Technology and Regulation

The Datafication of Wastewater:
Legal, Ethical and Civic Considerations

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Wastewater analysis and surveillance are well-established practices whose use has dramatically expanded during the COVID-19 pandemic. In this article, we argue that the extraction of diverse types of data from wastewater is part of the larger phenomenon of 'datafication'. We explore the evolving technologies and uses of wastewater data and argue that there are insufficient legal and ethical frameworks in place to properly govern them. We begin with an overview of the different purposes for wastewater data analyses as well as the location and scale of collection. We then consider legal and ethical principles and oversight frameworks that shape current approaches to wastewater collection. After situating wastewater collection within its particular civic context, we argue in favour of greater engagement with legal and ethical issues and propose doing so through a civic perspective. Our paper concludes with a discussion of the normative shifts that are needed and how we might achieve these.

1. Introduction

Technological advances increasingly enable the 'datafication' of features and activities of everyday life. Datafication is a term coined by Cukier and Mayer-Schonberger in 2013, and defined as "the ability to render into data many aspects of the world that have never been quantified before".[1] Refrigerators are now "smart" enough to nudge us when we run low on milk. Fitness trackers and other wearable devices enable our "quantified sel[ves]".[2] Datafication has important implications for individuals and communities. Not only does it permit the extraction of intelligence from multiple new sources, these data can be combined with other available data in new forms of data analytics and in artificial intelligence (AI) processes. This paper brings a new analytic perspective to a public health research practice that has rapidly accelerated in deployment during the COVID 19 pandemic. It identifies and evaluates how the process of datafication of wastewater raises important legal, ethical and civic issues that are yet to be satisfactorily addressed.

Wastewater analysis is the taking of samples from wastewater, typically from municipal wastewater systems, in order to test for the presence of certain substances ingested by or present within humans that pass into human waste. Wastewater analysis has been used to detect the presence of narcotics, cannabis or pharmaceuticals,[3] as well as infectious diseases such as hepatitis A,[4] polio,[5] and salmonella.[6] It is currently used for a variety of purposes, including public health surveillance and research more broadly. Over the first 22 months of the COVID-19 pandemic, we saw the rapid deployment of wastewater research and surveillance beyond the pilot testing scale. Over 1000 cities worldwide have used this technology. As of January 2022, there were over 3274 testing sites in 58 countries with the data being shared on over 110 dashboards[7] The capacity to use wastewater analysis for more targeted purposes – including law enforcement – is advancing with technology.

Wastewater analysis has some significant advantages over other forms of data gathering. In the case of infectious diseases, relying upon human test results or reported cases will undercount the

1 Kenneth Cukier and Viktor Mayer-Schoenberger, 'The Rise of Big Data' [2013] 92 *Foreign Aff* (May/June), 3, 29.

2 Gary Wolf, 'The quantified self' (*TED*, June 2010) https://www.ted.com/talks/gary_wolf_the_quantified_self accessed 2 November 2021.

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3 Tim Werschler and Andrew Brennan, 'Wastewater-Based Estimates of Cannabis and Drug Use in Canada: Pilot Test Detailed Results' (*Statistics Canada*, 26 August 2019) https://www150.statcan.gc.ca/n1/pub/11-621-m/11-621-m2019004-eng.htm accessed 19 January 2021; Wayne Hall and others, 'An analysis of ethical issues in using wastewater analysis to monitor illicit drug use' [2012] 107(10) Addiction https://doi.org/10.1111/j.1360-0443.2012.03887 accessed 26 January 2021.

4 Giuseppina La Rosa and others, 'Surveillance of hepatitis A virus in urban sewages and comparison with cases notified in the course of an outbreak' [2014] 14(1) *BMC Infect Dis* 419 https://doi.org/10.1186/1471-2334-14-419 accessed 20 January 2021.

5 Pedro Más Lago and others, 'Poliovirus Detection in Wastewater and Stools Following an Immunization Campaign in Havana, Cuba' [2003] 32(5) *Int J Epidemiol* 772 https://doi.org/10.1093/ije/dyg185 accessed 20 January 2021.

6 Sabrina Diemert and Tao Yan, 'Clinically Unreported Salmonellosis Outbreak Detected via Comparative Genomic Analysis of Municipal Wastewater Salmonella Isolates' [2019] 85(10) *Appl Env Microbiol* https://aem.asm.org/content/85/10/e00139-19 accessed 1 January 2021.

7 'COVIDPoops19 Dashboard' (*covid19wbec.org*) https://www.covid19wbec.org/covidpoops19 accessed 11 October 2021. At the time of writing, there were 57 countries with known monitoring initiatives.

prevalence of the disease especially where individuals are asymptomatic, misdiagnosed, or do not seek testing or treatment.[8] Reliance on reporting by medical practitioners may also produce uneven results.[9] Further, test results may be delayed by technical or staffing limitations, by inconsistencies in reporting techniques, or for other reasons.[10] By contrast, where wastewater systems are municipal, wastewater testing is generally considered to be more comprehensive (as most people living in communities with municipal servicing use sanitary toilets) and it has an important spatial dimension because municipal infrastructure is a permanent asset with its location a matter of public record. The advantages of wastewater analysis for public health surveillance became clear during the COVID-19 pandemic. The number of asymptomatic cases, combined with the limited capacity for testing in some jurisdictions and delays in testing results, highlighted the usefulness of wastewater analysis for developing a better understanding of the presence of the virus. It became clear, for example, that wastewater testing could indicate a rise in infections prior to those infections manifesting themselves.[11] It provided a much clearer picture of the prevalence of different strains of the virus,[12] including variants of concern such as Omicron.[13] It also enabled more targeted surveillance of particular locations.[14] The success of wastewater analysis during the pandemic will likely normalize its use as a public health monitoring tool.

Once normalized, the gathering of data from wastewater may expand to purposes beyond public health monitoring. For example, the potential for wastewater analysis has already been recognized for the collection of statistical data.[15] Wastewater analysis has also been used to detect chemicals used in making homemade explosives for domestic terrorist attacks,[16] and to assess the prevalence of antidepressant usage,[17] to give just two examples. The expansion of usage is consistent with the broader phenomenon of "function creep" which can lead to unintended and sometimes negative consequences.[18] Thompson et al. flag examples from South Korea and Germany where COVID-19 wastewater data were subsequently used for other purposes.[19] The testing of wastewater for the presence of illegal drugs may be useful from a public health point of view; the same data could be used to make decisions about the allocation of policing resources or the development of law enforcement measures.[20]

Although the practice of extracting data from human wastewater predates the COVID-19 pandemic, the pandemic has given a high profile to wastewater analysis for public health purposes. Its usefulness in detecting the virus, identifying dominant strains, and serving as an early warning system for outbreaks has been an important tool for many governments struggling to appropriately and efficiently deploy public health resources and to craft public health measures.[21] The pandemic circumstances have accelerated the use and extended the scale of wastewater surveillance both within and outside the public health context. In exploring the ethical, legal and civic issues relating to the datafication of wastewater, this paper questions whether we have the appropriate normative frameworks in place to address its present and future implications.

In this paper we identify the legal, ethical and civic implications of the datafication of wastewater, and argue for governance frameworks that take into account these issues. We do not argue for a ban on the extraction of data from wastewater; rather, we maintain that current approaches to wastewater in law, research ethics, and civics, underestimate the potential impact of the datafication of wastewater, leading to important governance gaps. We begin with an overview of different types of wastewater data analyses, including who uses wastewater analysis and where collection takes place. We then consider the current legal and ethical principles that shape (or avoid shaping) wastewater analysis practices, as well as the current civic context for wastewater collection. We next identify the gaps in oversight. Our examples of wastewater analysis are drawn from many different jurisdictions. While we address ethical and normative issues that are

8 Diemert and Yan (n 6). With the rise of the Omicron variant, we are also seeing an uptick in researchers heralding wastewater-based epidemiology as a vital tool in the pandemic toolkit. (See: Justin Chandler, 'What our sewage can (and can't) tell us about the spread of omicron', (*TVO*, January 17 2022) https://www.tvo.org/article/what-our-sewage-can-and-cant-tell-us-about-the-spread-of-omicron; Joan B Rose, 'Variants, Wastewater-based epidemiology and data sharing' (International Water Association, January 6 2022) https://iwa-network.org/variants-wastewater-based-epidemiology-and-data-sharing accessed January 30, 2022; Amy E Kirby and others, 'Notes from the Field: Early Evidence of the SARS-CoV-2 B.1.1.529 (Omicron) Variant in Community Wastewater — United States, November–December 2021' (*MMWR Morb Mortal Wkly Rep* 2022) 71:103–105 http://dx.doi.org/10.15585/mmwr.mm710a5 accessed January 30, 2022; Itay Bar-Or and others, 'National Scale Real-Time Surveillance of SARS-COV-2 Variants Dynamics by Wastewater Monitoring in Israel' (2021) *medRxiv* https://doi.org/10.1101/2021.12.26.21268420 (preprint) accessed January 30, 2022.)

9 Diemert and Yan (n 6).

10 Diemert and Yan (n 6).

11 Jordan Peccia and others, 'Measurement of SARS-CoV-2 RNA in Wastewater Tracks Community Infection Dynamics' (2020) 38 *Nat Biotech* 1164.

