

# Surveillance via wastewater monitoring and nasal self-collection of specimens (The SWANSS Study): A CFIR-informed qualitative study with key carceral and healthcare stakeholders

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## Research Article

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# Abstract

## Background

Implementing public health interventions can be challenging in carceral settings. Jails are institutions with the shortest lengths of stay, resulting in frequent turnover and constantly shifting populations. Jails had particularly acute challenges during the early stages of the COVID-19 pandemic, when incarcerated persons were highly susceptible to infection and severe disease. The purpose of this study was to identify barriers and facilitators to wastewater-based surveillance (WBS) and nasal self-testing (NST) as a combined strategy of COVID-19 surveillance in Fulton County Jail (FCJ), Atlanta, Georgia. Implications for efficient and effective infectious disease testing among this susceptible population are relevant for ongoing surveillance for current endemic pathogens and future epidemics.

## Methods

We utilized a multilevel, theory-informed qualitative approach to conduct semi-structured one-on-one and small group interviews with nine distinct jail stakeholder groups: jail custody leadership, administrators, officers, maintenance workers, Georgia Department of Health's COVID-19 testing contractor, jail health care leaders, nursing staff, laboratory leadership and staff. Interview guides and analyses were informed by the Consolidated Framework for Implementation Research (CFIR). We used directed content analysis to identify domains within CFIR reflecting barriers and facilitators to WBS combined with NST in large urban jail settings.

## Results

Twelve interviews were conducted with administrative, healthcare, maintenance, custody, and laboratory personnel from July 2022 to November 2022. Seven CFIR constructs were identified as barriers, sixteen as facilitators, and one as a neutral factor for the implementation of WBS combined with NST. Jail stakeholders underscored the relative advantage for self-testing, highlighted limited resources, and expressed concerns for sustainability of WBS due to competing priorities. Many of the stakeholders within the jail setting that were interviewed had hierarchical organizational structures, which made decision-making processes regarding WBS and NST complex and challenging to implement.

## Conclusions

Given the political, structural, and organizational factors in a jail setting, innovations such as NST and WBS require a rigorous implementation strategy supported by ongoing engagement and collaboration with a multitude of stakeholders.

# Background

The United States experienced a high mortality rate in the first years of the COVID-19 pandemic [1]. Due to high risk for transmission of airborne pathogens, carceral settings require rigorous surveillance and ongoing mitigation [2–4]. Improved surveillance efforts applying new and improved diagnostic methods have aided pandemic control efforts. These advancements are of particular importance in prisons and jails, which have played an important role in the spread of SARS-CoV-2, accounting for many of the largest single-site outbreaks [3, 5].

The Fulton County Jail (FCJ) is a 2688-bed capacity facility, situated in the northwestern section of Atlanta, Georgia [6]. High rates of incarceration led to average daily populations exceeding capacity during the pandemic. FCJ's incarceration rate, which was approximately 400/100,000 adults at the start of the epidemic, was almost three times higher than comparable urban counties [7]. Social distancing protocols slowed court activities and transfers to state prisons, further exacerbating overcrowding [8]. FCJ accommodated overcrowding by housing many residents in communal areas outside of the jail's two-person cells. Residents not in cells were assigned plastic stackable bunk containers, or boats, to sleep on the floor. As a result, interventions like social distancing within cell blocks were difficult to implement. While Georgia experienced an incidence of COVID-19 that aligned with nation's average [9], the number of cases in the jail were disproportionately high.

Wastewater-based surveillance (WBS) for diseases such as COVID-19 provides an opportunity to passively monitor for infectious disease and serves as an early warning system for outbreaks within communities and congregate settings [10, 11]. WBS is advantageous given that SARS-CoV-2 can be detected in wastewater before clinical symptoms appear and for entire populations without individual testing. WBS data can also be used in tandem with clinical testing data provided by Polymerase Chain Reaction (PCR) and antigen testing; it can hasten the response to an outbreak and guide public health decision making [10]. We have previously demonstrated that WBS combined with NST is convenient and accurate, and acceptable among residents of FCJ [12–14]. The first objective of the SWANSS (Surveillance via Wastewater monitoring And Nasal Self-Collection of Specimens) study was to find a correlation between WBS and NST in a carceral setting [14]. The second objective was to understand the barriers and facilitators to implementing WBS coupled with low-cost (\$10–25 per test), high throughput individual NST for SARS-CoV-2 through stakeholder engagement at FCJ. Data from this study were used to understand if and how these approaches could be scaled and sustained in other U.S. carceral settings for COVID-19 and other emerging and important pathogens [14].

