Towards estimating the uncertainty of illicit drug consumption from wastewater

Jörg Rieckermann and Christoph Ort

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# Take Home Messages

<table>
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<th>We can assess the uncertainty of estimated substance loads in wastewater.</th>
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<td><strong>Deal with uncertainties from WW sampling:</strong></td>
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<th>We cannot (yet) assess the uncertainty of estimated consumption in the population.</th>
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<td><strong>Behavior in the wastewater system:</strong></td>
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<td><strong>Population estimates/ Normalization</strong></td>
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A SURVEY BY THE SEWAGE SWAB METHOD OF LATENT ENTERIC INFECTION IN AN URBAN AREA

By B. Moore, B.Sc., M.B., B.Ch., B.A.O., Public Health Laboratory, Exeter, Col. E. L. Perry, D.S.O., M.R.C.S., L.R.C.P. (Medical Officer of Health) and S. T. Chard, M.S.I.A., Public Health Department, Sidmouth

(With 4 Figures in the Text)

A simple technique for the location of enteric carriers in towns by means of serial sewage examinations has been described in two earlier papers by Moore (1948, 1950). The principle underlying this method is essentially that some form of continuous sampling of the sewage passing along a particular sewer should be a more sensitive index of the passage of enteric organisms than the examination of bulk samples of sewage, taken from the sewer at times which could not be related in advance to the personal habits of a hypothetical excreter of enteric organisms proximal to the point of sampling. It was found that a gauze swab immersed in the flowing sewage for 48 hr. was an effective trap for enteric

A SURVEY BY THE SEWAGE SWAB METHOD
ENTERIC INFECTION IN AN URBAN COMMUNITY

BY B. Moore, B.Sc., B.Ch., B.A.,
Col. E. L. Perry, D.S.O., M.R.C.S., L.R.C.P.

(Written Figures in this article)

A simple technique for the location of enteric organisms in sewage examinations has been described in two papers (1949 and 1950). The principle underlying this method is the continuous sampling of the sewage passing along a section of pipe, and a more sensitive index of the passage of enteric organisms, based on the comparison of bulk samples of sewage, taken from the sewer, with that of bulk samples of sewage, taken from the sewage, is that the latter is related to the personal habits of a hypothetical population of enteric organisms proximal to the point of sampling. It was shown that a Moore swab immersed in the flowing sewage for 48 hr. was an effective

A SURVEY BY THE SEWAGE SWAB METHOD OF LATENT ENTERIC INFECTION IN AN URBAN AREA

BY B. MOORE, B.Sc., M.B., B.Ch., B.A.O., Public Health Officer.

COL. E. L. PERRY, D.S.O., M.R.C.S., L.R.C.P. (London),

S. T. CHARD, M.S.I.A., Public Health Inspector.

(With 4 Figures in the Text)

A simple technique for the location of enteric carriers in sewage examinations has been described in the Journal of Hygiene (1950). The principle underlying this method was the continuous sampling of the sewage passing through a more sensitive index of the passage of enteric organisms and a routine testing of bulk samples of sewage, taken from the sewer at times related in advance to the personal habits of a hypothetical excreta. It was found that a gauze sponge swab immersed in the flowing sewage for 48 hr. was an effective trap for enteric carriers.

CONCLUSION

The results suggested that the generalized swabbing programme in Aberdeen offered little prospect of tracing undetected *S. typhi* excreters. The small size of sewer needing to be sampled would have rendered the programme beyond the resources of all concerned. It is likely that the results were depressed partly by antibiotic therapy, use of disinfectants and by the presence of *S. paratyphi B*. In tracing unknown excreters of *S. typhi* it is less likely that antibiotics or disinfectants would be in use and better results might be attainable, but, in communities of any size, *S. paratyphi B* appears likely to impair results.

On balance, the results support the suggestion (Moore *et al.* 1952) that, in sewer swab surveys, sampling should begin at sewers draining 50 to 100 houses to give reasonable chance of success in tracing *S. typhi* carriers.

