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

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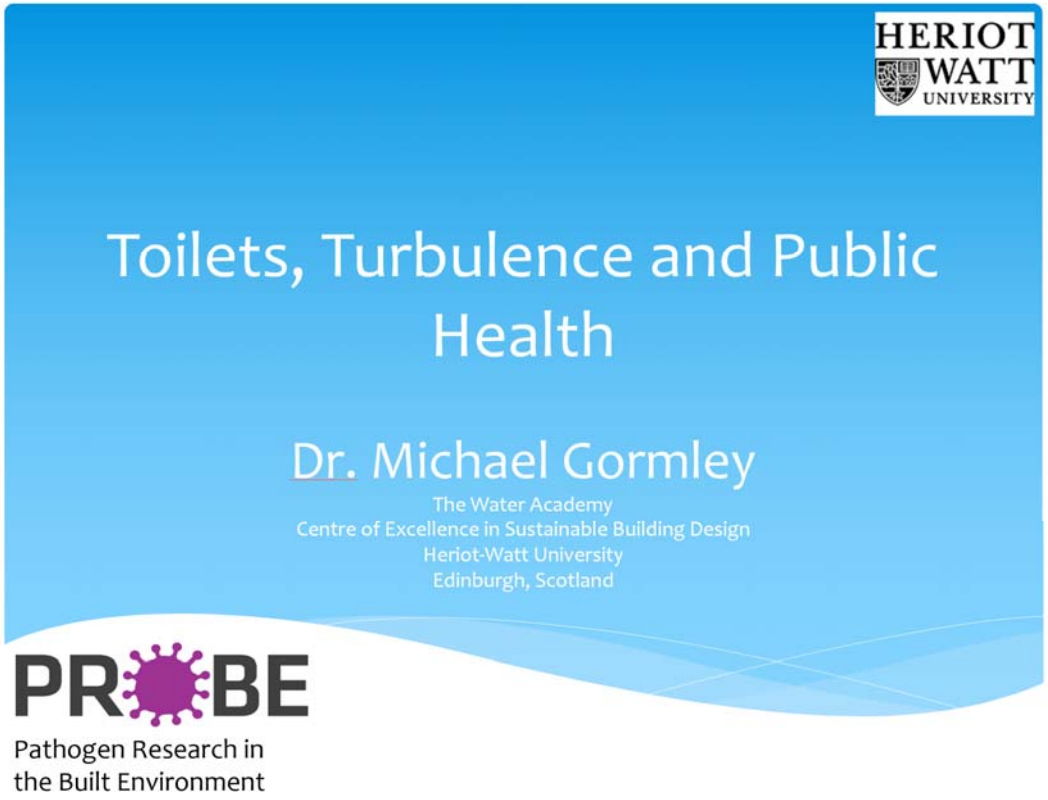
Contents

