CHALLENGES ASSESSING AND TREATING WASTEWATER FROM BIOTECHNOLOGY SCALE UP OPERATIONS

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Overview

> Existing wastewater pretreatment system
> Wastewater characteristics
> Wastewater challenges
> Root cause evaluation
> Short and long term action
> Questions

Wastewater Pretreatment System

Original Design - 2006
Dual Stage pH adjustment system
> 1,300 Gallon Tank w/mixers (2)
> Acid & Caustic Meter Pumps
> Run pH 6-8

Discharge Characteristics
> 5000+ GPD flow
> Vivarium
> Glass washers
> Chemistry and Bio labs

MWRA Permit
Occasional odors

Wastewater Pretreatment System

Facility Modifications since Original Design (2006)

Vivarium decommissioned

Facility Upgrade Program
> Multiple Renovations
> Consolidation of Labs from other sites
> New glasswashers, Autoclaves, Reactor Washing
> Increased number of labs
> Commissioned SUL with 1200 L bioreactor

Significantly lower flow than design, ~1000 GPD,

Little to no weekend flow

Spike loads of nutrient rich media from bio labs and SUL

Wastewater Pretreatment System

SUL Waste Discharges

SUL Operations

- > 1200 L Reactor, Batch and fed batch operation
- > Daily flow of sterile waste media to drain
- > Batch discharge of sterilized reactor at end of run
- > Discharge of dilute buffers from downstream and cleaning water

SUL Effect on WWPT System

- > Small/steady flow of high BOD, N, and micronutrients
- > Spike loads of full bioreactor tank, spikes of dilute cleaning waste
- > Noticeable change in odor and complaint frequency
- > No shift in wastewater system operational or sampling parameters

Wastewater Challenges

Approximately 3-6 months after commissioning of new labs

Elevated phenol levels detected at WWTP discharge

Internal sampling of both WWT tanks confirmed upward shift in phenol levels

Preliminary data seemed to correlate phenol to SUL reactor discharge

Internal EHSS site team assembled to investigate root cause

Preliminary Root Cause

Did the chemists start discharging phenol from their lab?

> No - no new chemical, not enough phenol in existing material

Did the cleaners start using phenol based material?

> No - no new chemicals, not enough phenol in existing material

Did construction or maintenance discharge phenol?

> No - no chemical discharge, not enough to produce observed levels

Did the SUL discharge phenol?

> No - chemical and disinfectants did not contain phenol
> No - analysis of reactor waste and fresh media indicated no phenol
> No - components in feed media such as tyrosine did not “trick” phenol lab test

Preliminary Root Cause

Hints

> Phenol level & odors appeared to correlate with SUL reactor discharge
> Phenol levels & odors dropped off when SUL stopped discharging
> Phenol levels & odors abated for 1 to 2 weeks after WWPT drain & scrub
> During a series of no flow days, phenol rose from ND to 2-3ppm, then back to ND
> During no flow periods, pH in tanks & discharge would "wander" up 1-1.5 units

Working theory

> Native microbes in WWPT converting SUL wastes into phenol?

Preliminary Root Cause

Experiment

> Mix 1.8 L from WWPT tank with 0.2 L SUL waste, mix 24 hours, test for phenol

Results

Sample	Mix Time	Phenol Level (PPM)	Comment
WWPT Tank 1	0 hrs	5	Control
WWPT Tank 1	24 hrs	5	Control
WWPT Tank 1 + SUL	24 hrs	11	Microbial Action?
SUL	24 hrs	ND	No Phenol in SUL
WWPT Tank 1 + SUL + Bleach	24 hrs	ND	Oxidation?

Next Steps

Short Term Containment

> Plumb SUL drain to tote

> Haul Waste Offsite for treatment

Contacted Tighe & Bond

> Duplicate Initial Experiments

> Confirm or Refute Initial Working Theory

> Fully Characterize Phenol Generation Mechanism

> Propose and Test Pretreatment Alternatives

> Provide Short Term and Long Term Treatment Options

Phase 1 – Evaluation - Theory

High strength waste (N, C, P)

Indigenous microbes

Long retention times

Creation or release of phenol under varying conditions

Phase 1 – Evaluation - Theory

Use seed from wastewater treatment system

Samples tested

> Raw wastewater
> SUL permeate
> 1:10 dilution of ww with SUL
> 1:10 dilution with oxidizer (chlorine bleach)

