Application of fast scanning triple quadrupole tandem liquid chromatography-mass spectrometry (LC-MS/MS) in population health assessment

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(Presenting for an international collaborative team)

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William Manning: GIS Staff
Richard Dalton: Environmental Compliance Supervisor
Christopher Garcia: Environmental Compliance Specialist
Andrea Glass: Fire Department
Phillip Brown: Civil Engineer
Hillary Cummings: Tempe Community Council Program Director
AND MANY OTHERS

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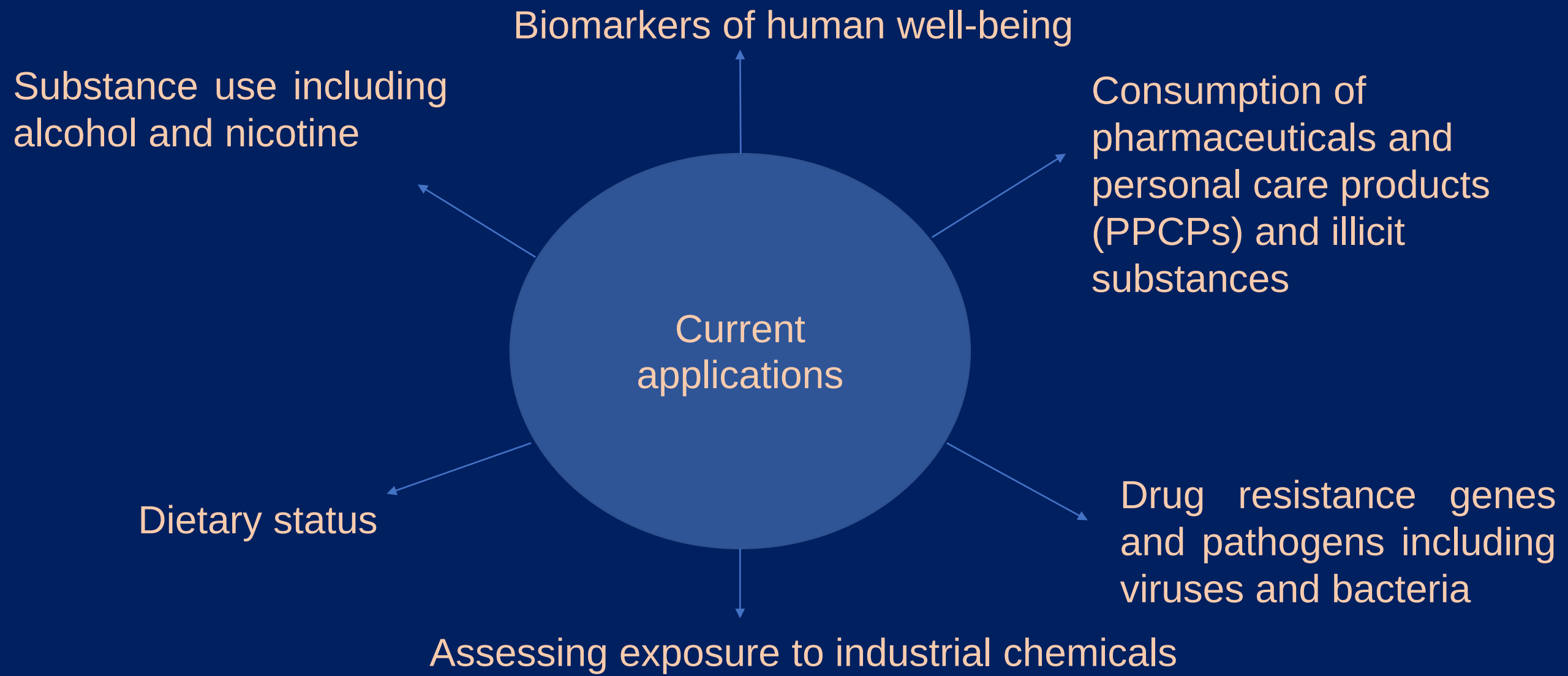
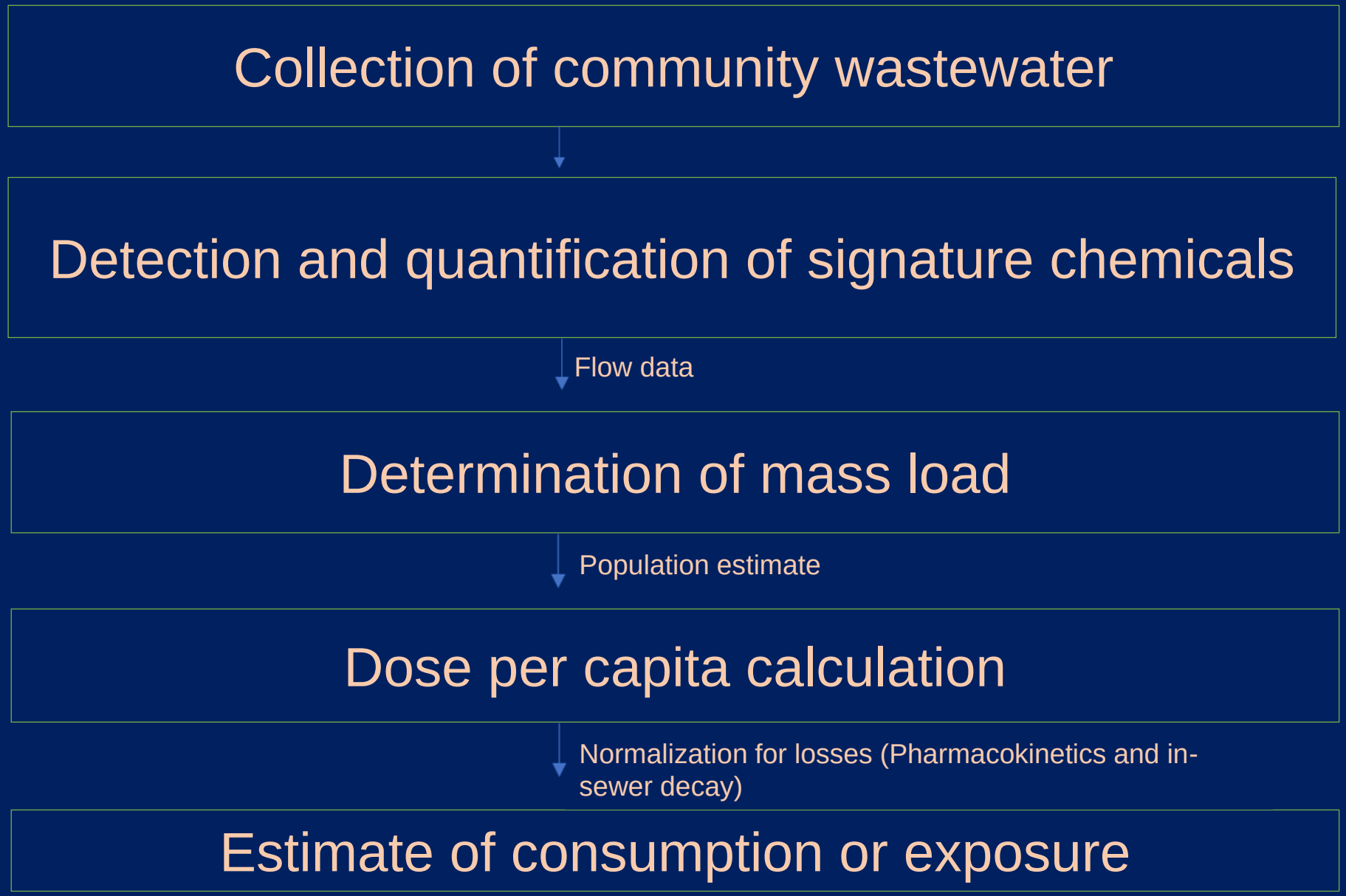
Population health assessment

- SARS-CoV-2 monitoring has emphasized the attractiveness of population health assessment using wastewater-based epidemiology (WBE)
- A rapid, non-invasive, and cost-effective public health surveillance tool at near-real time scale
- WBE is now being widely practiced and here we present some data from pre-COVID WBE adopters

