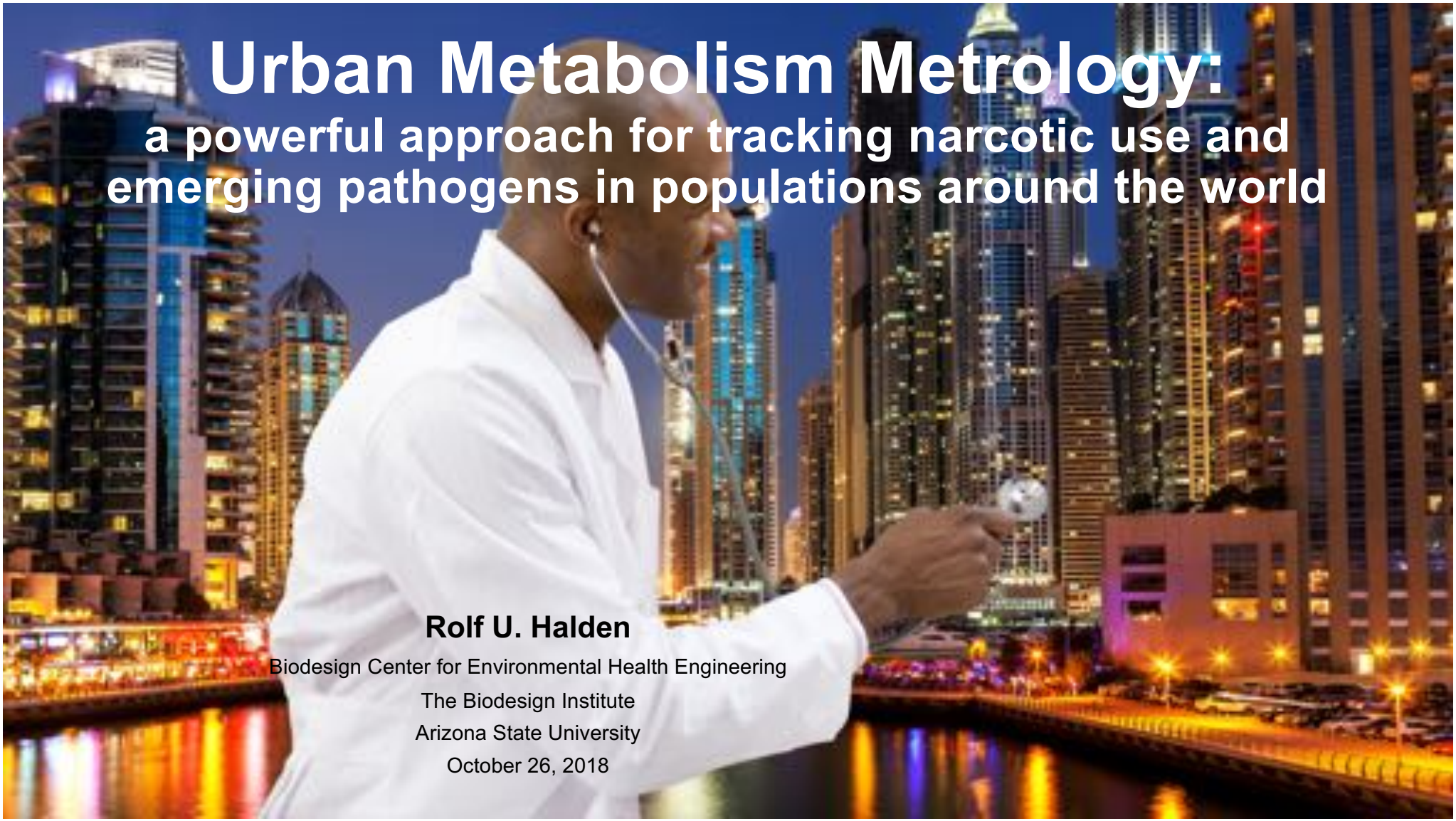


Urban Metabolism Metrology:

a powerful approach for tracking narcotic use and emerging pathogens in populations around the world

Rolf U. Halden

Biodesign Center for Environmental Health Engineering

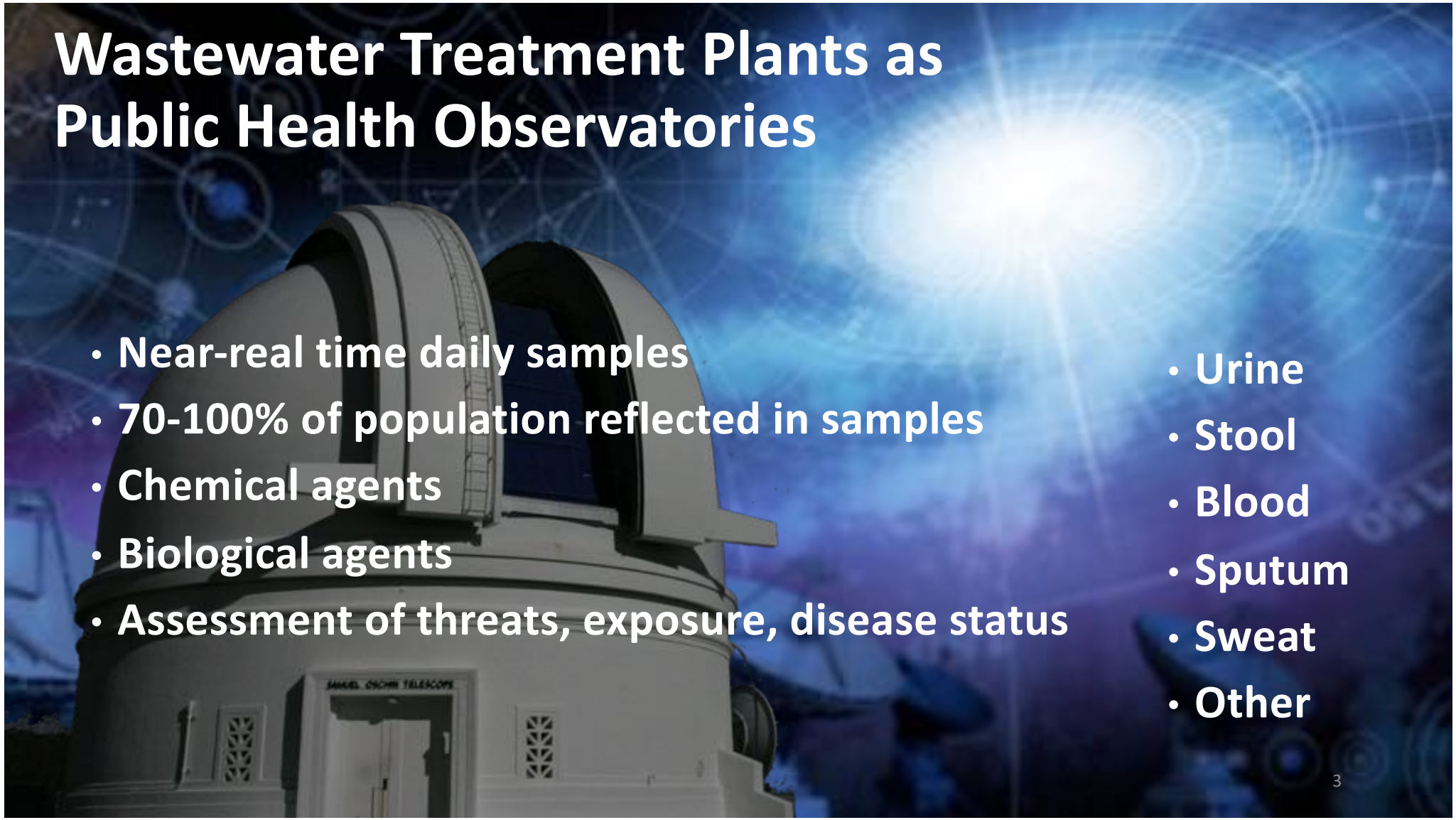
The Biodesign Institute

Arizona State University

October 26, 2018


Diagnosing Cities
in Near Real-Time
Your
Community's
Health
Wastewater
Diagnostics
Population Health
& Sustainability
Assessment

Wastewater Treatment Plants as Public Health Observatories

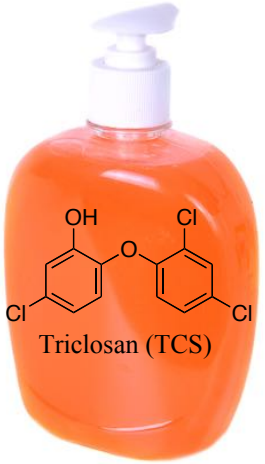


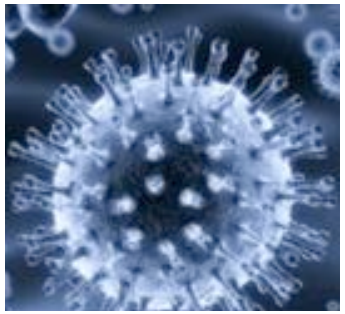
- Near-real time daily samples
- 70-100% of population reflected in samples
- Chemical agents
- Biological agents
- Assessment of threats, exposure, disease status

