Water and Sanitation Studies for the City of Paraty, Brazil

Water Solutions

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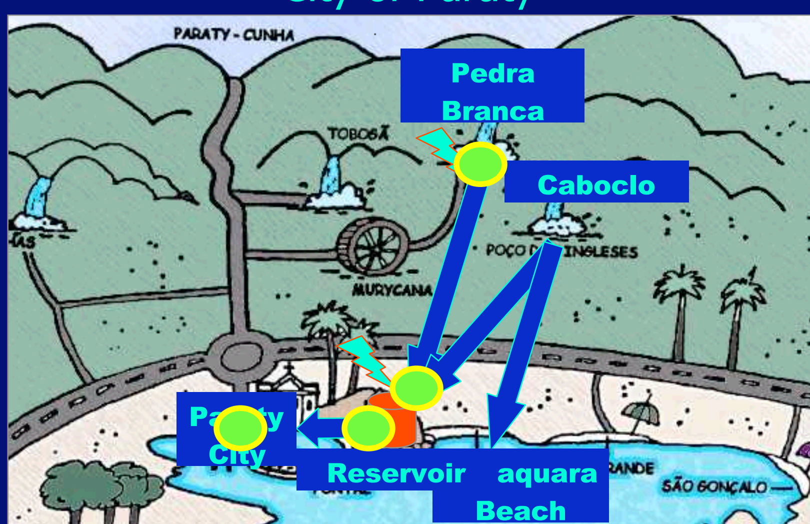
Background on Paraty

- Municipal in the State of Rio de Janeiro
  - Area: 930 km^2
  - Population: 30,000
    - Urban 15,000
- Tourist city: UNESCO World Heritage Site Candidate
- Three main sections:
  - Historical downtown
  - “Upper” part of city
  - “Ilha das Cobras”

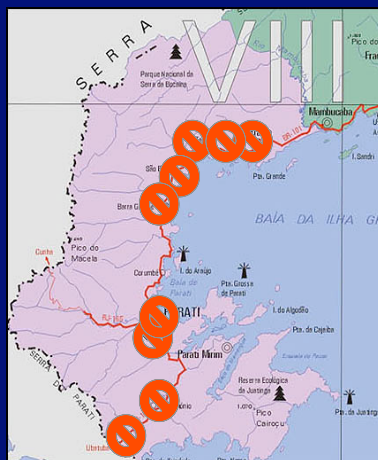
Water and Sanitation Service Coverage and Health Consequences

- Developing countries have prevalent health problems due to lack of water and sanitation.
- Paraty's service coverage:
  - 60% potable water; 12% sewerage connection
- Water and sanitation-related diseases
  - 32% of all hospital admissions in Brazil
  - >100 diarrhea cases/month (443 diarrhea cases from 9/02 to 12/02) in Paraty
  - Include: diarrhea, typhoid, viral hepatitis A, cholera, dysentery, guinea worm disease

Drinking Water Supply System – City of Paraty

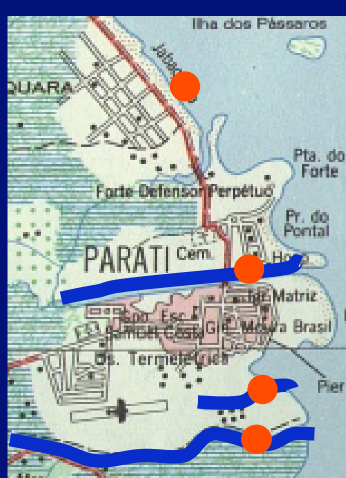


Prob. 1: Drinking Water Quality



- 64% of Municipality's water sources (21% of which were chlorinated) did not comply with drinking water standards.
- 24% of City's chlorinated water did not comply.

Prob. 2: Heavily Contaminated Surface Waters



- Jabaquara Beach:
  - Inadequate for primary contact recreation (e.g. swimming)
- Perequê River and Matheus River
  - Inadequate for secondary contact recreation (e.g. wading, fishing, and hunting)
- Sewage canal, an open channel of surface water that transports wastewater from houses to Paraty Bay, has qualities of raw sewage.