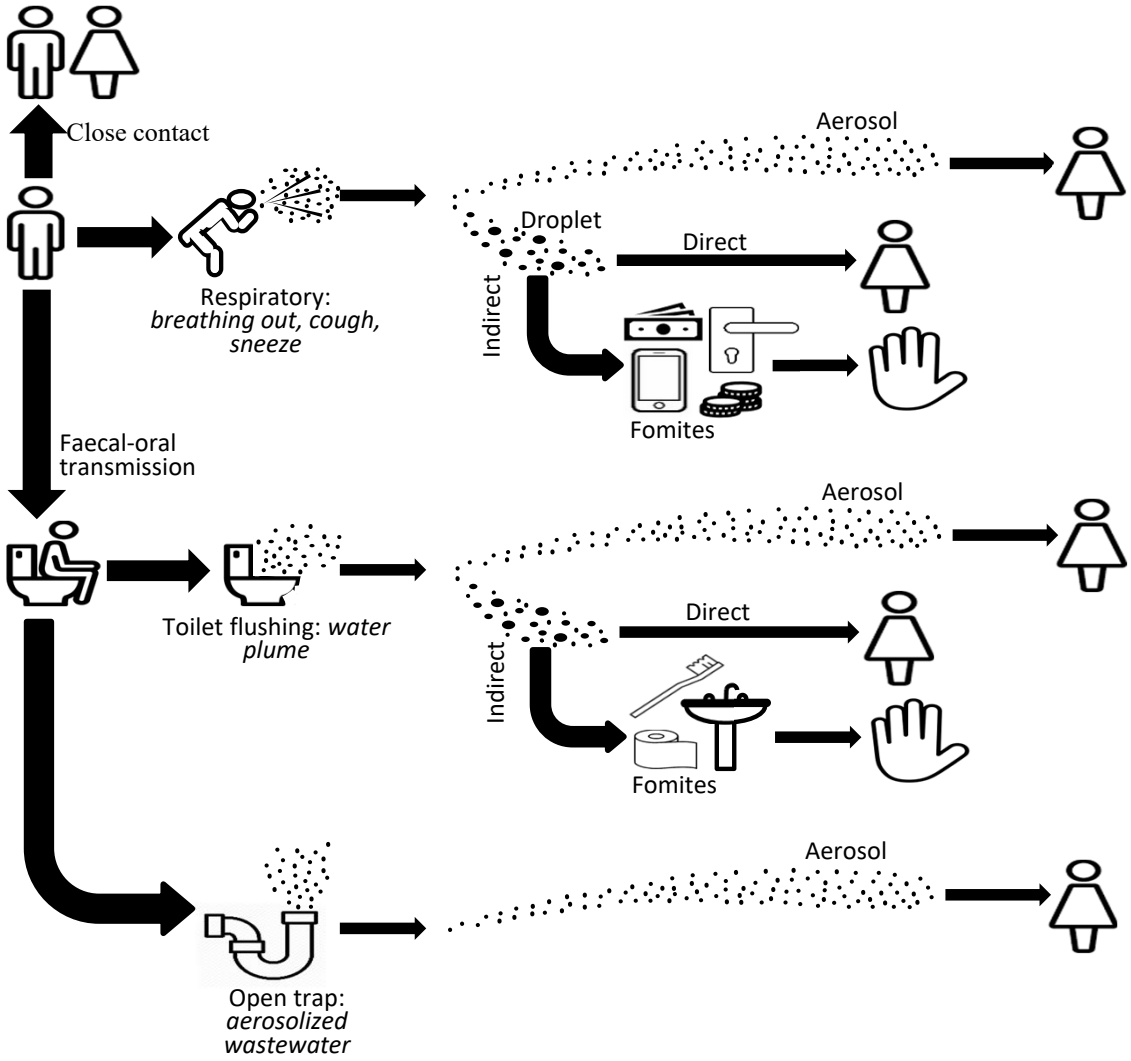
- Aerosol and droplet transmission dynamics
- Is disease transmission via Plumbing systems a real problem?
- Wastewater based epidemiology – the bigger picture
- Concluding remarks

EWTS Chicago 2016



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

Particle	Size	Reach	Characteristic
Droplet	> 5 µm	≤ 1m	Can be deposited on surfaces and fomites. Can contain respiratory pathogens.
Aerosol	≤ 5 µm	> 1m	Can be transported in airstreams and remain persistent in the air for long time periods. Can be inhaled.
Bioaerosol	≤ 5 µm	> 1m	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.

- **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**

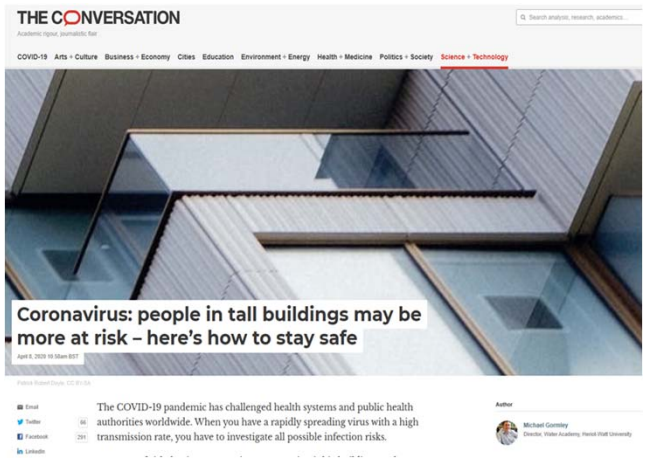
Is there really a potential problem?

THE LANCET
Global Health
Volume 8, Issue 5, May 2020, Page e643

Correspondence

COVID-19: mitigating transmission via wastewater plumbing systems

Michael Gormley [a] ✉, Thomas J Aspray [b], David A Kelly [a]



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Pandemics: Why Buildings are Hazards

May 07, 2020

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

Annals of Internal Medicine®

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Original Research | 15 December 2020

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

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

Ann Intern Med. 2020 Sep 1 : M20-6134. PMCID: PMC7472653
Published online 2020 Sep 1. doi: 10.7326/M20-6134 PMID: 32870706

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

Michael Gormley, PhD, CEng

ELSEVIER

Journal of Hazardous Materials
Volume 430, 15 May 2022, 128475

Research Paper

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

Qun Wang [a, 1], Zhang Lin [b, 1], Jianlei Niu [c, 1], Garnet Kwan-Yue Choi [d, 1], Jimmy C.H. Fung [e], Alexis K.H. Lau [e], Peter Louie [f], Kenneth K.M. Leung [f], Jianxiang Huang [g], Pan Cheng [a], Pengcheng Zhao [a], Wenzhao Chen [a], Sheng Zhang [b], Liye Fu [c], PW Chan [h], Ann Han Wong [i], Herman Tse [d], Sally Cheuk Ying Wong [d] ... Yuguo Li [a, 1] ✉

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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?