12 See, e.g.: Zachary Green, 'UNLV Professor Tests Sewage for New COVID Strains' (*Nevada Public Radio*, 4 December 2020) https://knpr.org/knpr/2020-12/unlv-professor-tests-sewage-new-covid-strains accessed 30 October 2021.

13 See, e.g.: Wei Lin Lee and others, 'Quantitative detection of SARS-CoV-2 Omicron variant in wastewater through allele-specific RT-qPCR', [2021] *medRxiv* 2021.12.21.21268077 https://doi.org/10.1101/2021.12.21.21268077; Angel Adegbesan, 'Omicron's Spread Through U.S. Cities Is Shown in Wastewater Study', [2021] (*Bloomberg*, 20 January 2022), https://www.bloomberg.com/news/articles/2022-01-20/omicron-s-spread-through-u-s-cities-shown-in-wastewater-study accessed 24 January 2022.

14 See, e.g.: Steve E. Hrudey and Bernadette Conant, 'The devil is in the details: emerging insights on the relevance of wastewater surveillance for SARS-CoV-2 to public health', [2021] *J Water Health* jwh2021186, https://doi.org/10.2166/wh.2021.186.

15 Werschler and Brennan (n 3).

16 Sally C Gamble, Luiza C Campos and Ruth M Morgan, 'Detection of Trace Peroxide Explosives in Environmental Samples Using Solid Phase Extraction and Liquid Chromatography Mass Spectrometry' [2017] 18 *Env Forensics* 50 https://doi.org/10.1080/15275922.2016.1263901 accessed 20 January 2021; Helena Rapp-Wright and others, 'Suspect Screening and Quantification of Trace Organic Explosives in Wastewater Using Solid Phase Extraction and Liquid Chromatography-High Resolution Accurate Mass Spectrometry' [2017] 329 *J Hazard Mater* 11 https://doi.org/10.1016/j.jhazmat.2017.01.008.

17 Chris D Metcalfe and others, 'Antidepressants and Their Metabolites in Municipal Wastewater, and Downstream Exposure in an Urban Watershed' [2010] 29 *Env Toxicol Chem* 79; Elda M. Melchor-Martínez and others, 'Antidepressants Surveillance in Wastewater: Overview Extraction and Detection' [2021] 3 *CSCEE* 100074.,

18 Bert-Jaap Koops defines 'function creep' as "an imperceptibly transformative and therewith contestable change in a data-processing system's proper activity". Bert-Jaap Koops, The concept of function creep, *Law, Innovation and Technology* [2021], 13(1), 29-56, https://doi.org/10.1080/17579961.2021.1898299, 53.

19 Janelle R Thompson and others, 'Making Waves: Wastewater Surveillance of SARS-CoV-2 for Population-Based Health Management' [2020] 184 *Water Res* 116.

20 Elizabeth E Joh, 'COVID-19 Sewage Testing as a Police Surveillance Infrastructure' [2020] *SSRN Electronic Journal* https://www.ssrn.com/abstract=3742320 accessed 11 January 2021.

21 Luke S Hillary and others, 'Monitoring SARS-CoV-2 in Municipal Wastewater to Evaluate the Success of Lockdown Measures for Controlling COVID-19 in the UK' (2021) 200 *Water Res* 117214.

capable of some level of generalization across jurisdictions, specific illustrations are drawn predominantly from Canada and the US. Our paper concludes with a discussion of the normative shifts that are needed and how we might achieve these.

2. Typologies of Wastewater Data Analyses

When thinking about the legal, civic, and ethical implications of the extraction of human-derived data from wastewater, it is helpful to consider the different practices at issue.

Table I: Typology of Wastewater Data Collection & Analyses

Entity	Purpose	Example(s)	Legal Framework
Public Health Authority	Community Health Monitoring	COVID-19 Wastewater Testing22 Other testing to detect or monitor disease outbreaks (e.g.: polio,[23] salmonellosis[24])	Public health legislation
National Statistics Organization	Statistical Data Gathering	Estimates of cannabis and drug use (e.g.: Statistics Canada)[25]	Legislation governing the collection of national statistics
Other Public Agency	Data collection for public purposes	European Monitoring Centre for Drugs and Drug Addiction – studies assessing drug use across multiple EU cities[26] The US Centre for Disease Control and the Department of Health and Human Services – both studying the building of a national wastewater surveillance system to track infectious diseases, drug use, and chronic disease[27] Institute of Environmental Science and Research (NZ) – testing for drug residue to inform policing28	Enabling legislation of the public agency
Universities	Research on the presence of various substances/viruses using wastewater data	Epidemiology (e.g., COVID-19, illegal drug use, anti-depressant use); environmental research (e.g., residue of artificial sweeteners as markers of presence in water systems)	Research ethics frameworks
Institutional Settings	Managing disease outbreaks; Detecting illicit substances	COVID-19 analysis of college dorm and campus wastewater[29] Wastewater analysis in the prison system[30]	Institutional governance framework

For each actor, we offer examples of the type of activity, and provide a general indication of the applicable legal framework that enables the collection. Actual frameworks may vary from one country to another. The frameworks do not necessarily specifically address wastewater testing. Nevertheless, they may set some boundaries for data-gathering that are relevant to wastewater. An illustration can be found in the broad powers that are often given to public health authorities to gather data.[31] We note that our typologies consider the extraction of data from wastewater other than for the operation of the wastewater system itself.

Different activities attract divergent levels of scrutiny and may be subject to different legal and normative frameworks. In this section we offer two distinct, but not mutually exclusive, ways of characterizing these activities. The first typology (Table I) is organized according to the actor involved in the extraction of human data from wastewater.

Our scan of academic literature, media reports and grey literature revealed that for the most part, those currently extracting data from wastewater are public entities or are university-based researchers.[32] Use in institutional settings may include both public and private sector actors, since in some jurisdictions prisons and universities may be privately owned and operated, even if they receive public funds and/or serve public purposes. Wastewater testing has predominantly been used for public health or epidemiological purposes, although use in institutional settings includes specific intelligence-gathering about the tested-for substances in those locations. Although COVID-19 has raised the profile of wastewater testing for public health purposes,

22 COVIDPoops19 Dashboard (n 7).
23 Pedro Más Lago and others (n 5)
24 Sabrina Diemert and Tao Yan (n 6)
25 Werschler and Brennan (n 3).
26 'Wastewater analysis and drugs — a European multi-city study' (*European Monitoring Centre for Drugs and Drug Addiction*, June 2021) https://www.emcdda.europa.eu/publications/html/pods/waste-water-analysis_en, see also: 'ColoSSoS - Collaboration on Sewage Surveillance of SARS-CoV-2' (*Water Research Australia*, 2021) https://www.waterra.com.au/project-details/264.
27 Aparna Keshaviah, Xindi C Hu and Marisa Henry, 'Developing a Flexible National Wastewater Surveillance System for COVID-19 and Beyond' [2021] 129 Environ Health Perspect 045002, https://doi.org/10.1289/EHP8572.
28 Police Media Centre, 'Wastewater Testing for Drugs to Commence in Auckland and Christchurch' (New Zealand Police, 2021) https://www.police.govt.nz/news/release/wastewater-testing-drugs-commence-auckland-and-christchurch accessed 15 October 2021.
29 Adam J Gushgari, and others, 'Tracking narcotics consumption at a Southwestern U.S. university campus by wastewater-based epidemiology', [2018] 359 J Hazard Mater 437, 437-444. https://doi.org/10.1016/j.jhazmat.2018.07.073; Jocelyn Kaiser, 'Poop Tests Stop COVID-19 Outbreak at University of Arizona' (*Science*, 28 August 2020) https://www.science.org/content/article/poop-tests-stop-covid-19-outbreak-university-arizona accessed 15 October 2021.; Alex Brizee, 'It's in the Wastewater: How Arizona Universities Are Testing for COVID-19' (*The Arizona Republic*, 13 January 2021) https://www.azcentral.com/story/news/local/arizona-education/2021/01/13/how-asu-nau-and-ua-testing-wastewater-covid-19/6340627002 accessed 4 February 2022.
30 See, e.g.: Alex J Brewer and others, 'Wastewater testing compared with random urinalyses for the surveillance of illicit drug use in prisons' [2016] 35(2) *Drug Alcohol Rev* 133.
31 In the Province of Ontario (Canada), for example, the Health Promotion and Protection Act (RSO 1990, c H7, s. 5) specifically authorizes public health agencies to collect and analyse epidemiological data.
32 For example, the Canadian Water Network provides maps that show areas of Canada in which wastewater data are public-facing, the varying levels of data use, and whether data are used by a public lab, university, or both. See: Canadian Water Network, 'COVID-19 Wastewater Coalition Maps' (*Canadian Water Network*, 11 May 2021) https://cwn-rce.ca/covid-19-wastewater-coalition/covid-19-wastewater-coalition-maps accessed 15 September 2021.

these practices predate COVID-19, and have been used to test for the presence of a variety of different diseases. The collection of data from wastewater generally fits within the conventional legal or ethical frameworks applicable to the institutions that engage in the data gathering.[33] We found no jurisdiction that had an overarching legal or ethical framework that governed access to and use of public wastewater facilities for research or data-gathering purposes.[34]

A second way of thinking about the extraction of human-derived data from wastewater relates to the location or level at which data collection takes place. Table II distinguishes between wastewater testing activities based on where the testing takes place within the sewage system. In its guidance on wastewater surveillance, the US Center for Disease Control (CDC) distinguishes between "community" and "targeted" surveillance, based on the location of the sampling within the wastewater system.[35] We have adapted this vocabulary to our typology that considers the location of wastewater sampling.