Learning from wastewater

Possible questions

- Annual consumption estimates of illicit drugs in a community/region
- Relative changes in an urban catchment over time
- Spatial differences across a region
- Absolute instantaneous number of drug users in a city
- Ratio of cocaine vs. heroin users
- ...
Learning from wastewater
Possible questions

- Annual consumption estimates of illicit drugs in a community/region
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...
Learning from wastewater

The question at hand, data and model are interrelated!

Question
How many COC users?

Data
24-hr composite samples
volume-proportional

Model
stationary
back-calculation
Back-calculating used amounts

Schematic representation

Back-calculating used amounts
How to assess the involved uncertainties?

Uncertainty of observed illicit WW mass loads
Linear error propagation

\[ L_{BE} = Q \cdot C \cdot f_s \]

\[ u(L_{BE}) = \sqrt{\left(\frac{u(Q)}{Q}\right)^2 + \left(\frac{u(C)}{C}\right)^2 + \left(\frac{u(f_s)}{f_s}\right)^2} \]
Uncertainty of observed illicit WW mass loads

Two approaches to deal with uncertainties from WW sampling

Apply a sampling scheme that minimizes the sampling uncertainty

Assess uncertainties that arise from WW sampling with a dynamic model and stochastic simulation

\[ L_{BE} = Q \cdot C \cdot f_s \]

\[ u(L_{BE}) = \sqrt{ \left( \frac{u(Q)}{Q} \right)^2 + \left( \frac{u(C)}{C} \right)^2 + \left( f_s \right)^2 } \]
Back-calculating used amounts
Dynamic stochastic model of illicit drug loads

- Illicit drug consumption
  - Metabolism
    - Excretion pattern
      - Urinary excretion
        - Wastewater
          - Sewage system
            - Wastewater treatment plant (WWTP)

- Concentrations illicit drugs and metabolites in wastewater
  - Flow rate (L/day)

- Mass loads illicit drugs and metabolites (g/day)
  - Back calculation
    - Amount used illicit drug (g/day)

- Sample collection in WWTP (influent)
  - Inhabitants served WWTP
    - Amount used illicit drug (g/day per 1000 inhabitants)

- Sample preparation analysis with LC-MS

- Sampling + monitoring

- Epidemiology of Drug Use
- Pharmacokinetics
- Voiding
- Mobility of the population
- Sewer transport and transformation
Back-calculating used amounts
Dynamic stochastic model of illicit drug loads

J. Rieckermann, A. Chiaia, J. Field Hard data on hard drugs? (in prep.)
Model output: dynamic load series
3 weeks, San Diego, USA

n = 1000

q·BE [ng/s]
Model output: dynamic load series
24 hrs, Basel (grey), Lucerne (red), CH
Sewer system and WWTP
Dirty, complex and dynamic systems
Inlet of a STP with \(~100,000\) inhabitants

**Flow measured online in effluent of primary clarifier**

\((\pm 10\% \text{ oscillation due to operation fine screen})\)

120 grab samples at 2 minute time intervals influent primary clarifier


Sampling for PPCPs in wastewater systems: A comparison of different sampling modes and optimization strategies.
Consequences for sampling (24h-composite sample)

Model input
- Number of pulses (level of activity)
- Initial pulse duration (appliance)
- Transformation in sewers (flow distances, dispersion)

Sampling for PPCPs in wastewater systems: A comparison of different sampling modes and optimization strategies.
Sampling for PPCPs in wastewater systems: A comparison of different sampling modes and optimization strategies.
Each WWTP (and urban drainage system) is unique. Concentrations and loads can be subject to high short-term fluctuations.

Conventional sampling devices are not suitable to sample for micropollutants in sewer systems.

Systems analysis is required to determine appropriate sampling mode and frequency (substance, site and location specific) - or “sophisticated sampling”.

Sampling uncertainty (0-100% or more) is rarely considered but can be larger than uncertainty due to chemical analysis.