Proposed Policy/City's Needs

- Wastewater collection infrastructure and treatment plant
  - Limit pollution of rivers and beaches
  - Reduce risks to health
  - Improve aesthetics in the city.
- Drinking water treatment plant
  - Removal of particulate matter by filtration
  - Effective disinfection

Cost Estimate for Improvements

- Criteria:
  - Population = 15,000; 3x increase in summer
  - Flow = 3 mgd (assuming 180 L/capita-day)
- Wastewater treatment plant + infrastructure:
  - Total annual cost = Annual O&M + Amortized capital cost (20 years at 6 percent) = R$ 0.5 million
- Drinking water treatment plant:
  - Conventional filtration or Direct filtration
  - Total annual cost = R$ 1 million

Cost vs. Willingness to Pay

- Cost for improvement:
  - R$ 32/household-month (w/o meter)
  - R$ 0.35/m^3 (w/ meter)
- Willingness to pay (WTP):
  - WTP = current payment for existing services + bottled water + (min wage lost from sickness)

    = R$7+ R$36 (assuming 2L/capita-day) + (R$7/capita-day)

    = R$43 ~ R$50/household-month
- Willingness to Pay > Cost for improvement

The Need for Infrastructure Development

Propose a design of a wastewater collection system for the Historical Center of Paraty, Brazil.

Design Considerations

- High water table
- Flat land
- No vehicles
- Roads in poor condition
- No basements
- Underground structures (water distribution system, telephone line, nonfunctional sewer collection system)
- Recent Survey: 415 residential lots, 211 commercial lots, 6 vacant lots, and 66 other lots

Potential Collection Systems

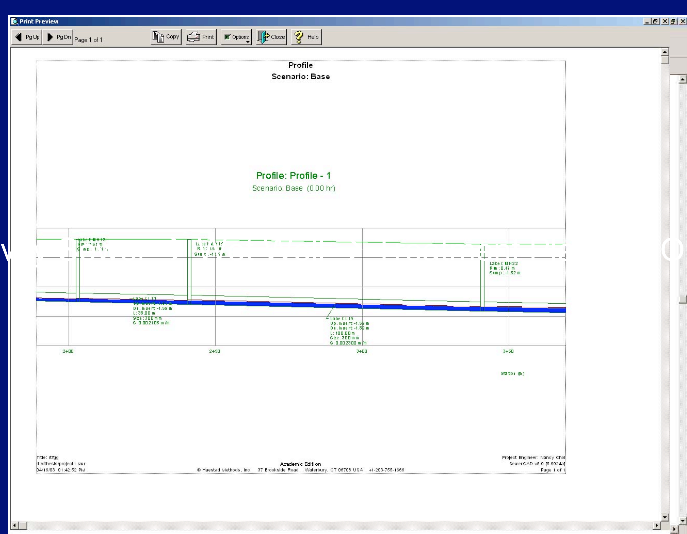
- Conventional Gravity Sewers
- Pressure Sewers
- Vacuum Sewers
- Small-diameter Gravity Sewers

System Criteria

- Expandable: Future collection additions
- Economical: Low cost system
- Adaptable: Flexible to seasonal fluxes
- Simple: Ease of operation and maintenance

