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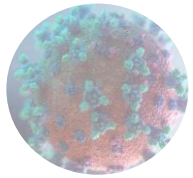
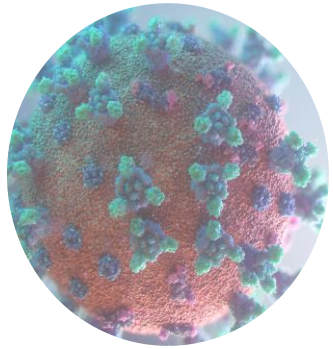
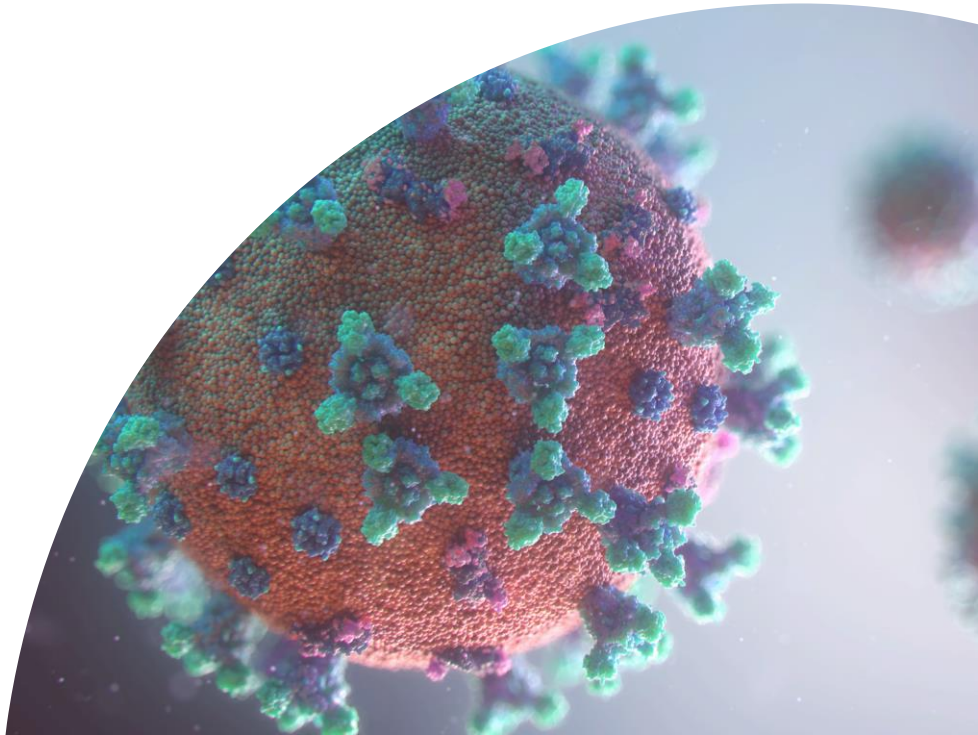




Wastewater for Health

Developing a global wastewater epidemiology service that delivers public health benefits and manages current and future outbreaks



Dr Olivia Bailey *Olivia-x.Bailey@arup.com*

19/04/2022

Realising Value in WBE

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Wastewater- based epidemiology holds a mirror to public health that doesn't lie…

UK WBE Covid-19 Response

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COVID-19 Lockdown
The global pandemic triggers National Lockdown

WBE modelling tools
Arup continues developing WBE tools, testing at city-scale

Advanced modelling techniques
Arup investigates wider health markers and source tracing methods

2020 — 2021 — 2022

UK Government looks to WBE
Arup supports UK Government as they consider WBE as a means for controlling the spread of COVID-19

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

Sensors

Other Data

Describe

Emulate

Predict

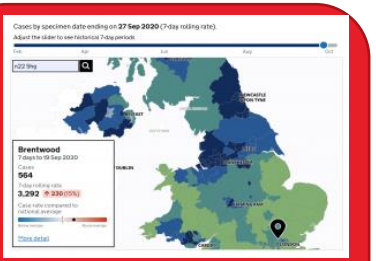
Prescribe

Action: Local intervention, monitoring etc

Network Model

Policy

Rainfall Model



Covid Case Numbers

How does WBE work?