Monitoring public health status



Typical workflow of WBE study



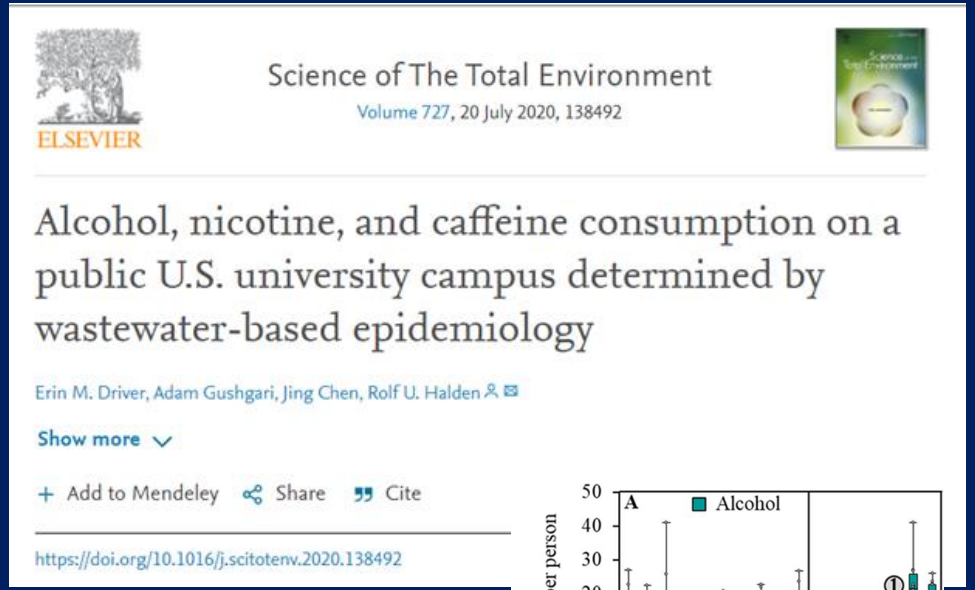
Typical approach of sample processing and analysis workflow in our lab

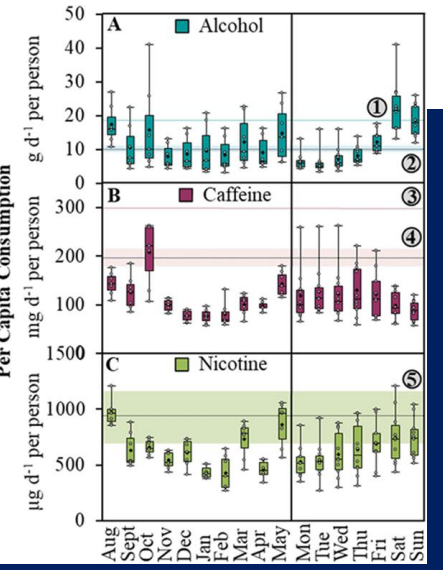
Sample Collection → Sample Prep / Internal Std. Addition → Sample Extraction → Elution → Extract Blowdown Reconstitution → LC-MS/MS Analysis

Data published from our lab

Estimation of substance use in the university campus via WBE

- First university-wide assessment of nicotine, alcohol, and caffeine consumption via WBE
- Estimates of per capita alcohol consumption agreed with self reported surveys
- Universities may benefit from the cost-effective WBE tool to manage health of students

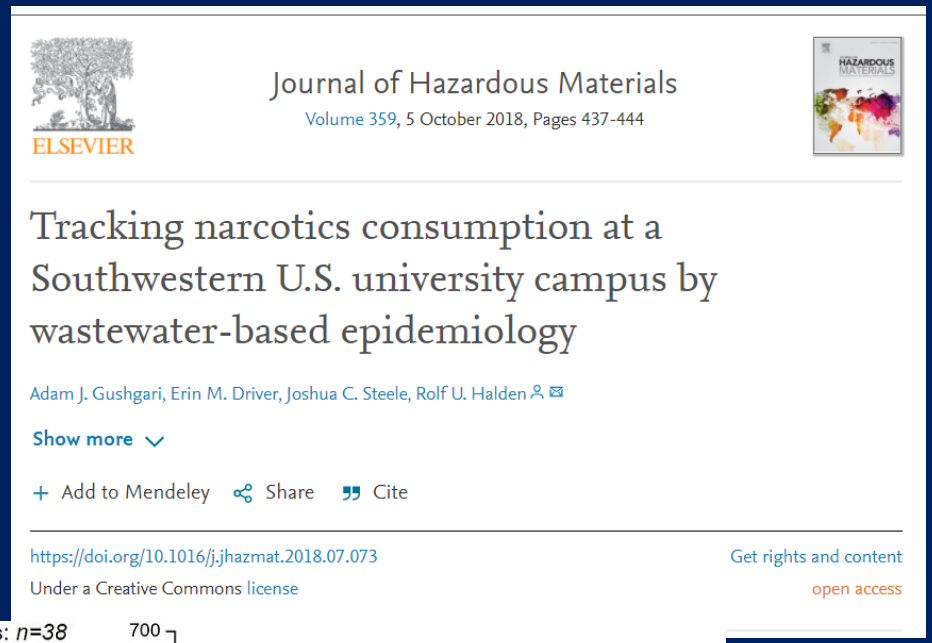


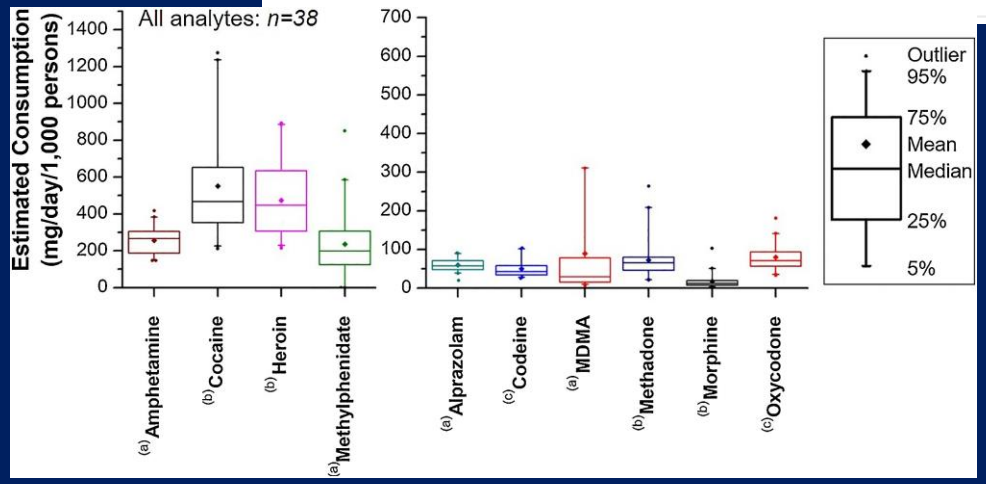


Driver, E.M., Gushgari, A., Chen, J. and Halden, R.U. 2020. Alcohol, nicotine, and caffeine consumption on a public U.S. university campus determined by wastewater-based epidemiology. Science of The Total Environment 727, 138492.

Estimation of substance use in the university campus via WBE

- First reported detection of norfentanyl in U.S.
- Estimated heroin consumption exceeded national rate
- Estimated consumption of Attention deficit hyperactivity disorder (ADHD) medication was in-line with other U.S. campus studies

