I. Setting the stage

Aparna Keshaviah
Mathematica Policy Research
Can Wastewater Testing Improve Public Health and Well-Being?

Wastewater Symposium
Washington, DC

May 16, 2017

Aparna Keshaviah, Sc.M.
Thanks…
Substance Abuse and the Opioid Epidemic
Scope of the Opioid Epidemic

- Costs = $42B/yr
- 2015: 33,000+ OD deaths
- Rural & Urban
  - Increases in nearly every U.S. county
  - Prescription use differs: recreational vs workplace injury
Complexities of Studying Drug Use

**UNINTENDED CONSEQUENCES**

**Policy Ex. 1**
Legalize marijuana

$\rightarrow$ Shift in drug production: marijuana to heroin

**Policy Ex. 2**
Curb over-prescribing

$\rightarrow$ Shift in affordability: prescriptions to heroin

$\downarrow$
Increased transmission of HIV, Hepatitis C from injecting drugs
Complexities of Studying Drug Use

MULTIPLE STAKEHOLDERS

Policy Ex. 1
Legalize marijuana

Policy Ex. 2
Curb over-prescribing

CO state legislature (amendment 64)
Local marijuana distributors, wholesalers
Illicit growers, transporters, security
Sinaloa cartel
Border patrol

FL Governor (bill HB 7095)
FL prescribing physicians
FL pharmacies (online)
WV Drug users
WV (Huntington) police
Wastewater: A ‘New’ Data Source
Overview of Wastewater Testing

• Mandatory sampling

• Routine testing for (90+ contaminants)

• Identity-blind data
Benefits & Barriers

**Benefit**

- Near real-time information
- Fairly comprehensive coverage
  - 81% of U.S. households
- Standardized infrastructure to study program impacts
- Unbiased reporting versus:
  - Surveys: Non-response, underreporting
  - Medical data: Requires medical visit
  - Crime data: Vary by resource allocation
- Enables study of emerging substances & interactive effects

**Barrier**

- Lack of awareness
- Methods not fully developed
  - detection limits
  - non-routing testing for drugs
- Calibration needed
  - Sewer designs & operation
  - Rainfall amounts
  - Population changes (events/tourism)
- Cross-agency coordination
  (who oversees? who pays?)
Potential Uses of Wastewater

Snapshots: Understand what drugs are being used
   – Identify emerging substances

Trends: Calculate rates of change in use over time
   – Test effectiveness of a new program or policy

Hotspots: Identify geographic concentrations of use
   – Useful for resource allocation

Pair with other sources synergistically
Symposium Overview

TOPICS
- Wastewater (+ methods)
- Public health/safety needs (+ applications)

FORMAT
- Presentation
  - Panel
  - Q&A

OUTPUT
- Alignment in needs across domains
- Cross-cutting goals, shared purposes
For More Information

• Aparna Keshaviah
  – AKeshaviah@mathematica-mpr.com
II. Information gaps that inhibit effective policy development

Terry Zobeck
Office of National Drug Control Policy
II. Information gaps that inhibit effective policy development

Chris Jones

Office of the Assistant Secretary for Planning and Evaluation
The Opioid Epidemic:
Epidemiology and Surveillance

Wastewater Symposium
Washington, DC

May 16, 2017

Christopher M. Jones, Pharm.D., M.P.H.
Acting Associate Deputy Assistant Secretary, Science and Data Policy
Office of the Assistant Secretary for Planning and Evaluation
U.S. Department of Health and Human Services (HHS)
Trends in Past-Year Misuse of Rx Opioids and Heroin Use

Source: Substance Abuse and Mental Health Services Administration's National Survey on Drug Use and Health (NSDUH) 2002–2015.
Trends in Opioid Use Disorder

Source: Jones, C.M., analysis of the NSDUH 2002–2015, PUF.
Rates of Opioid Use Disorder and Drug Overdose Deaths by State

Rate of Opioid Use Disorder

Rate of Drug Overdose Deaths

Opioid Epidemic and Increasing Injection Drug Use

Rising rates of hepatitis C (HCV)

Source: Suryaprasad et al. (2014); Peters et al. (2016).

HIV outbreak in Scott County, Indiana, in 2015

Source: Suryaprasad et al. (2014); Peters et al. (2016).
Counties Deemed Highly Vulnerable to Rapid Spread of HCV or HIV

Source: Van Handel et al. (2016).
Synthetic Opioid Deaths Closely Linked to Illicit Fentanyl Supply

Source: Drug Enforcement Administration; CDC’s NVSS (2017).
NFLIS = National Forensic Laboratory Information System.
Age Distribution of Opioid Deaths in 2015

Source: CDC's NVSS (2016).
Opioid Overdose Deaths by Sex, 2015

Source: CDC's NVSS (2016).
Opioid Overdose Deaths by Urbanicity, 2015

Source: CDC's NVSS (2016).
Fentanyl and Counterfeit Products Broaden At-Risk Population

- Reports of fentanyl being pressed into counterfeit tablets and sold as commonly abused opioids and benzodiazepines
- Reports of people who thought they were using cocaine but were actually using fentanyl
Heroin and Synthetic Opioids Driving Increase in Cocaine-Related Deaths

Source: Jones et al. (2017).
HHS Opioid Strategy

- Surveillance goal: improve timeliness and specificity of surveillance activities to inform policy and programmatic efforts
- This will help HHS be prepared for and responsive to the evolving epidemic
For More Information

• Christopher Jones
  – Christopher.Jones@HHS.GOV
Audience Q&A

Looking ahead to the next three to five years, do you think wastewater testing should focus on:

• A) Opioids
• B) Cocaine
• C) Marijuana
• D) Emerging substances
• E) All of the above
III. Public health applications of wastewater testing

Dan Burgard
University of Puget Sound

Caleb Banta-Green
University of Washington

Kevin Bisceglia
Hofstra University
Wastewater Testing:
A Pipeline to Public Health Data