Wastewater analysis can be conducted at different scales of collection ranging from accessing the collective sewage output of thousands of households (community-level), to the outputs of large buildings or complexes (targeted collection), and to outputs from individual residences or septic tanks (small-scale collection).

To date, most wastewater research and surveillance activities have used community-level samples, where the data are anonymous. However, more targeted surveillance is possible. For example, wastewater testing has been used to monitor for COVID-19 outbreaks in specific areas (such as college campuses or dorms),[36] or for drug use in places like prisons.[37] Table II also includes mobile/robotic data-gathering, as these technologies are growing in sophistication,[38] and allow for a much more location-specific collection of wastewater.

33 For example, the Canadian Water Network refers to Canadian public health ethics frameworks and their application to COVID-19, but these are not specifically adapted to the wastewater context. See: Public Health Agency of Canada, 'Public Health Ethics Framework: A Guide for Use in Response to the COVID-19 Pandemic in Canada' (*Government of Canada*, 16 February 2021) https://www.canada.ca/en/public-health/services/diseases/2019-novel-coronavirus-infection/canadas-reponse/ethics-framework-guide-use-response-covid-19-pandemic.html accessed 15 October 2021.

34 The Canadian Water Network has produced ethical guidance for wastewater surveillance which heavily relies on the WHO's ethical guidance for public health surveillance. This voluntary code intended is to fill a perceived gap in governance. See: Canadian Water Network, 'Ethics and communications guidance for wastewater surveillance to inform public health decision-making about COVID-19' (*Canadian Water Network*, September 2020) COVID19-Wastewater-Coalition-Ethics-and-Communications-Guidance-v4-Sept-2020.pdf (cwn-rce.ca), accessed 15 October 2021; World Health Organization, 'WHO Guidelines on Ethical Issues in Public Health Surveillance' (Geneva: *World Health Organization*, 2017) Licence: CC BY-NC-SA 3.0 IGO, https://apps.who.int/iris/bitstream/handle/10665/255721/9789241512657-eng.pdf accessed 15 October 2021..

35 Centers for Disease Control and Prevention, 'Sampling Strategy: Where, How, and What to Sample' (*Centers for Disease Control and Prevention*, 23 November 2020) https://www.cdc.gov/coronavirus/2019-ncov/cases-updates/wastewater-surveillance/developing-a-wastewater-surveillance-sampling-strategy.html accessed 5 February 2021.

36 Walter Q Betancourt and others, 'COVID-19 Containment on a College Campus via Wastewater-Based Epidemiology, Targeted Clinical Testing and an Intervention' [2021] 779 *Sci Total Environ* 146408.

37 Brewer and others, (n 31).

38 See, e.g.: Micromole, http://micromole.eu accessed 30 October 2020; Emine Saner, 'The Smart Toilet Era Is Here! Are You Ready to Share Your Analprint with Big Tech?' (*The Guardian*, 23 September 2021) https://www.theguardian.com/lifeandstyle/2021/sep/23/the-smart-toilet-era-is-here-are-you-ready-to-share-your-analprint-with-big-tech accessed 15 October 2021.

Data collection is not limited to wastewater treatment plants and their technicians; private companies can also provide services that are meant to support wastewater treatment effectiveness. Multiple vendors already offer various services at different stages of the wastewater treatment process, some containing surveillance-like capabilities, including AI-enabled technologies.[39] The possibility of Public-Private Partnerships troubles the matter further, as it may have implications for responsibility for governance.

Table II: Location of Data Collection

Scale of Collection	Characteristics	Examples
Community	Testing takes place on wastewater from downstream locations (e.g., at a treatment plant) to gather data at the community level. Data is from a broad geographical area and is not linkable to specific individuals or even specific areas	Municipal COVID-19 wastewater testing, sampling of wastewater for statistical purposes
Targeted	Testing occurs before wastewater from a particular area or building enters the main system. This data will provide information about a specific community or group	Campus-based COVID-19 wastewater testing
Small scale	Testing at a highly localized scale (e.g., septic systems) or the use of robotic technologies to gather location-specific data from throughout the sewage system.	Assessment of drug use or disease outbreaks at a more localized level[40]

Although current wastewater analysis activities occur mostly at the community level and primarily for public health purposes, more focussed collection as well as the development of robotic collection technologies increasingly permit the targeting of specific communities or buildings (e.g. university residences,[41] prisons),[42] raising privacy and surveillance issues. In addition, it is only a matter of time before it is possible to target the wastewater of a specific dwelling place,[43] creating the potential for the use of these technologies in policing, as well as in a potentially broad range of private sector profiling activities, with the attendant privacy issues.[44]

As will be seen in the discussion that follows, wastewater analysis practices are governed along two axes represented by these typologies. The nature of the data-collecting entity – its legal and governance structures – may set rules for how it conducts its activities. These rules are typically not specific to wastewater – they may govern all of the organization's data-gathering activities. For example, national statistical organizations may have broad data collection mandates that enable the collection of statistical data from diverse sources, subject to stringent requirements for the protection of privacy through aggregation and other statistical techniques. University researchers who receive public funding are generally required to comply with ethical codes for research on human subjects, although,

39 See, e.g., 'Wastewater testing that doesn't waste your time.' (*Opseyes*, 2020) https://opseyes.com accessed 21 October 2021.

40 Kelsey Tsipis, 'Tracking Opioids Beneath the Streets' (*Nova*, 22 August 2018) https://www.pbs.org/wgbh/nova/article/tracking-opioids-beneath-the-streets accessed 30 October 2021.

41 See, e.g., Betancourt and others (n 36); Gushgari (n 30); Kaiser (n 30).

42 See, e.g., Brewer and others (n 31).

43 Saner (n 38).

44 Joh (n 20).

as will be discussed below, data-extraction from wastewater may not be considered human-subject research. Essentially, however, the nature of the institution can provide at least some kind of normative framework for data collection.

The scale and location of data collection are also relevant because of the extent to which it may permit the identification of either individuals or groups. If data about specific individuals is gathered by state agents, in many countries, constitutional privacy rights apply (although as will be discussed below, this is not necessarily the case). If groups or communities are identified, this may raise legal and ethical issues, particularly if the data are relied upon to make decisions about the allocation of resources, including, for example, public health or law enforcement resources.

There is, in fact, some interaction between the two typologies we present. Because the datafication of wastewater has, to date, been carried out largely at the community level, assumptions have been that the data are not personal data and thus do not raise particular ethical issues. These assumptions may be reflected in existing governance frameworks such as research ethics board (REB) guidance. For example, where wastewater data are used in research, they might also not be categorized as human subject research, and thus would be exempt from ethics review. More generally, to the extent that the data are treated for legal and ethical purposes as general environmental data, they may also not be subject to requirements for transparency, community-based consent, or public consultation.

3. The Human Subject, Privacy, and Wastewater Data

Law tends to crystallize how privacy and other interests are understood; and systems such as public health surveillance and research ethics typically draw upon these legal frameworks. This section considers the relationship between wastewater data and individuals or communities from a privacy law perspective. It notes how privacy law is evolving to respond to growing datafication – in ways that should produce impacts in ethical and public health surveillance contexts.

Specific laws vary from one jurisdiction to another. Thus, our focus is on issues that may be present in many expressions of data protection and privacy law, and that are relevant to thinking about how data extracted from wastewater are treated. Different legal systems will have their own vocabulary or legal tests, and ti is not the goal of this paper to catalogue or compare these. Instead, we consider three main privacy issues that are relevant to the law and ethics of wastewater testing. These are: the distinction between identifiable and deidentified data; whether the law recognizes group or collective privacy claims; and whether the extraction of data from wastewater by the state engages any expectations of privacy. We provide examples and illustrations from Canadian and, in some cases, US law.

3.1 Personal data/de-identified data

Data protection laws, where they exist, typically apply to personal data – in other words, data about identifiable individuals. For example, in Ontario's public sector data protection law, personal information is defined as "recorded information about an identifiable individual".[45] In the EU's General Data Protection Regulation (GDPR), personal data are defined as "any information relating to an identified or identifiable natural person ('data subject')". This provision goes on to specify that "an identifiable natural person is one who can be identified, directly or indirectly, in particular by reference to an identifier such as a name, an identification number, location data, an online identifier or to one or more factors specific to the physical, physiological, genetic, mental, economic, cultural or social identity of that natural person".[46] California's public sector data protection law defines personal information as "any information that is maintained by an agency that identifies or describes an individual, including, but not limited to, his or her name, social security number, physical description, home address, home telephone number, education, financial matters, and medical or employment history".[47]

According to these definitions, community-level wastewater data would not be personal information. When samples are used to test for presence of target substances such as narcotics or a particular virus there is no way to tell where the samples originated and therefore no way to link them back to a particular individual or household. Hall et al. claim that general population wastewater data is anonymous "because wastewater samples come from an environmental source, so confidential information is protected".[48] There is a further problem with finding such data to be personal information: the data are not about individuals. The purpose of such wastewater testing may be disease monitoring or the gathering of statistics, for example. Thus, the data tell us about the presence of disease in the community, not the presence of disease in an individual. Such privacy principles can inform research ethics. For example, university research ethics boards may not consider this type of research to be human-subject research because what is being analyzed is wastewater and the substances it contains and there is no presumed link to human subjects.[49]

Small-scale wastewater collection at the level of a single dwelling might also not fit the standard definition of "information about an identifiable individual" since there might be several people living in the dwelling from which data are collected. Hall et al. mention that special spaces such as entertainment venues, prisons, schools and workplaces have a low likelihood of identifying individuals through wastewater data studies, despite their targeted character.[50] The smaller the dwelling (e.g., a single-family home) the closer the data is to being personal data. Witzler and Wagner suggest that under the GDPR, data may be considered personal data "when the data is likely to have an impact on the individual or her position in comparison to others or the data can be used to describe the individual in one way or another."[51]

3.2 Group privacy

A growing number of privacy scholars have raised concerns about 'group' or 'collective' privacy.[52]. This type of interest is significant in

45 *Freedom of Information and Protection of Privacy Act*, RSO 1990, c F31, s 2(1).