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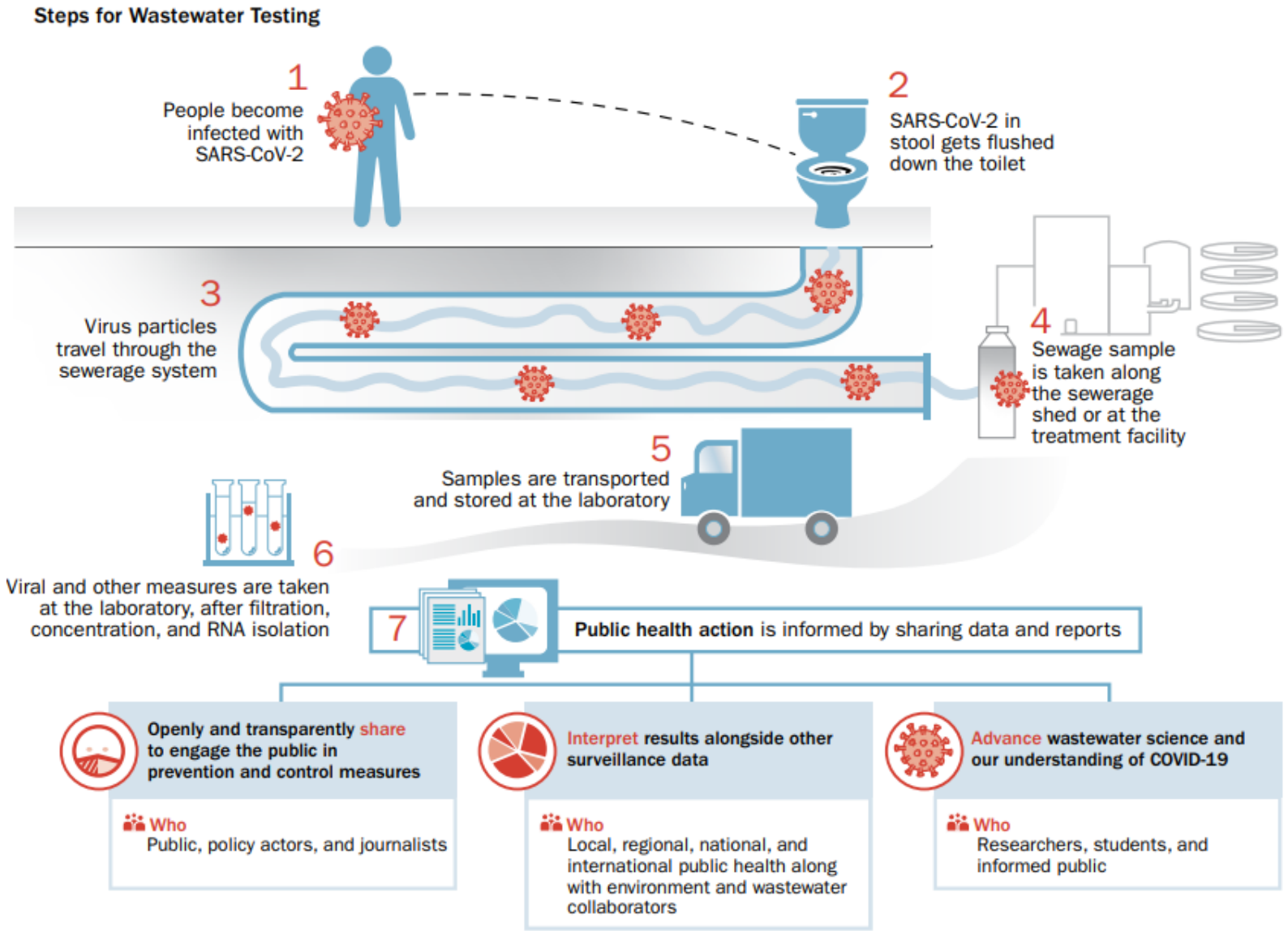

"Manuel, Doug; Amadei, Carlo Alberto; Campbell, Jonathon R.; Brault, Jean-Martin; Veillard, Jeremy. 2022. Strengthening Public Health Surveillance Through Wastewater Testing : An Essential Investment for the COVID-19 Pandemic and Future Health Threats. World Bank, Washington, DC. © World Bank. https://openknowledge.worldbank.org/handle/10986/36852 License: CC BY 3.0 IGO."