Conditions controlled

> pH (hi, neutral, low)
> Aerobic conditions
> Anaerobic conditions

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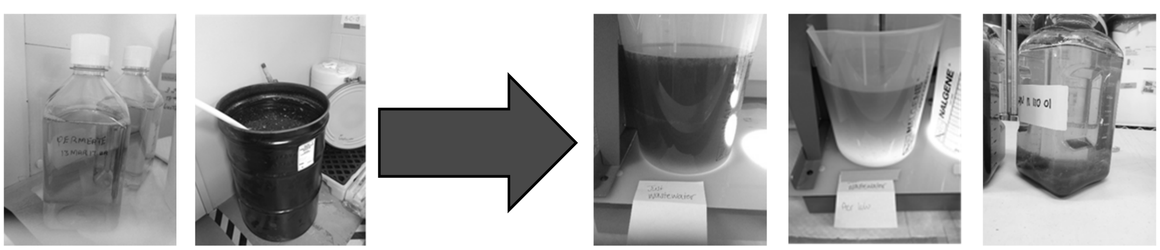
Phase 1 – Evaluation - Approach



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Phase 1 – Evaluation - Approach

Phase 1 – Evaluation - Findings

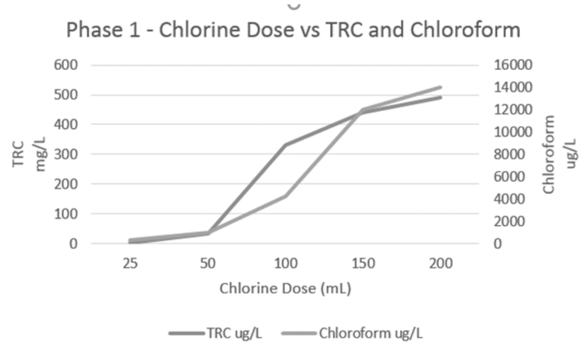
Higher and lower pH generated less phenol

