Communities of Practice for Wastewater and Environmental Surveillance in Low-Resource Settings:

Approaches for Implementation

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Suggested citation. Communities of Practice for Wastewater and Environmental Surveillance in Low-Resource Settings: Approaches for Implementation. Alexandria: Water Environment Federation; 2024. License: CC BY-NC-SA 4.0

Funding acknowledgement. This product was funded by the U.S. Centers for Disease Control and Prevention's (CDC) Antimicrobial Resistance Solutions Initiative through the Global Antimicrobial Resistance Laboratory and Response Network and by Cooperative Agreement Number CDC-RFA-CK21-2104 (Protecting and Improving Health Globally: Building and Strengthening Public Health Impact, Systems, Capacity and Security), which funded the Water Environment Federation. Development and production of this document was also made possible through funding from CDC to the Association of Public Health Laboratories under Cooperative Agreement CDC-RFA-GH20-2109 (Global Health Security Partnerships: Expanding and Improving Public Health Laboratory Strategies and Systems). Its contents are solely the responsibility of the authors and do not necessarily represent the official views of CDC or the U.S. Government.

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Abbreviations

AR: Antimicrobial resistance

ARG: Antibiotic resistance gene

APHL: Association of Public Health Laboratories

CDC: U.S. Centers for Disease Control and Prevention

CoP: Community of Practice

EU: European Union

IANPHI: International Association of National Public Health Institutes

JMP: WHO/UNICEF Joint Monitoring Programme for Water Supply, Sanitation and Hygiene (JMP)

LMICs: Low- and middle-income countries

NGO: Non-governmental organization

NWSS: U.S. National Wastewater Surveillance System

PCR: Polymerase chain reaction

PPE: Personal protective equipment

QA: Quality assurance

RNA: Ribonucleic acid

SFD: excreta flow diagram, also described as a shit flow diagram

U.S.: United States

WBE: Wastewater-based epidemiology

WBS/WWBS: Wastewater-based surveillance

WDS: Wastewater disease surveillance

WEF: Water Environment Federation

WES: Wastewater and environmental surveillance

WWS: Wastewater surveillance

Glossary

Adaptive management: an intentional approach to making decisions and adjustments in response to new information and changes in context (USAID, 2021)

Asynchronous communication: any form of communication that does not require real-time responses, i.e. there may be lag time between when information is sent and when it is received, considered, and responded to (e.g. message boards, email)

Clinical surveillance: A standard component of public health surveillance systems that involves reporting of health events by health professionals, based on diagnosis by a health professional and/or laboratory confirmation of disease, and can also include surveillance of symptoms (syndromic surveillance) in healthcare or other settings

Composite sample: made up of multiple pooled **grab samples** collected at a specified frequency over a set period, often facilitated by an automatic sampler. Considered more representative of community fecal contributions than grab samples.

Community of Practice: a group of people who share a concern or a passion for something they do and learn how to do it better as they interact regularly.

Environmental monitoring: routine testing of air, soil, water, or surfaces to identify potential exposure hazards. Detections are used to protect health.

Environmental surveillance: systematically testing air, soil, water, or surfaces and using detections to assess community health. Testing is followed by interpretation of the data to inform public health practice. For the purposes of this document, environmental surveillance will refer specifically to fecally-impacted/human-impacted waters.

Fecal sludge: concentrated layer of solids settled to the bottom of on-site sanitation technology (inclusive of used water and cleansing materials). In sewered systems, fecal sludge can also refer to settled solids in the wastewater treatment processes. But the focus of this document is on-site sanitation.

Grab sample: a volume of wastewater, fecal sludge, or surface water collected rapidly at a single moment in time. May be less representative of community fecal contributions than composite samples and are highly influenced by fluctuations in wastewater flow and composition.

Metadata: information describing the characteristics of data (Johnson et al., 2016).

Non-sewered sanitation: a sanitation system for fecal sludge that is not connected to a networked sewer system. Ideally, the fecal sludge is collected, conveyed, and treated, allowing for its safe reuse or disposal.

Passive sampling: deploying an absorbent material in the wastewater, drainage, or surface water flow for a specified period to allow the target of interest to associate with the material. At the end of the sample collection period, the material is transported to a laboratory for processing and analysis.

Pepper mild mottle virus: a plant virus found in human feces globally due to consumption of peppers and pepper-containing processed foods. When found in water sources, it is correlated with fecal contamination and can be used as a fecal indicator (Kitajima et al., 2018).

Personal protective equipment: equipment used to prevent or minimize exposure to hazards (WHO, n.d.). For workers who may come into contact with wastewater or fecal sludge, this may include goggles and face mask or face shield to protect eyes, nose, and mouth from splashes of human waste, liquid-repellant coveralls to keep human waste off clothing, and waterproof gloves and boots to prevent exposure to human waste (CDC, 2021). See *also Sequence for donning and doffing personal protective equipment (PPE)*, Appendix A.4.

Public health surveillance: continuous, systematic collection, analysis, and interpretation of health-related data needed for the planning, implementation, and evaluation of public health practice (Thacker & Birkhead, 2008). In this paper, 'other public health surveillance systems/data' is inclusive of case-based surveillance, syndromic surveillance, serosurveillance, and any other form of public health surveillance system/data outside WES.

Wastewater surveillance: systematic sample collection, processing, and analysis of untreated wastewater from a sewered sanitation system, followed by interpretation of the wastewater data to inform public health practice; also known as wastewater-based surveillance, wastewater-based epidemiology, and wastewater disease surveillance.

Executive Summary

Communities of practice (CoPs) played a vital role in connecting wastewater surveillance practitioners in the United States during the COVID-19 pandemic, fostering equitable access to critical information and resources as they rapidly established surveillance programs and innovated in real time. Well-structured CoPs in low- and middle-income countries (LMICs) could provide similar support for practitioners within local and regional governments, institutions, non-governmental organizations (NGOs), and private entities wishing to initiate and sustain wastewater and environmental surveillance (WES) programs. WES aims to provide information on the contributing population's health and involves the systematic sampling from wastewater, environmental, and non-sewered sources, processing and analyzing the samples for the presence or quantity of specific targets and interpreting the data to inform public health practice. This Communities of Practice for Wastewater and Environment Surveillance in Low-Resource Settings: Approaches for Implementation document (CoP Document) will serve as a resource for those considering or initiating a CoP for WES, particularly in LMICs. It will help prospective WES CoP facilitators and funders to better understand:

- *The purpose of CoPs and how they might benefit WES practitioners* – A CoP is "a group of people who share a concern or a passion for something they do and learn how to do it better as they interact regularly," (Wenger-Trayner & Wenger-Trayner, 2015). All CoPs share three primary characteristics: a domain of interest, a related community, and a common practice. WES CoPs can support practitioners in sharing best practices and navigating challenges.
- *The general steps required to set up a WES program* – A WES program consists of sample collection, sample processing and analysis, data interpretation and sharing, and data application and use. Fulfilling these program components requires careful planning and execution by a multidisciplinary team. Although this CoP Document does not go into the details of how to set up a WES program, it does walk through the general steps needed in many contexts.
- *Options for WES CoP structure and organization* – There are several options for structuring CoP leadership and the CoP itself. The leadership group provides strategic direction for the CoP, and its members should be selected to represent the various parties involved. This equitable representation gives a voice to groups who may not typically be heard. A foundational step in establishing a successful CoP is defining its mission and goals, which shape many aspects of the CoP

including the participant recruitment strategy, meeting format, and other planned interactions.

- *CoP operations, including communication, meeting structure, and technology usage* – This CoP Document lays out the key steps for determining how a CoP will operate, including identifying the preferred meeting and/or discussion platform, meeting structure and cadence, securing funding, and outlining recruitment strategies.
- *How to implement and sustain a CoP* – Although an organization, individual, or small group may be responsible for initiating the WES CoP, the CoP should not be fully developed by the initiating entity. A CoP should be designed to grow based on continual experimentation and adaptive management, seeking feedback and open communication from members. Such agility enables CoPs to adapt quickly in the rapidly changing WES landscape. This CoP Document also provides contextual knowledge, possible topics to address as a CoP, and resources to support the CoP in its startup phase.

1. Overview

1.1 Purpose of this CoP Document

Communities of practice (CoPs), as defined in section 1.3, have served an important role connecting wastewater surveillance practitioners in the United States with each other and with the resources they need. Well-structured CoPs in low- and middle-income countries (LMICs) could provide similar support for practitioners within local and regional governments, institutions, non-governmental organizations (NGOs), and private entities wishing to initiate and sustain wastewater and environmental surveillance (WES) programs. WES, as described in sections 1.2 and 1.4, aims to provide information on the contributing population's health and involves the systematic sampling from wastewater, environmental, and non-sewered sources, processing and analyzing the samples for the presence or quantity of specific targets, and interpreting the data to inform public health practice. This *Communities of Practice for Wastewater and Environment Surveillance in Low-Resource Settings: Approaches for Implementation* document (CoP Document) will serve as a resource for those considering or initiating a CoP for WES, particularly in LMICs. It will help prospective WES CoP facilitators to better understand:

- the purpose of CoPs and how they might benefit WES practitioners;
- options for WES CoP structure and organization;
- CoP communication and meeting structure; and
- how to implement and sustain a CoP.

