COVID-19 and Beyond: Implications for Building Wastewater Systems.

Michael Gormley
Professor of Public Health and Environmental Engineering
Heriot-Watt University – Edinburgh - Scotland
Contents

• Aerosol and droplet transmission dynamics
• Is disease transmission via Plumbing systems a real problem?
• Wastewater based epidemiology – the bigger picture
• Concluding remarks
Toilets, Turbulence and Public Health

Dr. Michael Gormley

The Water Academy
Centre of Excellence in Sustainable Building Design
Heriot-Watt University
Edinburgh, Scotland

Set out the public health challenges for building wastewater systems and implications for a possible pandemic
Transmission dynamics of any aerosolised pathogen (including SARS-CoV-2)
Plumbing in post-Covid times: Wasterwaster DWV Systems

- SARS-CoV-2 does not need to enter lungs for infection to occur therefore droplets and aerosols are implicated in transmission.
- Fomite plays a role, primarily as a result of droplets

<table>
<thead>
<tr>
<th>Particle</th>
<th>Size</th>
<th>Reach</th>
<th>Characteristic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Droplet</td>
<td>&gt; 5 µm</td>
<td>≤ 1m</td>
<td>Can be deposited on surfaces and fomites. Can contain respiratory pathogens.</td>
</tr>
<tr>
<td>Aerosol</td>
<td>≤ 5 µm</td>
<td>&gt; 1m</td>
<td>Can be transported in airstreams and remain persistent in the air for long time periods. Can be inhaled.</td>
</tr>
<tr>
<td>Bioaerosol</td>
<td>≤ 5 µm</td>
<td>&gt; 1m</td>
<td>An aerosol that contains respiratory allergens or pathogens. Can be transported in airstreams and remain persistent in the air for long time periods. Can be inhaled.</td>
</tr>
</tbody>
</table>
Is there really a potential problem?

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Correspondence

COVID-19: mitigating transmission via wastewater plumbing systems

Michael Gormley *, Thomas J Aspray †, David A Kelly *

Pandemics: Why Buildings are Hazards

Wastewater systems in tall buildings are a transmission pathway for pathogens. Despite robust evidence (and clear solutions), standards, codes and regulations have failed to respond and present a public health risk.

Michael Gormley (Heriot Watt University) explains a neglected area of public health and building design: the plumbing systems for wastewater. What can building designers and regulators can do to reduce the hazard of disease transmission in tall buildings?

Lessons from SARS
Probable Evidence of Fecal Aerosol Transmission of SARS-CoV-2 in a High-Rise Building

Min Kang, MSc*, Jianjian Wei, PhD*, Jun Yuan, MSc*, Juxuan Guo, MSc, .. View all authors +

Author, Article and Disclosure Information

https://doi.org/10.7326/M20-0928

Eligible for CME Point-of-Care

SARS-CoV-2: The Growing Case for Potential Transmission in a Building via Wastewater Plumbing Systems

Michael Gormley, PhD, CEng

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Spread of SARS-CoV-2 aerosols via two connected drainage stacks in a high-rise housing outbreak of COVID-19

Qun Wang 1,2,3, Zhang Lin 1, Jianlei Niu 6,1, Garnet Kwan-Yue Choi 6,1, Jimmy C.H. Fung 6,1, Alexis K. H. Lau 6, Peter Louie 1, Kenneth K.M. Leung 1, Jianxiang Huang 5, Pan Cheng 4, Pengcheng Zhao 4, Wenzhao Chen 4, Sheng Zhang 1, Liye Fu 1, PW Chan 1, Ann Han Wong 1, Herman Tse 1, Sally Cheuk Ying Wong 1, Yuguow Li 1, A 1, 8

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https://doi.org/10.1016/j.jhazmat.2022.128475

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Evidence?

• There is evidence of transmission but it isn’t conclusive and is limited.
• While faeces contains high quantities of viral RNA for SARS-CoV-2 there is no real evidence the virus can survive for any length of time in wastewater (although this may change close to the source and for short periods)
Does this mean we can ignore it?

No.

In my opinion, the research done as a result of the pandemic should act as a wake-up call for the industry.

An example to follow...
Vulnerability in Hotels

Sometimes two rooms are connected ‘back to back’ into a single drain

Distance between floor drains:
- Side by side ~ 2 m (6 ft)
- Vertical ~ 5 m (15 ft)

Section of plumbing system showing two vertical stacks
Side by side example

Back to Back bathrooms connected to same Stack

Liu, Jie et al. (2021)
Vulnerability in Hotels

• Floor drains persistently dry out in Hotels.
• Cleaning regimes encourage cleaners to fill floor drains
• In longer term no cleaning regime or vacant rooms – these will dry out.
• When empty, a pathway exists between rooms and airflow between them encouraged by bathroom ventilation fan.
• Smell is the main indicator (not an indicator that virus is present but that the seal has been lost)
Wastewater based Epidemiology (WBE) – why?

