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THE FUTURE OF WASTEWATER MONITORING FOR THE PUBLIC HEALTH

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INTRODUCTION

The COVID-19 pandemic has invited dramatic investment in and expansion of wastewater surveillance. This surveillance may enable early detection of an increasing presence of COVID-19 in the community. But the same technology may simultaneously or soon be turned to other uses, including for drug interdiction, community wellness, or environmental monitoring. All of these uses raise urgent legal and ethical questions.

Yet, the legal literature, to date, has almost uniformly failed to even consider the ramifications of wastewater-based epidemiology. Indeed, we are aware of only two articles discussing wastewater surveillance in the legal literature—one of which is our own prior work.[1] In our prior work, we have raised questions about the legal and ethical dimensions of wastewater surveillance in response to the COVID-19 pandemic.[2] That work arrived in the earliest days of the pandemic, when research efforts were not yet well established or as broadly implemented and when legal and ethical

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1. *See generally* Lance Gable, Jeffrey L. Ram & Natalie Ram, *Legal and Ethical Implications of Wastewater Monitoring SARS-CoV-2 for COVID-19 Surveillance*, 7 J.L. & BIOSCIS. 1, 1–11 (2020), https://doi.org/10.1093/jlb/lsaa039 [https://perma.cc/JM5Y-NAJM]; Elizabeth E. Joh, *COVID-19 Sewage Testing as a Police Surveillance Infrastructure*, 2 NOTRE DAME J. EMERGING TECH. 232, 237 (2021).

2. Gable et al., *supra* note 1.

consideration was focused almost exclusively on the drastic public health emergency at issue.

This Article thus expands the extant literature by considering the legal and ethical dimensions of wastewater surveillance more thoroughly and more broadly. It arrives at an auspicious time, as the United States moves into a vaccine-mediated phase in which COVID-19 is less likely to give rise to broad stay-at-home orders and more likely to trigger narrower, more targeted interventions. It seeks to offer guidance for the legal and ethical use of wastewater surveillance along two dimensions. The first dimension considers the circumstances under which wastewater monitoring should be deployed for detecting and responding to COVID-19 specifically. The second dimension zooms out, to consider whether and how this surveillance infrastructure, largely created in response to the COVID-19 pandemic, might be deployed for other uses, and examines the legal and ethical difficulties that may attend these broader uses.

This Article proceeds in three parts. Part I reviews the state of the science for wastewater-based epidemiology, focusing specifically on how this technique has been deployed to monitor for or detect the virus that causes COVID-19. One of the authors is a research scientist currently working to establish and oversee wastewater-based epidemiological efforts related to COVID-19 monitoring in the City of Detroit, Michigan, and Part I draws on that expertise.

Part II then moves from what is possible to what is legal and ethical. If wastewater-based epidemiology is to be deployed now and in the future for detecting and responding to COVID-19, what parameters should guide the collection of wastewater signals, and how should that data be used by policymakers and others to enact further public health protections?

Finally, Part III broadens its scope beyond COVID-19. Wastewater surveillance for COVID-19 sentinel surveillance can be well justified, provided guidelines are established ex ante for public health response to monitoring results. Other uses of wastewater surveillance infrastructure, however, may raise substantial privacy concerns, particularly if this infrastructure becomes denser and correspondingly more granular in the data it discloses. Such uses may, in turn, undermine both the legal soundness of and public trust in wastewater monitoring writ large. A brief conclusion follows.

I. THE TECHNOLOGY, GOALS, AND INFRASTRUCTURE OF COVID-19 WASTEWATER SURVEILLANCE

The development of wastewater surveillance for community monitoring of COVID-19 arose out of the realization that people with COVID-19 shed SARS-CoV-2 virus in their feces.[3] The methods relied on precedents of wastewater monitoring that had detected polio outbreaks,[4] identified other disease organisms in wastewater,[5] and measured markers of medically prescribed pharmaceuticals[6] and illegal drugs.[7] The whole genome sequence of SARS-CoV-2 was published in January 2020, soon after COVID-19 was first reported in China.[8] Knowledge of this sequence enabled scientists to develop molecular test methods in the United States[9]

3. Yifei Chen et al., *The Presence of SARS-CoV-2 RNA in the Feces of COVID-19 Patients*, 92 J. MED. VIROLOGY 833, 836 (2020), https://doi.org/10.1002/jmv.25825 [https://perma.cc/3M26-8N96]; Roman Wölfel et al., *Virological Assessment of Hospitalized Patients with COVID-2019*, 581 NATURE 465, 467 (2020), https://doi.org/10.1038/s41586-020-2196-x [https://perma.cc/2S9K-QCPW].

4. *See generally* Andrew F. Brouwer, Joseph N. S. Eisenberg, Connor D. Pomeroy, Lester M. Shulman, Musa Hindiyeh, Yossi Manor, Itamar Grotto, James S. Koopman & Marisa C. Eisenberg, *Epidemiology of the Silent Polio Outbreak in Rahat, Israel, Based on Modeling of Environmental Surveillance Data*, 115 PROC. NAT'L ACAD. SCIS. E10625 (2018), https://doi.org/10.1073/pnas.1808798115 [https://perma.cc/N2PQ-RVLB].

5. *See generally* Leo Heijnen & Gertjan Medema, *Surveillance of Influenza A and the Pandemic Influenza A (H1N1) 2009 in Sewage and Surface Water in the Netherlands*, 9 J. WATER & HEALTH 434 (2011), https://doi.org/10.2166/wh.2011.019 [https://perma.cc/E37H-ET2C].

6. *See generally* Yang Xiao, Xue-Ting Shao, Dong-Qin Tan, Ji-Hao Yan, Wei Pei, Zhuang Wang, Meng Yang & De-Gao Wang, *Assessing the Trend of Diabetes Mellitus by Analyzing Metformin as a Biomarker in Wastewater*, 688 SCI. TOTAL ENV'T 281 (2019), https://doi.org/10.1016/j.scitotenv.2019.06.117 [https://perma.cc/QB6F-J33R].

7. *See generally* Sara Castiglioni, Ettore Zuccato, Elisabetta Crisci, Chiara Chiabrando, Roberto Fanelli & Renzo Bagnati, *Identification and Measurement of Illicit Drugs and Their Metabolites in Urban Wastewater by Liquid Chromatography−Tandem Mass Spectrometry*, 78 ANALYTICAL CHEMISTRY 8421 (2006), https://doi.org/10.1021/ac061095b [https://perma.cc/59TB-KY77].

8. F. Wu et al., *Direct Submission: Severe Acute Respiratory Syndrome Coronavirus 2 Isolate Wuhan-Hu-1, Complete Genome*, GENBANK, Mar. 18, 2020, https://www.ncbi.nlm.nih.gov/nuccore/MN908947.3 [https://perma.cc/TU8F-C75V]; Fan Wu et al., *A New Coronavirus Associated with Human Respiratory Disease in China*, 579 NATURE 265, 265 (2020), https://doi.org/10.1038/s41586-020-2202-3 [https://perma.cc/9WZS-RQNM].

9. *Waterborne Disease and Outbreak Surveillance Reporting, National Wastewater Surveillance System (NWSS): A New Public Health Tool to Understand COVID-19 Spread in a Community*, CTRS. FOR DISEASE CONTROL & PREVENTION (Dec. 27, 2021) [hereinafter *A New Public Health Tool*], https://www.cdc.gov/healthywater/surveillance/wastewater-surveillance/wastewater-surveillance.html [https://perma.cc/ZFQ5-XELL]; CTRS. FOR DISEASE CONTROL & PREVENTION, 2019-NOVEL CORONAVIRUS (2019-NCOV) REAL-TIME RRT-PCR PANEL PRIMERS AND PROBES, May 29, 2020, https://www.cdc.gov/coronavirus/2019-ncov/downloads/rt-pcr-panel-primer-probes.pdf [https://perma.cc/V63M-CUXA].

and elsewhere.[10] Researchers soon determined that the molecular methods developed for clinical samples could also be applied to detect SARS-CoV-2 in sewage (wastewater) after modifications to take into account the dilution, large volumes of water, and interfering chemicals in wastewater.

Detecting SARS-CoV-2 in wastewater usually targets the same sequences in the virus as the clinical tests developed by the Centers for Disease Control and Prevention ("CDC"). The procedure involves collecting wastewater samples from sewers or influent wastewater treatment plants, concentrating RNA viruses in large volumes (10–500 mL) of wastewater down to less than one-tenth of a milliliter, and then assaying the RNA for the N1 and N2 sequences of the envelope protein genes using polymerase chain reaction ("PCR"), a molecular detection system.[11] Various PCR methods have been employed, some depending on conducting tens of thousands of nanoliter volume reactions simultaneously (droplet digital PCR) to obtain the greatest sensitivity for detecting as few copies of the SARS-CoV-2 virus as possible so that the earliest shedding of virus into wastewater might be detected.[12]

Since the markers of the virus are often found in wastewater a week or more in advance of clinical case positive tests and hospitalizations,[13] the consensus is that infected individuals begin to

10. *See generally* Victor M. Corman et al., *Detection of 2019 Novel Coronavirus (2019-nCoV) by Real-Time RT-PCR*, 25 EUROSURVEILLANCE 23 (2020), https://doi.org/10.2807/1560-7917.ES.2020.25.3.2000045 [https://perma.cc/4ZJU-L8AH].

11. Fatemeh Amereh, Masoud Negahban-Azar, Siavash Isazadeg, Hossein Dabiri, Najmeh Masihi, Mahsa Jahangiri-rad & Mohammad Rafiee, *Sewage Systems Surveillance for SARS-CoV-2: Identification of Knowledge Gaps, Emerging Threats, and Future Research Needs*, PATHOGENS, July 28, 2021, at 1, 3, 9–12, https://doi.org/10.3390/pathogens10080946 [https://perma.cc/QSY7-MN9C]; Shimoni Shah, Sylvia Xiao Wei Gwee, Jamie Qiao Xin Ng, Nicholas Lau, Jiayun Koh & Junxiong Pang, *Wastewater Surveillance to Infer COVID-19 Transmission: A Systematic Review*, SCI. TOTAL ENV'T, Jan. 15, 2022, at 3–4, https://doi.org/10.1016/j.scitotenv.2021.150060 [https://perma.cc/3YV2-WUY4]; Nicholas W. West, Adrian A. Vasquez, Azadak Bahmani, Mohammed Khan, James Hartrick, Carrie L. Turner, William Shuster & Jeffrey L. Ram, *Automated Method to Extract and Purify RNA from Wastewater Enables More Sensitive Detection of SARS-CoV-2 Markers in Community Sewersheds*, MEDRXIV, https://doi.org/10.1101/2022.04.03.22273370 [https://perma.cc/GZH4-YWR7].

12. Tao Suo et al., *ddPCR: A More Accurate Tool for SARS-CoV-2 Detection in Low Viral Load Specimens*, 9 EMERGING MICROBES & INFECTIONS 1259, 1259–60 (2020), https://doi.org/10.1080/22221751.2020.1772678 [https://perma.cc/Y7E6-CL2J].

13. Deepak Panchal, Om Prakash, Prakash Bobde & Sukdeb Pal, *SARS-CoV-2: Sewage Surveillance as an Early Warning System and Challenges in Developing Countries*, 28 ENV'T SCI. & POLLUTION RSCH. 22221, 22223, 22225–26 (2021), https://doi.org/10.1007/s11356-021-13170-8 [https://perma.cc/GV6F-BC9V]; Aikaterini Galani et al., *SARS-CoV-2 Wastewater Surveillance Data Can Predict Hospitalizations and ICU Admissions*, SCI.

shed the virus several days before they show COVID-19 symptoms. Individuals with asymptomatic COVID-19 infections also shed SARS-CoV-2,[14] and it is likely that vaccinated people who have breakthrough infections do so as well.[15]

Numerous cases now exist in which upward trends in SARS-CoV-2 markers in sewage from congregate living facilities such as dormitories have been used to trigger individual testing of residents by standard clinical tests.[16] As a result, asymptomatic residents were identified as positive for the virus and thereafter removed or isolated from the congregate facility, resulting in a return of the wastewater to a SARS-CoV-2-free status. The conclusion from such anecdotes is that a broader outbreak of the disease in the congregate facility was very likely averted.

This "early warning" use of wastewater monitoring and subsequent testing of individuals to prevent a larger outbreak fulfills one of the early stated goals of applying this technology. According

TOTAL ENV'T, Jan. 15, 2022, at 1–2, 6, 9, https://doi.org/10.1016/j.scitotenv.2021.150151 [https://perma.cc/3B29-N69B].

14. Bradley W. Schmitz, Gabriel K. Innes, Sarah M. Prasek, Walter Q. Betancourt, Erika R. Stark, Aidan R. Foster, Alison G. Abraham, Charles P. Gerba & Juan L. Pepper, *Enumerating Asymptomatic COVID-19 Cases and Estimating SARS-Cov-2 Fecal Shedding Rates via Wastewater-Based Epidemiology*, SCI. TOTAL ENV'T, Dec. 20, 2021, at 1–2, 6, https://doi.org/10.1016/j.scitotenv.2021.149794 [https://perma.cc/8U6N-8NFP]; *see* Smruthi Karthikeyan et al., *Rapid, Large-Scale Wastewater Surveillance and Automated Reporting System Enable Early Detection of Nearly 85% of COVID-19 Cases on a University Campus*, MSYSTEMS, July–Aug. 2021, at 1–3, https://doi.org/10.1128/msystems.00793-21 [https://perma.cc/2G2E-WH6E].

15. Ruian Ke et al., *Longitudinal Analysis of SARS-CoV-2 Vaccine Breakthrough Infections Reveal Limited Infectious Virus Shedding and Restricted Tissue Distribution*, MEDRXIV, Sept. 2, 2021, https://doi.org/10.1101/2021.08.30.21262701 [https://perma.cc/5RDN-CGTB] (preprint); Michael Klompas, *Understanding Breakthrough Infections Following mRNA SARS-CoV-2 Vaccination*, 326 JAMA 2018, 2018 (2021), https://doi.org/10.1001/jama.2021.19063 [https://perma.cc/8RDD-CVE6].