1.2 Wastewater and Environmental Surveillance

Wastewater and environmental surveillance offers an efficient, cost-effective public health surveillance strategy to track pathogens, pharmaceuticals, illicit drugs, antibiotic resistance genes (ARGs), and other health markers in untreated wastewater, fecal sludge, and fecally-impacted surface waters (Kirby et al., 2021; Pocock et al., 2020). Unlike other public health surveillance systems, the data collected by WES programs are independent of healthcare-seeking behavior and symptoms, and a single sample may represent tens to hundreds to thousands of individuals. These characteristics make WES a valuable complement to other public health surveillance data or public health decision-makers. The origins of WES date back to the first half of the 20th century, with the detection of *Salmonella* Typhi (Wilson, 1928) and poliovirus (Trask & Paul, 1942) in wastewater. Since the 1980s, WES

has been implemented to systematically detect poliovirus as part of polio eradication efforts (Pöyry et al., 1988; Manor et al., 2014; WHO, 2023b). The use of WES increased dramatically with the COVID-19 global pandemic when it was determined that SARS-CoV-2 genetic material could be detected in wastewater (Medema et al., 2020).

As with any public health surveillance program, the goal of WES is to inform and evaluate public health action, and not to collect data for the sake of data collection. Data collection that does not result in public health action takes vital, finite resources away from other critical prevention or response efforts. These public health actions can include public health communication, vaccination campaigns, mask mandates, or other measures appropriate for the pathogen or disease of interest. WES allows rapid detection and response to emerging infectious disease, making it a useful pandemic prevention tool. As the threat of antimicrobial resistance (AR) continues to grow, WES provides a tool for detecting ARGs and their spread (Hendriksen et al., 2019; Chau et al., 2022). WES enables the efficient collection of a large volume of data that would often not be feasible to gather clinically. This is critical in low-resource settings, where financial resources and clinical capacity are limited.

Since early 2020, the WES field has grown at a rapid pace, both in terms of advancements in the science and the number of active WES programs globally. This rapid growth poses challenges to WES practitioners who may not have access to current research and resources. Of the more than 4,600 WES sites documented globally as of December 2023, approximately 300 are located in LMICs (Naughton, 2021). This equates to fewer than 7% of the global WES sites being located in LMICs, despite these being home to more than 80% of the global population. In addition, most established WES programs are wastewater-focused (i.e., collect samples from centralized wastewater treatment plants, or from pumping stations or manholes within conventional sewer networks); relatively little WES research has been conducted in non-sewered settings in LMICs, resulting in a knowledge gap related to WES sampling and analysis in non-sewered settings. The decentralized and non-sewered sanitation systems prevalent in most LMICs increase the complexity of WES in terms of sample location selection, sample collection methods, and sample analysis. Many LMICs face barriers to initiating and sustaining WES programs, including gaps in knowledge and training related to WES, and limited financial resources and laboratory capacity. This is where communities of practice can come into play.

1.3 Communities of Practice

A community of practice (CoP) is "a group of people who share a concern or a passion for something they do and learn how to do it better as they interact regularly," (Wenger-Trayner & Wenger-Trayner, 2015). All CoPs share three primary characteristics:

1. A domain of interest – members have a shared interest and a collective competence within that domain.
2. A related community – members communicate with each other regularly, sharing information and building relationships.
3. A common practice – members develop shared resources over time that constitute a shared practice.

With the recognition that WES practitioners in the United States needed support in this rapidly growing field, the U.S. Centers for Disease Control and Prevention (CDC) initiated CoPs in 2020 for each of the three primary practice domains of the National Wastewater Surveillance System (NWSS), as shown in Table 1.

Table 1: NWSS primary practice domains

NWSS CoP	Members	Host	Primary means of communication
Health Departments	Epidemiologists and public health professionals from state, tribal, local, and territorial health departments	CDC	Monthly all-CoP virtual meetings, monthly virtual meetings with smaller cohorts, an online portal for resource sharing (including past presentations and a personnel directory) and peer-to-peer communication
Laboratories	Microbiologists, molecular biologists, and other laboratory specialists from public health and some academic laboratories	Association of Public Health Laboratories (APHL)	Monthly virtual meetings, peer-to-peer online communication portal
Utilities	Wastewater utility professionals	Water Environment Federation (WEF)	Monthly virtual meetings, annual in-person meetings, an online portal for resource sharing and peer-to-peer communication

Through monthly virtual meetings, online portals that facilitate peer-to-peer communication and resource sharing, and in-person and virtual events, these CoPs have helped practitioners efficiently share best practices and ideas for overcoming challenges.

In addition to the NWSS CoPs, there are other groups that support WES around the globe, including:

- the Wastewater-based Epidemiological Surveillance cluster run by the International Water Association
- the South African Collaborative COVID-19 Environmental Surveillance System (SACCESS) network in South Africa (Bust et al., 2022)
- the EU-WISH consortium in the European Union (EU) with high-level representatives from the major country and regional WES programs in the EU that interact via regular virtual meetings
- state-specific CoPs in the U.S. (such as in Arizona, California, and Colorado) with members from all relevant practice domains (wastewater utilities, health departments, and laboratories) within a specific geographic area that interact via virtual and/or in-person meetings
- the CDC-funded NWSS Centers of Excellence in the U.S. that serve as leaders in wastewater surveillance implementation and coordination (WEF, 2024)

As of March 2024, there are no CoPs specifically geared toward supporting WES practitioners in LMICs.

1.4 Setting up a WES program

Although this CoP Document aims to support the development of WES CoPs and will not go into the details of how to set up a WES program, the following describes the general steps required. As shown in Figure 1, a WES program consists of sample collection, sample processing and analysis, data interpretation and sharing, and data application and use. Fulfilling these program components requires careful planning and execution by a multidisciplinary team. These steps are relevant to many contexts, but some steps might only be applicable in certain situations, and additional steps may be required.