Wastewater Symposium
Washington, DC

May 16, 2017

Daniel A. Burgard • Kevin Bisceglia • Caleb Banta-Green
What Are Drug Epidemiology Goals? (broadly applies to other health behaviors)

• Track changes in use over time
  – Evaluate intervention impacts
  – Changes in use or supply

• Determine level of use (absolute or relative)
  – Determine prevalence
  – Prioritize interventions

• Identify/document new drugs
  – Identify new/incidental use
  – Alert public
  – Determine interventions
Drug Abuse Surveillance—Current Limitations

- Lack of geographic resolution: current surveys provide national-level drug use/abuse data but little at the state or substate level
- Lack of temporal resolution (annual data) and timely availability
- Population coverage: Large portion of drug-using community is currently excluded
- Small number of “events” in many jurisdictions
- Specific/actual drugs
Examples of Measurement Bias

• Mortality data: only true population-level data
  – “Tip of the iceberg” because mortality is biased toward more lethal drugs and lags behind entrance of drugs into the “market”

• Current surveys usually:
  – Rely on self-reporting
  – Exclude populations such as prisoners

• Calls to poison control centers may decline as physicians recognize drug-related health problems and gain experience in treatment
Essential Data Comparison Problem

WW is total population

Common data issues

- Missing highest-frequency users
- Only high-frequency users
- Populations being compared don’t align well
Raw Wastewater Influent

• Conveniently “focused” and sampled at a central location
• Least amount of degradation compared with effluent
• Preserves people’s privacy
• Samples collected daily
• Known flows for calculation of loads

http://www.kingcounty.gov/environment/wtd/About/System/West.aspx
Attributes of Data Derived from Wastewater Treatment Plants (WWTPs) (1)

• Cover much of the population
  – But areas with septic systems are not covered

• Known catchment areas

• Generally follow political boundaries
  – Aids comparisons with other data types
  – Increases utility for local planners

• GIS/mapping data often available from local municipalities
Attributes of Data Derived from WWTPs (2)

- Compound/drug specific
- Timely—available with short lag
- Time scalable (within day, day, month, year)
- Geographically scalable (could aggregate municipalities or go “upstream”)
Population Covered by WWTP

WWTPs cover 85% of the population of King County, Washington, based on place of residence: 1,482,427 of 1,737,034 residents.
Wastewater Catchment Areas for King County

- Multiple places
- Moderate size
- Alignment with cities varies
Wastewater-Based Epidemiology

- Environmental Scientists
- Wastewater Engineers
- Drug Epidemiologists

Wastewater-Based Epidemiology
Factors Affecting the Utility of Wastewater-Based Epidemiology

**SAMPLING**
- Collection mode/frequency
  - Grab
  - Composite
  - Passive
- Flow measurements
- Analyte stability
  - In-sewer transport
  - Sampling
  - Storage

**CHEMICAL ANALYSIS**
- Matrix effects
  - Use of labeled internal standards
- Analytical variability
- Calibration
  - Intraday precision
  - Interday precision

**DISCHARGE BACK-CALCULATIONS**
- Pharmacokinetics
  - Metabolite choice/parent drug
  - Excretion rates
- Dose estimates
  - Routes of administration
- Population estimates
  - Census data
  - Biomarker tracing
  - Variation
Wastewater Testing

• Types of samples
  – Grab samples
  – Composite (24 hour) time, volume, or flow
  – Passive sampling

• Approach and frequency affect the results substantially
Wastewater Collection

- Wastewater conveyance systems
  - Gravity-fed with or without pumps stations
- Locations
  - Treatment plants (downstream)
  - Sewer system (midstream)
  - Building/event/single location (upstream)
Wastewater Autosamplers

Flow meter

Refrigerated composite sampler at WWTP

Upstream composite sampler

Frozen composite
Deployed for 27 days

Deployed for five weeks compared with six-hour composites

Sci. Total Environ. 2014, 472, 9-12

Environ. Sci. Technol. 2011, 45(13), 5676-82
Wastewater as a Window into Public Health

• Prescription compliance and prevalence of specific ailments and health behaviors
  – Tamiflu compliance during flu outbreaks
  – Tobacco and alcohol use

• “Big-picture” trends in population health
  – Broad-spectrum antibiotics and OTC pain medicines?
  – Endogenous biomarkers of stress?
  – Trends in obesity through changes in gut microbiome

• Pathogen surveillance
  – Polio, hepatitis, and other disease vectors—track or predict outbreaks in near-real time?
  – Antibiotic resistance?
Adderall—mixed amphetamine salts

This path should correlate with times of academic stress

[Graph showing AMP ng/mg Creatinine levels for different periods: 1st week, Midterms, post-midterms, Last wk, Finals. The graph shows higher AMP levels during the Finals compared to other periods.]
The shading of the box indicates the amount of censoring, from lightest gray (heavily censored data) to black (complete data).

The label under the WWTP names and the background shading indicate which method is used to create the estimated yearly mean.
Methamphetamine Use in Washington State and Oregon

Figure 7: Methamphetamine index load (mg/person/day) mean with 95% confidence interval
Statistical Analyses

• Need to create:
  – Index load-estimated concentration of drug/metabolite, adjusting for sample preparation procedures, total wastewater flow, and population
  – Confidence bounds for estimate
• Address missing/censored data

Using wastewater-based epidemiology to estimate drug consumption—Statistical analyses and data presentation

Caleb J. Banta-Green, Alex J. Brewer, Christoph Ort, Dennis R. Heisel, Jason R. Williams, Jennifer A. Field
# Overview of Wastewater Testing for Drugs

