Improving Hydraulic Disinfection Efficiency: A South African Case Study

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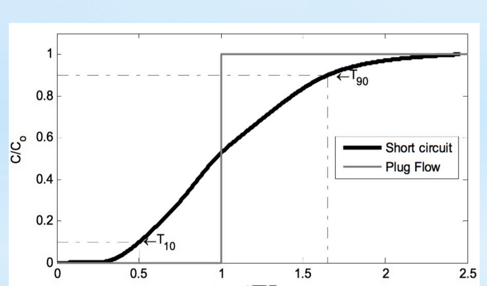
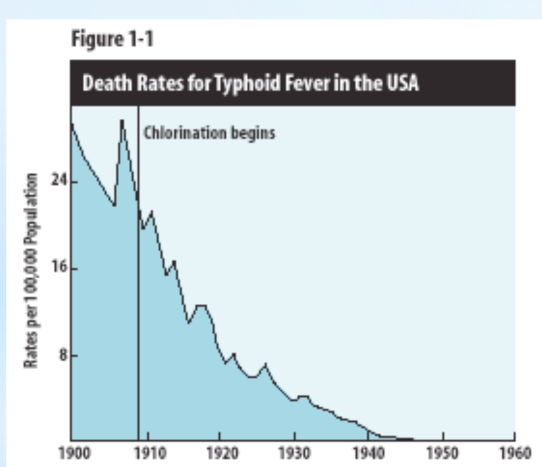
Drinking Water Disinfection

Water Disinfection

Chlorine:

- ***The Benefits of Chlorine***[8]
  - **Potent Germicide**
    Chlorine disinfectants can reduce the level of many disease-causing microorganisms in drinking water to almost immeasurable levels.
  - **Taste and Odor Control**
    Chlorine disinfectants reduce many disagreeable tastes and odors. Chlorine oxidizes many naturally occurring substances such as foul-smelling algae secretions, sulfides and odors from decaying vegetation.
  - **Biological Growth Control**
    Chlorine disinfectants eliminate slime bacteria, molds and algae that commonly grow in water supply reservoirs, on the walls of water mains and in storage tanks.
  - **Chemical Control**
    Chlorine disinfectants destroy hydrogen sulfide (which has a rotten egg odor) and remove ammonia and other nitrogenous compounds that have unpleasant tastes and hinder disinfection. They also help to remove iron and manganese from raw water.
- Cost (pure): \$0.15 per 100g[3]
- Concentration needed to disinfect water ~ 5mg/L
- Chlorine bleach can disinfect household water for less than US \$4/ year per family[4]





Source: US Centers for Disease Control and Prevention, Summary of Notifiable Diseases, 1997

The *CT* method:

- Used to ensure that drinking water has been sufficiently disinfected
  - Contact Time (*CT*) = the amount of time water is in contact with chlorine:

$$CT = C^*T_{10}$$

  - *C* = disinfection concentration at the outlet
  - T_{10} = time at which 10% of a given tracer concentration is observed at the outlet of the system during a tracer study

Baffling Factor:

- Used to determine the hydraulic disinfection efficiency
  - Baffling Factor (BF) = a normalized value determining nearness to plug flow (1):

$$BF = T_{10}/TDT$$

  - *TDT* = theoretical detention time

$$TDT = V_{system}/Q_{system}$$

  - V_{system} = lowest system volume during operation
  - Q_{system} = peak hourly flow-rate of the system

Qualitative Efficiency	BF	Geometric/Baffling Description
Very Poor	0.1	No baffles, agitated basin, very low length to width ratio, high inlet and outlet flow velocities
Poor	0.3	Single or multiple un-baffled inlets and outlets, no intra-basin baffles
Average	0.5	Baffled inlet or outlet with some intra-basin baffles
Superior	0.7	Perforated inlet baffle, serpentine or perforated intra- basin baffles, outlet weir perforated lauders
Perfect ("Plug Flow")	1.0	Very high length-to-width ratio (pipeline flow), perforated inlet, outlet, and intra-basin baffles

Table 1.1: Baffling Classification Table from the Benchmark Technical Guidance Manual (USEPA, 2003)

