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1

INTRODUCTION & BACKGROUND

Figure 1: Water cycle in Las Vegas (Source: Southern Nevada Water Authority website)
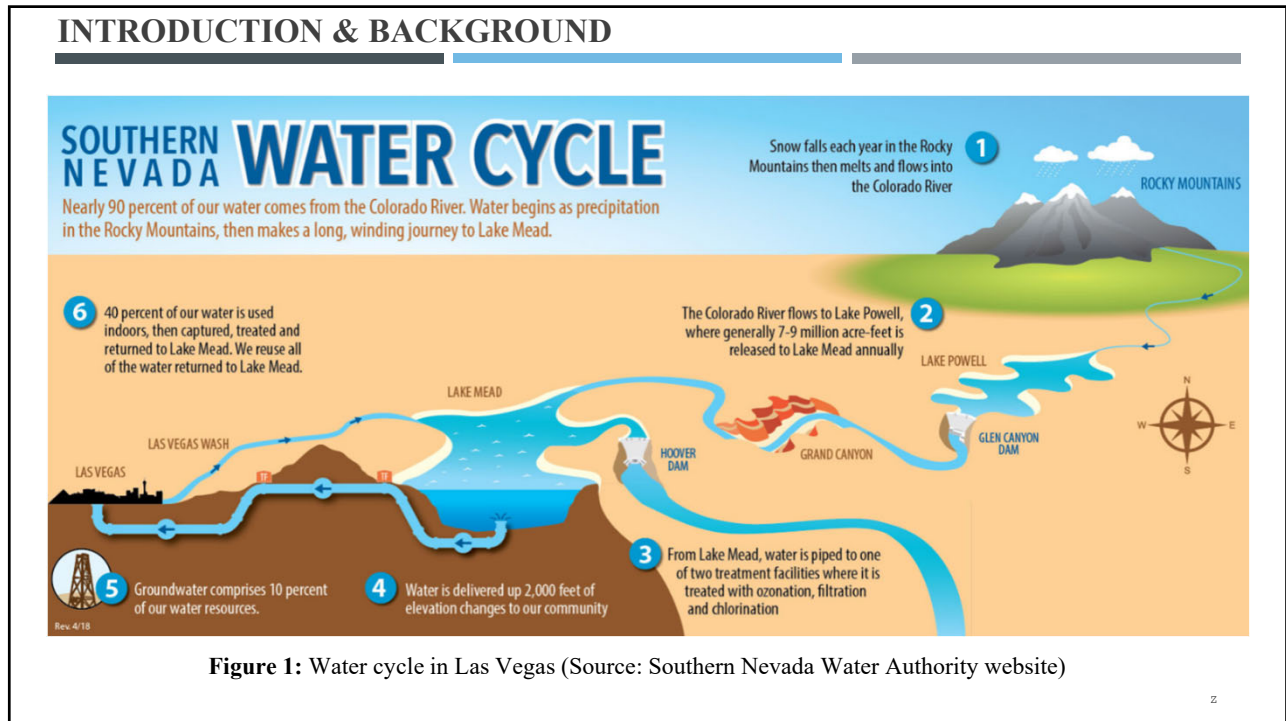
2

ISSUES AFFECTING WATER QUALITY

Figure 2: Las Vegas Wash and urban flood control channels after heavy rainfall

Figure 3: Formation of disinfection byproducts (DBPs)

Stormwater ➤

  chemical contaminants, precursors

Acronyms

HAN – Haloacetonitriles	DOM – Dissolved organic matter
THM – Trihalomethanes	HAAs – Haloacetic Acids
	NOAs – Nitrosamines

