UA WEST Center

Co-directors: *Ian Pepper and Shane Snyder*

Plugged into WEST:
New opportunities at the Water & Energy Sustainable Technology (WEST) Center

THE UNIVERSITY OF ARIZONA
WEST CENTER
WATER & ENERGY SUSTAINABLE TECHNOLOGY

Ian Pepper
University of Arizona

Presented:
WRRC Brown Bag Luncheon
April 26, 2017

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- CAP Water

1968 Colorado River Basin Act signed by Lyndon Johnson
- Colorado River water to Tucson via surface water canal

1973 Project initiation

1993 Implementation of CAP water unsuccessful

2000 Implementation successful: 144000 acre feet annually

2017 83% of Tucson Water used is CAP water

Water Sustainability

- CAP
- Water banking (1997)
- Water conservation (1970's)

Currently plenty of water, but....
things can change quickly

The Thirsty West: Can Tucson Survive Climate Change?

The desert city is low on water, with a booming population.

By Eric Holthaus ***March 11, 2014:***

California 2011

California 2014

Oroville Dam spillway 2017

The Path to Water Sustainability

1) National Science Foundation
Water Quality Center (I/UCRC)
1999-2008 $9,775,764

2) National Science Foundation
Water & Environmental Technology Center (I/UCRC)
2008-2018 $4,947,685

3) Water Village
2007-2011

Real-Time Sensor Lab

4) Water and Energy Sustainable Technology Center
2014-2024

WEST: A UA/Pima County Collaboration

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2011	Pima County invites Pepper/Snyder to lead a UA presence in the County Water Reclamation Campus
Dec. 2012	UA/County sign Intergovernmental Agreement - Pima County to fund new 22000 sq ft UA building - UA agrees to long-term commitment (5 years + 5 years renewal option) - Lease involves paying for utilities ($0 per sq ft space)
2013	Planning, design of building
2013	Construction initiated: duration = 18 months due to Hamilton bankruptcy
2016	UA moves in, ERL and Water Village moves to WEST

WEST: An “institutional level Center”

- Under the auspice of Research Discovery and Innovation (RDI)
- Co-directors report to Kimberley Espy (V.P. Research)
- WEST receives RDI support
- WEST is a unique facility available to campus faculty

Tours for interested parties:

- Faculty
- UA students in formal classes
- High school students
- State legislators and staffers
- Community groups

Research at WEST

- Need to have an idea (A great idea)
- Need to write a proposal
- Need to get it funded!

Advantages of Including WEST in the Proposal

- Can describe the unique features of WEST
- Can include state-of-the-art technology development
- Close interactions with public and private sectors
- Public/private partnerships

QUESTIONS ?

Examples of WEST Projects

UA Faculty Member	Funding	Project
Jim Field (CHEE)	NSF	Anammox side treatment of effluent
Jim Farrell (CHEE)	NSF	Zero Liquid Discharge
Don Gervasio (CHEE)	Tucson Water	Corrosion
Chuck Gerba (SWES/WEST)	USDA	Non traditional irrigation water
Kelly Reynolds (Public Health)	Tucson Water/WET)	Real-time detection of viruses

WEST Scholars

- Fellowships for three undergraduates
- Funding to allow undergraduate research
- Research must be done at WEST
- Three @ $7500 annually
- Call for applications in August of each year

ANYTHING MISSING HERE ?

INTERNSHIPS

- Public and private sectors sometimes want students to work on a project
- Need mechanisms to make this happen!

THOUGHTS ?

Industry Members brought in by Dr. Shane Snyder

SC Johnson
A Family Company

Dow

CalgonCarbon

IXOM

PWNT
Water Technology

Garver

Agilent Technologies

BDS
BioDetection Systems

GE Power & Water
Water & Process Technologies
Analytical Instruments

Tucson Water

Pima County

Metawater

CHPA
Consumer Healthcare Products Association

APE Research Council

xylem
Let's Solve Water

Just joined:

PepsiCo

NSF WET Center Members

TUCSON WATER

PIMA COUNTY
WASTEWATER RECLAMATION

AWQS International™
Automated Water Quality Systems

USA Sludge

ECOSPURE

TANK'S GREEN STUFF™

NORTHWEST BIOSOLIDS
Unearthing Sustainable Solutions

SYNAGRO
YOUR PARTNER FOR A CLEANER, GREENER WORLD

CITY OF PEORIA

SANITATION DISTRICTS OF LOS ANGELES COUNTY

CASA California Association of Sanitation Agencies

AVRA GRO SYSTEMS INC
Tucson, Arizona

WEST MAJOR FOCAL AREA: RECLAIMED WATER FOR POTABLE REUSE

RECLAIMED WATER FOR POTABLE REUSE

- Effluent from wastewater treatment plant plus advanced treatment
  - microfiltration
  - reverse osmosis
  - advanced oxidation
  - activated carbon

The Orange County Groundwater Replenishment System (GWRS)

Wastewater is conventionally treated at the Orange County Sanitation District before it flows to the GWRS, where it undergoes advanced state-of-the-art purification process consisting of three technologies.

1 Microfiltration → **2** Reverse Osmosis → **3** Advanced Oxidation via UV and H_2O_2 → **4** Discharge into injection well or percolation basins

OVERALL GOAL OF ADVANCED TREATMENT

- Ensure the safety of drinking water for consumers with respect to contaminants
  - online sensors for detection of contaminants in real-time
  - documentation of destruction of contaminants in real-time
  - conducted at WEST

Center Projects: Shane Snyder

Shane has multiple projects involving advanced treatment

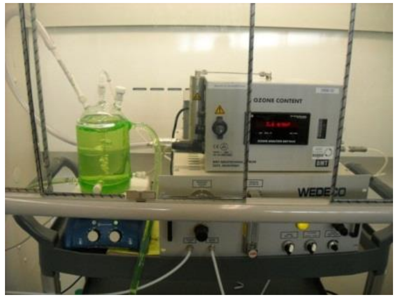
- RO
- AOP
- BAC

Today, only microbial projects presented (Ian)

Advanced Treatment Technologies (ATTs) for Water

Shane Snyder

Oxidative



Ozone

UV-AOP

Adsorptive

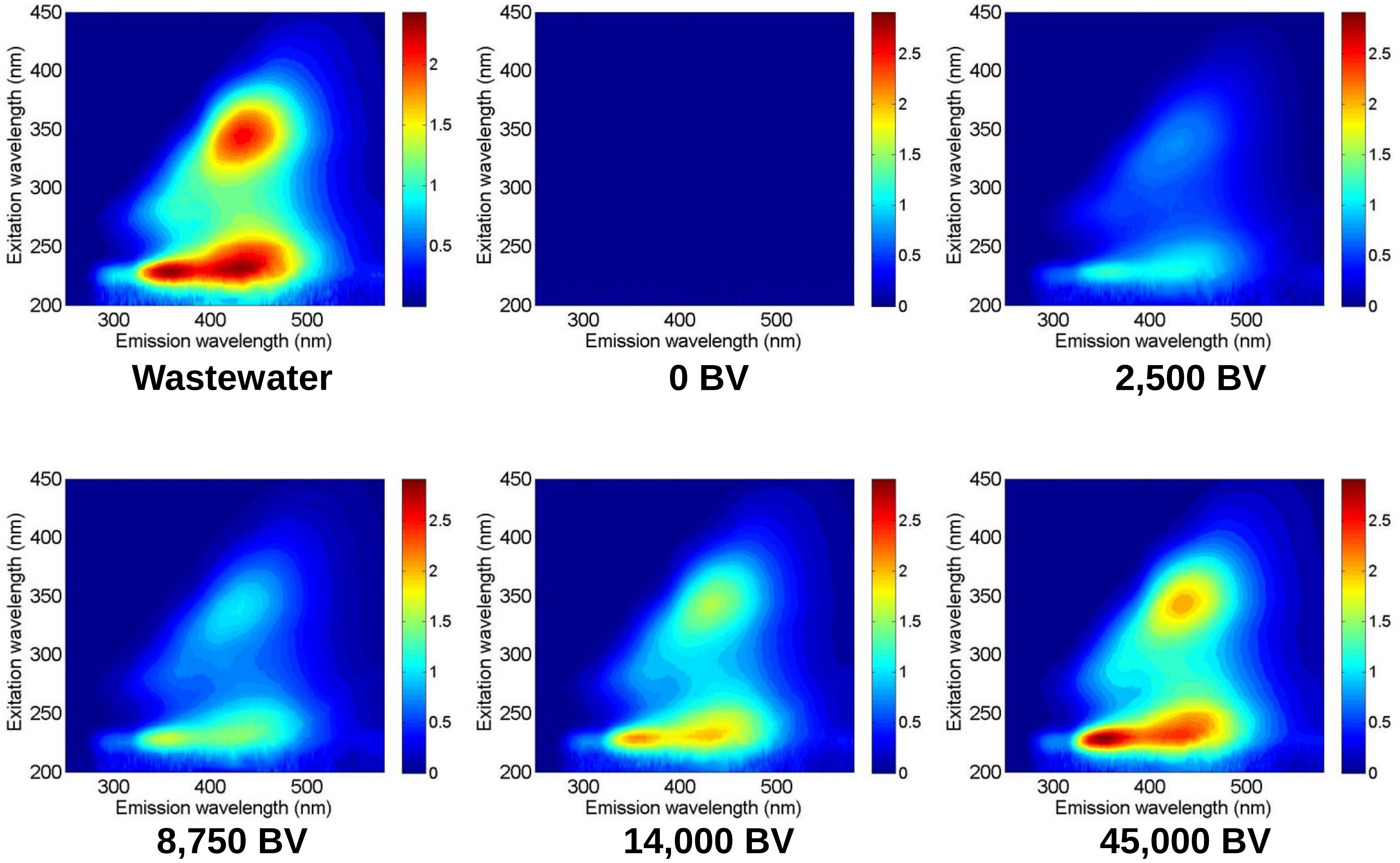
Pressure Filtration
Reverse Osmosis

Granular
Activated
Carbon

Granular Activated Carbon

Rapid Small Scale Column Tests (RSSCT)