- Urine
- Stool
- Blood
- Sputum
- Sweat
- Other

Outline

- Case study => antimicrobials & antibiotic resistance
- Opioid epidemic
- Surveillance of infectious diseases & resistance genes



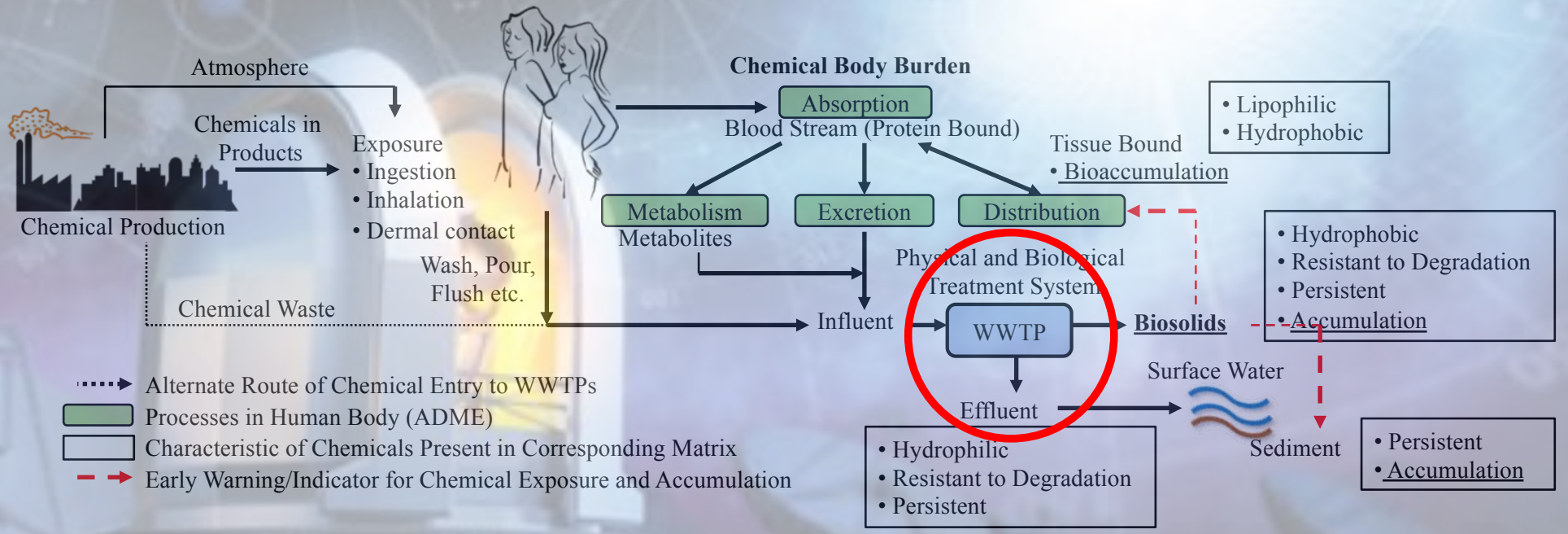


Heidler & Halden, Chemosphere 2007, 66(2):362-369

Image Credits: fair-use-internet sources

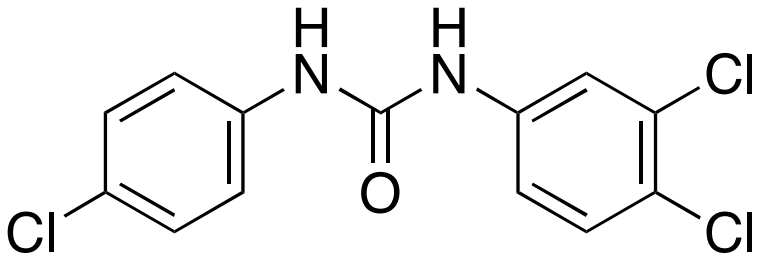
Wastewater Treatment Plants (WWTPs)

Accessing an underutilized 'Information Super Highway'

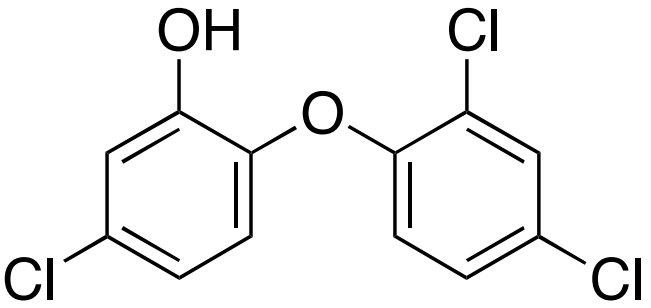


Venkatesan & Halden, 2014. *Sci. Rep.* 4, paper #3731

Successful Case Study: Antimicrobial Compounds



Triclocarban (TCC)



Triclosan (TCS)

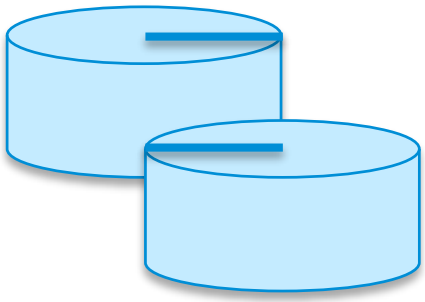
ES&T, 2014. 48(7):3603−3611

Wastewater-based Epidemiology

– Key Information from the Mouth of the WWTP

Centralized sewer system

Wastewater Treatment Plant (WWTP)

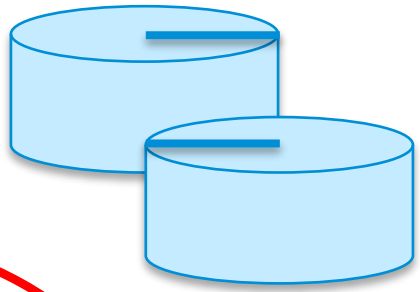


Anonymized, composited health information (in urine, stool, sputum & blood) **of the entire community**

UMM: Additional Critical Data Gleaned from WWTPs

http://pixgood.com/sch...ommunity-clipart.html

Wastewater Treatment Plant (WWTP)



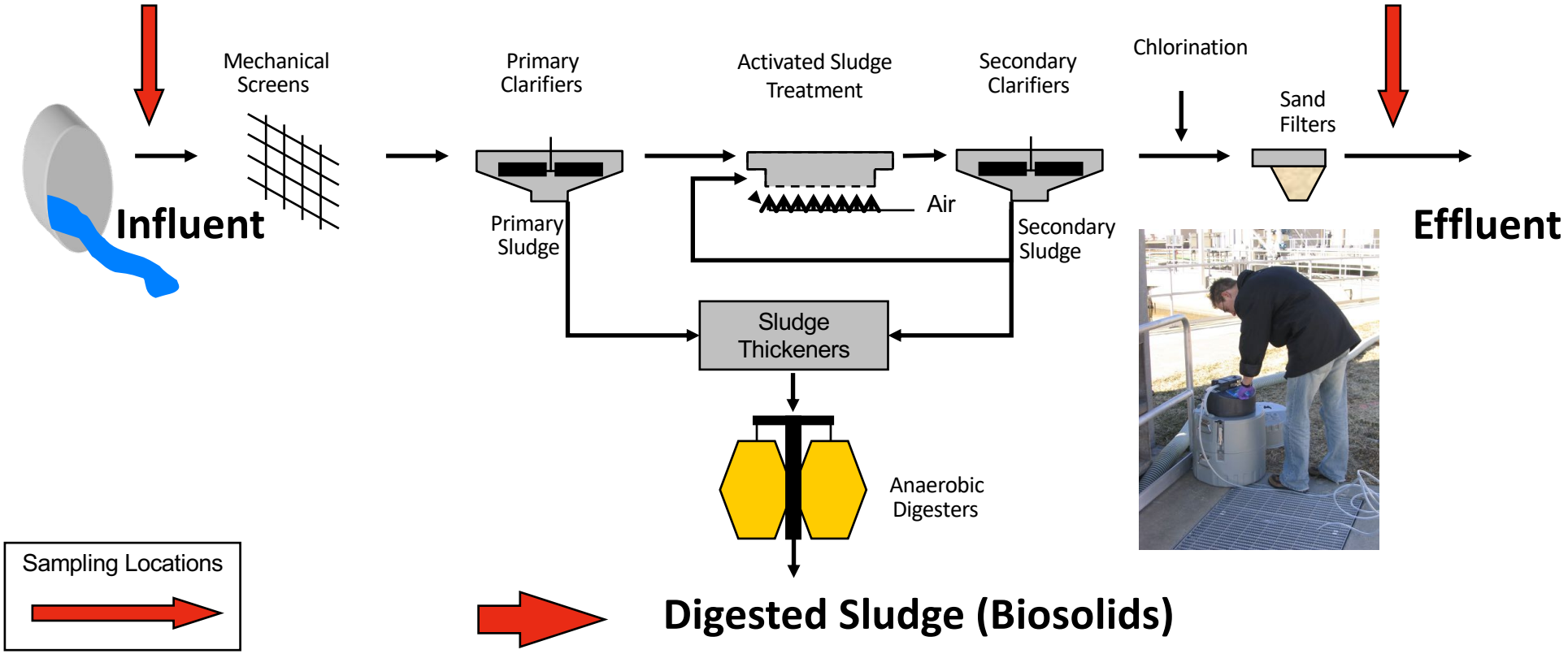
Persistent, water-soluble chemicals in effluent

Non-persistent, **green chemicals** degrade

Persistent, potentially bioaccumulative chemicals in sludge

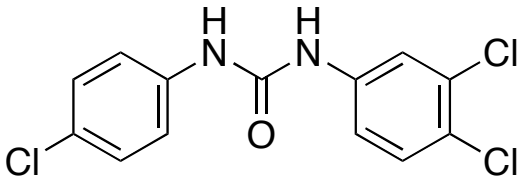
Halden, 2018

Antimicrobials: what quantity and where do they go?