<table>
<thead>
<tr>
<th>Drug</th>
<th>Studies/findings</th>
<th>Challenges/issues</th>
</tr>
</thead>
<tbody>
<tr>
<td>Illicit stimulants</td>
<td>Often detected</td>
<td>Sometimes below detection limits. Common drugs, deaths common.</td>
</tr>
<tr>
<td>Cannabis</td>
<td>Difficult to interpret</td>
<td>Very limited human metabolism data, in-sewer metabolism complicated.</td>
</tr>
<tr>
<td>Heroin</td>
<td>Difficult to detect and interpret</td>
<td>Degrades to nonspecific metabolites quickly. Seems ill-suited to wastewater testing.</td>
</tr>
<tr>
<td>Rx opioids</td>
<td>Most are easy to detect</td>
<td>High potency compounds, present at very low levels. Added value of wastewater testing?</td>
</tr>
<tr>
<td>Non-Rx opioids/fentanyls</td>
<td>Very difficult to detect</td>
<td>Very low concentrations. Major public health concern, high lethality. Presence/absence important.</td>
</tr>
</tbody>
</table>
Considerations Going Forward

• What do we really want to know?
• Is a specific drug present:
  – In our city?
  – At a specific venue?
• Comparing trends across place or time?
• What are the characteristics of the drugs, users, and system?
• Can the real questions of interest be answered with wastewater testing?
For More Information

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• Kevin Bisceglia, Ph.D.
  – Kevin.J.Bisceglia@hofstra.edu

• Caleb Banta-Green, Ph.D., M.P.H., M.S.W.
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Panel Discussion

Dan Burgard  
University of Puget Sound

Caleb Banta-Green  
University of Washington

Kevin Bisceglia  
Hofstra University

Katrice Lippa  
National Institute of Standards and Technology

Moira O’Brien  
National Institute on Drug Abuse
IV. Knowledge gaps in treatment of opioid/substance abuse

Melinda Campopiano

Substance Abuse and Mental Health Services Administration
Knowledge Gaps in Treatment of Substance Use Disorder

Wastewater Symposium
Washington, DC

May 16, 2017

Melinda Campopiano, M.D.
SAMHSA/CSAT
Number of People Ages 12 or Older with a Past-Year Substance Use Disorder: 2015 National Survey on Drug Use and Health (NSDUH)

No Past Year Substance Use Disorder
246.9 Million People (92.2%)

Past Year Substance Use Disorder
20.8 Million People (7.8%)

Notes:

The estimated numbers of people are people ages 12 or older in the civilian, noninstitutionalized population in the United States. The numbers do not sum to the total population of the United States because the population for NSDUH does not include people ages 11 or younger, people with no fixed household address (such as homeless or transient people not in shelters), active-duty military personnel, and residents of institutional group quarters (such as correctional facilities, nursing homes, mental institutions, and long-term care hospitals).

The estimated numbers of people with substance use disorders are not mutually exclusive because people could have use disorders for more than one substance.
Substate Reports: Illicit Drug Use in Past Month

Figure 1 *Illicit Drug Use in the Past Month* among Individuals Aged 12 or Older, by Substate Region: Percentages, Annual Averages Based on 2012, 2013, and 2014 NSDUHs


Substate Reports: Marijuana Use in Past Month

Figure 3  *Marijuana Use in the Past Month* among Individuals Aged 12 or Older, by Substate Region: Percentages, Annual Averages Based on 2012, 2013, and 2014 NSDUHs

NOTE: For substate region definitions, see the "2012-2014 National Survey on Drug Use and Health Substate Region Definitions" at http://www.samhsa.gov/data/.

Receipt of Specialty Treatment in the Past Year Among Adults Age 18 or Older Who Needed Substance Use Treatment in the Past Year: 2015 NSDUH

20.4 Million Adults Needed Substance Use Treatment

- 2.3 Million Received Treatment at a Specialty Facility for a Substance Use Problem (11.1%)
- 18.1 Million Did Not Receive Treatment at a Specialty Facility for a Substance Use Problem (88.9%)
Past-Year Substance Use Disorder (SUD) and Mental Illness (MI) Among Adults Age 18 or Older: 2015 NSDUH

- 43.4 Million Adults Had Mental Illness
- 35.4 Million Had Mental Illness, No SUD
- 19.6 Million Adults Had SUD
- 8.1 Million SUD and Mental Illness
- 11.5 Million SUD, No Mental Illness
Receipt of Mental Health Care and Specialty Substance Use Treatment in Past Year Among Adults Age 18 or Older Who Had Past-Year MI and SUD: Percentages, 2015 NSDUH

8.1 Million Adults with Co-Occurring Mental Illness and Substance Use Disorders

Notes:
Mental health care is defined as having received inpatient care or outpatient care or having used prescription medication for problems with emotions, nerves, or mental health. Specialty substance use treatment refers to treatment at a hospital (inpatient only), rehabilitation facility (inpatient or outpatient), or mental health center to reduce or stop drug or alcohol use or for medical problems associated with drug or alcohol use.
The percentages do not add to 100% due to rounding.
Treatment (1)

• What type of treatment is being provided, and where?

• How are medications and psychosocial services being provided, together and/or separately?
Treatment (2)

• What role does stigma play among providers, the public, and patients—broadly and for specific types of treatments?

• How does implementation of evidence-based treatment vary across communities?
Actual Use

• What drugs are being used, and how does this vary across communities?

• Does depersonalized information about substance use in a community increase or decrease prejudice and misinformation?
• Is it possible to find out when new synthetic substances become available in a community so we can warn the public and educate potential users to reduce morbidity and mortality?
Thank you!