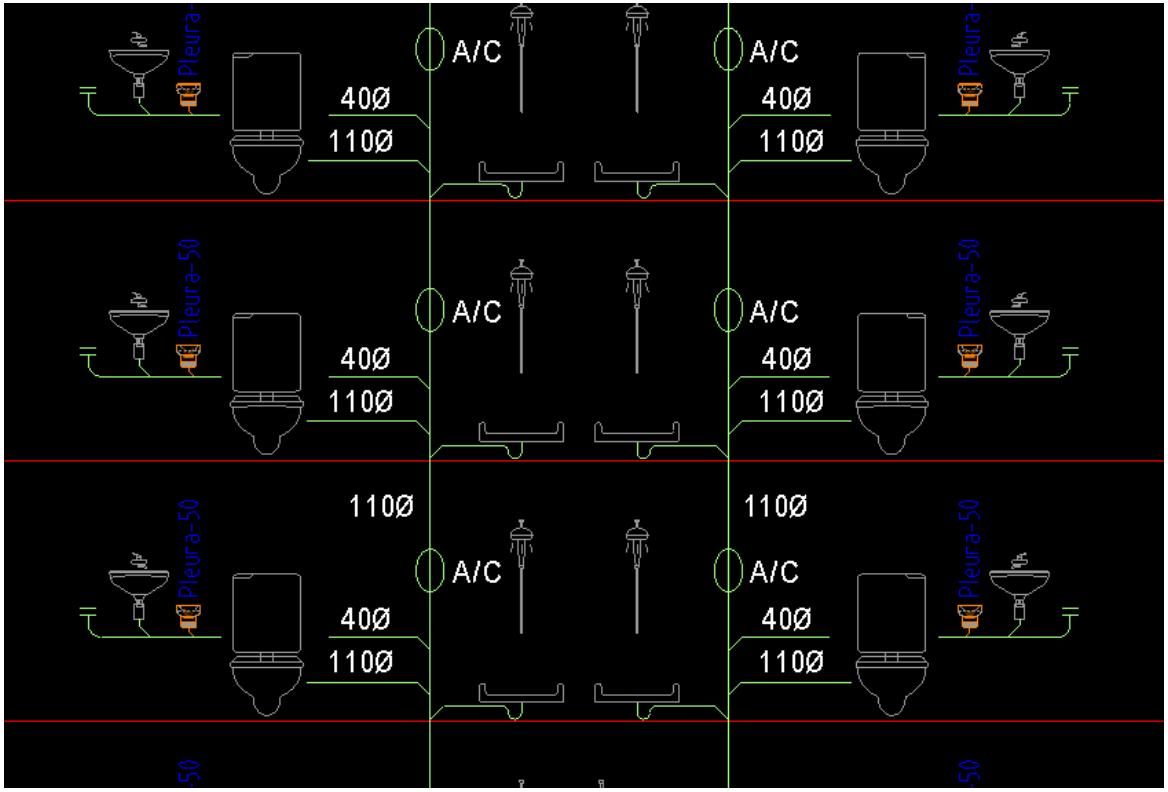
No.

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



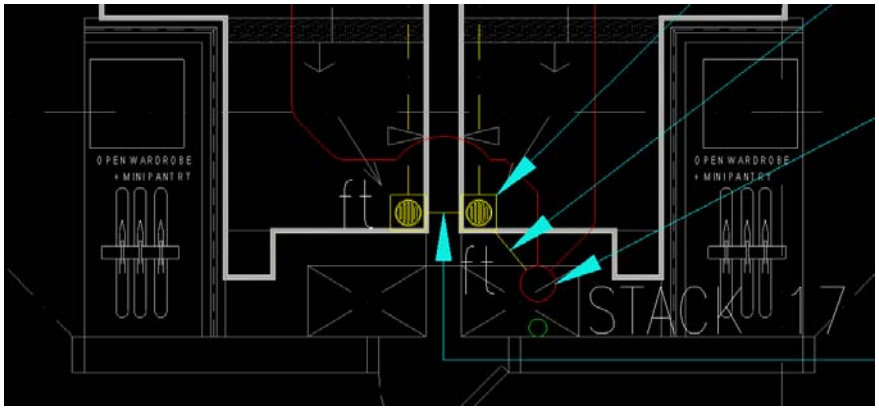
Section of plumbing system showing two vertical stacks