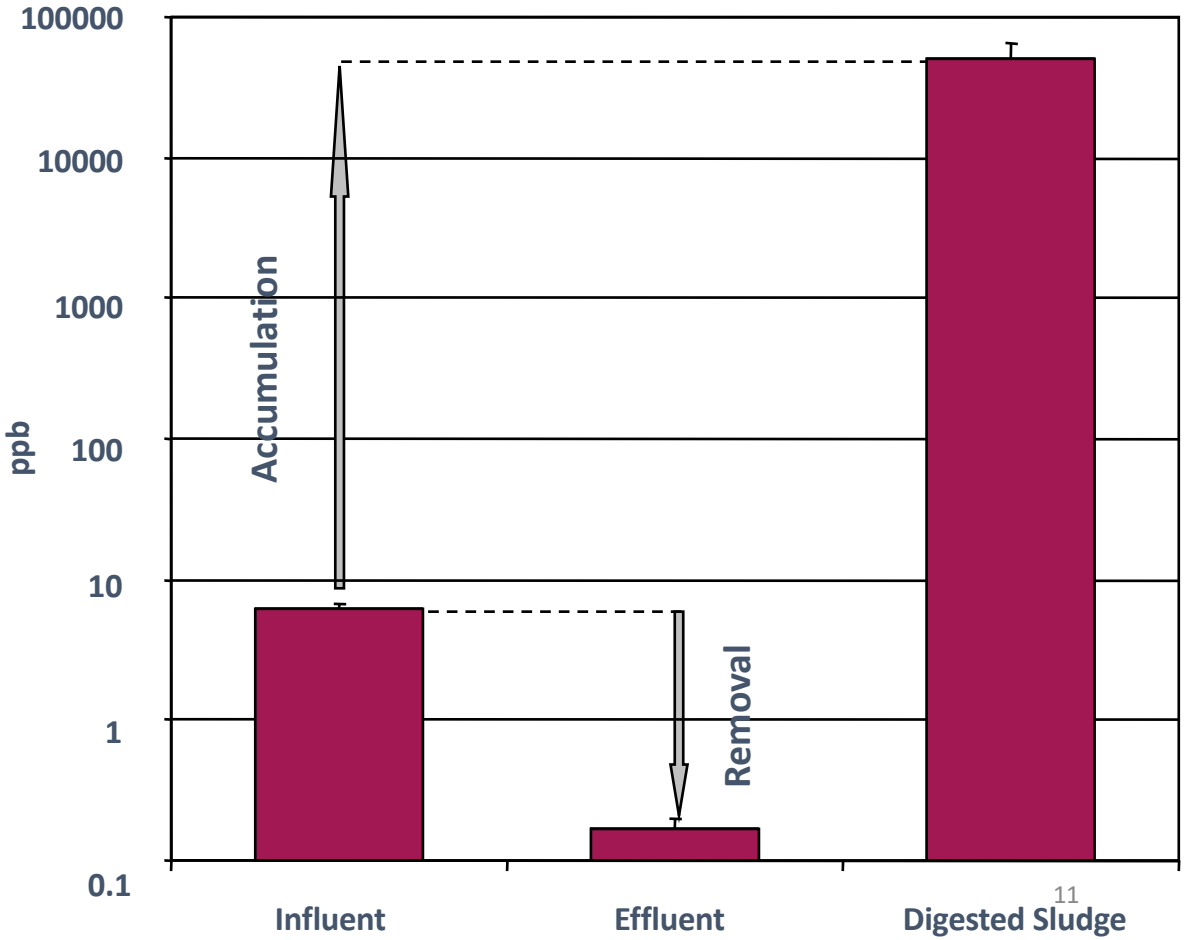


Heidler & Halden, ES&T 40:3634-9 (2006)

Removal ≠ Degradation

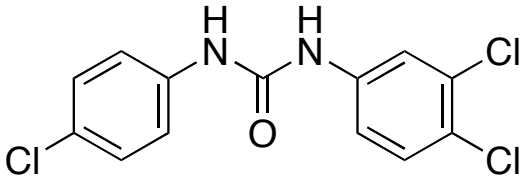


Triclocarban (TCC)

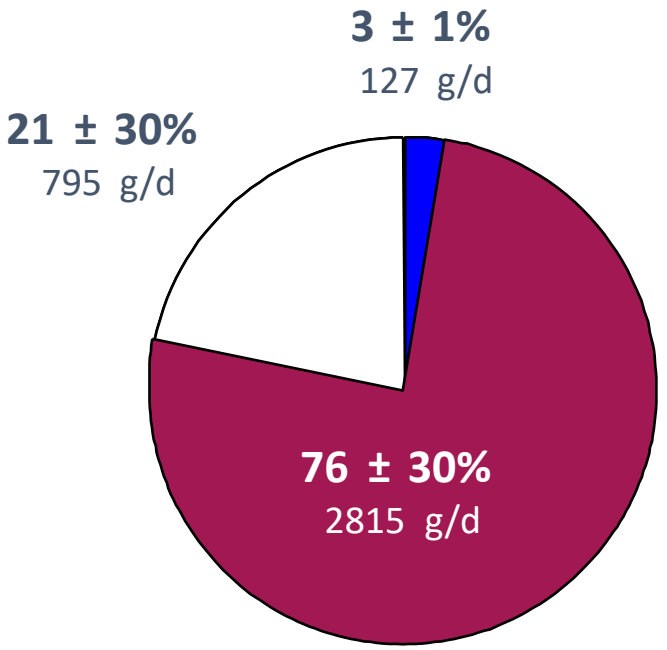


Heidler & Halden, ES&T 40:3634-9 (2006)

Mass Balance Assessment: Fate of TCC During Activated Sludge Treatment

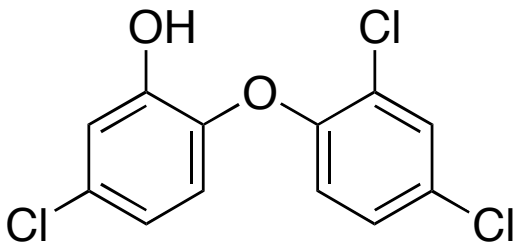


Triclocarban (TCC)

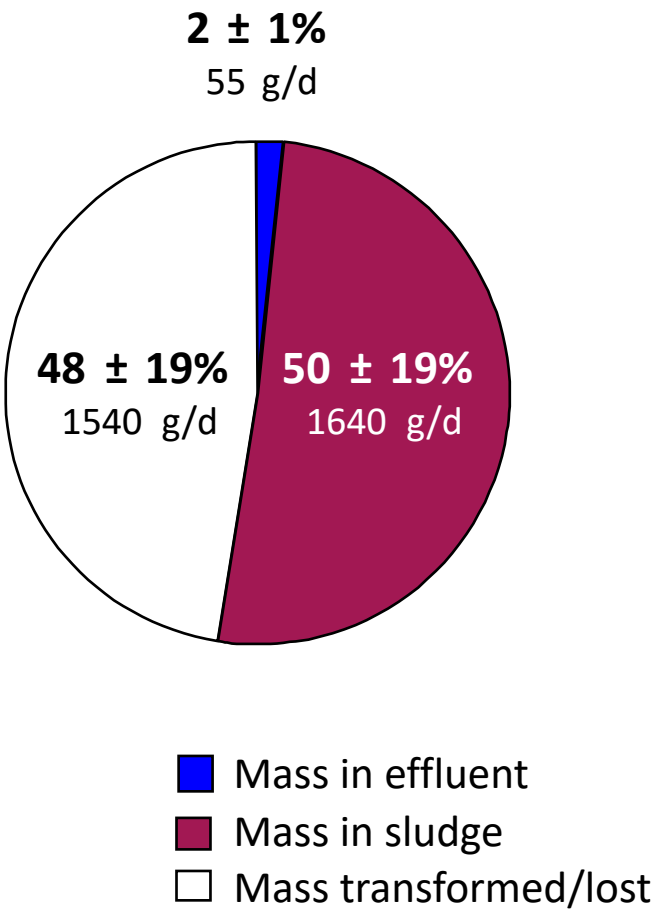


Heidler & Halden, ES&T 40:3634-9 (2006)

Mass Balance Assessment: Fate of Triclosan in Activated Sludge WWTP



Triclosan (TCS)



Heidler & Halden, Chemosphere 2007, 66(2):362-369

Scale-up of Uses and Production of TCC & TCS

Halden, ES&T, 2014. 48(7):3603−3611

What Happens to Antimicrobials in Soap?