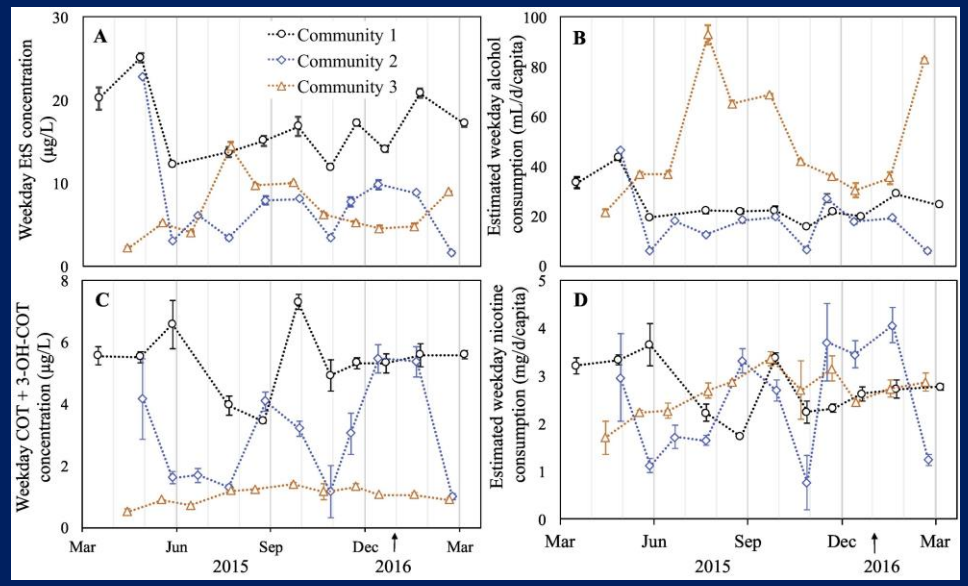


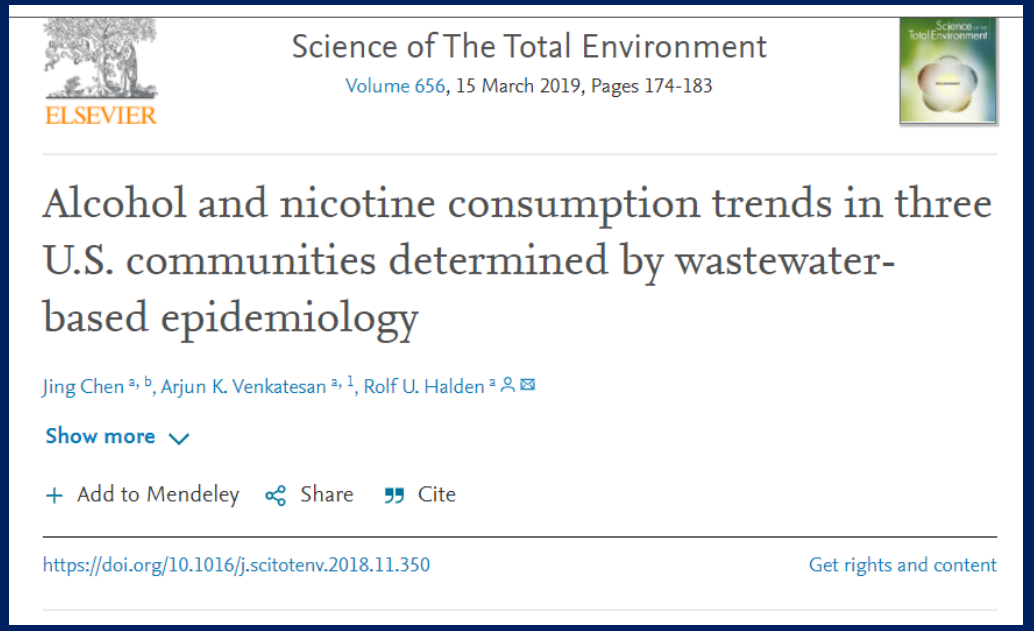


Gushgari, A.J., Driver, E.M., Steele, J.C. and Halden, R.U. 2018. Tracking narcotics consumption at a Southwestern U.S. university campus by wastewater-based epidemiology. Journal of Hazardous Materials 359, 437-444.

Estimation of substance use in the U.S. communities via WBE

- First wastewater-based assessment of drinking and smoking habits in 3 U.S. cities
- Wastewater-based estimates were in good agreement with survey statistics




ELSEVIER
Science of The Total Environment
Volume 656, 15 March 2019, Pages 174-183

Alcohol and nicotine consumption trends in three U.S. communities determined by wastewater-based epidemiology

Jing Chen [a, b], Arjun K. Venkatesan [a, 1], Rolf U. Halden [a]

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https://doi.org/10.1016/j.scitotenv.2018.11.350

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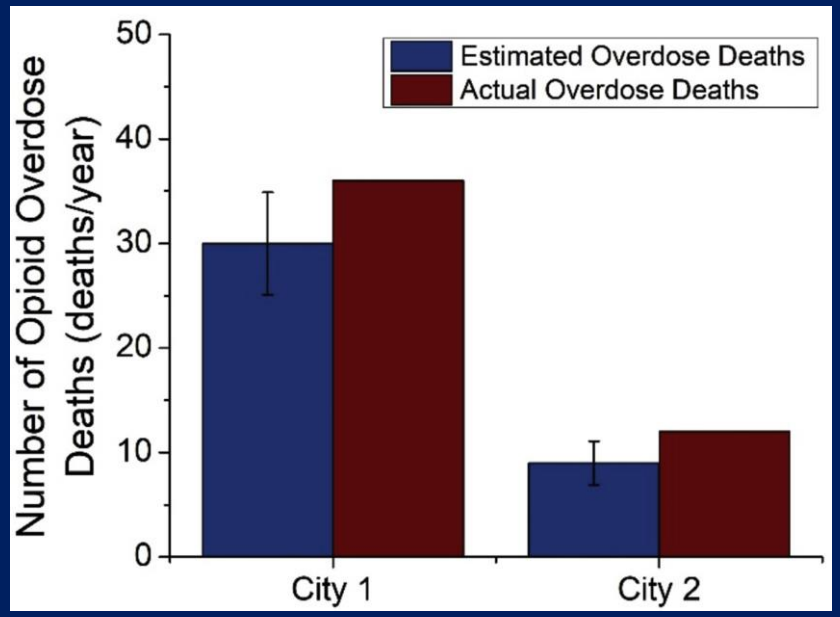
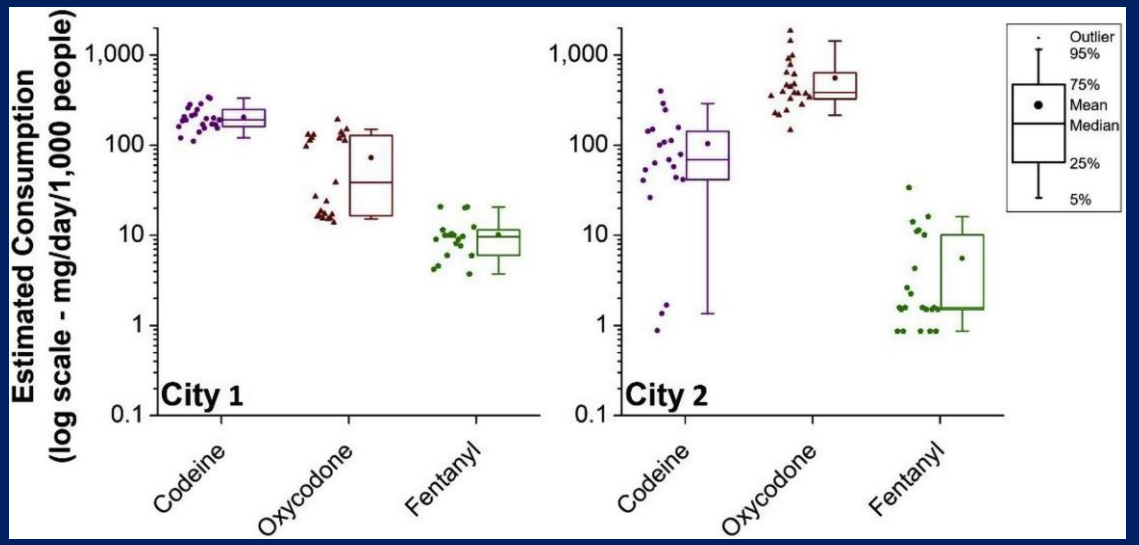
Chen, J., Venkatesan, A.K. and Halden, R.U. 2019. Alcohol and nicotine consumption trends in three U.S. communities determined by wastewater-based epidemiology. Science of The Total Environment 656, 174-183.

Estimation of substance use in the U.S. communities via WBE

- First estimation of opioids overdoses and deaths from WBE data.





Gushgari, A.J., Venkatesan, A.K., Chen, J., Steele, J.C. and Halden, R.U. 2019. Long-term tracking of opioid consumption in two United States cities using wastewater-based epidemiology approach. Water Research 161, 171-180.

Dietary status using WBE

- First application of a WBE approach for monitoring dietary trends in two U.S. communities.
- Measured phytoestrogens (plant-derived human biomarkers) in community wastewater

Assessing the Potential To Monitor Plant-Based Diet Trends in Communities Using a Wastewater-Based Epidemiology Approach

Arjun K. Venkatesan, Jing Chen, Erin Driver, Adam Gushgari, and Rolf U. Halden*

DOI: 10.1021/bk-2019-1319.ch010
Publication Date: June 24, 2019
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Chapter Views 52 Citations -
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Chapter 10, pp 187-198

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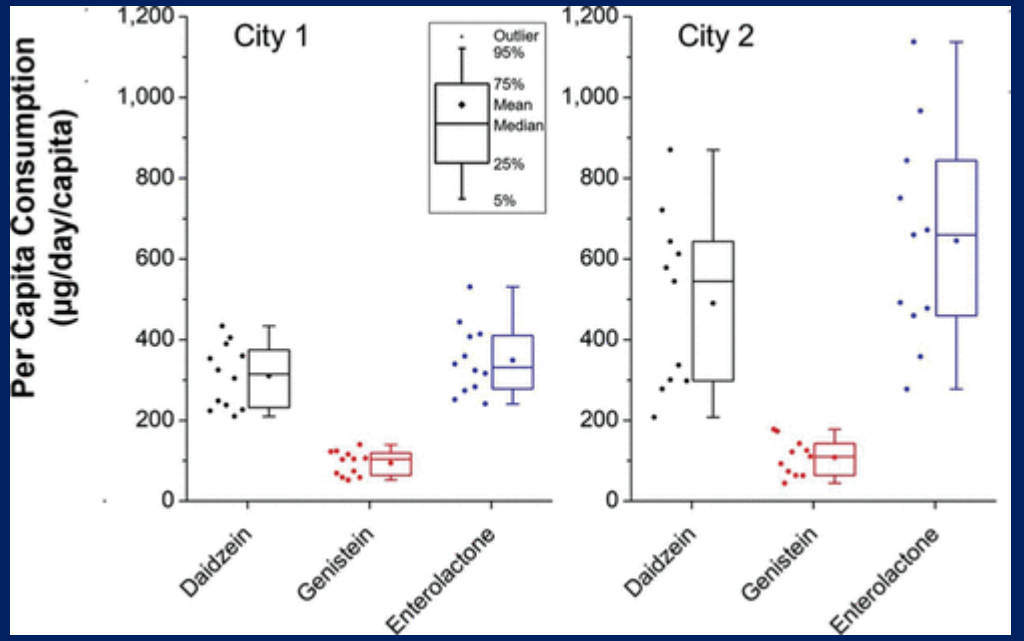


Venkatesan, A.K., Chen, J., Driver, E., Gushgari, A. and Halden, R.U. (2019) Wastewater-Based Epidemiology: Estimation of Community Consumption of Drugs and Diets, pp. 187-198, American Chemical Society.