SUL waste did not contain phenol

Use of chlorine bleach

> Addressed phenol generation
  - – Disinfection or oxidation

> Generated chloroform



Phase 2 – Evaluation - Objectives

Chlorine bleach dosing – additional analysis to fine tune

> Measure TRC vs phenol over time

> Sample chloroform generation

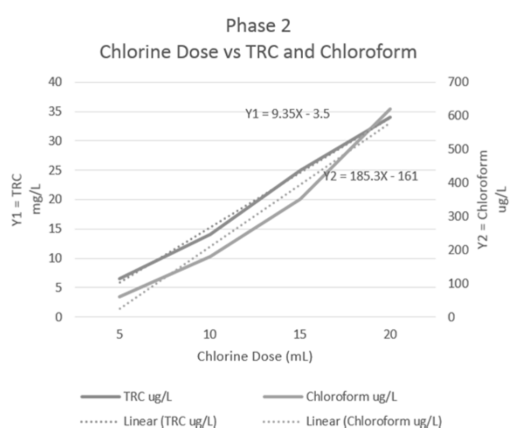
> Observe odors

Evaluate phenol generation over longer exposure durations

Identify predominant microbes

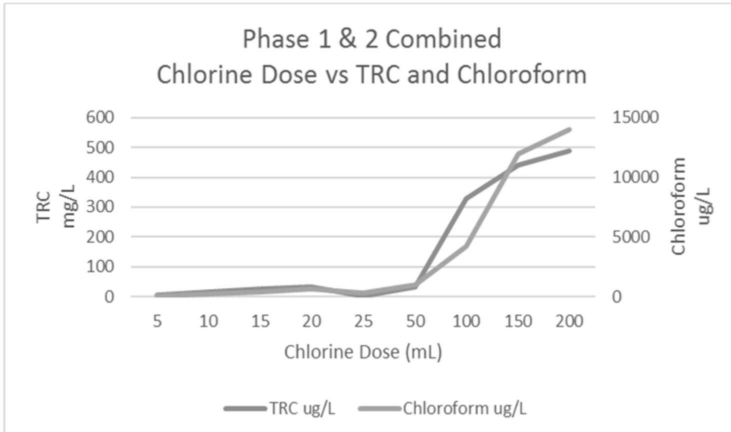
Phase 2 – Evaluation - Findings

Chloroform generation and TRC linear at lower dosages



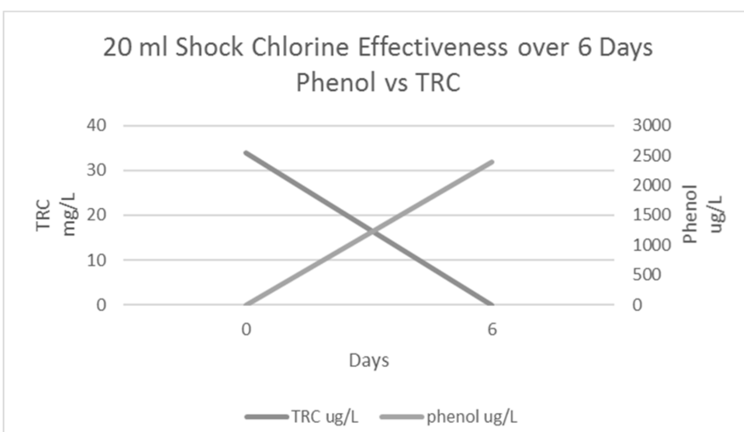
Phase 2 – Evaluation - Findings

Chlorine dosage closely resembles breakpoint chlorination curve



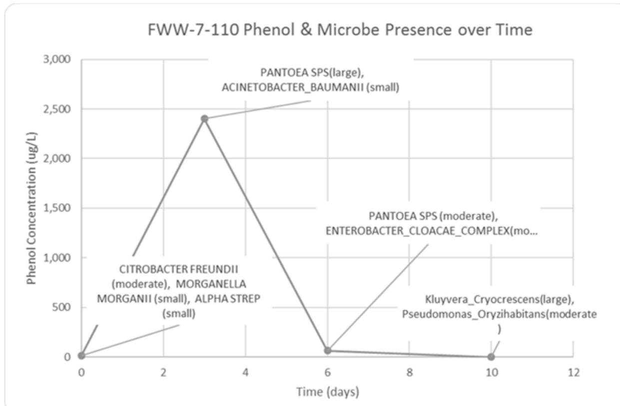
Phase 2 – Evaluation - Findings

Microbes consumed TRC over time



Phase 2 – Evaluation - Findings

Microbes exhibit endogenous decay after 3 days

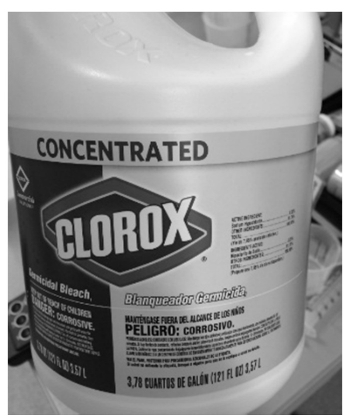


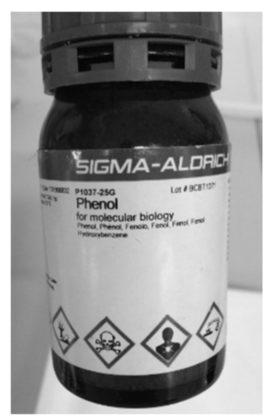
Phase 3 – Evaluation - Objectives

Disinfection power of alternatives

- > Short term exposure
- > Long term exposure

Oxidizing power of alternatives on phenol spike





Phase 3 – Chemical Alternatives

Selected

> Peracetic acid
> Hydrogen peroxide
> Hydrogen peroxide + catalyst
> Sodium Percarbonate

Reviewed

> Disinfection
> Oxidation
> Hazard classifications



Peracetic Acid

Commercial products

> Oxysan
> Mincare

$C_2H_4O_3$

Characteristics

> Health - 3
> Flammability – 2
> Reactivity – 2
> Strong odor
> Effective at pH of 7
> Will oxidize cell membranes
> Commonly used in biological laboratories

Sodium Percarbonate

Commercial products

> Oxyclean

> Laundry detergent

(Na_2CO_3-1.5H_2O_2)

Characteristics

> Health - 2

> Flammability – 0

> Reactivity – 1

> Strong oxidizer

> Disassociates into hydrogen peroxide and sodium carbonate (strong buffer)

