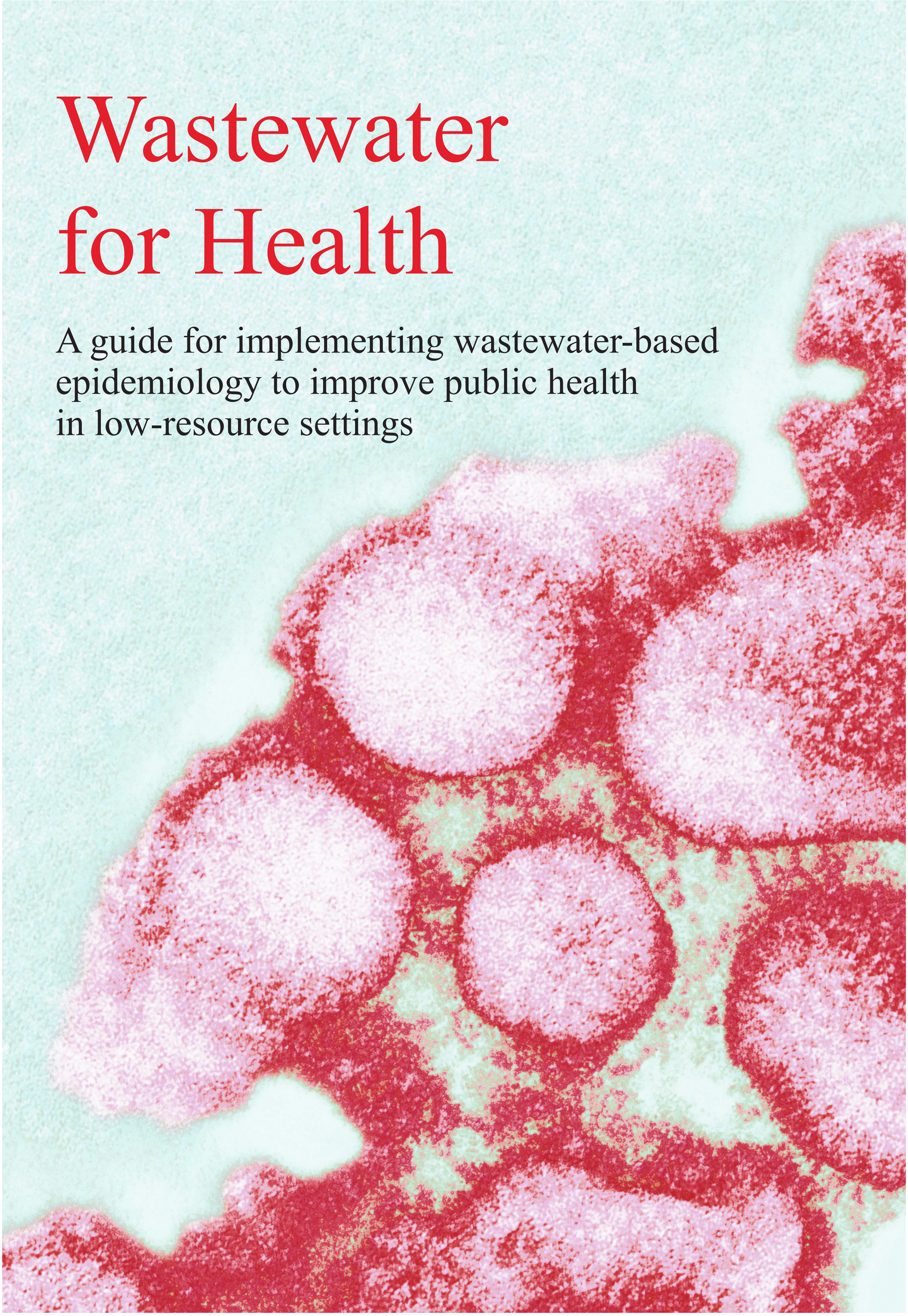
ARUP

Wastewater for Health

A guide for implementing wastewater-based epidemiology to improve public health in low-resource settings



Executive summary

Wastewater-based epidemiology (WBE) has proven an invaluable tool in the fight against COVID-19 in the UK and several other developed nations. Arup has been at the forefront of the effort in the UK to develop a strategic wastewater monitoring programme that could inform decision-making during the COVID-19 pandemic and beyond. However, of the 57 counties worldwide conducting wastewater monitoring, only 9 (16%) are from lower-middle or low-income countries.

There are a huge range of health markers, beyond coronavirus, that could be used to target health interventions to the areas that need it most. Implementing WBE could provide the world's most remote and vulnerable communities early warning and insights for factors such as infectious diseases (COVID-19, polio, influenza, Zika, etc.), antimicrobial resistance, pharmaceutical consumption (clinical and illicit), and allow monitoring of their environmental interactions.

This guidance document has been developed to support the implementation of a WBE capability depending on infrastructure and regional capacity. Infrastructure informs certain elements of the sampling approach but often the choice of testing capability is key to determining the insight possibilities. The design of a monitoring programme involves a series of choices which will be informed through stakeholder motivations. It is clear that several stakeholders share similar motivations for implementing a WBE programme, thus cross-sector working and ensuring clear communication within communities is key to success. It is the hope that this guidance will promote discussions around the value, ethics and practicalities of WBE in various infrastructure settings, stimulating improvement of public health globally.

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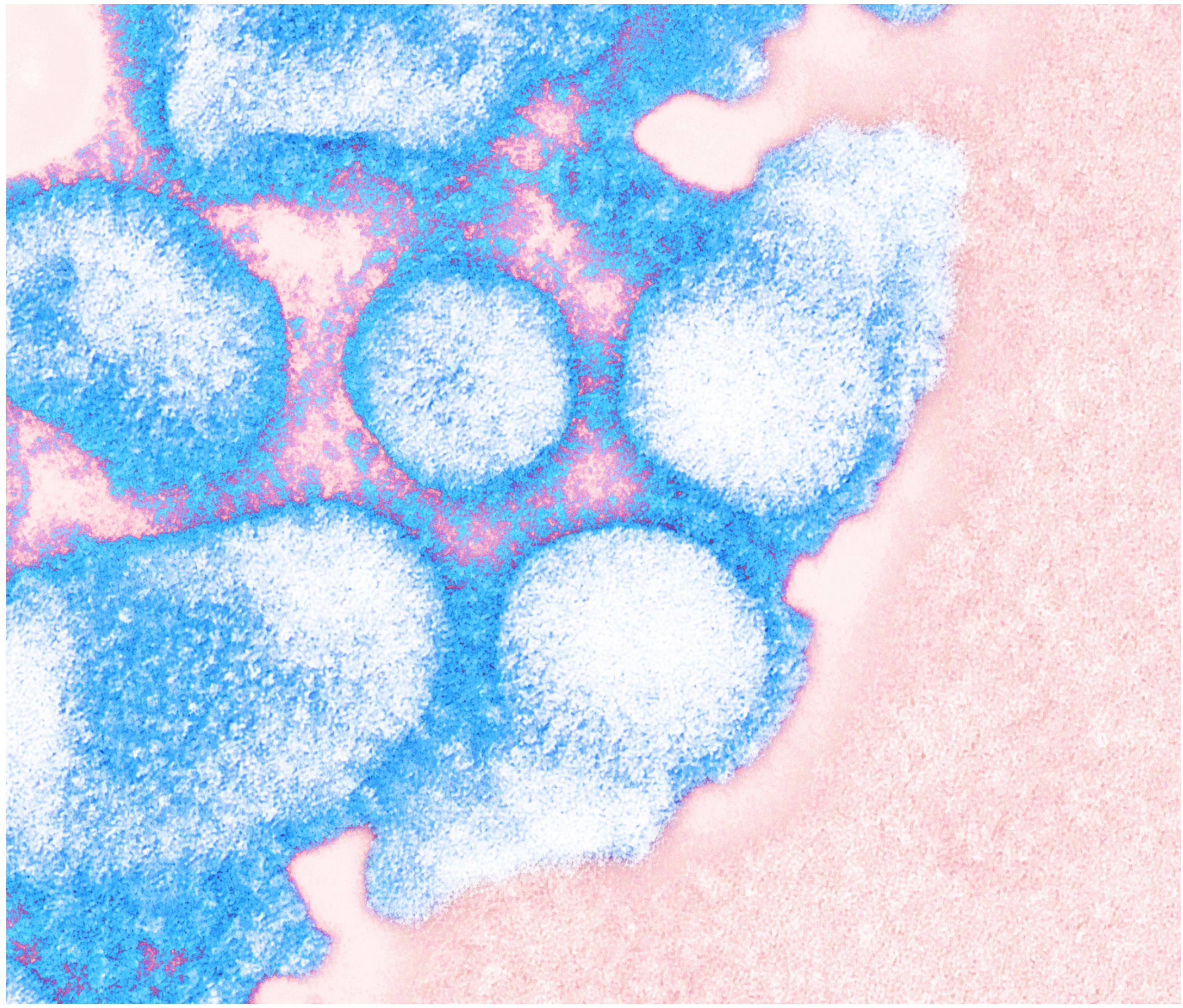


Introduction

Wastewater-based epidemiology (WBE) has proven an invaluable tool in the fight against COVID-19 in the UK and several other developed nations. This work explores the future of WBE as a global health monitoring system and aims to unlock its potential for transforming global health and policy development.