• Melinda Campopiano
  – Melinda.Campopiano@samhsa.hhs.gov
Panel Discussion

Melinda Campopiano
Substance Abuse and Mental Health Services Administration

Renee Johnson
Johns Hopkins University

Aleksandra Zgierska
American Society of Addiction Medicine
V. Successes and hurdles in international wastewater testing efforts

Jochen Mueller
University of Queensland
Introduction to Wastewater-Based Epidemiology

• Click here to watch a short video introducing wastewater-based epidemiology
Successes and Hurdles in International Wastewater Testing

Wastewater Symposium
Washington, DC

May 16, 2017

Jochen Mueller • Sara Castiglioni • Liesbeth Vandam • Kevin Thomas

On behalf of Sewage Analysis CORe group Europe (SCORE), the Australian National Wastewater Drug Monitoring Program, and related programs conducted by presenters
Monitoring in the EU: A Multisource Approach

Early Warning System

Tracking new drugs and emerging trends

- Hospital emergencies
- Forensic science, pill testing
- Internet monitoring
- Wastewater analysis
- Trendspotter studies
- Local/city networks

Routine monitoring/indicators: surveys, seizures, overdoses, etc.
SCORE as a Data Provider

Years participated
- >3
- 1 or 2
- new lab/city/country

Cities outside Europe
- AU/NZ (3)
- North America (3)
- South America (2)
- Asia (1)
- Martinique (1)

Labs
- 2011: 12
- 2012: 14
- 2013: 15
- 2014: 22
- 2015: 27 (28)
- 2016: (30)

Cities
- 2011: 19
- 2012: 23
- 2013: 42
- 2014: 50
- 2015: 67 (60)
- 2016: (70)

Countries
- 2011: 11
- 2012: 11
- 2013: 21
- 2014: 16
- 2015: 27 (24)
- 2016: (28)

Population
- 2011: 14.1
- 2012: 11.5
- 2013: 24.7
- 2014: 29.2
- 2015: 38 (31)
- 2016: (40)
EMCDDA Publication of Wastewater Findings

EMCDDA = European Monitoring Centre for Drugs and Drug Addiction
Cocaine Findings, 2016

Cocaine residues in wastewater in selected European cities: trends and most recent data

mg/1000 population/day


Antwerp  London  Barcelona  Milan
Paris  Zagreb  Oslo

NB: Mean daily amounts of benzoylcegonine in milligrams per 1 000 population. Sampling was carried out in selected European cities over a week in 2016. Source: Sewage Analysis Core Group Europe (SCORE).

European Monitoring Centre for Drugs and Drug Addiction
The Fundamentals...Simplified (1)

Mass of drug residues in wastewater [mg 1000p\(^{-1}\) d\(^{-1}\)]

\[
\frac{C_{i,ww}(S_{ww}) \cdot Q_{ww}}{P} \cdot \frac{1}{e_i} \cdot \frac{1}{d_i} \cdot \frac{1}{p_i} \cdot \frac{1}{t_i}
\]

- \(C_{i,ww}(S_{ww})\): concentration in a sample
- \(Q_{ww}\): sample volume
- \(P\): population
- \(e_i\): excretion
- \(d_i, p_i\): dose and purity
- \(t_i\): loss in sewer (transformation and sorption)

Roles:
- Analytical chemist
- Census
- Environmental engineer
- Sewage treatment plant operator
- Forensic scientist
- Addiction / prevention specialist
- Pharmacologist
Population-normalized drug consumed (M) estimated from:

\[
M_i = \frac{C_{i,ww} \cdot Q_{ww}}{\text{Population}} \cdot \text{CorrFac}_i \quad \text{in} \quad \frac{g}{\text{day} \cdot \text{person}}
\]

- \(M_i\): mass load of chemical normalized to sampling period (day) and population
- \(C_{i,ww}\): concentration in a sample; a function of concentration and analytical method
- \(Q_{ww}\): sampling; the smaller the catchment, the greater the sampling requirements; potential issue with sampling of hydrophobic chemicals
- \(P\): population; modelled from other markers; uncertainty in spatial > temporal trends
- \(\text{CorrFac}\): excretion, loss in sewer, and other factors
Uncertainties—Methamphetamine in Australia

- Trend observable
- Uncertainties relatively small
- Trend probably too big to explain by increase in purity/dose
- Trend holds across populations

Wastewater analysis—accurate and reliable for Methamphetamine

National ICE Taskforce

- Recommends wastewater analysis
- Control the ICE “epidemic”
### Some Opioids Targeted by Wastewater Analysis

<table>
<thead>
<tr>
<th><strong>Common Opioids</strong></th>
<th><strong>Metabolite/target</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Codeine</td>
<td>Codeine, Norcodeine, Codeine-6-glucuronide, <strong>Morphine</strong></td>
</tr>
<tr>
<td>Fentanyl</td>
<td>Fentanyl, Norfentanyl</td>
</tr>
<tr>
<td>Ketamine</td>
<td>Ketamine, Norketamine</td>
</tr>
<tr>
<td>Methadone</td>
<td>Methadone, EDDP</td>
</tr>
<tr>
<td>Morphine</td>
<td><strong>Morphine</strong>, Morphine-glucuronide</td>
</tr>
<tr>
<td>Oxycodone</td>
<td>Oxycodone, Noroxycodone, Oxymorphine</td>
</tr>
<tr>
<td>Heroin (diacetylmorphine)</td>
<td>6-monoacetylmorphine (6-MAM), <strong>Morphine</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Other opioids</strong></th>
<th><strong>Metabolite/target</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Ketamine</td>
<td>Ketamine, Norketamine</td>
</tr>
<tr>
<td>Buprenorphine</td>
<td>Buprenorphine, Norbuprenorphine</td>
</tr>
<tr>
<td>Hydrocodone</td>
<td>Hydrocodone, Norhydrocodone</td>
</tr>
<tr>
<td>Hydromorphone</td>
<td>Hydromorphone, Hydromorphone-glucuronide</td>
</tr>
<tr>
<td>Oxymorphine</td>
<td>Oxymorphone, Oxymorphine-glucuronide</td>
</tr>
</tbody>
</table>
Heroin Temporal Trends in Italy, EU

83
Australian National Wastewater Drug Monitoring Program

- Funded by the Australian Criminal Intelligence Commission
- Study illicit drugs, alcohol, tobacco
- Supported by state/territories

LEGEND

C = capital city wastewater treatment plant (WWTP); bimonthly sampling
r = regional WWTP; quarterly sampling
Opioid Trends in Adelaide, Australia