Laboratory Studies

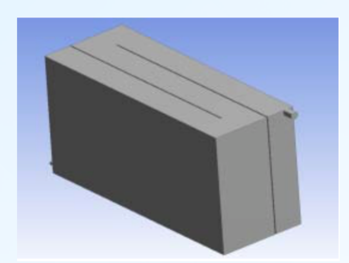
Baffling Factor Guidance Manual

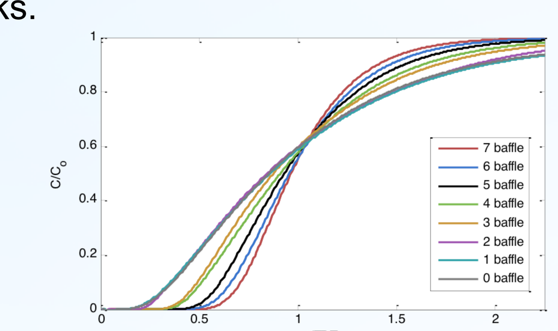
Baffling Factor Guidance Manual – Determining Disinfection Capability and Baffling Factors for Various Types of Tanks at Small Public Water Systems, CDPHE, March 2014

CSU's Department of Civil and Environmental Engineering collaborated with the Colorado Department of Public Health and Environment (CDPHE) - Water quality Control Division to conduct research for small-scale water systems (less than 5,000 gallons operating up to 50 GPM) as these systems accounted for 93% of EPA standard violations. Out of this research the "Baffling Factor Guidance Manual" was created which presents a few pre-engineered small-scale systems and system modifications which have been proven to increase the disinfection efficiency; maximizing their ability to achieve and comply with EPA requirements.

Baffles:

- Internal baffling within large, rectangular contact tanks has been shown to help reduce the occurrence of dead zones and short circuiting so was implemented in small-scale tanks.

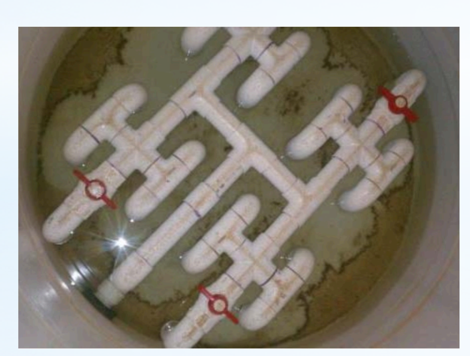


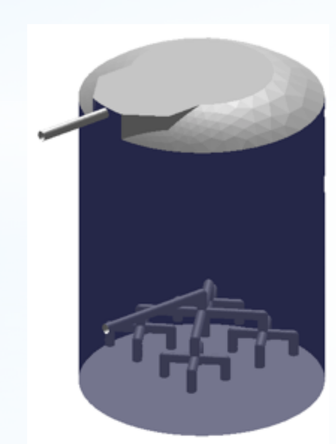


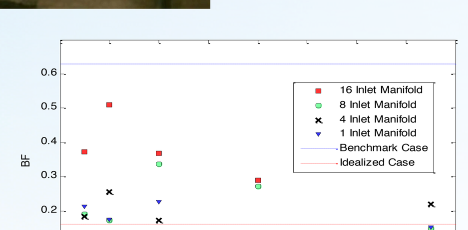
- The ratio of baffle opening length (L_{bo}) to tank length (L_T) is important, as well as channel width (W_{ch}) to L_{bo}

Inlet manifolds:

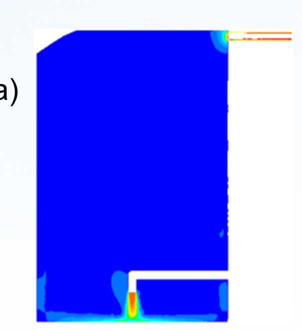
- Changing the inlet configuration spreads the flow from the inlet around the diameter of the tank so that the flow approaches plug flow.







(a)

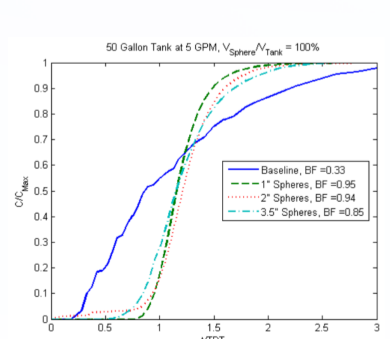


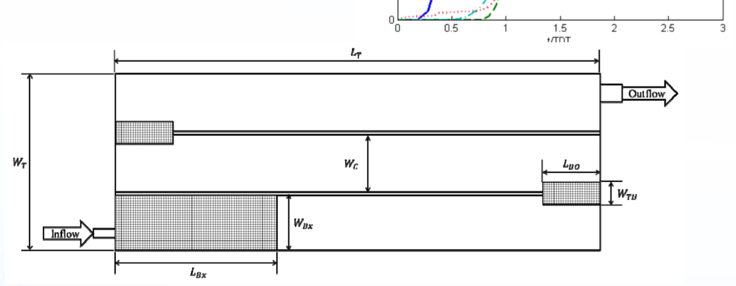
(b)

- Velocity contours show that a 16-manifold inlet (b) vs. a single elbow inlet facing downward (a) dramatically reduces the amount of dead space in a vertical cylinder tank.