Distance between floor drains:

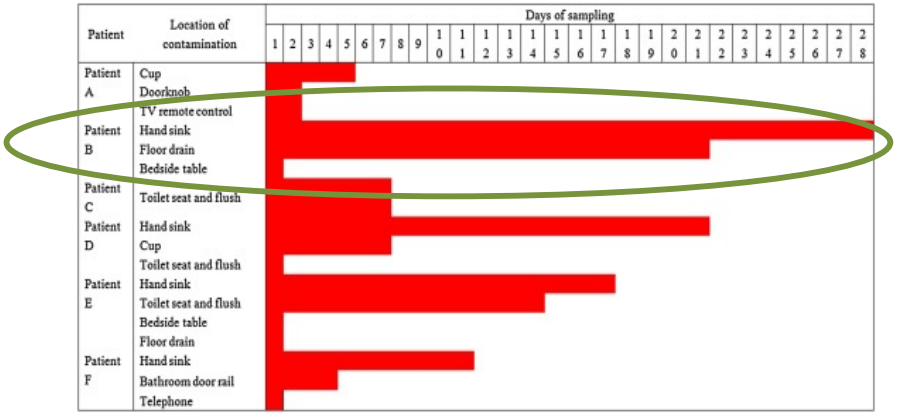
Side by side ~ 2 m (6 ft)

Vertical ~5m (15ft)

Side by side example



Back to Back bathrooms connected to same Stack



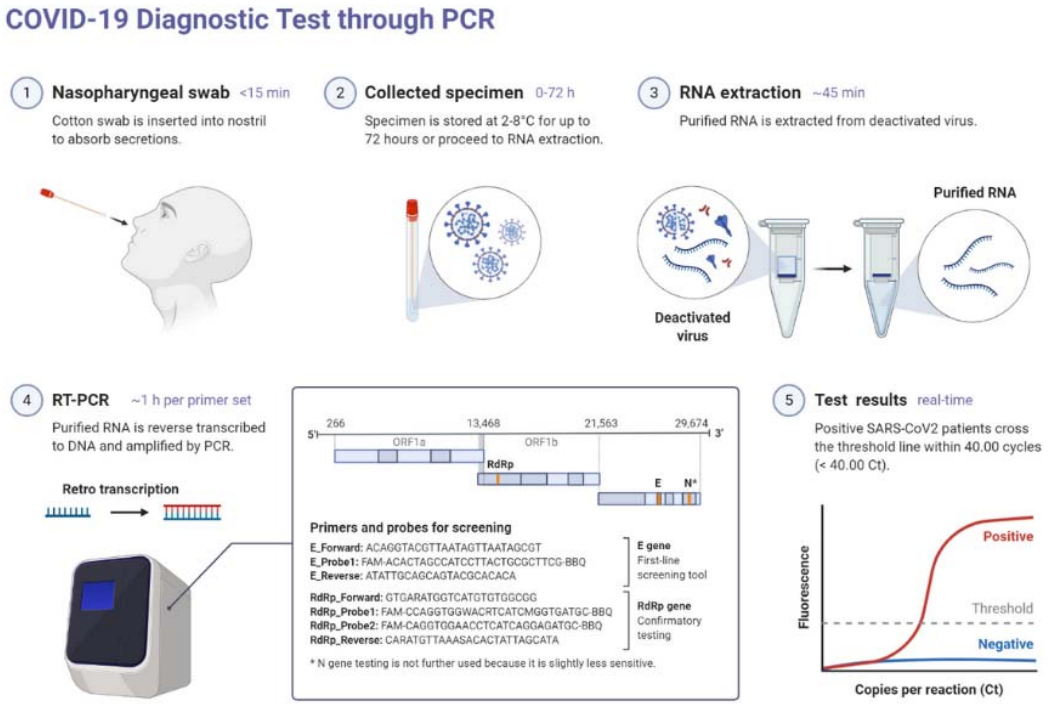
Patient	Location of contamination	Days of sampling
		1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28
Patient A	Cup	
	Doorknob	
	TV remote control	
Patient B	Hand sink	
	Floor drain	
	Bedside table	
Patient C	Toilet seat and flush	
Patient D	Hand sink	
	Cup	
	Toilet seat and flush	
Patient E	Hand sink	
	Toilet seat and flush	
	Bedside table	
	Floor drain	
Patient F	Hand sink	
	Bathroom door rail	
	Telephone	