46 EU General Data Protection Regulation (GDPR): Regulation (EU) 2016/679 of the European Parliament and of the Council of 27 April 2016 on the protection of natural persons with regard to the processing of personal data and on the free movement of such data, and repealing Directive 95/46/EC (General Data Protection Regulation), OJ 2016 L 119/1.

47 Information Practices Act of 1977 - California Civil Code section 1798, art 2 (1798.3).

48 Hall and others (n 3) 1769

49 See discussion in Section 4 "Ethical Oversight & Gaps in Wastewater Data Collection Efforts" below.

50 Hall and others (n 3) 1770.

51 Normann Witzleb and Julian Wagner, 'When is Personal Data "About" or "Relating to" an Individual? A Comparison of Australian, Canadian, and EU Data Protection and Privacy Laws' [2018] 4-1 *CJCCL* 293, 30.

52 See, e.g., Linnet Taylor, Luciano Floridi and Bart van der Sloot(eds), *Group Privacy: New Challenges of Data Technologies* (Springer 2017); Brent Mittelstadt, 'From Individual to Group Privacy in Big Data Analytics' (2017) 30 *PhilosTechnol* 475.

the big data/AI environment since the collection of data about groups may be used in profiling and to make determinations that affect both groups and their individual members. As Taylor et al. note, with big data, "[d]ata is analysed on the basis of patterns and group profiles; the results are often used for general policies and applied on a large scale".[53] Data may also be collected directly about communities and used to develop policies or guide resource-allocation among different communities. An example from the wastewater context might be determining in which neighborhoods there are high levels of opioids in wastewater and then targeting these communities for increased policing as opposed to public health intervention. Such uses of data may exacerbate existing systemic discrimination, where over-policing maps onto prohibited grounds of discrimination.

The more targeted the collection, the greater the implications for group privacy interests. Thompson et al. note that although specific individuals may not be identifiable, vulnerable populations could face potential harms with small scale sampling such as over-surveillance and restrictive policies.[54] They also suggest that small-scale wastewater surveillance of smaller communities should be disclosed to affected individuals, to bolster public legitimacy and trust.[55]

With group privacy, the individual interest in dignity and autonomy that is typically a part of privacy may be reflected instead in more collective interests. As Kammourieh et al. note, group privacy has some links to community self-sovereignty.[56] Although Taylor et al. find some legal footing for group privacy rights, they acknowledge that the concept is nascent and precarious.[57] Nevertheless, group privacy issues are important in thinking about how data may be used to target, profile or make decisions about groups (or individual group members). A normative basis for the concept of group privacy can be found emerging in some ethical frameworks.[58] The concept of group privacy – and of collective interests in data – is also important in thinking more broadly about obligations of transparency, consultation, and participatory governance.[59]

3.3 The reasonable expectation of privacy

In addition to data protection rights, many states have constitutional privacy protections that protect individuals from undue incursions on their lives by the state. In Canada and the United States, for example, privacy protections can be found in constitutional rights to be free from unreasonable searches and seizures by state actors (which can include law enforcement and public health officials).

The protection against unreasonable search and seizure relates to privacy interests that can be in one's person, one's property and/or one's information. The most robust protections are against intrusions on one's physical person. Because wastewater sampling and analysis are not physically invasive, this form of interest is unlikely to be engaged. Highly personal spaces are relatively well-protected against state intrusion; but there is a considerably reduced protection of privacy in public spaces, and sometimes none at all.[60] Because wastewater collection for analysis often occurs in public infrastructure and centralized locations, collection in such contexts is minimally invasive, at least from a spatial perspective. Collection even a short distance from a target's property line may also fail to trigger a territorial privacy interest.[61] A third category of privacy interest – informational privacy is highly contextual, and is usually only triggered where there is a reasonable expectation of privacy in the information sought or acquired by authorities.[62]

In the US, one of the contextual considerations is reflected in the third-party doctrine, which finds that there is no Fourth Amendment protection for information willingly provided to third parties (such as, in this case, a wastewater system).[63] Elizabeth Joh argues that in the US, mass sewage testing programs might nonetheless attract constitutional protection under the Fourth Amendment based on a US Supreme Court decision that found that because cellphone data was both highly revealing and 'inescapably' collected by multiple actors, its access by government, even in the hands of a third-party would constitute a search capable of triggering Fourth Amendment rights. With respect to more targeted and systematic forms of police wastewater data collection she writes: "With nearly 80 percent of American households linked to municipal sewage systems, a police sewage monitoring system would seem to qualify as practically 'inescapable'."[64]

A further challenge in the case of wastewater may come from jurisprudence about the abandonment of privacy interests. In both Canada and the US, for example, courts have ruled that there is no reasonable expectation of privacy in material that has been abandoned by the accused. In both jurisdictions, courts have ruled that police do not need warrants to search trash set out on the curb for pickup, because the garbage and the information it contains has been 'abandoned'

53 Linnet Taylor, Luciano Floridi and Bart van der Sloot, 'Introduction' in Linnet Taylor, Luciano Floridi and Bart van der Sloot (eds), *Group Privacy: New Challenges of Data Technologies* (Springer 2017) 5.
54 Thompson and others (n 19) 4.
55 Thompson and others (n 19).
56 Lanah Kammourieh and others, 'Group Privacy in the Age of Big Data', in Linnet Taylor, Luciano Floridi, Bart van der Sloot (eds), *Group Privacy: New Challenges of Data Technologies* (Springer 2017) 37-66.
57 Taylor and others (n 53) at 11.
58 See: Luciano Floridi, 'Open Data, Data Protection, and Group Privacy' [2014] 27 *Philos Technol* 1; Ethical frameworks such as the CARE principles: Research Data Alliance International Indigenous Data Sovereignty Interest Group, 'CARE Principles for Indigenous Data Governance' (September 2019) The Global Indigenous Data Alliance,https://static1.squarespace.com/static/5d3799de8456040000199cd24/t/5da9f4479e-cab221ce848fb2/1571419335217/CARE+Principles_One+Pagers+FINAL_Oct_17_2019.pdf accessed 27 January 2022); and the Eurocities principles: Eurocities, 'Eurocities principles on citizen data' (March 2019), https://eurocities.eu/wp-content/uploads/2020/08/EUROCITIES_citizen_data_principles_final-2.pdf accessed 27 January 2022) provide examples of approaches that recognize a community interest in data collected from the community.
59 This is also related to the civic component of our discussion in Part 4. See: Teresa Scassa, 'Designing Data Governance for Data Sharing: Lessons from Sidewalk Toronto' [2020] *TechReg* 44, https://doi.org/10.26116/techreg.2020.005.
60 See, e.g.: Elizabeth Paton-Simpson, 'Privacy and the Reasonable Paranoid: The Protection of Privacy in Public Places', [2000] 50(3) *UofT LJ* 305-346.
61 For example, the Canadian Supreme Court of Canada has found that data collection using a digital ammeter (a device installed on the power lines as they enter a particular property) did not engage the accused's territorial privacy interests because the data were collected from a point off his property. A narrow majority of the court stated: "The location where the search took place was not the home but the transformer box where the power lines entering the home could be accessed." *R v Gomboc* 2010 SCC 55 (CanLII), [2010] 3 SCR 211, https://canlii.ca/t/2dhlk [48]. Instead, they applied a more contextual approach that focused on the information being gathered, leading to the conclusion that there was no unreasonable search or seizure.
62 *R v Gomboc* 2010 SCC 55 (CanLII), [2010] 3 SCR 211, https://canlii.ca/t/2dhlk [49]
63 In Canada, the voluntary sharing of data with third parties is also a factor to take into account in assessing whether there is a reasonable expectation of privacy in data for the purposes of assessing whether there has been an unreasonable search or seizure. See, e.g.: *R. v. Tessling*, 2004 SCC 67 (CanLII), [2004] 3 SCR 432 [32].
64 Joh (n 20). In the U.S., see: *California v Greenwood*, 485 US 35 (1988).

by the target of the search.[65] By analogy, courts may determine that wastewater data have been 'abandoned' when they are flushed into the municipal sewage system. Thus, even if the data reveal information related to the 'biographical core' of the individual, their abandonment erases the privacy interest.[66]

The strong dissenting opinion of Justice Rosalie Abella in R v Patrick[67] (a case in which the majority of the Supreme Court of Canada ruled that garbage set out for collection was 'abandoned', thus negating any reasonable expectation of privacy) illustrates the problems with the abandonment approach in an increasingly datafied society. Justice Abella observed that "[w]hat we inelegantly call "garbage" may contain the most intensely personal and private information about ourselves".[68] Her analysis focused on "the reasonable expectations of an individual regarding the information that emanates from the home".[69] She rejected the idea that abandonment was determinative of privacy interests, characterizing it instead as just one factor for consideration. She also distinguished between abandonment of objects and abandonment of the information they contain. One can intend to abandon an object without surrendering an expectation of privacy in its contents. To apply this concept to wastewater, a person may abandon their bodily waste when they flush the toilet, but they do not necessarily abandon their privacy interest in the data about them that can be extracted from that waste. Justice Abella noted that those who abandon garbage to the municipal waste disposal system expect that it will enter that system; they do not expect that it will be intercepted and examined.