COVID-19 Diagnostic Test through PCR

1. Nasopharyngeal swab – 15 min
   Cotton swab is inserted into nasopharynx to absorb secretions.

2. Collected specimen – 0-72 h
   Specimen is stored at 2-8°C for up to 72 hours or proceed to RNA extraction.

3. RNA extraction – 45 min
   Purified RNA is extracted from deactivated virus.

4. RT-PCR – 1 h per primer set
   Purified RNA is reverse transcribed to DNA and amplified by PCR.

5. Test results – real-time
   Positive SARS-CoV2 patients cross the threshold line within 40.00 cycles (< 40.00 Ct).

Primers and probes for screening

- E Forward: AGAAAACACATGACACATCTTATACAC
- E Reverse: ATATGGCAAGAATAGCACA
- RdRp Forward: GTTCCCATTTCTTATGTAAGG
- RdRp Probe: PAN-ECAS9/229AAATCTTTGGTATGCBB
- RdRp Reverse: PAN-ECAS9/229AAATCTTTGGTATG
- RdRp Q1: PAN-ECAS9/229AAATCTTTGGTATGC

* E gene is further used because it is slightly less sensitive.
What this gives us

• On an individual level this gives us information on whether an individual is infected or not.

• On a population level it gives us data on the progress of the disease which can trigger policy interventions.

• It is, in effect, a survey.
Wastewater Based Epidemiology

Wastewater based epidemiology offers the opportunity to track the disease at the population level without testing individuals. It also allows data to be gathered anonymously from ‘hard to test’ places like Prisons, Education establishments, airports and ports in general.
WBE in Buildings

WBE is usually based on samples obtained outside buildings in sewer manholes.

At Heriot-Watt University we have been working on novel approaches to WBE using our knowledge of Aerosolisation of pathogens within the system.
Bioaerosol test rig dynamics
Alternative Novel Approaches

- Wastewater based epidemiology provides a means to establish the prevalence of a disease in the community by analysing the wastewater.
- Has been used for years for diseases such as Polio
- Urgent need to expand the knowledge base on WBE – can be done inside buildings too.
Aerosols and Droplets from a Toilet flush

Typical aerosol spike inside drainage system from a toilet flush
Emissions of pathogens from systems

- Emission of particles follows similar pattern to toilet flush
- A 6 l toilet flush produces the same number of particles as a person talking loudly for 6 and a half minutes.
- Number of particles are proportional to the flush volume of the toilet.

Extracting SARS-CoV-2 RNA from aerosols and droplets

SKC Biosampler (left) and Wet Cyclone sampler (right).
Challenges

• Representing true system operation (including external influences)

• Surrogate pathogens

• Sampling
Surrogates

- Pseudomonas putida (bacteria)
- Porcine Respiratory and Reproductive Virus Syndrome (PRRSv)
- Pepper Mild Mottled Virus (PmmoV)
Typical concentrations

Viral concentrations measured in the field are typically in the range $10^3 - 10^5$ gene copies/litre (gc/litre) and since this is typically flushed into a toilet and mixed with multiple litres of water it means that a high concentration of raw virus is required to make a reasonably accurate viral load in the wastewater, typically $10^6 - 10^{10}$ gc/litre. Producing this amount of virus for a single flush is challenging.
Sampling challenges (PRRSV)

Hogan et al., 2005

PRRS – size 50-65nm

Li et al., 2005

Size of PRRS and relative efficiency of SKS sampler is of concern.
Pepper mild mottle virus (PMMoV) was recently found to be the most abundant RNA virus in human feces, and is a plant virus belonging to the genus Tobamovirus in the family Virgaviridae.

The occurrence and persistence of PMMoV in natural and engineered water systems means that it’s presence can be an indicator of water quality.

It is a good candidate for a surrogate for viral presence in building wastewater systems.
PMMoV

PMMoV is found in high quantities in Tabasco sauce – $10^{7-8}$ gc/millilitre
Detection of PMMoV by qPCR

![Graph showing concentration vs extracted viral quantity from sampler]

- Extracted viral quantity in sample (gc/litre)
- Concentration - ml PMMoV mix/6 litres (flush volume)

Concentration vs extracted viral quantity from sampler

- Log scale on the x-axis and y-axis
Concluding remarks

1. The risk of cross contamination via building drainage sanitary plumbing systems is still a real threat although SARS-CoV-2 has not posed the risk once imagined.

2. Likely transmission routes for disease have been presented, and in particular COVID-19, since we are still in the midst of the pandemic, however we may have been lucky in that the virus does not survive well in wastewater.

3. Wastewater based epidemiology offers opportunities for obtaining population level data on disease prevalence. This can be aggregated down to building level.

4. Whilst we are almost two years into the pandemic it is clear that SARS-CoV-2 is here to stay and that the work being carried out now in establishing transmission dynamics particularly through WBE) should be continued apace as we do not know when the next inevitable pandemic will be.

5. Other pathogens are still of concern and research into transmission of disease via sanitary plumbing systems should continue – particularly in the area of Anti-microbial resistance (AMR).
Thank you for listening