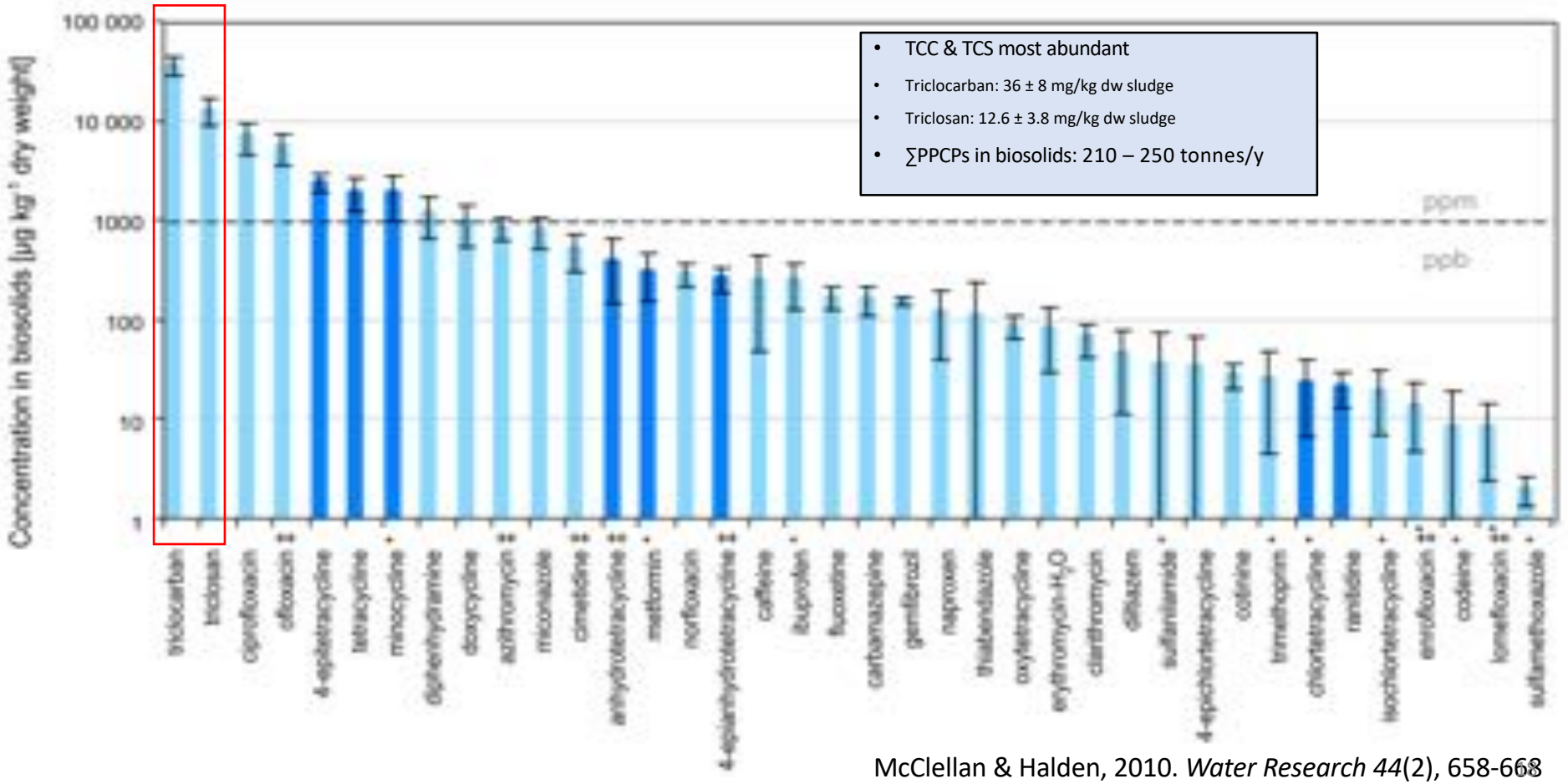
About 450,000 lbs/y of triclosan and triclocarban are applied inadvertently on U.S. agricultural land via sewage sludge disposal

Pathway for contamination of water and food with antimicrobials and drug-resistant pathogens

Environ. Sci. Technol. 2014, 48, 3603−3611

Antimicrobials: from production to use to wastewater to fertilizer to crops to food.

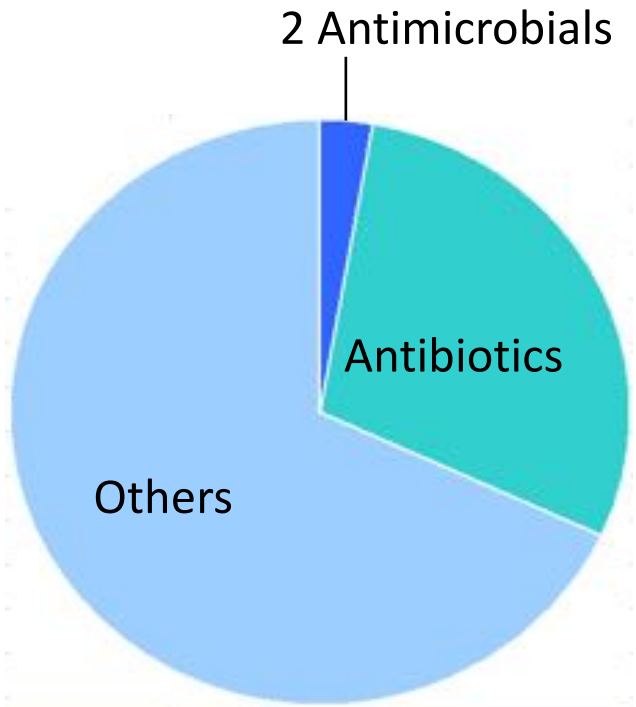
Pharmaceuticals in NSSS Samples from 2001



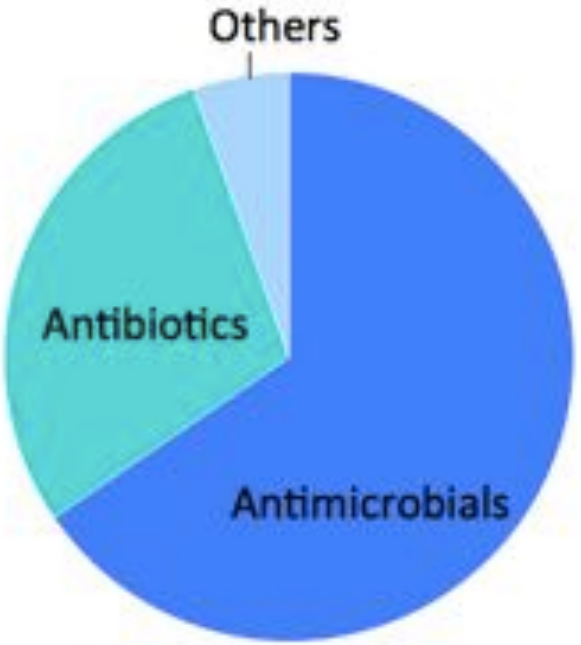
- TCC & TCS most abundant
- Triclocarban: 36 ± 8 mg/kg dw sludge
- Triclosan: 12.6 ± 3.8 mg/kg dw sludge
- ∑PPCPs in biosolids: 210 – 250 tonnes/y