Wastewater effluent on GAC treatment: Evaluation by fluorescence via excitation emission matrix



WEST Unique Capabilities – High Bay

- Co-located with Agua Nueva Wastewater Treatment Plant
- Range of water qualities plumbed in
    - Potable *Water*
    - *Reclaimed* Water
    - Wastewaters
- Intermediate, Field-scale treatment
- Flow-through capabilities for reclaimed water
- Multiple advanced technologies

Interactions with WEST/Tucson Water

WEST Sensor Lab

- Real-time Sensors for Microbial and Chemical Contaminants

- Existing Projects:
  - WateReuse Foundation 14-01
  - Evaluation of New Microbial Sensor (AWQS)

On-line sensor infrastructure in the Real-Time Sensor Lab

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Real Tech	HF scientific	HACH	GE	s::can	xylem	WET Labs	JMAR	Instant BioScan	microLAN
Real UVT Online	MicroTol3 Turbidity Analyzer	GuardianBlue Event Monitor	Sievers 5310C On-Line TOC Analyzer	Spectro::lyser	NiCaVis 705 IQ	SAFire	BioSentry	BioScan (RMS-W)	ToxControl Toxicity Analyzer

General parameters		Organic parameters		Inorganic parameters		Microbial parameters	
pH	HACH GuardianBlue Event Monitor	UVT 254 (%)	Real Tech Real UVT Online	Chlorine (mg/L)	HACH GuardianBlue Event Monitor	Total cell count (counts/100mL)	AWQS Lumin Ultra
Temperature (°C)	HACH GuardianBlue Event Monitor	UVA 254 (cm^{-1})	Real Tech Real UVT Online; xylem NiCaVis 705 IQ	NO_3-N (mg/L)	s::can Spectro::lyser; xylem NiCaVis 705 IQ	Toxicity (%)	
Conductivity (μS/cm)	HACH GuardianBlue Event Monitor	DOC (mg/L)	s::can Spectro::lyser; xylem NiCaVis 705 IQ				
Turbidity (NTU)	HACH GuardianBlue Event Monitor; s::can Spectro::lyser; HF scientific MicroTol3 Turbidity Analyzer	TOC (mg/L)	HACH GuardianBlue Event Monitor; s::can Spectro::lyser; GE Sievers 5310C On-Line TOC Analyzer; xylem NiCaVis 705 IQ				
		Fluorescence (A.U.)	WET Labs SAFire				

Real-Time Sensors for Microbes

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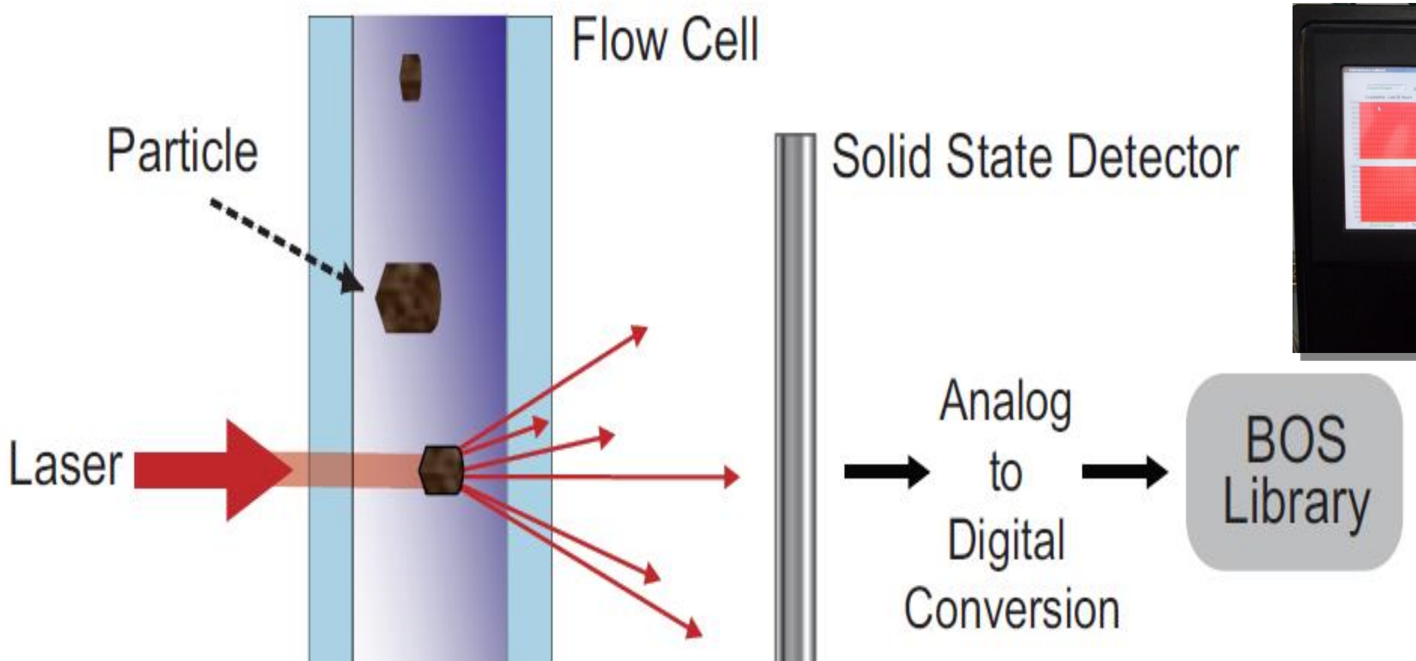
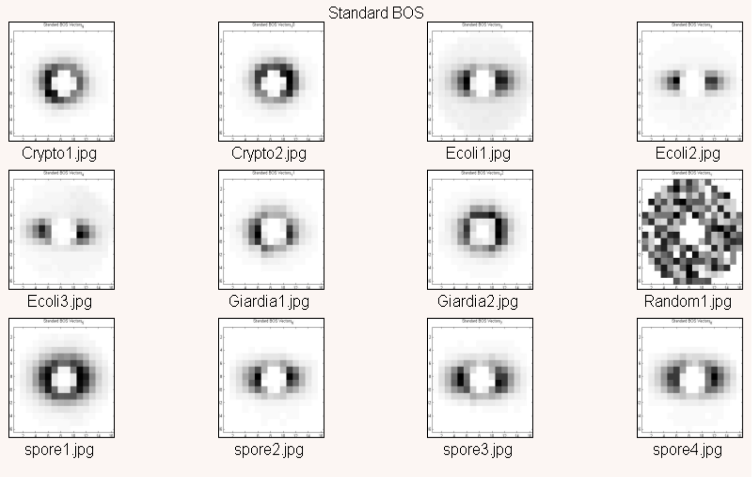
Detection of Microbial Contaminants





BioSentry Detection of *Escherichia coli*

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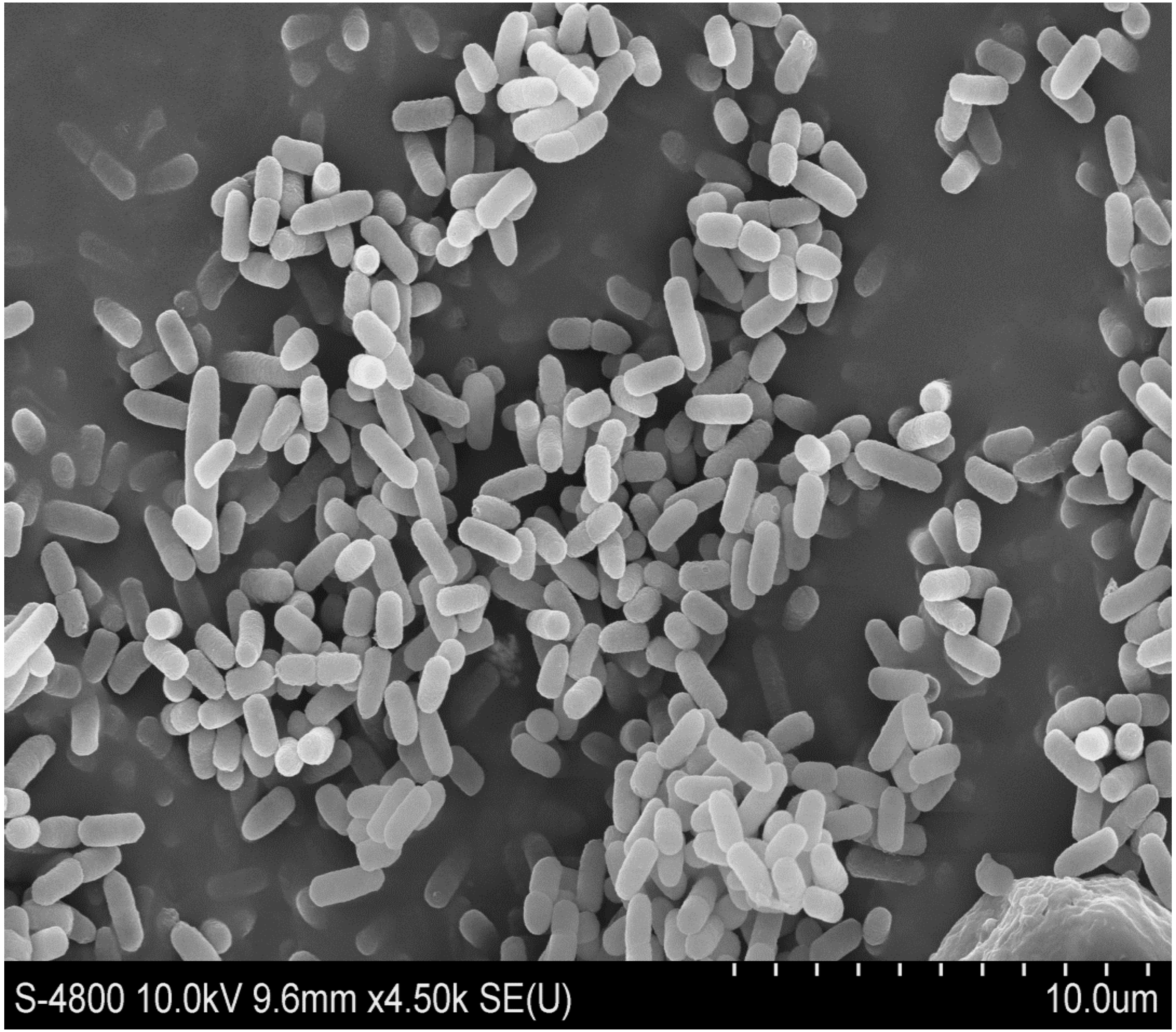

