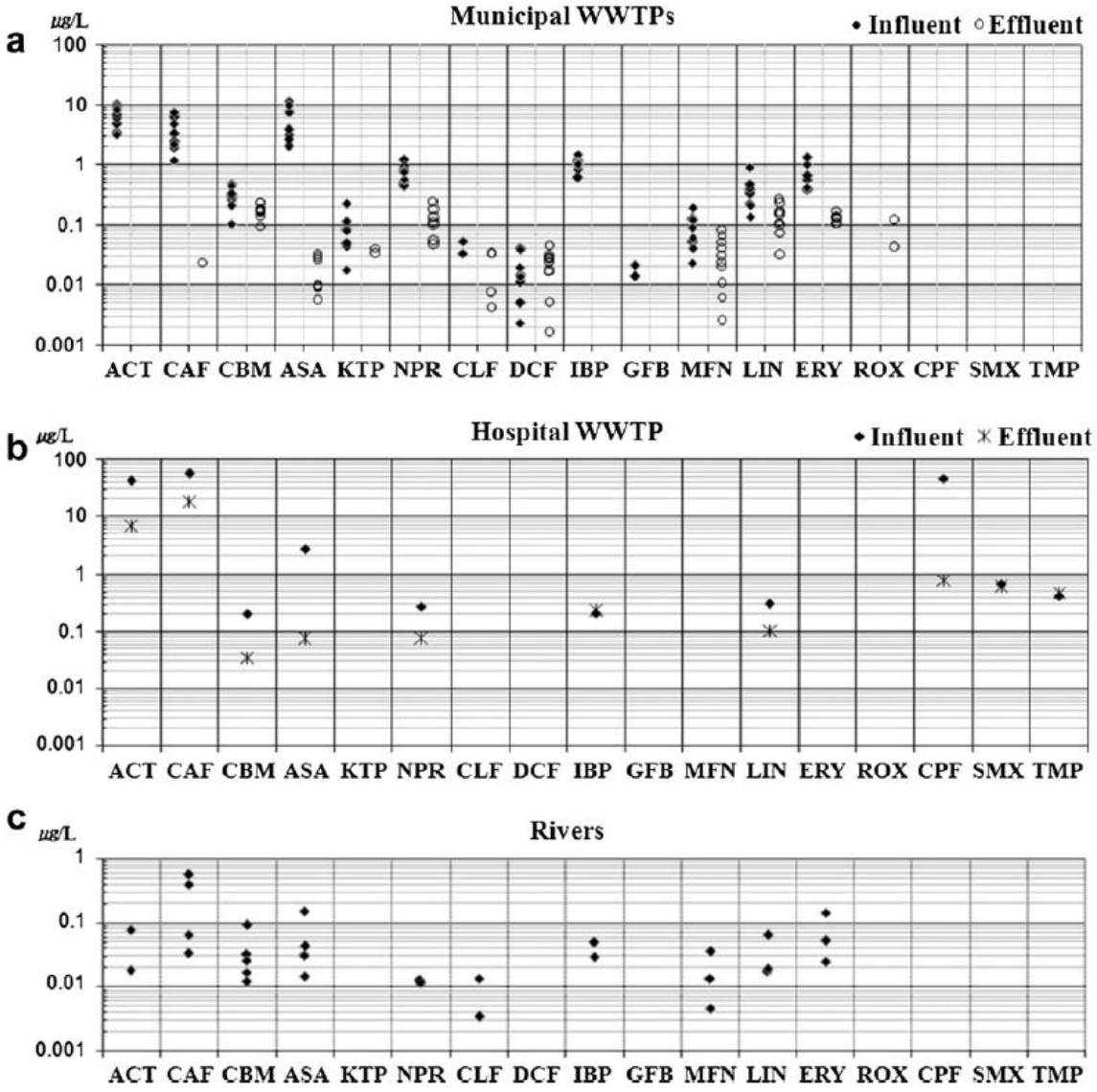
Agriculture

WWTP

DWTP

Industry

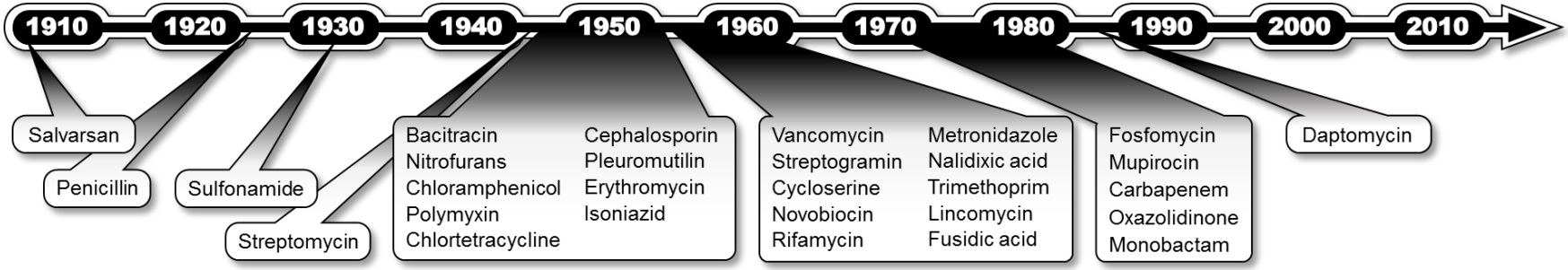
PPCPs in Wastewater Effluent



Sim et al., 2010

Evolution of Microbial Contaminants

- The development of antibiotics caused the occurrence of super-bacteria
- Ironically, wastewater treatment processes have been good incubators of super-bacteria



What about disinfectant-resistant bacteria?

Great Pacific Garbage Patch and Plastic Pollution

Paradigm Shift

√ **The most pressing problems have changed and are more complicated**

- **Problems in the past**

  - Streams were “on fire” due to point source discharges
  - Fish kills, eutrophication
  - Fecal contamination
  - Rampant air pollution (sulfur, particles, smog)
  - Pesticides

- **Problems in the present**

  - Climate change (mitigating and adapting)
  - Biodiversity losses
  - Nonpoint sources; hypoxia
  - Shale gas; energy/water
  - Water reuse; water/energy
  - Micropollutants (EDCs, PPCPs)

Estimation and Magnitudes

- In this class, you will need:
  - Problem solving and estimation skills
  - Common sense for magnitudes.

For example, how much water and wastewater is produced in 1 day in Seoul?

Warm–Up Exercises

1. Exhausting Fossil Fuel Resources

- Based on 1980 oil consumption rate, how long will worldwide reserves last?

2. Sulfur Emissions