3

ISSUES AFFECTING WATER QUALITY

Figure 5: 2019 Point-in-time Statistics; Help Hope Home website

Figure 4: Homeless encampments in and around urban wash channels

Homelessness ➤

  chemical and microbial contaminants

4

ISSUES AFFECTING WATER QUALITY

Figure 6: Discharge of treated wastewater effluent

Treated wastewater ➔
    chemical contaminants, precursors

Figure 7: Four wastewater effluent discharges that feed the Las Vegas Wash
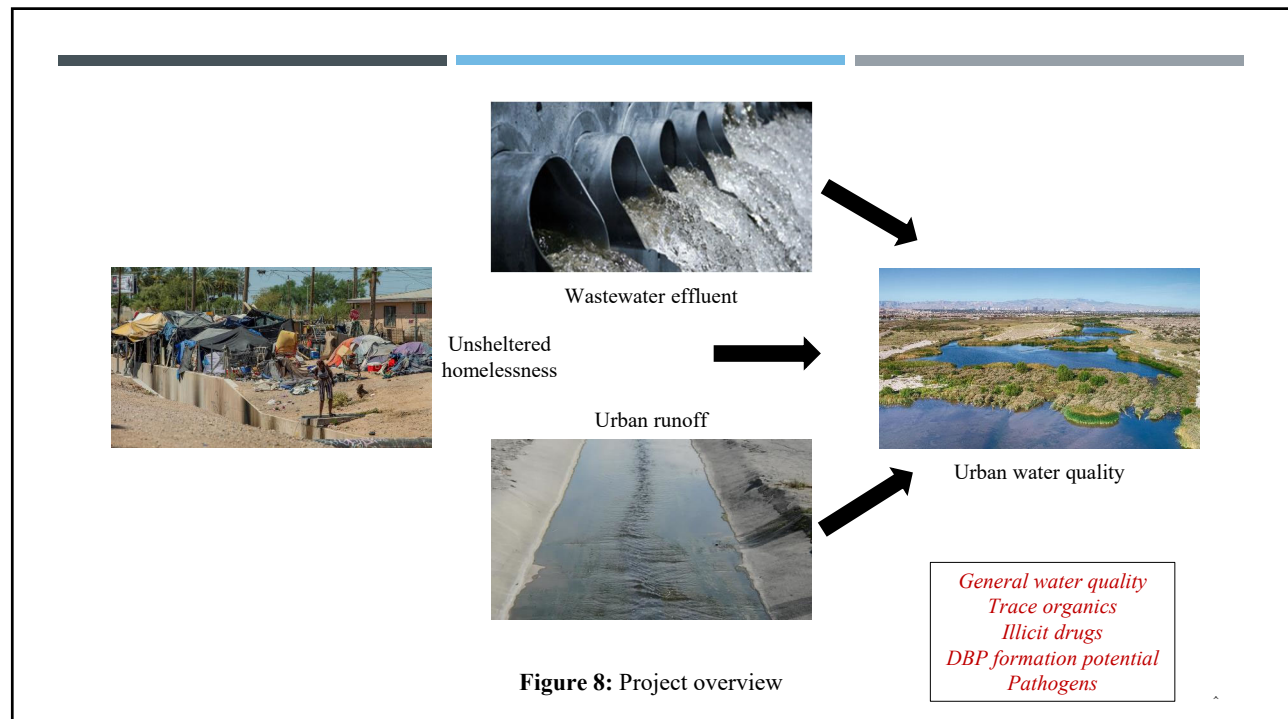(Credit: Las Vegas Review Journal)

5

Wastewater effluent

Unsheltered homelessness

Urban runoff

Urban water quality

General water quality
Trace organics
Illicit drugs
DBP formation potential
Pathogens

Figure 8: Project overview

6

QUESTIONS

- How do the flood control infrastructure and wastewater effluents impact the urban water quality of Las Vegas?
    - i. Can the influence of wastewater effluents, urban runoff, and unsheltered homelessness on water sources impact the DBP formation potential or chemical or microbial levels?
    - ii. What are the relative contaminant loads (e.g., illicit drugs, DBP precursors) from different sources?

- How can we differentiate contamination sources (e.g., human waste, wastewater effluent, stormwater runoff) in an urban setting to determine the relative contribution of each source?
    - i. Can we develop chemical fingerprints to differentiate contamination sources?
    - ii. Can we develop trace organic fingerprints to differentiate contamination sources?

- What is the pathogenic risk to people who are exposed to water in the Las Vegas Wash?
    - i. Are there suitable viral indicators?
    - ii. Can we apply quantitative microbial risk assessment (QMRA)?