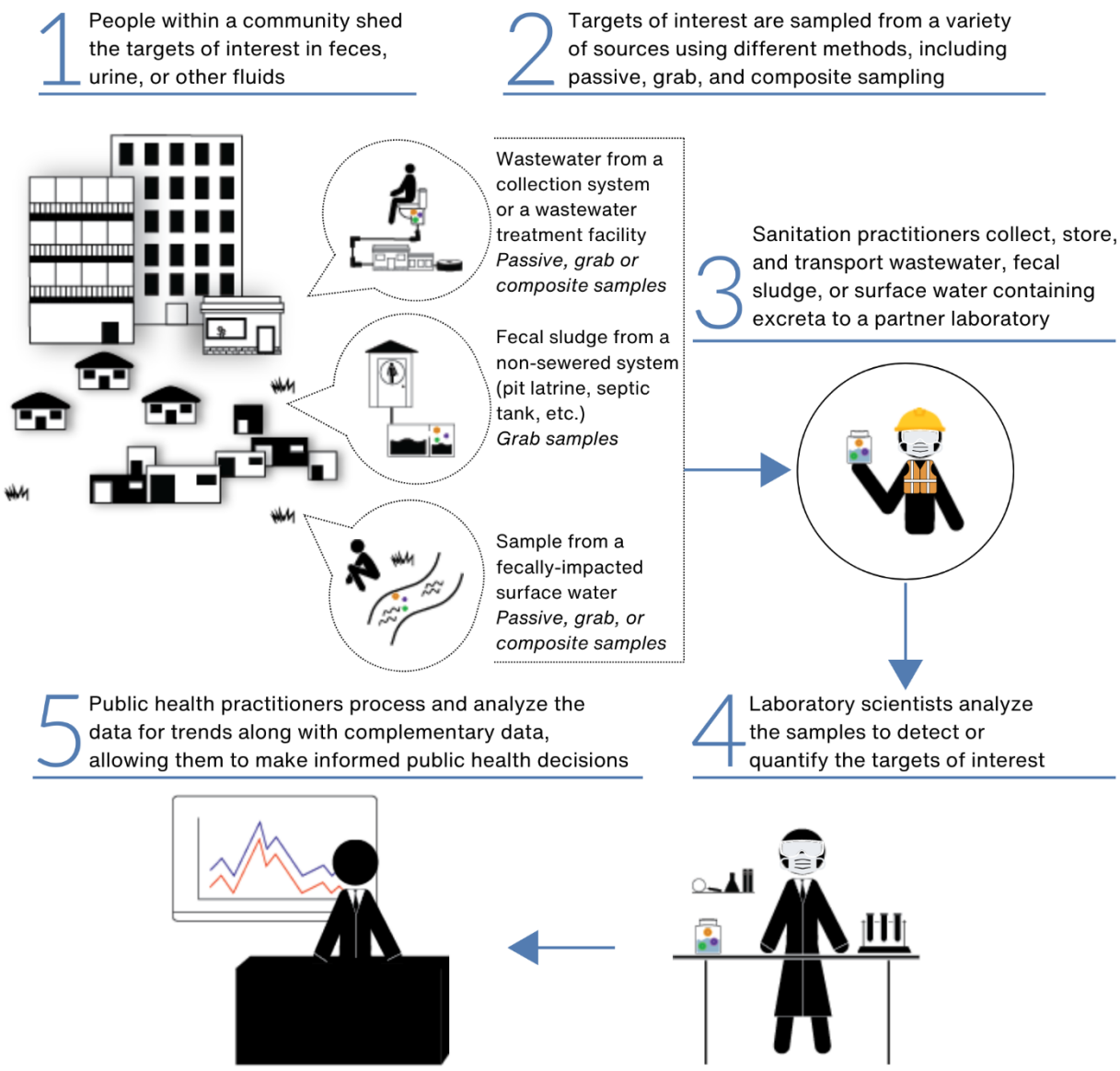

Figure 1: Overview of the WES process

As a prerequisite for initiating a WES program, the local sanitation systems and the laboratory capacity for processing and testing samples should be assessed. It is important to note that most of the laboratories already doing WES in LMICs will likely be polio-specific or polio-adjacent laboratories. Whether a country has an existing WES program or is considering initiating one, it is important for WES practitioners and country-level ministries to understand how their local sanitation systems impact WES sampling strategies and data interpretation. For example, a country with predominantly sewered sanitation, particularly in urban areas, will want to focus on collecting samples from the sewer network or from wastewater treatment plants.

Alternatively, non-sewered settings may place a higher priority on environmental surveillance within their WES program. Laboratory capacity should also be assessed prior to initiating a WES program because if there is no way to test samples within a timeframe appropriate for the target of interest, then the WES program should not move forward until testing capacity is available. See Box 1 for tools that may support the initiation of a WES program.

1.4.1 Identification of the multidisciplinary team and definition of team member roles

A functioning WES program requires representatives from three primary practice domains:

1. **Sanitation practitioners** are typically responsible for collecting, storing, and transporting samples of wastewater, fecal sludge, or surface water that contains human feces. They often also support identification of sample collection sites. The sampling team may include wastewater treatment plant operators, field technicians, environmental engineers, environmental scientists, or other representatives of a wastewater utility or organization involved in fecal sludge management.
2. **Laboratory scientists** (including bioinformaticians) analyze the samples to identify and/or quantify trends/levels of specific targets. They should be trained in environmental microbiology and use appropriate equipment, validated analytical methods, and quality assurance controls to ensure data reliability.
3. **Public health practitioners** may include biostatisticians, epidemiologists, public health generalists, healthcare providers, and administrators from local

Box 1: WES program initiation tools

Sanitation Landscape Data Tool

A Sanitation Landscape Data Tool, developed by WEF, can assist in the synthesis of country-level data from the WHO/UNICEF Joint Monitoring Programme for Water Supply, Sanitation and Hygiene (JMP) (JMP, 2024) and, in some cases, city-level sanitation data from an Excreta Flow Diagram (SFD) (SuSanA, 2018). The tool walks users through the process of obtaining relevant data from multiple data sources. The predominant sanitation types are then summarized, which may be helpful for Ministries of Health or local health officials to consider prior to initiating WES programs. See https://globalwes.org/data-tool

Laboratory Assessment Tool

A Laboratory Assessment Tool, developed by APHL and CDC, can inform the CoP leadership group on the current capacity for WES within the laboratory network and what capacity exists for expansion. The laboratory assessment is best utilized when sent to all local, regional, and national laboratories and completed by those most familiar with the laboratory work (i.e. laboratory managers or staff). See https://globalwes.org/lab-tool

or regional health departments, ministries of health, hospitals, and other institutions who identify targets of interest, process and analyze the data, alongside complementary data, and determine whether public health action is required.

Team members for a WES program will come from many different disciplines across these practice domains. For a new WES program, individuals from the appropriate domains should be identified to fill key program roles. Representatives from NGOs, industry, and research institutions may also play a role in the WES program, particularly if there is a lack of capacity within one of the three primary practice domains. Some specific program roles might include those shown in Table 2.

Table 2: Some typical roles for WES multidisciplinary team members

WES program role	Typical expertise of person in role	Responsibilities
Program manager	Experienced project manager from any discipline familiar with WES	Coordinate regular meetings; monitor compliance with plans and protocols; and oversee program execution
Sampling lead	Sanitation practitioner familiar with the required sampling techniques and locations	Identify sampling location(s) and sample collection team; ensure samples are collected according to a pre-defined frequency
Analytical testing lead	Microbiologist, molecular biologist, or other laboratory specialist familiar with the required analytical methods	Perform laboratory testing and/or identify sample analysis team; ensure sample testing conforms with protocol
Data lead	Biostatistician, epidemiologist, or public health generalist familiar with data analysis approaches	Perform ongoing data analytics and/or identify data analytics team; ensure data are shared in a timely manner
Public health lead	Public health practitioner	Ensure data are used for public health action

The roles and responsibilities of each position should be documented by the program team and periodically reviewed to ensure they are still serving the program. Memoranda of understanding may be useful for interorganizational cooperation so that all partners understand their responsibilities.

1.4.2 Identification of public health data needs and establishment of public health action protocols

Once the WES program team is convened, a typical next step is to define the goals of the WES program and the public health action(s) that will be prompted by surveillance data. This may include:

- identifying the target(s) of interest (e.g. pathogens, ARGs) for which the WES program will be testing;
- identifying the purpose of the testing, such as detecting the presence of targets in a community or monitoring trends of those targets;
- identifying the public health actions that can be taken in response to positive detections, increasing trends, or decreasing trends;
- documenting the planned public health actions or criteria for determining public health actions.

1.4.3 Development of a sampling plan

There are many approaches to sample collection, which can vary greatly depending on the circumstances. A sampling plan is typically used to document where to sample, how often to sample, what to sample, how to sample, and how to safely collect, store, and transport samples (CDC, 2023).

Where to sample: A sampling site may be selected to cover a certain portion of the population, provide data on high-risk communities, or provide data for communities where clinical testing is unavailable or underutilized. It is critical to define the population represented by each sample:

- Wastewater surveillance: Defining the sewer catchment area upstream of the sampling point requires knowledge of the sewer network and sewer connections. Sewer maps can aid in defining sewer catchment areas, delineating which houses, institutions, or other buildings may feed into the sewer upstream of the collection point.
- Environmental surveillance: Defining the population represented by a surface water sample requires topographical information for the area. Non-sewered settings located within the drainage basin of the sampling point are likely to contribute to the environmental surveillance sample.

Other considerations include the accessibility, safety, and security of the location.

How often to sample: An appropriate sampling frequency should be selected for each target of interest. For example, a testing program for SARS-CoV-2 might

choose to take samples two to three days per week to identify trends in the data more quickly and accurately, whereas a polio surveillance program might rely on monthly testing to detect the presence or absence of poliovirus.

How to sample: As described in Table 3, the three main types of samples are passive samples, grab samples, and composite samples.

Table 3: WES sample collection methods

Sample collection method	Description	Pros	Cons
Passive sample	- Collected by deploying a device into the wastewater or surface water of interest for a specific amount of time (Schang et al., 2021) - The sampler contains adsorbent material, such as cotton gauze, an electronegative membrane, or other material that interacts with the sample, which can be contained in a housing or tied directly to a string - The sample in the adsorbent material is processed after the passive sampler is removed from the environment	- Inexpensive - Low-theft value - Minimal maintenance requirements - Does not require electricity - Less labor-intensive with no specialized skills required	- Results difficult to quantify, due to unknown volume flowing through sampler, though quantification may be estimated with normalization to a fecal indicator, as discussed in Table 4 below. - The string anchoring the passive sampler can break, and the sampler can be lost
Grab sample	- A specific volume of wastewater, surface water, or sludge is collected at a single point in time - Samples represent a single moment in time	- Can be collected rapidly using simple equipment - Inexpensive - Does not require a power source - Results are quantifiable	- Highly influenced by fluctuations in flow and composition - Likely to be less representative than composite samples, particularly when deployed in smaller systems
Composite sample	- Collected by pooling multiple grab samples at a specified frequency over a set time period (CDC, 2023a) - Often facilitated by an automatic sampler - Samples can be time proportional (i.e. sub-samples are collected at equal time intervals during the	- Results are quantifiable - Samples are considered more representative of community fecal	- Equipment is expensive - Requires a power source (electricity or battery) - Equipment footprint can be large - Equipment may be susceptible to theft

	sample period) or flow proportional (i.e. sub-samples are collected at equal flow intervals, regardless of the time between sub-samples during the sample period). Flow proportional samples require a flow meter.	contributions than single grab samples (see above) - Sampling is usually automated	- Equipment maintenance can be challenging and expensive; parts and service may be hard to acquire in some locations

What to sample:

- *Liquid wastewater* collected from within a sewer collection system or at the influent of a treatment plant.
- *Sludge*, such as primary sludge from a treatment plant or fecal sludge from a communal pit latrine, septic tank, or other containment chamber within a non-sewered system.
- *Liquid samples* from fecally-impacted surface waters, including open drains or rivers.