Sampling for PPCPs and illicit drugs in wastewater systems: Are your conclusions valid? A critical review.
Case study: Switzerland
Uncertainties from WW sampling, 5 catchments

Mathieu, et al. Monitoring cocaine and its main metabolite benzoylcgonine in wastewater samples from Switzerland using gas chromatography-mass spectrometry and high performance liquid chromatography-tandem mass spectrometry to estimate drug abuse, submitted to Water Research
Back-calculating used amounts
How to assess the involved uncertainties?

**Uncertainty of estimated no. of users**

„Known unknowns“

<table>
<thead>
<tr>
<th>Sewage epidemiology methodology part</th>
<th>Possible bias</th>
<th>Solution + Future research</th>
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<tr>
<td>Concentrations of illicit drugs and/or metabolite(s) in influent wastewater</td>
<td>1/Abuse of illicit drugs not detected by WWTP</td>
<td>1/Performance of stability tests and adsorption experiments</td>
</tr>
<tr>
<td></td>
<td>2/No distinction in different chiral forms in analytical methods</td>
<td>2/Include chiral separation in analytical methods if necessary</td>
</tr>
<tr>
<td></td>
<td>3/Dumping of (large) amounts of illicit drugs via sewage system</td>
<td>3/Identify preferably metabolite(s) originating from human metabolism</td>
</tr>
<tr>
<td>Back-calculations from concentrations in wastewater to an amount of used illicit drug (g/day)</td>
<td>4/Inefficient analytical techniques</td>
<td>4/Organisation of interlaboratory tests and ring tests</td>
</tr>
<tr>
<td>A. Flow rate of wastewater</td>
<td>5/Excretion rates of illicit drugs and/or metabolites after human consumption</td>
<td>5/Strong control of wastewater flow at WWTP</td>
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<tr>
<td>B. Excretion rates of illicit drugs and/or metabolites after human consumption</td>
<td>1/Errors on measurement of flow rate in WWTP</td>
<td>1/Estimate standard deviation of measurements</td>
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<td>2/Experiments executed on a limited numbers of subjects</td>
<td>1-2/ Further pharmacokinetic studies with larger number of subjects, different routes of intake, use patterns, ...</td>
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<td>3/Experiments are executed with rather old techniques</td>
<td>3/ Monitor number of inhabitants for each collected sample separately by various indicators (e.g. energy consumption, other human by-products in wastewater, calculable based on N, P excretion, ...)</td>
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<td>4/Excretion rates are depending on various factors or are varying inter-individual (pH of urine, route of intake, dose,...)</td>
<td>1-3/ Detailed socio-epidemiological research</td>
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<td>5/Fluctuating number of inhabitants served by a WWTP (tourists, commuters, holidays,...)</td>
<td></td>
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<tr>
<td>Amount of inhabitants served by a WWTP to normalise the calculate amount of used illicit drugs for the amount inhabitants of the WWTP region (g/day per 1000 inhabitants)</td>
<td>1/Different routes of intake correspond sometimes with different dosages</td>
<td></td>
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<tr>
<td>Standard dose of illicit drug to calculate amount of doses consumed in WWTP region (doses/day per 1000 inhabitants)</td>
<td>2/Different drug markets</td>
<td></td>
</tr>
<tr>
<td>Consumption pattern of “average user“ to calculate prevalence of illicit drug use in certain region</td>
<td>3/Different habits in consumption (light users, heavy users, occasional users)</td>
<td></td>
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<td>1/Type of drug (used on regular base vs party drug, constant dose,...)</td>
<td>1-2/ Detailed socio-epidemiological research</td>
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<td>2/Type of users (light users, heavy users, occasional users,...)</td>
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We can assess the uncertainty of estimated substance loads in wastewater.

Deal with uncertainties from WW sampling:
- Truly flow-proportional sampling procedure
- Dynamic model of WW loads and stochastic simulation

We cannot (yet) assess the uncertainty of estimated consumption in the population.

Behavior in the wastewater system:
- Transport and transformation processes
- Sewer leakage

Population estimates/ Normalization