- How many tons of sulfur were liberated to the atmosphere in the coal burned worldwide in 1980?

3. Food Consumption

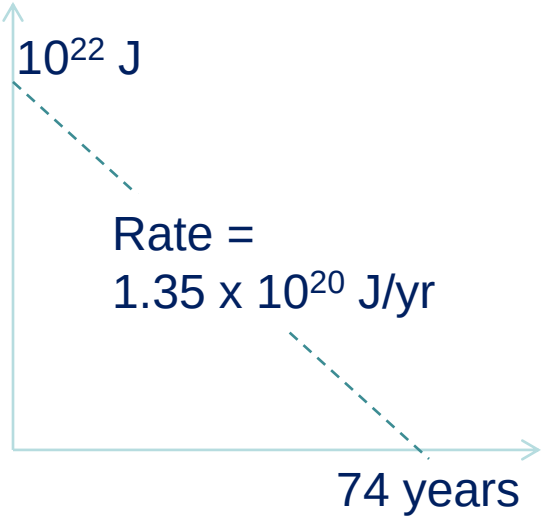
- What fraction of the annual plant growth on earth (primary productivity) is eaten by humans?

Warm–Up Exercises

1. Exhausting Fossil Fuel Resources

- From data found in literature:
- $$\text{Lifetime} = \frac{\text{quantity of resource}}{\text{rate of consumption}}$$

$$\text{Lifetime} = \frac{1.0\times10^{22}\ J}{1.35\times10^{20}\ J/yr}$$



- Lifetime = 74 years
- What assumptions do we need to question - about reserves and consumption rate?

Warm-Up Exercises

2. Sulfur Emissions

- How many tons of sulfur were liberated to the atmosphere in the coal burned worldwide in 1980?
  - Worldwide energy consumption from coal: 90×10^{18} J
  - Energy content of coal: 30×10^{9} J/ton
  - Sulfur content of coal: 2.5% by weight

  Try it!

Warm–Up Exercises

3. Food Consumption

What fraction of the annual plant growth on earth is eaten by humans?

- Average person consumes: 2.5 x 10^6 cal/day (9.0 x 10^8 cal/yr)
- Assuming world has 7.0 x 10^9 people
- World consumption is: 6.3 x 10^{18} cal/yr (2.6 x 10^{19} J/year)
- Net primary production = 3.0 x 10^{21} J/year

Humans consume:

$$\frac{2.6\times10^{19}\ J\ /\ year}{3.0\times10^{21}\ J\ /\ year}\times100\% = 0.9\%$$