Homelessness

Wastewater Effluent

Stormwater / Flood Control

7

METHODOLOGY

- 20 different locations throughout the Las Vegas Valley watershed

- 8 Sampling events over 3 years
    - "wet" and "dry"

- Samples were tested for water quality parameters, fecal indicator bacteria, human associated microbial markers, 52 anthropogenic trace compounds, and DBP FPs (THMs, HANs, & NOAs)
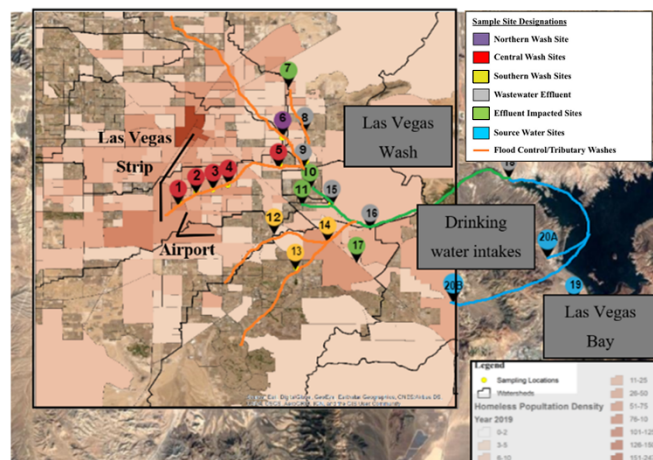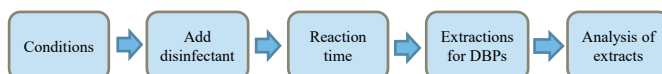

Figure 9: Map of Southern Nevada showing sampling locations and homeless density population

DBP Formation Potential test process

Conditions → Add disinfectant → Reaction time → Extractions for DBPs → Analysis of extracts

8

Slide 9

UHVXOWV) GIVFXVVIRQ

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Characterizing the chemical and microbial fingerprint of unsheltered homelessness in an urban watershed

Daniel Gerrity [a,b,*], Katerina Papp [a], Eric Dickenson [a], Meena Ejjada [b], Erica Marti [b], Oscar Quinones [a], Mayra Sarria [b], Kyle Thompson [a,c], Rebecca A. Trenholm [a]

9

Slide 10

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Microbial markers as contamination fingerprints

- Fecal indicator bacteria (FIB) were lowest in wastewater effluent and the source water
  - Due to disinfection (treatment) and dilution within Lake Mead
- FIB were significantly higher ($\rho<0.05$) in central wash sites associated with homelessness
  - Average relative loading >50%
- No significant difference for FIB between central and northern wash sites
  - Additional human inputs to northern site?

Is there any significant difference between wastewater effluents and non wastewater impacted sites?

How can we differentiate contamination sources (e.g., human waste, wastewater effluent, stormwater runoff) in an urban setting to determine the relative contribution of each source?

Sample Site Designations
- Northern Wash Site
- Central Wash Sites
- Southern Wash Sites
- Wastewater Effluent
- Effluent Impacted Sites
- Source Water Sites
- Flood Control/Tributary Washes

FIB could be used to indicate direct contamination by waste, but it cannot differentiate animal species → nonspecific microbial marker

Figure 10: Fecal indicator bacteria counts by location

10

Results & Discussion

Microbial markers as contamination fingerprints

- Non-human-specific bacteria (GenBac3, Camp2) were present at all locations
- One fecal indicator virus (pepper mild mottle virus, PMMoV) was significantly lower in southern wash sites and source water
  - Locations not directly influenced by homelessness or disinfected wastewater effluent; dilution in source water
- Human-specific bacteria (HF183) were not detected in southern wash sites
- 16S rRNA were used to characterize the microbial community at different sites
  - Differing communities by location; cannot distinguish source (unsheltered homelessness, effluent)

PMMoV and HF183 can be used to indicate direct contamination by human waste → specific human microbial markers

Is there any significant difference between wastewater effluents and non wastewater impacted sites?