How to collect, store, and transport samples:

Samples should be collected, stored, and transported in a manner that protects workers and prevents sample degradation. Those collecting samples should follow occupational safety practices (CDC, 2024b) that may include engineering and administrative controls, handwashing, specific safe work practices, and the use of personal protective equipment (PPE) normally required when handling untreated wastewater and fecal sludge. For composite and grab samples, the volumes collected should allow for at least two replicates of sample to be processed, allowing for a back-up sample, an archived sample, or a replicate if needed (APHL, 2022b). Any required metadata, such as date and time of collection, location, and sample type, should be recorded when the sample is taken (CDC, 2023b; NOAA, n.d.). Metadata for environmental and non-sewered samples will vary from wastewater samples. See Box 2 for selected metadata that may be required for different types of samples.

If refrigeration of samples is required for the target(s) of interest, samples should be refrigerated as soon as possible during the collection process at temperatures no higher than 4 °C (39 °F) and then transported to the testing location as quickly as possible (same day or next-day) with cold packs. Many US jurisdictions designate wastewater samples as "UN3373, Biological substances, Category B" for shipment. Category B substances are infectious substances, including those transported for diagnostic or investigational purposes (such as for wastewater surveillance), that are "not in a form generally capable of causing permanent disability or life-threatening or fatal disease in otherwise healthy humans or animals when exposure to it occurs" (PHMSA, 2020). APHL's Packing and Shipping Guidance for Biological Substances, Category B Specimens (APHL, 2022a) offers instructions on how to package Category B substances for shipment. If possible, samples should be processed within 24 hours of collection to prevent sample degradation and ensure data is actionable. Remaining samples should be frozen at -70°C for archiving, avoiding more than one freeze-thaw cycle if future analysis is anticipated.

Box 2: Selected metadata (not comprehensive)

All samples: *date and time of collection, sample location including GPS coordinates, sample type (composite, grab, passive), sample matrix (wastewater, primary sludge, septic tank, pit latrine, dry pit latrine, surface water body, drainageway), time between collection and arrival at laboratory, temperature of sample at collection and at arrival, institution type if sample represents a single institution or building, estimated number of people represented by the sample, general site conditions*

Wastewater samples: *flowrate, sampling frequency for composite samples, pretreatment conditions if any*

Non-sewered samples: *point on the sanitation service chain where sample was collected (i.e. containment, conveyance, treatment), time elapsed since last emptying, addition of chemicals or additives*

Environmental samples: *recent rainfall/weather data, presence of trash (rubbish, litter), general observations/conditions*

Passive samples: *time of placement and time of removal of the sampler, type of passive sampler and adsorbent material used*

1.4.4 Development of a laboratory analysis protocol

The laboratory analysis protocol, as outlined in APHL's SARS-CoV-2 Wastewater Surveillance Testing Guide for Public Health Laboratories, should specify each of the steps for processing and testing the samples and laboratory controls, the required personnel, space and equipment needs, and the health and safety protocols to be observed (APHL, 2022b). The required laboratory analysis steps may vary depending on the target of interest, the sample type, and the surveillance program goals. For example, analytical methods to test for SARS-CoV-2 in wastewater using polymerase

chain reaction (PCR) usually includes inactivation, concentration, extraction, and quantification steps, but these steps may be different for other targets of interest. For instance, if the target of interest needs to be cultured or isolated prior to molecular analysis to be interpreted, then inactivation and concentration steps would likely not occur. Several laboratory methodologies and technologies may exist to process and test samples and can be selected based on cost, supply chain availability, personnel requirements, and other factors.

Measures should be taken to ensure that the testing results are accurate and repeatable. Quality assurance (QA) control procedures, such as those described in Table 4, are critical for evaluating data quality. However, this table is not comprehensive of all controls that may need to be run to interpret molecular methods.

Table 4: Selected quality assurance controls

Controls	Description	Interpretation
Positive control	A sample of nuclease-free water that has a known quantity of the target of interest added to it. It is processed and run in parallel to the samples	If the positive control is negative for the target of interest, there has been a failure during sample processing
Negative control	A blank sample of nuclease-free water that is processed and run in parallel to the samples	If the negative control is positive for the target of interest, there is evidence of cross-contamination
Matrix spike	A known quantity of a target of interest is added to an aliquot of the wastewater, surface water, or fecal sludge (matrix) being tested.	If the matrix spike is negative for the target of interest AND the positive control is positive, this indicates that there are significant inhibitory substances in the sample. Dilutions of the matrix spike can be run to assess the level of inhibition
Human fecal normalization control	Organisms or compounds specific to human feces are measured to estimate the human fecal content in a sample	Levels of the human fecal normalization control can indicate the extent of dilution of the sample. Normalizing samples based on a human fecal indicator ensures comparability among samples taken at different times from a single sample point.

The results of the testing must be documented in a reliable data management system, which should include features such as protected online storage and access, and use of sample IDs to link all metadata and QA data with sampling data. After

testing is complete, all samples, reagents, and contaminated material must be decontaminated and/or disposed in accordance with all applicable regulations. All steps in the analytical workflow, including processing times, should be documented.

Rapid, easy-to-use testing technologies may exist for certain targets (Daigle et al., 2022; Zhu et al., 2022). If there is insufficient laboratory capacity for sample processing, particularly in remote settings or emergency contexts, the feasibility of rapid, easy-to-use testing methods could be investigated. These testing methods should be seen as secondary to building laboratory capacity, as increased laboratory capacity will contribute to the sustainability of WES programs.

1.4.5 Development of data processing and sharing protocol

The data should be processed and logged in a manner that facilitates data analyses and sharing, while maintaining acceptable data privacy. Controls should be put in place to protect the privacy of small communities and vulnerable populations, such as limiting public data sharing to populations above a certain size threshold, avoiding public data sharing for selected vulnerable populations as appropriate, and not disclosing the exact location of sampling sites. The data processing and sharing protocol should identify the individuals responsible for processing and sharing the data, as well as those individuals and groups who should receive the data and in what format. The data sharing frequency should be selected and documented for the different data user groups (e.g. internal team members, decision makers, general public).

1.4.6 Procurement of equipment and supplies

It is critical that all equipment and supplies required for sampling, testing, data processing, and data sharing are available when needed to avoid delays in sample testing. Supplies may need to be ordered many months in advance due to global procurement chain challenges. A plan for reordering consumables, considering availability, expiration dates, and shipping times, as well as other site-specific constraints, should be developed. Suppliers for all equipment and supplies and service providers for equipment maintenance and repair should be identified, noting service schedules for equipment.

1.4.7 Program initiation

Once the planning steps are complete and the sampling, testing, and data protocols are in place, the WES program can begin. It can be helpful to identify a start-up period to allow for troubleshooting, follow-up training, and streamlining of data

processing and data sharing procedures. Protocols should be reviewed on a regular basis, with procedures adjusted as necessary.

2. Considerations before creating a CoP

"A community of practice does not come about out of thin air. People are already involved in practice, with successes and struggles. There are already pockets of conversation. The point is for the community to discover itself and see a value proposition in moving ahead. This includes finding people who are willing to take leadership in starting the community." (Wenger-Trayner et al., 2023)

"There is no recipe for a successful community of practice, no single approach that will guarantee a successful outcome. In this sense, there are no correct or incorrect ways to convene a community of practice. The point is to form a sustained learning partnership that creates value for members and their organization and is responsive to their needs and aspirations; it is not to comply with a formula. Each community of practice will be unique and reflect all at once the DNA of the organization, the specificity of the domain, and the participation of its members." (Wenger-Trayner et al., 2023)

As highlighted in Section 1, WES CoPs have supported practitioners in the United States in sharing best practices and navigating challenges. Part of the success of these CoPs is likely attributed to their intentional development. To ensure a CoP is sustainable, aligned, and effective, there are several factors to consider prior to beginning.

2.1 Facilitators and Leadership Groups

One of the first considerations before developing a CoP is to identify a facilitator and establish a leadership group (e.g., advisory committee, advisory council, steering committee). The facilitator is an organization or individual responsible for the administrative aspects of the CoP, such as setting agendas and steering the discussions. The leadership group provides strategic direction for the CoP. Those that make up the leadership group should be selected to represent the parties involved in the CoP. A small group (6-7 people) may be most efficient and effective. Together, the facilitator and leadership group are responsible for setting the initial structure and guidelines for the CoP by determining the scale, goals, and operations. The CoP may benefit from a written charter, inclusive of these initial decisions (structure of the CoP, roles/responsibilities of leaders and members, guidelines, processes), which can be reviewed/updated annually.