# Methods

We conducted a qualitative study to understand the perspectives of key stakeholders in the implementation of WBS in combination with NST at FCJ, applying a well-established implementation science framework. Our goal was to gain insights on experiences with COVID-19 mitigation efforts, strategies for implementing WBS coupled with NST, and recommendations for sustainability.

## Setting

From 2021 to 2022, FCJ daily populations averaged 2700 persons per day—well over capacity—98% of whom were male [15]. FCJ's main facility has 78 housing units of about 30–40 two-man cells each. In 2021 alone, there were over 17,000 bookings; about 92% of FCJ residents await trial [7, 16]. All women, except for those in need of medical care within the main jail's infirmary, are housed in a separate facility.

SARS-CoV-2 testing at FCJ was performed by the medical vendor contracted to provide jail medical services, and third-party partners. The jail's medical team began opt-out rapid antigen testing for COVID-19 during the intake process in 2021 [14]. Additional SARS-CoV-2 testing was provided by the Georgia Department of Health (GDPH) using an outside contracted company, which also supplemented the vaccination efforts by the medical staff.

In early 2021, Emory as a subcontractor to Ceres Nanoscience (Manassas, VA) began city-wide WBS for SARS-CoV-2. FCJ was one of the sites in the program. Later that year, with funding from the Bill & Melinda Gates Foundation, the Center for the Health of Incarcerated Persons (CHIP) at Emory University and Northwell Health (New Hyde Park, NY) began the SWANSS implementation study of self-collected nasal swab collection of specimens for PCR testing in tandem with WBS [13]. Opt-out nasal swab screening by laboratory-based PCR was conducted from October 2021–May 2022 on a weekly basis, in randomly chosen housing units, averaging 300 tests per week. Results of the project indicated the correlation between community viral load found in wastewater and percent positive test results, which supported the use of WBS as a reliable proxy measurement of prevalence within the jail population [14]. Study budget included off-duty jail personnel, who served as security escorts during testing. Dye testing was conducted to map sewage lines, which led to the ability to pinpoint the source of wastewater on a building and housing block level, confirmed by jail architectural blueprints. Northwell Health provided the laboratory services to run the PCR diagnostic tests.

## Recruitment, sampling, and data collection

We recruited key stakeholders assisting in the implementation of WBS and NST at FCJ from nine different cadres: jail custody leadership, administrators, officers, maintenance workers, GDPH's COVID-19 testing contractor, jail health care leaders, nursing staff, laboratory leadership and staff. Individuals were purposively sampled based on their involvement with the SWANSS study. Officers, for instance, had previously escorted study staff at some time during the testing period. After obtaining written informed consent, we conducted one-on-one and small-group interviews. The latter were conducted with at most three individuals to accommodate scheduling logistics and availability. All interviewees were eligible for an elective gift card for their time.

## Analysis

To provide a structured approach to understanding real-world implementation outcomes, we used the Consolidated Framework for Implementation Research (CFIR) [17] to design our interview guide and inform our thematic analysis. CFIR as a framework has proven effective in the assessment of facilitators and barriers in implementation science and prospective intervention outcomes [18, 19]. There are 5 comprehensive domains [20] with each domain consisting of 4 up to 12 constructs:

1. Intervention characteristics domain includes constructs highlighting the aspects of an intervention that may impact implementation success.
2. Outer setting domain includes constructs related to the external influences on intervention implementation.
3. Inner setting domain includes constructs depicting the characteristics of the implementing organization.
4. Characteristics of individuals domain includes constructs capturing the individuals' beliefs, knowledge, self-efficacy, and personal attributes that may affect implementation.
5. Process of implementation domain includes constructs describing the stages of implementation.