16. *See, e.g.*, Walter Q. Betancourt et al., *COVID-19 Containment on a College Campus via Wastewater-Based Epidemiology, Targeted Clinical Testing and an Intervention*, SCI. TOTAL ENV'T, July 20, 2021, at 1, https://doi.org/10.1016/j.scitotenv.2021.146408 [https://perma.cc/Q549-NK9K]; Lisa M. Colosi et al., *Development of Wastewater Pooled Surveillance of Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) from Congregate Living Settings*, 87 APPLIED & ENV'T MICROBIOLOGY, 1, 8–9, 11, 13 (2021), https://doi.org/10.1128/AEM.00433-21 [https://perma.cc/XPA7-9HQM]; Cynthia Gibas et al., *Implementing Building-Level SARS-CoV-2 Wastewater Surveillance on a University Campus*, SCI. TOTAL ENV'T, Aug. 15, 2021, at 1, https://doi.org/10.1016/j.scitotenv.2021.146749 [https://perma.cc/H346-Y752]; Laura C. Scott, Alexandra Aubee, Layla Babahaji, Katie Vigil, Scott Tims & Tiong Gim Aw, *Targeted Wastewater Surveillance of SARS-CoV-2 on a University Campus for COVID-19 Outbreak Detection and Mitigation*, ENV'T RSCH., May 29, 2021, at 3, https://doi.org/10.1016/j.envres.2021.111374 [https://perma.cc/KMP7-S999]; Mark E. Sharkey et al., *Lessons Learned from SARS-CoV-2 Measurements in Wastewater*, SCI. TOTAL ENV'T, Dec. 1, 2021 at 1, 2, 10, https://doi.org/10.1016/j.scitotenv.2021.149177 [https://perma.cc/3QQ4-QCBP].

to Dr. Joneigh Khaldun, the former chief medical executive for the state of Michigan, the state set up twenty wastewater test facilities across the state in order to "provide an early warning sign" of an increase in COVID-19 disease in the community.[17] And indeed, during the delta variant mediated outbreak that began during the summer of 2021, researchers detected SARS-CoV-2 in wastewater even before the rise of clinically recorded cases over that period.[18]

However, "early warning" is only one of the explicit goals for this technology. Section A briefly assesses the goals—and progress toward achieving them—that scientists and policy makers have identified for wastewater monitoring. Section B then reviews existing and proposed investments and infrastructure for wastewater surveillance that form the basis for current and potential future applications of this technology.

A. *Assessing Proposed Goals for Wastewater Surveillance*

1. To "provide an early warning sign and help communities target public health actions to prevent further spread"[19]

Numerous projects have demonstrated statistically reliable correlations between wastewater detections of SARS-CoV-2 and the rise of reported cases and deaths in their communities days or even weeks later.[20] However, only a few published examples can be found (other than at university campuses, discussed below) in which public health entities have acted on SARS-CoV-2 wastewater surveillance data at early stages of new outbreaks in ways that likely reduced a predicted outbreak. A project in Germany claimed an average ten-day early warning signal "resulted in very efficient, proactive [public health] management."[21] Separately, researchers described proactive clinical testing and medical

17. Press Release, Mich. Dep't of Health & Hum. Servs., New Funding Announced for Continued COVID-19 Wastewater Monitoring (June 24, 2021), https://www.michigan.gov/coronavirus/0,9753,7-406-98158-562538—,00.html [https://perma.cc/ZYU6-QQQQ].

18. *See, e.g.*, Eric Baerren, *Key Predictor Points to Imminent COVID Outbreak*, MORNING SUN (Aug. 2, 2021, 8:12 AM), https://www.themorningsun.com/2021/08/01/msn-l-new-covid-outbreak-7-30-21 [https://perma.cc/597D-7NHH].

19. Press Release, Mich. Dep't of Health & Hum. Servs., *supra* note 17.

20. Shah et al., *supra* note 11.

21. Katalyn Roßmann et al., *Innovative SARS-CoV-2 Crisis Management in the Public Health Sector: Corona Dashboard and Wastewater Early Warning System Using the Example of Berchtesgadener Land*, 65 BUNDESGESUNDHEITSBLATT - GESUNDHEITSFORSCHUNG - GESUNDHEITSSCHUTZ 367, 369 (2022), https://doi.org/10.1007/s00103-021-03425-7 [https://perma.cc/KQ6H-BZ84].

treatment in a community in Brazil in response to SARS-CoV-2 wastewater monitoring.[22] In the United States, a CDC report indicated that states have "used wastewater data to allocate testing resources . . . and forecast clinical resource needs at the community level."[23] The Ohio Department of Health has set a criterion for notifying local health departments of an event if a tenfold increase in SARS-CoV-2 levels over those detected in the past two samples has been observed.[24] Nevertheless, public health actions in response to wastewater data may have been limited because many departments may believe they need more evidence that these data are reliable and meaningful in order to rely on them for policy decisions.

2. To Complement Clinical Tests and Case Reporting Where Timely COVID-19 Clinical Testing Is Underutilized or Unavailable[25]

One barrier to achieving this purpose is that places lacking medical infrastructure for testing may similarly be lacking the wastewater infrastructure for supporting this public health purpose.[26] An example is South Africa, which developed SARS-CoV-2 wastewater surveillance to assess community levels of disease where medical infrastructure was lacking—and for which the authors acknowledge that forty percent of households are not connected to the sewer system.[27] A similar situation may apply in rural and inner-city areas of the United States.

22. Tatiana Prado et al., *Wastewater-Based Epidemiology as a Useful Tool to Track SARS-CoV-2 and Support Public Health Policies at Municipal Level in Brazil*, WATER RSCH., Mar. 1, 2021, at 2, https://doi.org/10.1016/j.watres.2021.116810 [https://perma.cc/EXS7-WZ8T].

23. Amy E. Kirby et al., *Using Wastewater Surveillance Data to Support the COVID-19 Response — United States, 2020–2021*, 70 MORBIDITY & MORTALITY WKLY. REP. 1242, 1243 (2021).

24. *Id.*

25. *A New Public Health Tool*, *supra* note 9; *see also* Press Release, Mich. Dep't of Health & Hum. Servs., *supra* note 17 (identifying a related objective in the State of Michigan to "provide information on the virus within populations . . . who do not seek health care").

26. Juliana Calabria De Araujo et al., *SARS-CoV-2 Sewage Surveillance in Low-Income Countries: Potential and Challenges*, 19 J. WATER & HEALTH 1, 3 (2021).

27. Heather Richardson, *How Waste Water Is Helping South Africa Fight COVID-19*, NATURE (May 24, 2021), https://www.nature.com/articles/d41586-021-01399-9 [https://perma.cc/F6YL-RP7D].

3. To Provide Data at the Sub-County Small Sewershed Level[28]

One of us is providing wastewater data in the city of Detroit for twenty sewersheds that range in population from 100 to approximately 35,000 people.[29] While collection of data at wastewater treatment plants may track the overall progress of the pandemic, data from smaller sewersheds are reportedly more useful for focusing public health efforts and education.[30]

4. To Inform Targeted Testing of People Living in Congregate Housing (e.g., Students in Dormitories) to Ward off Potential Outbreaks[31]

This purpose has probably been the most consistently successful public health result of SARS-CoV-2 wastewater monitoring. Numerous universities throughout the world are conducting wastewater monitoring for SARS-CoV-2.[32] Several have published peer-reviewed reports on their success at detecting wastewater signals, triggering intensive testing, and isolating asymptomatic students who tested positive and could have potentially infected other students if this triggered testing had not occurred.[33] On the other hand, the effectiveness of this approach depends on the willingness of students to comply with testing requests. While some universities report greater than ninety-five percent testing compliance,[34] others have indicated that only seventy percent of students complied with the request.[35] The effectiveness of this use of wastewater surveillance may wane as COVID-19 becomes an endemic disease with low overall health impact on young, mostly vaccinated students.

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28. *A New Public Health Tool*, *supra* note 9.

29. *Wayne State University SARS-CoV-2 Monitoring in the City of Detroit*, RAM LAB WSU, https://www.ramlabwsu.org/sars-cov-2-monitoring.html [https://perma.cc/XYH3-WX7K].

30. *See* Prado et al., *supra* note 22, at 8–9.

31. *Campus Health: Novel Coronavirus (COVID-19)*, HOPE COLL., https://hope.edu/coronavirus [https://perma.cc/UFE8-G2EV].

32. *E.g.*, *COVIDPoops19 Dashboard*, COVID-19 WBE COLLABORATIVE, https://www.covid19wbec.org/covidpoops19 [https://perma.cc/RPT7-JR9U].

33. *E.g.*, Betancourt et al., *supra* note 16, at 2; Colosi et al., *supra* note 16, at 2, 11; Gibas et al., *supra* note 16, at 2; Scott et al., *supra* note 16, at 2, 7; Sharkey et al., *supra* note 16, at 2, 4, 10.

34. *See* Scott A. Travis et al., *Providing a Safe, In-Person, Residential College Experience During the COVID-19 Pandemic*, FRONTIERS PUB. HEALTH, June 23, 2021, at 1, 3, https://doi.org/10.3389/fpubh.2021.672344 [https://perma.cc/YF7B-AQCW].

35. *See* Gibas et al., *supra* note 16, at 6.

5. To Use Population-Wide Data from Wastewater Surveillance to Inform Modeling Efforts to Trace the Dynamics of Virus Transmission Within Human Populations[36]

Several researchers have reported successful use of wastewater and COVID-19 case data in their modeling efforts, as described in a review of ninety-two such studies.[37] For example, one model was successfully used to predict hospital admissions likely to occur several days after wastewater signaled a turning point in the presence of virus in the wastewater stream.[38] Moreover, a model for predicting viral disease based on wastewater and other inputs is in development for southeast Michigan to "assist public health official decisions regarding safety preparedness."[39]

6. To Use Archived Wastewater Samples for Retrospective Investigations of a Pathogen's Circulation[40]

Retrospective analyses of wastewater have been used successfully to assess the effectiveness of lockdown procedures that were implemented early in the pandemic.[41] One retrospective study compared wastewater detections to contact notifications and positive tests. This study concluded that "non-detect" results in wastewater were not effective evidence of no infections, but that positive detections were good predictors that infections would be

36. *See* Fuqing Wu et al., *SARS-CoV-2 Titers in Wastewater Are Higher than Expected from Clinically Confirmed Cases*, 5 MSYSTEMS, Aug. 2020, at 1, 7, https://doi.org/10.1128/mSystems.00614-20 [https://perma.cc/HA6M-RZEU]; S. Wurtzer, V. Marechal, J.M. Mouchel, Y. Maday, R. Teyssou, E. Richard, J.L. Almayrac, L. Moulin, *Evaluation of Lockdown Effect on SARS-CoV-2 Dynamics Through Viral Genome Quantification in Waste Water, Greater Paris, France, 5 March to 23 April 2020*, EUROSURVEILLANCE, Dec. 17, 2020, at 38, 39, 42, https://doi.org/10.2807/1560-7917.ES.2020.25.50.2000776 [https://perma.cc/XUF3-FZJA].

37. Shah et al., *supra* note 11, at 2, 33.

38. Galani et al., *supra* note 13, at 9.

39. Brijen Miyani, Xavier Fonoll, John Norton, Anna Mehrotra, Irene Xagoraraki, *SARS-CoV-2 in Detroit Wastewater*, J. ENV'T ENG'G, Nov. 2020, at 6, https://doi.org/10.1061/(ASCE)EE.1943-7870.0001830 [https://perma.cc/5N55-RYLU].

40. Wurtzer et al., *supra* note 36, at 39.

41. Luke S. Hillary et al., *Monitoring SARS-CoV-2 in Municipal Wastewater to Evaluate the Success of Lockdown Measures for Controlling COVID-19 in the UK*, WATER RSCH., July 15, 2021, at 2, https://doi.org/10.1016/j.watres.2021.117214 [https://perma.cc/CR9C-XUZ8]; Bo Li, Doris Yoong Wen Di, Prakit Saingam, Min Ki Jeon, Tao Yan, *Fine-Scale Temporal Dynamics of SARS-CoV-2 RNA Abundance in Wastewater During a COVID-19 Lockdown*, WATER RSCH., June 1, 2021, at 2, https://doi.org/10.1016/j.watres.2021.117093 [https://perma.cc/34DR-8LXJ].

present if clinical testing were undertaken.[42] Such retrospective studies represent successful acquisition of knowledge for handling the current and future pandemics.

7. To Reveal Community Vulnerabilities or Susceptibilities as a Function of Race, Ethnicity, Socioeconomic Status, Occupation, Age, and Climate, Among Others[43]

One recent study in Brazil focused on the presence of SARS-CoV-2 in wastewater (as well as upstream versus downstream river measurements) from vulnerable rural communities and transient workers facilities thought to have low sanitation standards.[44] The study detected SARS-CoV-2 markers at least one week prior to confirmation of clinical cases in these areas.[45] Although this study emphasized the likely vulnerability to COVID-19 due to the population's low socioeconomic and transient status[46], no systematic comparison of wastewater detection from populations with varying racial, socioeconomic, or other potential indicators of vulnerability seems to have been reported yet.

8. To Evaluate Vaccination Efficacy at a Community Level[47]

A recent study on a college campus found that, for several weeks after the second of two vaccination injections, formerly high wastewater signals fell to much lower levels.[48] More studies are needed to determine whether this result is due to a decrease in the number of infected people or due to vaccination causing infected people to shed less virus into the waste stream, or both. Others have proposed using wastewater monitoring to identify areas

42. *See generally* H.S. Camphor, S. Nielsen, Z. Bradford-Hartke, K. Wall & R. Broome, *Retrospective Epidemiological Analysis of SARS-Cov-2 Wastewater Surveillance and Case Notifications Data – New South Wales, Australia, 2020*, 20 J. WATER & HEALTH 103 (2021), https://doi.org/10.2166/wh.2021.275 [https://perma.cc/L8T3-2H7M].

43. Christian G. Daughton, *Wastewater Surveillance for Population-Wide Covid-19: The Present and Future*, SCI. TOTAL ENV'T, Sept. 20, 2020, at 4, https://doi.org/10.1016/j.scitotenv.2020.139631 [https://perma.cc/2SZ7-AXPD].

44. Gislaine Fongaro et al., *SARS-CoV-2 in Human Sewage and River Water from a Remote and Vulnerable Area as a Surveillance Tool in Brazil*, FOOD & ENV'T VIROLOGY, July 2021, at 1, https://doi.org/10.1007/s12560-021-09487-9 [https://perma.cc/2GTF-3WFW] (published electronically ahead of print).

45. *Id.*

46. *Id.*

47. *See* Amereh et al., *supra* note 11.

48. Aaron Bivins & Kyle Bibby, *Wastewater Surveillance During Mass COVID-19 Vaccination on a College Campus*, 8 ENV'T SCI. & TECH. LETTERS 792, 794 (2021).

where vaccination against COVID-19 is low, revealing "the human geography of unvaccinated communities" and facilitating targeted public health messaging.[49]

9. To Investigate the Spread of New Variants[50]

In 2021, as more infectious SARS-CoV-2 variants began to spread around the globe, several laboratories began to analyze wastewater to determine whether or when these variants appeared in their communities.[51] Recent wastewater data detected the rise of the delta and omicron variants in various communities.[52] Investigation of novel sequences in wastewater may be a means to discovering future variants at a community level,[53] which may influence public health responses to those variants.

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49. Ted Smith, Gail Cassell & Aruni Bhatnagar, *Wastewater Surveillance Can Have a Second Act in COVID-19 Vaccine Distribution*, JAMA HEALTH F., Jan. 2021, at 2, https://doi.org/10.1001/jamahealthforum.2020.1616 [https://perma.cc/54R7-WP4B].