The legal concept of abandonment has been examined in other cases, including ones involving DNA. Writing in the US context, Joh has expressed concerns that the Fourth Amendment is unlikely to protect against the collection of 'abandoned' DNA,[70] which she defines as "any amount of human tissue capable of DNA analysis and separated from a targeted person inadvertently or involuntarily, but not by police coercion."[71] Canadian courts have likewise been unimpressed by claims of unreasonable search and seizure in cases involving abandoned DNA. In one case, evidence leading to the accused's arrest was obtained by an undercover officer conducting a fake chewing gum survey. The accused's saliva, contained in used chewing gum he spit into a proffered cup, was matched with similar DNA connected to two sexual assaults. The Alberta Court of Appeal dismissed the accused's claim that his reasonable expectation of privacy was infringed, finding he had abandoned his saliva with the gum. Although a 2019 Quebec Court of Appeal decision distinguished between the abandonment of a physical item and the abandonment of a privacy interest in any DNA left on the item, [72] the majority of judges nonetheless found that given the non-intrusive means by which the DNA was collected, the general public understanding that DNA testing is a method of police investigation, and the fact that such testing is for comparative purposes and not to extract personal or medical characteristics from the data, there was no breach of Charter rights. Justice Ruel stated that the accused "knew or should have known that leaving bodily substances in public could eventually allow law enforcement to collect and analyze his DNA for comparative purposes".[73] Approaches to abandoned DNA are instructive, and demonstrate the challenges in locating rights against state intrusion even in more targeted wastewater surveillance practices.

The goal of this brief discussion has been to highlight some of the ways in which privacy laws and jurisprudence may leave problematic gaps when it comes to the datafication of wastewater. The legal protection available may depend on how and where the information is collected, and at what scale. Frameworks not adapted to concepts of group privacy may have difficulty addressing the collective analysis of data. Because of the nature of wastewater, the concept of abandonment will likely play an important role in determining privacy interests. These legal approaches may also feed into the ways in which other governance frameworks – including research ethics – treat wastewater analysis. If data are considered abandoned, for example, then there is no need to obtain consent to use them. The concept of abandonment also suggests an abandonment of interest in the data such that notice of collection may not be required. Even where it is understood that abandonment of a physical item is not the same as abandonment of DNA or other substances, a non-intrusive method of collection combined with a general understanding that such methods may be used for forensic purposes could limit any expectation of privacy.

4. Ethical Oversight & Gaps in Wastewater Data Collection Efforts

There is a distinction to be made between public health surveillance of wastewater and research carried out on wastewater samples. During the COVID-19 pandemic, the two have often overlapped, as epidemiologists and virologists have participated in the analysis of wastewater samples. However, in more normal conditions, wastewater surveillance is carried out by public health authorities – for public health purposes; while research on wastewater samples is conducted by researchers for a broad range of research purposes. This suggests a need for distinct normative frameworks. In setting guidelines for public-health wastewater surveillance, the World Health Organization (WHO) acknowledged the distinction between public health surveillance and research, as well as the governance gap when it comes to surveillance activities. The 2017 WHO Guidelines state: "As surveillance does not fall under the rubric of research, however, there has been no systematic framework for continuous ethical oversight or analysis of the challenges posed by surveillance activities".[74] For example, in the U.S., the Common Rule explicitly states that public health surveillance activities, "including the collection and testing of information or biospecimens, conducted, supported, requested, ordered, required, or authorized by a public health authority,"[75] are not to be considered research, and thus do not involve research ethics board oversight. The Canadian Wastewater Network has offered an extensive review of these guidelines in relation to COVID-19 wastewater surveillance. Overall, they note that wastewater surveillance in this context is "fundamentally an application of public health

65 *R v Patrick* 2009 SCC 17; Joh (n 20). In the U.S., see: *California v Greenwood*, 485 US 35 (1988).
66 See also: *R v Piasecki* 2017 ABQB 192, where the Alberta Court of Appeal stated "garbage that is factually abandoned can be seized without warrant when it is in an area that is neither controlled nor controllable by the target under surveillance, and which is generally accessible to the public."
67 *Patrick* (n 65).
68 *Patrick* (n 65) [76].
69 *Patrick* (n 65) [83].
70 Elizabeth E. Joh, 'Reclaiming 'Abandoned' DNA: The Fourth Amendment and Genetic Privacy' [2006] 100:2 *Northwestern U L Rev* 857-884 [880-81].
71 Joh (n 70) 857.
72 Justice Ruel stated that "the theory of abandonment is inconsistent with the protection of private informational data in a person's DNA." *D'Amico* c R 2019 QCCA 77 [349].
73 *D'Amico* (n 72) [352].
74 World Health Organization, 'WHO Guidelines on Ethical Issues in Public Health Surveillance' (Geneva: *World Health Organization*, 2017) Licence: CC BY-NC-SA 3.0 IGO, https://apps.who.int/iris/bitstream/handle/10665/255721/9789241512657-eng.pdf accessed 24 March 2021, 24.
75 45 CFR 46, s A §46.102(i)(2).

surveillance and must be governed by appropriate ethical guidance".[76]

Yet in spite of this dichotomy that distinguishes between public health surveillance and wastewater research on the basis that research is guided by ethics protocols, we note that research ethics boards currently treat wastewater-based research as falling outside the scope of their policies for research on human subjects, leaving little or no ethical governance for this form of research. For example, both Canada's Tri Council Policy Statement 2 (TCPS2)[77] and the United States' Common Rule[78] provide ethical guidance for human subject research, and support the decisions of research ethics boards not to regard wastewater-based research as not including human subjects (and thus exempt from ethics review).

Article 2.1 of the TCPS2 sets out the kinds of research that require research ethics board approval, with section (b) providing further categories: "human biological materials, as well as human embryos, fetuses, fetal tissue, reproductive materials and stem cells. This applies to materials derived from living and deceased individuals".[79] The application notes for Article 2.1 of the TCPS2 offer further guidance on this rule's categories for human biological materials.[80] While the TCPS2 does not explicitly mention wastewater, the kinds of biological materials found in wastewater may fit within its application. Even so, the TCPS2 explicitly states that research ethics boards have the final say on whether research is exempt from ethics review.[81]

This is important to note, as certain categories of research fall outside ethics review. Article 2.2 exempts from review information that is either publicly available through a mechanism protected by law, or information in which an individual would have no reasonable expectation of privacy.[82] In this way, broader privacy law norms such as those discussed in the previous section may have an impact on how the ethics of wastewater research are assessed. Additionally, chapter 12 of the TCPS2 details guidance on the use of human biological materials. However, the TCPS2 only applies to "human biological materials that may reasonably be expected to identify an individual, alone or in combination with other available information" the assessment of which "is made in the context of a specific research project".[83] So, it is unlikely that it provides a reason for research ethics boards to treat community members of a wastewater-based research project as human subject participants.

76 Canadian Water Network, 'Ethics and communications guidance for wastewater surveillance to inform public health decision-making about COVID-19' (n 34) 1.

77 Canadian Institutes of Health Research, Natural Sciences and Engineering Research Council of Canada and Social Sciences and Humanities Research Council, *Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans* (*Government of Canada*, December 2018) tcps2-2018-en-interactive-final.pdf (ethics.gc.ca) accessed 21 September 2021.

78 45 CFR 46 s A.

79 Canadian Institutes of Health Research, Natural Sciences and Engineering Research Council of Canada and Social Sciences and Humanities Research Council (n 77) 13.

80 Canadian Institutes of Health Research, Natural Sciences and Engineering Research Council of Canada and Social Sciences and Humanities Research Council (n 77) 15.

81 Canadian Institutes of Health Research, Natural Sciences and Engineering Research Council of Canada and Social Sciences and Humanities Research Council (n 77) 15.

82 Canadian Institutes of Health Research, Natural Sciences and Engineering Research Council of Canada and Social Sciences and Humanities Research Council (n 77) 15.

83 Canadian Institutes of Health Research, Natural Sciences and Engineering Research Council of Canada and Social Sciences and Humanities Research Council (n 77) 167.