We identified 24 constructs applicable to our study, as defined in the supplemental table. Below, we will discuss 3 out of 8 constructs from the Interventions Characteristics domain, 6 out of 10 constructs from the Inner Setting domain, and 2 out of 8 constructs from the Process domain. Transcripts were read by two analysts (KM and PB) and excerpts were coded as constructs of the CFIR through a deductive, iterative process. Discrepancies were discussed at weekly study meetings and resolved by consensus. At the end of the analysis, we did not note any new emerging themes indicating we were able to successfully reach content saturation.

Once compiled, each excerpt was coded using our determinant categories as either a 'barrier', 'facilitator', or 'neutral' based on valence scoring (-2 to + 2 with 0 indicated a neutral valence) [21]. A barrier was defined as any phenomenon that had an inferred negative impact on any aspect of implementation, real or abstract; a facilitator was any phenomenon inferred to have had a positive impact. Phenomena were categorized as neutral if they were inferred to have neither a negative nor a positive impact. Divergences were discussed until consensus was reached. Analysis was performed using Dedoose analytic software.

## Results

We interviewed 12 participants from July 2022 to November 2022. There were 36 eligible individuals approached in person, email, text, or a combination of methods and 24 did not respond to outreach. Stakeholders from the jail included 2 members of the administration/custody leadership, 3 healthcare leaders/staff, 1 member of the maintenance team leadership, and 3 correctional officers, as well as 2 participants from Northwell Lab, and 1 contracted healthcare provider employee.

In the sections below, we present key CFIR domains and related constructs organized according to those that were mentioned most frequently by participants. Tables 1–3 below define the CFIR constructs within each domain, N is the total number of times excerpts from key informant interviews were coded as a

construct and includes the total number of times an interview excerpt was categorized as either a barrier, familiar, or neutral; in addition to, a representative quote from interviews. A supplemental table includes additional domains and corresponding constructs. Notably, some excerpts were shared amongst the domains, but quotes were only included once within our tables.

Table 1

Intervention Characteristics Domain: CFIR-informed barriers to and facilitators of wastewater-based surveillance and nasal self-testing in the Fulton County Jail.

Identified constructs per CFIR domain	N	Barrier	Neutral	Facilitator	Representative quotes
A. INTERVENTION CHARACTERISTICS					
1. Relative Advantage  'Individuals' shared perception of the importance of implementation within the organization.'	10	2	3	5	<p>I guess a truth of the measurements or the testing compared to what we have – whether it's the measurements are high but we have a small number of positive cases or if the measurement is low and we have a higher number of positive cases inside the facility, just kind of compare the apples to the oranges and see what it looks like.</p> <p>Facilitator to WBS and NST, FCJ Sherriff's Leadership Office</p>
2. Adaptability  'The degree to which an intervention can be adapted, tailored, refined, or reinvented to meet local needs.'	17	7	4	6	<p>We had to get very creative because our facility for the most part is max to capacity, so we did a lot of movement around trying to get our inmates – create space. We had to create space to do isolations from the other general population. Of course, with staff we had to get creative – when COVID first came, we just didn't know, the 14 days – people were out 14 days at a time. That hurt us with trying to keep normal operations going, so we really, really kind of had to dig into the trenches. For the most part we had to create space, and we just kind of improvised where we had to just to continue our day-to-day operations. So, every day may have been different for us, you know? Whatever the situation was, we had to kind of accommodate.</p> <p>Facilitator to NST, FCJ Sherriff's Office Leadership</p>



Identified constructs per CFIR domain	N	Barrier	Neutral	Facilitator	Representative quotes
3. Complexity “Perceived difficulty of the intervention, reflected by duration, scope, radicalness, disruptiveness, centrality, intricacy and number of steps required to implement.”	13	7	4	2	<p>Well, this is a bit more complicated because this is a – you know, this jail system and Emory are in another state, so they’re not here. So, we had state boundary, you know, distance issues I suppose. You know, the jail was difficult because we couldn’t do our usual process which is conduct it by Wi-Fi, it would be real time that they would scan in samples right after the person’s done collecting. Instead, they were collecting and then having to take them somewhere else to scan them in, so that created difficulty.</p> <p>Barrier to WBS, Northwell Health, Senior Project Manager</p>

Table 3

Process Domain: CFIR-informed barriers to and facilitators of wastewater-based surveillance and nasal self-testing in the Fulton County Jail.