50. Amereh et al., *supra* note 11, at 1.

51. Yuehan Ai et al., *Wastewater SARS-CoV-2 Monitoring as a Community-Level COVID-19 Trend Tracker and Variants in Ohio, United States*, SCI. TOTAL ENV'T., Dec. 20, 2021, at 1, https://doi.org/10.1016/j.scitotenv.2021.149757 [https://perma.cc/JZ5C-5JY6]; G La Rosa et al., *Rapid Screening for SARS-Cov-2 Variants of Concern in Clinical and Environmental Samples Using Nested RT-PCR Assays Targeting Key Mutations of the Spike Protein*, WATER RSCH., June 1, 2021, at 1, https://doi.org/10.1016/j.watres.2021.117104 [https://perma.cc/9ZTB-EANL]; Davida S. Smyth et al., *Tracking Cryptic SARS-CoV-2 Lineages Detected in NYC Wastewater*, MEDRXIV, July 29, 2021, at 2, https://doi.org/10.1101/2021.07.26.21261142 [https://perma.cc/RF3X-YDJ5] (preprint); Galani et al., *supra* note 13, at 2.

52. Tanmay Dharmadhikari, Vinay Rajput, Rakeshkumar Yadav, Radhika Boargaonkar, Dhawal Patil, Saurabh Kale, Sanjay P. Kamble, Syed G. Dastager & Mahesh S. Dharne, *High Throughput Sequencing Based Direct Detection of SARS-CoV-2 Fragments in Wastewater of Pune, West India*, SCI. TOTAL ENV'T, Feb. 10, 2022 at 1, https://doi.org/10.1016/j.scitotenv.2021.151038 [https://perma.cc/85BN-V6YH]; Wei Yin Lee et al., *Quantitative SARS-CoV-2 Tracking of Variants Delta, Delta plus, Kappa and Beta in Wastewater by Allele-Specific RT-qPCR*, MEDRXIV, Aug. 6, 2021, https://doi.org/10.1101/2021.08.03.21261298 [https://perma.cc/V4YD-UAAA] (preprint); Karin Yaniv, Eden Ozer & Ariel Kushmaro, *SARS-CoV-2 Variants of Concern, Gamma (P.1) and Delta (B.1.617), Sensitive Detection and Quantification in Wastewater Employing Direct RT-qPCR*, MEDRXIV, July 16, 2021, at 3–4, https://doi.org/10.1101/2021.07.14.21260495 [https://perma.cc/Z8AA-RJLT] (preprint); Taxiarchis Chassalevris et al., *Wastewater Monitoring Using a Novel, Cost-Effective PCR-Based Method that Rapidly Captures the Transition Patterns of SARS-CoV-2 Variant Prevalence (from Delta to Omicron) in the Absence of Conventional Surveillance Evidence*, MEDRXIV, Jan. 30, 2022, at 1, https://doi.org/10.1101/2022.01.28.21268186 [https://perma.cc/6N24-X7WS] (preprint); Melissa K. Schussman, Adelaide Roguet, Angela Schmoldt, Brooke Dinan & Sandra L. McLellan, *Wastewater Surveillance Using ddPCR Reveals Highly Accurate Tracking of Omicron Variant Due to Altered N1 Probe Binding Efficiency*, MEDRXIV, Feb. 21, 2022, at 1, https://doi.org/10.1101/2022.02.18.22271188 [https://perma.cc/62T2-AMV2] (preprint).

53. *See, e.g.*, Rafaela S. Fontenele et al., *High-Throughput Sequencing of SARS-Cov-2 in Wastewater Provides Insights into Circulating Variants,* WATER RSCH., Oct. 15, 2021, at 1–2, https://doi.org/10.1016/j.watres.2021.117710 [https://perma.cc/U223-3QQS].

10. To Provide Reassuring Signals as Outbreaks Wane[54]

The potential to provide reassuring signals as an outbreak ends is less clear. COVID-19 patients who have recovered to the point that they no longer show positive clinical tests nevertheless continue to shed SARS-CoV-2 markers in their feces for considerable time afterward.[55] Recovered students who were released after isolation back into campus residences have added to the positive signal in wastewater even though they were thought to be noninfectious at that reentry stage.[56] Continued positive signals from recovered patients make it difficult to predict with confidence the end of a particular outbreak based on SARS-CoV-2 wastewater surveillance.

B. *Current and Proposed Investments, Infrastructure, and Uses of Wastewater Surveillance*

Wastewater monitoring is not a new endeavor; however, the biological monitoring in response to the COVID-19 pandemic represents a change in the type and purpose of monitoring from the past and an increase by orders of magnitude in investment and new infrastructure. Pre-pandemic wastewater monitoring largely focused on ensuring the cleanliness of water leaving a treatment plant. The National Pollutant Discharge Elimination System permit program created under the Clean Water Act requires wastewater treatment plants to monitor the plants' effluent before discharging it to the environment.[57] Accordingly, wastewater treatment plants utilize various analytical systems and laboratories for complying with discharge regulations.[58] However, influent monitoring typically has not been required.[59] The monitoring of SARS-CoV-2 in wastewater

54. *See* Gregory Barber, *One Way to Potentially Track Covid-19? Sewage Surveillance*, WIRED (Apr. 7, 2020, 8:00 AM), https://www.wired.com/story/one-way-to-potentially-track-covid-19-sewage-surveillance [https://perma.cc/DY8P-GNSW].

55. Katelyn Reeves et al., *High-Resolution Within-Sewer SARS-Cov-2 Surveillance Facilitates Informed Intervention*, WATER RSCH., Oct. 1, 2021, at 8, https://doi.org/10.1016/j.watres.2021.117613 [https://perma.cc/4FKZ-Y48B].

56. *Id.*

57. 33 U.S.C. §§ 1251, 1342; *see also About NPDES*, EPA, https://www.epa.gov/npdes/about-npdes [https://perma.cc/7W49-AVGG].

58. *See* Clean Water Act, 40 C.F.R. § 136.6 (2021) (outlining analytical requirements for wastewater treatment plants); *see generally* STATE OF MICH. DEP'T OF ENV'T QUALITY, LABORATORY TRAINING MANUAL FOR WASTEWATER TREATMENT PLANT OPERATORS (2010) (outlining safety guidelines for Michigan wastewater treatment plants).

59. *See* EPA, GUIDANCE MANUAL FOR PREVENTING INTERFERENCE AT POTWS 32 (1987), https://dep.wv.gov/WWE/permit/individual/Documents/Guidance_Preventing_Interference

occurs on the influent side, analyzing samples taken from sewers prior to reaching the plant or at the treatment plant itself.[60] Influent monitoring, if required for these proposed public health goals, represents a change in both type and purposes of wastewater monitoring.

The investment in SARS-CoV-2 monitoring has also been significant. For example, the state of Michigan has invested nearly $50,000,000 in funding new SARS-CoV-2 wastewater monitoring capabilities in nineteen laboratories across the state.[61] In 2020, the CDC initiated the National Wastewater Surveillance System (NWSS). Since September 2020, this has included approximately $220 million in grants for SARS-CoV-2 wastewater monitoring projects in thirty-one states, three local health departments, and two territorial public health departments.[62] Biobot Analytics has reported providing SARS-CoV-2 wastewater monitoring services for at least forty states.[63] In February 2022, the CDC added wastewater data to the its publicly available COVID-19 data tracker webpage.[64] Two internet sites, COVID19Poops[65] and Wastewater-Sphere,[66] have also catalogued and mapped more than ninety SARS-CoV-2 wastewater "data dashboards," reporting data for more than 2,000 sites being monitored in more than fifty countries.

_POTW.pdf [https://perma.cc/H92J-KHXH] (noting exceptions for monitoring of influent as may occur voluntarily to determine if interfering substances are present that may require specialized or unusual treatment to produce regulation-compliant discharge).

60. *See* Reeves, *supra* note 56, at 2.

61. Lynn Sutfin, *New Funding Announced for Continued COVID-19 Wastewater Monitoring*, MICHIGAN.GOV (June 24, 2021), https://www.michigan.gov/coronavirus/0,9753,7-406-98158-562538—,00.html [https://perma.cc/TZH9-9CBN]. Disclosure: co-authors Jeffrey L. Ram and Lance Gable are Principal and Co-Principal Investigators on multiple state-funded projects at Wayne State University for this purpose in Detroit, Michigan, totaling $3 million in funding.

62. Jill S. McClary-Gutierrez et al., *SARS-CoV-2 Wastewater Surveillance for Public Health Action*, EMERGING INFECTIOUS DISEASES, Sept. 2021, at e1–3, https://doi.org/10.3201/eid2709.210753 [https://perma.cc/5Z39-ZDU9].

63. Fuqing Wu et al., *Wastewater Surveillance of SARS-CoV-2 Across 40 U.S. States from February to June 2020*, WATER RSCH., Sept. 1, 2021, at 3, 5, 9–10, https://doi.org/10.1016/j.watres.2021.117400 [https://perma.cc/5EFK-HCF5].

64. Emily Anthes, *The C.D.C. Adds Wastewater Data to Its COVID-19 Tracker*, N.Y. TIMES (Feb. 4, 2022), https://www.nytimes.com/2022/02/04/world/cdc-wastewater-covid.html [https://perma.cc/PTY6-ZGAJ]; *see also SARS-CoV-2 RNA Levels in Wastewater in the United States*, CTRS. FOR DISEASE CONTROL & PREVENTION, https://covid.cdc.gov/covid-data-tracker/#wastewater-surveillance [https://perma.cc/N27N-A3MM].

65. *COVIDPoops19 Dashboard*, *supra* note 32.

66. *W-Sphere Map*, WASTEWATER SPHERE, https://sphere.waterpathogens.org/map [https://perma.cc/UG7A-UC4J].

The infrastructure investment is in both capital equipment and personnel. The risk associated with wastewater, especially prior to vaccines and effective treatments for COVID-19, required establishing new higher biosafety-level laboratories. Physical infrastructure investments included the purchase of autosamplers, centrifuges, and -80°C freezers.[67] Laboratories sought autosamplers and other machines at such a rate that many shortages occurred.[68] Some laboratories have invested in automated equipment for efficient isolation of the viral RNA.[69] Other laboratories have set up different systems dependent on filtration, qPCR, and other factors that require similar investments.[70] Investments in personnel include specialized training in microbiological and biosafety techniques for working safely with wastewater and SARS-CoV-2.

II. WASTEWATER SURVEILLANCE FOR COVID-19

The creation of a growing infrastructure for conducting COVID-19 surveillance through wastewater monitoring of SARS-CoV-2—as described in Part I—inevitably raises a number of urgent legal and ethical considerations. The data garnered from these surveillance systems hold significant promise for public health purposes and may greatly bolster efforts to target COVID-19 resources and intervention strategies effectively. However, the collection and use of wastewater samples to monitor COVID-19 may also generate information that implicates individual or group privacy concerns. Further, these data could increase the likelihood that residents in the surveilled areas will face additional COVID-19 mitigation efforts that impact their lives. As such, the justifications and processes for conducting COVID-19 wastewater surveillance and using the data obtained through these efforts must be carefully evaluated and meet rigorous legal and ethical standards.

67. Katherine Ellen Foley, *So Many Communities Are Testing Poop for Covid-19, Equipment Is Running Out*, QUARTZ (Oct. 1, 2020), https://qz.com/1910540/wastewater-testing-for-covid-19-is-straining-supply-chains [https://perma.cc/FX46-AQLS].

68. *Id.*

69. *See, e.g.,* Smruthi Karthikeyan & Greg Humphrey, *Automated High Throughput Viral Concentration from Wastewater Using the Kingfisher Flex Platform*, PROTOCOLS.IO (Nov. 19, 2020), https://www.protocols.io/view/automated-high-throughput-viral-concentration-from-bptemnje [https://perma.cc/DZ7Q-AKVE].

70. *See* Amereh et al., *supra* note 11, at 5–12.

A. *The Ethical Implications of Wastewater Surveillance for SARS-CoV-2*

The ethical case in favor of public health surveillance generally rests on the assumption that seeking data about the incidence, prevalence, and spread of public health risks serves broadly beneficent and utilitarian purposes. These risks include infectious disease outbreaks and causes of noncommunicable diseases, injuries, and other threats to health. Understanding the scope and magnitude of these risks may enable more effective intervention and mitigation strategies to prevent or reduce harm to population health. Public health ethicists have recognized an affirmative duty to conduct public health surveillance that centers its ethical justification on considerations of "the common good, equity, solidarity, reciprocity, and population wellbeing."[71]

Public health surveillance plays an essential role in identifying, tracking, and responding to infectious disease outbreaks in particular. The data obtained through various public health surveillance efforts can help ascertain a clear picture of an emerging or ongoing outbreak, providing necessary information about changing rates of infections, demographics of infected populations, and trends over time. These data also permit public health officials or others to take additional steps to mitigate the harm caused by the outbreak through targeted interventions, which can include—depending on the nature of the outbreak and the availability of countermeasures—individualized testing, pharmaceutical interventions like medications and vaccines, targeted distancing measures like quarantine and isolation, broader social distancing measures, education and outreach efforts, and evaluation of the effectiveness and success of public health interventions.[72]

It is these additional steps, however, that often give rise to ethical concerns about public health surveillance, particularly how surveillance may implicate individual privacy, autonomy, liberty, or bodily integrity.[73] The data generated through public health

71. Amy L. Fairchild, Ali Akbar Haghdoost, Ronald Bayer, Michael J. Selgelid, Angus Dawson, Abha Saxena & Andreas Reis, Comment, *Ethics of Public Health Surveillance: New Guidelines*, 2 LANCET PUB. HEALTH e348, e349 (2017), https://doi.org/10.1016/S2468-2667(17)30136-6 [https://perma.cc/JNK9-QUAJ].

72. *See generally* Amy L. Fairchild, Ronald Bayer & James Colgrove, *Privacy, Democracy and the Politics of Disease Surveillance*, 1 PUB. HEALTH ETHICS 30 (2008), https://doi.org/10.1093/phe/phn008 [https://perma.cc/64NR-G52Q].

73. *Id.*

surveillance has the potential to undermine health privacy for individuals, subject individuals to state-imposed restrictions like quarantine, isolation orders, or mandatory testing or treatment, and justify the enactment of community-wide social distancing measures. These actions and restrictions may be ethically appropriate and justifiable, particularly if they are well targeted and necessary to intervene in the face of a serious threat to public health. However, the use of liberty-limiting restrictions to protect public health must not be undertaken without serious contemplation and evaluation of the effects of these restrictions.[74] Injudicious revelations about individual or community health status can expose individuals or entire communities to discrimination, stigma, and animus.[75] Consequently, the collection and subsequent uses of data gathered from public health surveillance should balance the potential for positive health outcomes and other common goods against the potential imposition on privacy, freedom of movement, and other individual interests.[76]

Debate over the legal and ethical implications of conducting public health surveillance has a long and varied history, but the relationship between data collection, use, and privacy protection forms a consistent area of tension. Privacy considerations have gained more legal and ethical support over time vis-à-vis disease surveillance, but the collection of information for valid public health purposes remains widely accepted.[77]

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74. *See* Lindsay F. Wiley, *Democratizing the Law of Social Distancing*, 19 YALE J. HEALTH POL'Y L. & ETHICS 50, 106–18 (2020) (outlining principles for applying public health emergency powers); Lawrence O. Gostin & James G. Hodge Jr., *US Emergency Legal Responses to Novel Coronavirus: Balancing Public Health and Civil Liberties*, JAMA, Mar. 24, 2020, at 1131, 1131–32, https://doi.org/10.1001/jama.2020.2025 [https://perma.cc/3GXA-VUJF] (describing the balance between public health emergency powers and civil liberties in the COVID-19 response).

