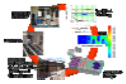
Class Logistics

- Field trip date
- Course notes – recommend printing PDF starting with Flow Control and Measurement

Outline

- Burden of unsafe water
- The Sustainable Development Goals
  - Safe and Improved…
- Intermittent Supplies
- The technology is well developed…
  - Cell phones vs. municipal water technology
- A role for universities



WHO World Health Organization Fact sheet on water (2017): The good news

- "In 2015, 71% of the global population (5.2 billion people) used a safely managed drinking-water service – located on premises, available when needed, and free from contamination."
- But let's bring skepticism to this statement
- This conclusion was made without collecting data on water quality in rural areas

UN Fact sheet on water (2017) The bad news

- 884 million people lack even a basic drinking-water service, including 159 million people who are dependent on surface water
- Globally, at least 2 billion people use a drinking water source contaminated with feces
- Contaminated water can transmit diseases such diarrhea, cholera, dysentery, typhoid, and polio
- Contaminated drinking water is estimated to cause 502 000 diarrheal deaths each year

UN Fact sheet on water (2015)

- By 2025, half of the world's population will be living in water-stressed areas.
- In low- and middle-income countries, 38% of health care facilities lack any water source, 19% do not have improved sanitation and 35% lack water and soap for handwashing.

Safe Tap Water According to the CDC

A Traveler's Guide to Tap Water
September 10, 2014 by Danny Ashton

Honduras Stats as of 2015 (from WHO)

- Population with sustainable access to an improved water source
  - Urban – 97.4%
  - Rural – 83.8%

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More Honduras Stats

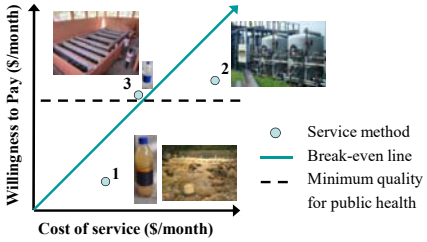
- In 2006, only 75% of the drinking water in urban areas was disinfected[2] and 10% of the wastewater that was collected received treatment.[3]
- In rural areas, it was estimated that only one-third of the systems provided continual service and less than 14% of the systems delivered disinfected water in 2004 .[4]

http://en.wikipedia.org/wiki/Water_supply_and_sanitation_in_Honduras

Value of Service and Willingness to Pay

- Economics background: **cost/quality framework**
  - How do we understand the failure of some systems?
  - Where is the "sweet spot" for sustainability?

1. Untreated river water at the tap
2. Traditional Mechanized plant
3. AguaClara plant



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Reina Amador Diaz: Tamara, Honduras

- "I used to boil the water for hours and it would still be dirty." As a cook, Dona Reina saves times by receiving clean water directly into her home. She used to worry about spreading illnesses when she cooked. "Now the water is pure; I know I am serving people healthy, clean food."
- Dona Reina says that the water treatment plant has attracted new residents. "We have cleaner water than the capital!"

Intermittent Supplies

- It is estimated that over one-third of the urban water supplies in Africa, and in Latin America and the Caribbean, and more than half those in Asia, operate intermittently.
- Why are supplies intermittent? Rolling blackouts
  - Crude form of rationing
  - Lack of meters
  - Leaking system – reduce amount of water lost
  - Some sections of the city might never receive water otherwise
  - Elevation challenges!

You just acquired a hotel in downtown Delhi, India

- Electricity is intermittent, what do you do?
- Water is intermittent, what do you do?
  - How can you get more water?
    -
    -
    -
  - How does each affect your water quality?

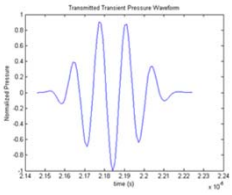
Leaks don't cause contamination unless the flow is INTO the pipe

- Necessary conditions:
  - Saturated contaminated soil
  - Leaky Pipe
  - Pressure outside pipe must exceed pressure inside pipe
- Potential Causes:
  - Negative pressure transients
  - Booster pumps

*Photo credits
Top: http://texas-slab-leak-repair.com/water_leak
Bottom: Emily Kumple

Booster pumps that pull water from the distribution system should be banned

Pressure Transients



Boster Pumps

Image credits: http://www.egr.msu.edu/~fultras-web/images/applications/gui/PressureWaveform.png
Emily Kumple

Consequences of Intermittent Supplies

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- Intermittent water supply is a significant constraint on the availability of water for hygiene
  - And personal hygiene is very important!!!
- Encourages the low-income urban population to turn to alternatives such as water vendors
  - That are expensive and from dubious sources
- Point of Use Storage
  - That may create risk of contamination
- Risks of distribution system contamination

Consequences of Intermittent Supplies

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- Contamination may also occur by intrusion of contaminated water into the pipelines through faulty joints, cracks, etc.
- Opportunity for contamination by siphoning
- Loss of chlorine residual in stagnant water
- The pipelines are subject to additional stress caused by transient flows (water hammer), affecting the durability of the system and weakening pipes and joints (more leaks…)
- Water waste increases
- Complaints about metering air (if there are meters)

Point of Use (or distributed) Storage

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- When there is frequent intermittence in the water distribution system, the consumers commonly build or buy domestic storage tanks
- Although these devices help to reduce hourly peaks in demand and mask short-term interruptions for users, they are often neither properly protected nor regularly cleaned and disinfected
- But they might be a very good idea!