It can be helpful to identify potential leaders who, as a group, have a deep understanding of WES and are dedicated to the CoP. Consistency is vital for any CoP, so whoever is chosen to serve in the leadership positions should have the availability

and desire needed. Responsibilities for the facilitator and leadership group should be set early so that expectations are clear.

Additionally, it is important to determine the rotation or succession of leadership to reduce the potential for burnout among current leaders and establish opportunities for new leaders to emerge and contribute to the long-term success of the CoP.

2.2 CoP Scale and Organizational Approach

Another important consideration is deciding who, in general, should make up the CoP. The leadership group will need to decide the scale, which could be local, provincial/state, national, or regional, as well as the organizational structure. These choices will depend on the needs of the CoP identified by the leadership group. Determining these participation boundaries will allow for effective mission and goal setting (discussed in 2.4). Box 3 includes information about a tool that may aid in CoP planning.

Box 3: CoP General Assessment Tool

To help the CoP facilitators and leadership groups establish a baseline of previous or current work being conducted, as well as interest from potential participants, APHL developed a CoP General Assessment. This assessment is designed to be sent to organizations, laboratories, academic institutions, or other public health stakeholders that may be interested in starting a WES CoP. This assessment can help the leadership group plan for CoP organization and recruitment. See https://globalwes.org/cop-tool

2.3 Options for CoP Organization

There are various organizational approaches for a CoP, many of which have shown success for WES CoPs in particular. Here are a few example structures that a leadership group may consider. These could be utilized individually, or multiple structures could be combined.

2.3.1 Geographic Area

One commonly chosen CoP organizational approach is geographic region, whether on the local, national, or regional scale. This approach can allow for common features including cultural considerations, language, climate, regulations, and target priorities. A local area CoP would likely have more commonalities between participants, while a larger scale regional CoP that may include various countries would have more variation in features but would also allow for more perspectives.

2.3.2 Practice Domain

Another option for CoP organization is practice domain. Separate CoPs may be set up for laboratories, utilities/water and sanitation service providers, ministries of health/health departments and/or industries involved in WES. This approach allows each group to share knowledge around unique experiences, initiatives, challenges, and solutions with others in their specific field of work. As outlined in section 1.3, this is how the NWSS CoPs are organized (with three CoPs: health departments, laboratories, utilities). Other types of contributors, such as academics and NGOs, may also benefit from a CoP, which could foster interdisciplinary discussions, promote research partnerships, and increase the practical application of surveillance findings.

Decisions around participant selection should be tailored to the CoP's mission and goals. Organizations and individuals should be recruited in a targeted way since CoPs function optimally when they operate with a focused approach. It may be beneficial to incorporate cross-CoP collaboration and interactions at a regular interval to foster new ideas and gain new perspectives across practice domains. However, an individual CoP may not benefit from accepting every interested party because it may lead to inefficiency, decreased engagement, resource strain, and goal misalignment. It is important to be sensitive to the fact that interest parties might reach out to join and not fit the criteria for participant selection. There are various ways to approach this scenario in hopes of avoiding any ill-will with individuals. The leadership group could create an application process for interested members. Alternatively, very clear recruitment restrictions could be decided upon upfront and adhered to as interested parties reach out. The restrictions can be shared with those interested to explain why they may not participate. If desired, the leadership group could identify small ways that those that are interested but outside of the scope of participant requirements could be involved. This could include having specific CoP meetings open to everyone or having email updates that can be shared widely.

2.3.3 Implementation Experience

A CoP could be structured based on participants' WES implementation experience and their need or interest in developing additional capabilities. This could either be for the CoP in its entirety or as a sub-group within a CoP preliminarily organized in a different way. These categorizations could include no experience implementing WES and no WES systems in place, foundational or early stages of implementation, and well-established surveillance programs (which can, if appropriate, be further divided). The CoP General Assessment may help guide these experience

determinations. This organizational approach allows for discussions and resource sharing around progress and challenges tailored to the specific stage of implementation. For example, it may be helpful for a regional CoP to exist between countries that are at similar stages of WES as these countries may be facing the same challenges.

Alternatively, if the goal of the CoP is to provide mentorship from well-established WES programs to programs in the early stages of development and therefore includes participants from every stage of implementation, it is important that all members are valued and engaged as learning can occur in both directions.

2.3.4 Topic Area/Preliminary Target(s)

A WES CoP could also be organized around a topic area or target(s) such as certain pathogens, emerging contaminants, or monitoring methods. The shared focus and interest may foster innovation and support participants in honing expertise in specific fields of WES. The decision of topic or target(s) should consider the scale and size of the CoP to not limit the group, while also being manageable. A one-pathogen focus could limit a national-level CoP, but if the focus is on too many pathogens, it could become unmanageable, and participants could become disengaged. Due to funding limitations, a CoP may begin with a focus on one target, as has been the case with SARS-CoV-2 during the 2020 pandemic. However, as surveillance expands to multiple targets, the CoP leadership group can consider growing the CoP focus to reflect the same.

This is not a comprehensive list of organizational structures. Primary sanitation type and primary language, among others, could be considered as well. The CoP leadership group's CoP organization choice is a critical decision and must align well with the development of the CoP's mission and goals.

2.4 Determine Mission and Goals

A foundational step in establishing a successful CoP is defining its mission and goals, which shape many aspects of the CoP including the participant recruitment strategy, meeting format, and other planned interactions.

2.4.1 Mission Statement

A mission statement briefly describes the purpose of an organization. It is important for a CoP to have a mission statement so that the overall aim and values of the group are clear to the facilitators, leaders, and members. An example CoP mission statement is as follows:

"The mission of this CoP is to advance judicious use of wastewater and environmental surveillance as a complementary surveillance tool by fostering collaborative research and knowledge exchange among experts in the field, with the aim of enhancing public health through the targeted monitoring of specific pathogens and application of innovative surveillance methods, thereby contributing to a safer and more sustainable community."

2.4.2 Goals

Along with a mission statement, goals should be established for the CoP that are specific, measurable, achievable, relevant, and time-bound (SMART). The criteria for SMART goals (PM4NGOs, 2020) are as follows:

- Specific – Indicators must be specific and focus on the change that is expected at each level. What or who is changing?
- Measurable – The indicator must be quantifiable and measurable. Can the indicator be assessed objectively and independently?
    - quantity – the expected numerical representation of what is to be achieved
    - quality – the narrative of pictorial description of the expected achievements
    - location – the geographic boundary of the expected achievements
- Achievable – Indicators must be attainable within the constraints of the project triangle (budget/resources, time/budget, and scope/quality).
- Relevant – Indicators must accurately measure the change the project aspires to generate. Does the indicator practically and cost-effectively measure the outputs, outcomes, and/or goal?
- Time-bound – The indicator should identify a specific time and date. By when will the indicator be achieved? Can the indicator be achieved within the established timeframe?

This type of goal-making will support the CoP in maintaining momentum by providing participants with achievable milestones, thus encouraging on-going engagement and enthusiasm. For a WES CoP, goals will likely focus on how the CoP can best serve participants and foster the community, considering the COP's experience with and capacity for WES. For example, a goal could be to host a series of 6 webinars within the first year of the CoP focused on different aspects of WES such as protocol development, data management, and data use.

2.5 CoP Operations

After establishing the mission and goals of the CoP, the next step is to determine how the CoP will operate. This includes identifying the preferred meeting and/or discussion platform, as applicable, securing funding, and outlining recruitment strategies.

2.5.1 Determine the Platform

Selecting the appropriate platform(s) for hosting CoP interactions can influence the accessibility, interactivity, and effectiveness of the community. When choosing the platform(s), consider the goals of the CoP which may include facilitating discussions, hosting webinars, and/or sharing documents among participants. As the various platforms specialize in different functionalities, it is crucial to consider the platform's accessibility to all participants including but not limited to internet access, data security, and language capabilities. Platforms including discussion boards, chat ability, and video conferencing functions allow for interactivity between participants of the CoP. User-friendly platforms prevent a steep learning curve allowing members to interact effectively. Additionally, some platforms may include subscription fees or maintenance fees that should be considered during platform selection.