Fast scanning mass spectrometer for population health surveillance

- Short LC-MS/MS run
- Better economy
- Less labor intensive
- More signature chemicals in single run

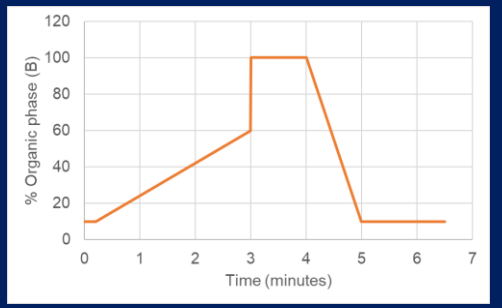
Collaborative data from an international study

Methods

- 24-hour composite community wastewater samples collected from the UK, USA, and Mexico.
- Samples filtered through membrane filters and directly injected to LC-MS/MS for the analysis
- Guard column alone was used for separation of analytes

LC parameters

- HPLC column used- Biphenyl guard column (5.0 × 3.0 mm, 2.7 µm particle size)
- LC used- Shimadzu Nexera™ X2 ultra-high-pressure LC
- MS used- Shimadzu LC-MS 8060
- Mobile phases- Ultrapure water (A) and a mixture of acetonitrile and methanol (50:50,v/v) (B), (0.1% formic acid added in mobile phases for pH control)
- Optimized injection volume- 10 µL
- Optimized gradient



Ng et al., 2020

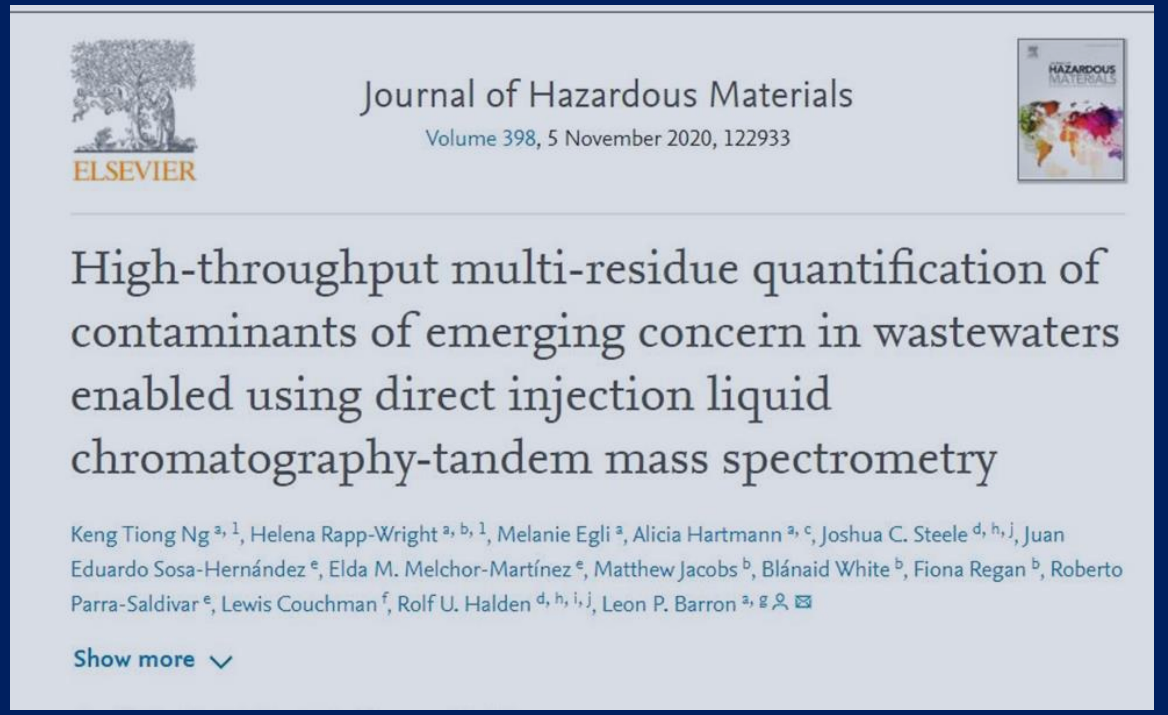
MS parameters

Nebulizing gas flow	3 L/min
Heating gas flow	10 L/min
Interface temperature	300°C
DL temperature	250°C
Heat Block temperature	400°C
Drying gas flow	10 L/min
Maximum dwell time	20 ms
Minimum dwell time	1 ms
Maximum loop time	0.572 ms

Ng et al., 2020

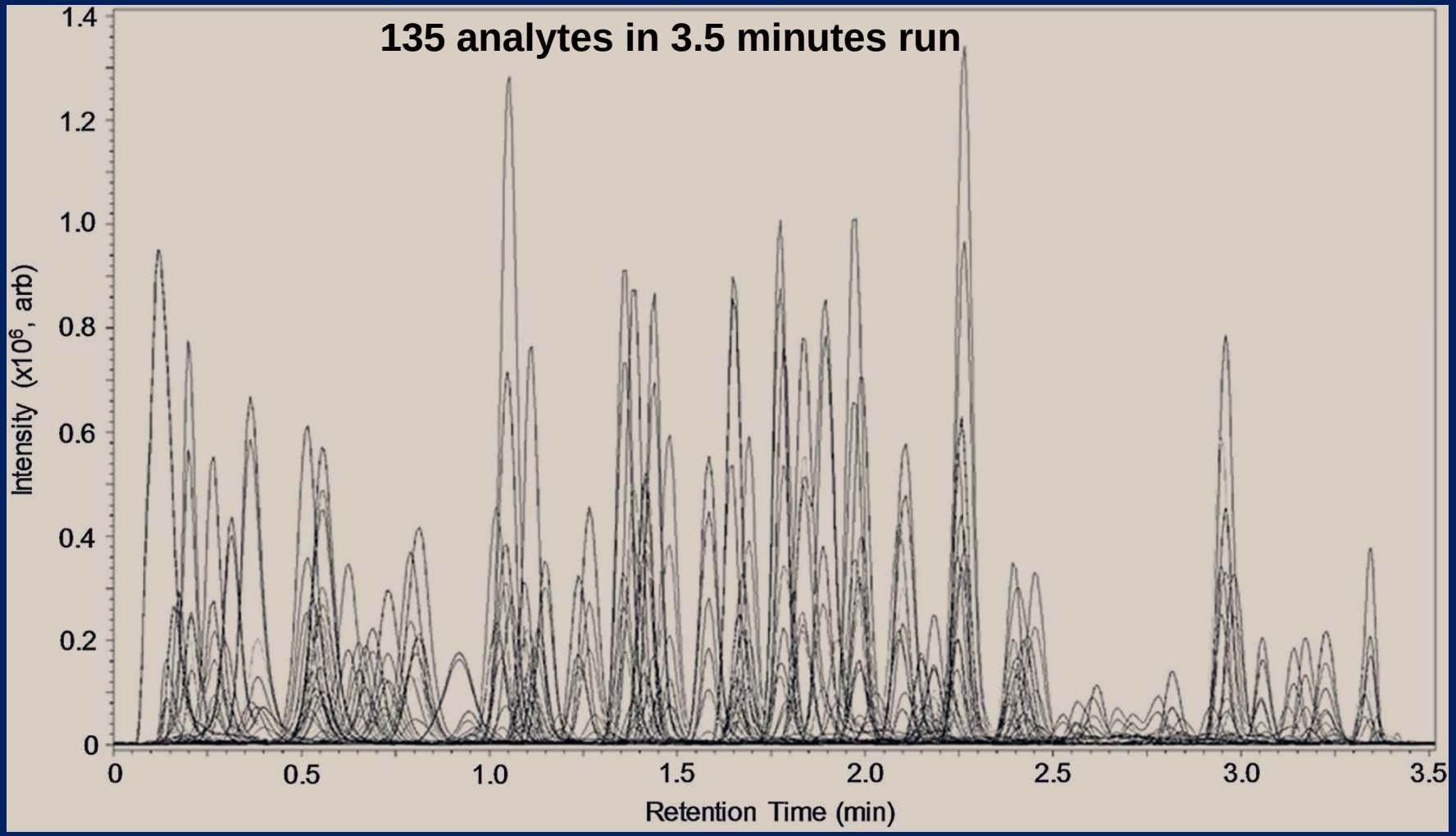
Results

- MS scan speed 30000 amu/sec
- Polarity switching speed of 5 ms
- 260 injections per 24 hours
- 135 analytes including pesticides, PPCPs, illicit drugs and their metabolites analyzed in 5 minutes
- 56 compounds quantified



Ng, K.T., Rapp-Wright, H., Egli, M., Hartmann, A., Steele, J.C., Sosa-Hernández, J.E., Melchor-Martínez, E.M., Jacobs, M., White, B., Regan, F., Parra-Saldivar, R., Couchman, L., Halden, R.U. and Barron, L.P. 2020. High-throughput multi-residue quantification of contaminants of emerging concern in wastewaters enabled using direct injection liquid chromatography-tandem mass spectrometry. Journal of Hazardous Materials 398, 122933.