Water Storage Tanks

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Eliminating Intermittency

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- Reduce demand – metering
  - Meters are expensive or (cheaper and unreliable)
- Eliminate leaks
- Reducing intermittency is a significant engineering and societal challenge
- We need engineers and social scientists to work together and come up with techniques to improve distribution system performance when the water supply is limited
- Community size may influence the solution

The Point of Use (POU) Treatment Option

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- A Hypothesis – Given that
  - centralized water supply systems always have leaks
  - intermittency is common when water is in short supply
  - contaminated water can flow into the supply pipes when they aren't pressurized
  - Centralized systems often fail to meet standards
- Household level (Point of Use) is the best option for drinking water treatment

Technology isn't the problem

- Former World Health Organization Director-General: Dr Gro Harlem Brundtland speech at Cornell University in 2005
- Loosely paraphrasing…
- We have the technology to solve the world's problems – what is missing is education, institutional capacity, and political will

Policy, Education, Institutions

AND

Technologies

Policy, Education, Institutions **and** Engineering

- You can sometimes compensate for poor engineering by providing more inputs
  - Energy – fossil fuels
  - Education
  - Money
  - Management
  - Labor
- You can sometimes reduce this burden on society by improving the technologies
- These factors are multipliers!!!!

Multipliers

Energy x Education x Money x Governance x Labor x Technology = ?

1x1x1x1x1x0=0

1x1x½x1x1x2=1

Suppose distillation were the only method that environmental engineers had developed to create clean water

- All water in pipes delivered to homes was unsafe
- What would you say is the limiting factor preventing implementation of safe piped water?
  - Weak institutions
  - Corruption
  - Weak Economies
  - Poor education
  - Inadequate technology
- What do you conclude?

Why aren't there better technology choices?

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- We have a solution that works for strong economies (conventional water treatment)
- Individual cities can't afford to hire consulting firms to conduct research to develop better technologies
- Each city chooses conservative existing designs
- The same is true for countries in the Global South (they can't afford the R&D to develop better technologies)

Continual optimization? Cell Phones vs. Water Treatment

- Why are cell phones continually getting cheaper and better?
- Why is conventional water treatment not enjoying a similar optimization?
  - Vendors, Consultants, Municipalities
  - What does each entity strive to obtain?

Cell Phones vs. Municipal Water Treatment

Global!	Cell phones	Municipal Water
Units per year	850,000,000	$\frac{100,000,000\ people/yr}{50,000\ people/plant} = 2000\ plants/year$
Companies	10?	100s?
Incentive	Improve technology & increase market share	Successful operation at handover of each customized plant

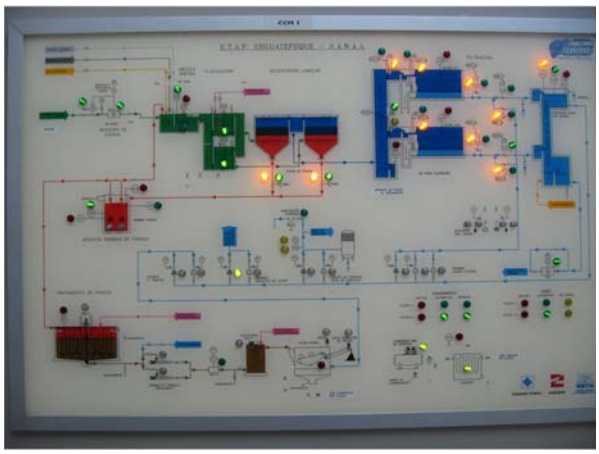
http://www.industry.siemens.com/Water/en/markets/p_02.htm

Why has the Private Sector Failed to Optimize Municipal Water Treatment?

- Research and development is expensive
- Low volume of units and customized designs for each site
- Long life of units
- Vendors want to sell hardware
- Consultants want to minimize liability for design
- Consultants use vendors to create their designs
- Vendor designs are patented to maintain market
- Can't risk failure on a unit – conservative design prevails
- **Ineffective feedback mechanism**

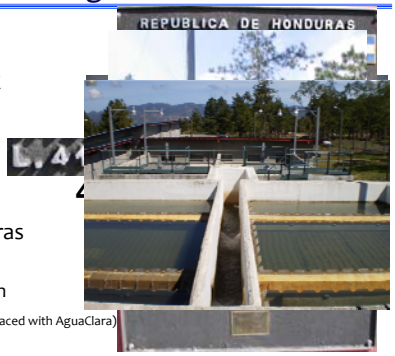

Package Plants


Dominant Design Constraint?



Both "advanced" and "appropriate" technologies can fail

- El Progreso,
  - Modular BEKOX
  - Vulnerable
- Siguatepeque
  - Civil Work
  - Vulnerable
- Marcala, Honduras
  - No chemicals
  - Upflow filtration
  - Abandoned (Replaced with AguaClara)



A Role for Universities

- Develop new knowledge
- Test the designs in full scale field trials
- Make that knowledge available to the global community
- Open source engineering!
- Capacity building: training the trainers
- Bring the power of automation to engineering design (Take Henry Ford's idea out of the realm of widgets and into the realm of knowledge)

Open-Source University-based Research and Development

Low Carbon Footprint Technologies

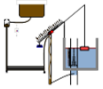
- Previous generations of engineers designed infrastructure that required cheap fossil fuel
- It is long past time for a new paradigm
- The original motivation for developing energy efficient technologies was the Global South, but many of these technologies will be the preferred option for wealthier communities too (Everyone likes cheaper, better, more reliable.)

Hypotheses: The Grand Experiment

- Technology should be designed based on the conditions under which it will operate
- For infrastructure it is more efficient to disseminate knowledge than hardware
- We can achieve higher coverage using a model of technology dissemination in which we share knowledge openly

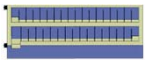
Where are we going?

The Challenge!

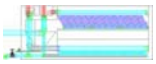


Control and measure flow

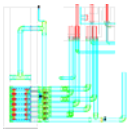
Rapid Mix



Flocculation



Sedimentation



Filtration

Disinfection