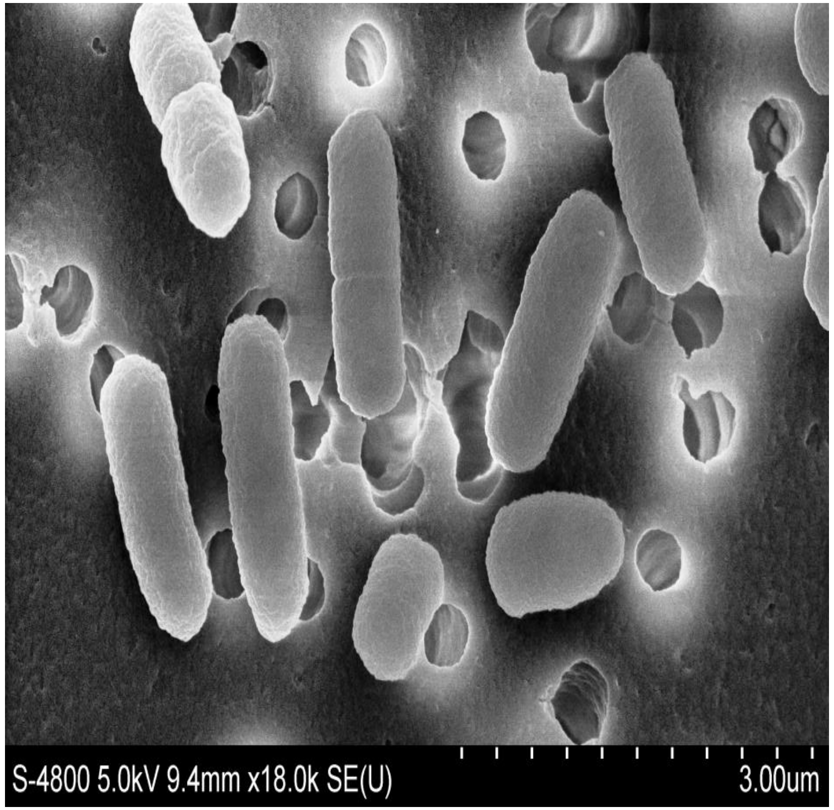

BioSentry Results for *E.coli*

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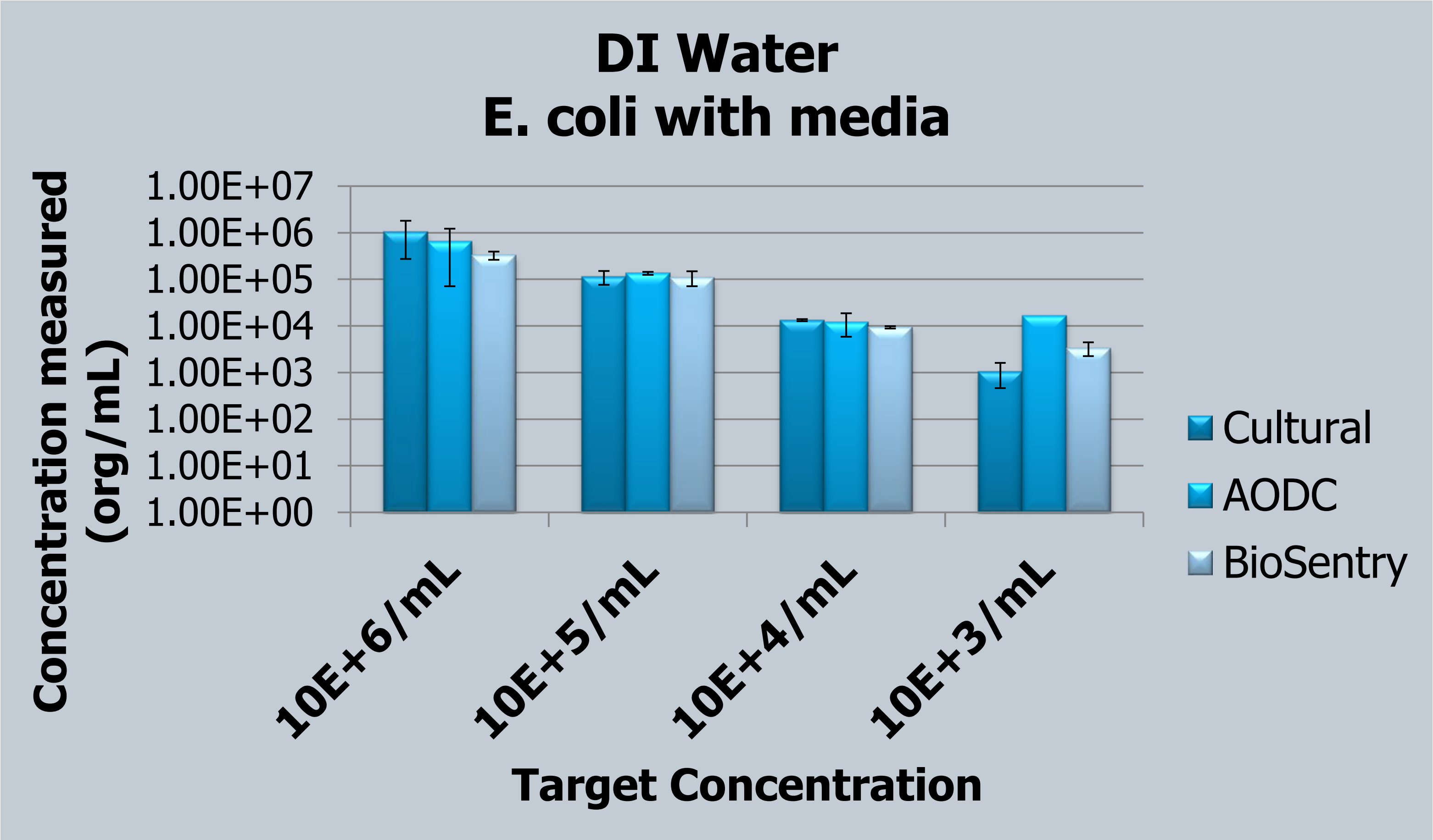
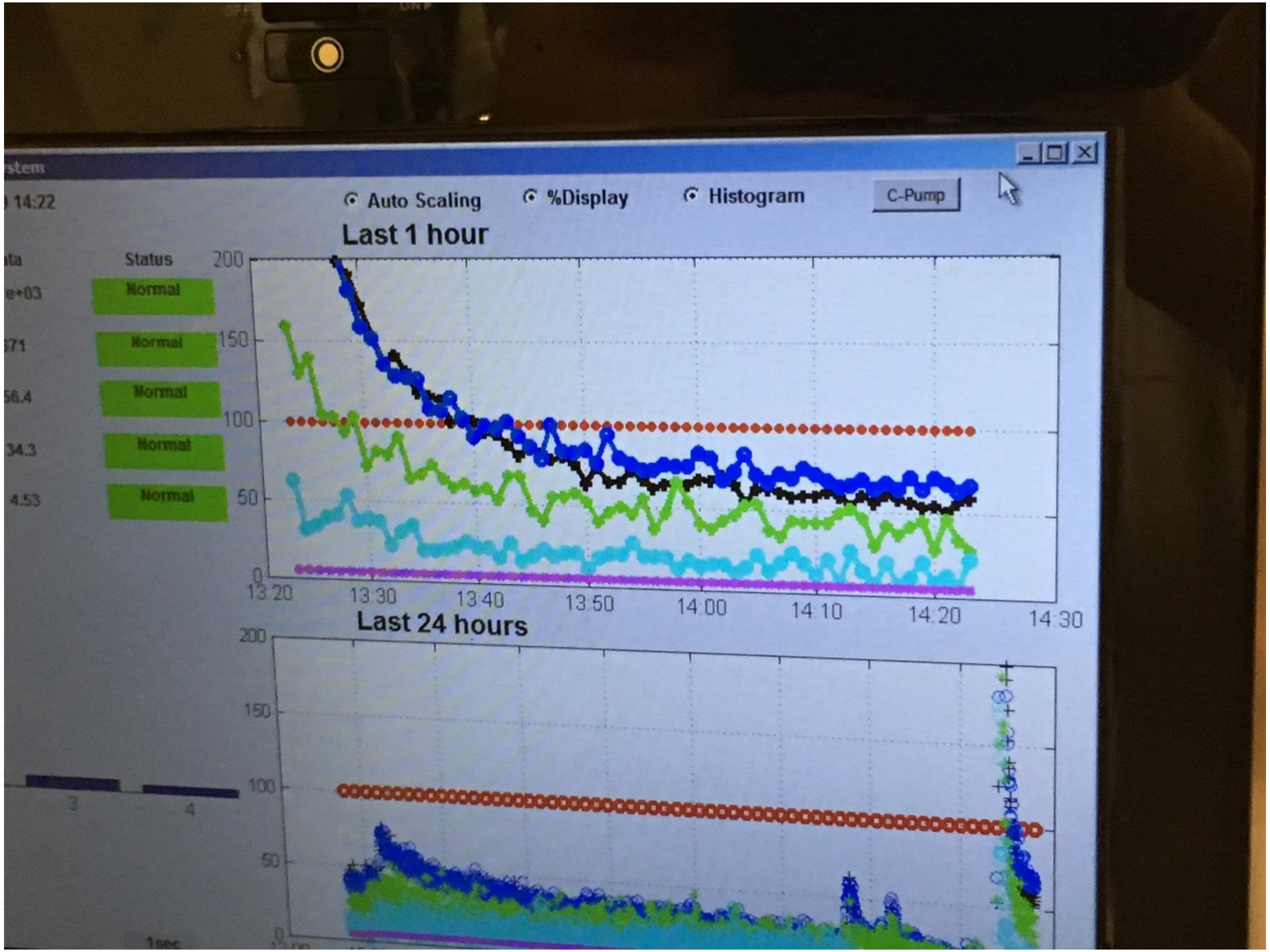