How can we differentiate contamination sources (e.g., human waste, wastewater effluent, stormwater runoff) in an urban setting to determine the relative contribution of each source?
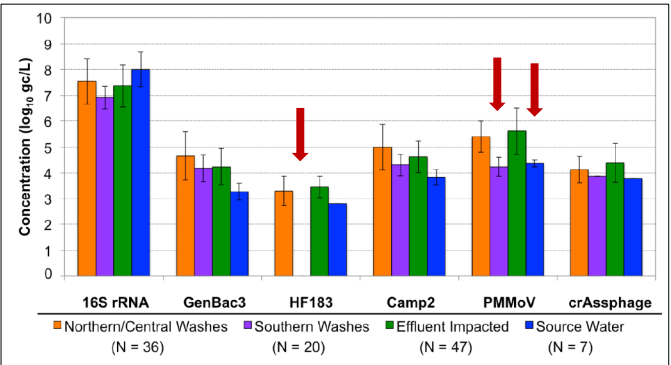
Figure 11: Indicator bacteria and virus concentrations by location

11

Chemical markers as contamination fingerprints

- 52 compounds tested at limited locations
  - Not analyzed in source water
- Several illicit drugs were more common in central wash sites (affected by homelessness): **heroin, amphetamine, methamphetamine, cocaine, morphine**
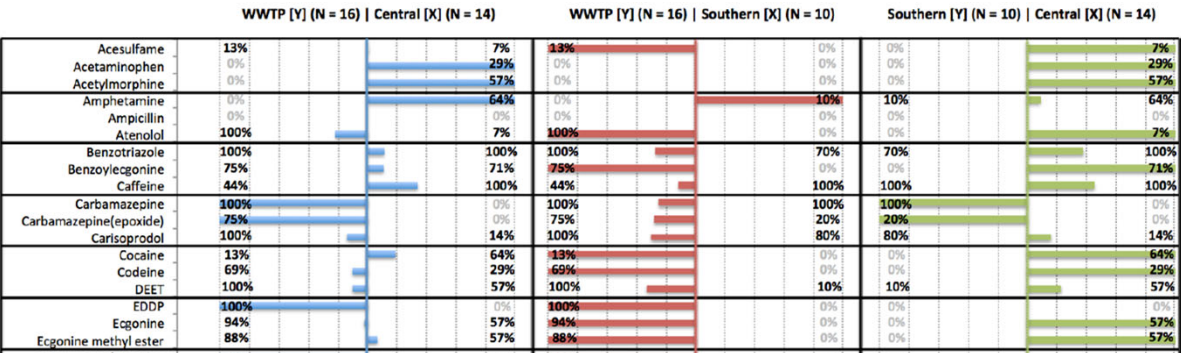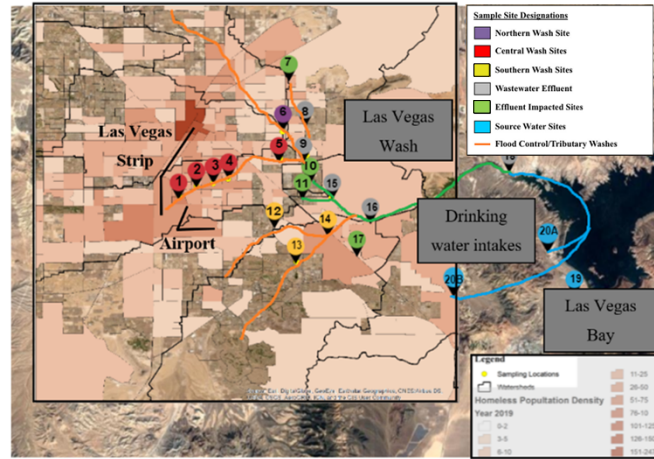 - These compounds may be in wastewater but are removed during wastewater treatment

Figure 12: Site comparisons of $\log_{10}$ fold changes in concentrations of trace organics, illicit drugs and metabolites

12

TOrCs mass loadings

$$100 \times \frac{Q_i \times C_i}{Q_{site16} \times C_{site16}} = percent\ mass\ loading$$

13

TOrCs mass loadings

- TOrCs having frequency of detection >25% was taken into consideration

- The combined WWTPs sites accounted for 93 – 99% of the total measured TOrCs at location 16