Identified constructs per CFIR domain	N	Barrier	Neutral	Facilitator	Representative quotes
E. PROCESS					
1. Planning  “The degree to which a scheme or method of behavior or task for implementing an intervention are developed in advance and the quality of those schemes or methods.”	12	2	2	8	<p>We set up a process early on that, once we got the protocol down, I think it went fairly smoothly.</p> <p>I think certainly from our perspective, for lots of reasons, the laboratory pieces are regulated, so we had limited flexibility in making modifications. From a pure testing perspective, we had no modifications to the protocol over the course of the study, because that would obviously have all sorts of other downstream implications. So it was just working through the protocol to meet [the study’s] needs – how to get individual sample, how to get patients or participants registered, how to get individual sample, how to get the results back to the individuals.</p> <p>Facilitator to WBS and NST, Northwell Health, Chief Medical Information Officer</p>

Additional Material
• File Name: Additional File 1
• File format: pdf (Link: <a href="https://drive.google.com/file/d/1m85jiwYGaFjeLkOKyggL2fuqrBrll_5-/view?usp=sharing">https://drive.google.com/file/d/1m85jiwYGaFjeLkOKyggL2fuqrBrll_5-/view?usp=sharing</a> )
• Supplemental Table 1. CFIR-informed barriers to and facilitators of wastewater-based surveillance and nasal self-testing in the Fulton County Jail.

Identified constructs per CFIR domain	N	Barrier	Neutral	Facilitator	Representative quotes
2. Engaging “Attracting and involving appropriate individuals in the implementation and use of intervention combined strategy of social marketing, education, role modeling, training and other similar activities.”	16	5	1	10	I stepped in. The way you congregate now. You won't be able to do it unless we can keep you safe in this environment. Explain won't have movement. The ventilation is not that great. You are co-herding around the table. You don't have face coverings on that we gave you. This is the best way to ensure that we don't have a widespread outbreak. If [you] sell it that way, they're generally agreeable.  Facilitator to NST, FCJ Sheriff's Office Leadership
Additional Material					
• File Name: Additional File 1					
• File format: pdf (Link: <a href="https://drive.google.com/file/d/1m85jiwYGaFjeLkOKyggL2fuqrBrll_5-/view?usp=sharing">https://drive.google.com/file/d/1m85jiwYGaFjeLkOKyggL2fuqrBrll_5-/view?usp=sharing</a> )					
• Supplemental Table 1. CFIR-informed barriers to and facilitators of wastewater-based surveillance and nasal self-testing in the Fulton County Jail.					

Themes related to the *adaptability* and *complexity* constructs within the *Intervention Characteristics* domain were the most frequently mentioned and deemed to be barriers despite the perceived *relative advantage* conferred by WBS and NST. Other constructs that were mentioned frequently from the *Inner Setting* domain, included *networks & communication* and *culture*, which were classified as facilitators, and *available resources*, which was identified to be a barrier. In the *Process* domain, both the *engaging* and *planning* constructs were deemed to be facilitators. Other CFIR constructs including *Formally appointed internal implementation leaders*, *External change agents*, *Evidence, strength and quality*, *Leadership engagement*, *Peer pressure*, and *Structural characteristics* were mentioned less frequently during the analysis.

#### Intervention characteristics domain

According to participants, *adaptability* and *complexity*, which describe the ability to tailor an intervention to meet specific needs and the difficulty of its implementation, respectively, were interrelated with one another and deemed to be overall barriers to WBS and NST. Multiple participants noted challenges related to their ability to modify the intervention based on situational factors in comparison to other interventions. For example, Northwell Health had implemented COVID-19 testing and the dissemination of results in other non-carceral congregate settings prior to this project; however, previous initiatives included access to cell phones for communication of results. Because cell phones are not permitted for residents

of carceral facilities, the SWANSS project was their first experience in which individuals were not able to receive their results. As such, a portal system needed to be implemented that was monitored by jail healthcare staff as discussed in Table 1.A3.

Similar perspectives were voiced in relation to complexity. Multiple participants including the Maintenance Team Leadership noted that they were not able to fulfill every call or request required to sustain WBS and NST. Other stakeholders voiced experiences regarding the complexities in coordinating with the study team. Officers' bandwidth during scheduled hours were limited, requiring overtime on off days or before/after shifts to assist with testing for same/next day compensation. Overall, stakeholders felt the program might be adoptable for less complex jails than FCJ.