Estimated Oxycodone Consumption

SA: Adelaide (average of 007, 013, 027 & 059)

Estimated Fentanyl Consumption

SA: Adelaide (average of 007, 013, 027 & 059)
Estimated Opioid Use in Adelaide (2011–2015)

Tscharke et al. 2016 (STOTEN)

Morphine

Codeine

Methadone

Heroin
Spatial Trends of Oxycodone Use in Australia

[Graph depicting estimated oxycodone consumption by state and year, showing national and regional averages.]
Attempting to Compare Use of Different Drugs

Victoria (VIC)

Western Australia (WA)

Estimated Consumption
[atoms / 1000 people / day]

- Capital Average
- Regional Average
- National Capital Average
- National Regional Average
Comparison with Other Data Sources

Trends in Milan, Italy, 2005–2011, from wastewater-based epidemiology

Epidemiological data—general population survey

Heroin

Significant decrease in 2008–2009

Zuccato et al. (2011)

Data reported in the Annual National Report in 2010

<table>
<thead>
<tr>
<th>Sostanze</th>
<th>2008</th>
<th>2009</th>
<th>Differenza</th>
<th>Scostamento % (Δ%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eroina</td>
<td>0.39</td>
<td>0.25</td>
<td>-0.14</td>
<td>-35.9</td>
</tr>
</tbody>
</table>

Similar decrease of heroin consumption from 2008 to 2009!
Triangulation of Drug Use

- Provide alternative perspectives to evaluate estimates
- Help target/identify new harms
  - What to look for in wastewater
- Include data about consumption habits/frequency
  - Use wastewater data to estimate number of users per type (occasional, regular, etc.)
- Intelligence about drug trafficking and criminal organizations
  - Estimate market size and/or share held by specific criminal organisations
Where to...?

Research Areas

- Triangulation (health, forensics criminology, sociology, politics)
- National and international collaboration
- Uncertainties (stability, excretion, population)
- Sampling methods and sewers
- Sampling and archiving (long-term timelines)
- Other applications (prisons, festivals, social events)
- Analytical advances (new markers, nontarget)
- National and international collaboration
- The Potential of Wastewater Testing for Public Health and Safety
Summary and Conclusion

• Wastewater analysis is now routinely used to monitor a wide range of drugs

• Routine programs in Europe and Australia include monitoring of trends of selected opioids

• Uncertainties exist with assessing use of various opioids
For More Information

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• Sara Castiglioni
  – S.Castiglioni@marionegri.it

• Liesbeth Vandam
  – Liesbeth.Vandam@emcdda.europa.eu
Panel Discussion

Jochen Mueller
The University of Queensland

Sara Castiglioni
Mario Negri Institute for Pharmacological Research

Frederic Been
University of Antwerp

Liesbeth Vandam
European Monitoring Centre for Drugs and Drug Addiction
Audience Q&A

If we think about how to translate the European monitoring system to the U.S., at what level should coordination begin?

• A) City/Town level
• B) Regional level
• C) State level
• D) National level
• E) All of the above
VI. Keynote Speaker

J.B. Wogan

Governing Magazine
VII. Knowledge gaps in prevention of opioid and other substance abuse

Jeffrey Locke
National Governors Association
How Governors and States Are Approaching the Opioid Epidemic

Wastewater Symposium
Washington, DC

May 16, 2017

Jeffrey Locke
National Governors Association (NGA)
Road Map to the Presentation

• NGA background
• Snapshot of the problem
• Challenges facing governors
• State efforts and progress
• Selected state strategies and trends
About the National Governors Association

Conference of Governors
The White House, 1908
Opioid Deaths by State, 1999–2014

2014 RAPID INCREASE IN RATES OF DRUG OVERDOSE DEATHS
Growth of Illicit Fentanyl

Note: Data show the number of fentanyl exhibits in NFLIS, 2004–2015.
Snapshot of Illicit Fentanyl Nationally
Challenges Facing Governors in the Opioid Crisis

• This crisis is affecting constituents’ lives
• The solutions are not simple
• The stigma surrounding opioid use disorder is changing
Governors have long been at the forefront of efforts to prevent and treat opioid addiction, working with health care providers, law enforcement and other stakeholders to mount a comprehensive response to the opioid crisis. Although there has been progress in recent years, inappropriate opioid prescribing continues to fuel one of the deadliest drug epidemics in our nation’s history, claiming the lives of 78 people every day. More Americans died from drug overdoses in 2014 than in any year on record. Driven by a spike in opioid-related deaths, drug overdose now surpasses motor vehicle crashes as the leading cause of injury death in the United States. While most opioid-related overdoses involve prescription painkillers, an increasing number are linked to heroin and fentanyl, a powerful synthetic opioid often packaged and sold as heroin. The consequences of the opioid epidemic continue to reverberate through society, ruining lives, devastating families and overwhelming the health care system, law enforcement and social services.

During the 2016 NGA Winter Meeting, governors agreed that collective action is needed to end the opioid crisis. With more lives lost every day, governors are redoubling their efforts to combat the epidemic with bold and thoughtful new strategies. While states play a central role in ending this public health and safety emergency, they cannot do it alone. Turning the tide on the epidemic requires a coordinated response across all levels of government and strong leadership from the private sector, including opioid manufacturers and prescribers.

With this compact, the undersigned commit to build on these efforts to fight opioid addiction by

- Taking steps to reduce inappropriate opioid prescribing, which may include:
  - Partnering with health care providers to develop or update evidence-based opioid prescribing guidelines, which may be informed by CDC’s guideline, and consider prescription limits with exceptions for certain patients and circumstances;
  - Requiring that physicians, osteopaths, nurse practitioners, physician assistants, dentists, veterinarians and all other opioid prescribers receive education on pain management, opioid prescribing and addiction throughout their training and careers;
  - Integrating data from state prescription drug monitoring programs (PDMPs) into electronic health records and requiring PDMP use by opioid prescribers and dispensers; and
  - Reducing payment and administrative barriers in Medicaid and other health plans to promote comprehensive pain management that includes alternatives to opioid painkillers.