75. *See* Jeremy Prichard, Wayne Hall, Pim de Voogt & Ettore Zuccato, *Sewage Epidemiology and Illicit Drug Research: The Development of Ethical Research Guidelines*, SCI. TOTAL ENV'T, Feb. 15, 2014, at 550, 551–53, https://doi.org/10.1016/j.scitotenv.2013.11.039 [https://perma.cc/9YH6-SKY4].

76. James F. Childress et al., *Public Health Ethics: Mapping the Terrain*, 30 J.L. MED. & ETHICS 170, 171–73 (2002) (outlining a series of steps to apply when evaluating the ethics of public health practices).

77. In the early twentieth century, public health officials would regularly publish personal information revealing health status, often publicly shaming individuals infected with tuberculosis or sexually transmitted infections in the name of protecting public health. As the HIV pandemic unfolded in the 1980s, advocates succeeded in obtaining strong privacy protections in many states by citing the privacy, discrimination, and stigma harms that named HIV surveillance would cause. *See generally* AMY L. FAIRCHILD, RONALD BAYER & JAMES COLGROVE, SEARCHING EYES: PRIVACY, THE STATE, AND DISEASE SURVEILLANCE IN

Ethicists have developed useful guidance for evaluating public health surveillance. Among the most thorough and well-developed guidance comes from a 2017 World Health Organization ("WHO") report that outlines seventeen specific guidance principles for assessing the ethics of public health surveillance.[78] The WHO principles provide a useful framework for situating the ethics of wastewater surveillance within the ethical principles of public health surveillance more generally.[79] These principles cover a broad spectrum of ethical considerations, and WHO highlights four ethical considerations as particularly important to public health surveillance: the common good, equity, respect for persons, and good governance.[80]

1. The Common Good

Public health surveillance can be considered a common good because of its potential to achieve public, population-level benefits that cannot be divided into private individual benefits or replicated by private individual actions.[81] The WHO principles suggest that public health surveillance systems should undergo preliminary and ongoing assessments to ensure that the data are being collected for clear, ethical, and legitimate public health purposes. Further, they suggest that all analysis, use, and dissemination of collected data occur in line with relevant and agreed-upon public health priorities.[82] The systems being developed and deployed to

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AMERICA (Univ. of Cal. Press 2007) (providing a detailed history of public health surveillance in the United States).

78. WORLD HEALTH ORG., WHO GUIDELINES ON ETHICAL ISSUES IN PUBLIC HEALTH SURVEILLANCE (2017). These guidelines build on earlier international efforts by the Council for International Organizations of Medical Sciences and the World Health Organization to develop ethical guidelines for epidemiological studies. *See* COUNCIL FOR INT'L ORGS. OF MED. SCIS., INTERNATIONAL GUIDELINES FOR ETHICAL REVIEW OF EPIDEMIOLOGICAL STUDIES (1991); COUNCIL FOR INT'L ORGS. OF MED. SCIS., INTERNATIONAL GUIDELINES FOR ETHICAL REVIEW OF EPIDEMIOLOGICAL STUDIES (2009).

79. Steve E. Hrudey, Diego S. Silva, Jacob Shelley, Wendy Pons, Judy Isaac-Renton, Alex Ho-Shing Chik & Bernadette Conant, *Ethics Guidance for Environmental Scientists Engaged in Surveillance of Wastewater for SARS-CoV-2*, 55 ENV'T. SCI. TECH. 8484, 8484 (2021), https://doi.org/10.1021/acs.est.1c00308 [https://perma.cc/WCX7-F8NV] (summarizing the results and recommendations of a group of experts convened by the Canadian Water Network that applies the WHO Guidelines to the ethics of wastewater surveillance for SARS-CoV-2.).

80. WORLD HEALTH ORG., *supra* note 78, at 21–22.

81. *Id.* at 21.

82. *Id.* at 25 ("Countries have an obligation to develop appropriate, feasible, sustainable public health surveillance systems. Surveillance systems should have a clear purpose and a plan for data collection, analysis, use and dissemination based on relevant public health priorities."); *id.* at 27 ("Countries have an obligation to develop appropriate, effective

detect and identify SARS-CoV-2 samples in wastewater appear to meet these criteria, at least in the context of their rapid creation in response to the serious and novel COVID-19 pandemic. Early detection of new COVID-19 outbreaks is a vital public health objective that remains necessary while the epidemic continues to spread and re-emerge in many communities. SARS-CoV-2 surveillance systems have a demonstrated potential to assist in this effort.[83] While the immediate public health purpose of SARS-CoV-2 surveillance is clear, many of the newly developed surveillance efforts have not made the details of their plans publicly available. These plans should, at a minimum, outline the processes for assessing the ethical or public health legitimacy of various possible uses of the data obtained through collection of wastewater samples. Furthermore, many of the publicly available plans have not articulated longer-term intentions for the ongoing operations and maintenance of these surveillance systems once the epidemic is under better control and the emergency circumstances have abated.[84]

Another key ethical principle addresses the quality and validity of the data.[85] The rapid development of methodologies for detection of SARS-CoV-2 has created a robust and evolving field of scientific inquiry. Nevertheless, as the surveillance work continues, scientists and technologists must continue to evaluate and refine the quality and validity of the data being collected and clearly ascertain the relationship between SARS-CoV-2 levels detected in wastewater and COVID-19 outbreaks in the population. Understanding the relationship between wastewater detection of SARS-CoV-2 virus and the magnitude of a potential COVID-19 outbreak has particular importance for determining whether the surveillance results will be considered sufficient justification for imposing, or removing, additional public health measures. Wastewater screening must have scientific validity before it may ethically be used for imposing restrictions such as movement restrictions or other community mitigation measures.

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mechanisms to ensure ethical surveillance."); *id.* at 29 ("Surveillance data should be collected only for a legitimate public health purpose.").

83. See *supra* Part I.

84. See *infra* section III.A.

85. WORLD HEALTH ORG., *supra* note 78, at 30 ("Countries have an obligation to ensure that the data collected are of sufficient quality, including being timely, reliable, and valid, to achieve public health goals.").

2. Equity

Equity—the notion that a just society must take steps to allow all humans to flourish even in the face of social inequality and disparate access to resources and health outcomes—constitutes an important cornerstone of ethical public health surveillance. Public health surveillance can and should collect, use, and disseminate information in a way that improves equity and reduces health disparities.

The inequitable effects of COVID-19 in the United States have been widely documented, with disproportionately high morbidity and mortality rates affecting Black and Indigenous populations.[86] These health disparities arise from many factors, including systemic racism and widespread, longstanding disinvestment in vulnerable communities.[87] Many of the initial government efforts to respond to the COVID-19 pandemic exacerbated these inequities.[88] Wastewater surveillance systems must be oriented toward health justice. In practice, this means that these systems must be scrutinized to ensure that collection, use, and dissemination of SARS-CoV-2 data do not impose additional unnecessary burdens on populations that are more vulnerable to disease or harm.[89] Advancing equity requires considering whether the release of surveillance

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86. *See, e.g.*, Eboni G. Price-Haywood, Jeffrey Burton, Daniel Fort & Leonardo Seoane, *Hospitalization and Mortality Among Black Patients and White Patients with Covid-19*, 382 NEW ENG. J. MED. 2534, 2534 (2020), https://doi.org/10.1056/NEJMsa2011686 [https://perma.cc/K8W9-3TSP]; Anneliese N. Luck, Samuel H. Preston, Irma T. Elo & Andrew C. Stokes, *The Unequal Burden of the Covid-19 Pandemic: Capturing Racial/Ethnic Disparities in US Cause-Specific Mortality*, SSM - POPULATION HEALTH, Dec. 22, 2021, at 1, https://doi.org/10.1016/j.ssmph.2021.101012 [https://perma.cc/WFH3-K8Q6]; Patricia K. Foo, Berenice Perez, Neha Gupta, Gerardo Jeronimo Lorenzo, Nana-Yaa Misa, Brissa Santacruz Gutierrez, Olivia Madison, U. Mini B. Swift & Erik S. Anderson, *High Rates of COVID-19 Infection Among Indigenous Maya at a US Safety-Net Health System in California*, 136 PUB. HEALTH REPS. 295, 295 (2021), https://doi.org/10.1177/0033354921990370 [https://perma.cc/8JJF-95CT]; Jessica Arrazola et al., *COVID-19 Mortality Among American Indian and Alaska Native Persons — 14 States, January–June 2020*, 69 MORBIDITY & MORTALITY WEEKLY REP. 1853, 1853 (2020), http://dx.doi.org/10.15585/mmwr.mm6949a3 [https://perma.cc/MP37-F3BC].

87. *See generally* Ruqaiijah Yearby & Seema Mohapatra, *Systemic Racism, the Government's Pandemic Response, and Racial Inequities in COVID-19*, 70 EMORY L.J. 1419 (2021) (applying the health justice framework to examine how systemic racism exacerbated health inequalities for racial and ethnic minorities during the COVID-19 response in the United States).

88. *Id.* at 1422.

89. WORLD HEALTH ORG., *supra* note 78, at 36 ("Surveillance of individuals or groups who are particularly susceptible to disease, harm or injustice is critical and demands careful scrutiny to avoid the imposition of unnecessary additional burdens.").

data is likely to generate discrimination or stigma towards groups in the communities or locations being evaluated.

Similarly, the selection of surveillance sites has complex equity implications. Targeting the creation of SARS-CoV-2 wastewater surveillance systems in higher-risk areas, or in areas with known congregate populations, may foster equity if this brings greater resources for detecting and addressing COVID-19 outbreaks in underserved populations, as long as necessary support is provided for members of these populations. Conducting wastewater surveillance within demographically diverse, well-sewered communities may also advance equity if it collects information equally from all individuals in the sewershed, regardless of differences due to race, class, utilization of health care systems for testing or vaccination, or employment. However, equity efforts may be undercut if the use of these surveillance data results in a disproportionate application of restrictive measures against members of surveilled versus non-surveilled communities, especially if additional support to help these communities is not forthcoming. Focusing surveillance on college and university campuses may concentrate resources on populations that are less vulnerable to COVID-19 morbidity and mortality compared with other affected communities, thereby potentially reducing overall equity. These considerations suggest that scientists and government officials who are planning and implementing SARS-CoV-2 wastewater screening systems should deliberately evaluate these and other factors to assess the equity implications of these surveillance systems.

3. Respect for Persons

Respect for persons—the core ethical consideration that recognizes and values individual interests and rights—represents yet another ethical foundation for public health surveillance. Public health surveillance systems must protect individuals and consider the effects of data collection, use, and dissemination on autonomy, privacy, bodily integrity, and other individual rights and interests.

Respect for persons underscores a number of important ethical precepts that correspond with individual rights and interests. Safeguarding individual privacy is foremost among these interests in the context of surveillance that collects health data, because collected information that can be linked to an individual's health status may be inappropriately disclosed.[90] Privacy violations can lead to discrimination and stigma, and can also result in a loss of trust and community support for public health measures.[91] Individually-identifiable health information should not be necessary to track potential new COVID-19 outbreaks, and SARS-CoV-2 wastewater surveillance programs should take care to mitigate against the development or use of such data. If surveillance data remains unidentifiable, the privacy risk to an individual from this surveillance does not override the potential public health benefit of more effectively tracking the epidemic and better targeting of testing and other resources.

Wastewater screening data for SARS-CoV-2 should remain anonymous and unlinkable to individuals. As wastewater screening technology and infrastructure develops, so does the likelihood that identifiable health data can be obtained through analysis of wastewater tests. If the wastewater screening site is sufficiently localized, such as samples obtained from a small catchment area or single building or facility, extra care must be applied to protect the health privacy of residents. Similarly, if advancement in technology permits individually-identifiable information to be ascertained—through genomic sequencing, for example—then the privacy risks increase dramatically. Linking a COVID-19 outbreak to a particular identifiable area or to a specific group of individuals could result in privacy violations, stigma, or discrimination.[92]

If public health officials or other authorities use data gathered through SARS-CoV-2 surveillance to implement restrictive or coercive measures to intervene and stop a localized outbreak, such actions could impose on autonomy, bodily integrity, freedom of movement, or other decisions otherwise under an individual's control. Such impositions are not inherently unethical, and these measures, which can include voluntary and compulsory testing, masking, quarantine and isolation, community-level movement restrictions, and other community mitigation requirements, may be

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90. *Id.* at 37 ("Governments and others who hold surveillance data must ensure that identifiable data are appropriately secured."); *id.* at 38 ("Under certain circumstances, the collection of names or identifiable data is justified."); *id.* at 40 ("Individuals have an obligation to contribute to surveillance when reliable, valid, complete data sets are required and relevant protection is in place. Under these circumstances, informed consent is not required.").

91. *See* Hrudey et al., *supra* note 79, at 8487.

92. McClary-Gutierrez et al., *supra* note 62, at e7 ("Data reporting standards could require exclusion of human genetic information and wastewater sample location information."); *see also infra* Part III.

justifiable if well-targeted toward stopping the spread of COVID-19. However, best practices suggest that any risks of harm or other impacts to individuals or communities should be identified and disclosed before surveillance is conducted, and these should be updated if new risks come to light.[93] Given the current uncertainties in the application of SARS-CoV-2 wastewater screening results, these results ordinarily should not justify coercive individual or community mitigation restrictions without subsequent additional investigation.[94]

Respect for persons entails an additional consideration in this context that links back to the common good justifications that undergird the surveillance system in the first place. Given the importance of developing surveillance systems with clear public health justifications, data gathered in SARS-CoV-2 wastewater surveillance systems should not ethically be used for purposes outside of public health.[95] Public health surveillance systems should affirmatively prohibit data from being misused for law enforcement purposes or other nonpublic health activities.[96]

4. Good Governance

Good governance is built upon the ethical principles of transparency, trust, accountability, veracity, community engagement, and cooperation. A public health surveillance system that strives to achieve good governance must operate openly and collaboratively foster broad-based community participation, accountable leadership, and accepted uses and stewardship of data collected through surveillance activities.

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93. WORLD HEALTH ORG., *supra* note 78, at 34 ("Those responsible for surveillance should identify, evaluate, minimize and disclose risks for harm before surveillance is conducted. Monitoring for harm should be continuous, and, when any is identified, appropriate action should be taken to mitigate it.").

94. Voluntary or compulsory testing might function as an appropriate means for accomplishing additional investigation, and therefore it may be appropriate in response to wastewater signals. Greater impositions may also be permissible in exceptional circumstances, for instance, where wastewater screening results indicated such high levels of SARS-CoV-2 that temporary immediate action to prevent COVID-19 spread would be necessary as additional testing of individuals was conducted.

95. WORLD HEALTH ORG., *supra* note 78, at 46 ("Personally identifiable surveillance data should not be shared with agencies that are likely to use them to take action against individuals or for uses unrelated to public health."). Some data sharing for purposes of research may be ethically appropriate and consistent with the public health purposes underlying the surveillance activities. *Id*. at 45 ("With appropriate justification and safeguards, public health agencies may use or share surveillance data for research purposes.").

96. *See infra* Part III.