Chromatograms of a mixture of CECs acquired by LabSolutions (version 5.93, Shimadzu)



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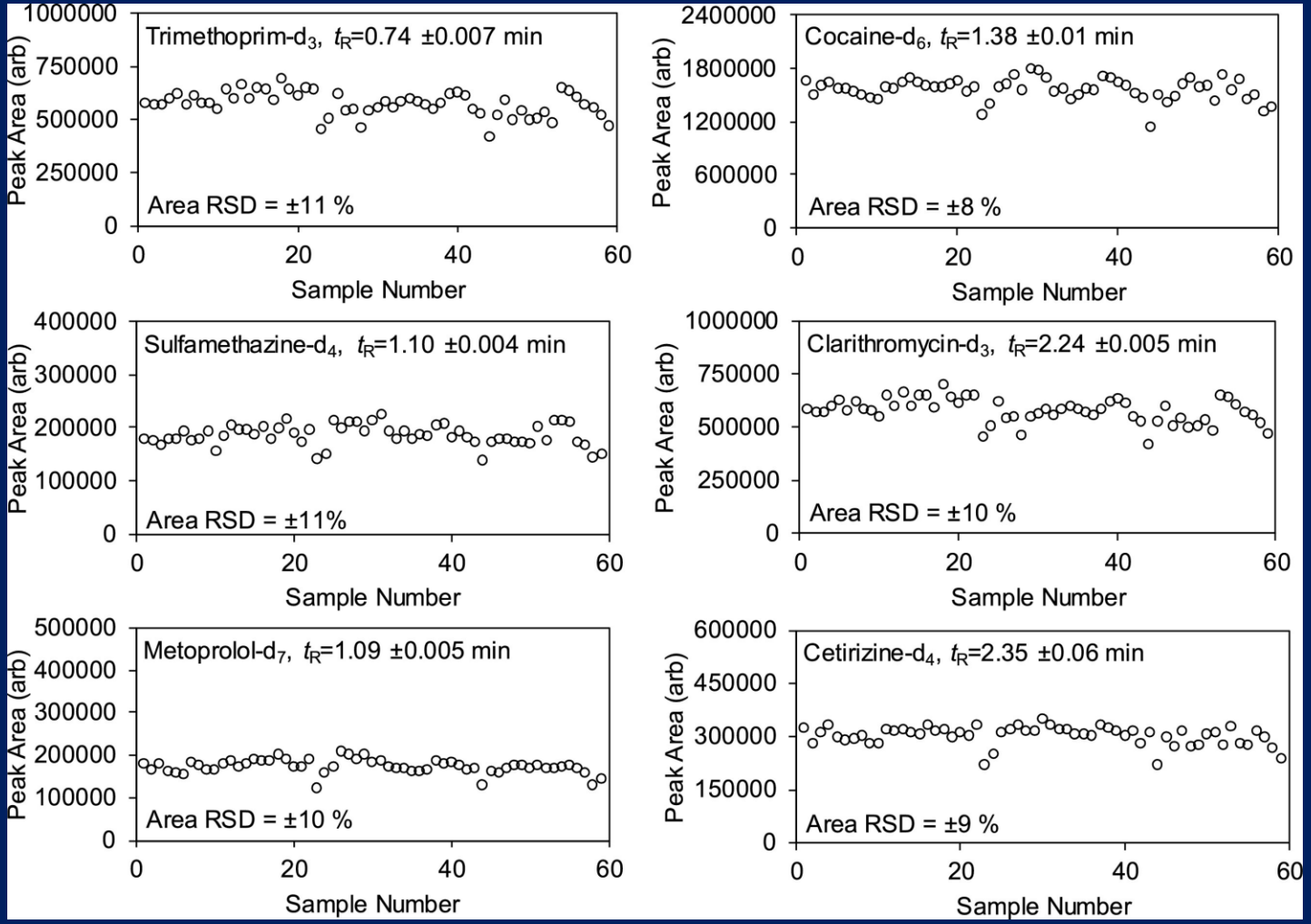
Peak area and retention time stability



Ng et al., 2020

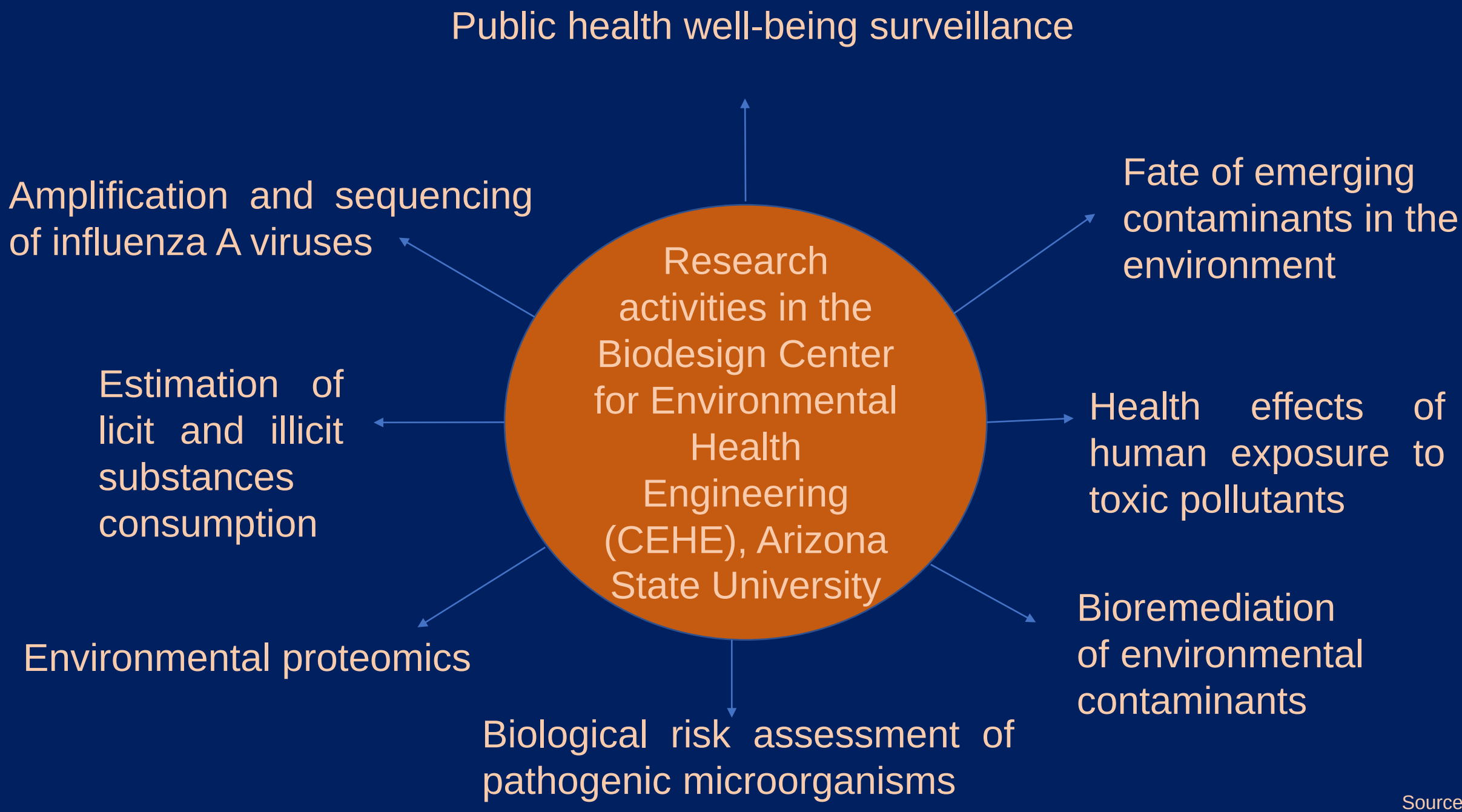
Analytical performance

	Linearity (R^2) (N>5)	Peak area precision (RSD %, n=6)		Matrix effect (% CV, n=6)		Inaccuracy (% CV)			Sensitivity	
		100 ng/L	1000 ng/L	100 ng/L	1000 ng/L	250 ng/L	750 ng/L	1000 ng/L	LLOD (ng/L)	LLOQ (ng/L)
Maximum	0.999	55	32	+337	+188	+66	+13	+9	533	1777
Minimum	0.967	2	1	-84	-60	-97	-54	-44	0.06	0.21
Absolute median	0.999	8	6	11	9	12	8	-4	9	31
Absolute mean (±Std dev)	0.998 (±0.0037)	11 (±10)	8 (±6)	20 (±34)	14 (±22)	16 (±14)	9 (±7)	-6 (±10)	29 (±55)	95 (±197)

Things to be aware of to ensure data quality

- Partitioning of analytes during sample filtration may have huge impact on what we measure

- A minimum of 20% loss of analytes featuring pH-dependent logarithmically transformed organic carbon-water distribution coefficient (log D_{OC}) of ≥3.0 (Deo and Halden, 2010)


Public health well-being surveillance
Amplification and sequencing of influenza A viruses
Fate of emerging contaminants in the environment
Research activities in the Biodesign Center for Environmental Health Engineering (CEHE), Arizona State University
Estimation of licit and illicit substances consumption
Health effects of human exposure to toxic pollutants
Environmental proteomics
Bioremediation of environmental contaminants
Biological risk assessment of pathogenic microorganisms

Source: ASU

Analytical services

- We are engaged in long-term, U.S. national monitoring with a growing network of over 220+ cities and community partners worldwide.
- We are being funded by sponsored research projects and by fee-for-service analyses.
- We analyze following biomarkers routinely under the umbrella of human health observatory (HHO).