Liu, Jie et al. (2021)

Vulnerability in Hotels

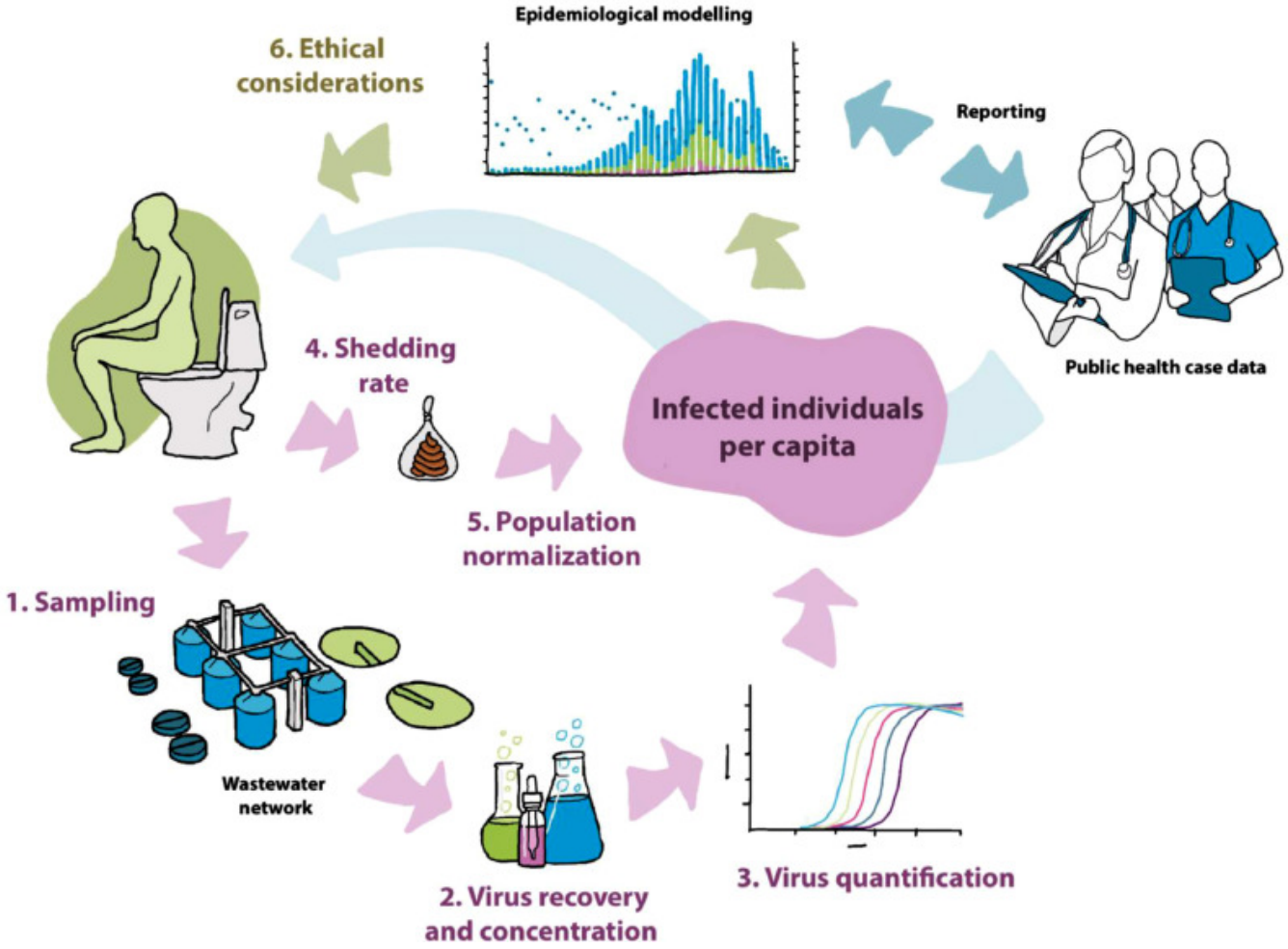
- Floor drains persistently dry out in Hotels.
- Cleaning regimes encourage cleaners to fill floor drains
- In longer term no cleaning regime or vacant rooms – these will dry out.
- When empty, a pathway exists between rooms and airflow between them encouraged by bathroom ventilation fan.
- Smell is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

Wastewater based Epidemiology (WBE) – why?