Random Packing Material:

- Random packing material creates a "porous wall" which causes a more uniform flow closer to plug flow.





- Random packing material was studied for use in cylindrical tanks as well as a baffled tanks

Live System Case Study

Technology Transfer

Research with the CDPHD on the pre-engineered small-scale disinfection tanks and modifications has concluded and since have been implemented within the state of Colorado. Studies have continued within the EFML group, with the basic notion that since these tanks and/or modifications are relatively simple and inexpensive, there is a possibility of transferring this technology to a developing nation where there is a significant need for safe, disinfected, water and result in a significant impact to the quality of life.

South Africa

Country Overview:[5]

- HDI – 0.666[7]
- Stable government
- Water rights
  - The Constitution of South Africa Provides for the right to water
  - 1997 - Water Services Act
  - 2001 – policy of free basic water
- Stake holders
  - Department of Water Affairs
  - Water Boards
  - Municipalities
- 2009 – only 5% of assessed water supply systems attained *Blue Drop Certification*

Quality of Drinking Water	
Colour Drop	Indication of Drop
blue drop	Blue Drop Certified, water is safe to drink
	Micro > 97% Chemical > 95%
	Micro > 97% Chemical < 95% (or no Information)
	Micro < 97% Chemical > 95%
	Micro > 90% < 95% Chemical > 90% < 95%
	Micro < 90% Chemical < 90%

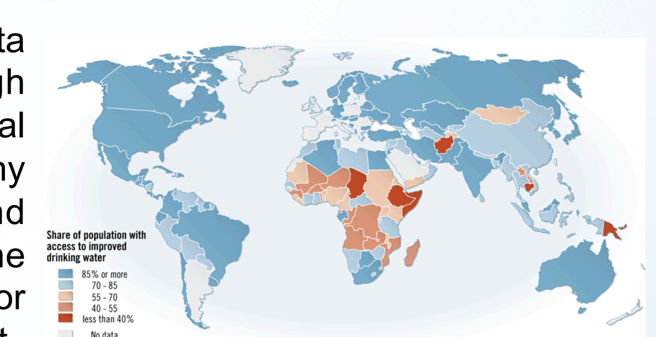
The 5 Key Performance Areas assessed for Blue Drop Certification 2011		
Colour codes		Appropriate action by municipality
	90-100%	Excellent situation, need to maintain via continued improvement
	75-=90%	Good status, improve on gaps identified to shift to 'excellent'
	50-=75%	Average performance, ample room for improvement
	33-=50%	Very poor performance, needs attention
	0-=33%	Critical state, need urgent attention

Small Water Treatment Plants[14]**:**

- Small Water treatment plants are systems that are installed in areas which are not well serviced and which do not normally fall within the boundaries of urban areas including
  - Water supplies from boreholes and springs which are then chlorinated
  - Treatment plants of small municipalities and establishments
    i.e. rural hospitals, schools, clinics and forestry stations
- Small Treatment plants, are similar to those in the US involving a multi-step process including: pre-treatment (if necessary), coagulation/ flocculation, sedimentation/floatation, filtration, stabilization, and disinfection
- The most common disinfection method is chlorination.
  - Gas/liquid Chlorination is most often used due to its cost-effectiveness but Sodium Hypochlorite and Calcium Hypochlorite are also sometimes used.
- Literature on SWTP in South Africa mention the concept of contact time, CT, and the use of baffles in order to increase the CT however there are no specifications of the baffling system nor specified CT standards
- Most of the plants are operating below the design capacity
  - The capacity varied between 0.3ML/d (55gpm) and 120 ML/d (22000gpm)
- Raw water source:
  - 86% use surface sources
  - 10% use groundwater
  - 4% a combination of both sources.
- 40% of the plants did not comply with the ideal target range of 0.3-0.6 mg/L free chlorine residual in the consumer's tap water
- In most cases, the flow rate of the water and the initial chlorine dose were not known resulting in under chlorinated drinking water

International Development Challenges[9]

The World Bank Group's data and other evidence suggest high incidents of challenged international development projects. There are many internal and external, visible and invisible factors that influence the environment and cause completed or in progress international development projects to be challenged. These factors have been classified into ten categories based on their nature; including issues of political, legal, cultural, technical, managerial, economical, environmental, social, corruption, and physical.