Communicable diseases	Antitussives	Barbiturates
Benzodiazepines	Hallucinogens	Dietary indicators
Cannabinoids/Synthetic	Antibacterial/Antimicrobial	Alcohol and tobacco
Antidepressants	Parabens	Stimulants
Z-drugs	Opioids	Fentanyl and fentanyl analogues
Volatile organic compounds	Illicit drugs	Additional medications

Human Health Observatory (HHO) at Arizona State University
... An Early Warning System Established in 2006

- >500 WWTPs globally; >400 in U.S.

  Representative of 15,000+ U.S. plants

  Unbiased national estimates
- >12% of U.S. pop.; >40M people
- >250M people worldwide
- Largest archive in the U.S./world

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

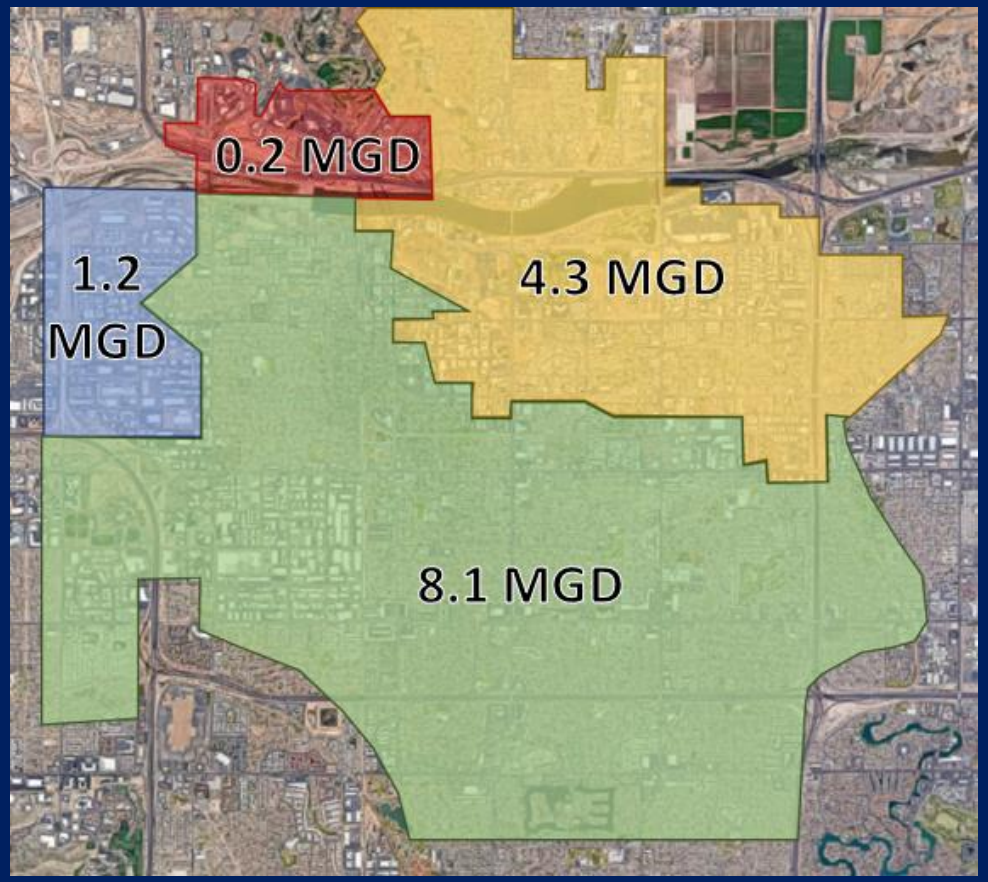
Venkatesan & Halden, 2014. *Environ. Sci. Pollut. Res.* 22 (3), 1577-1586

City of Tempe & ASU Collaboration

City of Tempe

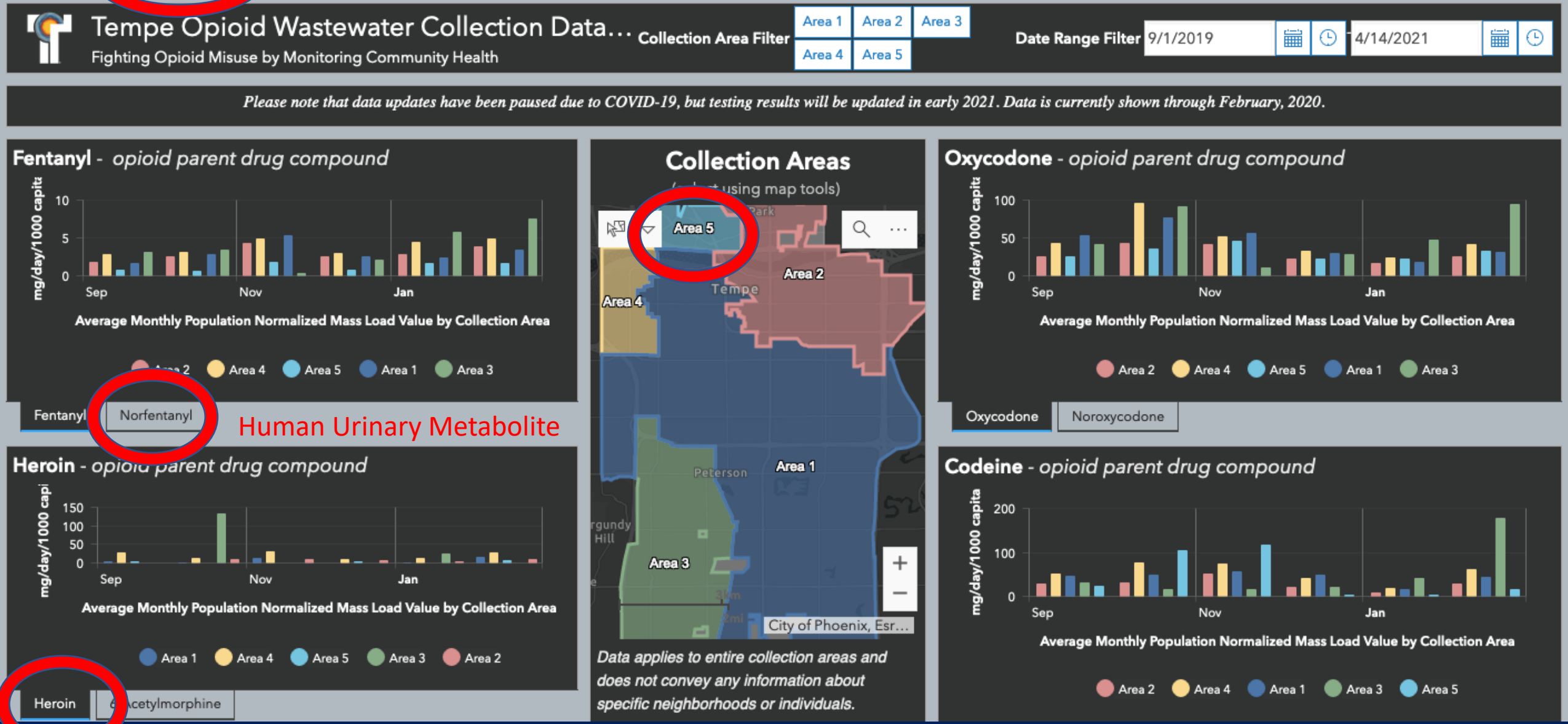
ASU Biodesign Institute
Arizona State University

Center For
Environmental Health Engineering



- First U.S. municipality to use WBE data in strategy development and implementation.
- Addressing opioid addiction, marijuana use, and alcohol consumption.
- $70,000 funding from City of Tempe and Arizona State University.
- City-wide capture of wastewater representing 185,000 contributing residents.
- Collaborative partnership with government, academia, industry professionals.