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



Source: Polo D, Quintela-Baluja M, Corbishley A, et al. Making waves: Wastewater-based epidemiology for COVID-19 – approaches and challenges for surveillance and prediction. Water Res. 2020;186:116404. doi:https://doi.org/10.1016/j.watres.2020.116404

Wastewater Based Epidemiology

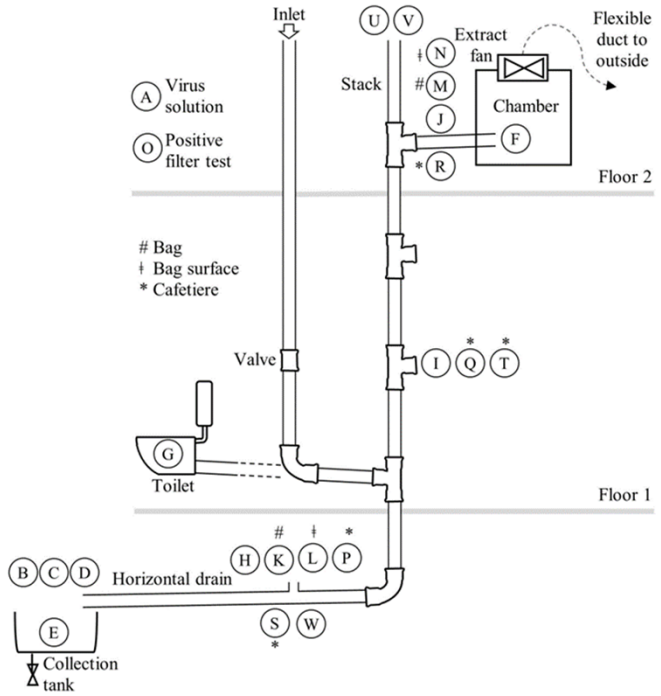
Wastewater based epidemiology offers the opportunity to track the disease at the population level without testing individuals. It also allows data to be gathered anonymously from ‘hard to test’ places like Prisons, Education establishments, airports and ports in general.