Despite challenges with adaptability and complexity, multiple stakeholders acknowledged the *relative advantage* or perceived importance of self-collected NST at FCJ when compared to testing led by medical staff. Participants felt self-collected nasal tests were more efficient due to the quick turnaround time of results and not having to wait on the availability of a provider to administer a test. Also considering that the NST and PCR methods were engineered to cost less than tests traditionally used for mass screening in jails (Table 1.A4). Stakeholders referred to the possibility of officers being trained to collect and complete regular testing if the SWANSS partnership concluded. Noting, the NST used does not require a healthcare provider to be present. The test also does not require deep nasopharyngeal samples, which residents prefer.

While stakeholders recognized the relative advantage associated with WBS for surveillance, they did express concern about its sustainability due to the novel and complex way in which it is implemented. Compared to other congregate settings, the intricacy of the jail highlighted the need for FCJ partners to be involved in this type of implementation strategy for sustainability purposes. Moreover, jail staff explained that movement of residents after positive wastewater and PCR tests to a designated pod is challenging and sometimes not feasible at a jail such as FCJ where populations is usually at or above capacity. A participant specifically noted how they had to create space to isolate residents (Table 1.A2). A COVID isolation zone for those who tested positive could house up to 32 individuals during their isolation periods, but this could not always be implemented, given security and other considerations governing housing.

(Table 1 here)

Inner setting domain

*Networks & Communication*, defined briefly as the quality of networks within an organization and the communication that ensues within those networks was deemed to be an overall facilitator in the implementation of WBS and NST. Among facility staff, discussion of COVID-19 mitigation efforts in response to WBS and NST results were incorporated at multiple touchpoints. For example, the facility has different communication channels accessible by all staff. Among residents, interactions with healthcare staff, signage, and resident briefings during officer shift changes were intended to keep them informed.

However, stakeholders mentioned a lack of WBS specific reports following testing results, which was an area needing perceived improvement. Jail management specified that ideally these reports would be accompanied by an impression of findings to stay informed on the wastewater signal in regular meetings with department heads. On the other hand, in terms of sustainability, participants shared it could be challenging for external stakeholders to get buy in for jail staff to be responsible for managing and reviewing the WBS results to further consistent internal communication.

*Culture* such as norms and values within the organization was another facilitator within the inner setting. Participants endorsed these initiatives to improve the quality of health within the institution as well as their own health. Participants recognized the risk of residents contracting COVID-19, and communal efforts were thought to be important to mitigate this risk. Cleaning the living quarters, isolating symptomatic residents, and vaccination requirements were all viewed to promote the prevention of disease spread.

*Access to knowledge & information*, described as the availability of necessary, quality information and its relevance to daily work, appeared to be a facilitator. One stakeholder provided their outlook on the sustainability of the intervention recognizing that the ability of comparing wastewater testing results to the number of positive cases in the facility could provide “truth of measurements” (Table 1.A1). Another stakeholder pointed out potential future changes in testing and using WBS as a tool for an additional data source (Table 2.C6).

Table 2

Inner settings Domain: CFIR-informed barriers to and facilitators of wastewater-based surveillance and nasal self-testing in the Fulton County Jail.

Identified constructs per CFIR domain	N	Barrier	Neutral	Facilitator	Representative quotes
C. INNER SETTING					
1. Networks & Communications  “The nature and quality of webs of social networks and the nature and quality of formal and informal communication within an organization.”	26	6	9	14	<p>We have daily toolbox talks and also monthly safety meetings, and I’m also a part of the safety committee – I get all these documentations from CDC about COVID. So we share this stuff with the staff pretty much daily. You know, I’m always telling people, because we do a turnover talk every day at 3:00 and one in the morning and I say be safe, where your mask. You know, so COVID has changed the dynamics when it comes to safety around here because at the end of the day that’s the hot topic. So I want to make sure that my team is aware that people got a little comfortable because they’re thinking it was over. But what you do outside of here, that’s different than what’s going on over here. This building here – I would never step foot up on that floor without a mask on. You know, I might come in here and take my mask off, but if I get on that elevator and go to a floor, I’m putting a mask on. But my team is very knowledgeable and very aware of COVID. It’s preached and practiced here daily. So there’s no misunderstanding. You know, I don’t want anybody on my staff to ever say I didn’t know that, because my team knows.</p> <p>Facilitator to WBS and NST, Maintenance Team Leadership</p>
2. Culture  “Norms, values and basic assumptions of a given organization.”	22	5	5	12	<p>As long as they don’t see people getting really, really sick, they say ‘whatever.’ But we can certainly encourage it, almost require it. Just can’t come out and commune with the rest of the group if you don’t participate.</p> <p>Facilitator to NST + WBS, FCJ Sherriff’s Office Leadership</p>