- Leading efforts to change the nation’s understanding of opioids and addiction, which may include:
  - Developing a communications strategy through the governor’s office to raise awareness about the risks of abuse associated with opioid use and reduce the stigma of addiction;
  - Establishing social media campaigns and integrating education into schools, athletic programs and other community-based settings to raise awareness about opioid abuse and addiction among youth and other at-risk groups; and
  - Partnering with professional associations to improve understanding of the disease of addiction among health care providers and law enforcement.

NGA OPIOID COMPACT
SIGNED BY 46
GOVERNORS IN
JULY 2016
www.nga.org
Governors Fighting the Opioid Epidemic

Finding Solutions to the Prescription Opioid and Heroin Crisis: A Road Map for States

NGA OPIOID ROAD MAP

www.nga.org
Opioid Road Map: Key Factors

FACTOR 1
Wider Availability of Prescription Opioids

FACTOR 2
Lack of Access to Treatment for Opioid Use Disorder

FACTOR 3
Changing Economics and Supply of Heroin

Increasing Prescription Opioid Misuse and Overdose

Increasing Heroin Use and Overdose

Underlying Biological and Social Risk Factors for Substance Use Disorder
Comprehensive Policy Framework for States

Overarching Prescription Opioid Misuse and Heroin Policy Framework

Health Care and Public Safety

Preventing Opioid Misuse and Overdose
- Health Care Strategies for Prevention and Early Identification
- Public Safety Strategies for Reducing Illicit Supply

Responding to Opioid Misuse and Overdose
- Health Care Strategies for Treatment and Recovery
- Public Safety Strategies for Response
Selected Prevention Strategies

• Develop and update guidelines for all opioid prescribers

• Limit new opioid prescriptions for acute pain, with exceptions for certain patients

• Develop and adopt a comprehensive opioid management program in Medicaid and in other state-run programs

• Remove methadone for managing pain from Medicaid’s preferred drug list
Selected Public Safety Strategies

Reducing supply of and demand for illicit opioids:

- Establish a collaborative information-sharing environment that breaks down silos across state agencies to better understand trends
- Use assets from partners to improve data collection and intelligence sharing to restrict the supply of illicit opioids
- Expand statutory tools for prosecuting major distributors
- Expand partnerships and data access to better target overprescribers
Selected Public Safety Strategies

Responding to the crisis:

• Empower, educate, and equip law enforcement personnel to prevent overdose deaths and facilitate access to treatment

• Reinforce use of best practices in drug treatment courts

• Ensure access to MAT in correctional facilities and upon re-entry into the community

• Strengthen pre-trial drug diversion programs to give people the chance to enter substance use treatment
Hot Topics from States

• Establish a collaborative data and information-sharing environment

• Limit new opioid prescriptions for acute pain, with exceptions

• Expand use of non-opioid therapies for pain

• Increase access to naloxone

• Expand and strengthen the treatment and recovery workforce

• Increase access to MAT in corrections and with re-entry
## Drug-Monitoring Data and Information Sharing

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<th>Law enforcement</th>
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<td>EMS naloxone deployment data</td>
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<td>Lab results (opioid and non-opioid pills, heroin,</td>
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<td>meth, cocaine, marijuana, bath salts)</td>
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<tr>
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<td>Addiction treatment admissions</td>
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<td>Shootings</td>
<td>Urinalysis results</td>
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Value of Real-Time Data

• States face a variety of data-related challenges, including:
  – Problems with data use agreements
  – Agency territory issues
  – Questions about personally identifiable information
  – Intergovernmental challenges
  – Privacy concerns

• States are facilitating data as quickly as they can for drug supply intelligence (e.g., stamps) and to push prevention and treatment resources toward overdose spikes
Potential Opportunities for Wastewater Testing

• May offer an additional layer for states to add to their data analysis

• A better picture of the epidemic, drug supply, and consumption patterns could help states guard against “squeezing the balloon”

• Previous studies exist on meth, MDMA, amphetamines, cocaine, heroin, methadone, and morphine in wastewater-based epidemiology in Nevada, Utah, South Carolina, Nebraska, and New York*

Questions and Challenges for Wastewater Testing

• States are focused on data (e.g., data to drive policy, data dashboards, DMI, etc.) to target limited resources

• Needs to help states target interventions proactively

• Will wastewater testing offer real-time estimates as a potential complementary tool?*

• Can it help alert LE to new substances and track changes in drug use over time?*

Questions and Challenges for Wastewater Testing

• What role does law enforcement have in working with wastewater treatment plants?

• What are the limitations in time frame analyses between drug use surveys and wastewater analysis?

• Challenges with financing—how can states afford to pilot programs or support this work?

• What types of conversations do state labs, wastewater plants, environmental quality agencies, and law enforcement need to have?
For More Information

• Jeffrey Locke, senior policy analyst
  – jlocke@nga.org
  – @jeffreyRlocke (Twitter)
Panel Discussion

Jeffrey Locke
National Governors Association

Capt. Juan Colon
New Jersey State Police

Jeff Beeson
High Intensity Drug Trafficking Area Program

Capt. Jen Fan
Substance Abuse and Mental Health Services Administration
Drug Monitoring Initiative:
A Drug Intelligence Capability for Healthcare & Public Safety Partners

Wastewater Symposium
Washington, DC

May 16, 2017

Captain Juan Colon – New Jersey State Police
New Jersey Office of the Attorney General
DMI DATA SETS COLLECTED

**Crimes**
- Drug Seizures/Lab results
  - Heroin
  - Pills
  - Methamphetamine
  - Cocaine
  - Marijuana Variants
  - Synthetics
- Shootings
- Gun Recoveries
- Drug Arrests
- LE Narcan Deployments