- The central wash site consisting of unsheltered homelessness accounted for 0.3 to 7%

- The lowest mass loadings came from downstream wash site accounting for 0.1 to 1.2%

- The measured and calculated mass loadings were similar; however, the discrepancies would be due to difference in flow, sorption, biodegradation, photolysis depending on the individual TOrCs
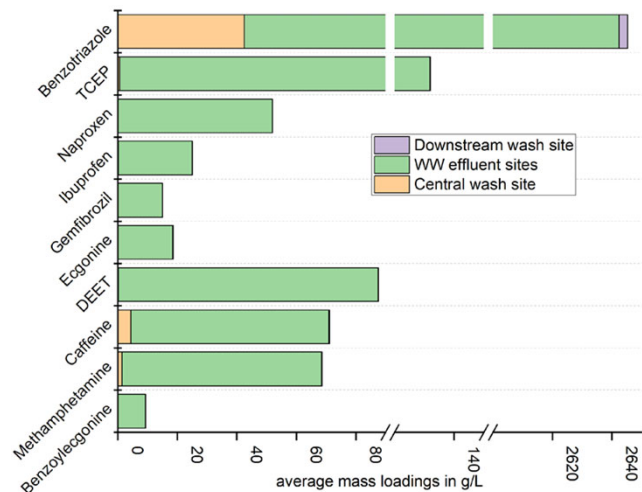
Meena Ejjada, PhD Candidate

Figure 13: Average mass loadings of all TOrCs at location 16 from all the combined wastewater effluent sites (sites 7, 10, 11, & 17), central wash (site 5), and downstream wash location (site 12)

14

Slide 15

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Illicit drugs & their metabolites

(Work in Progress)

- Measure drugs and metabolites in urban channels and treated effluent
- Use flow data to calculate mass loadings
- Back-calculate load based on metabolism data for parent drug or metabolite
- Use point-in-time census data to normalize concentration in a location

Mayra Sarria, PhD Candidate

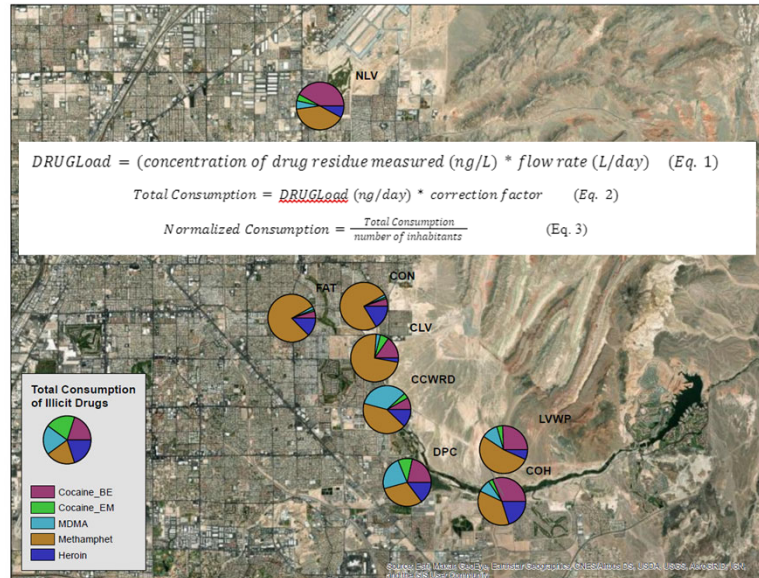Can we track drug consumption by people experiencing homelessness?

$$DRUGLoad = (concentration\ of\ drug\ residue\ measured\ (ng/L) * flow\ rate\ (L/day)\quad (Eq.\ 1)$$

$$Total\ Consumption = \underline{DRUGLoad}\ (ng/day) * correction\ factor\quad (Eq.\ 2)$$

$$Normalized\ Consumption = \frac{Total\ Consumption}{number\ of\ inhabitants}\quad (Eq.\ 3)$$

Total Consumption of Illicit Drugs
- Cocaine_BE
- Cocaine_EM
- MDMA
- Methamphet
- Heroin