Global uptake of WBE

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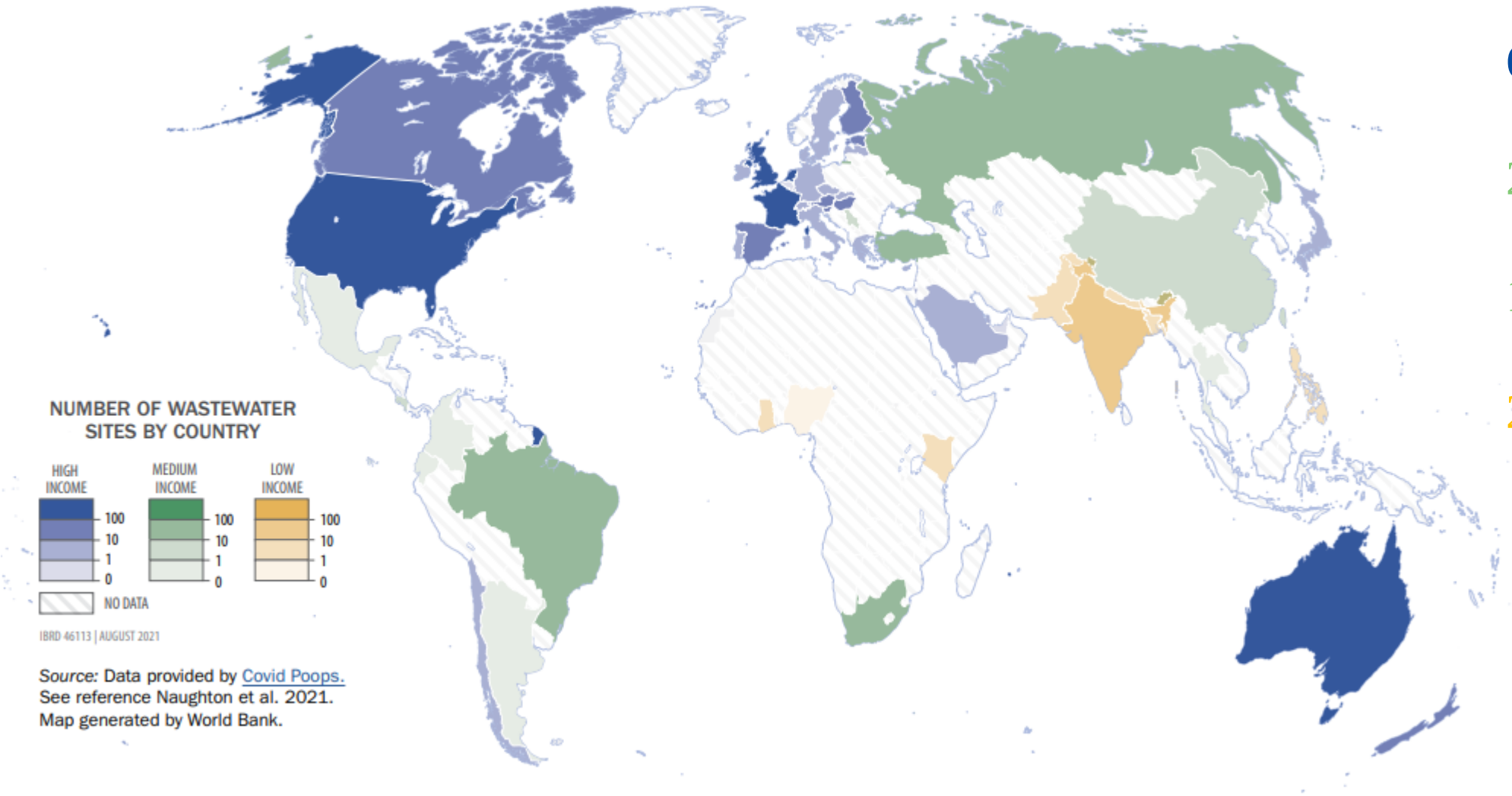
Figure 1. World Map of Wastewater Testing by Country



Source: Data provided by Covid Poops.
See reference Naughton et al. 2021.
Map generated by World Bank.

63% HIC

21% UMIC

14% LMIC

2% LIC

"Manuel, Doug; Amadei, Carlo Alberto; Campbell, Jonathon R.; Brault, Jean-Martin; Veillard, Jeremy. 2022. Strengthening Public Health Surveillance Through Wastewater Testing : An Essential Investment for the COVID-19 Pandemic and Future Health Threats. World Bank, Washington, DC. © World Bank. https://openknowledge.worldbank.org/handle/10986/36852 License: CC BY 3.0 IGO."

Global applicability of WBE

"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

"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

"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 Guidance Framework

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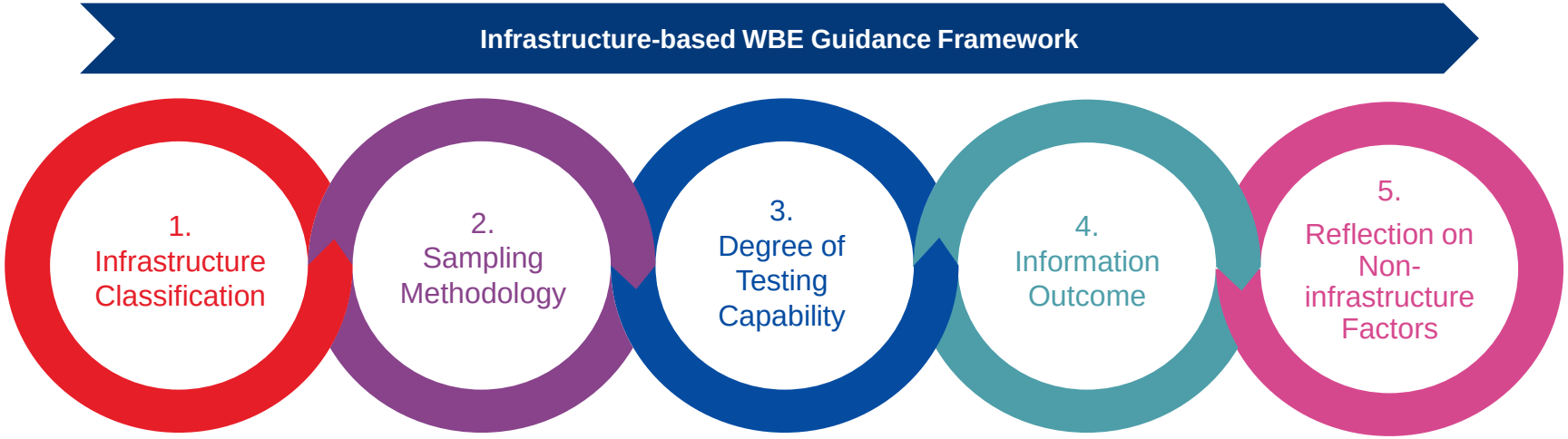
Developing an infrastructure-based WBE guidance framework