Similarly, the Common Rule from the U.S. regulates the conduct of researchers who collect biospecimens. However, the rule qualifies the definition of 'biospecimens' by referencing identifiable biospecimens with which the identify of a subject may "readily be ascertained by the investigator or associated with the biospecimen".[84] The rule also includes certain public health surveillance activities under the category of 'research', such as the authorized collection of identifiable biospecimens by a public authority. Importantly, the purposes of collection qualify the Common Rule's definition of research, limiting the scope to activities that are necessary to public health or criminal activities.[85] According to these definitions of research it might be argued that wastewater surveillance is a public health surveillance activity undertaken by an authorized public authority (although this excludes private actors). However, the Common Rule includes exemptions. Interestingly, secondary use of identifiable biospecimens is permitted so long as they are publicly available or the identity of the human subject is not capable of being readily ascertained.[86] Similar to the Canadian TCPS2, the Common Rule allows REBs the authority to approve or dismiss most research involving identifiable biospecimens.[87] Despite these sections of the Common Rule, it is most important to note that the categories the rule contemplates concern identifiable biospecimens, not biospecimens generally. The rule therefore likely does not apply to the biospecimens found in wastewater as we mention above, where those materials cannot be linked back to specific individuals.

The resultant picture is one in which there is generally no ethical framework either for wastewater research or surveillance. Nevertheless, the datafication of wastewater clearly implicates community interests in the study of wastewater data. Because of these community interests, it is to the civic governance contexts to which we now turn.

5. Civic Governance Issues Arising from Wastewater Data Collection

In the two preceding sections, we have identified legal and ethical gaps that emerge in relation to the datafication of human wastewater. In this section we focus on civic governance issues that also arise. Other public health surveillance and research efforts that gather data from humans may take place in formal settings such as public health clinics or in healthcare settings like hospitals or doctors' offices. In these settings, trained professionals gather personal health data from individuals. There is professional and workplace oversight of their efforts and the data they collect. There are rules and norms that frame the expectations of participants in this ecosystem. Wastewater data collection is different: these data from humans are gathered from an infrastructure system that is both fixed in location and in many cases publicly owned.

These two characteristics of the collection system signal the need to examine wastewater data collection through a civic perspective. In this paper, we use 'civic perspective' with the intent to capture local, municipal, public and collective interests which are different from the privacy and bioethical perspectives highlighted in this paper and also different from traditional private sector and research interests. The use of the phrasing "civic perspective" here is intentional and has precedents in other technology-related thinking and doing. The civic technology movement differentiates itself from regular technol-

84 45 CFR 46 s A, §46.102 (e)(1)(6).

85 45 CFR 46 s A, §46.102 (l)(2)-(3).

86 45 CFR 46 s A, §46.104 (d)(4)(i)-(ii).

87 45 CFR 46 s A, §46.109.

ogy with its focus on bridging public and private sector technology development.[88] The use of the "civic" modifier holds space for the inclusion of additional values and impacts. We see a similar approach with the use of the phrasing "public interest technology" which can be defined as "the application of design, data, and delivery to advance the public interest and promote the public good in the digital age".[89] Here again there is a deliberate and explicit emphasis placed on the public-interest elements of technology deployment.

5.1 Wastewater Data Gathering Uses Fixed Physical Infrastructure

The infrastructure that enables wastewater data-gathering is frequently the local sewer system and wastewater treatment facilities. In more rural communities these data are sometimes gathered from individual or community septic tanks. While wastewater treatment facilities and septic systems are more visible than sewer lines, all of these infrastructure elements are somewhat out of sight and out of mind. Nevertheless, they are permanent features in communities which means that their locations are detailed in public records. This permanence is important when we are evaluating the impacts of the datafication of wastewater because it makes it easier to potentially connect wastewater data back to specific communities and possibly specific households.

The Canadian Water Network group has begun to recognize privacy challenges in wastewater analysis:

> [...] as the size of the population contributing to a sewer network being sampled decreases, the likelihood increases that surveillance results can be linked to small groups of individuals, creating a risk of their identity being disclosed. This concern applies to surveillance of small communities, individual institutions, or sampling within a sewer network draining a small but geographically identifiable portion of that network. For example, sampling of a septic tank would be very identifiable as to source[90]

However, in general, those conducting wastewater surveillance or research projects tend to focus on the benefits of community collection without also explicitly considering how the spatially-specific nature of the data-gathering may present privacy challenges. For example, Public Health Ontario frames the practice in these terms: "wastewater surveillance may provide a non-invasive, anonymous and scalable method (single facilities/institutions to large cities) of obtaining pooled samples from a population within a geographic area at a point in time".[91] Here we see an emphasis on anonymous data gathering yet also a discussion about how the collection can take place at different scales and within specific geographic areas without further discussion of privacy concerns. This is perhaps not surprising; as French and Monahan note, public health authorities "have tended to distinguish surveillance of disease from surveillance of individuals".[92] The value of geographically-specific data-gathering is emphasized by a South Australian Health Department website that provides information about its COVID-19 wastewater surveillance program: "Testing wastewater can help track COVID-19 infections in the community and provide early warning of cases".[93] The geographically specific nature of the data collection is a significant reason why these data are so valuable from a public health perspective; at the same time, the geographically specific nature of the data may also present privacy concerns. New Zealand's information on COVID-19 wastewater testing program explains how it is used and allays public concerns about health risks, but does not address privacy.[94] These examples, among many, demonstrate how this kind of research is positioned and how the potential for data privacy concerns to emerge is either unaddressed or downplayed in service to other positive public health outcomes. The focus is on disease surveillance and the geographic dimension is linked to occurrence and spread of the disease rather than to the groups or individuals who are affected.

The reality is that the geographically-specific nature of the infrastructure is in tension with efforts to protect the privacy of individuals or communities. There is a hierarchy to the network of municipal sanitary sewers. Individual households connect to municipal sewer lines which then connect to larger sewer trunk lines carrying wastewater to municipal sewage treatment plants. It is possible to collect wastewater samples at different scales (see Table II). This means that location of the collection technology inside the sewer system has a direct impact on the numbers of people whose samples are collected.

But the potential for reidentification exists. Consider the early open data missteps from Transport for London in 2014.[95] In their laudable efforts to share data about the use of their bikeshare network, it was not long before data scientists connected these open datasets with other available data revealing quite specific findings about patterns of mobility behavior. Rocher et al. found that "99.98% of Americans would be correctly re-identified in any dataset using 15 demographic attributes" including zip (postal) codes.[96] Wastewater data collection technology is being used for smaller scale population collection (e.g., university residences) and for a range of public health surveillance objectives beyond the COVID-19 pandemic (e.g., legal and illegal drug use). Given the widespread availability of other non-wastewater data sets, careful attention must be paid to the potential for identification,

88 Cyd Harrel. *lA Civic Technologist's practice guide* (Five Seven Five Books 2020).

89 Tara Dawson McGuinness and Hana Schank, *Power to the Public: The Promise of Public Interest Technology* (Princeton University Press 2021).

90 Canadian Water Network, 'Ethics and communications guidance for wastewater surveillance to inform public health decision-making about COVID-19' (n 34) 9.

91 Public Health Ontario, 'Focus on Wastewater Surveillance of COVID 19' (*Public Health Ontario*, April 2021) https://www.publichealthontario.ca/-/media/documents/ncov/phm/2021/04/public-health-measures-wastewater-surveillance.pdf?la=en accessed 27 September 2021, 3.

92 Martin French and Torin Monahan, 'Dis-ease Surveillance: How Might Surveillance Studies Address COVID-19?' [2020] 18(1) *Surveill Soc* 1-11 https://ojs.library.queensu.ca/index.php/surveillance-and-society/index, 4.

93 Government of South Australia, 'COVID-19 Wastewater Surveillance Program', (n.d.), https://www.sahealth.sa.gov.au/wps/wcm/connect/public+content/sa+health+internet/conditions/infectious+diseases/covid-19/response+and+restrictions/covid-19+wastewater+surveillance+program accessed 27 January 2022.

94 Ministry of Health (NZ), 'COVID-19 Wastewater Testing', (n.d.), https://www.health.govt.nz/our-work/diseases-and-conditions/covid-19-novel-coronavirus/covid-19-health-advice-public/covid-19-wastewater-testing accessed 27 January 2022. A UK government information site also refers to mass testing of wastewater and its benefits during the pandemic, but does not address privacy issues: UK Parliament, 'Monitoring Wastewater for COVID-19', (n.d.), https://post.parliament.uk/monitoring-wastewater-for-covid-19 accessed 27 January 2022.

95 Leon Mirani, 'London's bike-share program unwittingly revealed its cyclists' movements for the world to see' (*Quartz*, 16 April 2014) https://qz.com/199209/londons-bike-share-program-unwittingly-revealed-its-cyclists-movements-for-the-world-to-see accessed 28 September 2021.

96 Luc Rocher, Julien M. Hendrickx and Yves-Alexandre de Montjoye, 'Estimating the success of re-identifications in incomplete datasets using generative models' [2019] 10 *Nat Commun* 3069, https://doi.org/10.1038/s41467-019-10933-3 accessed September 28, 2021.

re-identification and the implications of these findings.