What is wastewater-based epidemiology?

Wastewater-based epidemiology (WBE) has the potential to hold up a mirror to the health of society. It offers an opportunity to gather anonymised, honest data on the health of society, including factors such as disease prevalence, lifestyle choices and drug use. Humans can secrete biomarkers that indicate health many days before they develop symptoms. Analysing these biomarkers, found in sewage, can provide an early warning system for disease outbreaks and provide monitoring insights to inform policy or governance strategies directly linked to human health.

WBE has been used throughout the pandemic to detect SARS-CoV-2 in sewage and inform response. There are a huge range of health markers, beyond coronavirus, that could be used to target health interventions to the areas that need it most.

Wastewater for health

Use of wastewater-based epidemiology in low-resource settings

The COVID-19 pandemic has demonstrated the need for a global approach to health monitoring. Communities, predominantly in high-income countries, have been realising the benefits of WBE as an early warning system and a means to gather insight into public health.

Having experienced the value of this approach utilising developed sewerage infrastructure, we began exploring the potential that WBE holds for providing health insights for the world's most vulnerable and remote communities. This document describes the development of a guidance framework, intended to support the setup of wastewater monitoring programmes in low-resource settings. Through publishing this resource, we hope to promote discussion and share insight into the implementation of WBE in a variety of infrastructure settings.

2020

COVID-19 lockdown
The global pandemic triggers lockdowns worldwide

UK Government looks to WBE: Phase 1
Arup supports the UK Government as they consider WBE as a means to control the spread of COVID-19

2021

UK Gov WBE: Phase 2
Arup continues developing WBE tools, testing at city-scale

Global research programme
Arup launches investigation into the value of WBE and tests its applicability in low-resource settings

2022

UK Gov WBE: Phase 3
Arup investigates wider health markers and source tracing methods

Figure 1. A timeline describing Arup's involvement in wastewater-based epidemiology

"Wastewater-based epidemiology (WBE) is generally more important in a low and middle income country (LMIC) setting because preventative healthcare and resources are less available or not very reliable. WBE provides a way of flagging places within a community or network where limited resources can be most wisely used."

Prof. David Graham, Professor of Ecosystems Engineering
Newcastle University

How to use this guidance

Wastewater contains a plethora of health markers and designing a worthwhile approach will be a localised decision, dependent on local health priorities, access to healthcare and regional capacity.

Introduction to the infrastucture-based WBE guidance framework

This guidance framework is intended to promote discussion and provide support to those considering the setup of wastewater monitoring programmes, particularly in low-resource settings. This guidance considers five key areas:

1. Infrastructure classification
   Nine classifications of global wastewater systems have been defined. These use the 'Compendium of Sanitation Systems and Technologies'[1], defined in collaboration between EAWAG (Swiss Federal Institute of Aquatic Science and Technology) and IWA (International Water Association).
2. Sampling methodology
   For each system, the framework offers insight to the kind of sample that could be collected and what it is likely to represent (physically, demographically, and temporally).
3. Degree of testing capability
   Depending on the health marker of interest (whether viral, bacterial, chemical), there are a series of options available to analyse a wastewater sample, varying in complexity. The guidance includes a flowsheet of the processes involved and reviews commercially available capability.
4. Information outcome
   This section describes the outcomes/insights to public health that could be achievable through the various sampling and testing scenarios.
5. Reflections on non-infrastructure factors
   Social context is paramount to any WBE approach and thus we discuss key considerations and approaches in which to understand relevant local behaviours, cultural barriers, governance and stakeholders.

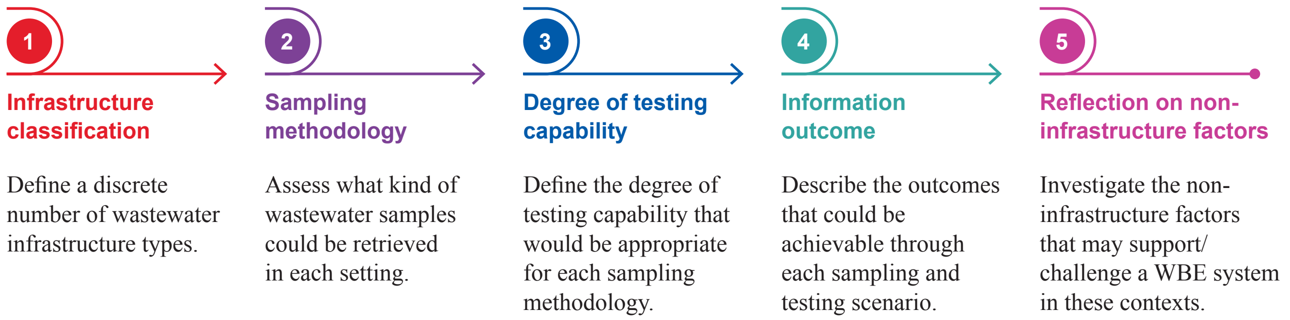
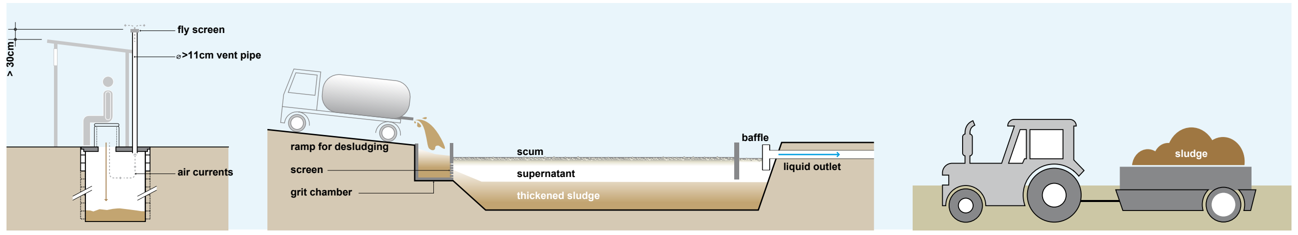


Figure 2. The structure of Arup's infrastructure-based WBE guidance framework

Infrastructure classifications

Nine classifications of global wastewater system have been defined using the EAWAG/IWA 'Compendium of Sanitation Systems and Technologies'[1]. Key attributes of each technology are highlighted with the aim of informing suitable wastewater-based epidemiology (WBE) technologies.

System 1: Single pit system



Technology overview

Use of a single pit which is either emptied periodically (can be up to 20 years!) or covered over so that a new pit should be constructed nearby.

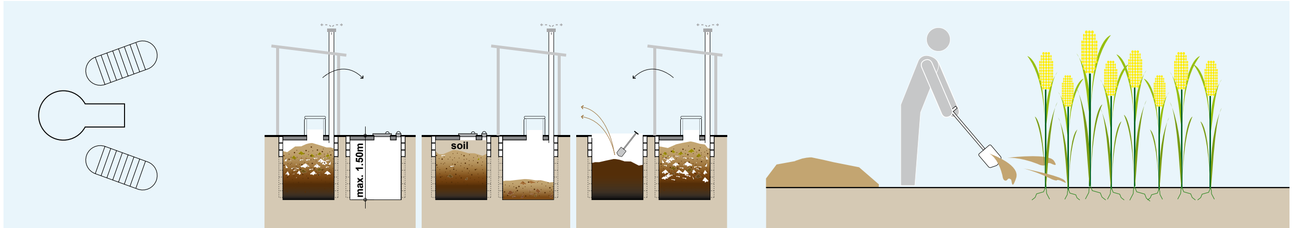
Useful information

- Emptying the latrine can vary in difficulty. Pits can be deep, typically only a few metres but may be up to 5 metres deep.
- Typically one or a few households would use each latrine.

Key characteristics

Uses Flushwater	Yes and No
Sludge to include faeces	Yes
Sludge to include urine	Yes
Sludge to include anal cleansing water	Yes and No
Sludge to include dry cleansing materials	Yes and No
Geography	Rural and peri-urban
Required human powered emptying	Yes
Regularly emptied	Unlikely/No

System 2: Waterless pit system without sludge production



Technology overview

System typically uses two alternating pits. One pit is first filled before being covered and temporarily taken out of service whilst the second pit is filled.