Summarized list of what to look for when choosing a platform:

- file storage, organization, and sharing
- ability to hold and record meetings (including meeting attendance capacity and call length restrictions, if applicable)
- usage capacity with limited internet bandwidth
- real-time translation features
- how widely it is used, which impacts how familiar people are with it and how easy it is to use
- mobile usage capability
- upfront cost and continuous fees

2.5.2 Funding and Sustainability

Funding needs for a CoP may vary depending on the staffing hours, platform(s) used, and plans for in-person meetings. Funds for facilitators and leaders' person-time to plan, organize, and run the CoP should be considered. Hours of work expected may be around 5-15/week for facilitators and 1-4/month for leaders, depending on CoP operations. As discussed previously, platforms for CoP member

interactions can vary in cost. If using a paid platform, consider a multiyear subscription that may reduce the overall cost. In person meetings can foster engagement, but are costly, so the facilitators and leadership group should think about how existing meetings (e.g., conferences, trainings) and trips can be utilized for in-person CoP interactions. It is helpful to create a budget outlining the anticipated costs and think through contingency plans for unexpected expenses or funding cuts.

When determining a funding source, it is advantageous to consider how the CoP will operate in the long term and the feasibility of sustained funding. CoP funding could come from organizational budgets, grants or sponsorship, or other participating organizations. It may be beneficial to diversify the funding streams to prevent vulnerability and reliance on a single funding source. By carefully considering funding and sustainability during the development of a CoP, a framework can be developed to support its long-term growth and success.

2.5.3 Recruitment

Two key steps in recruitment are to set parameters for attendees and to establish a clear recruitment process. Defining the CoP membership helps to foster a close-knit community and allows participants to feel comfortable sharing their work.

Define the criteria, such as qualifications, interests, or affiliations, in a manner that aligns with the goals of the CoP and ensures commonalities among participants. It is important to balance the desire for specific qualifications with an openness to diverse perspectives and backgrounds, encouraging potential members to explain how their experiences can benefit the CoP.

During the recruitment process, it is beneficial to communicate the CoP's mission and goals so that potential members and participants have a clear understanding of what the CoP aims to achieve, how they can contribute to the goals, and what they could gain from the CoP. Expectations for engagement and participation should also be communicated clearly so that potential members understand the level of commitment required, such as attending meetings, contributing to discussions, sharing knowledge, or other expectations that contribute to the CoP's mission. It can also be helpful to outline the benefits of the CoP membership and explain how participants can gain knowledge and understanding from their involvement through access to valuable resources, networking opportunities or other CoP benefits.

3.Implementation of a CoP

"The essential ingredient of a community's success is the active participation of members, who find value in the activities of the community. Their community is a place to "talk shop" and learn from each other's experience. They contribute to and benefit from its collective learning because it helps them address real challenges they face in their day-to-day lives." (Wenger-Trayner et al., 2023)

As discussed in Section 2, a CoP will need to be initiated and led by a facilitator and leadership group. But it also should be designed to grow based on continual experimentation with what does and does not work for the group's members. The following information will help CoP facilitators and leadership groups foster active participation and grow a CoP that members find valuable.

3.1 Contextual knowledge needed to support a WES CoP

3.1.1 Wastewater and environmental surveillance landscape

Understanding the WES landscape in the CoP region will help the CoP leadership group to better support members. The CoP leadership group may find the following questions helpful to better understand how WES has been implemented in the region.

- Where have WES programs been implemented? If unsure, begin by checking these resources:
    - Wastewater SPHERE (Global Water Pathogens Project, 2024)
    - COVIDPoops19 dashboard (Naughton, 2021)
    - local academics and research institutions
    - relevant local, regional, and national governmental bodies, which may include health departments, sewerage boards, and Ministries of Health, Water, and Environment
- Which pathogen(s) or non-infectious targets have been tracked? Are there plans for expansion to other targets? What are the priority targets for WES?
- Who has been involved in the WES work? Who are the key organizations and individuals? Would a stakeholder assessment be useful for better understanding who is involved, who should be involved, and how each organization should be involved?
- For how long was the WES conducted? Is it ongoing?
- What types of sources have been sampled (wastewater, fecal sludge, surface water)?

- What types of samples were collected (grab, composite, passive) and at what frequency?
- Which laboratories have been involved in the testing?
- Who has access to the data? Is it publicly available?
- Was the WES data integrated or compared with public health data or other data? How?
- How has the data been used? What were the public health actions resulting from surveillance work?
- Is any of the work ongoing? Are there plans for expanding ongoing WES work?
- How was the WES work funded? Is the funding ongoing?
- What challenges have WES practitioners faced?

If WES has not yet been conducted in the CoP region, see section 1.4, *Setting up a WES program*, for suggestions and resources on how to get started.

3.1.2 Knowledge gaps

Methods for WES will vary across geographical regions, due to differences in sanitation systems, resources, cultural practices, and targets of interest. Because most WES research and practice has been conducted in high-income countries within predominantly sewered sanitation systems, knowledge gaps currently exist, particularly related to sampling from non-sewered systems. Identifying knowledge gaps and collaborating with local researchers and WES practitioners to address these gaps can provide valuable region-specific support to CoP members. The following are examples of knowledge gaps that may be beneficial to address within LMICs, primarily utilizing non-sewered sanitation:

- As fecal sludge is highly variable, are there certain types of fecal sludge that can or cannot be sampled? (pit latrine, composting toilet, septic tank, etc.). Which targets can be identified in the different types of fecal sludge?
- How do sample collection methods vary for different types of fecal sludge?
- How do grab samples compare to other sample types? Are there ways to make grab samples more representative?
- How do non-sewage additives (e.g. ash, husks, wash water, trash) impact samples from pit latrines and other fecal sludge storage chambers?
- When sampling from a fecal sludge storage chamber, from what depth should the sample be collected? How do you collect samples that represent

the most recent fecal contributions? How do we know if a sample is representative of multiple users as opposed to a single user? Is it possible to estimate the date when the sludge was produced?

- Does the fecal sludge storage chamber emptying interval impact the viability or other characteristics of samples?
- What are best practices for identifying the population represented by the sample, without identifying specific individuals?
- Can samples from schools, hospitals, or other institutional settings be used as a proxy for community trends, particularly in locations where non-communal, non-sewered sanitation is prevalent? Are there certain communal sanitation locations that are most representative in terms of WES sampling?
- What are additional laboratory challenges that are common in the CoP region, such as unreliable electricity and supply chains? How can these challenges be addressed?
- Are there other laboratory methodologies or emerging technologies that may be more appropriate in resource-limited settings?
- Are there ways to normalize without flow, population, or fecal marker data? How do those compare to other forms of normalization?
- Are there best practices for community sensitization to sampling? Sampling in non-sewered settings often means the sampler is much closer to the community as opposed to sampling within sewered networks, which is often at a treatment plant.

Research gaps also exist related to environmental surveillance, including the following examples:

- How do animal inputs impact WES samples from environmental sources?
- How does weather (temperature and rainfall) impact samples?
- What are best practices for placing passive samplers in unprotected flowing water bodies?
- Does the depth of the passive sampler in a stream or river impact results?

3.2 How participants benefit from the CoP

Practitioners participating in the CoP gain valuable insights from the exchange of experiences and ideas with their peers. This knowledge exchange can be facilitated through both formal presentations and informal discussions to foster a culture of

continuous learning. CoP members share what has worked and what has not worked, challenges, and best practices, contributing to the collective wisdom of the group. The CoP serves as a valuable networking platform, allowing participants to establish connections and identify others working in the same domain, thereby fostering collaboration and a sense of community. Lastly, the CoP functions as a repository for a wealth of resources, knowledge, and current research, empowering members with readily accessible information to enhance their practices and stay informed about the latest developments in WES.

3.3 Content goals

The content covered by a WES CoP should be determined by the CoP itself, based on the needs of its members. Some possible topics to consider, particularly during the startup phase of the CoP, are included in the following sections.

3.3.1 Sample collection

Sample collection strategies will likely vary by region, and sample collection best practices should be discussed. Some sample collection considerations and discussion topics may include:

- understanding when different sample types (i.e. grab, composite, passive) are most appropriate
- sampling approaches for different matrices (i.e. wastewater, fecal sludge, surface water)
- estimating the contributing population for non-sewered and environmental samples
- sample storage and transportation best practices

3.3.2 Worker safety

Worker safety is of the utmost importance for WES practitioners, who are likely to come in contact with human feces. Understanding and sharing best practices to protect workers may be a valuable function of a WES CoP. Worker safety topics may include:

- PPE usage and personal protection measures, such as handwashing and personal hygiene
- required and recommended vaccinations
- tools and equipment best practices

- exposure/incident protocol
- worker safety/security related to violence, instability, or unrest in the region

3.3.3 Target-specific information

The targets of interest will vary over time and by region, depending on what is of most interest to local government and public health officials as well as funding availability. Coordinating the testing of specific targets throughout a region may help public health practitioners gain a more complete understanding of how a pathogen of interest is spreading. Target-specific information that may be useful to discuss within the CoP includes:

- regional targets of interest
- strategizing multi-target systems
- sampling strategies for various targets, including sampling frequency
- laboratory analysis protocols and assays for various targets
- potential public health actions for various targets

3.3.4 Funding for WES

Securing sustainable funding for WES may be a challenge and will be of interest to CoP members. The CoP could help members to create a unified voice to advocate for sustainable funding within the CoP region. Additionally, members could share successful funding strategies for others to use as a framework for seeking out funds. Although funding is likely country-specific, it would be helpful for practitioners to understand how other countries have found success. Possible funding sources may include the national government, philanthropic foundations, and research institutes.