One of the under-conceptualized potential outcomes of the datafication trend is the possibility that certain communities whose wastewater is evaluated are vulnerable to stigmatization or other negative outcomes. Take, for example, the private sector company Biobot which brands its mission as "population health insights powered by sewage".[97] Their technology is being used for COVID-19 detection but it was first deployed to inform public health interventions around opioid usage. One intervention saw the use of their technology in ten residential neighbourhoods in an undisclosed North Carolina city. "Ten sampling sites were selected to be a representative survey of the entire municipality by integrating sewer network and demographic GIS data".[98] Here we find a smaller-scale intervention focusing on illegal drug use. While the public health outcomes could be life-saving, other privacy and civic concerns arise.[99] Research is conclusive that equity-seeking and marginalized communities are subject to more surveillance[100] and that technology may have embedded biases.[101] Surveillance studies research has long flagged the potential for surveillance technology usage to result in social sorting[102] and our acuity about who is most impacted by this sorting practice is evolving. Wastewater data-gathering is not spatially-agnostic. Its spatially-specific focus informs where future public health actions should be directed while also creating the conditions for legal, ethical and civic challenges to emerge when it comes to reidentification and group privacy. Loukissas argues there is a need to "look at the data setting, not just the data set".[103] In this case, the setting is not just in a community but it is also a matter of who owns the infrastructure from which the data are gathered.

5.2 Wastewater Data-Gathering Takes Place via Publicly Owned or Operated Infrastructure

In addition to wastewater infrastructure being a fixed asset, this same infrastructure is typically municipally-owned. This public ownership adds additional civic dimensions to wastewater data-gathering; we should be mindful of the expectations of its users.

When community residents use their toilets, the extent to which they imagine their waste as contributing to public health data is debatable. In general, when people use public space and facilities, they bring with them a set of assumptions informed by norms and values associated with public and/or civic life.[104] Beyond legal permissions about what can and cannot happen in public space, there are expectations held by and placed upon the public that inform their use of that space. For example, there is a longstanding debate regarding the extent to which people should be exposed to billboards and other forms of advertising in public spaces.[105] Changes in technology have a long history of challenging our strongly held notions of public space.[106] From closed-circuit television cameras to smart-city sensors, in communities around the world, people are raising concerns about surveillance in public spaces because the very nature of the surveillance threatens the public nature of the space. In physically accessible public spaces, the public is usually informed about surveillance through tools such as signage. The extent to which the public is informed about the spatially specific datafication of their excretions remains uncertain.

When wastewater data-gathering is conducted via public infrastructure it is important to consider how the decision-making process unfolds to allow this data collection or research to take place. Who grants permission and does that decision-maker have sufficient civic authority to do so? Access to municipal sewers would require permission from public servants, but there are legal and ethical issues, as we have noted above, that might not be on the radar of these particular public servants. For example, do municipal wastewater treatment facility operators have professional training on these matters? These public servants might presume that someone else in the process is taking care of this oversight (e.g. academic researchers, public health officials) when the reality is that, as we have identified earlier, there are legal and ethical gaps in the governance of this datafication process. In other municipal decision-making processes in which activities have the potential to cause risk, there is municipal legal review and, in some cases, matters are decided by expert staff advising elected officials.[107] Here again we raise the consideration that this process of human wastewater data-gathering may be more complex in its legal and ethical considerations than elected officials could normally be expected to ascertain. So, we find ourselves in a situation in which important public health surveillance and research is taking place in an ecosystem in which the legal, ethical and democratic systems of oversight are fragmented, and perhaps insufficient. This challenge is not unique to the datafication of wastewater surveillance as we see it emerging from the introduction of other forms of disruptive

97 'Population health analytics powered by sewage' (*Biobot Analytics*, 2021) https://biobot.io Accessed Sept 27, 2021.

98 Norkio Endo and others, 'Rapid Assessment of Opioid Exposure and Treatment in Cities Through Robotic Collection and Chemical Analysis of Wastewater' 16 *J Med Toxicol* 195, 196 https://doi.org/10.1007/s13181-019-00756-5.

99 e.g. see: Thompson and others (n 19).

100 Meredith Broussard, Artificial Unintelligence (MIT Press: Cambridge MA 2019); Catherine D'Ignazio and Lauren F Klein, *Data Feminism* (MIT Press: Cambridge MA 2020); Virginia Eubanks, *Automating Inequality: How High-Tech Tools Profile, Police, and Punish the Poor* (New York: St. Martins Press 2018); Charlton D McIlwain, *Black software: The Internet and racial justice, from the AffroNet to Black Lives Matter* (New York: Oxford University Press 2020); Cathy O'Neil, *Weapons of Math Destruction: How Big Data Increases Inequality and Threatens Democracy* (New York: Crown Publishers 2016); Pamela Robinson and Peter A Johnson, 'Pandemic-Driven Technology Adoption: Public Decision Makers Need to Tread Cautiously.' [2021] 10(2) *IJEPR* 59 doi:10.4018/IJEPR.20210401.oa5.

101 Desiree Fields, David Bissell and Rachel Macrorie, 'Platform methods: Studying platform urbanism outside the black box' [2020] 41(3) *Urban Geography* 462 https://doi.org/10.1080/02723638.2020.1730642; Agnieszka Leszczynski, 'Glitchy vignettes of platform urbanism' [2020] 38(2) *Environ Plan D: Soc Space* 18 https://doi.org/10.1177/0263775819878721; Peter A Johnson, Pamela J Robinson and Simone Philpot, 'Type, tweet, tap, and pass: How smart city technology is creating a transactional citizen' [2020] 37(1) *Gov Info Q* 101414, https://doi.org/10.1016/j.giq.2019.101414.

102 David Lyon,'Surveillance, Security and Social Sorting: Emerging Research Priorities' [2007] 17(3) ICJR 161–170 https://doi.org/10.1177/1057567707306643.

103 Yanni Alexander Loukissas, *All Data are Local* (London: MIT Press 2019) 161.

104 There is a robust literature about public spaces and efforts to maintain its openness. See: Toni Miller, Laura Greenberg and Laier-Rayshon Smith, *Patterned Justice* (Just City Lab: Cambridge MA 2020); Jan Gehl and Birgitte Svarre, *How to study public life* (Washington: Island Press 2013); Zhixi Cecilia Zhuang, 'The negotiation of space and rights: Suburban planning with diversity' [2021] 62 *Urban Plan* 113, https://doi.org/10.17645/up.v6i2.3790.

105 Thomas Dekeyser 'Dismantling the advertising city: Subvertising and the urban commons to come' [2021] 39(2) *Environ Plan D: Soc Space* 309, https://doi.org/10.1177/0263775820946755.

106 Pamela Robinson 'Public Space in A Smart City' in Ahmed, Nasma, Matthew Claudel, Zahra Ebrahim, Christopher Pandolfi and Bianca Wylie (eds). *Some Thoughts* (2019) https://www.horizonbouwbv.nl/dk/587me175165u.

107 The land use planning approvals process is one good example. While the specifics vary by jurisdiction, experts generally weigh the costs and benefits of land development projects and offer a professional recommendation. Elected officials then decide whether to proceed.

technologies including CRISPR (gene-editing technology), cryptocurrencies, and Internet of Things devices.[108] We need to develop new, more responsive and timely governance regimes that anticipate the datafication impacts of new technologies.

6. Framing New Governance Efforts Needed for Wastewater Data-Gathering

Thus far, we have surveyed established governance frameworks that may or may not apply to wastewater surveillance and research. Existing legal, ethical, and civic rules and guidelines are useful as a starting point, but do not provide enough guidance to sufficiently monitor the datafication of wastewater and we caution against technologies running ahead of administrative frameworks. There are clear trends and concerns that fall outside these existing frameworks which should be addressed.

6.1 Purposes and the public good

Firstly, we should consider the purposes for which wastewater data are being collected, and whether those purposes are ethically actualized and managed. In this respect we should draw upon the emerging approaches to group privacy discussed above. The reinvigorated interest in wastewater surveillance to help track COVID-19 infections aligns with past public health purposes for wastewater data collection. As mentioned above, the technology has also been used to track environmental impacts, drug use, and even detecting explosives. Overall, these purposes align with public protection, however, the public good is not a sufficient justification for widespread surveillance. These considerations must be balanced against other ethical principles. This is particularly the case as wastewater surveillance and other forms of research on wastewater samples intersect. For example, Hall et al. provide an applied ethical analysis using four fundamental principles of biomedical and epidemiological research: respect for autonomy, non-maleficence, beneficence, and distributive justice.[109] They conclude that wastewater surveillance of illicit drug use does not raise major ethical concerns in large populations to find aggregate trends and evaluate drug policies. However, they note that ethical issues may arise where wastewater surveillance data are used to justify policy responses in specific settings (such as prisons or workplaces).[110] Gable et al. agree that there are no serious ethical concerns with secondary use of wastewater data for COVID-19 public health purposes, but the public policy interventions that result from key insights gained from wastewater research are important to consider thoughtfully. They note examples of possible rights-affecting situations such as more restrictive lockdowns that may result from policy reactions to wastewater surveillance data.[111] We must therefore pay close attention not only to whose wastewater data are being collected, but also to the purposes for which these data are used. Such purposes will likely change as the datafication of wastewater continues and new uses for data are explored.

The public good not only partially justifies wastewater surveillance from an ethical perspective, it also sets obligations on researchers, policymakers, government officials, and private companies. Data should not be collected without a plan to use information gathered from those data to benefit those from whom it comes. Even in an anonymized form, wastewater data originates from members of a community, and the data collection should primarily benefit those from whom the data originated.[112] Collection and use should also be proportionate and minimally invasive, with protocols (e.g., regarding retention periods) in place. Additionally, it is important that these obligations are adapted to progress alongside innovation in wastewater datafication technologies.