Whilst covered, the first pit can drain, decompose and transform into a nutrient-rich pit 'humus'. This organic material can be emptied and used locally for agricultural fertiliser. This then allows the users to return to using the first pit, whilst the same process occurs in the second.

Useful information

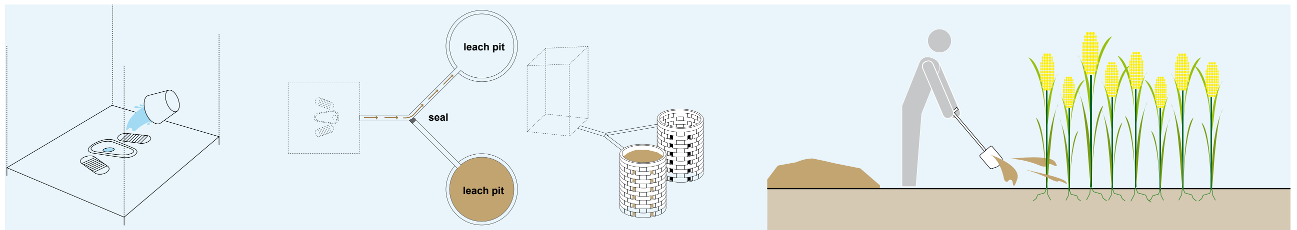
- High percentage of faeces in sludge as little or no water used for cleansing.
- Emptying completed once humus develops, approximately every six months but dependent on rate of decomposition.

Key characteristics

Uses Flushwater	No
Sludge to include faeces	Yes
Sludge to include urine	Yes and No
Sludge to include anal cleansing water	No
Sludge to include dry cleansing materials	Yes and No
Geography	Rural or urban*
Required human powered emptying	Yes
Regularly emptied	Yes

*Not possible in very space constrained sites but suitable for dense areas that cannot be served by trucks for mechanical emptying.

System 3: Pour flush pit system without sludge production



Technology overview

This technology utilises pour flush latrines and twin pits. Infiltration into the ground is allowed and decomposition causes a humus-like product to be produced which can be used in agriculture. The process works as follows (similar to system 2). The first pit is filled before being covered and temporarily taken out of service whilst the second pit is filled. Whilst covered, the first pit can drain, decompose and transform into a nutrient-rich pit 'humus'. This organic material can be emptied and used locally for agricultural fertiliser. This then allows the users to return to using the first pit, whilst the same process occurs in the second.

Useful information

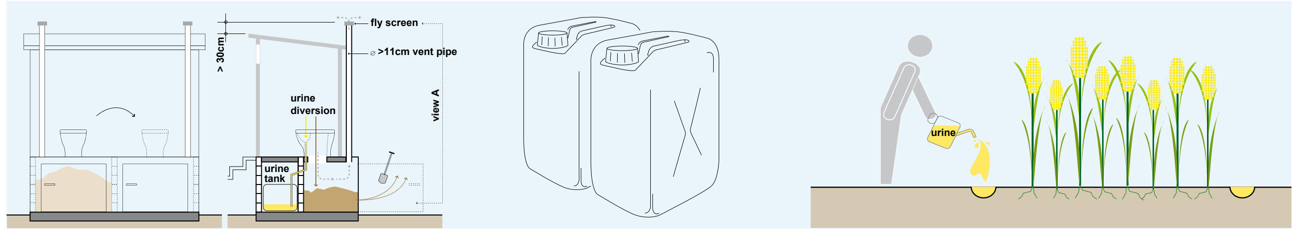
- A minimum of two years is needed for pit filling.

Key characteristics

Uses Flushwater	Yes*
Sludge to include faeces	Yes
Sludge to include urine	Yes
Sludge to include anal cleansing water	Yes*
Sludge to include dry cleansing materials	Yes
Geography	Rural and peri-urban areas with permeable soil
Required human powered emptying	Yes
Regularly emptied	Yes

* Only small quantities, otherwise results in excessive leachate.

System 4: Waterless system with urine diversion



Technology overview

This system separates urine and faeces, and aims to reduce water content as far as practicable to encourage dehydration and pathogen reduction.

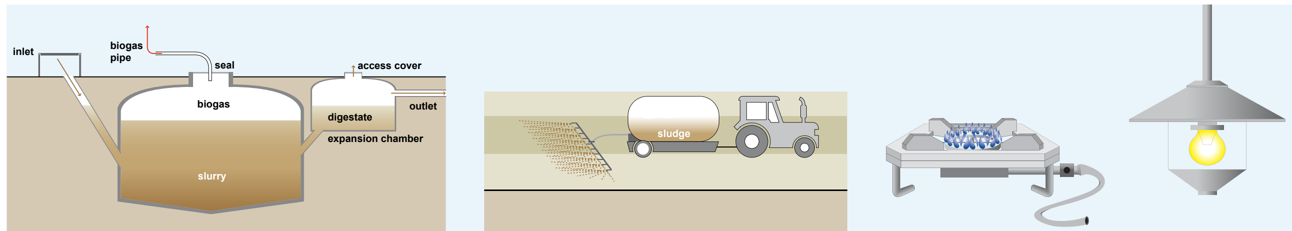
Useful information

• High faecal matter content in sludge due to lack of additional anal cleansing water and urine.

Key characteristics

Uses Flushwater	No
Sludge to include faeces	Yes
Sludge to include urine	No
Sludge to include anal cleansing water	No
Sludge to include dry cleansing materials	Yes
Geography	Ideal in water-scarce areas in both rural and urban environments
Required human powered emptying	Yes
Regularly emptied	Yes

System 5: Biogas system



Technology overview

Excreta is stored and collected in a biogas system, which can be used to meet local energy needs.

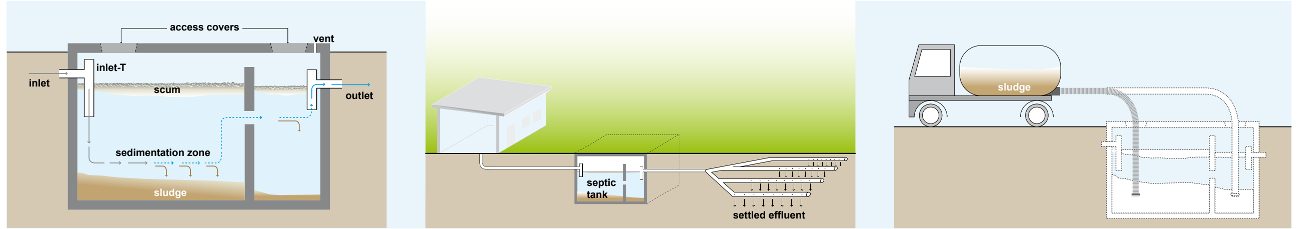
Useful information

• Care must be taken when working close to the biogas reactor. It is unlikely samples can be taken once the excreta reaches the reactor.

Key characteristics

Uses Flushwater	Yes or No
Sludge to include faeces	Yes
Sludge to include urine	Yes
Sludge to include anal cleansing water	Yes or No
Sludge to include dry cleansing materials	Yes
Geography	Best suited to rural and peri-urban areas where sufficient space and regular sources of organic substrate are available and there are uses for the digestate and biogas
Required human powered emptying	Yes
Regularly emptied	Yes

System 6: Blackwater treatment system with infiltration



Technology overview

This technology requires a pour flush or cistern flushing toilet. Inputs to the system are then processed through septic tank, Anaerobic Baffled Reactor (ABR) or Anaerobic filter. Effluent can be directly diverted to the ground or disposed through a soak pit or a leach field. Although it is not recommended, the effluent can also be discharged into the stormwater drainage network for water disposal/groundwater recharge. Meanwhile the sludge is transported and should be treated before disposal or use.

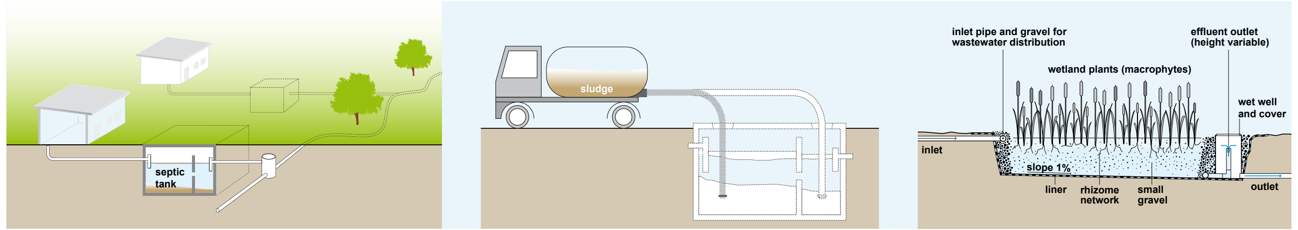
Useful information

• Typically this system would be used by several households.