1st Public, WBE-informed, Opioid Online Dashboard Worldwide



Story Map (How wastewater measurements are done): https://arcg.is/PKWuz

Dashboard (Opioid consumption in Tempe at the neighborhood level): https://arcg.is/ey0Ha

Developed 2018; Launched 2019

Tempe ARIZONA
Making waves in the desert

ASU Biodesign Institute
Arizona State University

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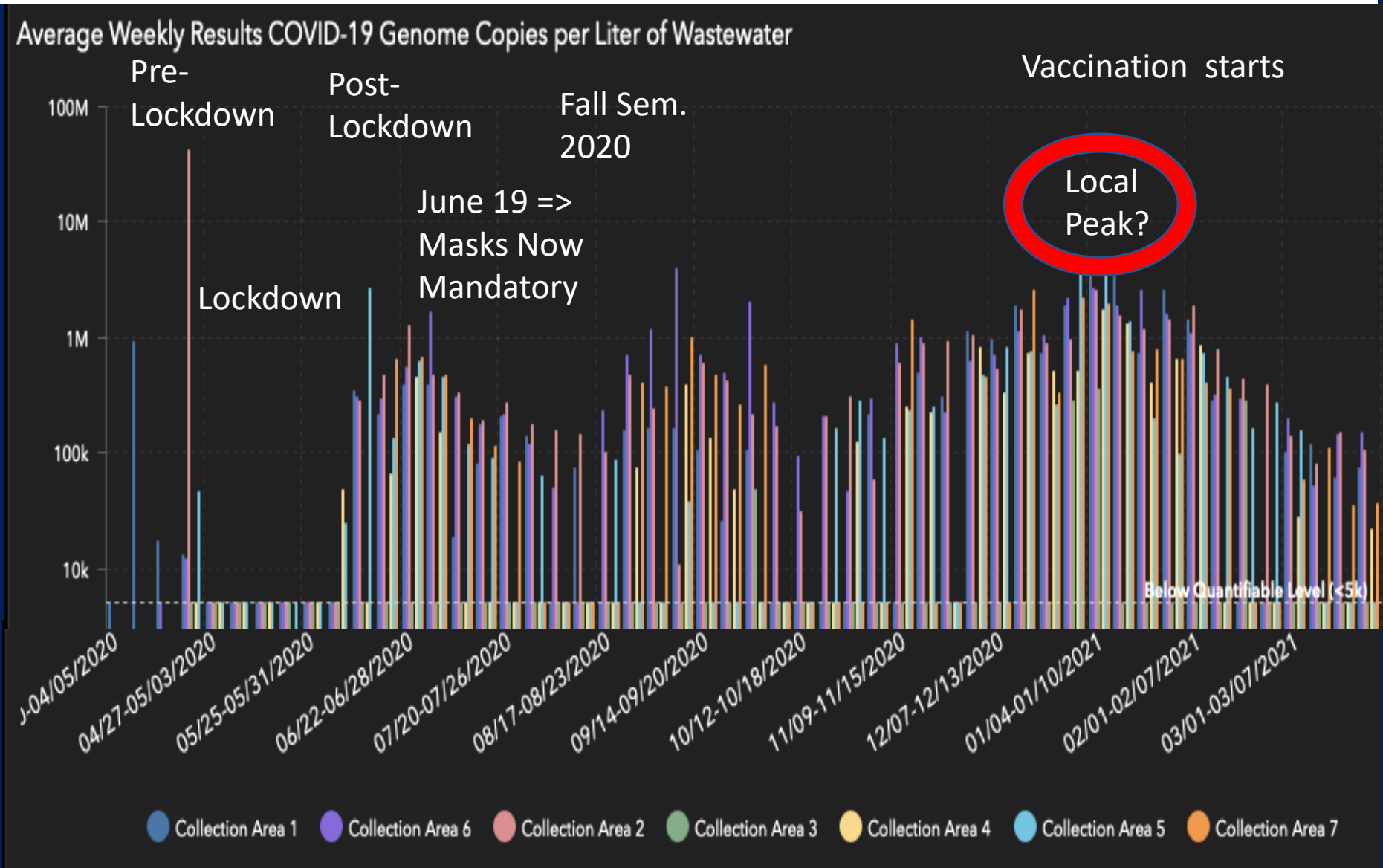
https://covid19.tempe.gov/

World's 1st WBE-informed COVID-19 Dashboard



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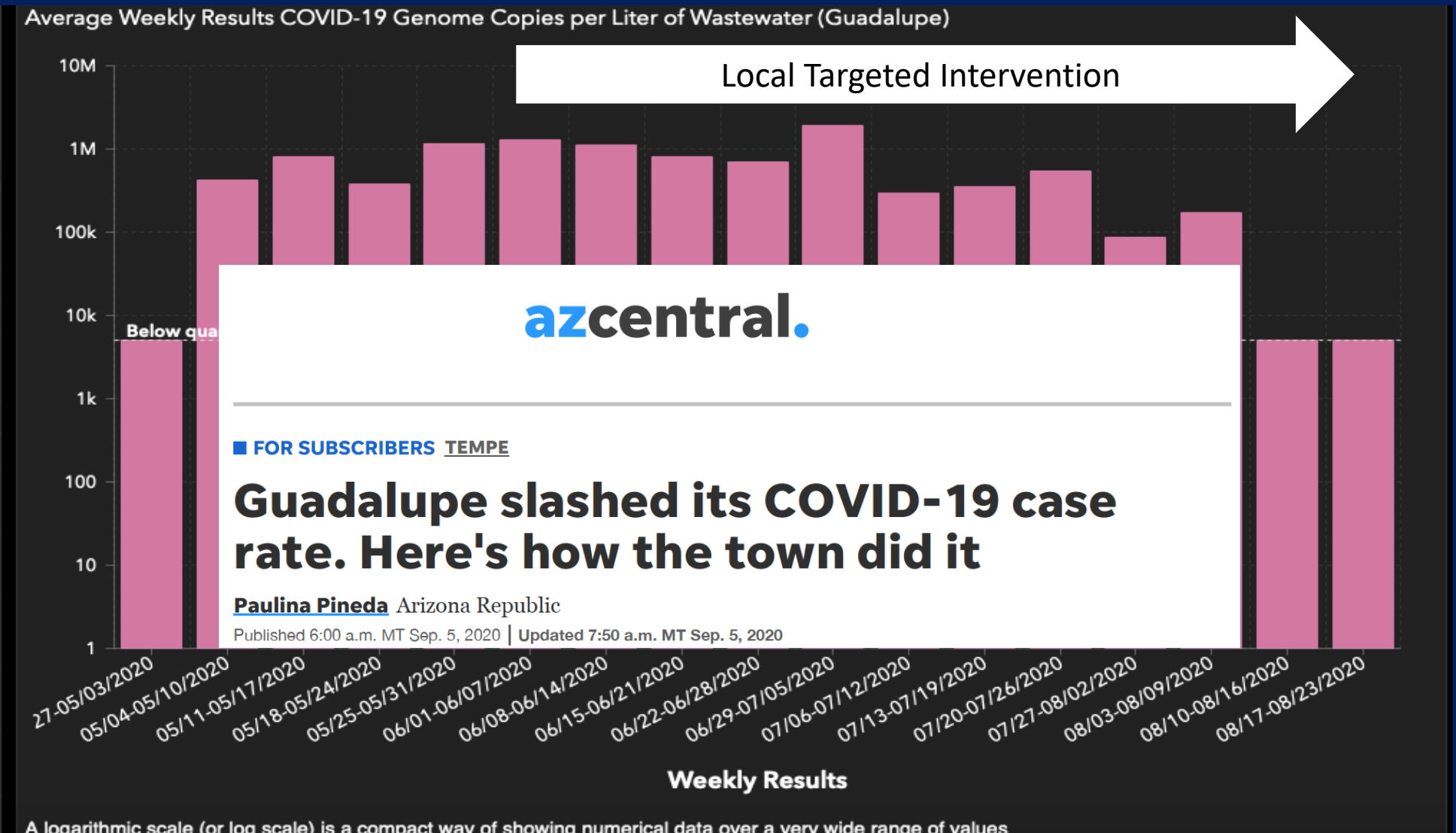
https://covid19.tempe.gov/



azcentral.

