

Pandemic infrastructure: epidemiology as compartmentalization

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Abstract: This article examines modes of containment and compartmentalization in epidemiology and pandemic response. Modern epidemiology is positioned as the key method in public health science and source of information for pandemic response policies. The epidemiological apparatus of observation works with tracking and sense-making techniques at the intersection of demography and biometrics. With late 20th century technoscientific developments, epidemiology has acquired a particular form of outcomes research. This includes a particular infrastructural enactment of the concept of ‘population’, prompting specific modes of data capture and containment that also feature in today’s coronavirus dashboards. Building on genomics data repositories, epidemiological study designs mediate data recombination that repurposes existing databases and promotes capture-all techniques for viral surveillance. Focusing on the orderings enacted by the epidemiological techniques in their formation, legacies, and actualizations, I discuss how data-intensive biosurveillance and efforts to foster openness are currently transforming the ‘epidemiologic gaze’. As ‘capture-all’ technologies operate across heterogeneous worlds, they fail to capture the implications of inequitably distributed risks and benefits in global health. Analyzing the apparatus of observation and capture in epidemiology can make room for engaging differently with numerous devices toward more equitable public health responses.

Keywords: epidemiology; infrastructure; calculative techniques; data practices; COVID-19

1. Introduction

Just a few years back, the topic of ‘epidemiology today’ would hardly have been concerned with a virus, and may have instead focused on non-transmissible chronic diseases. Academic epidemiology has been empha-

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sizing the acclaimed 20th century ‘epidemiological transition’ away from infectious disease and shifting the concerns of public health science toward chronic disease¹. This position, situated in western biomedicine and in the global north, implicitly assumed that the problems of infectious disease were to be solved through ‘economic development’. Moreover, during the second half of the 20th century, the science of epidemiology had transformed into a managerial toolbox of ‘outcomes research’², generalizing its field as the study of “distributions and determinants of health and disease in populations”³. Practiced as the study of patterns and determinants of health and disease in population groups, public health emerged as a biopolitical domain of population governance and individualized risk factor optimization⁴. However, controversies within epidemiology have questioned whether the future of the discipline would be in its development as a molecular science or as a social science, also challenging the one-approach-fit-all framework of risk factor epidemiology⁵. More recently, debates have focused on how digital epidemiology and new modes of intense data sourcing have begun to challenge established study designs⁶. Deliberations on epidemiology’s futures and methodologies have been tied to techno-scientific infrastructures which have many layers of history and politics. Social studies of medicine and public health have exposed racialized disparities and carved out a long history of struggle for more equitable public health⁷. Racialized epistemic infrastructures of western sciences are still shaping today’s technologies of automation, image recognition, machine learning and artificial intelligence techniques⁸.

¹ M. Susser, *Epidemiology Today: ‘a Thought-Tormented World’*, “International Journal of Epidemiology”, 18, 3, 1989, pp. 481-488.

² M. Jefford, M.R. Stockler, M.H. Tattersall, *Outcomes Research: What Is It and Why Does It Matter?*, “International Medical Journal”, 2003, 33, 3, pp. 110-118.

³ J. Last, *A Dictionary of Epidemiology*, Oxford University Press, New York 2001.

⁴ D. Lupton, *The Imperative of Health and the Regulated Body*, Sage, London 1995.

⁵ During the 1990s in the early genomics era, hopes for breakthroughs in genetic epidemiology through the study of genetic polymorphisms and susceptibility genes were centerstage. See M.J. Khoury, *Human Genome Epidemiology: Translating Advances in Human Genetics Into Population-Based Data for Medicine and Public Health*, “Genetics in Medicine”, 1, 3, 1999, pp. 71-73.

⁶ See for instance: A.E. Aiello, A. Renson, P.N. Zivich, *Social Media- and Internet-Based Disease Surveillance for Public Health*, “Annual review of public health”, 41, 2020, pp. 101-118; M. Höhle, *A statistician’s perspective on digital epidemiology*, “Life Sciences, Society and Policy”, 13, 1, 2017, p. 17.

⁷ A. Nelson, *Body and Soul: The Black Panther Party and the Fight Against Medical Discrimination*, University of Minnesota Press, Minneapolis 2013.

⁸ R. Amaro, *Machine diagnosis*, Onlineopen.org, 28 April 2020, <https://onlineopen.org/machine-diagnosis>

Technoscience has often been positioned as the way out of contemporary crisis, such as the energy crisis, climate change, or the current COVID-19 pandemic. Recently, many political programs have related to science as something solidified and fixed – where people either follow or deny science. Climate movements campaign for science and the model predictions for global warming, advocate with slogans such as “unite behind the science” or “the science is clear”⁹. Recognition and awareness of the urgency of climate change has been a significant struggle for scientists and climate movements alike, as action has been slow. Compared to the immediate urgency of the global pandemic due to a respiratory virus, climate issues have been conceived as a longer term concern. Across research areas, modelling has evolved into the dominant way of scientific sense making. This article focuses on some of the calculative infrastructures and epistemic legacies that continue to shape responses to the current pandemic.