Define a discrete number of wastewater infrastructure types.

Assess what kind of wastewater samples could be retrieved in this setting.

Define the degree of testing capability that would be appropriate for each sampling methodology.

Describe what outcomes each sampling and testing scenario would allow you to achieve.

Investigate the non-infrastructure factors that may support/challenge a WBE system in these contexts.

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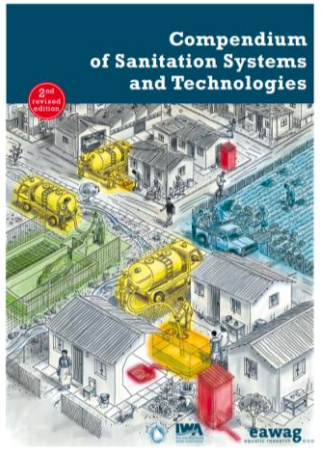
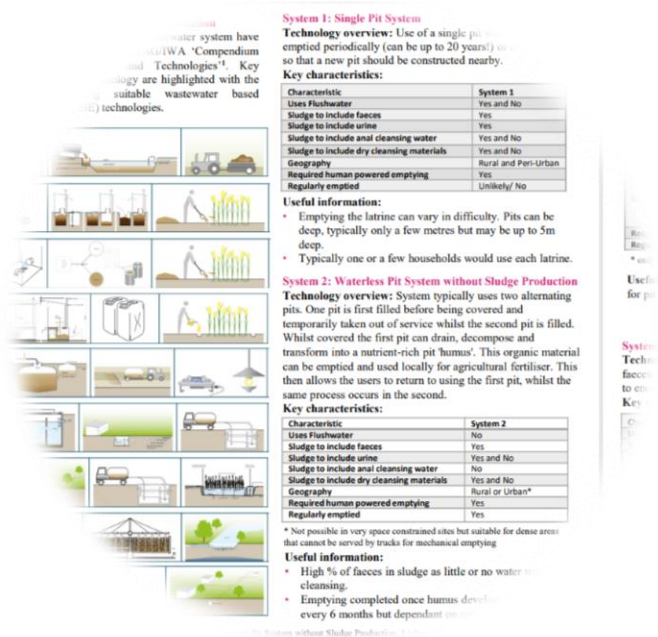
1. Infrastructure Classification

Define a discrete number of wastewater infrastructure types.

- Formulate a WBE approach related to a range of infrastructure settings
- Nine classifications of global wastewater system
- Using the EAWAG/IWA ‘Compendium of Sanitation Systems and Technologies’.
- Technical overview, key characteristics, useful information





System 1: Single Pit System

Technology overview: Use of a single pit ... emptied periodically (can be up to 20 years!) ... so that a new pit should be constructed nearby.

Key characteristics:

Characteristic	System 1
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

Useful information:

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

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.

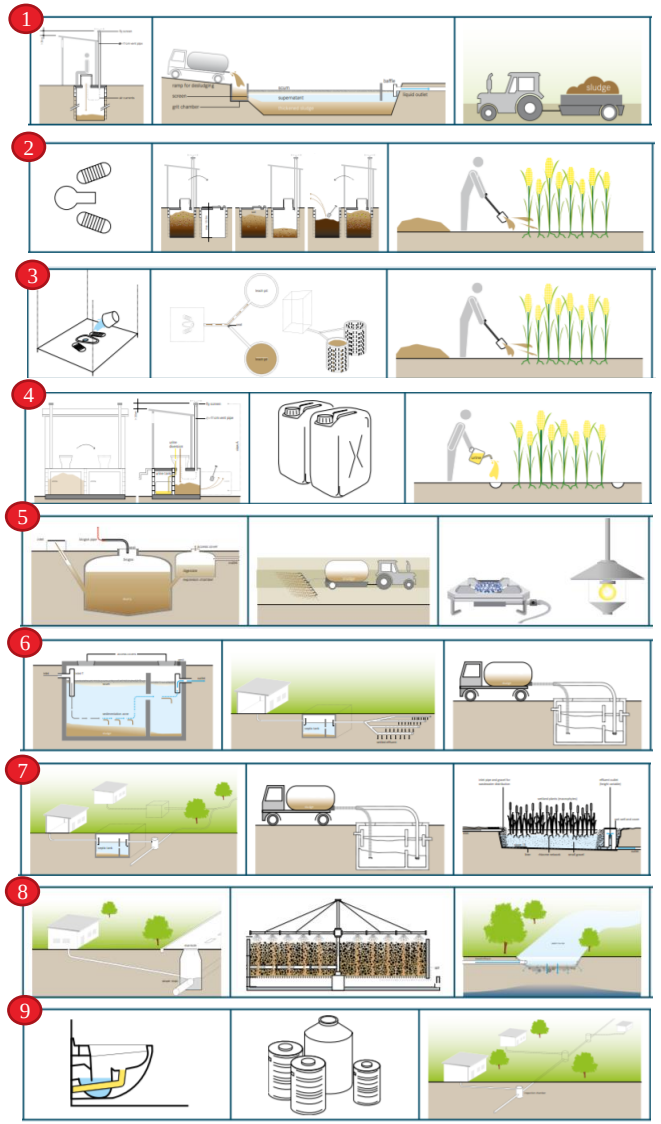
Key characteristics:

Characteristic	System 2
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

Useful information:

- High % of faeces in sludge as little or no water ... cleansing.
- Emptying completed once humus ... every 6 months but dependant ...



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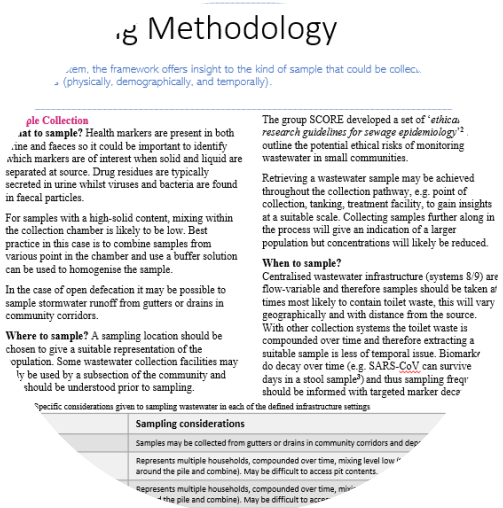
2. Sampling Methodology

Assess what kind of wastewater samples could be retrieved in this setting.

- What to sample?
- Where to sample?
- When to sample?
- How to sample?
- Sampling transport

		Informal Settlement	Urban	Peri-urban	Rural	Human emptying	Motorised emptying	Sewer	Ease of sampling	Representation scale
0	Open defecation	●								
1	Single pit system	●		●	●	●				
2	Waterless pit system with sludge production		●	●	●	●	●			
3	Pour Flush Pit System without Sludge Production	●		●	●	●				
4	Waterless System with Urine Diversion		●	●	●	●				
5	Biogas system			●	●		●			
6	Blackwater Treatment System with Infiltration			●	●		●			
7	Blackwater Treatment System with Effluent Transport		●				●			
8	Blackwater Transport to (Semi-) Centralized Treatment System		●	●				●		
9	Sewerage System with Urine Diversion		●	●				●		



g Methodology

em, the framework offers insight to the kind of sample that could be collec
(physically, demographically, and temporally).

ple Collection

at to sample? Health markers are present in both ine 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 point in the chamber and use a buffer solution can be used 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 opulation. Some wastewater collection facilities may y be used by a subsection of the community and should be understood prior to sampling.

The group SCORE developed a set of *'ethical research guidelines for sewage epidemiology'*[2] 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, tanking, 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 a 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 temporal issue. Biomarke do decay over time (e.g. SARS-CoV can survive days in a stool sample[8]) and thus sampling freq should be informed with targeted marker dec

Specific considerations given to sampling wastewater in each of the defined infrastructure settings

	Sampling considerations
	Samples may be collected from gutters or drains in community corridors and de
	Represents multiple households, compounded over time, mixing level low around the pile and combine). May be difficult to access pit contents.
	Represents multiple households, compounded over time, mi the pile and combine). May be difficult to ac