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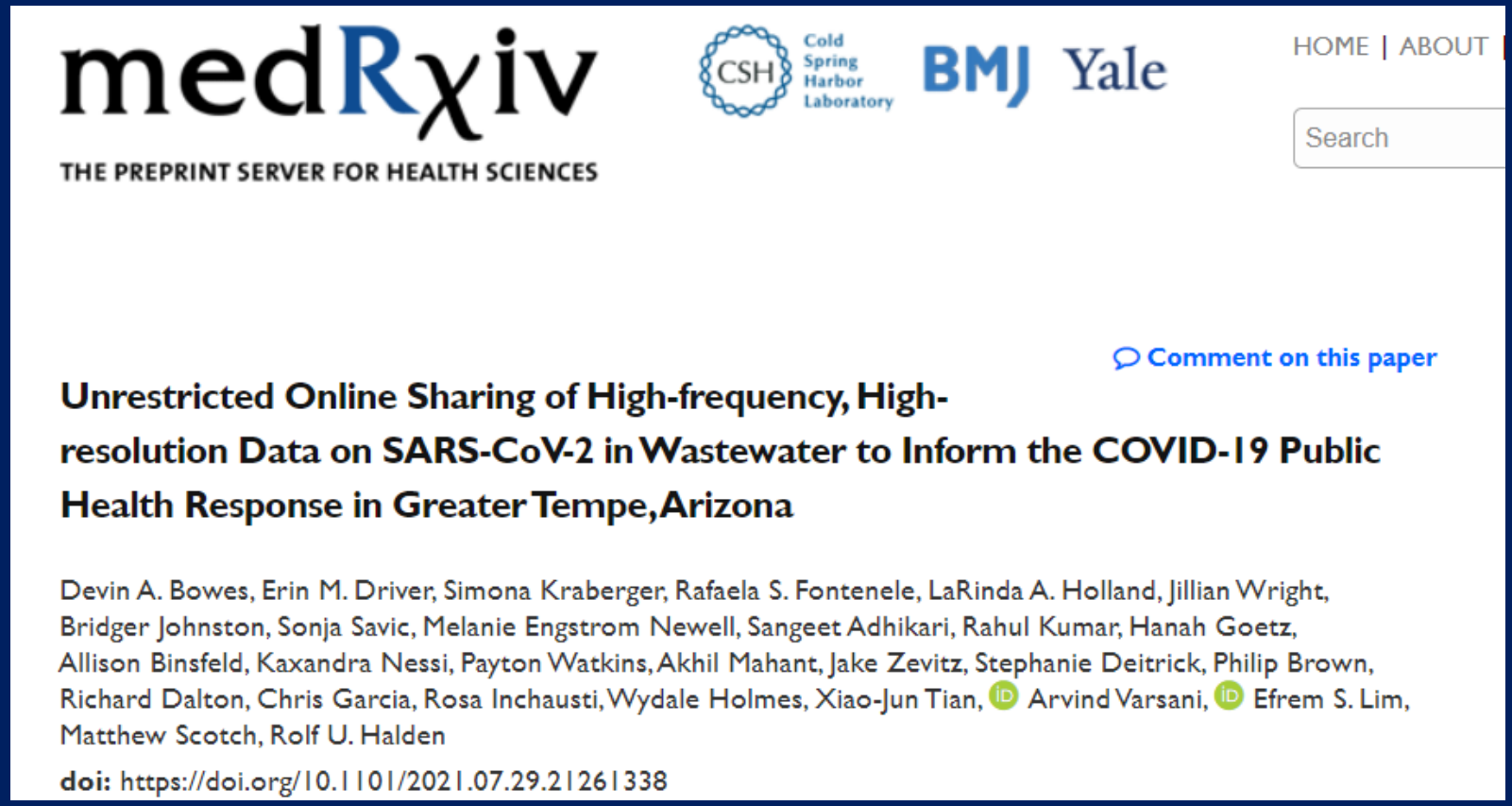
Guadalupe slashed its COVID-19 case rate. Here's how the town did it

Paulina Pineda Arizona Republic

Published 6:00 a.m. MT Sep. 5, 2020 | Updated 7:50 a.m. MT Sep. 5, 2020

Recent publication of our COVID-19 dashboard



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Unrestricted Online Sharing of High-frequency, High-resolution Data on SARS-CoV-2 in Wastewater to Inform the COVID-19 Public Health Response in Greater Tempe, Arizona

Devin A. Bowes, Erin M. Driver, Simona Kraberger, Rafaela S. Fontenele, LaRinda A. Holland, Jillian Wright, Bridger Johnston, Sonja Savic, Melanie Engstrom Newell, Sangeet Adhikari, Rahul Kumar, Hanah Goetz, Allison Binsfeld, Kaxandra Nessi, Payton Watkins, Akhil Mahant, Jake Zevitz, Stephanie Deitrick, Philip Brown, Richard Dalton, Chris Garcia, Rosa Inchausti, Wydale Holmes, Xiao-Jun Tian, Arvind Varsani, Efrem S. Lim, Matthew Scotch, Rolf U. Halden

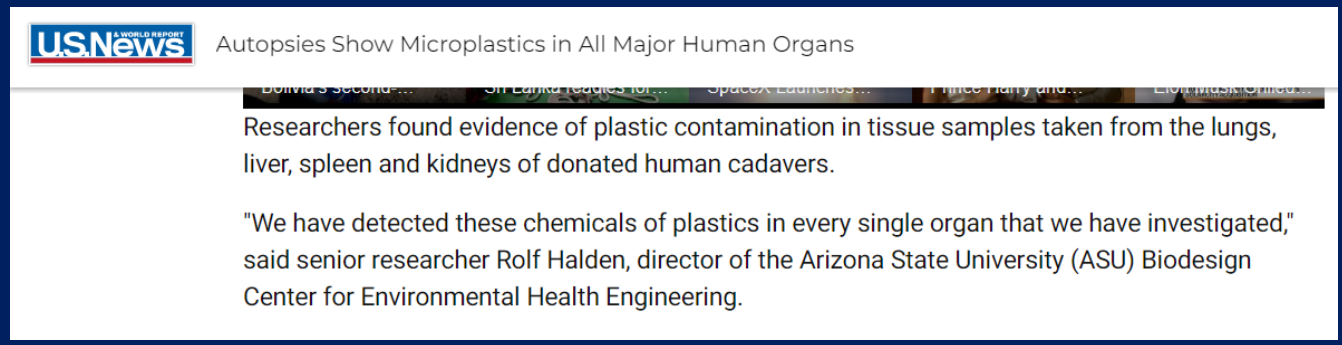
doi: https://doi.org/10.1101/2021.07.29.21261338

Media coverage for Biodesign Center for Environmental Health Engineering

Feb 02, 2019

June 30, 2020

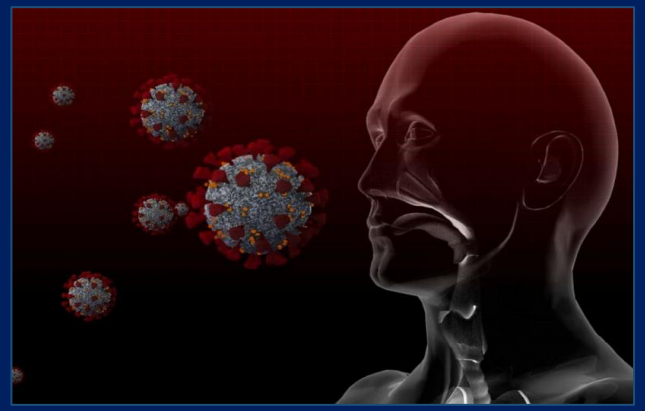
July 24, 2019



ONE WATER HEALTH

ASU Foundation Nonprofit Project

A Nonprofit Project of the ASU Foundation:
"We are dedicated to serve and protect vulnerable communities and environmental quality"



Near real-time monitoring of environmental toxins

Conduct population-level human health assessments

Seek opportunities to close the material loop

Monitoring Toxic Exposures of Vulnerable Populations

Published Data on >300 Analytes

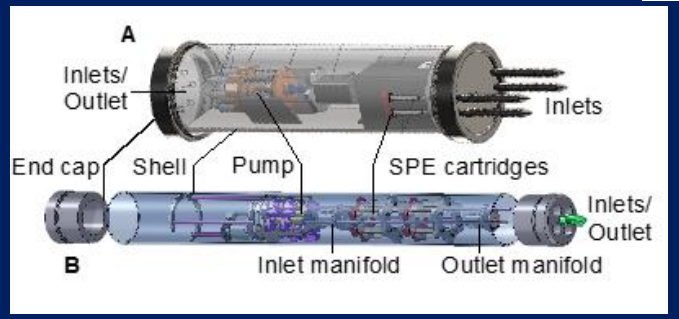
- Heavy metals
- Perfluorinated compounds
- Antibiotic resistance genes
- Plastic
- Industrial pollutants
- Radionuclides
- Bacterial pathogens
- Viruses
- Other

AquaVitas LLC

Dr. Adam J. Gushgari, PE
Chief Executive Officer

Water/Sewer Infrastructure Design
Chemical Wastewater Analysis
Data Modeling & Visualization

AquaVitas Presence & Repository Coverage



AquaVitas *In-Situ* (AV-*IS*) Patented WBE Sampler

Lessons learnt

- Economic differences between cities impacts data quality;
- Lack of knowledge/education regarding what wastewater-based epidemiology is and how data can be used;
- Without field standardization (field, lab, & data analysis) significant variation in results can exist.

20+ Years Experience in WBE

200+ Peer-Reviewed Publications

Proven Methods of Population Health Assessment

Developed & Executed U.S. Department of Health & Human Services Wastewater Monitoring Program for SARS-CoV-2

Has Served: U.S. Department of Health & Human Services, Local Government, State Government, Consulting Firms, Education, & Fortune 500 Companies

HHS US Nationwide COVID-19 WBE Monitoring – 320 City Phase
To potentially participate AT NO COST, contact: covid19@aquavitas.com

HHS & CDC Project

- Monitor 100 wastewater treatment plants & 10% of the U.S. population (Phase 1);
- Expand to 320 wastewater treatment plants & 30% of the U.S. population (Phase 2);
- Establish “best management practices” for wastewater surveillance efforts (Phases 1 & 2);
- Equip participants with wastewater data to manage pandemic locally (Phases 1 & 2)

DEPARTMENT OF HEALTH & HUMAN SERVICES · USA

CDC

CENTERS FOR DISEASE CONTROL AND PREVENTION

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THANK YOU FOR
YOUR ATTENTION

ANY QUESTIONS??