McClellan & Halden, 2010. *Water Research 44*(2), 658-668

Triclosan & Triclocarban: Regulatory Intervention



Number of Compounds, N = 72



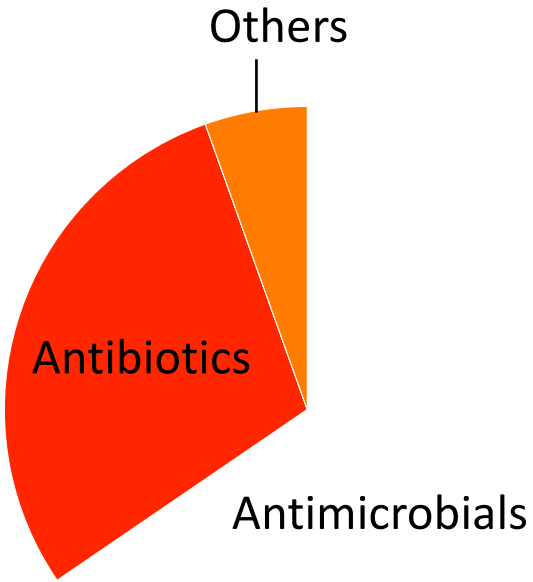
Mass of Compounds

EPA Method 1694

McClellan & Halden, Water Res. 44: 626-636

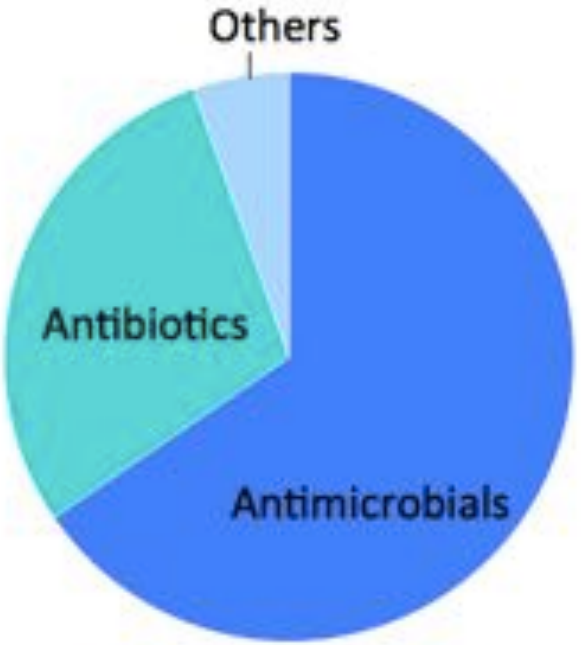
Impact of U.S. FDA Ban

U.S. Ban announced 2016, effective September 2017



Removal of TCS/TCC => 60% less PPCP mass in sludge

Halden, 2014. *ES&T* 48:3603−3611



Mass of Compounds

EPA Method 1694

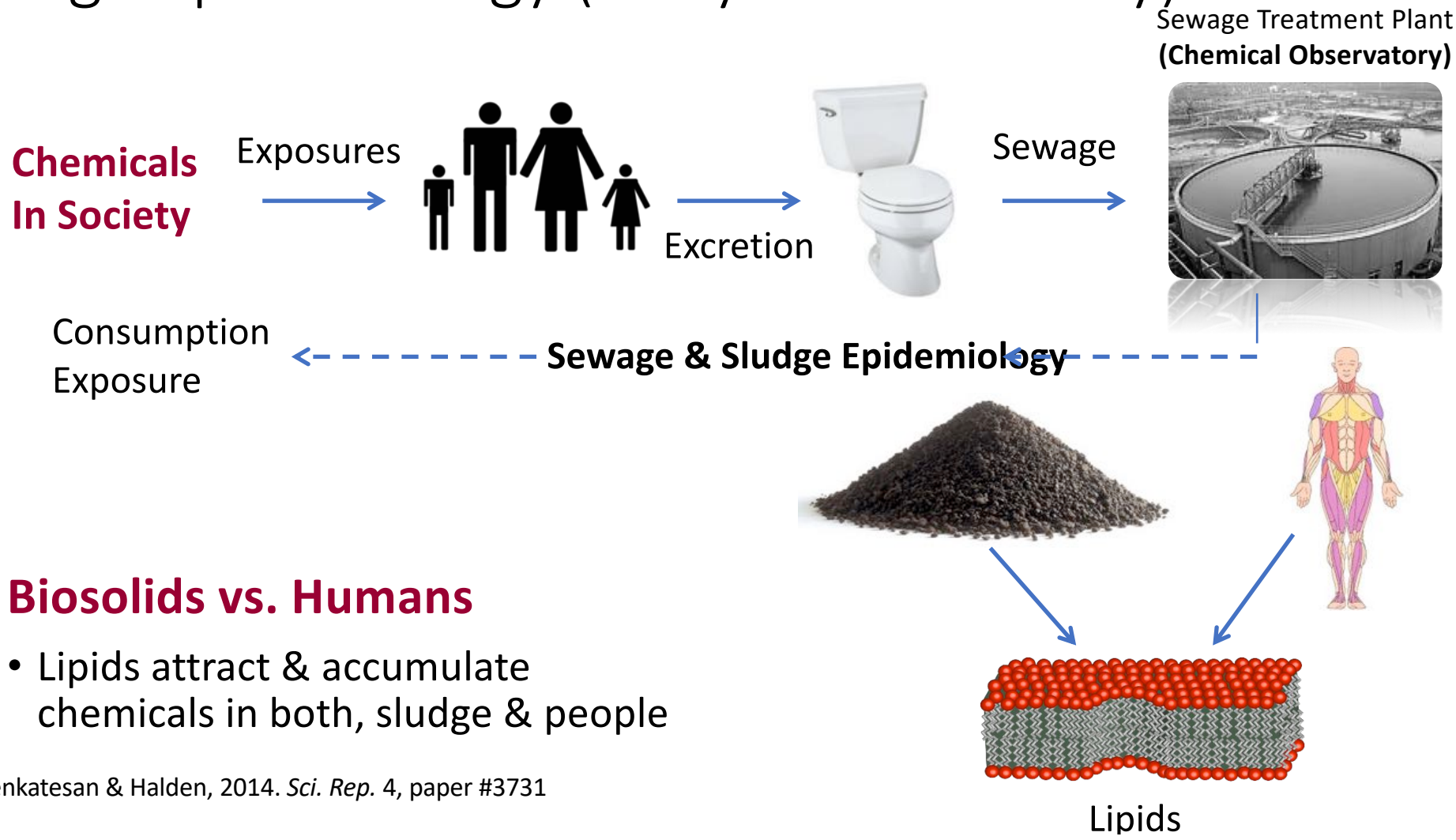
Human Health Observatory (HHO) at ASU

- >300 WWTPs globally; >200 in U.S.
  - Representative of 16,000+ U.S. plants
  - Unbiased national estimates
- >10% of U.S. pop.; >32M people
- >150M people worldwide
- Largest archive in the U.S./world
- Anonymity through size

Environ. Sci. Technol. 2014. 48, 3603−3611

Venkatesan & Halden, 2014. *Environ. Sci. Pollut. Res.* 22 (3), 1577-1586

Sludge Epidemiology (Body Burden Study)



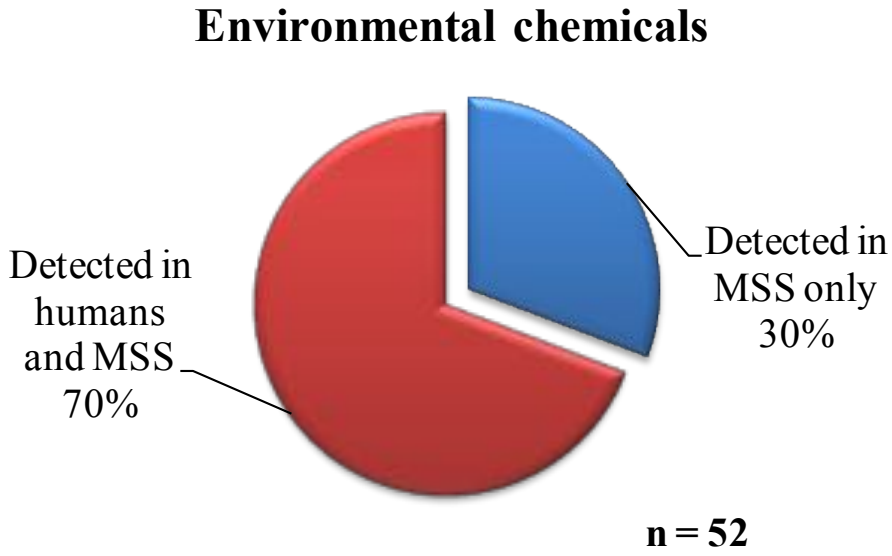
Biosolids vs. Humans

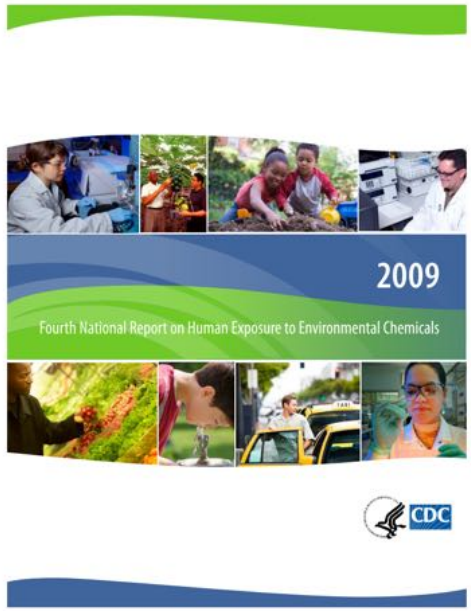
- Lipids attract & accumulate chemicals in both, sludge & people

Venkatesan & Halden, 2014. *Sci. Rep.* 4, paper #3731

Qualitative Info: Toxic Chemicals in U.S. People

- CDC national report on human exposure to environmental chemicals
- 139 chemicals detected in human samples, NHANES
- Compare with MSS (52 chemicals commonly screened)