Ethical good governance of wastewater surveillance systems requires deliberate and cooperative planning, transparency in collection processes and data disclosure, and community consultation and acquiescence.[97] Careful and cooperative planning of wastewater surveillance systems should precede the implementation of these systems. Presently, only some of the current SARS-CoV-2 wastewater surveillance systems have publicly outlined the scope and parameters of their activities. This paucity of publicly available information about the long-term prospects of these surveillance systems likely stems from their rapid assembly during the emergence of COVID-19 over the past two years. However, those who are supporting and operating wastewater surveillance systems—primarily public health officials and state leaders providing funding—should commit to clarifying the scope and parameters of the systems over the short and longer terms.

A thorough wastewater surveillance plan should not only identify the methods and frequency of sample collection, testing, and analysis, but also outline safety protocols for collection workers, and clear scientific methods that ensure data quality and validity. Once the data has been collected and analyzed, the surveillance plan should outline processes and policies about who receives the data, what constraints limit data sharing, and how and for how long the data is kept. For example, while local and state public health departments will usually take primary responsibility for tracking and disseminating the data, other interested parties may want to access this data as well.[98] The surveillance plan also should consider under what circumstances the data can be used as a justification to implement other public health measures. Further, the plan should address public access to the surveillance plans and protocols and the data collected through surveillance. Finally, the plan should explicitly identify benchmarks for when the surveillance program will be discontinued.

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97. WORLD HEALTH ORG., *supra* note 78, at 33 ("The values and concerns of communities should be taken into account in planning, implementing and using data from surveillance."); *id.* at 34 ("Those responsible for surveillance should identify, evaluate, minimize and disclose risks for harm before surveillance is conducted."); *id.* at 41 ("Results of surveillance must be effectively communicated to relevant target audiences."); *id.* at 44 ("During a public health emergency, it is imperative that all parties involved in surveillance share data in a timely fashion."); *id.* at 46 ("Personally identifiable surveillance data should not be shared with agencies that are likely to use them to take action against individuals or for uses unrelated to public health.").

98. For example, college and university leaders may want access to the data if the surveillance sites are located on their campuses, or management of a long-term care facility may seek this data if the surveillance site captures waste from their facility.

Development of a SARS-CoV-2 wastewater surveillance plan should incorporate both the expertise of public health officials and guidance from wastewater scientists who are conducting the surveillance and analysis. One persistent impediment to ethical implementation of SARS-CoV-2 testing has been gaps in communication and understanding between wastewater researchers and decision-makers at public health departments and universities.[99]

Equally important is seeking and receiving input from affected community members. Community engagement serves several purposes. First, community engagement in advance of implementing a new surveillance program enables those developing the program to understand and incorporate the values and concerns of the community into the processes that will guide how the data will be handled and used. Second, this process is an opportunity to educate community members about the proposed surveillance activities, and ideally, to get their assent for the program. Community assent is not required for public health surveillance, but obtaining assent is valuable and can form a foundation of trust and cooperation. Community engagement discussions also can alert community members to any risks of harm that could result both to those engaged in the data collection and use and to the population whose output is being measured. Such risks will likely be minimal for deidentified SARS-CoV-2 data. Third, this process, along with ongoing information sharing and opportunities for further discussion, can build and maintain essential community trust and support in the longer term for these public health efforts.

Transparency in both process and data dissemination comprise another aspect of good governance. Sharing deidentified surveillance results with other public health agencies has importance for epidemiological purposes, as well as for research and evaluation purposes.[100] Public release of deidentified surveillance data comports with ethical obligations of transparency and veracity. Public availability of the processes and protocols for wastewater sample collection and data uses promotes accountability. Moreover, transparency builds community trust and cooperation, both of which are vital to successful public health programs and better health

99. McClary-Gutierrez et al., *supra* note 62, at e1.

100. *See* WORLD HEALTH ORG., *supra* note 78, at 43 ("With appropriate safeguards and justification, those responsible for public health surveillance have an obligation to share data with other national and international public health agencies."); *id.* at 45 ("With appropriate justification and safeguards, public health agencies may use or share surveillance data for research purposes.").

outcomes. Timely information disclosure could also have the effect of providing a warning to residents of the surveilled areas of an emerging outbreak of cases before they would be detected by individual testing or by monitoring symptoms of affected people. All SARS-CoV-2 surveillance systems should make aggregated, deidentified data available to the public in a timely, regular, and accessible manner.

B. *Legal Implications of Wastewater Surveillance for SARS-CoV-2*

In our earlier work on this topic, we identified several legal issues that could arise from the collection and application of data obtained through SARS-CoV-2 wastewater surveillance.[101] While wastewater surveillance may implicate the Fourth Amendment, the collection of wastewater samples of SARS-CoV-2 is likely to be constitutionally permitted.[102]

A more complicated set of legal considerations attaches to the potential use of public health powers to implement interventions to mitigate the spread of COVID-19. Early in the pandemic, we discussed a range of possible public health interventions that might include voluntary, conditional, or mandatory testing of individuals for COVID-19; imposition of movement restrictions such as mandatory quarantine and isolation orders for individuals, or mass quarantines or cordons sanitaire for larger groups; and social distancing measures, such as business and school closures, movement restrictions, and gathering size limits.[103] Some of the more restrictive possible measures—mandatory testing, mass quarantines, and sanitary cordons—were not used in the COVID-19 response, and mandatory individual quarantine and isolation orders were used sparingly. Social distancing interventions, by contrast, were used in every state to varying degrees, along with widespread deployment of other community mitigation strategies such as mandatory physical distancing and face-covering requirements.[104]

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101. Gable et al., *supra* note 1, at 11.

102. *See infra* Part III.

103. Gable et al., *supra* note 1, at 8–11.

104. Lance Gable, *Distancing, Movement and Gathering Restrictions, and Business and Activity Control Measures*, *in* COVID-19 POLICY PLAYBOOK II: LEGAL RECOMMENDATIONS FOR A SAFER, MORE EQUITABLE FUTURE 33, 34–36 (Scott Burris, Sarah de Guia, Lance Gable, Donna E. Levin, Wendy E. Parmet & Nicholas P. Terry eds., 2021).

While often controversial, these social distancing measures were largely upheld in the face of constitutional challenges.[105]

Despite promises of its sentinel epidemiologic potential, wastewater screening does not seem to have been the impetus for the direct imposition of public health powers, aside from several examples, as described in Part I, where universities required students to undergo temporary quarantine and COVID-19 testing when wastewater sampled revealed a spike in SARS-CoV-2. Nevertheless, the legal validity of using wastewater surveillance data to justify the imposition of COVID-19 testing, quarantine or isolation orders for individuals, or social distancing or community mitigation orders is worth considering.

Public health officials could premise the imposition of conditional COVID-19 testing—with an alternative of quarantine—for all individuals in an affected area based on the detection of a heightened SARS-CoV-2 wastewater sample. Such a policy may raise First and Fourth Amendment concerns, as these individuals will have privacy, bodily integrity, and freedom of movement interests. If this situation were occurring in April 2020, courts would likely apply the special needs doctrine to uphold the testing requirement in the face of a Fourth Amendment challenge.[106] Likewise, requiring quarantine as an alternative option for those refusing testing would only be upheld so long as the public health officials could substantiate that quarantine serves a compelling public health purpose and was narrowly tailored to meet that purpose. The development of effective vaccines against the disease changes the underlying legal calculus for evaluating the use of public health powers. While the testing requirement may still meet the special needs doctrine threshold, imposing a quarantine order on an individual based on a wastewater signal alone is much less likely to meet the relevant constitutional standard.[107]

105. *Id.* at 35–37; *see, e.g.*, S. Bay United Pentecostal Church v. Newsom, 140 S. Ct. 1613, 1613 (2020) (upholding state authority to implement social distancing restrictions in response to COVID-19); Calvary Chapel Dayton Valley v. Sisolak, 140 S. Ct. 2603, 2603–04, 2615 (2020) (same); Hawse v. Page, No. 20cv588, 2020 U.S. Dist. LEXIS 82382, at *1–3, *13 (E.D. Mo. May 11, 2020) (same); McGhee v. City of Flagstaff, No. CV-20-08081, 2020 U.S. Dist. LEXIS 81369, at *1–2, *7–8, *17–18 (D. Ariz. May 8, 2020) (same). *But see* Tandon v. Newsom, 141 S. Ct. 1294, 1296–97 (2021) (prohibiting enforcement of California restrictions on private gatherings as applied to religious gatherings on Free Exercise grounds).

106. *See infra* section III.B.

107. The emergence of a new, more virulent strain of COVID-19 that evades vaccine protection, however, could change the legal calculus again.

The imposition of targeted social distancing or other community mitigation orders based on SARS-CoV-2 surveillance results are likely on firmer legal footing than public health orders targeted at individuals. Social distancing requirements, such as gathering size restrictions and person-to-person distancing and mitigation measures like mask-wearing, impose a relatively low burden balanced against a large public health upside. Even in a setting where many people are vaccinated, courts are likely to uphold a public health order that places reasonable restrictions designed to reduce the spread of COVID-19.

III. WASTEWATER SURVEILLANCE BEYOND COVID-19

Even as wastewater surveillance efforts have spun up in response to the COVID-19 pandemic, many involved in creating that infrastructure have had an eye on the future. After all, if such tools can detect COVID-19 in wastewater, what else can they detect, on what scale, and to what ends? This Part broadens our focus to consider the use of wastewater surveillance tools, techniques, and technology beyond the detection of SARS-CoV-2. Section A surveys the multiple applications of wastewater-based epidemiology beyond COVID-19. Section B then considers two possible secondary uses of wastewater surveillance that may raise legal and ethical difficulties: first, if wastewater surveillance is turned against individuals for criminal investigative purposes; second, if wastewater surveillance seeks medically sensitive data in the absence of a robust scientific basis and a well-justified plan of action in response to the data. Section C reflects on legally and ethically appropriate uses of wastewater surveillance, arguing that law enforcement or scientifically questionable wastewater surveillance programs may imperil public trust—an essential ingredient for successful public health efforts.

A. *Who Monitors for What?*

As set forth above, nearly every state has, by now, invested in SARS-CoV-2 wastewater surveillance efforts.[108] These programs

108. *See* Austin Osborne, *UAA Researchers Examine Wastewater to Assess COVID-19 Presence*, UNIV. OF ALASKA ANCHORAGE (Sept. 23, 2020), https://www.uaa.alaska.edu/news/archive/2020/09/covid-19-wastewater-testing-research.cshtml [https://perma.cc/TQL6-FUK6] (Alaska); *Wastewater Testing at UArizona Stops Coronavirus Spread; Garners National Attention*, UNIV. OF ARIZ. WATER & ENERGY SUSTAINABLE TECH. CTR. (Aug. 31, 2020), https://west.arizona.edu/news/2020/08/wastewater-testing-uarizona-stops-coronavirus-spre

ad-garners-national-attention [https://perma.cc/82Z5-Z66Z] (Arizona); Jaime Adame, *Project Tests for Covid-19 in Northwest Arkansas' Waste*, NW. ARK. DEMOCRAT GAZETTE (Sept. 28, 2020), https://www.nwaonline.com/news/2020/sep/28/project-tests-for-covid-19-in-waste [https://perma.cc/MV2L-U7XC] (Arkansas); *California Wastewater Utilities Participating in COVID Sewer Surveillance*, CAL. WATER ENV'T ASS'N, https://www.cwea.org/news/california-wastewater-utilities-participating-in-covid-19-sewer-surveillance [https://perma.cc/4QVM-WBAY] (California); *COVID-19 Monitoring in Wastewater*, COLO. DEP'T OF PUB. HEALTH & ENV'T (Jan. 27, 2021), https://covid19.colorado.gov/covid-19-monitoring-in-wastewater [https://perma.cc/8FF8-T4B5] (Colorado); YALE COVID-19 WASTEWATER TRACKER, https://yalecovidwastewater.com [https://perma.cc/2EP4-QFHX] (Connecticut); Dante LaPenta, *UD Researchers Study Wastewater to Detect COVID-19, Partner with New Castle County*, UNIV. OF DEL. (Jan. 15, 2021), https://www.udel.edu/udaily/2021/january/wastewater-testing-coronavirus-sewers-new-castle-county [https://perma.cc/T4FQ-AH4D] (Deleware); Marlowe Starling, *UF Researchers Turn to Sewage to Monitor COVID-19 on Campus*, HEALTH NEWS FLA. (Oct. 8, 2020, 8:01 AM), https://health.wusf.usf.edu/health-news-florida/2020-10-08/uf-researchers-turn-to-sewage-to-monitor-covid-19-on-campus [https://perma.cc/89RM-RUYM] (Florida); *Wastewater Surveillance for SARS-CoV-2 in Athens, GA*, CTR. FOR THE ECOLOGY OF INFECTIOUS DISEASES, UNIV. OF GA. (Apr. 7, 2022), https://www.covid19.uga.edu/wastewater-athens.html [https://perma.cc/LF8E-E8DG] (Georgia); Claire Caulfield, *UH Will Test Sewage at 11 Dorms This Fall to Help Prevent COVID-19 Outbreaks*, HONOLULU CIV. BEAT (June 11, 2021), https://www.civilbeat.org/2021/06/uh-will-test-sewage-at-11-dorms-this-fall-to-help-prevent-covid-19-outbreaks [https://perma.cc/C3KZ-KE8X] (Hawaii); *Current COVID-19 Wastewater Dashboard*, CITY OF BOISE (Apr. 6, 2022), https://www.cityofboise.org/departments/mayor/coronavirus-covid-19-information/wastewater-testing [https://perma.cc/AL2E-PZVT] (Idaho); *Illinois Department of Public Health and the Discovery Partners Institute Announce Statewide System to Monitor COVID-19 in Wastewater*, ILL. DEP'T OF PUB. HEALTH (May 24, 2021), https://dph.illinois.gov/resource-center/news/2021/may/illinois-department-public-health-and-discovery-partners-institute-announce-statewidesystem.html [https://perma.cc/A876-RYD7] (Illinois); ERICA WALKTER, KYLE BIBBY, ALEX PERKINS & JASE HIXSON, INDIANA WASTEWATER MONITORING PROGRAM: SAMPLING COMMUNITY SEWERSHEDS FOR SARS-COV-2 (2020), https://www.in.gov/ifa/files/Indiana-Wastewater-Monitoring-Report-2020.pdf [https://perma.cc/P59T-9Q7G] (Indiana); Press Release, City of Des Moines, Wastewater of over 500,000 Iowans Being Tested for COVID and Variants (July 26, 2021), https://www.dsm.city/news_detail_T2_R429.php [https://perma.cc/6HZ8-HF77] (Iowa); *Water & Waste*, KAN. DEP'T OF HEALTH & ENV'T, https://www.coronavirus.kdheks.gov/250/Water-Waste [https://perma.cc/RDC9-R4TY] (Kansas); *Co-Immunity Water Study*, UNIV. OF LOUISVILLE CHRISTINA LEE BROWN ENVIROME INST., https://louisville.edu/envirome/the-coimmunityproject/wastewater [https://perma.cc/R4MD-7WAU] (Kentucky); Samendra P. Sherchan, Shalina Shahin, Lauren M. Ward, Sarmila Tandukar, Tiong G. Aw, Bradley Schmitz, Warish Ahmed & Masaaki Kitajima, *First Detection of SARS-CoV-2 RNA in Wastewater in North America: A Study in Louisiana, USA*, 742 SCI. TOTAL ENV'T, June 30, 2020, at 1, 1, https://doi.org/10.1016%2Fj.scitotenv.2020.140621 [https://perma.cc/XGZ3-FJSS] (Louisiana); *Weekly Wastewater Sampling for the Presence of SARS-CoV-2*, UNIV. OF ME. SYS., https://www.maine.edu/together/wastewater [https://perma.cc/NM58-46YU] (Maine); *MDE Covid-19 Update*, MD. DEP'T OF THE ENV'T, https://mde.maryland.gov/Pages/MDE-COVID-19-Update.aspx [https://perma.cc/3A33-DKMB] (Maryland); *Wastewater COVID-19 Tracking*, MASS. WATER RES. AUTH. (Apr. 9, 2022), https://www.mwra.com/biobot/biobotdata.htm [https://perma.cc/9TBL-CW4T] (Massachusetts); *Wastewater Surveillance for COVID-19*, MICH. CORONAVIRUS, https://www.michigan.gov/coronavirus/0,9753,7-406-98163_98173-545439--,00.html [https://perma.cc/W3SY-THMV] (Michigan); Jeffrey L. Ram & William Shuster, *Wayne State University SARS CoV-2 Monitoring in the City of Detroit*, RAMLAB WSU, https://www.ramlabwsu.org/sars-cov-2-monitoring.html [https://perma.cc/NX26-V3PB] (Michigan); Kirsti Marohn, *Research: Scanning Wastewater Could Offer Advance Warning of COVID – or Other Viruses*, MPR NEWS (Mar. 5, 2021, 11:43 AM), https://www.mprnews.org/story/2021/03/05/research-scanning-wastewater-could-offer-advance-warning-of-covid-or-other-viruses [https://perma.cc/E73Z-