> Takes time to dissolve (residual solids)

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Hydrogen Peroxide (35%)

Commercial products

> Drug store disinfectant (3-5%)

H_2O_2

Characteristics

> Health – 3

> Flammability – 0

> Reactivity – 2

> Uses free oxygen radicals

> Very unstable (loses effectiveness with time and temp)

> Alone not a powerful disinfectant but improves with UV and ozone

> Oxygen off gassing

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Hydrogen Peroxide (35%)

Commercial products

> Drug store disinfectant

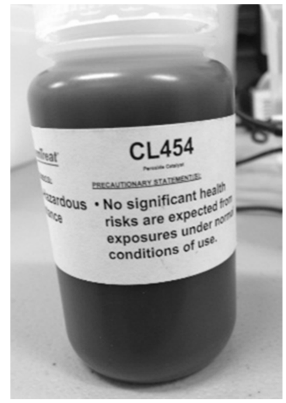
> Specialty chemical supplier

H_2O_2 + ferrous iron catalyst

Characteristics

> Fenton's Reaction

> Increases oxidation power



Phase 3 – Evaluation – Findings

Disinfectant/ Oxidizer	Phenol inhibition over time	Instantaneous oxidation of phenol	Hazard Level	Odors	Other Considerations
Chlorine Bleach	Yes	Yes	Moderate	No	Easy to purchase
Peracetic Acid	Yes	Incomplete	High	Strong	Common lab chemical
Sodium Percarbonate	Yes	Yes	Low	No	Residual solids Off-gassing
Hydrogen Peroxide	Yes	Incomplete	Low	No	Off-gassing
Hydrogen Peroxide + Catalyst	Yes	Yes	Low	No	Heavy off-gasing discoloration