Microbial sensor based on multi-angle light scattering (MALS)

New prototype sensor AWQS; MALS



Tail end of a spiking experiment

Norovirus Smartphone Detection using Fluorescent Microscopy

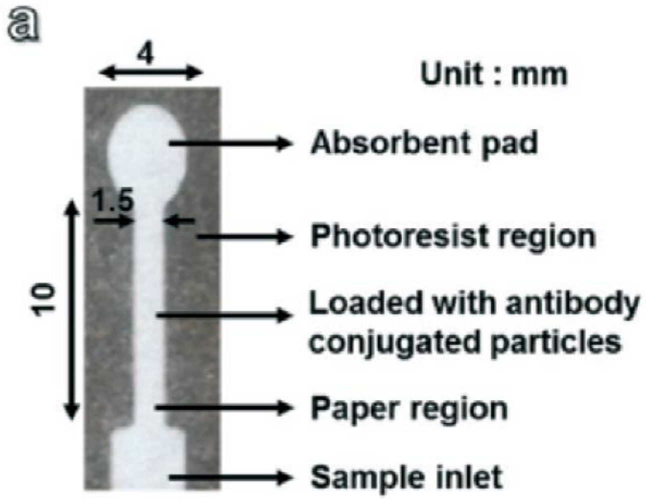
Kelly A. Reynolds

THE UNIVERSITY OF ARIZONA
MEL & ENID ZUCKERMAN COLLEGE OF PUBLIC HEALTH
Environment, Exposure Science & Risk Assessment Center

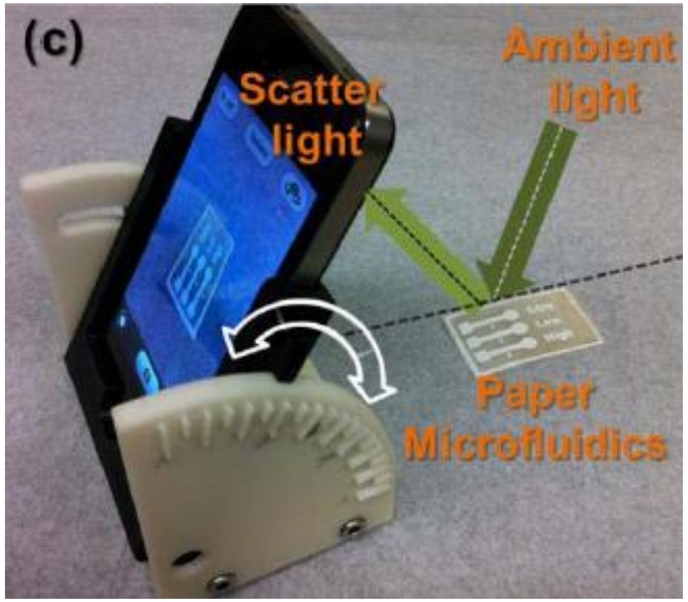
Jeong-Yeol Yoon
Soo Chung

COLLEGE OF AGRICULTURE & LIFE SCIENCES
COLLEGE OF ENGINEERING
Agricultural & Biosystems Engineering

Previous work:
Virus Detection on Paper Microfluidics using Smartphone Technology



- Single channel paper microfluidics
- Mie scattering of VP1 capsid antigen agglutination
- Smartphone software optimization (angle, intensity, light)



- Smartphone's digital camera used to detect light scatter intensity at optimal angle, arising from anti-virus conjugated microbead immunoagglutination on the paper chip

Conclusion & Future work

- Previous limit of detection: **10pg/mL** of anti-Norovirus conjugated particles using Mie scattering
- Current LOD improved to **1pg/mL**
- Semi-quantitative analysis by using difference of intensity (area of intensity)
- Next steps: experiment with measuring intensity change using Smartphone

SENSOR ISSUES

- False positives
- False negatives

  (Sensitivity of detection)

- Detection of chemical and microbial contaminants via a real-time trigger
- Identification of treatment failures
- Integration of software data management, e.g., Labview
- Development of SCADA system
- Sensor maintenance & cost evaluation
- Self-monitoring
- Self-healing concept

WEST Supporting Labs

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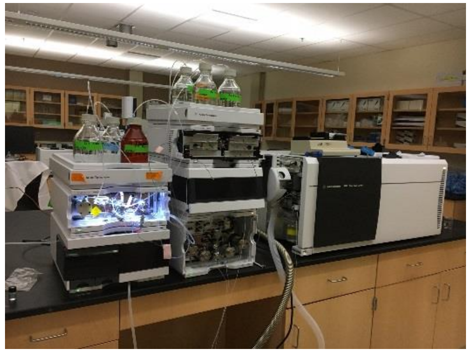
Aquatic Toxicology
(setup underway)



Bench Scale Lab
&
Testing Area

Analytical Labs:
- Cultural and molecular technologies
- Chemical Analysis for trace organics (Shane)



The Water Reclamation Campus

Tucson / Pima County:

- Wide Range of Water Qualities
- Direct sources of wastewater & reclaimed water
- Neighboring Wetlands
- Infiltration Basins
- Santa Cruz Riverbank filtration

Beyond Tucson:

- Central Arizona Project (CAP) water supply direct to Tucson
- Groundwater supplies

Enhanced Perception of the Use of Reclaimed Water for Potable Reuse: Converting Reclaimed Water into Beer

Jeff Prevatt (Pima County), Chuck Gerba (UA), and Ian Pepper (UA)

RATIONALE

- Reclaimed water can be subjected to advanced treatment to produce potable water safe for human consumption
- Biggest impediment is public perception – the "YUCK FACTOR"

Question: *How can this perception be changed?*
Answer: *Beer*

The “YUCK” Factor

- Term coined by University of Pennsylvania bioethicist Arthur Caplan
- Induced fear and repugnance of something even if it is not science based
- Examples:
  - “Toilet to Tap”
  - “Franken food”

Arizona Water Innovation Challenge

- Innovative solution for water sustainability in southwest AZ

- 35 team entries

- Pima County Wastewater Reclamation Department led our team along with

  -Tucson Water
  -Marana Water
  -Carollo Engineers
  -CH2M
  -AquaTecture
  -Clean Water Service
  and… The University of Arizona

- Prize = $302,500 funded by Arizona Community foundation and Water Now Alliance

Objectives

- Enhance public perception of reclaimed water for potable reuse
- Treat effluent from WWT to potable water standards via advanced treatment
- Convert the potable water into beer
- Ensure that the water is free of chemical **and microbial contaminants (WET Center focus)**

Approach (Overall)

- Build an advanced water treatment train on a mobile truck
- Drive truck to various towns in Arizona
- Treat effluent from WWTPs to potable standards
- Collaborate with local breweries to produce local beers
- Hold Beer Tasting Competition at National WateReuse meeting in Phoenix, September 2017

Approach (WET Center)

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- Analyze water for incidence of virus via qPCR and Cell Culture (CC)
  -Pepper mild mottle virus (qPCR)
  -Enterovirus (qPCR & CC)
  -Adenovirus (qPCR & CC)
  -Reovirus (qPCR & CC)

- Analyze sewage and final effluent after advanced treatment
- Need 12 log reduction of viruses from sewage to advanced treated water