3XMC] (Minnesota); *The Sewershed Surveillance Project*, MO. DEP'T OF HEALTH & SENIOR SERVS. (Apr. 8, 2022), https://storymaps.arcgis.com/stories/f7f5492486114da6b5d6fdc07f81aacf [https://perma.cc/575E-AYWX] (Missouri); *Wastewater Testing and COVID-19*, HEALTHY GALLATIN, https://www.healthygallatin.org/coronavirus-covid-19/wastewater-data [https://perma.cc/9NNA-QJHG] (Montana); *Wastewater Testing for COVID-19 Could Help Predict Surges of the Virus*, DAUGHERTY GLOBAL INST. AT THE UNIV. OF NEB., https://waterforfood.nebraska.edu/resources/fy-2020-annual-report/research/faculty-fellow-research/wastewater-testing-for-covid-19-could-help-predict-surges-of-the-virus [https://perma.cc/7KM8-5WJL] (Nebraska); Natalie Bruzda, *Testing Wastewater for COVID-19*, UNIV. OF NEV., LAS VEGAS (Nov. 20, 2020), https://www.unlv.edu/news/release/testing-wastewater-covid-19 [https://perma.cc/PL3Q-HX2R] (Nevada); Geosyntec Consultants, Inc., *Using Sewage to Fight the Pandemic: Municipalities Find an Early Warning for SARS-CoV-2 Virus with Wastewater Monitoring*, N.H. MUN. ASS'N, https:// www.nhmunicipal.org/town-city-article/using-sewage-fight-pandemic-municipalities-find-early-warning-sars-cov-2-virus [https://perma.cc/M747-G5V8] (New Hampshire); Rodrigo Torrejon, *Sewage Test in N.J. County Looking to Catch COVID-19 Outbreaks 2 Weeks Ahead*, NJ (Nov. 20, 2020, 6:41 PM), https://www.nj.com/coronavirus/2020/11/sewage-test-in-nj-county-looking-to-catch-covid-19-outbreaks-2-weeks-ahead.html [https://perma.cc/LP2D-JB4X] (New Jersey); Press Release, Maddy Hayden, Commc'ns Dir., N.M. Env't Dep't, Fighting the Pandemic from the Sewers: COVID-19 Wastewater Surveillance Program Shows Early Success (Jan. 11, 2021), https://www.env.nm.gov/wp-content/uploads/2021/01/2021-01-11-Wastewater-surveillance-program-early-success-1.pdf [https://perma.cc/H7L7-R8R5] (New Mexico); *COVID-19 Wastewater Testing*, N.Y.C. ENV'T PROT., https://www1.nyc.gov/site/dep/whats-new/covid-19-wastewater-testing.page [https://perma.cc/89T3-HNMK] (New York); *Wastewater Monitoring*, N.C. DEP'T OF HEALTH & HUM. SERVS., https://covid19.ncdhhs.gov/dashboard/wastewater-monitoring [https://perm a.cc/KD2W-85FR] (North Carolina); Renee Cooper, *North Dakota Begins Testing Sewage for COVID-19 Variants*, KX NEWS (Apr. 7, 2021, 9:53 PM), https://www.kxnet.com/news/local-news/north-dakota-begins-testing-sewage-for-covid-19-variants [https://perma.cc/84ZA-5EF6] (North Dakota); *Ohio Coronavirus Wastewater Monitoring Network*, OHIO DEP'T OF HEALTH (Apr. 7, 2022), https://coronavirus.ohio.gov/dashboards/other-resources/wastewater [https://perma.cc/2B3U-Z47N] (Ohio); Dale Denwalt, *Yes, Scientists Are Studying Your Poop to Track New COVID-19 Variants. Here's How It Works*, OKLAHOMAN (Apr. 11, 2021, 6:01 AM), https://www.oklahoman.com/story/business/2021/04/11/oklahoma-scientists-use-sewage-to-track-spread-covid-19-variants/7122772002 [https://perma.cc/A427-BCEX] (Oklahoma); Monica Samayoa & Jes Burns, *How Sewage Led Researchers to Contagious COVID-19 Variant in Central Oregon*, OR. PUB. BROAD. (Jan. 29, 2021, 8:01 PM), https://www.opb.org/article/2021/01/29/oregon-coronavirus-variants-uk-south-africa-wastewater-testing [https://perma.cc/XZ5Y-ULKE] (Oregon); Sara LaJeunesse, *Wastewater Sampling May Give Advanced Warning of Potential COVID-19 Outbreaks*, PENNSTATE (Sept. 20, 2020), https://www.psu.edu/news/research/story/wastewater-sampling-may-give-advanced-warning-potential-covid-19-outbreaks [https://perma.cc/948 Z-PKLN] (Pennsylvania); *How Much Virus Is in the Water? Narragansett Bay Commission Participates in National COVID-19 Study*, GOLOCALPROV (Jan. 24, 2021), https://www.golocalprov.com/news/How-Much-Virus-Is-in-the-Water-Narragansett-Bay-Commission-Participates-in [https://perma.cc/3G4N-U6WE] (Rhode Island); *COVID-19 Wastewater Dashboard*, CLEMSON UNIV. (Apr. 7, 2022), https://www.clemson.edu/covid-19/testing/wastewater-dashboard.html [https://perma.cc/8CC5-T6TA] (South Carolina); *SDARWS COVID-19 (Coronavirus) Updates*, S.D. ASS'N OF RURAL WATER SYS. (Mar. 26, 2020), http://www.sdarws.com/covid-19-update.html [https://perma.cc/QMJ2-VYVU] (South Dakota); Kirstie Crawford, *University of Tennessee COVID-19 Wastewater, Saliva Sampling Testing Underway*, WATE (Sept. 24, 2020, 8:02 AM), https://www.wate.com/news/university-of-tennessee-covid-19-wastewater-saliva-sampling-testing-underway [https://perma.cc/NUH7-TU5E] (Tennessee); *Wastewater Surveillance for SARS-CoV-2 in Bexar County, TX*, KAPOOR LAB, https://ceid.utsa.edu/vkapoor/research/wastewater-covid [https://perma.cc/JN9E-JW9J] (Texas); *SARS-CoV-2 Sewage Monitoring*, UTAH DEP'T OF ENV'T QUALITY (Feb. 16, 2022, 9:36 AM), https://deq.utah.gov/water-quality/sars-cov-2-sewage-monitoring [https://perma.cc/C9ZE-TRDL] (Utah); Katharine vary widely in their scope, funding, and funding source.[109] But nearly all share at least one feature in common: publicly available information discloses no termination date for these surveillance programs.[110] Indeed, the few programs that identify tentative end dates tie those dates to the duration of existing grant funding.[111] This suggests that money drives the duration of these programs, rather than any determination that ending such programs is legally or ethically necessary or appropriate. Alternatively, political considerations may drive wastewater surveillance programs to justify their existence in other ways, including by monitoring for other substances or for other purposes.

These additional uses are many. First, wastewater monitoring for other viral surveillance was already in use before the pandemic. For instance, in one oft-cited precedent of wastewater monitoring for polio virus, detection of that virus in wastewater in Israel prompted a massive vaccination campaign to control an outbreak.[112] Tempe, Arizona, has used wastewater to monitor for influenza virus and plans to test its use for monitoring for other viruses, such as measles.[113] Researchers have suggested that these

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Huntley, *Burlington Wastewater Testing Finds UK Variants of COVID*, WCAX (Feb. 11, 2021, 4:44 PM), https://www.wcax.com/2021/02/11/burlington-wastewater-testing-finds-uk-variants-of-covid [https://per ma.cc/8ZKB-2GRJ] (Vermont); *Wastewater Surveillance Sentinel Monitoring Program*, VA. DEP'T OF HEALTH, https://www.vdh.virginia.gov/environmental-health/wastewater-surveillance-for-covid-19 [https://perma.cc/H3QW-22AN] (Virginia); Callie Craighead, *University of Washington Tests Wastewater to Track COVID-19 Outbreaks in Seattle Neighborhoods*, URBAN@UW (Jan. 16, 2021), https://urban.uw.edu/news/wastewater-track-covid19 [https://perma.cc/QP8L-LHTA] (Washington); Jessica Lilly, *Marshall Researchers Test for COVID-19 in Wastewater Samples*, W. VA. PUB. BROAD. (Apr. 20, 2021, 4:11 PM), https://www.wvpublic.org/health-science/2021-04-20/marshall-researchers-test-for-covid-19-in-wastewater-samples [https://perma.cc/4WYS-C2ZS] (West Virginia); *COVID-19: Wisconsin Coronavirus Wastewater Monitoring Network*, WIS. DEP'T OF HEALTH SERVS. (Mar. 28, 2022), https://www.dhs.wisconsin.gov/covid-19/wastewater.htm [https://perma.cc/NT5J-3Y3F] (Wisconsin); *Wyoming COVID-19 Wastewater Monitor*, WYO. PUB. HEALTH LAB'Y, https://covidwastewatermonitor.wyo.gov [https://perma.cc/86QK-JECB] (Wyoming); Andrew Giambrone, *D.C. Will Study Its Sewage to Find Clues of COVID-19 Hotspots*, DCIST (Dec. 16, 2020, 11:44 AM), https://dcist.com/story/20/12/16/dc-water-covid19-hotspots-waste water-study-hhs [https://perma.cc/4NY4-PY9D] (District of Columbia). At this time, there is no evidence of such research in Alabama and Mississippi.

109. *See* sources cited *supra* note 108.

110. *See* sources cited *supra* note 108.

111. *See, e.g.*, Press Release, Mich. Dep't of Health & Hum. Servs., *supra* note 17 (identifying July 31, 2023, as the end date on the "[t]imeline of COVID-19 wastewater surveillance activities in Michigan" and noting that there is "[f]unding for this project . . . through July 31, 2023").

112. Brouwer et al., *supra* note 4, at E10625–26.

113. *See* Megan Molteni, *Sewage Sleuths Helped an Arizona Town Beat Back Covid-19. For Wastewater Epidemiology, That's Just the Start*, STAT (June 16, 2021), https://www.statnews.com/2021/06/16/sewage-sleuths-helped-an-arizona-town-beat-back-covid-19-for-wastewater-epidemiology-thats-just-the-start [https://perma.cc/5ULD-G7VQ].

technologies could be applied to other viral targets as well. Hepatitis A virus in wastewater correlates with case levels in the community, for example, suggesting that wastewater monitoring for this virus could provide actionable information for public health officials.[114] Hepatitis E virus, norovirus, astrovirus, and others can also be detected in wastewater.[115] Many other viruses have been detected in wastewater[116] and suggested as candidates for "routine monitoring."[117]

Wastewater surveillance of nonbiological targets, such as illicit drugs and pharmaceuticals, have also been proposed and in some cases implemented. These applications use the same sample collection infrastructure but different analytical methods. Even before COVID-19 arrived in the United States, Tempe, Arizona, had already deployed wastewater surveillance to detect opioid use on a "neighborhood-by-neighborhood" basis.[118] More recently, the city expanded its routine wastewater surveillance efforts to include monitoring for "molecular traces of . . . alcohol, asthma medications, and stress hormones, and biomarkers of exposure to toxic fumes like benzene."[119] Several European projects have also employed wastewater monitoring of opioids as a means to target drug-control efforts.[120] Cannabis products have been monitored in wastewater to determine the impact of legalization.[121] More

114. C. McCall, H. Wu, E. O'Brien & I. Xagoraraki, *Assessment of Enteric Viruses During a Hepatitis Outbreak in Detroit MI Using Wastewater Surveillance and Metagenomic Analysis*, 131 J. APPLIED MICROBIOLOGY 1539, 1540 (2021), https://doi.org/10.1111/jam.15027 [https://perma.cc/U5DY-7EGS].

115. Hao Wang, Julianna Neyvaldt, Lucica Enache, Per Sikora, Ann Mattsson, Anette Johansson, Magnus Lindh, Olof Bergstedt & Helene Norder, *Variations Among Viruses in Influent Water and Effluent Water at a Wastewater Plant over One Year as Assessed by Quantitative PCR and Metagenomics*, APPLIED & ENV'T MICROBIOLOGY, Dec. 2020, at 2, https://doi.org/10.1128/AEM.02073-20 [https://perma.cc/264R-PQE7]; McCall et al., *supra* note 114, at 1539.

116. *See* Camille McCall, Huiyun Wu, Brijen Miyani & Irene Xagoraraki, *Identification of Multiple Potential Viral Diseases in a Large Urban Center Using Wastewater Surveillance*, WATER RSCH., Oct. 1, 2020, at 1, 1–2, https://doi.org/10.1016/j.watres.2020.116160 [https://perma.cc/6RM3-YTJY].

117. Wang et al., *supra* note 115, at 9.

118. *See* Molteni, *supra* note 113.

119. *Id.*

120. *Monitoring 2020*, SCORE, https://score-cost.eu/monitoring2020 [https://perma.cc/L6ZL-8RZ7]; *The Primary Role of microMole*, MICROMOLE, http://micromole.eu/#about [https://perma.cc/E9GE-8P65].