Figure 14: Illicit drug and metabolite loads (not corrected or normalized)

15

Slide 16

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Illicit drugs & their metabolites

- Legalized drugs found in wastewater effluent and not in central wash sites: codeine, hydrocodone, oxycodone, methadone
- Prescription meds (e.g., carbamazepine) in southern wash sites indicate wastewater influence
  - May be due to septic tank leaks
- Illicit and prescription drugs can indicate contamination by direct human waste or septic tank leaks
- Difficult to isolate stormwater contribution – same chemicals, different concentrations

Mayra Sarria, PhD Candidate

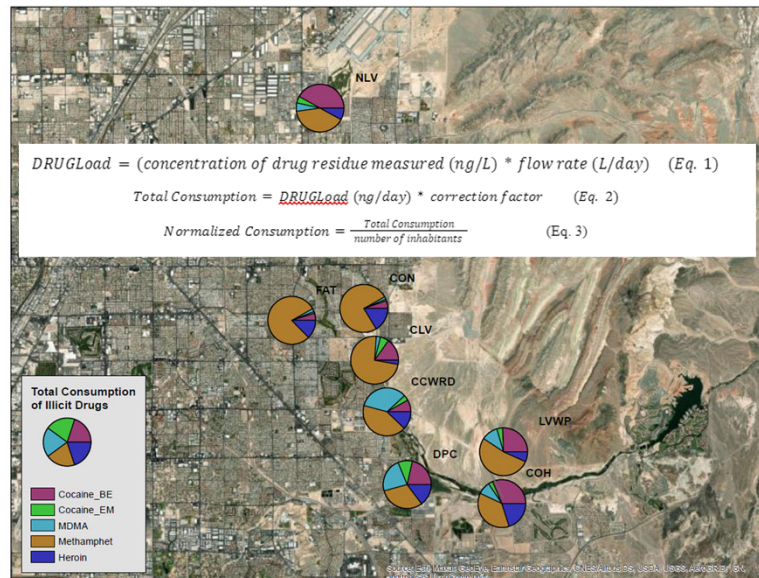Can we track drug consumption by people experiencing homelessness?

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Total Consumption of Illicit Drugs
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- MDMA
- Methamphet
- Heroin

Figure 14: Illicit drug and metabolite loads (not corrected or normalized)

16

8

RESULTS & DISCUSSION

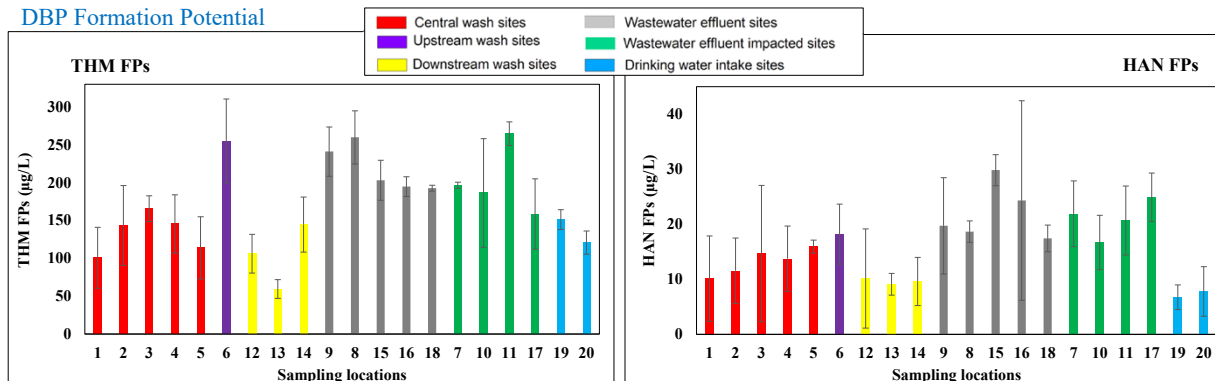What are the relative DBP precursor loads from different sources?