Update

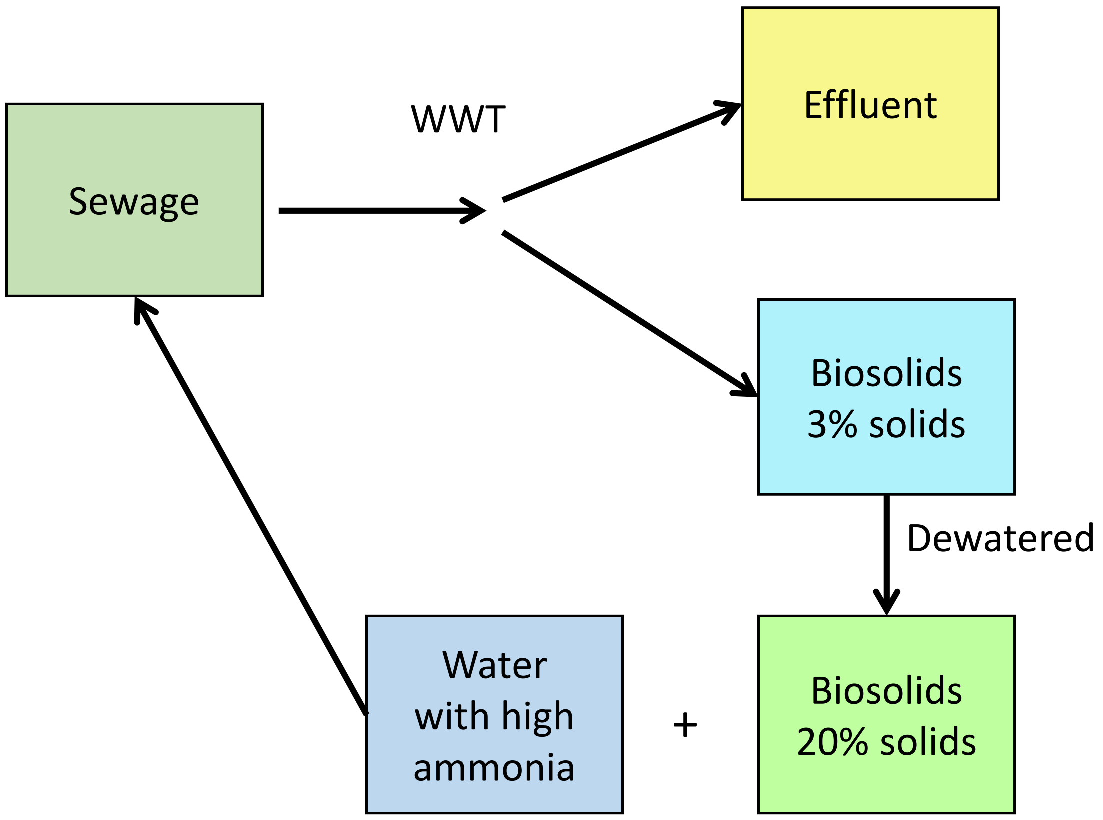
- Treatment train being built
  -Microfiltration, RO UV-AOP BAC


PLASTIC PIPE FITTINGS
PLASTIC PIPE FITTINGS
TARE WT. 7340
BRUTE


We're looking for you...
Are you a cutting edge brewery interested in demostrating enviromental stewardship?
...Join the challenge!
You will use water of our purification system to craft a beer to compete in our contest
ARIZONA PURE WATER BREW CHALLENGE
AZPUREWATERBREW.ORG

ANAMMOX FOR SIDE STREAM TREATMENT OF EFFLUENT

Jim Field (UA), Jeff Prevatt (Pima County), Chuck Gerba (UA), and Ian Pepper (UA)



Tres Rios WWTP: The Problem

- 0.5 mgd of water from the dewatering process
- High ammonium (1000 ppm)
- When put back into headworks, requires additional O_2 for nitrification
- Requires additional energy and $$$

Tres Rios WWTP: The Solution

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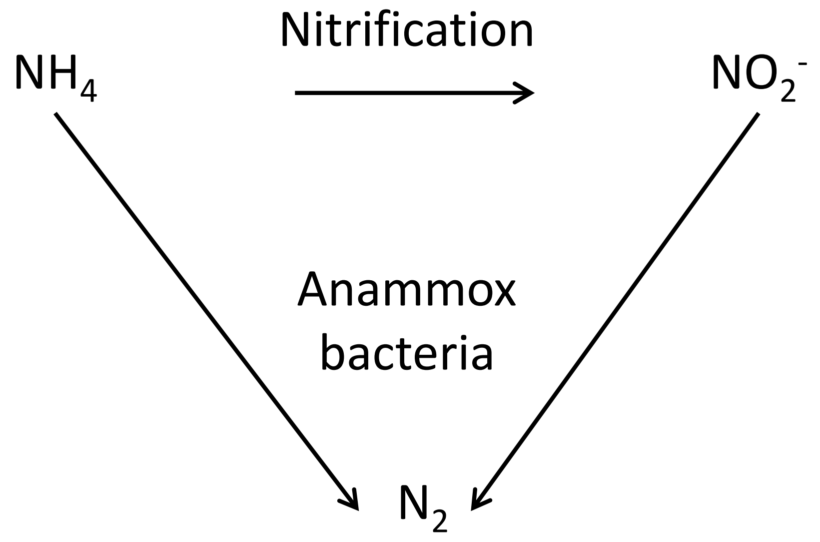
THE ANAMMOX PROCESS

- Microbial process
  - anaerobic oxidation of ammonium to N_2 using nitrite as a terminal electron acceptor



ANaerobic **AMM**onium **OX**idation

Anammox Autotrophic Consortia

- Aerobic ammonia oxidizing bacteria (AOB)

  +

- Anaerobic ammonium oxidizing bacteria (Anammox)

- Anitamox source of culture:

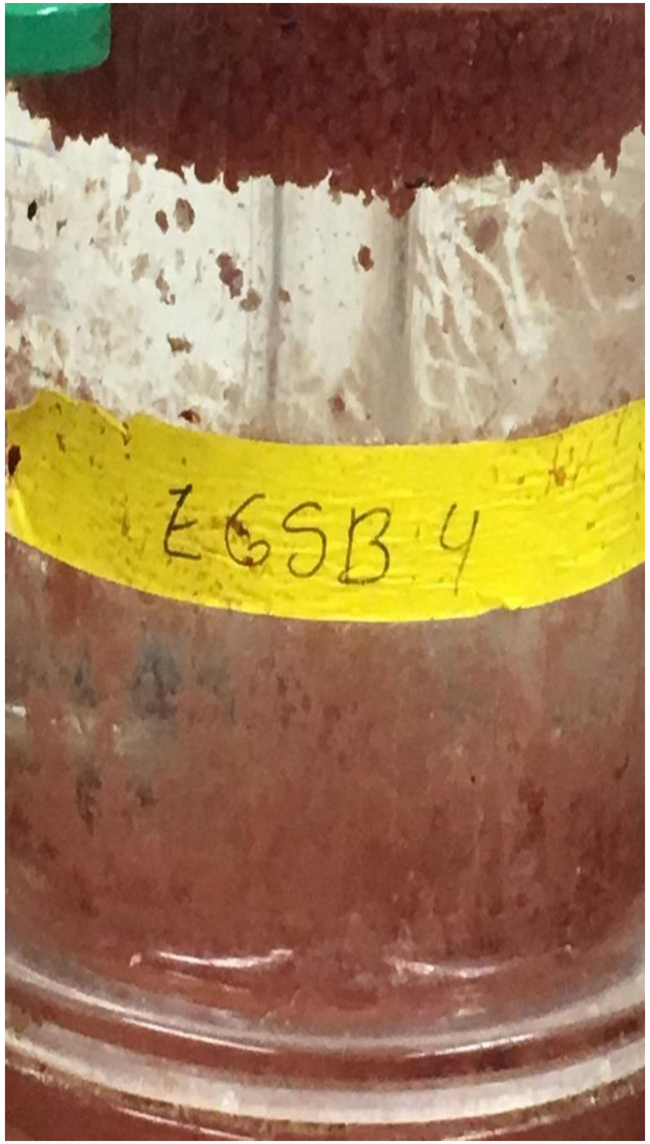
  $2.5m

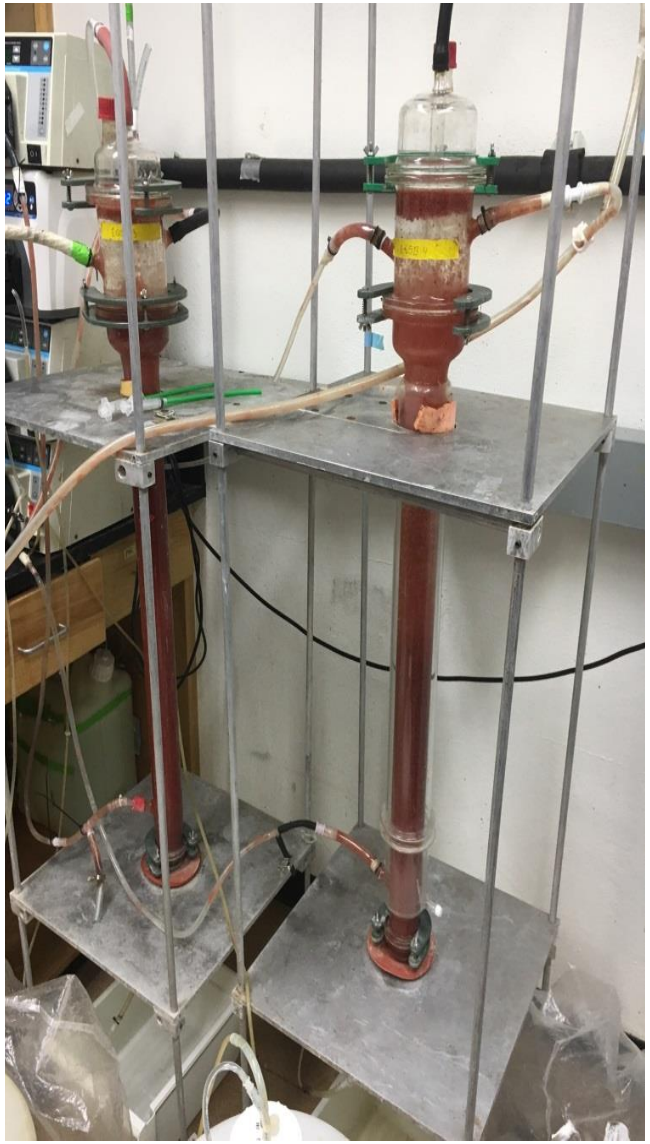
- Our source (Jim Field):