121. Daniel A. Burgard et al., *Using Wastewater-Based Analysis to Monitor the Effects of Legalized Retail Sales on Cannabis Consumption in Washington State, USA*, 114 ADDICTION 1582, 1582–83 (2019).

generally, Sims and Kasprzyk-Hordern,[122] have noted an even broader range of targets and community objectives, including monitoring for markers related to cannabinoids, opioids, heroin, cocaine and methamphetamines,[123] alcohol consumption,[124] tobacco use,[125] and metabolism of psychoactive substances.[126] Oxidative stress markers have been suggested as markers that reflect general community health.[127] Research using wastewater measurements, which could lead to their application in surveillance, have

122. Natalie Sims & Barbara Kasprzyk-Hordern, *Future Perspectives of Wastewater-Based Epidemiology: Monitoring Infectious Disease Spread and Resistance to the Community Level*, ENV'T INT'L, June 2020, at 4, https://doi.org/10.1016/j.envint.2020.105689 [https://perma.cc/B4J4-RS4Y].

123. Sara Castiglioni, et al., *supra* note 7, at 8421; M. Rosa Boleda, M. Teresa Galceran & Francesc Ventura, *Trace Determination of Cannabinoids and Opiates in Wastewater and Surface Waters by Ultra-Performance Liquid Chromatography-Tandem Mass Spectrometry*, 1175 J. CHROMATOGRAPHY A 38, 38–39 (2007); Barbara Kasprzyk-Hordern, Richard Dinsdale & Alan J. Guwy, *Multiresidue Methods for the Analysis of Pharmaceuticals, Personal Care Products and Illicit Drugs in Surface Water and Wastewater by Solid-Phase Extraction and Ultra Performance Liquid Chromatography–Electrospray Tandem Mass Spectrometry*, 391 ANALYTICAL & BIOANALYTICAL CHEMISTRY 1293, 1293–94 (2008).

124. Malcolm J. Reid, Katherine H. Langford, Jørg Mørland & Kevin V. Thomas, *Analysis and Interpretation of Specific Ethanol Metabolites, Ethyl Sulfate, and Ethyl Glucuronide in Sewage Effluent for the Quantitative Measurement of Regional Alcohol Consumption*, 35 ALCOHOLISM: CLINICAL & EXPERIMENTAL RSCH. 1593, 1593 (2011); Tim Boogaerts, Adrian Covaci, Juliet Kinyua, Hugo Neels & Alexander L.N. van Nuijs, *Spatial and Temporal Trends in Alcohol Consumption in Belgian Cities: A Wastewater-Based Approach*, 160 DRUG & ALCOHOL DEPENDENCE 170, 171 (2016); Yeonsuk Ryu et al., *Increased Levels of the Oxidative Stress Biomarker 8-Iso-Prostaglandin $F_{2\alpha}$ in Wastewater Associated with Tobacco Use*, SCI. REPS., Dec. 15, 2016, at 1–2, https://www.doi.org/10.1038/srep39055 [https://perma.cc/K9MH-6T23].

125. Tania Rodríguez-Álvarez, Rosari Rodil, María Rico, Rafael Cela & José Benito Quintana, *Assessment of Local Tobacco Consumption by Liquid Chromatography–Tandem Mass Spectrometry Sewage Analysis of Nicotine and Its Metabolites, Cotinine and Trans-3′-Hydroxycotinine, After Enzymatic Deconjugation*, 86 ANALYTICAL CHEMISTRY 10274, 10274 (2014), https://doi.org/10.1021/ac503330c [https://perma.cc/7W3E-HY9Y]; Sara Castiglioni, Ivan Senta, Andrea Borsotti, Enrico Davoli & Ettore Zuccato, *A Novel Approach for Monitoring Tobacco Use in Local Communities by Wastewater Analysis*, 24 TOBACCO CONTROL 38, 38 (2015), https://doi.org/10.1136/tobaccocontrol-2014-051553 [https://perma.cc/66U5-TUKU]; Ryu et al., *supra* note 124, at 1–2; Foon Yin Lai, Frederic Been, Adrian Covaci & Alexander L.N. van Nuijs, *Novel Wastewater-Based Epidemiology Approach Based on Liquid Chromatography–Tandem Mass Spectrometry for Assessing Population Exposure to Tobacco-Specific Toxicants and Carcinogens*, 89 ANALYTICAL CHEMISTRY 9268, 9268 (2017), https://doi.org/10.1021/acs.analchem.7b02052 [https://perma.cc/REF7-CVTS].

126. Juliet Kinyua, Adrian Covaci, Walid Maho, Ann-Kathrin McCall, Hugo Neels & Alexander L.N. van Nuijs, *Sewage-Based Epidemiology in Monitoring the Use of New Psychoactive Substances: Validation and Application of an Analytical Method Using LC-MS/MS*, 7 DRUG TESTING & ANALYSIS 812, 812–17 (2015), https://doi.org/10.1002/dta.1777 [https://perma.cc/8LCT-NYJR].

127. Ryu et al., *supra* note 124, at 1–2; Natalie Sims, Jack Rice & Barbara Kasprzyk-Hordern, *An Ultra-High-Performance Liquid Chromatography Tandem Mass Spectrometry Method for Oxidative Stress Biomarker Analysis in Wastewater*, 411 ANALYTICAL & BIOANALYTICAL CHEMISTRY 2261, 2261–62 (2019), https://doi.org/10.1007/s00216-019-01667-8 [https://perma.cc/DF2T-WPZG].

correlated the presence of metformin (prescribed to upwards of eighty percent of type 2 diabetes patients, depending on region) in wastewater to population levels of diabetes.[128]

Meanwhile, private enterprise has also entered the field. Aquavitas, a private company seeking to promote wastewater surveillance, explains that it has "examined hundreds of chemical and biological agents in municipal wastewater, including narcotics, opiates, influenza, SARS-CoV-2, stress hormones, alcohol and nicotine."[129] All this, the company exhorts, can assist "public, private, corporate and government entities to protect human health, maximize productivity and minimize risk and liability."[130] The company's CEO reports that one city expressed interest in "monitoring for molecules that people with Alzheimer's disease shed into their blood and urine. Another one is interested in cancer. One client, a private high school with a strict vegetarian diet policy, contracted Aquavitas to look for signs their students were sneaking animal products on the sly."[131]

In sum, COVID-19 may have been the instigator for substantial investments in wastewater surveillance infrastructure, but that is unlikely to be its only use. Few of the new programs established since the COVID-19 pandemic began have clearly articulated plans for their termination or clearly stated restrictions barring other use of their infrastructure. The introduction of private, for-profit entities as well as a host of local, state, regional, and national government efforts presage a long term, and growing, role for wastewater surveillance.

B. *Deliberating About Downstream Uses*

In light of the broad range of uses to which wastewater surveillance may be put, legal and ethical analysis of secondary uses of wastewater surveillance infrastructure and data is urgently

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128. Xiao et al., *supra* note 6, at 281–86; Yuexin Tang, Tracey Weiss, Jinan Liu, Swapnil Rajpathak & Kamlesh Khunti, *Metformin Adherence and Discontinuation Among Patients with Type 2 Diabetes: A Retrospective Cohort Study*, J. CLINICAL & TRANSLATIONAL ENDOCRINOLOGY, June 2020, at 1, https://dx.doi.org/10.1016%2Fj.jcte.2020.100225 [https://perma.cc/B5TK-ZKXL].

129. *About Aquavitas*, AQUAVITAS, https://aquavitas.com/about [https://perma.cc/HZG5-38VV]. Aquavitas is not the only private, for-profit company selling wastewater monitoring technology and services. Another is Biobot Analytics. *See About – Biobot*, BIOBOT, https://biobot.io/about [https://perma.cc/2TZE-EZ54].

130. *About Aquavitas*, *supra* note 129.

131. Molteni, *supra* note 113.

needed. This section considers constitutional constraints on wastewater surveillance programs serving two different kinds of purposes: for law enforcement use and for public health or wellness purposes.[132]

Wastewater surveillance may raise constitutional concerns as the data it generates becomes more granular and individualized.[133] Current wastewater surveillance in the United States and Europe for illicit drugs raises the specter of law enforcement encroachment into this public health space.[134] The European Union's microMole project is closely on point.[135] This effort is designed to "track down the production of illicit substances by being installed in the sewage systems."[136] As its creators candidly explain, the "primary role of microMole is to aid law enforcement in investigating crime related to the production of synthetic drugs" through "continuous examination of wastewater flow."[137] The temptation to repurpose public health surveillance tools for law enforcement goals may well be substantial.

Yet such use might impinge on constitutionally protected privacy rights. The Fourth Amendment of the U.S. Constitution guarantees the "right of the people to be secure in their persons, houses, papers, and effects, against unreasonable searches and seizures."[138] Ordinarily, the government must obtain a warrant, supported by probable cause, before conducting a search intended to discover evidence of criminal conduct.[139] But not all government

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132. These two categories of goals are not always entirely distinct. In some instances, they may overlap, as where a city conducts wastewater monitoring for opioid use, which may inform both public efforts to treat or respond to drug addiction, as well as law enforcement efforts to identify and prosecute illicit drug users. Moreover, particularly in the absence of robust regulation, data generated for one purpose may be made available for another.

133. In addition, wastewater surveillance may implicate statutory protections when undertaken by private (or public) entities, for instance, under the Americans with Disabilities Act of 1990, 42 U.S.C. § 12112 (prohibiting employment discrimination on the basis of disability), the Genetic Information Non-Discrimination Act of 2008, 42 U.S.C. § 2000ff–1(a) (prohibiting employment discrimination because of genetic information), or other laws. But as most wastewater surveillance related to COVID-19 is currently conducted by public entities, this Article focuses on possible Fourth Amendment pitfalls to these efforts.

134. *See* Molteni, *supra* note 113; Joh, *supra* note 1, at 236–37.

135. *See* MICROMOLE, http://micromole.eu/#home [https://perma.cc/CVY7-CV7V]; *see also* Joh, *supra* note 1, at 236.

136. *The Main Objective of microMole,* MICROMOLE, https://micromole.eu/#about [https://perma.cc/HPL3-PEEF].

137. *Id.*

138. U.S. CONST. amend. IV.

139. *See* Carpenter v. United States, 138 S. Ct. 2206, 2221 (2018) (quoting Vernonia Sch. Dist. 47J v. Acton, 515 U.S. 646, 652–53 (1995)) ("Although the 'ultimate measure of the

efforts to ferret out unlawful conduct amount to a search. Rather, the Supreme Court of the United States has explained that the government engages in a "search" when the place, thing, or information that the government seeks to examine is one in which an individual has an "expectation of privacy . . . 'that society is prepared to recognize as reasonable.'"[140] In the absence of a reasonable expectation of privacy, the Court has held, no search has occurred.

Typically, courts assessing wastewater surveillance in the context of the Fourth Amendment have concluded that there is no reasonable expectation of privacy in wastewater "irretrievably flowing into the public sewer."[141] In *Riverdale Mills Corp. v. Pimpare*, the First Circuit likened wastewater that would soon join the public sewer to garbage left on the curb for municipal collection.[142] The Supreme Court has held that individuals may claim no reasonable expectation of privacy in the latter, as any expectation will have been abandoned along with the trash at the curbside.[143] Other wastewater cases have relied on *Riverdale Mills* to reach similar conclusions.[144]

But these cases have not precluded all such expectations of privacy. The cases have largely involved searches of corporate wastewater related to enforcement of environmental regulations, which may impact the expectations of privacy analysis. In *Riverdale Mills*, for instance, the court noted that "[t]he commercial context is relevant; this may reduce Riverdale's expectation of privacy somewhat."[145] Similarly, in *Every v. Town of Littleton*, the court explained that "[t]he Supreme Court has held that an 'owner

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constitutionality of a governmental search is "reasonableness,"' our cases establish that warrantless searches are typically unreasonable where 'a search is undertaken by law enforcement officials to discover evidence of criminal wrongdoing.'").

140. *Id.* at 2213 (quoting Smith v. Maryland, 442 U.S. 735, 740 (1979) (quoting Katz v. United States, 389 U.S. 347, 361 (1967) (Harlan, J., concurring))).

141. Riverdale Mills Corp. v. Pimpare, 392 F.3d 55, 64 (1st Cir. 2004) (emphasis omitted); *see also* United States v. Spain, 515 F. Supp. 2d 860, 865 (N.D. Ill. 2007); United States v. Hajduk, 396 F. Supp. 2d 1216, 1225 (D. Colo. 2005) (holding that defendants had no reasonable expectation of privacy in their wastewater flowing into a public sewer).

142. *See* 392 F.3d at 64.

143. *See* California v. Greenwood, 486 U.S. 35, 40–41 (1988).

144. *See Spain*, 515 F. Supp. 2d at 865–66; *Hajduk*, 396 F. Supp. 2d at 1225–26; *see also* Every v. Town of Littleton, 380 F. Supp. 3d 173, 179 (D.N.H. 2019) (holding that defendant lacked standing to assert's corporation's Fourth Amendment rights but opining that *Riverdale Mills* strongly suggests that there was no cognizable expectation of privacy regardless).

145. *See* 392 F.3d at 64; *see also Hajduk*, 396 F. Supp. 2d at 1226 (finding *Riverdale Mills* persuasive and explaining that the expectations of privacy analysis "depends on a variety of factors, including . . . whether the premises are residential or commercial").

or operator of a business has an expectation of privacy in commercial property,' but that expectation 'is different from, and indeed less than, a similar expectation in an individual's home.'"[146] If wastewater surveillance efforts seek data about natural persons in the course of criminal investigations (say regarding illicit drug use observable in wastewater), the expectations of privacy analysis might look different.

Moreover, recent judicial solicitude for Fourth Amendment claims in inescapably shared, yet deeply sensitive, personal data may suggest that the analogy to garbage left at the curbside is inapposite. The Supreme Court has recognized that the collection and analysis of biological samples—including urine—intrude upon reasonable expectations of privacy and thus constitute searches governed by the Fourth Amendment.[147] Does the fact that wastewater surveillance collects that biological sample from the sewer rather than at its source render an expectation of privacy unreasonable? The Supreme Court has recently suggested that the answer may be "no."

In *Carpenter v. United States*, the Supreme Court explained that the Fourth Amendment requires the government to obtain a warrant to gain access to individuals' cell phone location data from their cell phone providers.[148] Although cell phone location data may seem far removed from wastewater data, the Court's analysis in *Carpenter* is instructive. The Court had long maintained that information voluntarily conveyed to another, like matter discarded in the trash, is devoid of any reasonable expectation of privacy.[149] But in *Carpenter*, the Court held that cell phone location data is different.[150] Among other features, the Court emphasized that this data is both deeply sensitive (revealing the whole of one's personal movements) and not genuinely voluntarily shared (in view of the ubiquity and necessity of the modern cell phone).[151] Our

146. 380 F. Supp. 3d at 179.

147. *See* Vernonia Sch. Dist. 47J v. Acton, 515 U.S. 646, 652 (1995) ("[S]tate-compelled collection and testing of urine . . . constitutes a 'search' subject to the demands of the Fourth Amendment."); Nat'l Treasury Emps. Union v. Von Raab, 489 U.S. 656, 665 (1989) (holding that urine tests are searches); Skinner v. Ry. Lab. Execs. Ass'n, 489 U.S. 602, 617 (1989) (holding that urine tests are searches).

148. *See* 138 S. Ct. 2206, 2220–21 (2018).