Regarding government responses to the COVID-19 crisis, the World Health Organization (WHO), together with other international agencies, recently issued a statement on how the pandemic has also been an “infodemic”¹⁰. Examining the countless and often skewed mapping attempts of regional pandemic situations in the US, human geographer Taylor Shelton pointed to a shift towards a ‘post-truth’ disposition in contemporary social life” and an unparalleled “post-truth pandemic”¹¹. Concerned about some trends in deconstructionist science studies, climate change denial and creationism in the US as symptoms of a larger crisis of expertise, Bruno Latour once noted that critique (of science) “had run out of steam”¹². While climate science and action has involved decades of slow processes in scientific committees such as the Intergovernmental Panel on Climate Change (IPCC), the COVID-19 pandemic brought science in the making into the public arena in unprecedented ways.

Data collection, developing metrics, and modelling are important for scientific predictions and policy responses. In a paper on epidemiologi-

⁹ See for instance Fridays for Future, <https://fridaysforfuture.org/>

¹⁰ WHO, *Managing the COVID-19 infodemic: Promoting healthy behaviours and mitigating the harm from misinformation and disinformation*. Joint statement by WHO, UN, UNICEF, UNDP, UNESCO, UNAIDS, ITU, UN Global Pulse, and IFRC, Geneva 2020, <https://www-who-int/news/item/23-09-2020-managing-the-covid-19-infodemic-promoting-healthy-behaviours-and-mitigating-the-harm-from-misinformation-and-disinformation#:~:text=An%20infodemic%20is%20an%20overabundance,of%20groups%20or%20individuals>

¹¹ T. Shelton, *A Post-Truth Pandemic*, “Big Data & Society”, July 2020. doi:10.1177/2053951720965612.

¹² B. Latour, *Why Has Critique Run Out Of Steam? From Matters of Fact to Matters of Concern*, “Critical Inquiry”, 30, 2004, pp. 225-248.

cal models of COVID-19, Warwick Anderson examined how modelling became the dominant mode of knowledge in pandemic response and called for a more heterogeneous and critical account of modelling¹³. At the same time, modelling practices also worked to expose to the broader public the heterogeneous processes of science in the making: how model predictions can change on a daily basis with new data, adjustments in modes of counting or virus mutations, and methods development. The evolving, unpredictable situation with exposures and protective measures hitting unequally, seemed to additionally fuel the crisis of expertise. Uncertain and dynamic, once the models became temporarily solidified and entered the policy-making processes, measures like restricting contacts or closing schools resulted in unprecedented repercussions to everyday life.

This paper centres on compartmentalization and ordering of data, their historical formation, and performative re-articulation. I attend to how emergent online dashboards and their publics as well as quests for openness and transparency are transforming the ‘epidemiologic gaze’. What kind of collective sense-making takes place with calculative infrastructures, as they are put to work, maintained, consulted, and used for infection tracking and policy-making?¹⁴ How do measurement infrastructures and semi-automated reporting encounter and “techno-digest”¹⁵ the virus during a pandemic? Or, vice versa, how does the virus traverse through nature-culture networks, mutate, and modify socio-technical arrangements? Beginning with technoscientific apparatus and epidemiological population thinking, this paper discusses the workings of emergent global tracking devices. Hence, it sets out to examine emergent ‘capture-all’ approaches in monitoring and data stockpiling on the one hand and

¹³ See W. Anderson, *The Model Crisis, or How to Have Critical Promiscuity in the Time of COVID-19*, “Social Studies of Science”, 51, 2, 2021, pp. 167-188. For modelling and publics, see C. Montgomery, L. Engelmann, *Epidemiological Publics? On the Domestication of Modelling in the era of COVID-19*, “Somatosphere. Science, Medicine and Anthropology”, 10 April 2020.

¹⁴ While numerous apps for tracking of proximity to an infected person or contact tracing have been developed, this paper focuses on epidemiological infrastructures of counting cases, measuring incidence and comparing rates. For analyses of apps, see for instance L.C. Graham, *Making Sense of Algorithms: Relational Perception of Contact Tracing and Risk Assessment during COVID-19*, “Big Data & Society”, January 2021. doi:10.1177/2053951721995218.

¹⁵ For the concept of ‘techno-digestion’, see D. Haraway, *A Manifesto for Cyborgs: Science, Technology, and Socialist Feminism in the 1980s*, “Australian Feminist Studies”, 2, 4, 1987, pp. 1-42. For an account of epidemiological practice, building on the concept of techno-digestion, see S. Bauer, *Indexing, Coding, Scoring: The Engine Room of Epidemiology and its Routinized Techno-Digestions*, “Somatechnics”, 9, 2-3, 2019, pp. 223-243.

the trajectory of the virus through socio-epidemiological assemblages on the other hand.