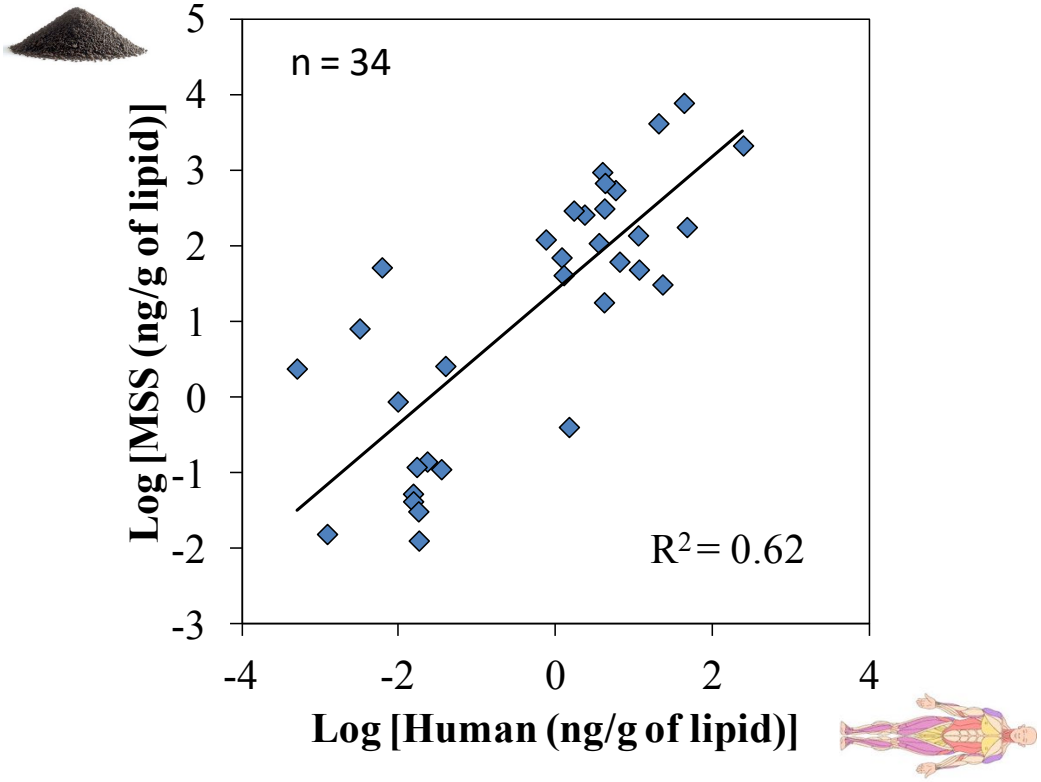




- 36 detects our of 52
- **~70% overlap**

Venkatesan & Halden, 2014. *Sci. Rep.* 4, paper #3731

Quantitative Info:
Chemical Body Burden in Humans



- Lipid-normalized concentration
  - Chemicals detected in human serum and tissues

- **Indicator** of chemical body burden in humans
- Biosolids are a sentinel matrix; not the source of exposure
- **'Early warning system'**

Venkatesan & Halden, 2014. *Sci. Rep.* 4, paper #3731

Community Wastewater – A Public Health Indicator

- Usage rate of chemicals (e.g., drugs) in communities
  - Proportional to levels in untreated wastewater
- Economical and accessible epidemiological data
- **Anonymous**

Chemicals; drugs

Population chemical use

Urinary & fecal excretion

WWTP - Measurement of chemicals, drugs and metabolites

$$\text{Per capita consumption} = \frac{\text{Mass of chemical/drugs}}{\text{Population}}$$

Metrics and Biomarkers Monitored

Metrics	Parameter	Biomarkers and Proxies
Diet	Soy/Vegetables Meat	Phytoestrogens Creatinine
Lifestyle	Cigarette smoking Alcohol ingestion Substance Abuse	Tobacco metabolites Ethanol and metabolites **Opioids,** morphine, heroin, etc.
Health	Stress Infectious Diseases	Cortisol, cortisone **Viruses, bacteria, resistance genes**
Environment	Unsustainable chemicals	Persistent and toxic chemicals added to household and personal care products
Indicators for chemical body burden	Human metabolites of unsustainable chemicals	Urinary and fecal metabolites and other bioaccumulative chemicals

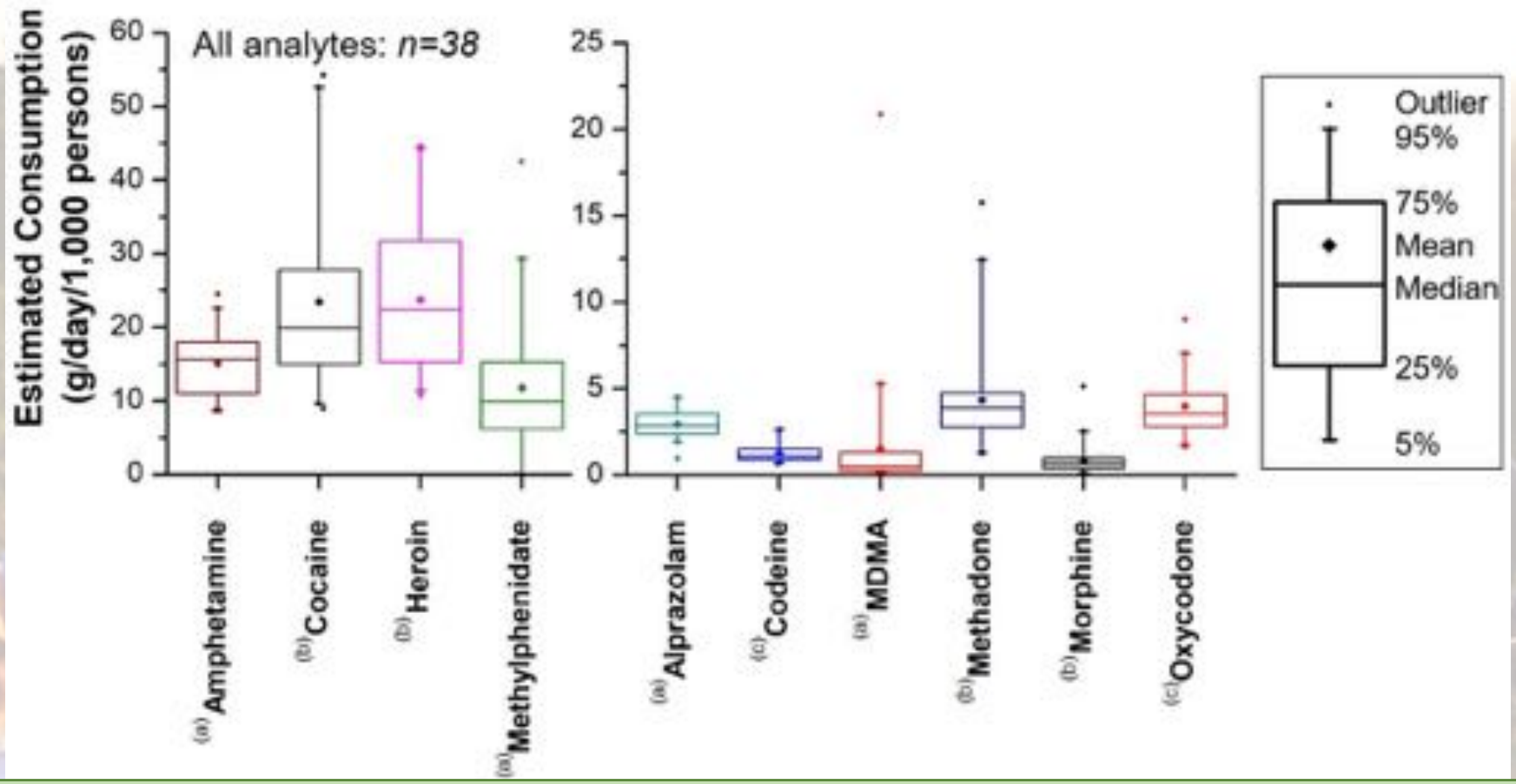
Evidence-based Decision-making in Public Health

- **ASU is partnering with communities across the U.S. and worldwide to improve public health, focusing on**
  - Chemical threats
  - Biological threats
  - Sustainability
- **E.g., Informing the selection and optimization of interventions for combating:**
  - Abuse of opioids, alcohol, marijuana, smoking, etc.
  - Spread of toxic chemicals and diseases

Targeted Narcotics

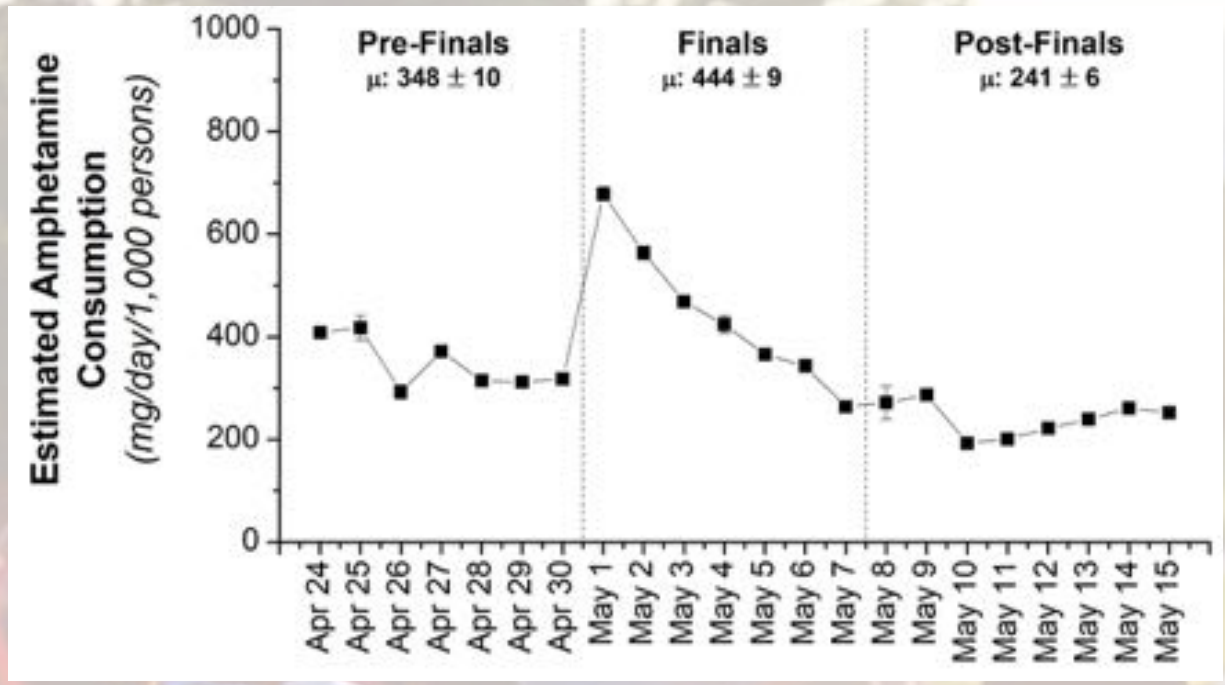
Gushgari, A.J., Driver, E.M., Steele, J.C., Halden, R.U., 2018. Tracking narcotics consumption at a Southwestern U.S. university campus by wastewater-based epidemiology. Journal of Hazardous Materials.