In developing such regimes, there are some emerging norms from which we can draw. The WHO Guidelines on Public Health Surveillance offer broad ethical guidance for public health monitoring activities. The adaptation of these guidelines to the wastewater context by the Canadian Water Network demonstrates the appropriateness of this framework, as well as the importance of developing transparent and consultative approaches, even when the surveillance appears, on its face, to be beneficial and non-invasive.

Concrete measures that can be taken to address these concerns can include adapting REB oversight to the particular context of wastewater research. This may be part of a broader movement to adapt ethical oversight to address concerns about the potential impacts of big data on group privacy, and the need to address potential group impacts through the research ethics process. At the infrastructure governance level, providing access to infrastructure for wastewater analysis or surveillance activities should involve some sort of assessment and oversight process that may include lawyers, bioethicists and urban planners, as well as public input, perhaps through community governance tables.

6.2 Location matters

The location of wastewater data collection is also important. Targeted or small-scale wastewater surveillance may increase the likelihood that specific information about a community can be unearthed. Datafication of wastewater may lead to profiling of certain communities, where data are analyzed and information about those communities is extrapolated. The role of governance and oversight is of higher importance in these focused contexts. Additionally, potential harms through data aggregation must be considered. When wastewater data are studied by themselves the risk of identifying individuals is low, however this may not be true when those data are studied in connection with other kinds of data. There may be benefits to this kind of research, but since it is impossible to ask for individual consent to data use, combining wastewater data with other data should be done with care and oversight.

One simple short-term action is that wastewater infrastructure owners and operators (e.g., local governments) could provide formal notification to users about wastewater surveillance and research taking place – this could occur through information provided in utility bills as well as on relevant public websites.[113] In locations where col-

108 Araz Taeihagh, M Ramesh and Michael Howlett, (2021), 'Assessing the regulatory challenges of emerging disruptive technologies' [2021] 15 *Regul Gov* 1009-1019 https://doi.org/10.1111/rego.12392.

109 Hall and others (n 3) 1769.

110 Hall and others (n 3) 1771.

111 Lance Gable, Natalie Ram and Jeffrey L Ram, 'Legal and Ethical Implications of Wastewater Monitoring of SARS-CoV-2 for COVID-19 Surveillance' [2020] 7 *J Law Biosci* https://doi.org/10.1093/jlb/lsaa039 accessed 14 January 2021,10-11.

112 Values of this kind are increasingly found in ethical principles regarding data collected from the public. See, for example: Eurocities (n 58); CARE (n 58).

113 Examples of public notice about wastewater testing include: Ministry of Health (NZ), 'COVID-19 Wastewater Testing' (n.d.) https://www.health.govt.nz/our-work/diseases-and-conditions/covid-19-novel-coronavirus/covid-19-health-advice-public/covid-19-wastewater-testing accessed January 26 2022; State Government of Victoria (AU), 'Wastewater testing' (n.d.) https://www.coronavirus.vic.gov.au/wastewater-testing accessed 26 January 2022; Gov.UK, 'EMHP wastewater monitoring of SARS-CoV-2 in England: 1 June to 20 September 2021', 28 October 2021 https://www.gov.uk/government/publications/monitoring-of-sars-cov-2-rna-

lection is quite specific (e.g., residences, congregate living), signage could also be used. The more targeted the testing program, the more specific the notice requirement should be.

6.3 Rethinking waste

We should also question what it means to characterise data gathered from wastewater as 'waste'. A large part of the justification for using wastewater data is that such data are disconnected from identifiable individuals. They are therefore considered suitable for social and scientific study. However, this perspective is political. As Benjamin Hurlbut explains in the context of human embryo 'waste': "The idea that embryos-as-waste are inevitable and that the practices that generate them are beyond the remit of public regulatory authority has shaped the kind of ethical assessment and deliberation that is seen as requisite for the use of human embryos or their derivatives in research."[114] Hurlbut argues that public and private biobanking institutions transform human biological materials into valuable research resources. Importantly, ethical oversight is an integral part of that process. Hurlbut's conclusion is that in some cases we are led to ethical ambivalence where we should be deliberating on the moral status of the subject of our research.[115] The similarities between Hurlbut's analysis of biobanks and the datafication of wastewater are striking. It is clear to see how the public and private institutions that surveil wastewater by reference to a public good argument that claims anonymity of wastewater data might in turn transform wastewater into something normatively unimportant in the public eye. In reality, genuine deliberation is necessary for this work, and we should be careful of the transformative nature of datafication.

In fact, when we more broadly position wastewater research as a process of datafication of wastewater, it becomes clear that the collection and use of these data need to be treated with the same normative attention as other research efforts despite not being categorized as human-subject research. The absence of research ethics oversight creates a gap in terms of risks, impacts and their mitigation. That gap should be filled by transparency and accountability processes and community engagement. Additionally, the datafication of wastewater triggers the need for data governance. If we only imagine wastewater surveillance as public health surveillance (i.e., as the surveillance of disease and not people or communities), we do not pay close enough attention to data privacy issues both in terms of expectations and (re)identifying individuals. This is why we need a robust wastewater data governance system. To achieve this, there is a need to first to consider who the actors are in current wastewater surveillance and research and who those actors should be.

Governance can occur through REBs, but also through data governance entities established at the local level that are either purpose-specific or that are established to deal with a broader range of urban data governance issues. Rethinking 'waste' is also important as wastewater collection technologies advance to facilitate more targeted collection and analysis, possibly rendering specific individuals identifiable for law enforcement or other purposes. In this context, the combination of the inevitability of the use of wastewater systems by individuals and the privileged access of state actors to these systems should prompt a shift in already problematic concepts of 'abandoned' data in human waste.

6.4 Participatory governance

Given the legal, ethical and civic considerations framed here, the ecosystem of participants needs to extend beyond scientists in their labs and public health officials. Thompson et al. warn that "wastewater surveillance must not be unilaterally undertaken by regulatory agencies and private industry but should substantively include diverse representatives of the public interest".[116] The range of actors can include multiple levels of government such as local government, as well as sanitation engineers and wastewater technicians. Local governments' staff are already well aware of the need to be mindful about how their activities impact people differently. Because local governments serve all people, not just some, they must tread carefully to equitably share resources and ensure that new actions do not disproportionately impact particular communities. Through service provision and tax collection, municipal governments are highly informed about the diversity of their community members and their myriad needs and challenges. The broader expertise of local government is an important input into wastewater surveillance efforts because this research has the potential to impact communities of people quite differently. And, depending on the nature of the data gathering and the communities from which is it gathered, researchers and public health officials might consider working more directly with the community members themselves.[117] The rallying cry "nothing about us without us" from community members is important to consider for researchers who seek to include potentially impacted community members in their projects. This community member inclusion the research design phase will raise researchers' awareness of the potential impacts of their project before any potential impacts actually result.

7. Conclusions

Wastewater research and surveillance are in line with the trend towards the datafication of every aspect of our lives. An otherwise harmless social necessity – the disposal of human waste – has become an opportunity for increased technological surveillance. So far, the uses of this technology have primarily been aimed at enhancing the public good. It is also understandable that most people would not put much thought into what happens with their human waste. Nevertheless, the mundane nature of conducting research with wastewater as a data source provides added reasons to critically examine its benefits and drawbacks. It would be all too easy for the technology to run ahead of governance without due consideration.

Public health surveillance is not usually concerned with collecting information from identifiable individuals, and so this activity is seen as having few, if any, ethical or privacy impacts. Research and public health surveillance activities often overlap, and research ethics protocols may exclude wastewater data extraction from review on the basis that it is not research on human subjects. The view that extracting data from wastewater has little implication for individuals is reinforced by legal approaches. Privacy analysis tends to exclude wastewater data extraction both on the basis that the data cannot be linked to identifiable individuals and, if they could, that there is no reasona-

in-england-wastewater-monthly-statistics-1-june-to-20-september-2021/emhp-wastewater-monitoring-of-sars-cov-2-in-england-1-june-to-20-september-2021 accessed 26 January 2022.

114 J Benjamin Hurlbut, 'Promising Waste: Biobanking, Embryo Research, and Infrastructures of Ethical Efficiency' (2015) 33 *Monash Bioeth Rev* 301, 320.

115 Hurlbut (n 114), 320-321.

116 Thompson and others (n 19) 4.

117 There are robust literatures about participatory and collaborative governance models to which researchers can turn. See, e.g., Stephern Greenwood, Laurel Singer, and Wendy Willis, *Collaborative governance: Principles, processes and practical tools* (Routledge 2021). Municipal agencies, boards and commissions along with established community-based organizations may have natural constituencies of people to engage as well.

ble expectation of privacy in the data. The practice of extracting these data from publicly owned infrastructure should also be considered from a "civic perspective" that encapsulates local, municipal, public and collective impacts of this data collection. The civic perspective is under-conceptualized in wastewater data gathering practice and research.

Our near future is likely to present more and more specific and locationally-precise forms of collection. This technology could soon be in our homes creating opportunities to expand the range and volume of data collected that are directly tied to a small number of individuals in a known location. These technological advances add to the need to develop more robust data governance regimes.

As the deployment of wastewater research and surveillance technology accelerates and expands, and as new forms of technology emerge, the data governance approach that we propose is a necessary prerequisite to future public heath success. Not only do we need robust public health and research practices, we need good data governance and hygiene to support them.

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