Key characteristics

Uses Flushwater	Yes
Sludge to include faeces	Yes
Sludge to include urine	Yes
Sludge to include anal cleansing water	Yes
Sludge to include dry cleansing materials	Yes
Geography	Ground conditions must allow safe infiltration
Required human powered emptying	Yes, although usually mechanised/uses a vehicle
Regularly emptied	Yes

System 7: Blackwater treatment system with effluent transport



Technology overview

Typically, a pour flush or cistern flush toilet will be used at household level for this technology. At household level, solids and liquids are separated. Treated effluent is then collected and treated again usually through constructed wetlands, used in agriculture, or discharged to a water body. Meanwhile the sludge is transported and should be treated before disposal or use.

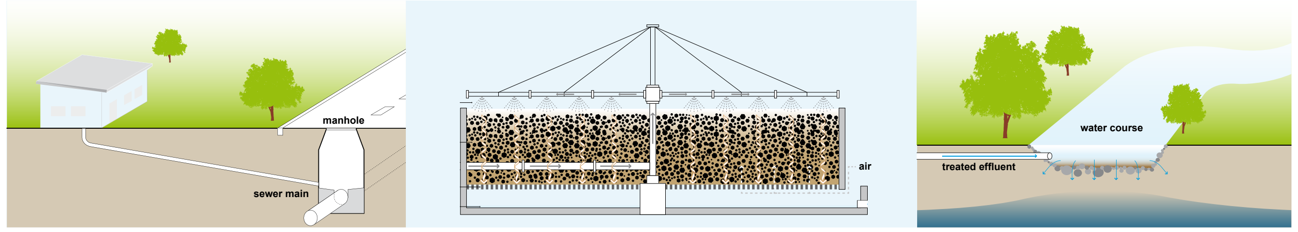
Useful information

• Mixing with effluent produced at different times is mixed with new effluent.

Key characteristics

Uses Flushwater	Yes
Sludge to include faeces	Yes
Sludge to include urine	Yes
Sludge to include anal cleansing water	Yes
Sludge to include dry cleansing materials	Yes
Geography	Urban settlements where the soil is not suitable for the infiltration of effluent
Required human powered emptying	Yes, although usually mechanised/uses a vehicle
Regularly emptied	Yes

System 8: Blackwater transport to (semi-) centralised treatment system



Technology overview

This technology is typically used with pour flush or cistern flush toilet. Flows are then conveyed directly (without collection or storage) to a (semi-) centralised treatment facility.

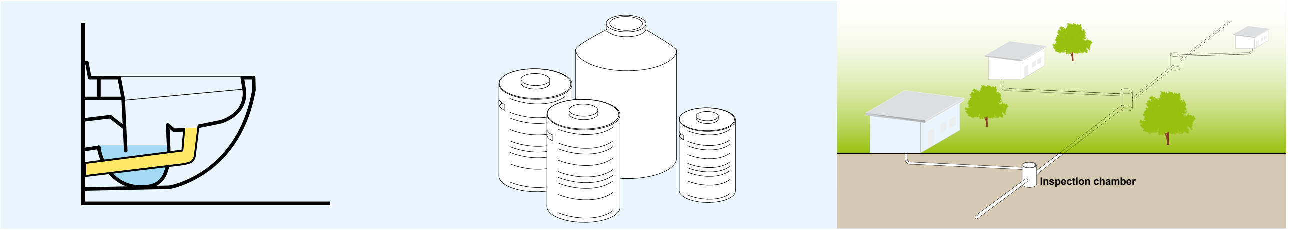
Useful information

• Could be mixed with stormwater and greywater, further diluting the proportion of faecal matter.

Key characteristics

Uses Flushwater	Yes
Sludge to include faeces	Yes
Sludge to include urine	Yes
Sludge to include anal cleansing water	Yes
Sludge to include dry cleansing materials	Yes
Geography	Dense, urban and peri-urban settlements, where there is little or no space for on-site storage technologies or emptying
Required human powered emptying	No
Regularly emptied	Yes, via piped network

System 9: Sewerage system with urine diversion



Technology overview

System separates urine and water in the cistern so that the urine can be used separately, for example as a fertiliser.

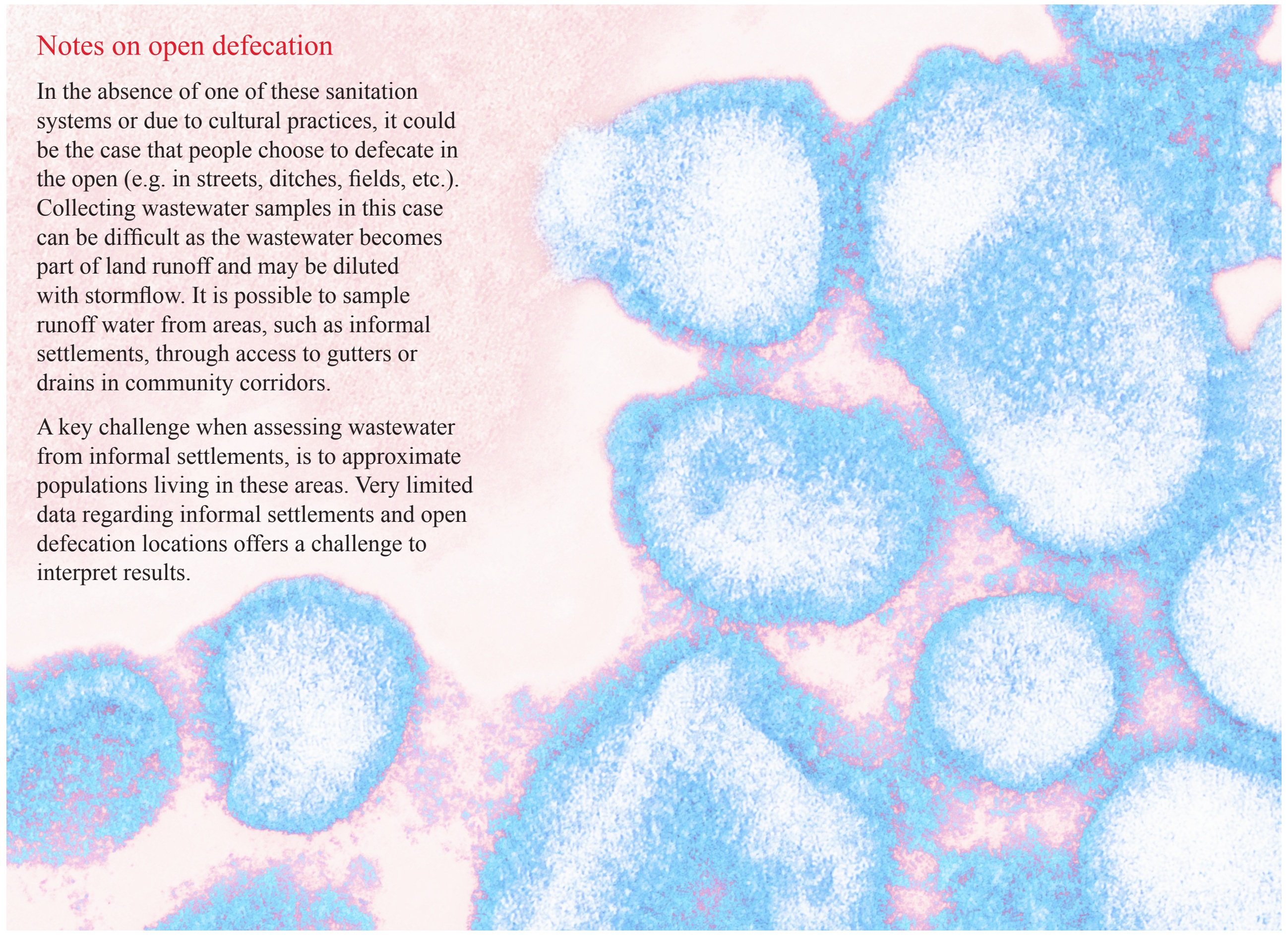
Useful information

• This technology is rare and a high capital investment is needed.

• Blackwater is mixed with stormwater and greywater, further diluting the proportion of faecal matter.

Key characteristics

Uses Flushwater	Yes
Sludge to include faeces	Yes
Sludge to include urine	No
Sludge to include anal cleansing water	Yes
Sludge to include dry cleansing materials	Yes
Geography	Urban and peri-urban areas
Required human powered emptying	No
Regularly emptied	Yes, via piped network



Notes on open defecation

In the absence of one of these sanitation systems or due to cultural practices, it could be the case that people choose to defecate in the open (e.g. in streets, ditches, fields, etc.). Collecting wastewater samples in this case can be difficult as the wastewater becomes part of land runoff and may be diluted with stormflow. It is possible to sample runoff water from areas, such as informal settlements, through access to gutters or drains in community corridors.