Consumption of Narcotics on a Uni. Campus



Gushgari, A.J., Driver, E.M., Steele, J.C., Halden, R.U., 2018. Tracking narcotics consumption at a Southwestern U.S. university campus by wastewater-based epidemiology. Journal of Hazardous Materials.

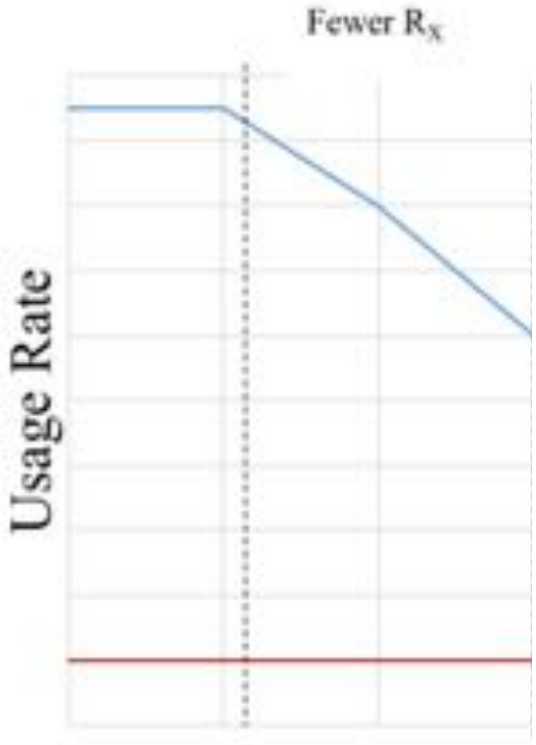
ADHD Drug Use (e.g., Adderall) During Finals



- 3-Week Wastewater Project
- During Spring 2017 Finals (April-May)
- Captured between 15,000-50,000 contributors

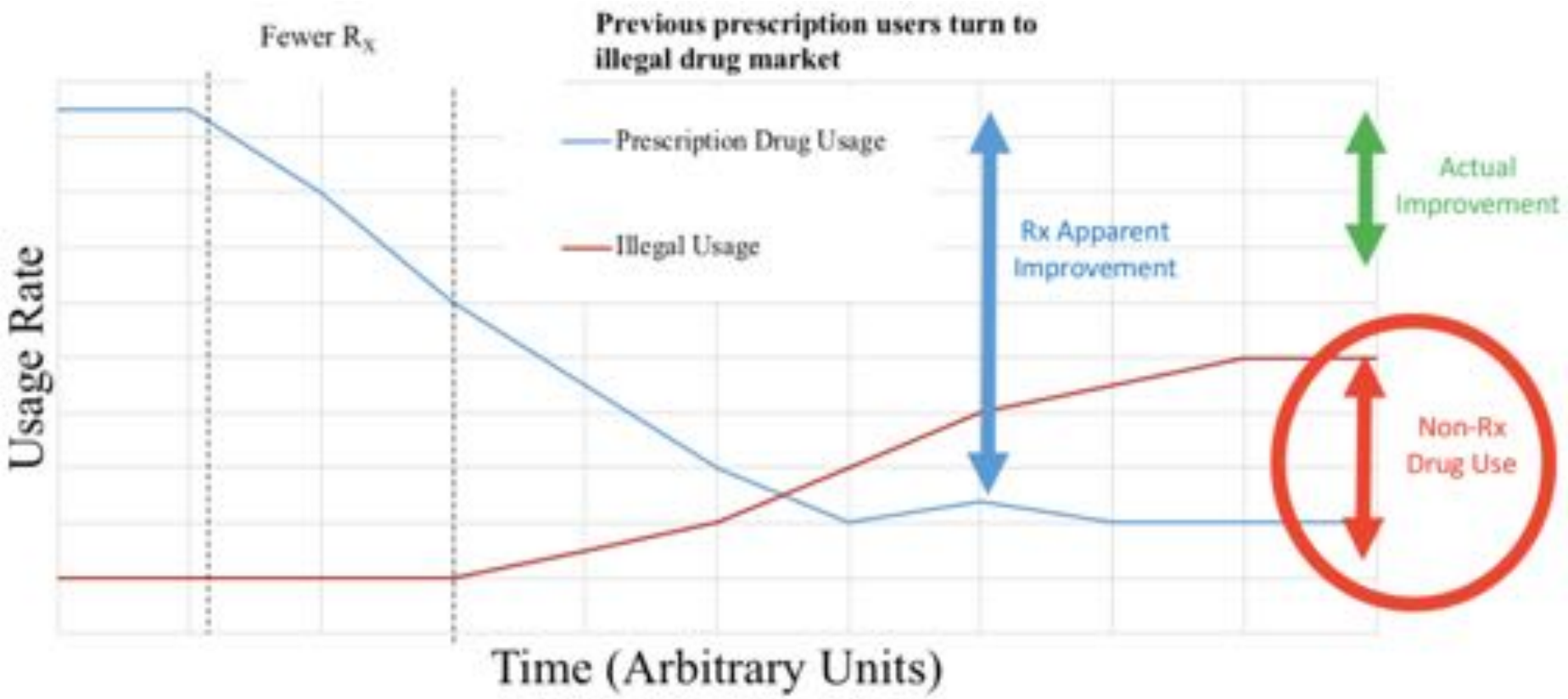
Gushgari, A.J., Driver, E.M., Steele, J.C., Halden, R.U., 2018. Tracking narcotics consumption at a Southwestern U.S. university campus by wastewater-based epidemiology. Journal of Hazardous Materials.

Are Rx opioid users switching to illicit street drugs?