**Health/Human Services**
- EMS Narcan Deployment Data
- Toxicology Data on Overdose Deaths
- Prescription Drug Monitoring Program
- Addiction Treatment Admissions
  - Children and Families
  - DHS
- Urinalysis results
- Medicaid Data
# Forensic Crime Lab
## Drug Examination Results

### NJSP OFS Heroin Glassine Stamp Data

**November 10, 2015**

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ALERT!
5 or more administrations
10 mile radius
12 hours

Fatal & Non Fatal Overdoses
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### Opioid-Related Categories: 1/1/2015 to 6/30/2016

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*Source: New Jersey Office of the State Medical Examiner, 2015 Drug Related Deaths.*
### Opioid-Related Rankings: 1/1/2015 to 6/30/2016

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<th>Fentanyl Submissions</th>
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*Source: New Jersey Office of the State Medical Examiner, 2015 Drug Related Deaths.*
LE & EMS Naloxone Administrations - Atlantic County
January 1, 2015 to September 30, 2016

EMS = 822 (87%)
LE = 119 (13%)
TOTAL = 941

In NJ, Atlantic County ranked:
7th in total administrations (7%)
3rd in EMS administrations (8%)
13th in LE administrations (3%)

Totals are labeled in grey.
LE & EMS Naloxone Administrations - Atlantic County
January 1, 2015 to September 30, 2016

67% of naloxone administrations occurred between 1 PM and midnight.

TIME OF DAY

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<th>5 - 8 AM (81)</th>
<th>9 AM - NOON (161)</th>
<th>1 - 4 PM (206)</th>
<th>5 - 8 PM (244)</th>
<th>9 - MIDNIGHT (179)</th>
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Legend:
- RED: MONDAY (109)
- GREEN: TUESDAY (112)
- PURPLE: WEDNESDAY (116)
- BLUE: THURSDAY (139)
- ORANGE: FRIDAY (169)
- NAVY: SATURDAY (166)
- YELLOW: SUNDAY (130)
## Identification Of At-Risk Individuals

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For More Information

• Captain Juan Colon
  – LPP5039@GW.NJSP.ORG
  – 609-498-5885
VIII. Using advanced analytics to enhance decision making

Ravi Goyal
Mathematica Policy Research
Using Advanced Analytics to Enhance Decision Making

Wastewater Symposium
Washington, DC

May 16, 2017

Ravi Goyal • Sarah LeBarron • Jonathan Geller • Jiaqi Li • Ellen Bouchery • Aparna Keshaviah
Background

• The opioid epidemic is a complex problem requiring a multifaceted, collaborative approach by agencies, including those in public health and law enforcement\textsuperscript{1, 2}

• Collaborative, data-driven efforts should become standard practice in developing, assessing, and adjusting policies and programming\textsuperscript{2}

• Techniques to conduct analytics have greatly advanced in the past several years

Objectives

• Investigate what can be learned about the opioid epidemic in Massachusetts (MA) by combining multiple data sets aggregated at the city/town level
  – Wastewater will most likely be collected at centralized locations, such as treatment facilities
  – Wastewater data will most likely be combined with data at a regional/community level because linkage to individual-level data will be challenging

• Compare our findings with those conducted by linking dataset at the individual-level
Study

• Main
  – Predict opioid-related fatality rates (deaths per 100,000 residents) for each city or town in MA based on data from previous years

• Secondary
  – Identify data sets from federal and state agencies that provide information on the epidemic
  – Identify appropriate analytical methods
MA Opioid-Related Overdose Deaths

Number of Deaths

Year

Rate per 100,000 Residents

Number of Deaths

Rate per 100,000 Residents
MA Information

- Population: 6.8 million
- Number of counties: 14
- Number of cities and towns: 351
  - Smallest: Gosnold—77 (2015 est.)
  - Largest: Boston—667,137 (2015 est.)
Analytic Components

Multidimensional

Spatial

Forecasting

Machine Learning
### Multidimensional

<table>
<thead>
<tr>
<th>Domain</th>
<th>Source</th>
<th>Variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outcome</td>
<td>MA DPH</td>
<td>• Number of opioid overdose deaths (per 100,000 residents)</td>
</tr>
<tr>
<td>Demographics</td>
<td>MA State Data Center</td>
<td>• Population per city/town in MA</td>
</tr>
<tr>
<td></td>
<td>2015 American Community Survey five-year estimates</td>
<td>• Median age</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Percent male residents</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Percent white residents</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Percent uninsured</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Percent unemployed</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Median income</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Percent disabled</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Percent who have public health insurance</td>
</tr>
<tr>
<td>Prescriptions</td>
<td>MA Prescription Monitoring Program</td>
<td>• Number of opioid prescriptions</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Percent of people with a class II opioid prescription</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Percent of people with activity of concern (shop around)</td>
</tr>
<tr>
<td>Treatment for addiction</td>
<td>MA Bureau of Substance Abuse Services</td>
<td>• Percent of drug treatment admissions with opioids as the primary drug</td>
</tr>
<tr>
<td>Law enforcement</td>
<td>National Incident-Based Reporting System</td>
<td>• Number of drug-related offenses</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Number of crimes against society</td>
</tr>
<tr>
<td>Spatial</td>
<td>MA Office of Geographic Information</td>
<td>• Latitude</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Longitude</td>
</tr>
</tbody>
</table>
Spatial

- Latitude and longitude
- Distance from Boston
- Average death rate in contiguous cities/towns

Opioid overdose deaths per 100,000 residents (2015)

- 0.0 - 0.9
- 1.0 - 16.9
- 17.0 - 32.9
- 33.0 - 444.4
In predictive analytics, it is critical to develop a framework that will enable an accurate assessment of the predictive power of the model; this assessment differs from traditional statistical methods because prediction aims to extrapolate results to a future population.