Identified constructs per CFIR domain	N	Barrier	Neutral	Facilitator	Representative quotes
<p>3. Tension for Change</p> <p>“The degree to which stakeholders perceive the current situation as intolerable or needing change.”</p>	8	3	3	2	<p>It just kind of – I think our practices never really changed. We’ve always – We know that COVID still exists in our communities. So we still do things on an air of caution because everybody’s still required to wear their masks, staff and inmates when they’re back there in direct contact. So that’s never changed. We still do our sanitizing. We still do our decontaminations with our sprayers. So none of that has changed. But it just continued to let us know that it’s still existing.</p> <p>Barrier to WBS and NST, FCJ Sherriff’s Leadership Office</p>
<p>4. Relative Priority</p> <p>“Individuals’ shared perception of the importance of implementation within the organization.”</p>	6	5	0	1	<p>I don’t think that surveillance is realistic right now. I think that people have veered away from that. I think that that’s important during the acute phase of a pandemic, but I think that we’re over that bump. I think now with the pandemic, it’s kind of socially endemic, we’re living with COVID and there’s less surveillance and more just treating people as they’re actually ill from COVID, not just when they have COVID, but if they’re actually ill. More like the flu.</p> <p>Barrier to WBS and NST, Northwell Health, Senior Project Manager</p>
<p>5. Available Resources</p> <p>“The level of resources dedicated for implementation and on-going operations, including money, training, education, physical space, and time.”</p>	26	4	2	2	<p>If we had more nurses, we can tackle more floors or more areas at a faster rate opposed to hitting one floor, maybe a floor and a half once a week. We can have more staff when we deal with certain floors, because certain floors with different inmates, more staffing helps, period. The more you’ve got, it makes everyone’s job easier.</p> <p>Barrier to NST, FCJ Healthcare Staff</p>

Identified constructs per CFIR domain	N	Barrier	Neutral	Facilitator	Representative quotes
6. Access to Knowledge & Information  “Ease of access to digestible information and knowledge about the intervention and how to incorporate it into work tasks.”	9	3	1	4	<p>I wasn't really familiar with wastewater testing until I started hearing about it, and then once I started hearing [study staff] talk about it, it became more prevalent to me, because I started hearing it in the news media. And then when I started seeing the results come back and there was some COVID – positive COVIDness in the wastewater I was like, wow, this is interesting, and it really became relevant, because I noticed that yes, COVID was still here in the building when we was getting the positive results back from the wastewater. So when it decreased I didn't hear anything about the positives being in the wastewater. So now in our facility today we see some spikes of COVID coming back in our inmate population, I'm really curious if there's any positive COVIDness in the wastewater. Since then we just recently have some inmates here now that are COVID positive. And it just kind of stopped at a moment, and then I can tell it's starting to pick back up.</p> <p>Facilitator to WBS, FCJ Healthcare Staff</p>

*Available resources* inclusive of space, time, money, staff, and supplies was a barrier. Most jail staff agreed that there is not much space within the facility. Overcrowding leads to residents living in communal spaces rather than an enclosed cell. Therefore, NST requires more security to control zones to test residents. If there was more cell space, testing cells door-to-door would be more secure. In addition to this being a safety concern when gathering NST, it makes it difficult to dedicate zones for the movement of positive COVID-19 cases that arise resulting in an infected resident living amongst other uninfected residents often. Furthermore, stakeholders noted that the facility is always experiencing staffing challenges. When visiting certain floors of the jail, there is a needed amount of security that was not regularly available during testing times.