DBP Formation Potential

Legend: Central wash sites · Upstream wash sites · Downstream wash sites · Wastewater effluent sites · Wastewater effluent impacted sites · Drinking water intake sites

THM FPs

Figure 15: The THM FPs from all site locations

HAN FPs

Figure 16: The HAN FPs from all site locations

- Trend: Chloroform > Dichlorobromomethane > Dibromochloromethane > Bromoform
- Dichloro- and dibromoacetonitrile (DCAN, DBAN) were the major species among all the locations, followed by BCAN
- Highest THM FPs and HAN FPs were found at wastewater effluent-impacted sites, wastewater effluents, and upstream wash sites
- Significant THM FPs and HAN FPs were found at central sites influenced by unsheltered homelessness

Meena Ejjada, PhD Candidate

17

RESULTS & DISCUSSION

Legend: Central wash sites · Upstream wash sites · Downstream wash sites · Wastewater effluent sites · Wastewater effluent impacted sites · Drinking water intake sites

Relative DBP Formation Potential

- Significant amount of precursors from central, upstream, and downstream wash sites
- Unsheltered homelessness sites contributed to significant amount of THM and HAN precursors
- Relatively fewer precursors from wastewater effluent and wastewater effluent influenced sites
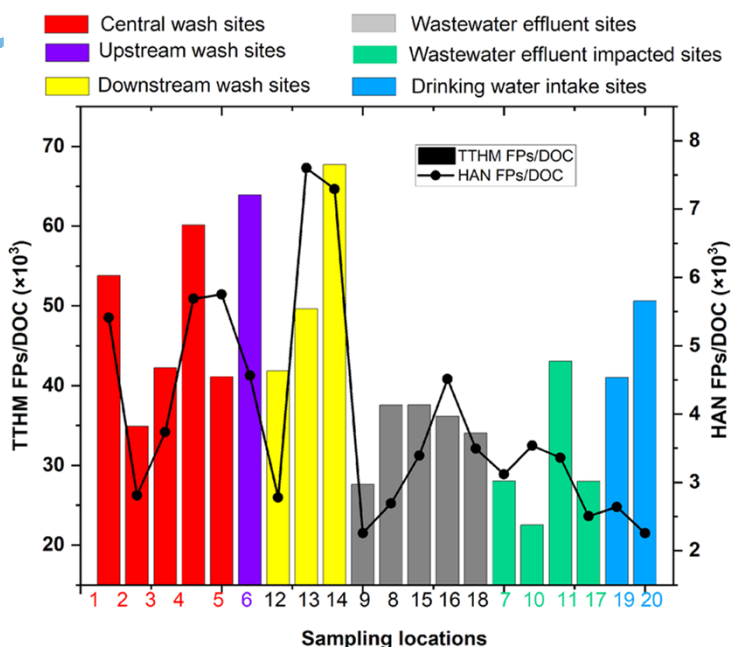

Figure 17: The precursors of THM FPs and HAN FPs from all site locations

Meena Ejjada, PhD Candidate

18

9

CONCLUSIONS

- PMMoV and HF183 could be used to indicate direct contamination by human waste as they are specific human microbial markers
- Illicit drugs were prevalent at sites associated with homelessness while wastewater effluent contained prescription and legalized drugs
- Trace organic loads going to the Las Vegas Wash are >90% from treated wastewater; small fraction from unsheltered homeless
- A significant amount of THM and HAN precursors were found at sites which are influenced by unsheltered homelessness

IMPLICATIONS FOR URBAN WATER SYSTEMS

- When considering mass loads, even low concentrations can be a concern → treated wastewater dominates over small flows of higher concentration TOrCs
- Unsheltered homelessness may affect environmental and public health through microbial contamination
- Communities with indirect or direct water reuse may be more susceptible to chemical and microbial contamination – will depend on resiliency and robustness of the drinking water infrastructure

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19

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Team Members

- UNLV – Dr. Erica J. Marti, Mayra Sarria, Meena Ejjada
- UNLV – Dr. Christie Batson, Ashley Bunn
- SNWA – Dr. Daniel Gerrity, Dr. Katerina Papp, Dr. Eric Dickenson, Dr. Kyle Thompson, Dr. Rebecca Trenholm

NSF Award #1832713

SOUTHERN NEVADA
WATER AUTHORITY

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zx

20