Design: Conventional Gravity Collection System

Grav

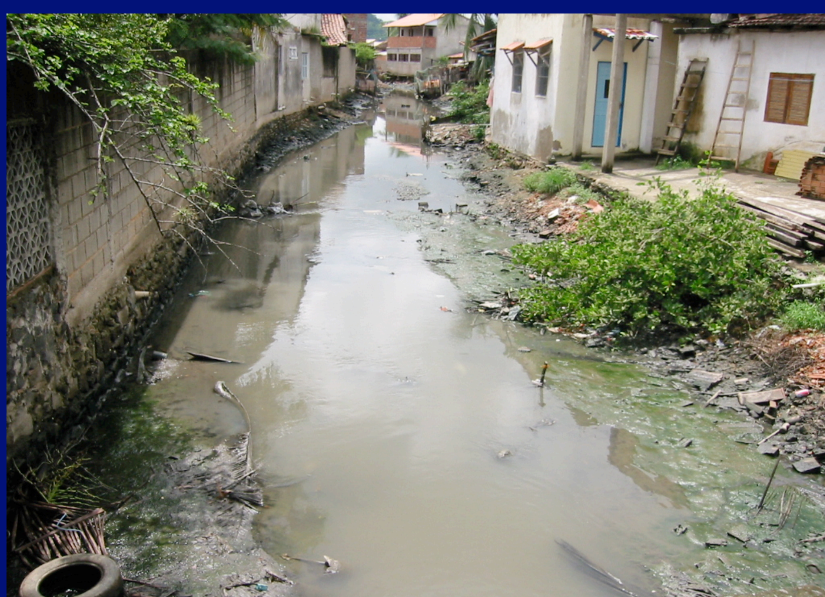


utfall

Results

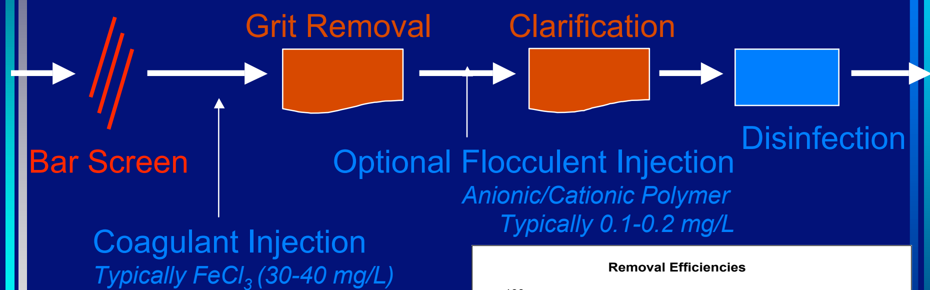
Label	Quantity	Construction Costs ($US)	Non-Construction Costs ($US)	Total Cost ($US)
Outlet	1	1,105	0	1,105
Manhole	22	29,433	0	29,433
Gravity Pipe	22	245,069	0	245,069
Total Cost: Base				275,606

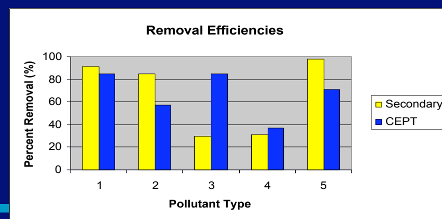
Total Flow = 2 million liters/day = 0.8 cfs



Treatment Process Steps

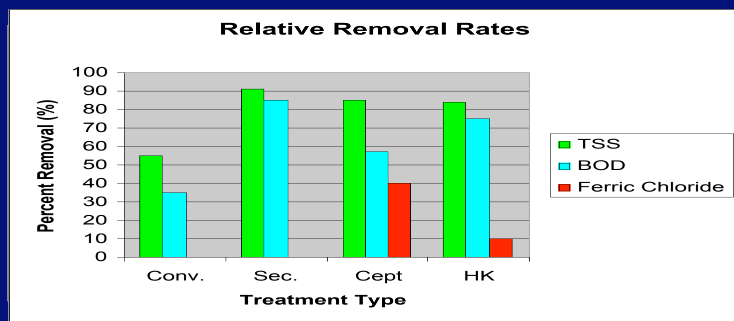
Chemically Enhanced Primary Treatment





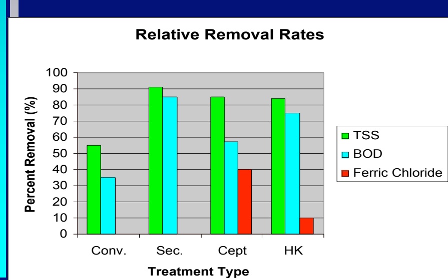
Jar Testing

Seawater: Coagulation Enhancement



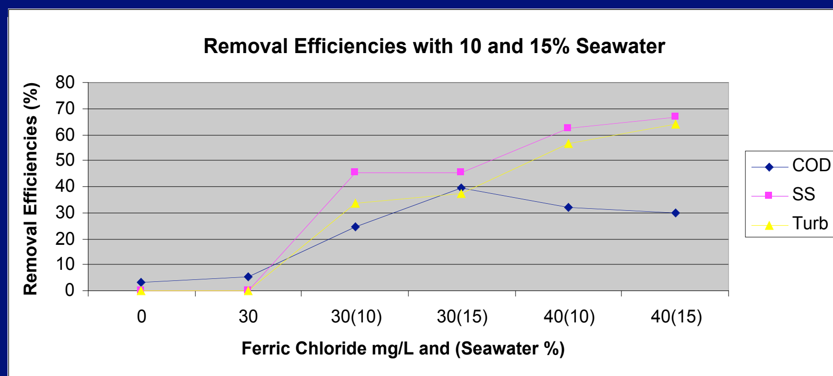
Seawater: Case study and Method

- Inspired by the Hong Kong Stone Cutter's Island Wastewater treatment plant
- Mg^{+2} ions replace Fe^{+3} to interact with negatively charged wastewater particles and form a solid precipitate.
- In Paraty, jar test were conducted to test efficiency of SS, COD, and turbidity removals using seawater.



Flow Rate	3.7 m3/sec	Influent BOD	156 mg/L
SOR	66 m/d	Effluent BOD	39 mg/L
Ferric Chloride	10 mg/L	Influent TSS	200 mg/L
Seawater	20%	Effluent TSS	32 mg/L
Anionic Polymer	0.1 mg/L		

Results



Seawater as an economic coagulant ?