3.3.5 Ethics

Ethics, as related to WES, may vary by region and is a topic that the CoP should discuss regularly and adapt as needed. Possible ethical considerations to discuss include:

- protecting marginalized groups
- protecting community privacy
- considering taboos and cultural norms around handling and testing fecal samples that may influence acceptance of testing
- ensuring WES programs are equitably distributed country-wide
- evaluating who should be included in decision-making and how to involve

general community members (non-CoP members)

- addressing additional considerations that may arise if testing for high-risk substances, including illicit substances
- considering data ownership and who benefits if the data is monetized
- ensuring the purpose of WES is for public health benefit (WHO, 2017)

3.3.6 Inclusion of community members in WES

Many community members will be interested in the WES sampling process, the results, and the use of the data. Community interests are likely to overlap with the ethical considerations described above. Including behavioral scientists on the WES implementation team and ensuring information is available with plain language explanations is critical to ensuring that WES program information is accessible to community members. Some ways to involve community members in the WES process may include:

- community meetings
- focus groups
- informational flyers
- a public dashboard for data sharing

3.3.7 Data management, interpretation, and application

Developing protocols for managing and using large amounts of data is critical to the success of a WES program. Some data-related topics to consider including for CoP discussion:

- data management application options
- data security
- data sharing
    - what data is shared (appropriate anonymization of data)
    - who data is shared with (WES practitioners, the public)
    - how/where data is shared
- how to integrate wastewater and environmental data with clinical, public health and other data sources
- recommendations for initiating public health actions, based on the analyzed data

- interpreting clinical and WES data for public health action

3.4 Feedback and adaptive management of the CoP

Although an organization, individual, or small group may be responsible for initiating the WES CoP, the CoP should not be fully developed by the initiating entity. A CoP is inherently iterative, as the group determines how the CoP can better serve its needs and makes changes accordingly. A transparent CoP leadership structure, which is shaped by the CoP members and representative of the different interests within the group, will help members to take ownership of the CoP and feel comfortable providing constructive feedback. Regular, open communication between the CoP leadership group and members is critical, and as new knowledge is gained, the CoP must be flexible enough to adapt to the new information. There should be several ways for members to provide feedback, which may include:

- polls during meetings or using an online platform to vote on CoP meeting and resource topic preferences
- surveys at the end of meetings or via an online platform about the usefulness of the meeting, topic, presenter(s), etc.
- online suggestion box to which feedback can be submitted at any time
- a CoP-specific email address that is monitored by CoP leadership
- designated times during meetings for open feedback and discussion
- structured discussions with CoP leadership about what is working and what is not

Through open, regular communication among CoP members and between members and leaders, the CoP will remain relevant and helpful to its members.

3.5 Role of academic organizations

As discussed above, most WES research has been conducted in high-income countries with sewered sanitation systems and knowledge gaps remain. Partnering with academic organizations may provide the CoP with opportunities to influence the research agenda, ensuring that research is relevant to WES practice in the CoP region. Ways to include academic organizations in the CoP may include:

- having representatives from academic organizations in the CoP leadership
- inviting academic organizations to present to the CoP, providing an opportunity for both researchers and CoP members to ask questions of each other

- sharing information with the CoP about relevant published literature, conferences, or other events
- collectively prioritizing which research gaps should be addressed most urgently and presenting these prioritized gaps to academic organizations

Fostering connections between the CoP and academic organizations may help the CoP to guide the WES research agenda and grow the knowledge base within its region.

3.6 Technology usage

Use of communication technology, both synchronous and asynchronous, may be necessary to facilitate communication among CoP members who are geographically dispersed. CoP leadership may develop criteria to use when selecting technology tools for the group. Such criteria may include:

- free and accessible to members to minimize barriers for usage
- capable of expanding to accommodate the ultimate expected CoP size
- secure, or is regularly updated to incorporate security features
- includes the features the CoP thinks will be useful to facilitate communication (e.g. message boards, polls)

Having multiple communication options is important for facilitating participation of members with different needs. These technologies should be considered helpful tools, but if members are not actively engaged or do not value membership, it is unlikely that that these technologies will build a community.

3.6.1 Asynchronous communication

There are many tools available to facilitate asynchronous communication among CoP members, including email lists, message boards, phone-based messaging groups, and social media groups. Websites and services may be designed to provide a customized online "home" for the CoP. Asynchronous communication may better accommodate members who live in different time zones or who have commitments that prevent them from attending meetings, either in-person or online. Some members may feel more comfortable contributing to asynchronous conversations via written text than speaking in front of a group.

3.6.2 Synchronous communication

Online teleconferencing and videoconferencing are used widely across the globe, thanks in part to the COVID-19 global pandemic. CoP members will likely be familiar

with several online meeting platforms. When considering videoconferencing, limited bandwidth availability may be a factor, so some CoP regions may prefer to limit video usage. Whether teleconferencing or videoconferencing, enabling a live chat during meetings provides another option for participation that some members may find preferable. Conferencing tools, such as polling, breakout rooms, and whiteboards, may further increase participation and facilitate quick feedback from members.

3.6.3 Hybrid communication

Although online communication may be used more frequently than in-person meetings for WES CoPs, members may choose to take advantage of regional meetings or conferences that CoP members may be attending. In-person interactions are valuable and often lead to informal discussions and brainstorming of new ideas. For these situations, a hybrid approach that accommodates both those who are attending in-person and remotely may be the best option. If holding a hybrid meeting, care should be taken to ensure that in-person and remote participants are able to participate equally and effectively.

3.7 Other implementation concerns/suggestions

Implementing a CoP that may span several countries and time zones throughout a diverse region will lead to additional challenges to be addressed by CoP leadership.

- Multiple languages/language barriers – either a common, working language should be selected for the CoP, or live translation services should be made available.
- Time zones – with CoP members spanning multiple time zones, care should be taken to find meeting times that are acceptable for all time zones represented. Asynchronous communication options will offer those in other time zones or with inflexible work hours opportunities to participate in the CoP on their own schedule.
- Varied sanitation types – with a variety of sanitation types represented within the CoP, successful sampling strategies will vary as well. Setting up specialty groups within the CoP membership and/or breakout rooms during regularly scheduled meetings may help those with similar contexts to better communicate and learn from each other.
- Multiple practice domains within the CoP – if the CoP is defined broadly as a WES CoP, practitioners from multiple practice domains will be represented. Similar to the varied sanitation types discussed above, providing opportunities

for practitioners within a single practice domain to communicate will be critical.

- Funding for the CoP – facilitating a CoP will require funding, as subscriptions, websites, and other tech tools may have a cost associated with them. Paid positions may also be required to successfully facilitate the CoP, as it is a time-consuming role. Is it realistic to ask CoP leaders to volunteer their time? Or should leadership positions be paid? How will these costs be funded?
- Terminology and jargon – because WES is inherently interdisciplinary, CoP members may find that terms that are common in one field may be unfamiliar in others. Maintaining a list of WES-specific terminology may be useful so that all members can be made aware of the jargon used by other practitioners.

3.8 Potential challenges and lessons learned

Based on experiences initiating, facilitating, and leading the NWSS CoPs in the US, the following challenges and "lessons learned" may be helpful to those starting WES CoPs:

- Lack of engagement from CoP members – this can be addressed by offering multiple communication channels, and consistent messaging and opportunities for interaction
- Lack of availability of leadership to meet and contribute, related to the fact that the leadership positions may be on a voluntary basis – this can be addressed by minimizing the number of leadership meetings and giving the CoP leadership opportunities outside of meetings to weigh in with their opinions (via online polls, email exchanges)
- Dilution of CoP information in a world otherwise chock full of information – this can be addressed by consistent messaging through multiple channels but with brief messages; don't be afraid to repeat information or cover topics more than once.
- Lack of clarity on how to define the boundary of CoP membership – this can be addressed by having a plan from the start about how to address this "membership creep" and erring on the side of inclusivity. If the CoP is meant to capture a particular sector (e.g., public health), should professionals from other sectors (e.g., water) be included? If the CoP is geography-based, should professionals interested in joining from outside the CoP geography be included? These questions should be answered from the start.

- Difficulty maintaining CoP materials in a cohesive, readily-accessible way – this can be addressed by choosing a technology tool, such as an online document sharing platform (e.g. One Drive or Google Docs), that makes it easy to archive (and search for) materials.
- Challenges prioritizing CoP meeting/resource topics – this can be addressed by leaning on the CoP leadership, but also requesting feedback from the CoP members, is key here.