**Model development:**
data from all MA cities/towns on or before 2014

**Validation:**
data from 2/3 of MA cities/towns for 2015

**Testing:**
data from 1/3 of MA cities/towns for 2015
Interpretable

- Poisson regression
  - A generalized linear model form of regression analysis used to model count data
- Penalized regression
  - A regression analysis method that performs regularization
- GAM
  - A generalized linear model in which the predictor depends linearly on unknown smooth functions of some predictor variables
- Decision trees
  - A statistical method for multivariable analysis in which a decision tree is created to classify observations
- Random forests
  - An ensemble learning method that constructs a multitude of decision trees and outputs the average prediction across the individual trees

Prediction

Machine Learning
Results (same scale)

Observed

Predicted

Opioid overdose deaths per 100,000 residents (2015)

- 0.0 - 0.9
- 1.0 - 16.9
- 17.0 - 32.9
- 33.0 - 444.4

Opioid overdose deaths per 100,000 residents (2015)

- 0.0 - 0.9
- 1.0 - 16.9
- 17.0 - 32.9
- 33.0 - 49.6
Results (data-specific scale)

**Observed**

**Predicted**

<table>
<thead>
<tr>
<th>Opioid overdose deaths per 100,000 residents (2015)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0 - 0.9</td>
</tr>
<tr>
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</tr>
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<td>17.0 - 32.9</td>
</tr>
<tr>
<td>33.0 - 444.4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Opioid overdose deaths per 100,000 residents (2015)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.3 - 8.2</td>
</tr>
<tr>
<td>8.3 - 15.1</td>
</tr>
<tr>
<td>15.2 - 22.0</td>
</tr>
<tr>
<td>22.1 - 49.6</td>
</tr>
</tbody>
</table>
Findings

Aggregate-level predictions

• May have potential to predict broad ranking of a city/town based on overdose death rate (e.g., if death rate is among top 25% across MA)

• Most of the predictive power was derived from the opioid-related fatality rate of the previous year

• Aggregated statistics on demographics, prescriptions, treatment, and drug-related crimes was only weakly correlated with death rates

• Challenges arise for towns with small populations
Finding from MA DPH analysis

Individual-level associations

• People who died from opioid-related overdoses are much more likely to have an illegally obtained substance present in post-mortem toxicology

• People on opioid agonist treatments after a nonfatal overdose are significantly less likely to die

• Women are significantly more likely than men to receive opioids from 3+ prescribers and to fill them at 3+ pharmacies

• Risk of opioid overdose death after incarceration is 56x higher than for the general public
Discussion

• Value of wastewater on prediction
  – Real-time data

• Integrating wastewater data with existing data
  – Aggregate vs. individual-level analysis
  – Not always perfectly aligned with county or town borders
For More Information

• Ravi Goyal, Ph.D.
  – rgoyal@mathematica-mpr.com
Using Advanced Analytics to Identify and Reduce Prescription Drug Fraud and Abuse

Wastewater Symposium
Washington, DC

May 16, 2017

Jaya Tripathi
jtripathi@mitre.org
Multi-pronged Approach to Mining your Data

- **exploration**
  - histograms, PCA, t-SNE, clustering, visualizations, other statistical analyses

- **transformation**
  - timeline summaries, feature engineering

- **geo-spatial analytics**
  - ‘hot spots’, correlation studies using other datasets

- **graph analytics**
  - tripartite graphs, connectivity, entropy and motifs

- **machine learning**
  - predictive models, ‘ground truth’, validation
some examples of applications of the techniques …
Exploration

Age Gender Histogram

3D Scatter Plot

95K (people) under 10 yrs. of age!
Geo-Spatial and Graph Analytics

Heat Map

Doctor Shopping networks

What areas of Indiana have the most patients oxymorphone?

<table>
<thead>
<tr>
<th>Rank</th>
<th>ZCTA</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>47348</td>
</tr>
<tr>
<td>2</td>
<td>47170</td>
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<td>47359</td>
</tr>
<tr>
<td>9</td>
<td>46996</td>
</tr>
<tr>
<td>10</td>
<td>46721</td>
</tr>
</tbody>
</table>
Risk Scoring with Classification Systems

Engaged human experts for ‘ground truth’

Employed Supervised Machine Learning Models

Random Forest Algorithm

Gains Chart

\[ \text{gain} = \frac{\text{accurate prediction}}{\text{all predictions}} \]
IX. Steps to advance wastewater testing for decision making

Craig Thornton
Mathematica Policy Research

Jon Glaudemans
United Rheumatology
If given $100 to invest in any of the four critical pathways below, how much would you invest in each?

• A) Testing methods
• B) Proof-of-concept pilot studies
• C) Data/metric integration
• D) Leadership and collaboration
X. Closing remarks and synthesis

Aparna Keshaviah
Mathematica Policy Research
Closing Remarks & Synthesis

Wastewater Symposium
Washington, DC

May 16, 2017

Aparna Keshaviah, Sc.M.
Critical Needs (per participant survey)

What are your top 3 critical needs or challenges in your day-to-day work addressing the opioid crisis and other substance abuse issues?*

- Lack of resources: 80%
- Lack of adequate data: 60%
- Lack of coordination between stakeholders: 60%
- Policies/programs cannot fully address breadth of problem: 40%
- Difficulty in proposing/implementing new policies/programs: 20%
- Insufficient buy-in from colleagues or stakeholders: 0%

*Based on 19 participants who answered this question in the participant survey
Possible Futures

**Short- and Mid-term**
- Cost-benefit analysis
- Pilot studies
  - Applications
  - Participating communities
  - Funding sources
- Collaborative research groups

**Long-term**
- Coordinating center (cross-agency)
- Standardized procedures (protocols, central testing labs, etc.)
- Data warehouse (multi-drug)
- Monitoring system (large-scale)

- Special report forthcoming -
For more information

• Jennifer de Vallance
  – JdeVallance@mathematica-mpr.com

• Aparna Keshaviah
  – AKeshaviah@mathematica-mpr.com