A key challenge when assessing wastewater from informal settlements, is to approximate populations living in these areas. Very limited data regarding informal settlements and open defecation locations offers a challenge to interpret results.

Sampling methodology

For each system, the framework offers insight to the kind of sample that could be collected and what it represents (physically, demographically, and temporally).

Sample collection

What to sample?

Health markers are present in both urine and faeces so it could be important to identify which markers are of interest when solid and liquid are separated at source. Drug residues are typically secreted in urine whilst viruses and bacteria are found in faecal particles.

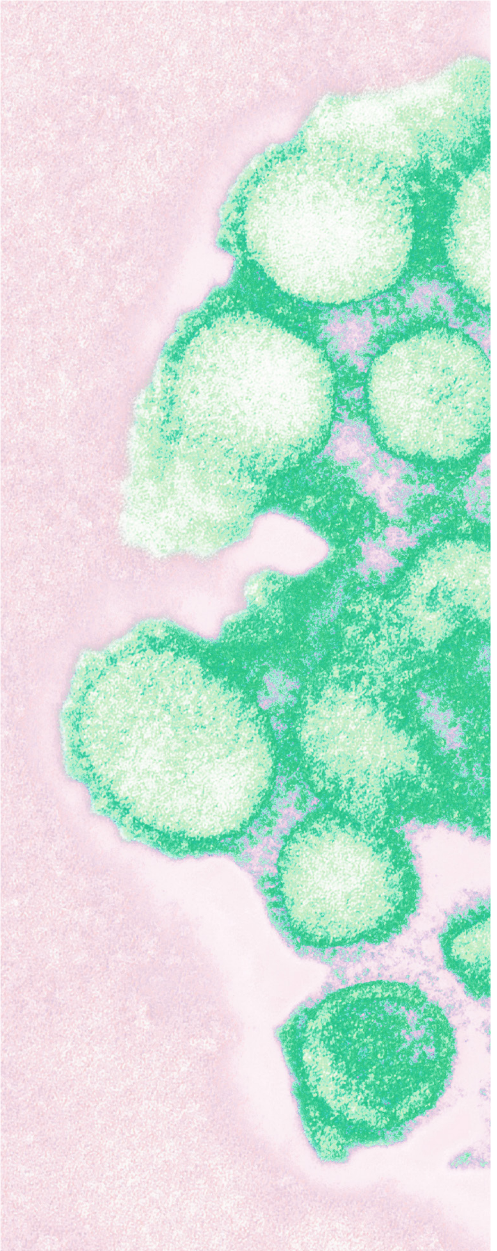
For samples with a high-solid content, mixing within the collection chamber is likely to be low. Best practice in this case is to combine samples from various points within the chamber and use a buffer solution to homogenise the sample.
In the case of open defecation it may be possible to sample stormwater runoff from gutters or drains in community corridors.

Where to sample?

A sampling location should be chosen to give a suitable representation of the population. Some wastewater collection facilities may only be used by a subsection of the community and this should be understood prior to sampling.

The group SCORE developed a set of 'ethical research guidelines for sewage epidemiology'[2] to outline the potential ethical risks of monitoring wastewater in small communities.

Retrieving a wastewater sample may be achieved throughout the collection pathway (e.g. point of collection, tankering, treatment facility), to gain insights at a suitable scale. Collecting samples further along in the process will give an indication of a larger population but concentrations will likely be reduced.



When to sample?

Centralised wastewater infrastructure (systems 8/9) are flow-variable and therefore samples should be taken at times most likely to contain toilet waste, this will vary geographically and with distance from the source.

With other collection systems, the toilet waste is compounded over time and therefore extracting a suitable sample is less of a temporal issue. Biomarkers do decay over time (e.g. SARS-CoV can survive 4-22 days in a stool sample[3]) and thus sampling frequency should be informed using targeted marker decay rates.

How to sample?

Grab sampling – a dipper/collection bucket is used to retrieve a wastewater sample and transfer to a sample bottle.

+ Easy, cheap, little resources needed
- Represents a single moment in time, risk of contact with wastewater, variation in sample collection

Automatic sampling – a pump draws wastewater from the source through a hose into a sample bottle.

+ Quick, hygienic, can represent a period of time and reduces human error
- Cost, power requirement

There are various methods to sample automatically:

Composite – a series of samples taken over a period of time, collected in one bottle. Intervals can be defined by the user related to time (e.g. sample every five minutes), flow (e.g. sample when flow is >x) or volume (e.g. sample when x m^3 has passed by). Each sample represents an average or composite of the wastewater during a given interval.

Sequential – single or multiple samples are collected within each bottle, the bottles are switched at a time interval defined by the user. Each sample represents the wastewater at the given time interval.

Passive vs active samplers

Passive samplers are designed to be placed within the wastewater source for a period of time and often include a membrane that has affinity with the biomarkers of interest. The sampler can be retrieved after a duration and analysed for presence of health markers.

+ Easy, cheap, can represent a period of time

- Cannot represent concentration

Active samplers can be used to take a sample at a specified time or duration and could include a biomarker-affinity membrane or a sample reservoir.

+ Possibility for remote sensing, more control than passive

- More costly, may require power

Sample transport

Preserving the sample

Decay rates vary for different wastewater markers so the rule of thumb is to maintain wastewater samples at 4ºC. The following methods can be used to keep samples cool:

- Permanent refrigerated (AC Power)
- Portable (ice/gel packs)
- Potable refrigerated (AC Power/battery)

Notes on chemicals: Microorganisms in wastewater can start to metabolise chemicals in wastewater very quickly. Therefore, samples for chemical analysis should be frozen as soon as possible or stored on dry ice during transport for analysis.

Developing simpler techniques

Techniques to transfer DNA/RNA from a wastewater sample onto filter paper are now the subject of R&D, this would not require the refrigeration or transport of wastewater sample bottles which holds many logistical benefits, especially in remote, resource-constrained settings.

System	Sampling considerations
Open defecation	Samples may be collected from gutters or drains in community corridors and dependent on land runoff.
1. Single pit system	Represents multiple households, compounded over time, mixing level low (take multiple scoops from around the pile and combine). May be difficult to access pit contents.
2. Waterless pit system without sludge production	Represents multiple households, compounded over time, mixing level low (take multiple scoops from around the pile and combine). May be difficult to access pit contents.
3. Pour flush pit system without sludge production	Represents multiple households, compounded over time, higher level of mixing. May be difficult to access pit contents.
4. Waterless system with urine diversion	Represents multiple households, compounded over time, mixing level low (take multiple scoops from around the pile and combine), separate urine/faecal samples (choose according to target marker).
5. Biogas system	Represents multiple households/wider community, compounded over time/temporal flowing system, if tankered sludge represents multiple areas, need to access sample before reactor inlet.
6. Blackwater treatment system with infiltration	Represents multiple households, compounded over time/temporal flowing system, need to access septic tank (possible impact of setting), higher liquid content.
7. Blackwater treatment system with effluent transport	Represents multiple households, compounded over time/temporal flowing system, need to access septic tank (possible impact of setting), sample effluent at tanker/treatment facility, higher liquid content.
8. Blackwater transport to (semi-) centralised treatment system	Represents wider community, temporal flowing system/sewered, dilute sample, higher liquid content.
9. Sewerage system with urine diversion	Represents wider community, temporal flowing system/sewered, dilute sample, higher liquid content, possible to retrieve separate urine/faecal samples (choose according to target marker).

Degree of testing capability

Depending on the health marker of interest (viral, bacterial and/or chemical) there are a series of options available, varying in complexity, used to analyse a wastewater sample. The guidance includes a flowsheet of the processes involved and reviews commercially available capability.

Bacterial analysis (e.g. AMR)

Quantitative analysis

Quantitative sample analysis, e.g. E.coli, ESBL-E/Coli concentrations and proportion AMR

Equipment	Rating
Spread plate	1 ▲ £
Membrane filter methods	1 ▲ £

Purification and isolation of presumptive target organisms

Select five representative colonies from TBX + CTX plates and streak to purification. To create pure isolates, process described in Global Tricycle Surveillance – ESBL-E.coli[10]

Identify presumptive target organisms

Biochemical identification methods (conventional and automated) biochemical identification methods used as routine in the laboratory – procedure included in annexes Global Tricycle Surveillance – ESBL-E.coli[10]

Biological / Viral analysis

Nucleic acid extraction

Extraction of nucleic acid from DNA/RNA

Equipment	Review
Column affinity	3 ▲ £
Magnetic beads	2 ▲ £
Paper-based	1 ▲ £

Amplification

Amplification of the DNA/RNA targets to enable analysis. This could target single or multiple markers; e.g. high throughput PCR (HT-PCR) allows up to 384 markers to be tested at once.