*Relative priority*, another assessment of importance, was also a barrier. Similar to concerns about sustainability of WBS, as discussed by the interviewee in Table 2.C4, participants felt the prioritization of WBS may waver during different phases of the COVID-19 pandemic. Consistent with all of the above, *Tension for change* or the shared perspective that change is required was a borderline barrier or neutral. Within the jail setting, adoption of new interventions like WBS and NST over traditional surveillance methods could be hindered by other priorities that require more attention when the status of jail activities is more intense.



(Table 2 here)

## Process domain

Both the *planning* and *engaging* constructs, defined as the quality preparation of intervention plans ahead of implementation and the involvement of appropriate stakeholders, respectively, were determined to be facilitators. Before the SWANSS study, surveillance was based off entry screening and residents reporting symptoms to staff. Opt-out testing for the entire jail population then became available. Jail administrators encouraged officers to engage with residents and explain the purpose of testing to address those who may be reluctant to participate week-to-week (Table 3.E2).

It was suggested by the Maintenance Team Leadership that the study team engage more with the maintenance staff by meeting them for an informational session, so they understand the purpose of WBS and its extension beyond opening a manhole to test the wastewater. With WBS, someone in a managerial position needs to delegate which contracted maintenance worker is assigned to accompany study team. The current stakeholder in the role suggested that the SWANSS team share testing plans with jail partners sooner to improve engagement. Participants mentioned that more than a 24-hour notice is needed for WBS coordination between the maintenance team, study staff, and the sheriff's department to prevent partners from coming on site and not having escorts to complete sampling or testing.

During the initial phases of the study, the SWANSS team worked closely with a laboratory to develop protocols and plan testing strategies. Throughout the study, there was more flexibility for protocol changes to fit the study team's needs during deployment such as how to register individual residents, how to organize residents as samples were taken, and how to report results to individuals. For example, the SWANSS team adjusted their NST strategy by using electronic real time recording instead of printed materials to effectively screen and test as many people as possible. But there was less flexibility for modifications of the laboratory protocol to follow typical regulations.

(Table 3 here)

## Discussion

In this study, examined the implementation of WBS coupled with NST for SARS-CoV-2 in a large urban U.S. jail facility. Our study design and data analysis were guided by the CFIR to determine which constructs were barriers or facilitators to the implementation of WBS and NST at an urban mega-jail. Participants included correctional leadership, healthcare, and maintenance staff at FCJ as well as other significant stakeholders that were offsite but still involved in the development of the WBS and NST program. While these diverse perspectives highlighted important advantages to WBS and NST, they also underscored challenges with implementation in a complex carceral setting. [10]Alignment of organizational culture, good internal communications, and access to knowledge and information were necessary for the intervention's success. Most stakeholders were excited about the ability to represent the jail population in a WBS sample as well as the benefits of WBS coupled with NST for improving

mitigation efforts. Despite these attainments, adaptability and complexity were the most frequently mentioned constructs and barriers to WBS. Challenges related to adaptability were primarily due to technological limitations such as the inability to bring cell phones into the jail setting. Challenges related to complexity were due to the multiple contact touchpoints required between the study team and the jail staff for WBS sample collection. There are attributes of this intervention that could have hindered the success of its implementation [19] in a carceral setting and it might be important that future similar interventions heavily focus on the intervention's characteristics.

Stakeholders emphasized the nature of the jail's rapidly evolving environment, and how the setting impacted the ability to test, which in turn can affect activities and strategies necessary to implement WBS and NST. This includes the need to consider the perspectives of numerous stakeholders requiring strong communication when coordinating activities. Although healthcare staff were less involved in routine testing, they performed a central role using wastewater and individual testing results to help monitor and communicate outbreak control measures within the jail. Maintenance staff were also not involved in sample collection but involved in wastewater testing logistics and access to testing locations. Being more engaged and providing adequate, timely planning between groups at the facility could increase staff's willingness to assist.

To sustain a WBS program without an external partner, reallocation of resources within the jail would need to occur. A study in Canadian prisons on hepatitis C screening also found available resources as a barrier because of the lack of staff able to assist within facilities [21]. FCJ staff reported being strained by everyday work duties, so the addition of new personnel would help to mitigate that strain. This could include a wastewater surveillance administrator that builds a team with existing staff, or it could also be outsourced to a commercial entity with expertise in WBS. The number and need for companies able to develop programs and provide commercial laboratory wastewater testing services increased during the height of the pandemic with the development of a national wastewater surveillance program. Despite intervention characteristics being identified as implementation barriers in this jail setting, stakeholders reported they thought WBS and NST would still be more effective than jail medical providers testing symptomatic residents.