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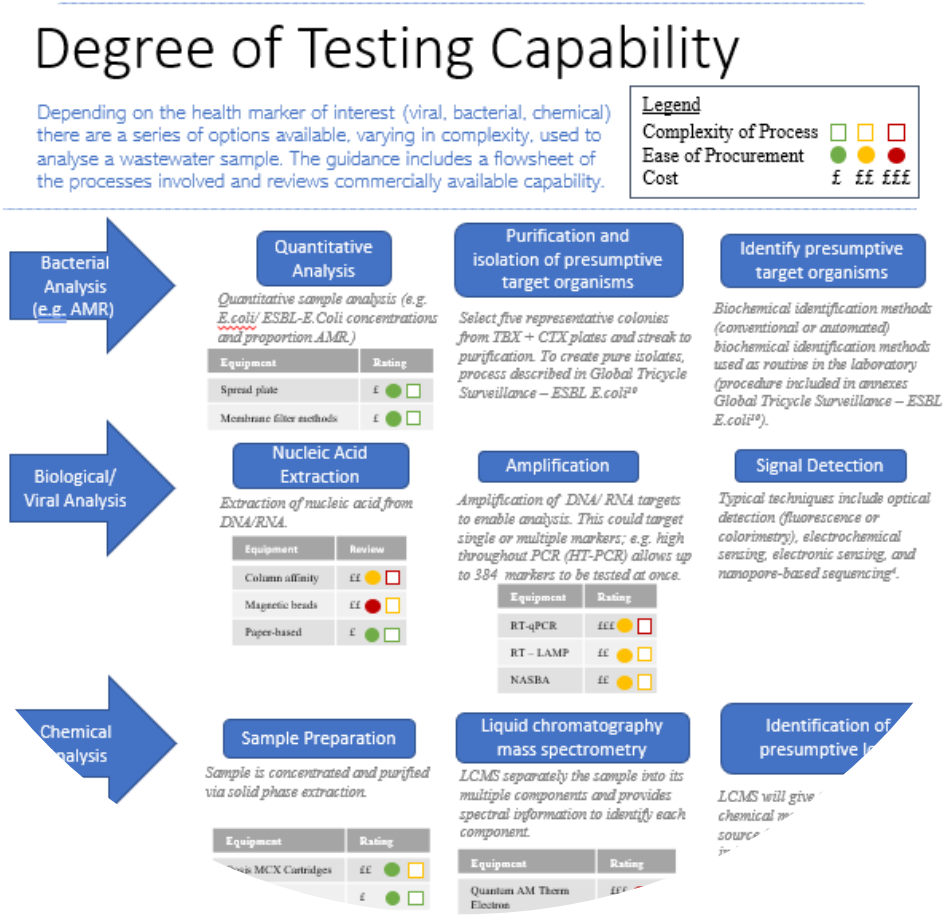
3. Degree of Testing Capability

Define the degree of testing capability that would be appropriate for each sampling methodology.

- Type of Analysis
  - Bacterial, Biological, Viral, Chemical
- Commercial options review
  - Process complexity
  - Ease of procurement
  - Indicative cost



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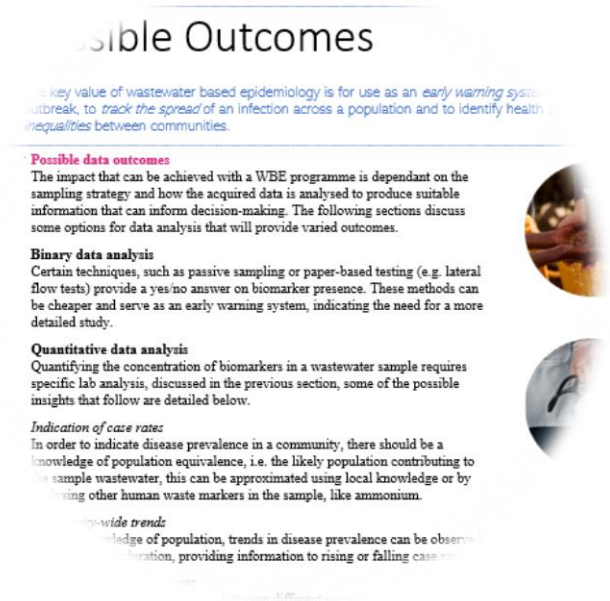
4. Information Outcome

Describe what outcomes each sampling and testing scenario would allow you to achieve.

- Binary outputs
  - Early-warning systems
  - Highlight need for more detailed testing
- Quantitative outputs
  - E.g. indication of infection rates, community-wide trends, intercommunity trends
- Stakeholder motivations and beneficiaries



sible Outcomes

key value of wastewater based epidemiology is for use as an *early warning syst* outbreak, to *track the spread* of an infection across a population and to identify health *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 sample wastewater, this can be approximated using local knowledge or by sing other human waste markers in the sample, like ammonium.

-wide trends

ledge of population, trends in disease prevalence can be obser ration, providing information to rising or falling case

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

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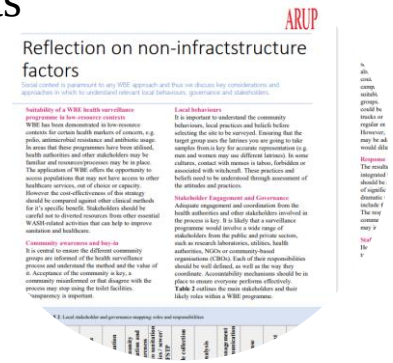
5. Reflection on Non-infrastructure Factors

Investigate the non-infrastructure factors that may support/challenge a WBE system in these contexts.