149. *See* Smith v. Maryland, 442 U.S. 735, 745–46 (1979); United States v. Miller, 425 U.S. 435, 440 (1976); Natalie Ram, *Genetic Privacy After* Carpenter, 105 VA. L. REV. 1357, 1369–70 (2019) (describing the genesis of the "third party" doctrine).

150. *See* 138 S. Ct. at 2217.

151. *Id.* at 2217–20.

contributions to wastewater are similarly sensitive and inescapable.[152] Nearly eighty percent of U.S. households are connected to municipal sewer systems,[153] and both by biology and by law, individuals must use the bathroom several times each day.[154] Thus, courts should recognize that wastewater surveillance of natural persons may raise significant Fourth Amendment concerns.

Another feature of wastewater surveillance that may affect the Fourth Amendment analysis is that it typically occurs on a population-wide basis, in which data about any single individual's input is irretrievably mixed with data about others.[155] In one sense, this population-wide surveillance might raise additional concerns, as it creates a "too permeating" form of "surveillance."[156] In another sense, however, this population-level data collection could negate the Fourth Amendment's applicability. Irretrievable aggregate data, in theory, poses little risk to individual privacy because little individualized information is discernible.

But wastewater surveillance is not inherently or necessarily aggregate in the data it discloses. As cases like *Riverdale Mills* indicate, individual signals can be obtained.[157] Moreover, as wastewater surveillance proliferates, sampling areas are likely to become smaller and their data more granular. Private companies engaged in wastewater surveillance already tout the increasing granularity of their data. For instance, "[a]nalyzing wastewater before it converges and mixes downstream at treatment facilities permits Biobot to measure drug use of not only an entire city but also of specific locations, down to areas of a few thousand people."[158] Similarly, Aquavitas has disclosed a proposal for monitoring for animal proteins in the wastewater of a single school, suggesting

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152. *See* Joh, *supra* note 1, at 238–39 (drawing on *Carpenter* to suggest that wastewater monitoring may well constitute a "search" under the Fourth Amendment).

153. *See A New Public Health Tool*, *supra* note 9 ("Nearly 80 percent of United States households are served by municipal sewage collection systems.").

154. *See* Taunya Lovell Banks, *The Disappearing Public Toilet*, 50 SETON HALL L. REV. 1061, 1073–74 (2020) (describing the criminalization of public urination).

155. *See* Prichard et al., *supra* note 69, at 551 (observing that "[r]elated domains of human research ethics provide little guidance . . . because the intermingled urine of many [thousands] of people cannot be used to identify individual [data]"). An exception might be if the government sought to identify a particular individual human's DNA in wastewater, rather than a signal of a nonhuman target.

156. *Carpenter*, 138 S. Ct. at 2214.

157. *See generally* Riverdale Mills Corp. v. Pimpare, 392 F.3d 55 (1st Cir. 2004).

158. Justin Chen, *Scientists Can Track the Spread of Opioids in Sewers. But Do Cities Want to Know What Lies Below?*, STAT (June 26, 2018), https://www.statnews.com/2018/06/26/wastewater-epidemiology-biobot-opioids [https://perma.cc/KX9P-6ETU].

that small scale data may be realizable—and with the ability to identify rule breakers.[159]

Existing COVID-19 wastewater programs also suggest that single block or even single building surveillance is within the reach of current efforts. As described above, existing monitoring already approaches this level, including wastewater monitoring of sewersheds containing as few as 100 people.[160] Other examples are similar. Louisiana State University ordered members of fraternities and sororities with houses on its Sorority Row to undergo COVID-19 testing after its wastewater monitoring detected "high traces" of the virus sampled nearby.[161] Somewhere along the spectrum from an entire wastewater treatment plant drainage system, to a neighborhood sewershed, to a nursing home or meat processing plant, to a single home, wastewater surveillance may well disclose sufficiently individualized information to implicate the Fourth Amendment.[162]

Even in instances where wastewater surveillance may constitute a Fourth Amendment search, the purpose of the search may affect its appropriateness. The Supreme Court has distinguished between searches conducted pursuant to "the State's general interest in law enforcement" and those justified by "special need[s]" divorced from such interests.[163] For the former, a warrant is typically

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159. *See* Molteni, *supra* note 113.

160. *See* RAM LAB WSU, *supra* note 29.

161. *See* Jeremy Krail, *Several LSU Greek Chapters Must Test for COVID After 'High Traces' of Virus Found in Wastewater System*, WBRZ (Aug. 18, 2021), https://www.wbrz.com/news/several-lsu-greek-chapters-must-test-for-covid-after-high-traces-of-virus-found-in-wastewater-system [https://perma.cc/T2QW-RS22].

162. *See, e.g.*, Gable et al., *supra* note 1; Christopher L. Hering, Note, *Flushing the Fourth Amendment Down the Toilet: How Community Urinalysis Threatens Individual Privacy*, 53 ARIZ. L. REV. 741 (2009) (arguing that at least some uses of community urinalysis technology should be deemed a Fourth Amendment search). Indeed, within the ethics literature, "[i]t is generally accepted that populations [greater than] 10,000 [are] enough to give anonymity and will pose no risk to smaller groups of people." Sims & Kasprzyk-Hordern, *supra* note 115, at 9; *see also* Jake W. O'Brien et al., *A National Wastewater Monitoring Program for a Better Understanding of Public Health: A Case Study Using the Australian Census*, 122 ENV'T. INT'L 400, 403 (2019) (observing that wastewater studies "involving small populations require risk mitigation strategies to meet ethical considerations").

163. Ferguson v. City of Charleston, 532 U.S. 67, 79 (2001); *see also id.* at 88 (Kennedy, J., concurring) ("The traditional warrant and probable-cause requirements are waived in our previous cases on the explicit assumption that the evidence obtained in the search is not intended to be used for law enforcement purposes."); Chandler v. Miller, 520 U.S. 305, 314 (1997) (explaining that the "special needs" cases require searches to be justified by "concerns other than crime detection"); Skinner v. Ry. Lab. Execs. Ass'n, 489 U.S. 602, 619 (1989) (permitting programmatic, suspicionless searches where justified by "special needs, beyond the normal need for law enforcement" (quoting Griffin v. Wisconsin, 483 U.S. 868, 873 (1987))).

required and programmatic or suspicionless searches are forbidden.[164] For the latter, a warrant is typically not required and constitutional analysis seeks to balance compelling government interests served by searches against the privacy interests of those subject to potential search.[165] As we have explained elsewhere, the hallmark of "special needs" analysis is reasonableness, including whether such searches "are narrowly tailored, likely to succeed."[166]

As applied to wastewater surveillance, this analysis could yield divergent results. Law enforcement use of wastewater surveillance information to investigate individuals—for instance, for purposes of drug enforcement—would likely fail Fourth Amendment analysis in the absence of a warrant. Many other uses of wastewater surveillance, however, would proceed under "special needs" analysis and a warrant would not be required.

But the mere invocation of "public health" or "community wellness" ought not insulate such programs from critical review.[167] Both policymakers contemplating wastewater surveillance programs, and citizens and courts scrutinizing established programs, should take seriously the command to act reasonably. At a minimum, because "special needs" analysis includes consideration of whether the contemplated searches are "likely to succeed," this assessment must include an explicit analysis of whether a program's goals, methods, and data are reasonably justified on a scientific basis.[168]

Under this rubric, wastewater surveillance efforts may raise concerns insofar as they seek medically sensitive data in the absence of a robust scientific basis or plans for acting in response to data signals. SARS-CoV-2 wastewater surveillance programs developed and implemented consistent with the ethical guidance set

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164. *See* Indianapolis v. Edmond, 531 U.S. 32, 44, 48 (2000) (declining to endorse drug interdiction roadblocks due, in part, to the fact that driving is a relatively common activity and interdicting drugs is not closely tied to automobile safety); *Ferguson*, 532 U.S. at 86; *Chandler*, 520 U.S. at 308.

165. *See* Natalie Ram & David Gray, *Mass Surveillance in the Age of COVID-19*, 7 J.L. & BIOSCIS. 1, 5 (2020), https://doi.org/10.1093/jlb/lsaa023 [https://perma.cc/B6SU-DGCV] (describing the special needs doctrine and its requirement for reasonableness).

166. *Id.* at 10.

167. *See generally id.* (detailing and applying a framework to guide special needs analysis).

168. *Id.* at 9 (citing DAVID GRAY, THE FOURTH AMENDMENT IN AN AGE OF SURVEILLANCE 267 (2017)). In addition to assessing scientific validity, data gathering, aggregation, storage, access, analysis, and use are critical programmatic features that should inform the constitutional and policy analysis, as are consideration of whether a program has an identified termination date and audit procedures. *Id.* at 11.

forth in Part II would very likely satisfy the demands of robust special needs analysis, even as research on the relationship between SARS-CoV-2 signals in wastewater and COVID-19 infections in the population continues to be refined.

But other uses are less clearly justified. One might question, for instance, what Tempe, Arizona hopes to learn by monitoring its wastewater for stress hormones—and what it plans to do if that data reveals a spike in those hormones.[169] If the city's goal is to gain a rough measure of its citizen's mental health,[170] one might express concern not only about the scientific validity of this surveillance tool, but also about the propriety of the city government inquiring into its residents' mental health en masse. The same is true for wastewater monitoring of asthma medications, at least insofar as the goal of such surveillance is "to help inform [the city's] tree planting campaigns."[171] Wastewater monitoring is a potent surveillance tool. Its deployment ought to be limited to instances in which its use is well justified and closely regulated against abuse. Not every program will qualify.

C. *Public Trust for Public Health*

Even if wastewater surveillance programs rarely constitute "searches" for purposes of the Fourth Amendment, the foregoing analysis should inform policy debates surrounding the deployment and use of such programs. The use of wastewater-derived data for law enforcement or "wellness" purposes without a sound scientific basis may well undermine the public trust that is essential for successful and well-grounded public health efforts to flourish.

Public trust is essential to the success of public health initiatives.[172] As the COVID-19 pandemic has repeatedly demonstrated, where trust ebbs, public health efforts can face decline or outright failure, with concomitant negative impacts on the health of individuals and of the community. This is most evidently true for

169. *See* Molteni, *supra* note 113.

170. *See* Email from Megan Molteni to Natalie Ram (June 1, 2021, 09:58 AM) (on file with author).

171. *Id.*

172. *See* Emily Berman, Leah R. Fowler & Jessica L. Roberts, *Trustworthy Surveillance?* 6–7 (Aug. 19, 2021) (unpublished manuscript) (on file with author) ("In the context of public health and other more cooperative endeavors, . . . simply asserting that data collection will respect an individual's privacy and autonomy is not enough. Government entities must take affirmative steps to differentiate themselves from coercive surveillance to cultivate public trust, and then prove themselves worthy of that trust.").

public health efforts that require voluntary and community-wide participation, like mask-wearing or vaccination.[173] In these instances, an erosion of public trust robs a public health effort of crucial community-wide participation, thus rendering it less effective.

Alternatively, lack of confidence about one form of public intervention may spread, effectively contaminating and undermining other, less controversial interventions. The public response to the COVID-19 pandemic is illustrative. Skepticism expressed by some about COVID-19 vaccines has fed into political resistance to vaccination requirements.[174] Unfortunately, this resistance has now begun to contaminate other, well established[175] requirements for childhood vaccination.[176]

Public discomfort and mistrust of some wastewater surveillance efforts might function similarly. For instance, invasive wastewater surveillance programs that seek to ferret out sensitive medical information about the populace or to tie individuals to criminal wrongdoing through their unavoidable effluent may cast a pall on wastewater monitoring writ broadly. This is so even if these less

173. *See, e.g.*, Roy M. Anderson & Robert M. May, *Vaccination and Herd Immunity to Infectious Diseases*, 318 NATURE 323, 323 (1985) ("The development of a safe, effective and cheap vaccine, however, is only a first step (albeit an essential one) towards community-wide control. Epidemiological, economic and motivational issues are at least as important as technological ones.").

174. *See, e.g.*, Jonathan Weisman & Sheryl Gay Stolberg, *As Virus Resurges, G.O.P. Lawmakers Allow Vaccine Skepticism to Flourish*, N.Y. TIMES (July 20, 2021), https://www.nytimes.com/2021/07/20/us/politics/republicans-coronavirus.html [https://perma.cc/HM77-7X7R]; Ron DeSantis (@GovRonDeSantis), TWITTER (Oct. 30, 2021, 1:00 PM), https://twitter.com/govrondesantis/status/1454493304377135109 [https://perma.cc/TFL2-GD2W]. These doubts, though loudly expressed, are not scientifically well-grounded. *See, e.g.*, Lisa Maragakis & Gabor David Kelen, *Is the COVID-19 Vaccine Safe?*, JOHNS HOPKINS MED. (Jan. 4, 2022), https://www.hopkinsmedicine.org/health/conditions-and-diseases/coronavirus/is-the-covid19-vaccine-safe [https://perma.cc/Y934-8VME]; *Safety of COVID-19 Vaccines*, CTRS. FOR DISEASE CONTROL & PREVENTION (Feb. 14, 2022), https://www.cdc.gov/coronavirus/2019-ncov/vaccines/safety/safety-of-vaccines.html [https://perma.cc/2HN9-2PYL].

175. *See States with Religious and Philosophical Exemptions from School Immunization Requirements*, NAT'L CONF. OF STATE LEGISLATURES (Nov. 22, 2021), https://www.ncsl.org/research/health/school-immunization-exemption-state-laws.aspx [https://perma.cc/JN9B-RE7T] (describing how many states exempt individuals from vaccination requirements for medical, religious, moral, or other reasons).

176. *See* Stephen Loiaconi, *Partisan Divide over Existing Child Vaccine Mandates Deepens Amid Pandemic*, KATV (Oct. 14, 2021), https://katv.com/news/coronavirus/partisan-divide-over-existing-child-vaccine-mandates-deepens-amid-pandemic [https://perma.cc/KK8G-9KGK]; Michael Ollove, *Most States Are Wary of Mandating COVID Shots for Kids*, STATELINE (Jan. 7, 2022), https://www.pewtrusts.org/en/research-and-analysis/blogs/stateline/2022/01/07/most-states-are-wary-of-mandating-covid-shots-for-kids [https://perma.cc/826K-6NXA] (observing that the anti-vaccine movement has dramatically increased its donations and reach during the COVID-19 pandemic, though thus far, "policy experts say they don't see signs that the opposition to COVID-19 vaccine requirements is morphing into generalized pressure on schools to get rid of longstanding requirements for other vaccines").

savory uses of wastewater surveillance do not rise to the level of Fourth Amendment searches or impinge on constitutionally-protected privacy interests, as construed by courts. If this happens, the public might reject as illegitimate other uses of this technology, including well-grounded, scientifically valid uses that may be crucial for successful public health efforts. Accordingly, policymakers contemplating wastewater surveillance must establish appropriate processes to regulate its use and assure its application only to ethical, legal, and scientifically justified applications.

CONCLUSION

Wastewater monitoring may be a crucial tool in the fight against COVID-19. Scientific validity and rigor, ethical and legal analysis, and explicit guidance for secondary uses of this surveillance infrastructure or the data it may generate are necessary. Only with these prerequisites in place can this growing surveillance methodology enhance public trust and public health.