- Seawater is responsible for 20% increases in removal efficiencies of SS, Turbidity and COD at the same $FeCl_3$ concentration
- Significant reductions in required volume of $FeCl_3$
- Ideal for treatment plants with easy access to the ocean
- Easier handling and storage requirements compared to other chemical coagulants
- More research is needed on a pilot test scale but data from this project is positive.
- Hong Kong, Norway, San Diego and Boston examples.

CEPT & Disinfection

- Why does CEPT efficiently and economically produce a disinfected effluent?
  - Quality
    - Lower coliform concentration in the effluent from CEPT settling tank
  - Cost
    - Lower amount of a disinfection agent required

Disinfection - Chlorine

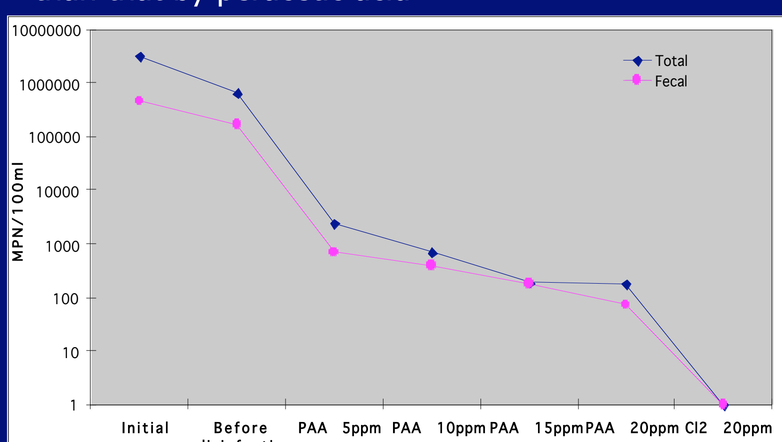
- Disinfection & Effects of Seawater Addition on Chlorination Process
- Chlorine
  - Most commonly used throughout the world
  - Inexpensive equipment and operation
  - Easy to apply and measure
  - DBP : THMs, AHHs

Disinfection - Alternatives

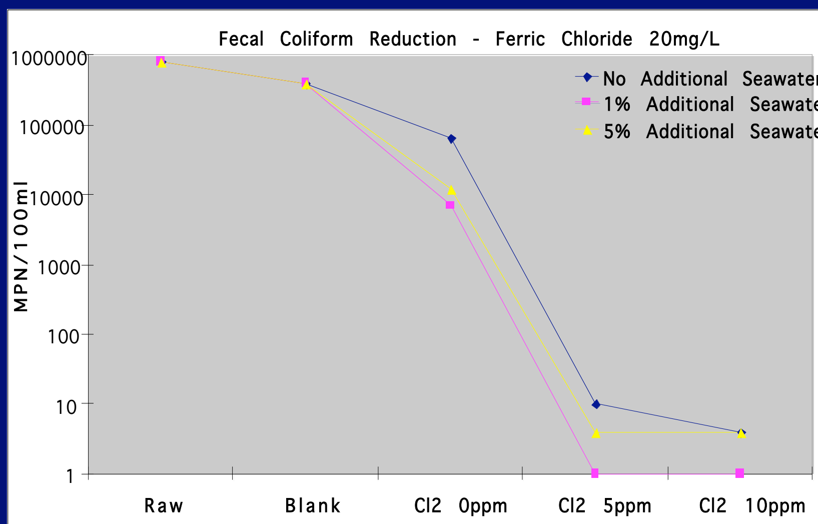
- Peracetic Acid (PAA)
  - Solution containing acetic acid, hydrogen peroxide, peracetic acid, and water
  - Efficient bactericide and virucide
  - Not influenced by pH
  - Short contact time
  - No formation of DBPs
  - Biodegradable Products : Acetic Acid
- Ozone
- UV Radiation

Disinfection – Paraty, Brazil

- Coliform removal efficiency by chlorine was higher than that by peracetic acid.



Disinfection – Deer Island



Disinfection - Results

- Effect of seawater addition
  - Reduced coliform level in the effluent from CEPT
- Disinfection is essential for the WWTP.

Conclusions

- Wastewater infrastructure and treatment and drinking water treatment for the city.
- A conventional gravity collection system is a feasible solution because of:
  - Relatively low costs
  - Simple operation and maintenance
  - Ease of expandability to future connections
  - Adaptability to seasonal changes
- Chemically Enhanced Primary Treatment is the recommended treatment alternative for Paraty.
- Seawater addition is a promising coagulation enhancement mechanism.
- Seawater addition improves the rate of coliform removal.
- Need to consider the use of PAA as an alternative disinfection agent

Thank You

- Professor Donald Harleman
- Frederic Chagnon
- Dr. Ricardo Tsukamoto

QUESTIONS ?