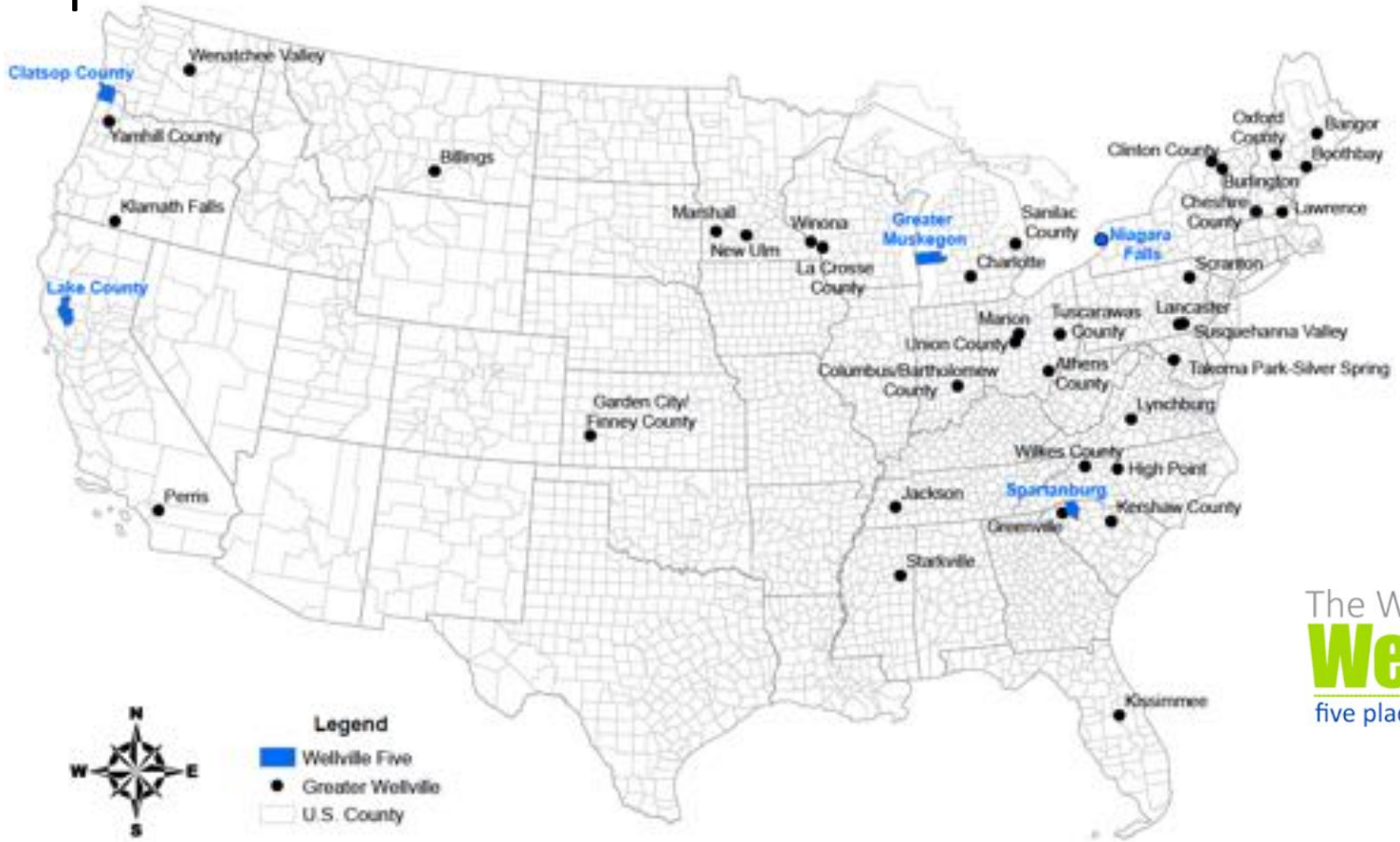
Halden 2018

Are R_x drug users switching to illicit street drugs?



Halden 2018

Wellville Challenge: Showing Health Improvements in 5 Years



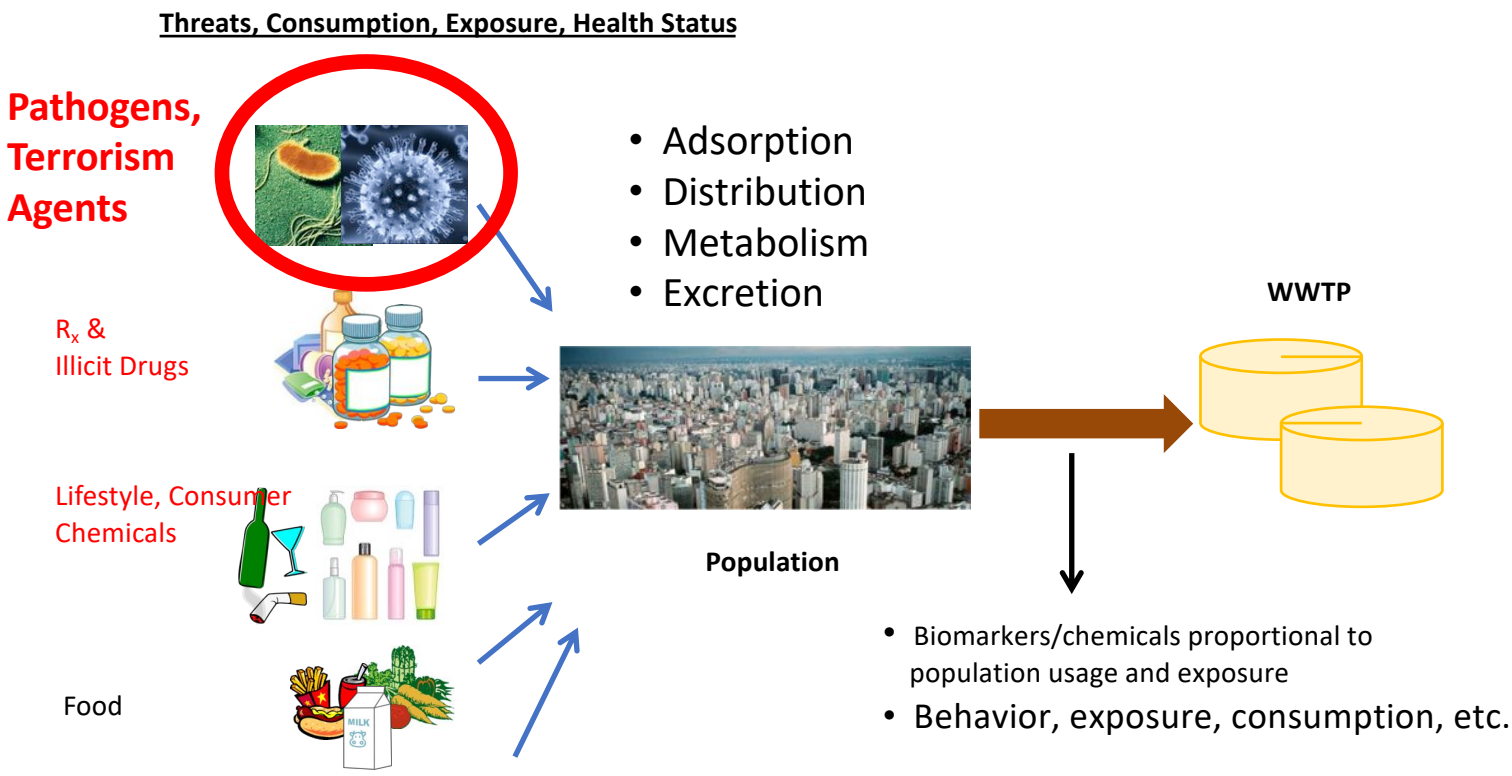
The Way to Wellville
five places. five metrics. five years.

- **Facilitating Evidence-based Decision-making for Global Health Outcomes**
- **Sustainability impacts related to global health can be difficult to measure. Apply near real-time WBE/UMM as a diagnostic tool**
- **Grow and scale the impact of UMM internationally:**
  - **Arizona State University (ASU);**
  - **Ireland, led by Dublin City University (DCU);**
  - **United Kingdom, led by King's College London (KCL); and**
  - **Mexico, led by Tecnológico de Monterrey (Tec).**
- **Annual membership for institutions**

U.S.
U.K.
Ireland
Mexico

https://sustainabilityoutcomes.org/global-health-outcomes/

Infectious Disease Surveillance



Human Health: Toxic Exposures, Biomarkers of Disease, Cancer, Stress Hormones

NATURE MEDICINE | VOL 24 | OCTOBER 2018 | 1484–1490 | www.nature.com/naturemedicine

Tracking Infectious Diseases with ASU's HHO

RH (Presenter) Matthew Scotch Arvind Varsani

Human Health Observatory (HHO) at Arizona State University's Biodesign Institute

Surveillance of known disease agents & discovery of 1000s of new DNA & RNA viruses

NATURE MEDICINE | VOL 24 | OCTOBER 2018 | 1484–1490 | www.nature.com/naturemedicine

Public Health Protection Using the Human Health Observatory

Identify chemicals/biologicals that…

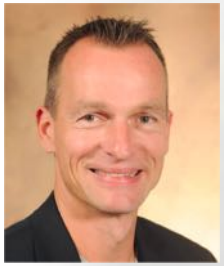
- are present in our cities (chemical inventories)
- **show persistence, pose threat**
- cause **harmful human exposures**
- produce **harmful transformation products**
- **bioaccumulate** in people
- cause infectious diseass

Advantages of HHO Approach

- Less time & cost than traditional monitoring
- Whole population assessment
- Non-invasive sampling
- Near real-time data

Sci. Rep. 2014, 4:3731

Human Health Observatory at ASU



- How can we help you?
- Chemical agents?
- Biological agents?
- Point of Contact:
  - Arizona State University
  - Biodesign Center for Environmental Health Engineering
    rolf.halden@asu.edu

Acknowledgments

Prof. Matthew Scotch
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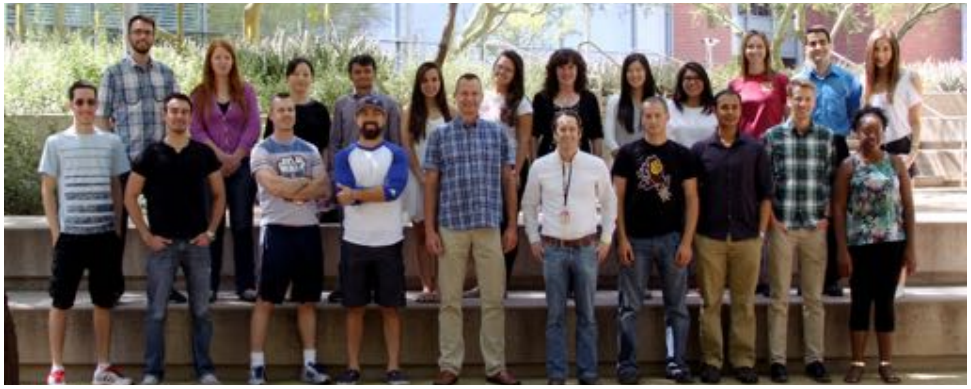
Isaac Roll
Sam Supowit
Hansa (Done) Magee
Ben Pycke
Kristin McClellan
Evelyn Walters
Randhir Deo
Talia Chalew
Thayer Young
Amir Sapkota
Daniel Paull
Rick Stevens
Harry McCarty
AND MANY OTHERS

NIEHS R01ES015445; R01ES020889
ESTCP 200914; ESTCP 201122



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