- Community awareness and buy-in
- Local behaviours
- Stakeholder engagement and governance
- Staff safety and dignity
- Capacity building
- Managing insights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Reflection on non-infractstructure factors

Stakeholders	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 laboratory					●	●	●			●
Utilities				●	●	●	●			
Universities					●	●	●			●

Continuing development and engagement

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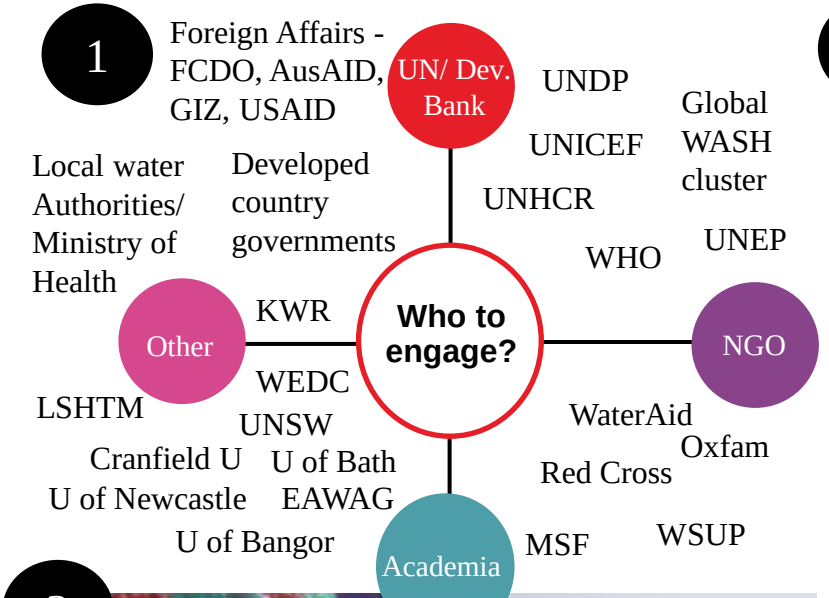
1



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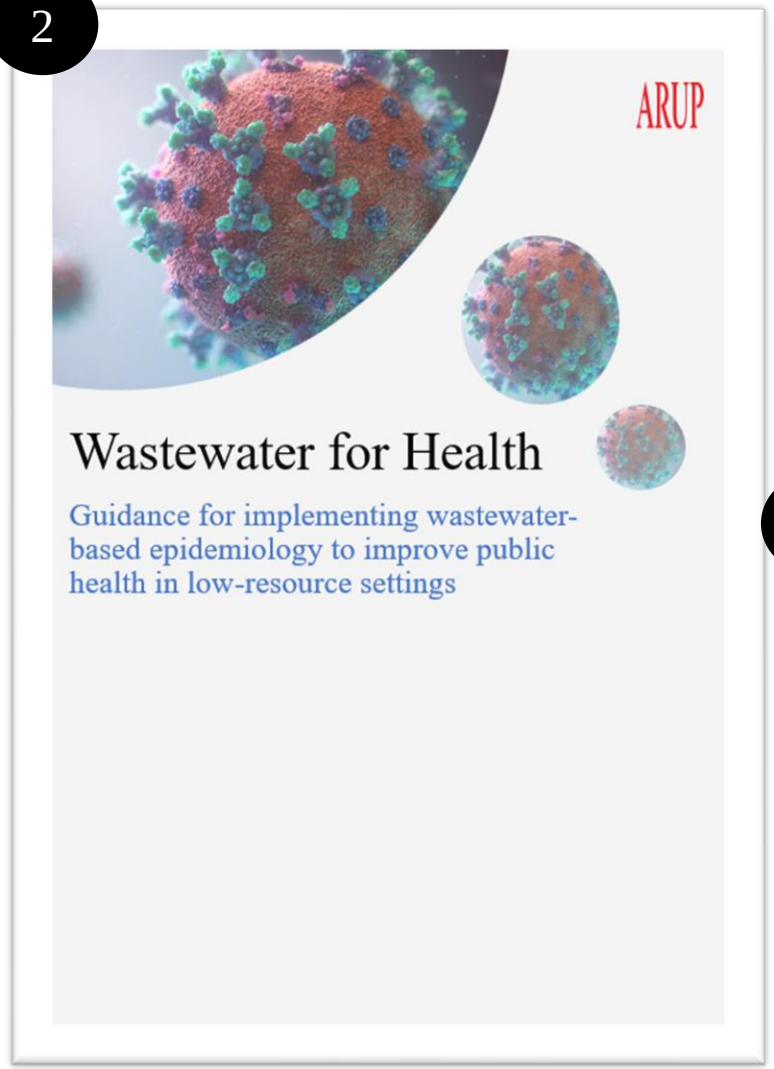