  $0

Anammox Bacteria

Jim Field's culture





Advantages of Anammox vs Nitrification/Denitrification

- Reduced aeration energy
  - 63% reduction in oxygen demand

- No supplemental carbon required
  - 100% reduction

- Less biomass (biosolids) produced
  - 80% reduction

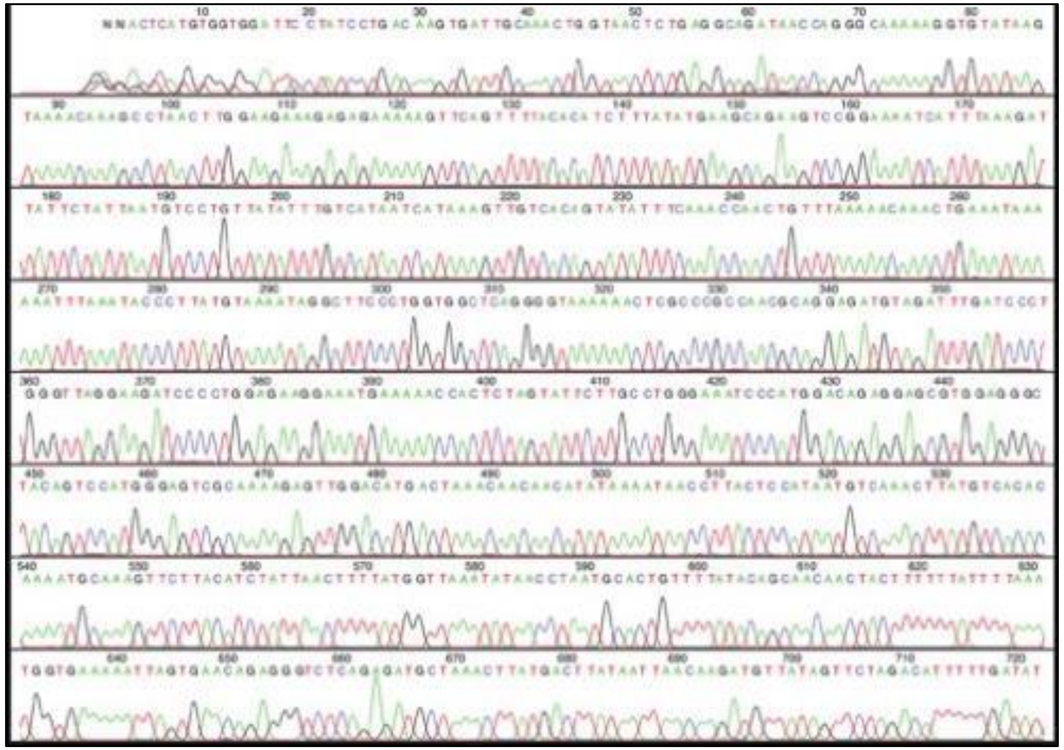
Next Generation Sequencing for Process Control

Evaluate the use of 16S and 18S Illumina high-throughput sequencing technology as a process control and optimization tool for microbial consortia:

- Characterize microbial biomass and community structure
- Assess metabolic activity of microbial consortia via gene expression
- Determine impact of anammox on community membership and gene functionality

Activated Sludge Sample

DNA Extraction Kit



Sequencing Output Example

Influence of Anammox on Viral Inactivation

- Analyze water from the dewatering process for incidence of virus via qPCR and cell culture (cc)
  - Pepper mild mottle virus (qPCR)
  - Enterovirus (qPCR & cc)
  - Adenovirus (qPCR & cc)
  - Reovirus (qPCR & cc)

- Analyze final effluent for viruses after anammox treatment

Approach: Sidestream Treatment

January 2017 Phase 1 Pilot-Scale

- 30 to 500 gallon reactors
- Operational for 12 months

January 2018 Phase 2 Full-Scale Sidestream Treatment

- Anticipated savings for Tres Rios ≃ $0.5m annually

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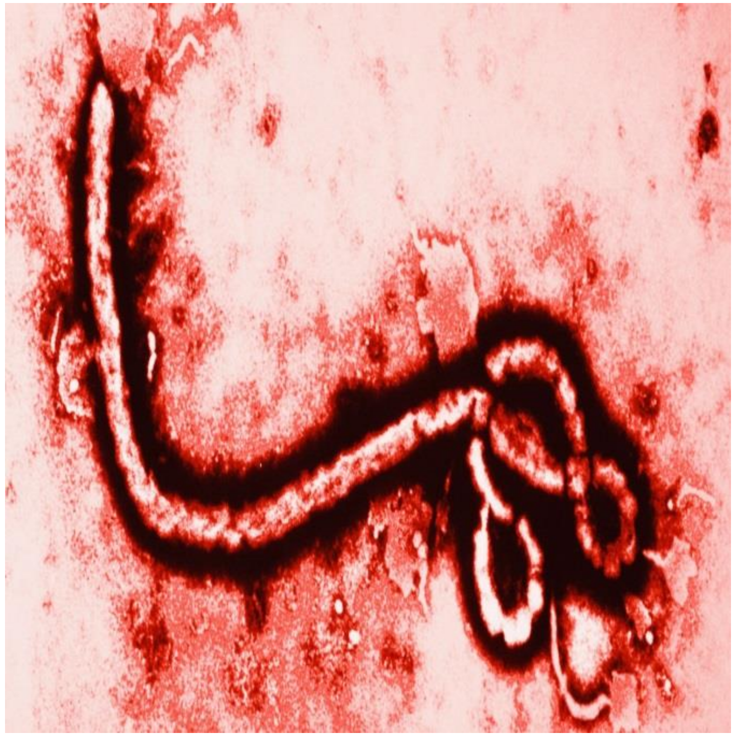
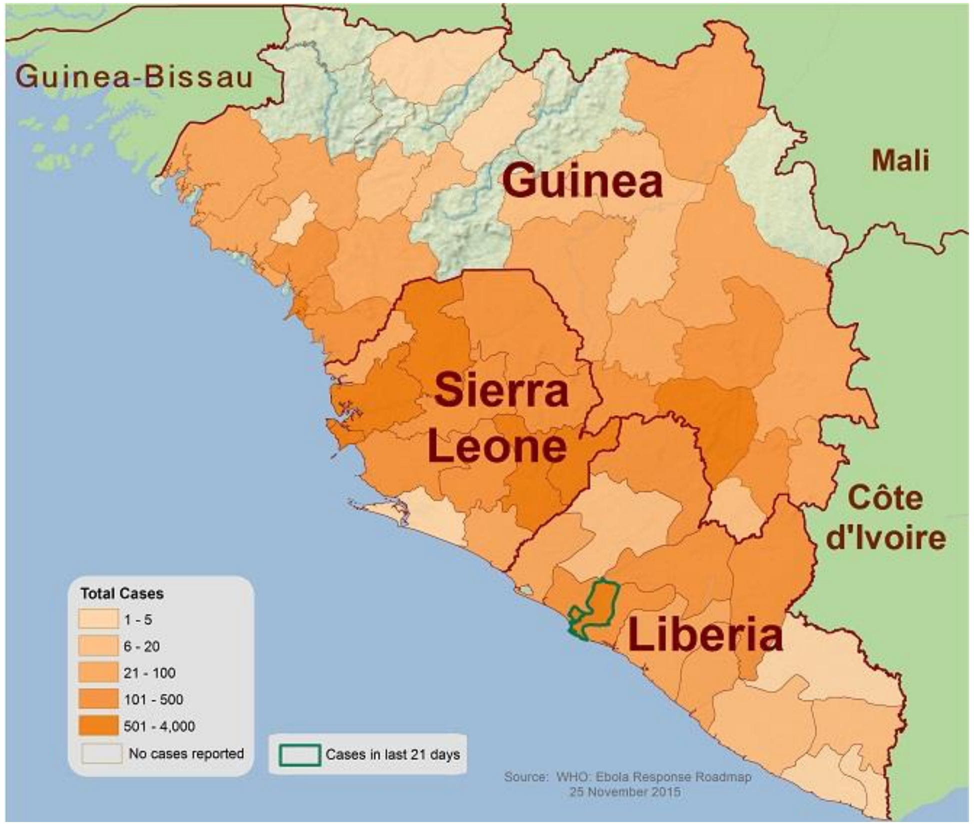
EBOLA: Does it Survive in Sewage and During Wastewater Treatment?

Chuck Gerba
The University of Arizona



Implications of Ebola on

- 2014 Outbreak in West Africa: Sierra Leone and Liberia
  - **24,797** suspected cases
  - **~12,000** laboratory confirmed cases
  - **8,764** deaths
- Guinea continues to see widespread transmission with **3,351** laboratory confirmed cases and **2,536** deaths (**75.7%** Case-fatality rate)
- Ability to spread to US, UK, Italy, Spain, Nigeria, Mali and Senegal



Funded by CASA

FATE OF EBOLA IN THE ENVIRONMENT

- Concern over exposure via contaminated sewage
- Is current guidance adequate for waste disposal down the toilet?
- Need to determine fate of Ebola during wastewater/biosolids treatment

OBJECTIVE

Utilize viral surrogates for Ebola to evaluate its fate during toilet disposal and biosolids treatment

APPROACH

- Survival in human waste that could be flushed down the toilet with and without disinfection
- Survival during mesophilic and thermophylic anaerobic digestion of sewage sludge

SURROGATES

- MS-2
- Phi-6 (lipid containing phage)
- Murine norovirus

Impact of Flushing on Restroom Contamination

- MS-2 coliphage
  - Inoculum titer: ≈1xE+11 PFU
- Collect toilet bowl sample of water
- Water samples taken after 1, 2 and 3 flushes
- Sample fomites in restroom for aerosolized virus contamination

