Appropriate Technology for Water Treatment in Developed and Developing Countries

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Okun Memorial Symposium
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My preparation

- Review Schulz/Okun book
- Email request to friends and colleagues
- Google keyword search
- UNC photo album
Projected Global Growth Rates Across Water/Wastewater Technology Spectrum

Water Treatment Markets - CAGR 2005-2011

Source: GE Water Presentation, CDM Water Forum, 2007
UN Millennium Development Goal for Water and Sanitation

Goal:
Cut in half by 2015, proportion of people without sustainable access to safe drinking water and basic sanitation

Benefits:
- $1 investment earns economic return of $3-4
- 10% global reduction of diarrheal episodes
- $7.3 billion health-related cost avoidance
- $750 million global value of adult working days due to less illness

USA Millennium Challenge Corporation:
$530 million invested in 7 partner countries thru 2008
Defining Appropriate Technology (AT)

Working Definition

“Design practice, whether it be in a developed or developing country, should strive to optimize the total investment of available capital, material and human resources, recognizing the limited resources of each that may exist.”

Daniel Okun, 1984
Defining Appropriate Technology (AT)

**Economic Considerations**

**Developed Countries:**

“An investment of about $600,000 in capital equipment would be warranted to replace an around-the-clock attendant in USA based upon total cost of $20,000 per year for each of four persons, 15-year life of equipment and 10% interest.”

**Developing Countries:**

“$20,000 might be the maximum investment warranted, based upon a wage of $1,000 per year, 10-year equipment life and 20% interest.”

Daniel Okun, 1984
Common attributes of water treatment technologies in developed countries

- Proprietary equipment, chemicals and support services
- Highly automated and instrumented plant
- High-rate processes
- Multi-stage advanced treatment barriers
- New focus on sustainability (triple bottom line)
Common attributes of sustainable water treatment projects in developing countries

- Labor-intensive solutions
- Reliance on hydraulic solutions
- Locally produced equipment
- Indigenous chemicals
- Low-rate processes
- Basic treatment processes
- Manual operation, monitoring and control
Typical reasons for widespread use of “IT” in developing countries

- Expatriate engineers only familiar with highly mechanized treatment processes used back home
- Utility managers desire “only the best” which erroneously means the latest or most complex technology
- Turnkey contractors typically select capital-intensive designs because of greater profitability
- Professors tend to focus on most advanced technology so students are not exposed to technology appropriate to developing countries

Seeds of Change:
- Engineers Without Borders
- Water For People and Water Corps
- University of Colorado Curriculum on Engineering for Developing Countries

- Professors tend to focus on most advanced technology so students are not exposed to technology appropriate to developing countries
Advanced Water Treatment Processes in Developed Countries

Conventional Treatment

Advanced Ozone/BAC Treatment
Advanced Water Treatment Processes in Developed Countries

- Ozone and Ozone/AOP
- UV Disinfection and UV/AOP
- High-Rate Clarification
- Ion Exchange Processes (MIEX)
- Biological Filtration
- MF/UF Pressure Membranes
- MF/UF Submerged Membranes
- On-Site Chlorine/Hypo Generation

Advanced Membrane/Ozone/BAC Treatment
High-Rate Clarification (Superpulsator, DAF, Actiflo)

- Effective removal of turbidity, color and TOC
- 5 to 20 times smaller footprint than HF sedimentation basins
- Equipment-intensive processes
- Energy-intensive processes
- Retrofit vs. physical expansion tradeoffs
Ozone Disinfection/Oxidation

- Powerful disinfectant (Giardia, Crypto, virus)
- No chlorinated DBPs
- Multiple oxidation benefits (T&O, Fe/Mn, Color, pesticides, PPCPs)
- May require control strategies for removing BDOC and bromate
- New technologies for improved G/L mixing and MTE
**UV Disinfection/AOP**

- Cost-effective *for Giardia/Crypto disinfection (but not virus)*
- BAT for unfiltered supplies
- BAT for nitrosamines removal (NDMA)
- UV/AOP effective for T&O removal but requires:
  - 10-30 times more power
  - Peroxide quenching system

![Graph showing UV Power Requirements and Peroxide Levels](image)
Low-Pressure MF/UF Mer

- Low turbidity (< 0.05 NTU)
- > 4-log *Giardia* and *Cryptosporidium* removal
- Less reliance on pretreatment
- Smaller footprint
- Proprietary process
- Fully automated process
- Requires piloting to determine flux rates and fouling characteristics
- Cost-competitive with conventional treatment
Source Selection and Treatment Requirements in Developing Countries

Basic Water Treatment Processes:

- Pretreatment for Sediment Removal
- Locally Available Chemicals (Alum, Iron Salts, Lime, Hypochlorite)
- Solution-Type Chemical Feeders, Saturators
- Hydraulic Mixing and Flocculation
- Horizontal-Flow Sedimentation
- Rapid Filters with Inter-Filter Backwash
- Slow Sand Filters

1. Groundwater: Pumping & Possibly Chlorination
2. Lakes or Streams: Slow Sand Filtration
3. Rivers: Pretreatment and SSF
4. Turbid Rivers: Conventional Treatment
Hydraulic Mixing and Flocculation

- Mixing achieved by head loss (not horsepower)
- Weirs/flumes can provide near instantaneous mixing
- No imported equipment
- Simplified O&M
- Tapered flocculation without flow short-circuiting
- Mixing energy dependent on plant flow
Slow Sand Filters

- No power or chemicals
- Significant bacteria reduction (3-4 log)
- Built with local labor and materials
- Cleaned by unskilled labor
- Requires large land area (FLR = 0.1 gpm/sft)
- Limited to turbidity < 50 NTU
Kiosk Membrane Treatment System (*SkyJuice Foundation*)

- Treats turbid water sources (500 NTU) without chemicals
- Significant protozoa/bacteria removal (3-4 log)
- Requires only 1 m of head for operation
- Manually backflushed
- Can produce 10,000 liter/day
- $2,000/unit
- AT for entrepreneurial water vendors
Kiosk Membrane Treatment System
(SkyJuice Foundation)
HWTS Ceramic Filter Systems
(Potters for Peace—Ron Rivera)

- Colloidal silver-enhanced ceramic water purifier
- 30 filter factories worldwide
- 300,000 filters serving 1.5 million people
- Profitable microenterprises
- Produces 1–3 liters/hr
- $10–15/unit with plastic receptacle and tap

“There is now conclusive evidence that simple, acceptable, low-cost interventions at the household level are capable of dramatically improving the microbial quality of household water and reducing the attendant risk of diarrheal disease and death.”

Mark Sobsey, UNC
WHO Report, 2002
CDM Engineers Without Borders

- Fall 2007—Launched Partnership Program
- EWB Local Chapter Representatives
  - ~27 chapters to date
  - Acts as liaison to local CDM office, contact point
- Funding set aside for employee grants
  - Up to $2,500 per employee
  - Covers travel/professional costs
  - Not intended for project fundraising
Here’s to the WRE Class of 1982!

SCHULZ/OKUN BOOK DOWNLOADED AT:
https://webfiles.colorado.edu/mgold/www/Surface%20Water%20Treatment%20in%20Developing%20Communities.pdf