4. Wrap-up

Wastewater and environmental surveillance facilitates the cost-effective collection of community health data, enabling public health agencies to target interventions where they are most needed. WES has the potential to improve health equity, but only if it can be successfully implemented in low-resource settings. LMICs face unique challenges when implementing WES programs, particularly in terms of constrained resources, limited laboratory capacity, unreliable supply chains, and limited research on implementation in non-sewered settings. This CoP Document is designed to help potential CoP facilitators, leaders, and funders better understand how to initiate and sustain CoPs for WES, particularly in low-resource settings.

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Appendix A - Resources

A.1 Sampling resources

Developing a Wastewater Surveillance Sampling Strategy (archived) (CDC, 2023a)

Wastewater Sampling (U.S. EPA, 2023)

A.2 Analytical resources

A Compendium of Emerging South African Testing Methodologies for Detecting of SARS-CoV 2 RNA in Wastewater Surveillance (WRC, 2020)

SARS-CoV-2 Wastewater Surveillance Testing Guide for Public Health Laboratories (APHL, 2022b)

A.3 Case studies

A Compendium of U.S. Wastewater Surveillance to Support COVID-19 Public Health Response (U.S. EPA, 2021)

COVIDPoops19 Dashboard (Naughton, 2021)

Wastewater SPHERE Network (Global Water Pathogens Project, 2024)

A.4 General resources

Environmental surveillance for non-sewered communities: a tool for disease mitigation in developing countries (Pillay et al., 2022)

Environmental surveillance for SARS-CoV-2 to complement other public health surveillance (WHO, 2023a)

Guidelines on Environmental Surveillance for Detection of Polioviruses (WHO, 2015)

The International cookbook for wastewater practitioners - Vol. 1 SARS-CoV-2 (European Commission, 2024)

National Wastewater Surveillance System (NWSS) (CDC, 2024a)

Network of Wastewater Based Epidemiology (NWBE) (WEF, 2024)

Sequence for donning and doffing personal protective equipment (PPE) (CDC, n.d.)

South African Water Research Commission COVID-19 Surveillance Programme (WRC, 2021)

Tracking SARS-CoV-2 and Its Variants in Wastewater (Diamond, 2022)

Transforming Disease Detection Through Wastewater Surveillance (Rockefeller Foundation & Mathematica, 2022)

Wastewater Surveillance for Public Health Monitoring (UN Water Conference 2023 - Side Event W17 video stream) (Ministry of Health, Republic of Türkiye, 2023)

Wastewater-based Disease Surveillance for Public Health Action (NASEM, 2023)

Wastewater Surveillance Programs for COVID-19 and Other Pathogens Led by African National Public Health Institutes (IANPHI, 2022)

A.5 Community of Practice resources

Communities of practice within and across organizations: a guidebook (Wenger-Trayner et al., 2023)

Introduction to Communities of Practice (Wenger-Trayner & Wenger-Trayner, 2015)

Appendix B - Case study

This brief case study highlights the success of the NWSS laboratory CoP, hosted by APHL.

Mission statement: The mission statement for the NWSS laboratory CoP helps to drive the community towards a common goal. The mission statement is as follows: to provide a digital platform and monthly call forum where state and local laboratory members can converse and share resources to best support their jurisdiction's current (SARS-CoV-2) and future wastewater surveillance needs.

Leadership: The NWSS laboratory CoP is led by APHL staff in collaboration with the CDC NWSS team and an advisory group. The wastewater surveillance laboratory advisory group is an experienced group that consists of the CDC NWSS laboratory team lead, 6-8 state/local laboratory CoP members, and a WEF representative. The group meets monthly for an APHL-led advisory group meeting to help plan CoP calls and discuss wastewater surveillance laboratory successes, challenges, and resource needs, as well as actions to address these items.

Platforms and logistics: APHL has used both Zoom and Microsoft Teams for the NWSS laboratory CoP monthly calls. Both platforms allow for screen sharing, polling, type-chatting, and many attendees. The Higher Logic APHL "CoLABorate" platform (figure B1) provides CoP members with a virtual location to pose questions to colleagues and discuss best practices through an email discussion forum. APHL also posts agendas, minutes, presentations, recordings, and other resources here for members to access.

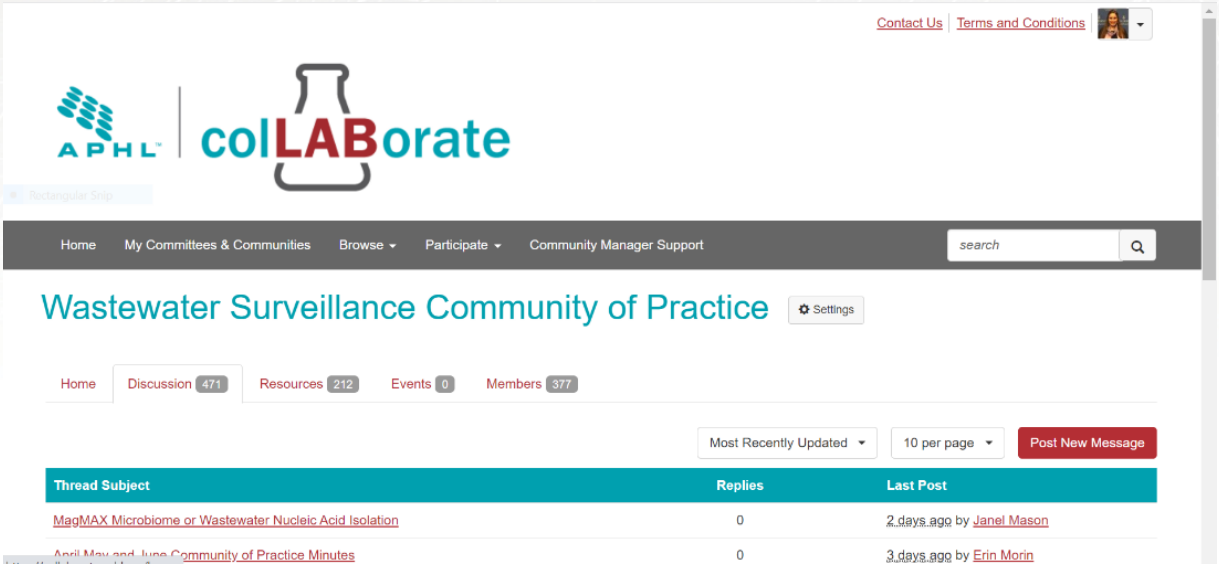

Figure B1: the home page of APHL's higher logic "ColLABorate" platform

Agendas are provided to the CoP in advance of the call either through ColLABorate or email. They outline call topics and times allotted for presentations as well as speakers and their credentials. The facilitator always leaves ample time for questions and discussion at the end of the call. If the community has a habit of being quiet on calls, APHL's facilitator might add questions to the agenda or email members in advance to ask them to share their experience on a relevant topic to help foster discussion. APHL sends out a bi-yearly wastewater surveillance survey to determine the capability, capacity, and needs of members performing wastewater surveillance. The survey results are used to help address any needs through potential CoP agenda topics. The notes for the laboratory CoP are uploaded to the ColLABorate site after each call and include outlines of the presentations, links to the slide decks and presentation questions and answers. Each agenda section is hyperlinked to its starting point in the recording.

Funding Sustainability: In the United States, all CoP funding has been provided by CDC. Through NWSS, CDC has developed a new national surveillance system for infectious diseases that is intended to provide additional information to complement other public health surveillance systems. NWSS has been written into the National Biodefense Strategy and is viewed as a long-term investment to enable better national preparedness and response to infectious disease threats.

Recruitment: APHL limits the NWSS laboratory CoP to any governmental (state or local public health, environmental or agricultural) or other (university, contract) laboratory that is submitting data to the CDC's Data Collection and Integration for Public Health Event Response (DCIPHER) platform, a cloud-based platform used to

collect, share, and link outbreak data from multiple sources, via their health departments. University and contract laboratory partners must be vetted by the jurisdiction submitting NWSS data. Federal partners are also welcome to participate.

Additional Wastewater Groups: The NWSS Laboratory CoP (APHL) hosts a few technical user groups to provide informal venues where laboratory scientists can discuss testing challenges and successes. APHL leads a monthly technical user group for any CoP members to discuss specific testing issues. Calls start with an open forum and then transition to a round robin where jurisdictions provide an update, pose challenges they are facing and ask questions to the group. If any questions are unable to be answered, APHL staff work to find an answer and follow up. It may be valuable to partner with laboratory vendors to host calls specific to instrument platforms. In addition to the QIAGEN Technical User Group, other vendors are also beginning to develop user groups. APHL has partnered with QIAGEN to host small technical user groups of 4-5 jurisdictions to create a community of laboratories just starting to use QIAGEN instruments for wastewater surveillance. The QIAGEN team provided presentations on the different types of testing, a discussion forum, and troubleshooting assistance. Jurisdictions often communicate with each other outside of the calls. The small groups may consider publishing a paper at the end of their joint experience.