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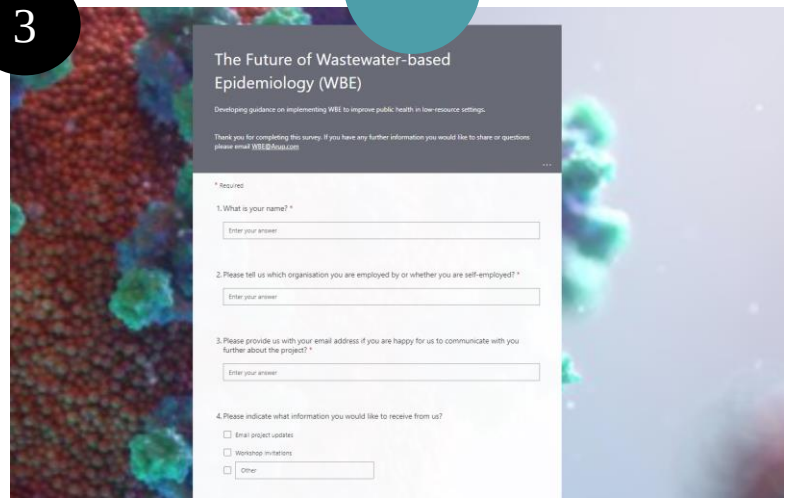

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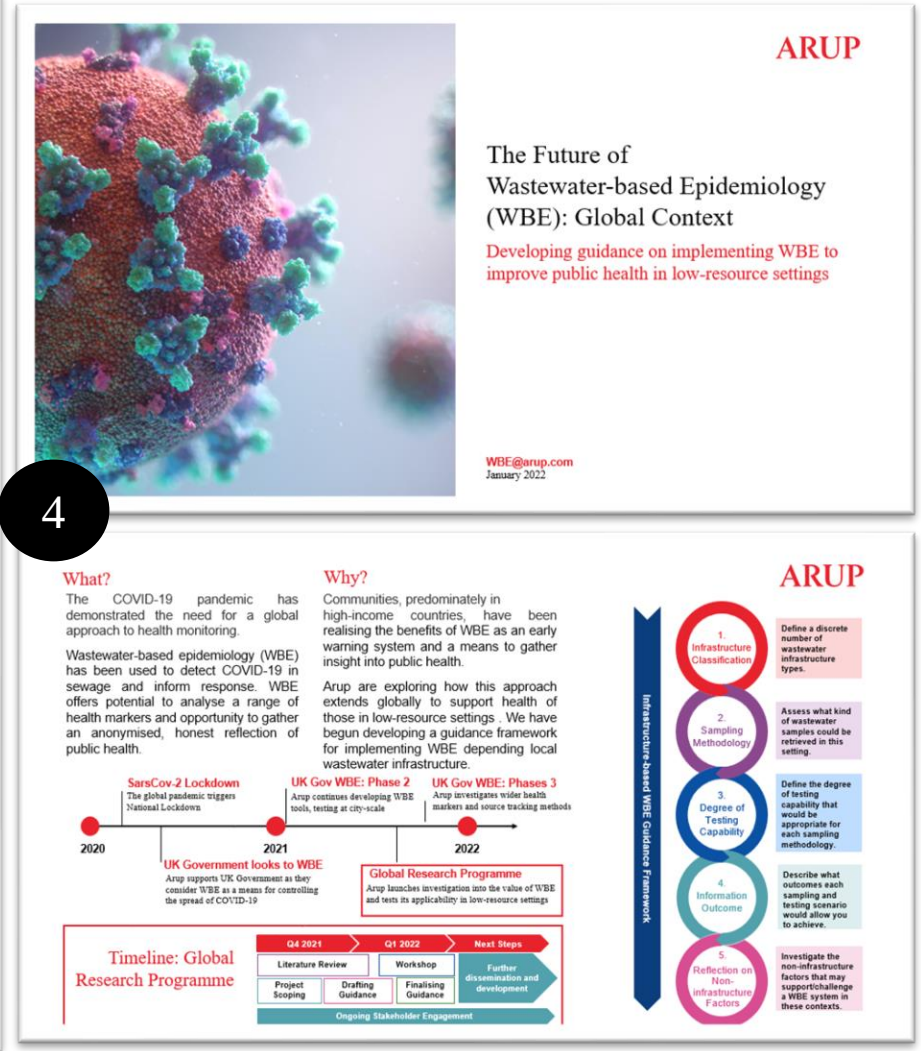

1.Stakeholder mapping, 2. Guidance document, 3. Stakeholder engagement survey, 4. Engagement postcard, 5. Project email address

5

WBE@arup.com

Reflections and Next Steps

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The power of wastewater-based epidemiology ….

- Opportunity **for early warning of health emergencies**, identification of health deprivation and pinpointing pollution hotspots.
- Cost effective health assessment tool for low-resource settings
- Focusing allocation of resources to the most vulnerable

What's next….

- Testing: Continued engagement with WASH and SME partners
- Pilot study: apply this framework to further assess the applicability of a WBE as a global health monitoring tool.

"Wastewater-based epidemiology (WBE) is generally more important in a 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

Email WBE@arup.com to find out more

Contact Details

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Register interest and keep updated
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