Equipment	Rating
RT-qPCR	3 ▲ £
RT – LAMP	2 ▲ £
NASBA	2 ▲ £

Signal detection

Typical techniques include optical detection (fluorescence or colorimetry), electrochemical sensing, electronic sensing and nanopore-based sequencing[4]

Chemical analysis

Sample preparation

Sample is concentrated and purified via solid phase extraction

Equipment	Rating
Oasis MCX cartridges	2 ▲ £
Methanol primer	1 ▲ £

Liquid chromatography mass spectrometry

LCMS separates the sample into its multiple components and provides spectral information to identify each component

Equipment	Rating
Quantum AM therm electron	3 ▲ £
Symmetry C18 column	1 ▲ £
Synergy 4 column	1 ▲ £

Identification of presumptive load

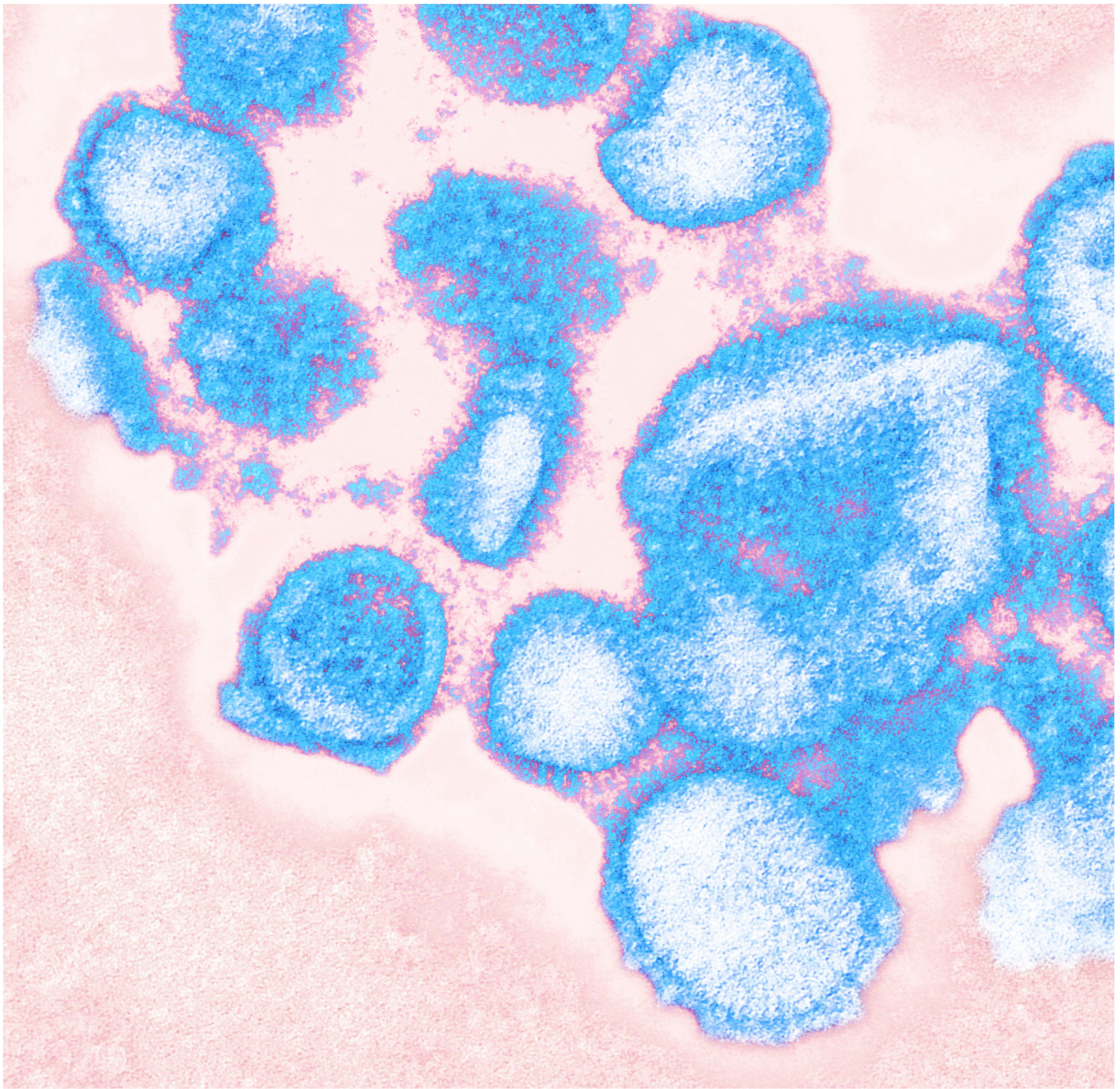
LCMS will give the concentration of chemical markers in a sample. The source flow rate can be used to indicate daily loadings and population data can be used to normalise the markers for a contributing population[5]

Legend			
Complexity of process	1	2	3
Ease of procurement	▲	▲	▲
Cost	£	£	£

Integrated technologies

There are also a number of field-based techniques developed for pathogen testing available, which reduce the need for manual and lab operations.

Type	Relevant products	Assay time	Rating
Lab-in-a-cartridge	– BioFire COVID-19 test, BioFire (US) – Xpert Xpress SARS-CoV-2 test, Cepheid (US)	45 mins	1 ▲ £
Lab-in-a-box	– ID NOW platform, Realtime SARS-CoV-2 assay, Abbott (US)	5~13 mins	1 ▲ £
Lab-in-a-plate	– n2000TM RealTime SARS-CoV-2 EUA test, Abbott (US)	24 hours	1 ▲ £
Lab-in-a-tube	– Panther Fusion® SARS-Cov-2 assay, Hologic (US)	2.4 hours	1 ▲ £
Automated RT-PCR	– Roche's Cobas SARS-CoV-2 test, Roche (US) – BioGX SARS-CoV-2 reagents for, Becton, Dickinson (BD) (US)	3-8 hours	1 ▲ £



Information outcomes

The key value of wastewater-based epidemiology is for use as an early warning system for disease outbreak, to track the spread of an infection across a population and to identify health trends and inequalities between communities.

Possible data outcomes

The impact that can be achieved with a WBE programme is dependant on the sampling strategy and how the acquired data is analysed to produce suitable information that can inform decision-making. The following sections discuss some options for data analysis that will provide varied outcomes.

Binary data analysis

Certain techniques, such as passive sampling or paper-based testing (e.g. lateral flow tests) provide a yes/no answer on biomarker presence. These methods can be cheaper and serve as an early warning system, indicating the need for a more detailed study.

Quantitative data analysis

Quantifying the concentration of biomarkers in a wastewater sample requires specific lab analysis, discussed in the previous section, some of the possible insights that follow are detailed below.

Indication of case rates – In order to indicate disease prevalence in a community, there should be a knowledge of population equivalence, i.e. the likely population contributing to the sampled wastewater, this can be approximated using local knowledge or by analysing other human waste markers in the sample, like ammonium.

Community-wide trends – Without knowledge of population, trends in disease prevalence can be observed over a sampling duration, providing information on rising or falling case rates.

Intercommunity comparisons – This can also be used to compare between different communities, overlaying demographic data to shed a light on vulnerability hotspots or health inequality.

Researchers predict and monitor COVID-19 in fragmented sewerage systems in Jaipur.[6]

Researchers in India successfully predicted a second wave of COVID-19, despite the fragmented sewer system, by sampling at nine treatment facilities.

Stakeholder motivations and beneficiaries

Motivations \ Stakeholders	Local government	National government	Healthcare providers	NGOs	CBOs	Communities	Funding agencies	Researchers
Early warning system for disease	▲	▲	▲	▲	▲	▲	▲	
Preventative measures	▲	▲	▲	▲				
Monitor trends/disease spread	▲		▲					
Monitor impact of policy/design decisions	▲	▲		▲				
Monitor pollution	▲			▲	▲			
Understand lifestyle/habits				▲				▲
Quantify exposure risks	▲	▲	▲	▲				
Community health improvement	▲	▲	▲	▲	▲	▲	▲	
Evidence policy/decision-making	▲	▲		▲				
Prioritise resources	▲	▲	▲	▲			▲	
Future infrastructure investment decisions	▲			▲			▲	
Monitoring impact of infrastructure investments	▲			▲				
Inform design approaches				▲			▲	▲
Identify inequalities			▲	▲			▲	▲

Legend
Beneficiaries

Data Triangulation

Where possible, WBE data should be used in conjunction with other available datasets to provide evidence for public health decision making. For example, comparing wastewater data with case rates, hospitalisation rates, death rates etc. can add confidence to the process and provide a solid basis for intervention.

Reflection on non-infrastructure factors

Social context is paramount to any WBE approach and thus we discuss key considerations and approaches in which to understand relevant local behaviours, governance and stakeholders.