Testing Conclusions

Chlorine bleach most effective

> Oxidizes phenol

> Inhibits microbial activity

Maintain optimum TRC

> Inhibit microbial growth

> Minimize chloroform generation

Moving Forward

Short term

> Monitor TRC, phenol and chloroform levels

> Install temporary chlorine dosing system

Moderate term

> Design chlorine dosing system with TRC controller

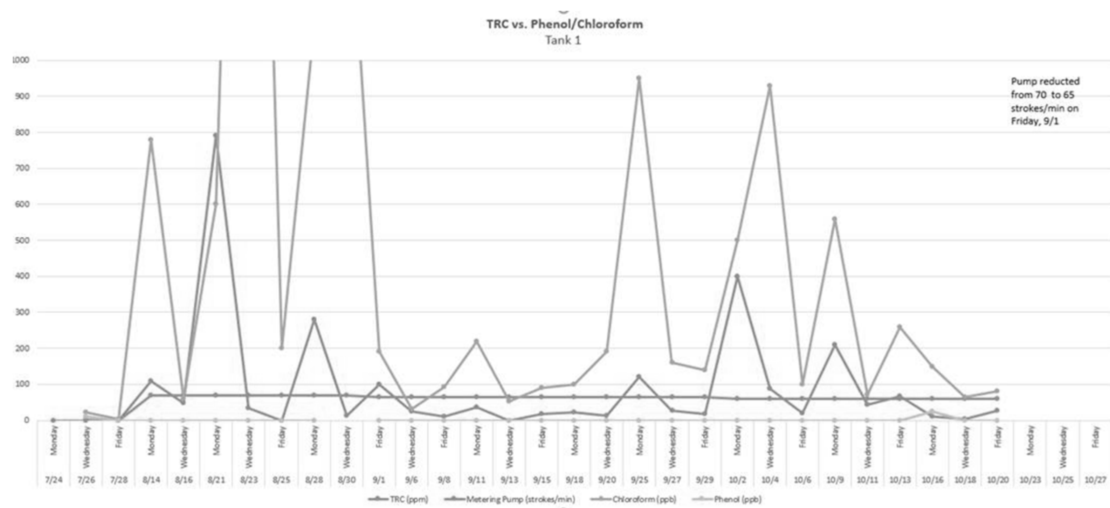
Long term – WWT Redesign

> Decrease residence time

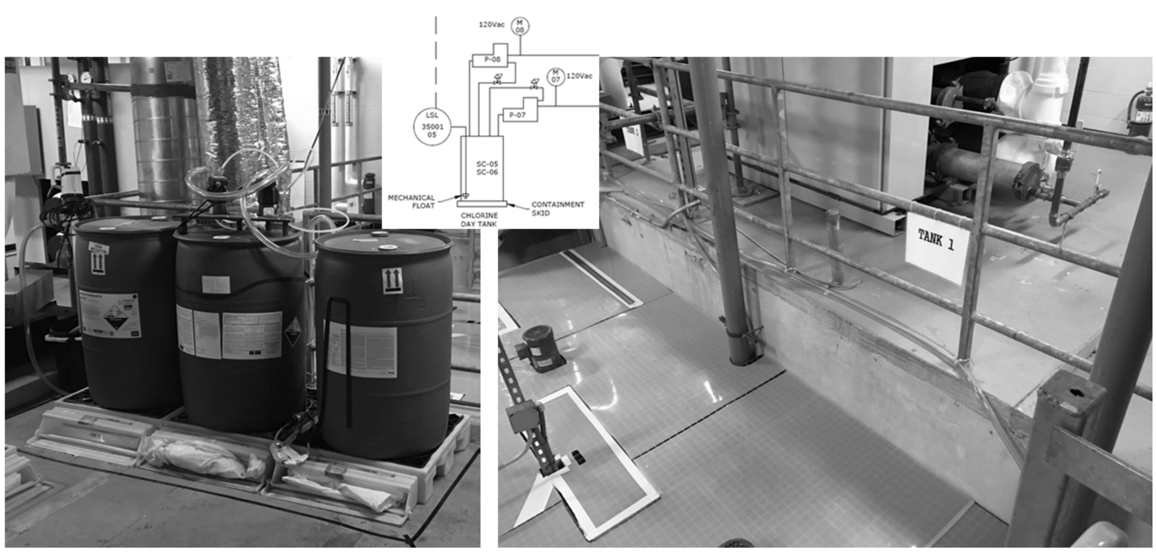
> Improve chemical addition

> Redesign tanks for easy cleaning

Short Term – Trend Sampling



Short Term - Temporary Bleach Dosing System



Moderate Term – TRC Controller

In-line chlorine analyzer

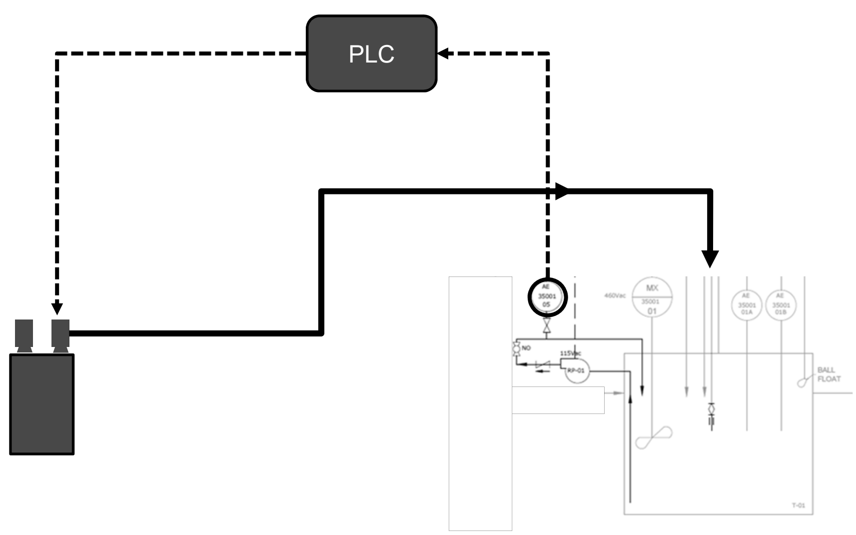
Feedback control to PLC

Maintain total residual chlorine at 20-30 mg/L

Continue monitoring and trending

> Phenol
> TRC
> Chloroform

Moderate Term – TRC Controller



Moderate Term – TRC Controller

Reduce reactor sizes to minimize detention time

Active ventilation

Process-like equipment

Automated disinfection controls

Minimize surfaces for biological growth

Conclusions

Biological activity can have adverse impacts

Bigger is not always better

Approach wastewater treatment as a “process”

Biological reactions can generate regulated paramters

Questions

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