Ebola

Occurrence of MS-2 norovirus after a toilet flush

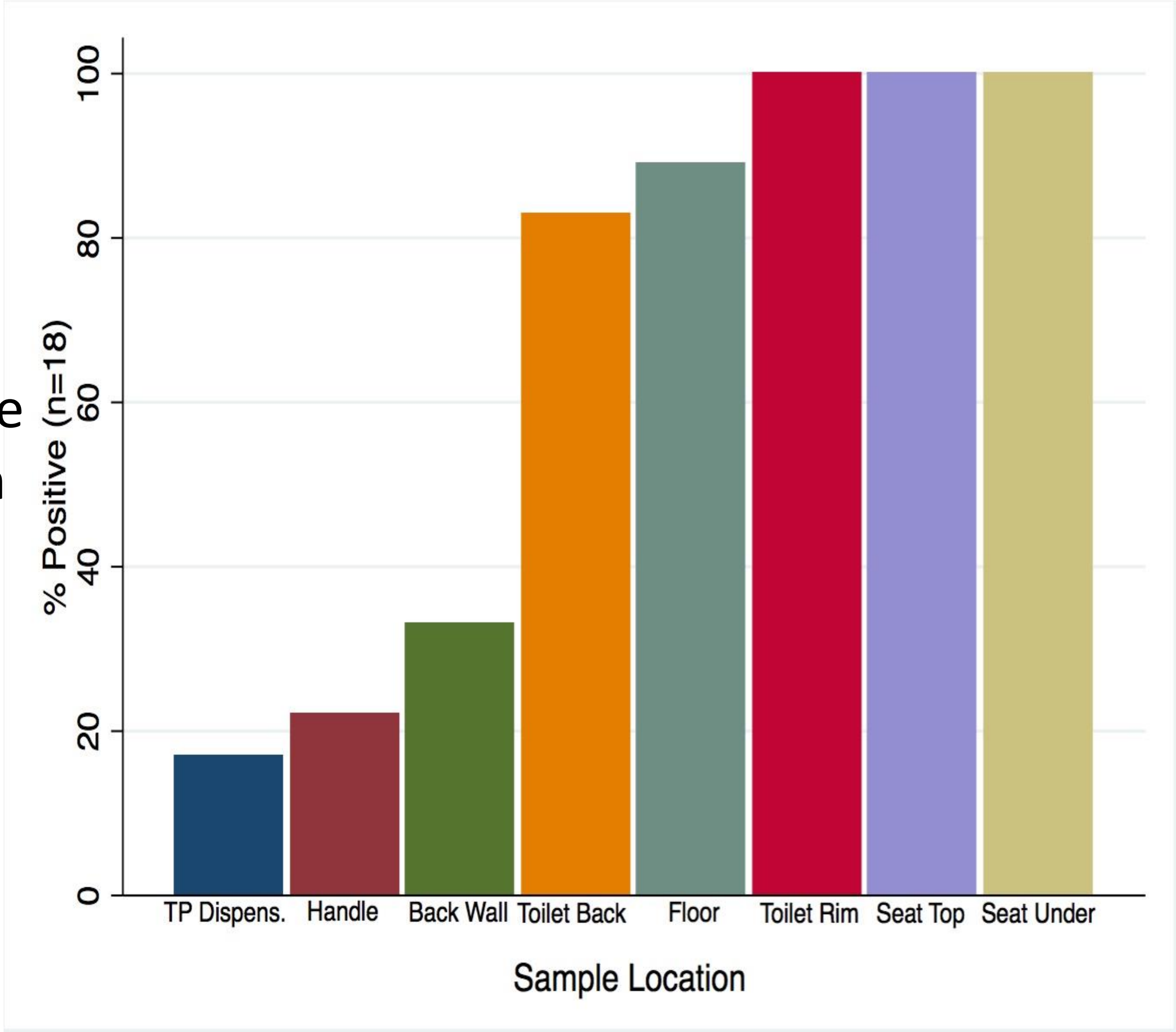
Surface Contamination of Fomites

Geometric Mean Concentrations, by Sample Site (n=18)	
Sample Site	**Mean ± SD (Log_{10} PFU) per surface ($100\ cm^2$)**
Flush Handle*	1.65 ± 0.91
Toilet Back	2.89 ± 1.04
Back Wall	1.63 ± 1.36
Floor	3.44 ± 1.08
Toilet Paper Dispens.	1.49 ± 1.41
Toilet Bowl Rim	3.88 ± 1.59
Toilet Seat Top	4.21 ± 1.26
Toilet Seat Underside	4.22 ± 1.26

*denotes $90 cm^2$ total surface area

Percent of Sites in which MS2 was Detected (N=18)

**Only 1/54 flush water samples positive. No positive water samples with ANY treatments.



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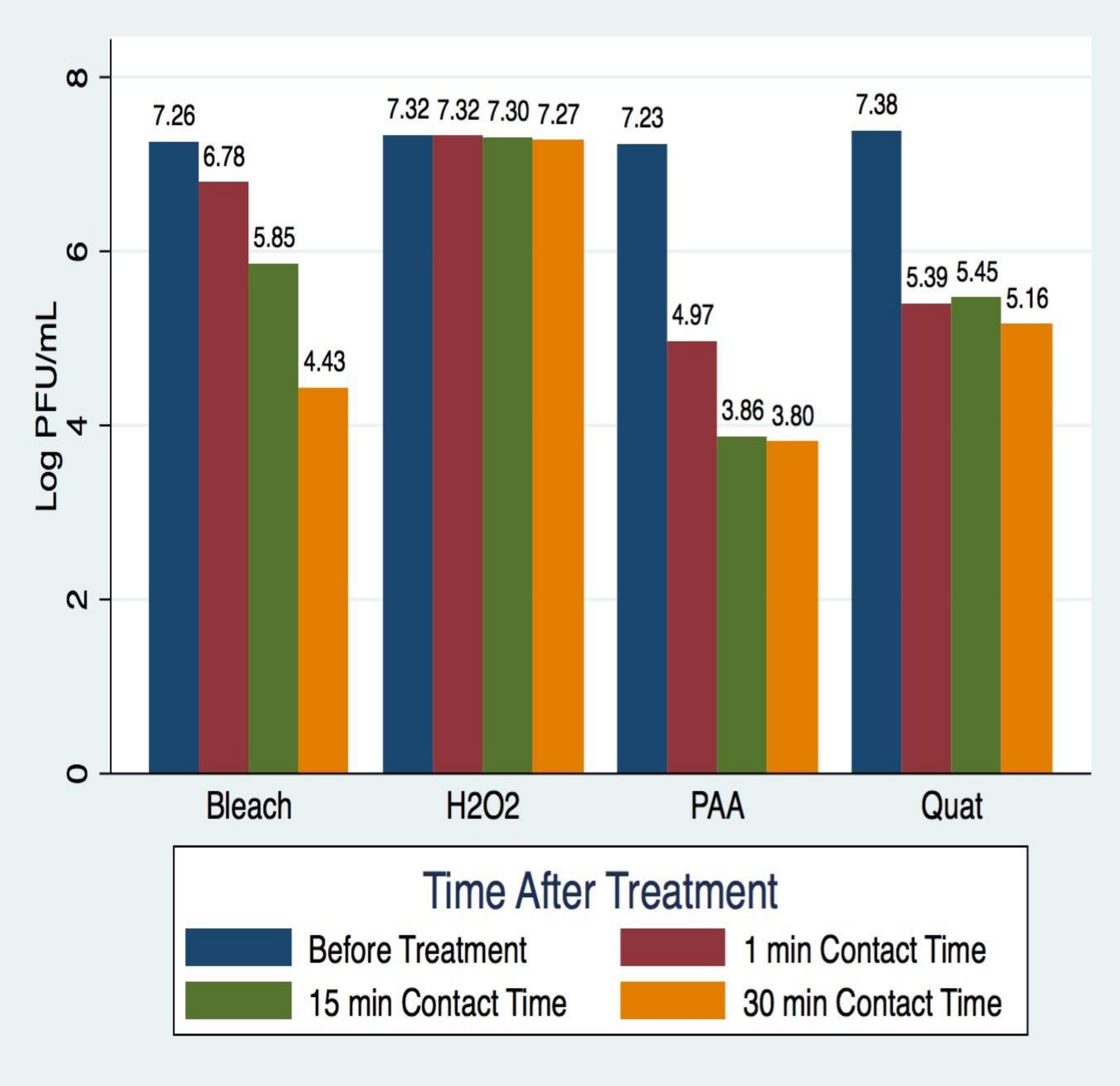
Disinfectant Efficacy for Toilet Water*

Log-reduction (per mL) by treatment and contact time			
Treatment	1 minute	15 minute	30 minute
Chlorine Bleach	0.48	1.4	2.83
Hydrogen Peroxide	0.01	0.03	0.06
Quaternary Ammonium	1.99	1.93	2.22
Peracetic Acid	2.26	3.37	3.43

*1 liter of trypticase soy broth added to bowl to stimulate bodily fluids

Log Survival of MS2 by Tested Disinfectants



TOILET STUDY CONCLUSIONS

- Flushing virus contaminated water leads to significant contamination of fomites within bathroom.
- Efficacy of disinfectants greatly reduced in presence of high organic load within toilet.
- Efficacy of disinfectants:
  - Peracetic acid > quaternary ammonium > bleach

RECOMMENDATIONS

- Disinfection of waste should be practiced, when possible
- Surface disinfection still very important after flushing waste to eliminate fomite transmission potential
- Peracetic acid or quaternary ammonium should be used for short contact times (1 min)