Suitability of a WBE health surveillance programme in low-resource contexts

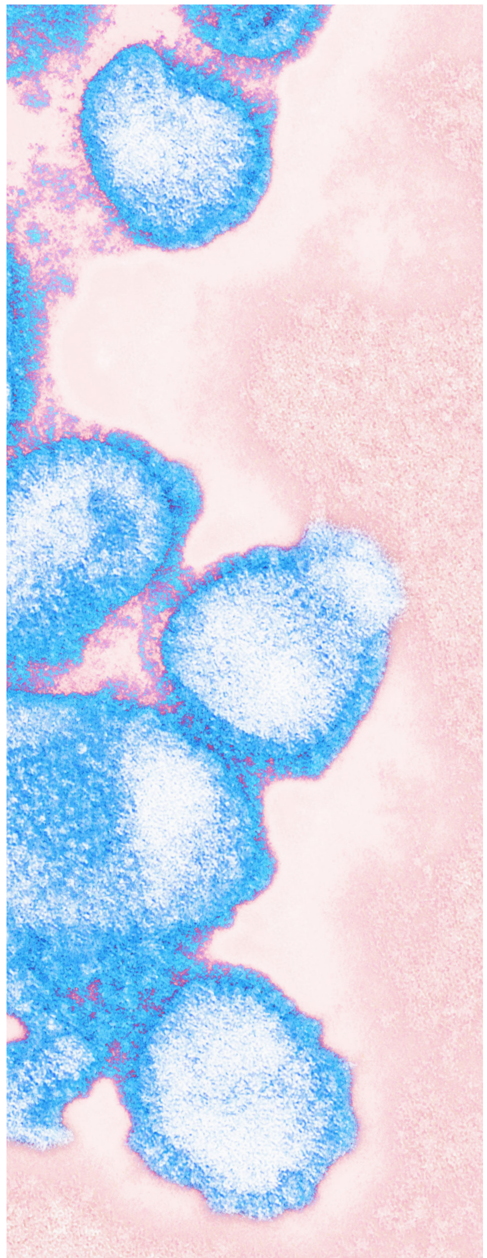
WBE has been used in low-resource contexts to monitor several health markers of concern, including polio, antimicrobial resistance and antibiotic usage. Where these programmes have been utilised, health authorities and other stakeholders may have some existing resources and processes in place. WBE offers the opportunity to assess populations that may not have access to other healthcare services, out of choice or capacity and allows resources to be targeted to maximise cost efficiency. Stakeholders should be careful not to divert resources from other water, sanitation and hygiene (WASH) related activities essential for improving sanitation and healthcare.

Community awareness and buy-in

It is crucial that different community groups are informed of the health surveillance process, understand its methods and value. Community acceptance is key, if misinformed or if they disagree with the process, they may stop using the toilet facilities. Transparency is important.

Local behaviours

It is important to understand the community behaviours, local practices and beliefs before selecting a monitoring site. Ensuring target groups use the sample site facilities is key for accurate representation (e.g., men and women may use different latrines). In some cultures, contact with menses is taboo, forbidden or associated with witchcraft. These practices and beliefs need to be understood through assessment of the attitudes and practices.



Local stakeholder and governance mapping: roles and responsibilities

Stakeholders	Process phase	Legislation	Coordination	Community consultation and awareness	Access to sanitation facilities/ sewer/FSTP	Sample collection	Analysis	Data management and communication	Response	Enforcement	Training
Public health authorities		▲	▲	▲		▲	▲	▲	▲	▲	▲
Households				▲	▲				▲		
NGOs			▲	▲	▲	▲	▲		▲		▲
CBOs				▲	▲				▲		▲
Private laboratories						▲	▲	▲			▲
Utilities					▲	▲	▲	▲			
Universities						▲	▲	▲			▲

Stakeholder engagement and governance

Adequate engagement and coordination from the health authorities and other stakeholders involved in the process is key. It is likely that a surveillance programme would involve a wide range of stakeholders from the public and private sectors, such as research laboratories, utilities, health authorities, non-governmental organisations (NGOs) or community-based organisations (CBOs).

Each of their responsibilities should be well defined, as well as the way they coordinate. Accountability mechanisms should be in place to ensure everyone performs effectively. The table above outlines the main stakeholders and their likely roles within a WBE programme.

Sample population

Ensuring a representative sample population with different demography may be challenging in an informal setting. Special care should to be taken to not use an already stigmatised community or a population group that could be stigmatised based on the results of a WBE campaign. Samples and collection points should offer suitable anonymisation to avoid stigmatising small groups. To ensure a representative, anonymised sample, it could be considered to take them from the desludging trucks or transfer tanks if existing and collection is regular enough to minimise sample degradation. However, depending on the sludge characteristics, water may be added to ease the desludging operations which would dilute the sample.

Response

The results from the sampling strategy should be integrated with other surveillance information and there should be a plan in place for how to respond in the case of significant health-related discoveries (such as a dramatic rise in cases of infectious disease). This should include thresholds in which the response plan is triggered. The response should be managed such that the community do not feel targeted or stigmatised, which may impact future buy-in.

Staff safety and dignity

Health and safety measures need to be followed when taking samples. The personnel in charge should wear appropriate personal protective equipment (PPE), such as protective outerwear, gloves, boots, medical mask, goggles and/or a face shield. Procedures should be in place to minimise spills and sanitise equipment and clothing. Care should be taken when taking samples from deep pits and adequate risk assessments should be conducted. The approach should ensure that there is no stigma attached to staff managing sample collection, particularly with faecal matter. Any stigmatisation issues should be addressed through community education and public campaigns.

Capacity building

Relevant training will need to be provided to the staff involved in the different aspects of the health surveillance programme. Training may include sample collection, laboratory analysis and data communication methods. It would be highly recommended to build the capacity of personnel responsible in order to collect data regarding community knowledge, attitudes and practices (KAP) to inform the approach. This is a sensitive topic and providing adequate training to consult and inform the community has proven key for good data collection and community knowledge.

Environment

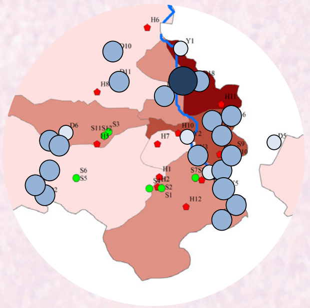
Wastewater samples should be disposed of safely without polluting the environment or posing risk to public health.

Managing insight

It is important to share insights gained through WBE, contributing to a collective effort to improving human health on a global scale. Sharing data in the public domain is important for communities to see the benefits of WBE and will improve acceptance, however, some aspects may warrant restricted access due to sensitivity or political/ethical reasons. Several digital platforms exist for sharing WBE data across borders (e.g., COVID-19 WBE Collaborative, Global Water Pathogens Project, and Sewage Analysis CORe group Europe) which are essential for shared learnings.

However, clear governance and communication strategies should be in place to ensure this data is shared in a meaningful way, in consistent formats, that can translate across borders. Dashboards are a useful visualisation tool for observing trends but should be carefully planned to support data triangulation and integration which will improve confidence and promote truly actionable insights for stakeholders.

Case studies



Tackling antimicrobial resistance (AMR) through training in New Delhi (India)[8]

Researchers from Newcastle University (UK) have been studying antibiotic resistance in LMICs for many years. Their work has included demonstrating the value of training community correspondents within informal settlements in New Delhi.

Correspondents were trained to lead KAP data collection for WASH and antibiotic resistance surveys. This resulted in multiple benefits including improving the quality of data, building field team confidence and empowering the community through knowledge sharing.

Urban water profiling in South Africa[9]

Researchers from University of Bath (UK) and Stellenbosch University (SA) have been sampling water discharge into the Eerste River river catchment in South Africa to indicate environmental pollution and antimicrobial resistance through use of pharmaceuticals. This work includes monitoring discharge from wastewater treatment plants as well as surface water runoff from informal settlement. This work is key for identifying pollution hotspots and reducing impacts such as rising antimicrobial resistance.

Practices among faecal sludge operators in Bengaluru (India)[7]

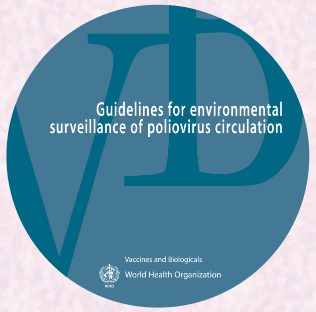
Faecal sludge management is usually an informal sector that is not always regulated and if practiced without following adequate guidelines can pose a risk for operators. In different cultural contexts, dealing with faecal matter can be seen as a shameful task and operators may suffer from stigmatisation. In Bengaluru, a study was conducted to understand the practices of faecal sludge operators and their standing in society. The most common operational hazards found were injuries and social stigma. 86.7% of the operators surveyed felt that their job was attached to social stigma.