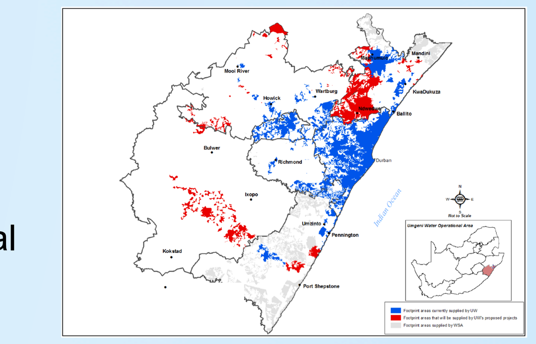
Case Study

Collaborative Partner:

- Umgeni Water

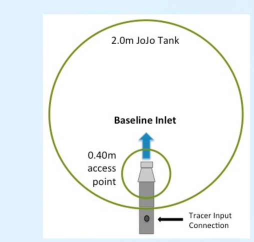
Location:

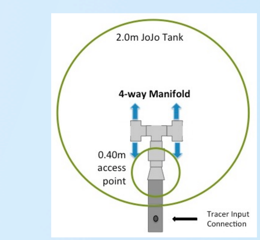
- Rosetta Waterworks, KwaZulu-Natal

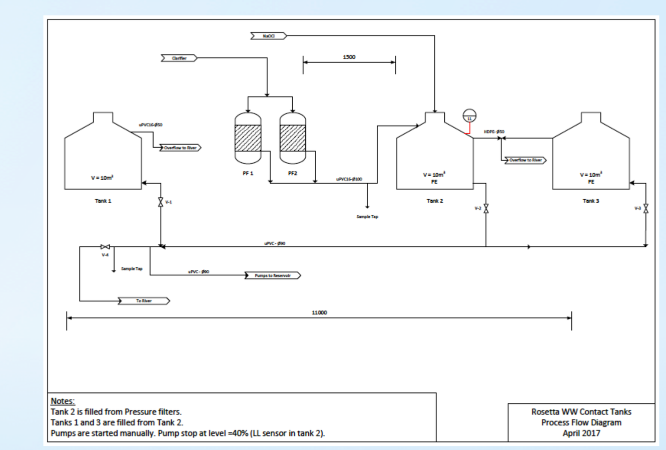


Objective:

- Assess hydraulic disinfection efficiency of a small water works
- Design and implement a practical inlet manifold modification on a live system to improve CT

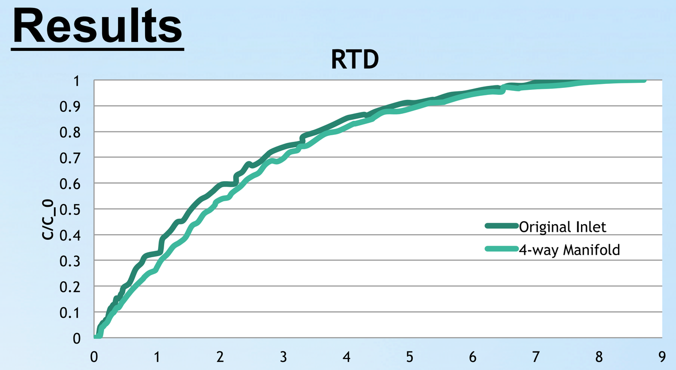






Results

The baffling factor of the JoJo tank, 40-50% full, with a horizontal inlet with inline dosage was ~0.24. Once the modification was implemented the baffling factor increased to ~0.34, a 40% improvement.



Future Research

Looking forward, we are hoping to widen our scope to assess different types of contacting systems used nationally in South Africa. We plan on using ANSYS Fluent, a CFD software, to aid us in best designing practical and cost effective modifications to improve the hydraulic disinfection efficiency of these small waterworks. The intended product from this study is a guidance document aimed at plant operators on how to practically assess and modify existing systems.

Acknowledgements

We would like to acknowledge the CDPHE for their collaboration and contribution as well as the many former CSU MS students, Qing Xu, Jordan Wilson, Zachary Taylor, Taylor Barnett, Justin Kattnig, Jeremy Carlston, and Yishu Zhang, who contributed to the research of these pre-engineered small disinfectant tanks. I would like to acknowledge Umgeni Water for their willingness, resources, and enthusiasm in collaborating with us, permitting this study to occur. Also a special thanks to the Monfort Professorship for funding to pursue the transfer of this technology to South Africa.

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