EcōsPure

Smart Polymers and Reduced Consumptive Water Use of Turfgrasses

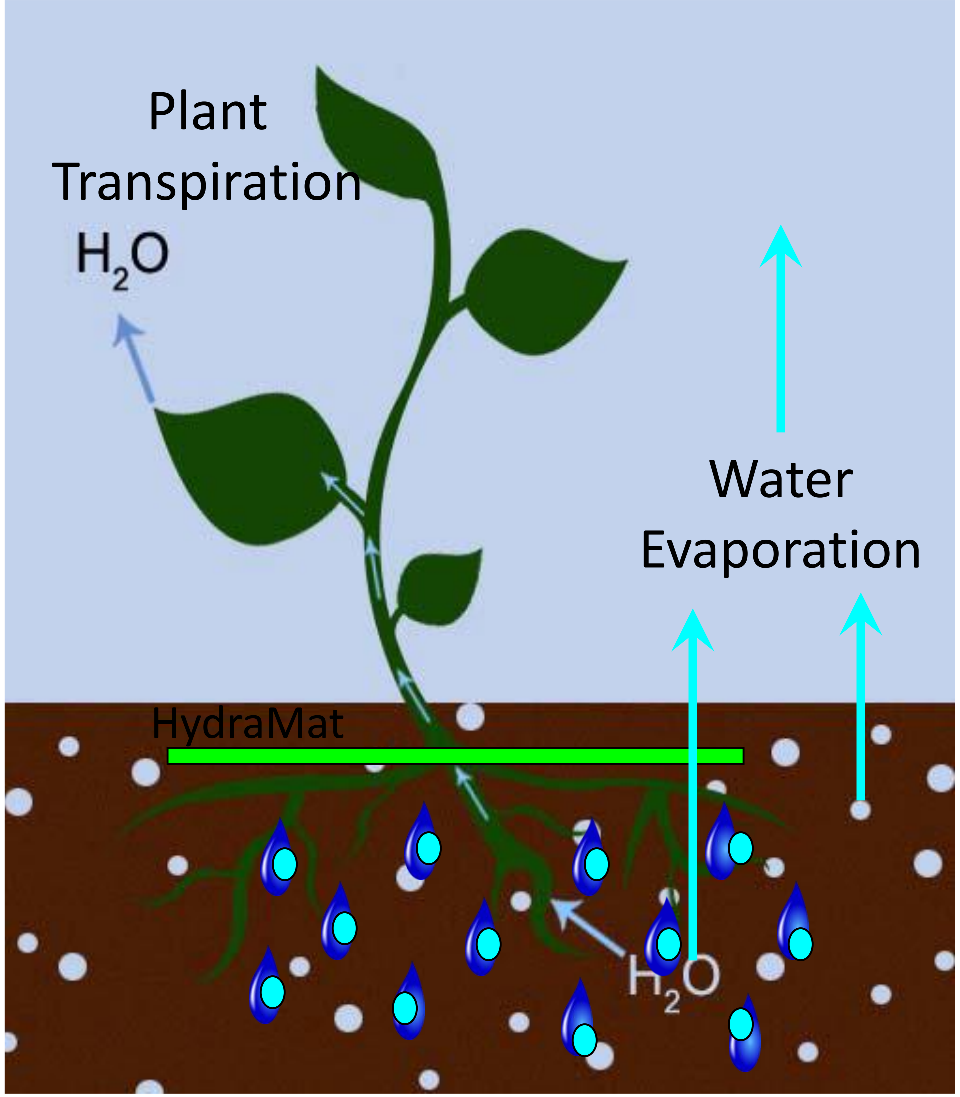
Innovative Polymers

New polymer applied to a porous fabric (Hydramat) reduces consumptive water use of turgrasses by reducing evaporation from soil

- Polymer is polyethylene glycol (PEG) based
- Elastomeric polymer with small (nm) pores
- High surface area creates cool subsurface micro-climate that condenses water vapor

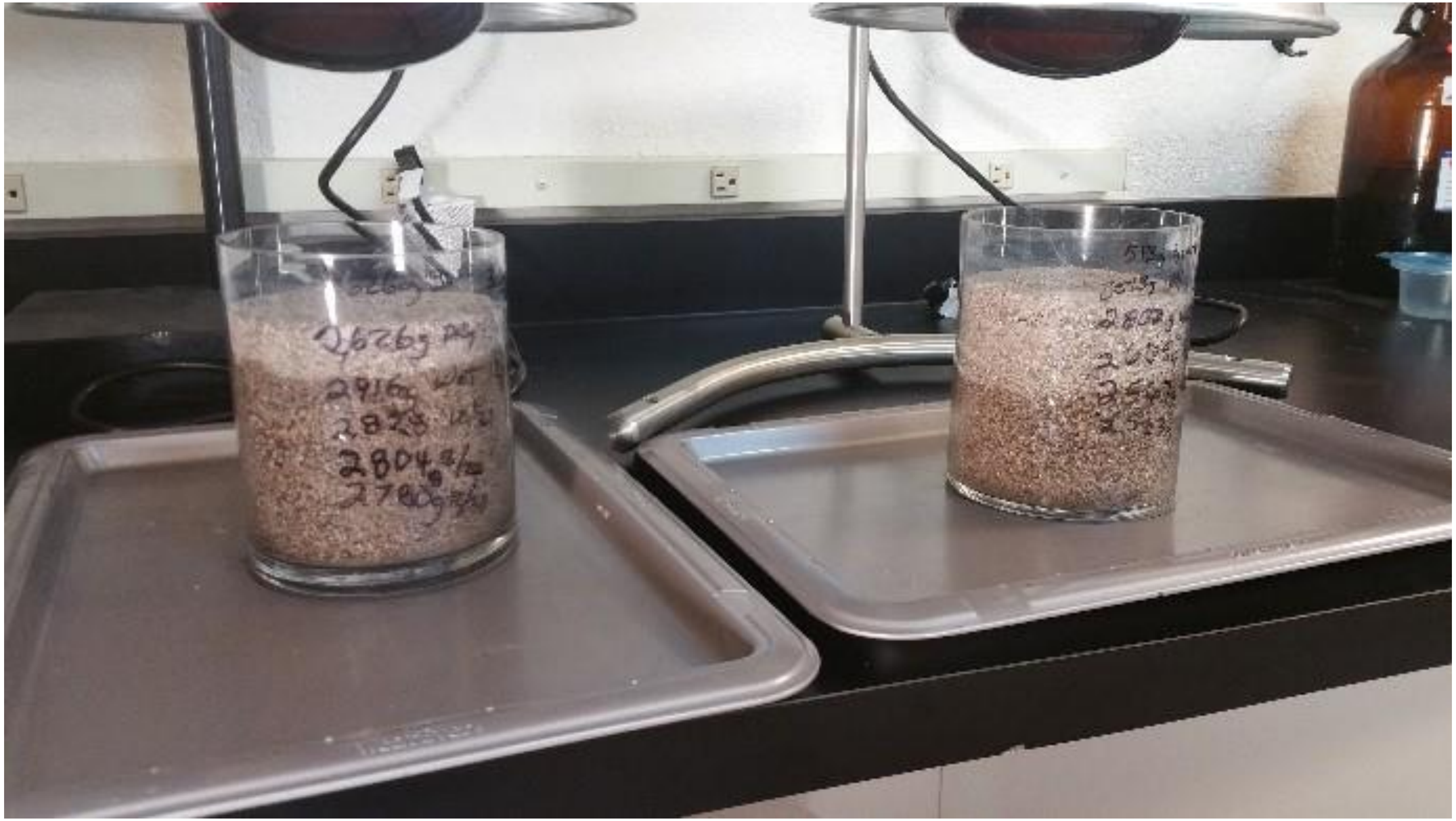
How HydraMat Works

- HydraMat slows down evaporation of water
- Reduces irrigation water use by 50% or more



HydraMat™ by EcōsPure

Hydramat vs No Hydramat



Objectives

- Demonstrate proof-of-concept for reduced consumptive water use of turgrasses through the use of Hydramat
- Evaluate the effect of Hydramat on plant root growth and soil bacteria

Approach

- PEG polymer applied to porous fabric which is layered beneath turfgrass sod
- Soil moisture sensors used to determine when the turfgrass should be irrigated, amount of irrigation water applied is recorded
- Soil cores taken periodically for heterotrophic plate count analysis and soil moisture content
- Root growth evaluated after 8 weeks
- Four replicates each of control (sod) and treated sod (Hydramat)


PIONEER
LANDSCAPING MATERIALS INC.


TO CONSERVE GROUNDWATER, THIS PROPERTY IS IRRIGATED WITH RECLAIMED WATER
DO NOT DRINK FROM THE IRRIGATION SYSTEM
NO TOME AGUA DEL SISTEMA DE RIEGO


TO CONSERVE GROUNDWATER, THIS PROPERTY IS IRRIGATED WITH RECLAIMED WATER
DO NOT DRINK FROM THE IRRIGATION SYSTEM
NO TOME AGUA DEL SISTEMA DE RIEGO

Key Deliverables

- Proof of concept for new technology to reduce water use by turfgrass
- Evaluation of effects of Hydramat on plant root growth and soil bacteria
- Final Report

Assessment of Innovative and Advanced Technologies for Control of Microbial Pathogens

- Molecular and microbial technologies for water treatment
- Antimicrobial coatings for use in the health care environment
- Development of innovative antimicrobials for wash water in the food industry
- Quantification of RO and ultrafilter membranes for removal of emerging viral pathogens – full scale systems
- Removal of emerging viral pathogens by advance oxidation processes – full scale systems

Interactions with WEST/Federal Government

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CONSERVE
Sustainable Water Reuse~Food~Health

Determine suitability of non-traditional irrigation waters for food crops – USDA funded center

Kelly Bright

Channah Rock
Chuck Gerba - $1.7m

CPS
CENTER for PRODUCE SAFETY

1) New indicators of viruses in water
2) Use of next generation sequencing to develop new indicators of water quality
3) Occurrence of the protozoan *Cyclospora* in water and wastewater.

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