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

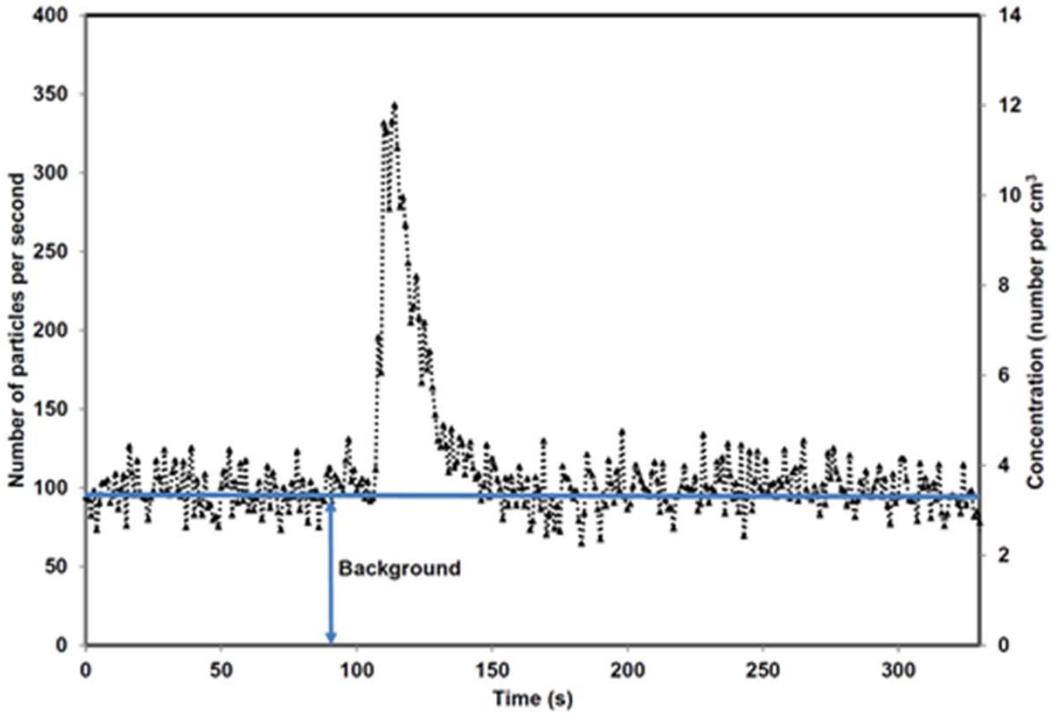


Bioaerosol test-rig showing the configuration of the system and the test-points

Alternative Novel Approaches

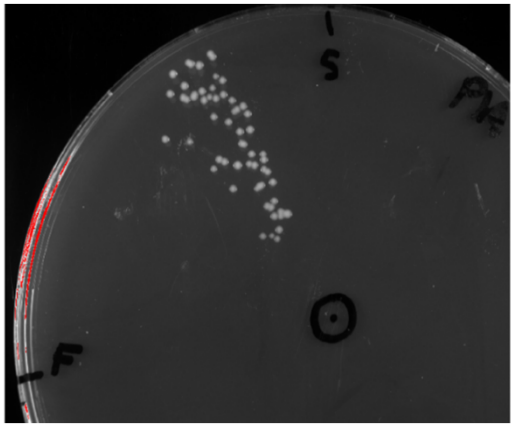
- Wastewater based epidemiology provides a means to establish the prevalence of a disease in the community by analysing the wastewater.
- Has been used for years for diseases such as Polio
- Urgent need to expand the knowledge base on WBE – can be done inside buildings too.

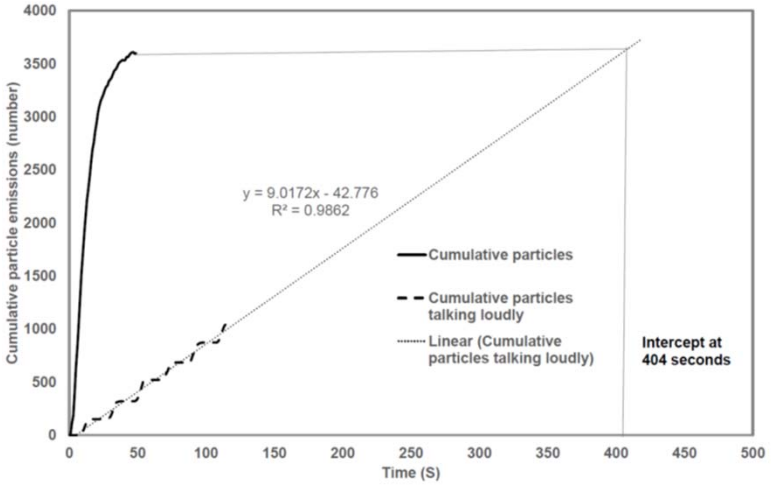
Aerosols and Droplets from a Toilet flush



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.

Gormley M, Aspray TJ, Kelly DA. Aerosol and bioaerosol particle size and dynamics from defective sanitary plumbing systems. Indoor Air 2021;n/a. https://doi.org/https://doi.org/10.1111/ina.12797.

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

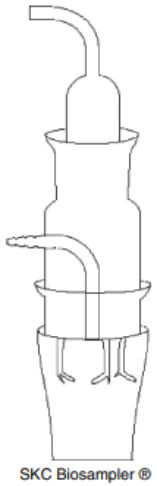
- Pseudomonas putida (bacteria)
- Porcine Respitory and Reproductive Virus Syndrome (PRRSv)
- Pepper Mild Mottled Virus (PmmoV)

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)



PRRS – size 50-65nm

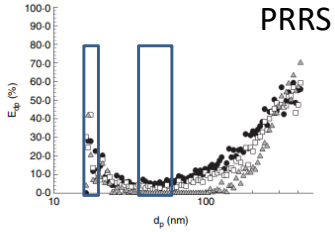


Fig. 4 Collection efficiency as a function of particle diameter with a sampling flow rate of 12·5 l min^{-1} for the (●) All Glass Impinger 30, (□) SKC BioSampler® and (△) frit bubbler. Data shown are the average of five test runs for each sampler

Hogan et al, 2005

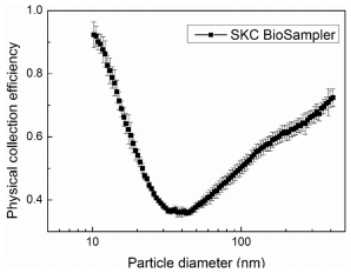
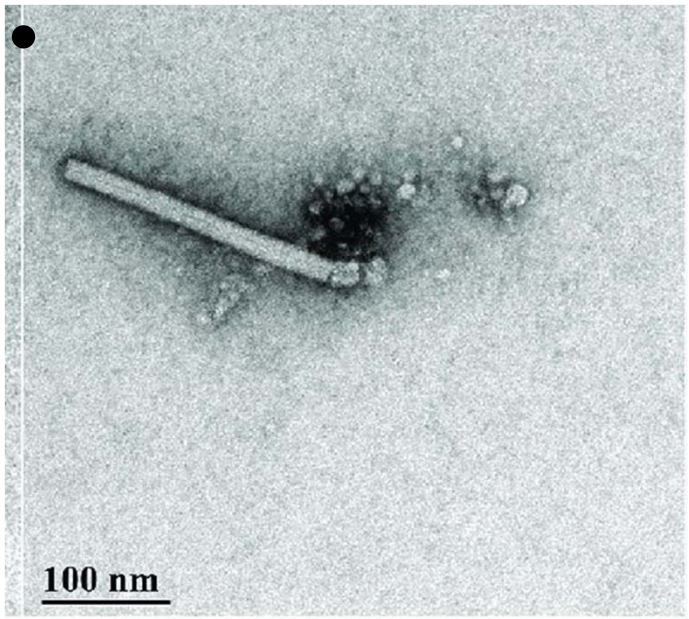