None of them reported the use of the full PPE required. This study highlights the importance of information and training among the sanitation workers to perform their job safely, but also the importance of information and communication activities among the community about the key tasks performed by workers to destigmatise their occupation.

Global Tricycle Surveillance
ESBL E.coli

"One Health" approach to AMR[10]

The Tricycle protocol was developed by the World Health Organization (WHO) to provide a standard protocol for integrated global surveillance of an indicator of antimicrobial resistance [extended spectrum beta-lactamases (ESBL) producing Escherichia coli] across the human, animal and environmental sectors. This protocol includes standard methodologies for implementing in low resource settings to help establish AMR surveillance, including wastewater monitoring.



Eradicating polio with environmental surveillance[11]

The WHO also developed guidelines for environmental surveillance of poliovirus circulation highlighting the need for a clear plan to be developed that clearly indicates reporting responsibilities to ensure that all epidemiological information regarding polio circulation is shared effectively. They comment on laboratory resources, training of personnel, and validation of adopted laboratory procedures.

Reflections and next steps

Reflecting on WBE in low-resource settings

The value of wastewater-based epidemiology as a global health monitoring system has been proven through the COVID-19 pandemic. However, this approach has predominately been used in developed sewerage systems and little is known about its potential in low-resource settings. It is the hope that this guidance will promote discussions around the value, ethics and practicalities of WBE in various infrastructure settings and support creation of WBE capability worldwide. WBE offers a powerful tool to assess various health markers, such as infectious diseases (COVID-19, polio, influenza, Zika, etc.), antimicrobial resistance, pharmaceutical consumption (clinical and illicit), and allows monitoring of their environmental interactions. This provides opportunity for early warning of health emergencies, identification of health deprivation and pinpointing pollution hotspots.

WASH stakeholder group workshops

Throughout this project, we have been working with WASH stakeholders and subject-matter experts to test concepts, exploring opportunities and barriers. Following the publication of this manual, we plan to deepen stakeholder conversations regarding WBE in low-resource contexts and strengthen our resources to best support implementation of wastewater-based epidemiology to improve public health globally.

Further testing of concepts in a pilot study

Through engagement workshops with WASH stakeholders, we hope to identify suitable use cases for a pilot study to apply this framework and further assess the applicability of WBE as a global health monitoring tool.

"Wastewater monitoring is most critical in places that lack centralised healthcare because it can triage health at community scales. Therefore, developing WBE guidance for such settings is a key step in protecting and improving health among the most vulnerable."

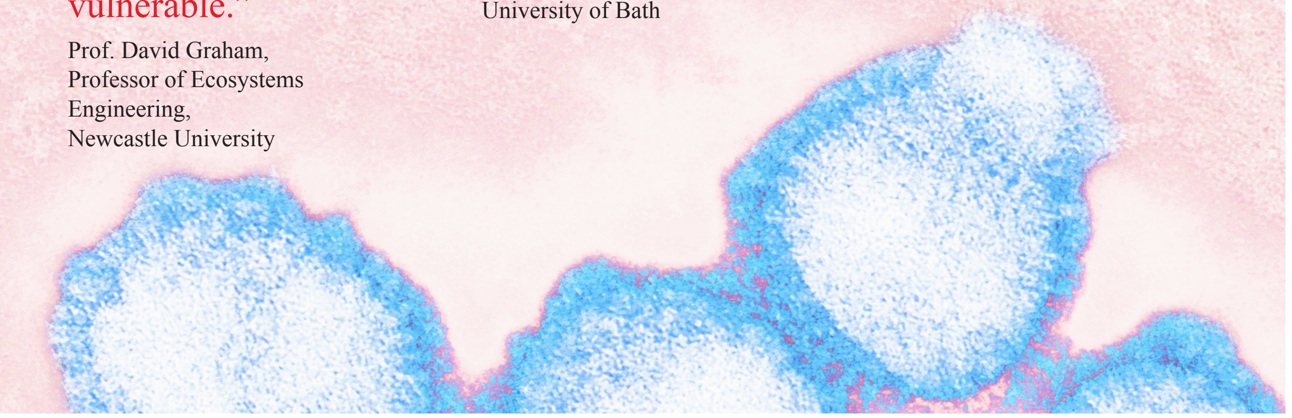
Prof. David Graham,
Professor of Ecosystems Engineering,
Newcastle University

"WBE has a great potential to provide cost effective public health surveillance in low-resource settings. To be implemented globally, WBE needs to be equipped with low-cost technology applicable in remote settings."

Prof. Barbara Kasprzyk-Hordern,
Professor of Environmental and Analytical Chemistry,
University of Bath

"WBE will allow better disease surveillance and control in many low-income countries. It will allow valuable healthcare resources to be targeted in a more cost-effective way."

Prof. Davey Jones,
Professor of Soil and Environmental Science,
Bangor University



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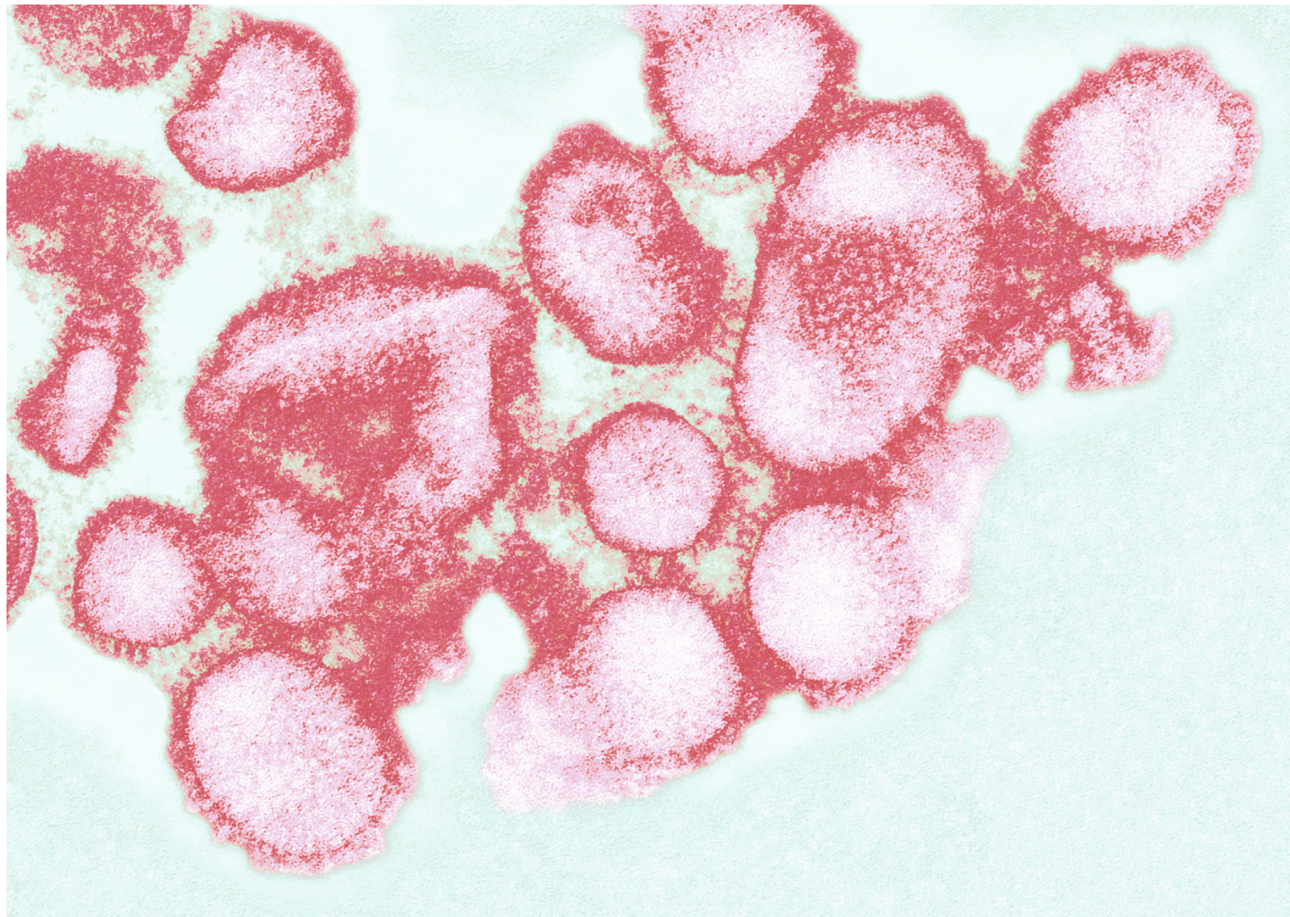

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