Cost was noted as a challenge to this intervention, which has often been cited as a barrier to jail-based interventions [22, 23]. Therefore, other considerations include the responsibility of funding the program after the departure of the academic partner. In addition, the jail will need access to similar resources provided by the academic partner, possibly accessible via the local health department. Contributions could include coordinator of logistics, testing personnel, plus laboratory support for both WBS and NST services with an adequate, timely turnaround. Officers could be trained to become testing personnel, but current staffing shortages and challenges with dual loyalty may preclude this strategy [24].

Noting the interest by jail stakeholders as documented above, the relative prioritization of WBS could rise with broadening support in institutional-level wastewater monitoring for infectious diseases by local public health departments. This partnership could help provide technical assistance and

recommendations for facilities. Specifically, they can address the complexity of jail operations regarding resident movement and infection control. For instance, due to the short nature of jail stays, it may take their expertise in public health decision-making when interpreting positive wastewater results without a positive NST since infected individuals contributing to wastewater viral loads can soon get released before public health action is taken. Future WBS implementation research in carceral settings could focus on funding, policies, and public health officials buy-in to partner with jails and to sustain successful programs.

Our study has some limitations. This study was conducted in one large jail system in the Southern U.S., so generalizability may be limited to other settings. We had a small sample size due to competing priorities among stakeholders and potentially incorrect contact information, however, the 12 individuals interviewed included a diverse group of stakeholders with varied involvement in the program and no new information emerged in the final few interviews, indicating data saturation. However, 24 stakeholders did not respond to multiple requests to participate in the study. The three stakeholder groups that were not interviewed for this report included residents, the public health department, and academic partners, introducing potential biases in our data. Implementation of the described study also required coordination among these three groups along with the nine cadres of stakeholders who were interviewed so this could introduce additional potential bias. Despite these limitations, by evaluating implementation barriers and facilitators to jail based WBS and NST, this study adds to the paucity of literature on COVID-19 mitigation strategies in carceral facilities. Our data, presenting perspectives of key stakeholders will aid in informing future programs for carceral facilities that aim to incorporate WBS and individual testing for COVID-19 with possible extension to other infectious diseases such as influenza, HIV, TB, among other pathogens.

## Conclusion

Using the CFIR model, we identified several barriers and facilitators to WBS combined with NST as a method to mitigate the impacts of COVID-19 and improve surveillance in carceral settings. Engaging diverse stakeholders is imperative to address the structural, organizational, and political factors that can impact the implementation of effective mitigation strategies.

## Abbreviations

Center for the Health of Incarcerated Persons (CHIP), Consolidated Framework for Implementation Research (CFIR), Coronavirus Disease 2019 (COVID-19), Fulton County Jail (FCJ), Georgia Department of Health (GDPH), nasal self-testing (NST), Polymerase Chain Reaction (PCR), severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), Surveillance via wastewater monitoring and nasal self-collection of specimens (SWANSS), wastewater-based surveillance (WBS).

## Declarations

Ethics: This study was submitted to the Institutional Review Board committee of Emory University, Atlanta, Georgia, USA, which determined the project was exempt from oversight.

Consent for publication: Not applicable

Availability of data and materials: The data set analyzed during the current study is available from the corresponding author on reasonable request.

Competing interests: AS has consults for the Correctional Health Committee of the Medical Association of Georgia and CanHepC. She has received grants through her University from Gilead Sciences. Other authors declare that they have no competing interests.

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Authors' contributions: KM was a major contributor in writing the manuscript. AS was the principal investigator and contributed to revisions of the paper. EO and VP conducted interviews. VP coordinated and assisted during interviews. SK coordinated, assisted during interviews, and contributed to revising the manuscript. KM and PB analyzed and interpreted the qualitative data. PB consolidated data into a results table. MJA managed manuscript writing and guided the qualitative analysis. MF revised multiple iterations of the manuscript. All authors read and approved the final manuscript.

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