Fig. 2. The physical collection efficiency of the SKC BioSampler. *The flowrate was kept constant at 12.5 L/min. Results are based on the average of 9 test runs.

Size of PRRS and relative efficiency of SKS sampler is of concern.

Li et al, 2005

PMMoV



Electron microscopy of PMMoV

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 Virgoviridae.

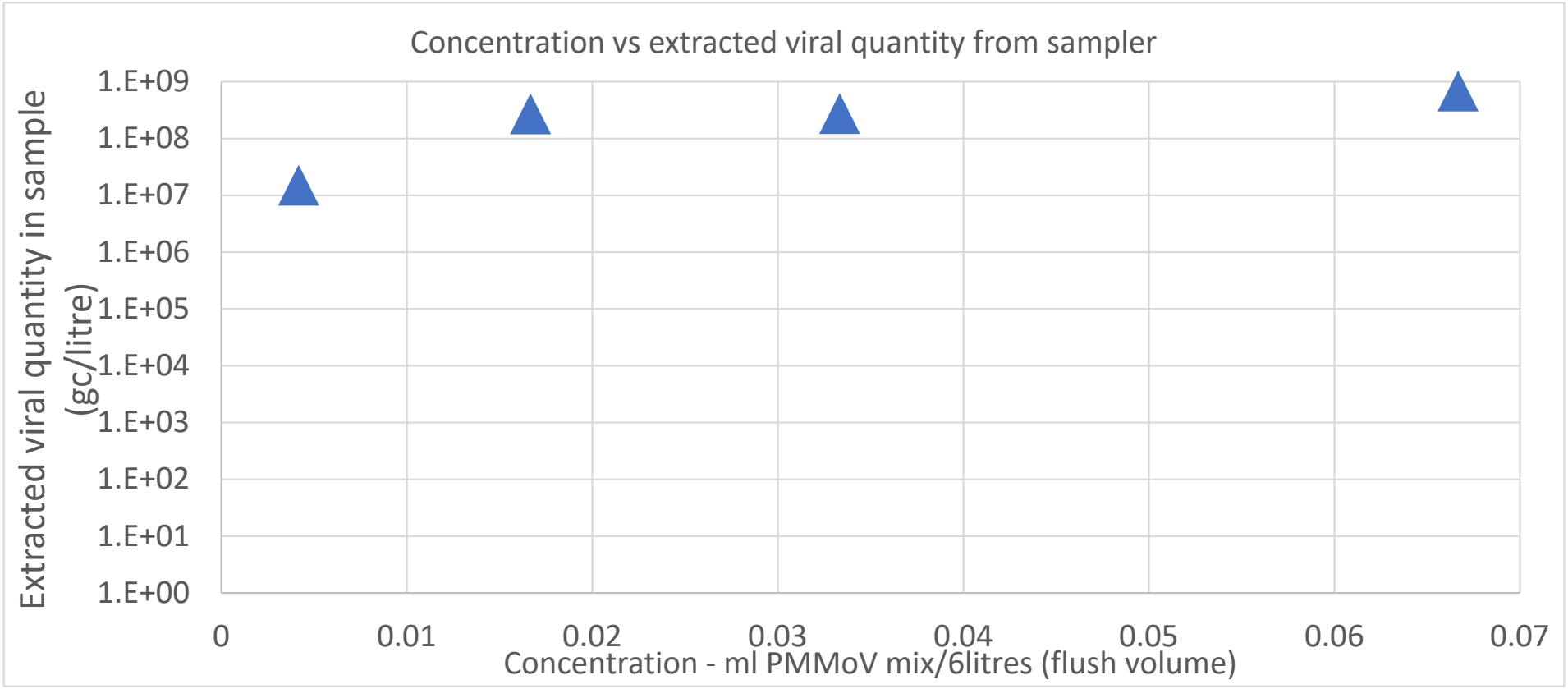
The occurrence and persistence of PMMoV in natural and engineered water systems means that it's presence can be an indicator of water quality.

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



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