2. *Technoscience and its apparatus of observation*

In the midst of a global pandemic and a rise of post-truth attitudes in politics, studying the making of epidemiological numbers in terms of a stabilization process can look troubling. This paper proposes to examine those troubles by building on two strands of technoscience studies: studies of technoscientific apparatus and critical studies of infrastructures. While technoscience is needed to respond to the virus, this should not prevent the modes of engagements with technoscience from working against the violence imbued in technomodernity and towards more equitable relations, human and more-than-human. In other words, we need to work, as feminist technoscience studies scholar Michelle Murphy put it in studying chemical infrastructure, “*with and against technoscience*”¹⁶. This includes staying attentive to new societal segmentations introduced through technoscientific ‘solutions’, while working to transform the epistemic infrastructures into workable means toward social and environmental justice.

In order to study the technoscientific apparatus, it is helpful to look into the theorization of phenomena by feminist science studies scholar Karen Barad¹⁷. Going beyond the analysis of models in terms of representation, Barad’s *Meeting the Universe Halfway* opens up for a more symmetric account of the apparatus of observation and the phenomena under study. In this conceptualization, measurement devices and recorded phenomena “intra-act,” as phenomena are both produced and have agency; they remain in tension, their very materialities resist and leave traces in the apparatus of observation, which generates data within the apparatus’ inscription devices. Such an approach opens up for diffracting epidemiological practices of registering, abstracting, and modelling, while acknowledging the agency of the emergent phenomena beyond their constructedness. Imbued with agency within the measurement set-up, the phenomena stabilized in those settings

¹⁶ M. Murphy, *Alterlife and Decolonial Chemical Relations*, “Current Anthropology”, 32, 4, 2017, pp. 494-503.

¹⁷ K. Barad, *Meeting the Universe Halfway. Quantum Physics and the Entanglement of Matter and Meaning*, Duke University Press, Durham 2007.

are already conditioned by infrastructural legacies and traditions of scientific observation. Epidemiological devices – study designs, transmission models from previous epidemics, and statistical decision criteria – can be understood as sites where multiple ‘intra-actions’ take place.

For a closer analysis of ‘intra-actions’ within epidemiological data work, one also needs to attend to the procedures of quantification and the workings of epidemiological enumeration, from measurement to policy effects. As empirical philosopher Helen Verran notes, “thinking about numbers takes them as inseparable from the practices in which enumerated material entities come to life, and as semiotically agential. [...] It recognises that the workings of numbers are deeply embedded in and constitutive of the real – they lubricate its happening”¹⁸. Adopting such a symmetric move in grasping the workings of numbers in epidemiological surveillance and pandemic response, this contribution combines insights from the conceptualization of ‘intra-action’ and examinations of numbers as agential and relational.

Taking up approaches of infrastructure studies to address public health practices redirects the focus on data collecting, scoring and decision support systems. These have proliferated in the healthcare sector as techniques for optimization of health-related outcomes, including economic efficiency. However, monitoring works with both epistemic and mundane infrastructures. Several decades after the “epidemic of signification” described by cultural studies scholar Paula Treichler in her account of the HIV/AIDS epidemic¹⁹, we are witnessing another iteration in an ongoing “epidemic of indexing”²⁰. These are linked to accelerated modes of data recombination and the troubled legacies of racialized knowledge production which are still present in demography and biometrics and become reactivated in new techniques of indexing. There are ongoing processes of “retrofitting”²¹ in epidemiology’s knowledge infrastructures, including classifications and analytic methods. Epidemiological infrastructure work also involves mundane data work, development of data collection standards building on existing classifications, and programmed interfaces for enumeration to be maintained and cared for. In

¹⁸ H. Verran, *Number*, in N. Wakeford, C. Lury (eds.), *Inventive Methods: The Happening of the Social*, Routledge, Abingdon 2010, pp. 110-124, 112.

¹⁹ P.A. Treichler, *AIDS, Homophobia and Biomedical Discourse: An Epidemic of Signification*, “Cultural Studies”, 1, 3, 1987, pp. 263-305.

²⁰ S. Bauer, *Indexing, Coding, Scoring*, cit.

²¹ C. Howe, J. Lockrem, H. Appel et al., *Paradoxical Infrastructures: Ruins, Retrofit, and Risk*, “Science, Technology, & Human Values”, 41, 3, 2016, pp. 547-565.

this paper, infrastructure is mobilized as a generative term, as an analytic entry into the epistemic infrastructure, the data labour, and the enactment of particular relations in and through pandemic infrastructures²².

Technoscience went together with unprecedented economization of many domains of society, including public health. In many European countries, with new public management and privatization of parts of the health sector, the basic maintenance of core public health and care provision – and in particular its unprofitable groundwork – has been subjected to budget cuts over the past decades and in particular following the 2008 financial crisis²³. The pandemic has exposed this neglect of public health infrastructures, which governments in many western countries had downsized rather than invested in. Interestingly, in the US, public health had actually moved to center stage due to biosecurity concerns following the 9/11 related anthrax attacks. The increased attention, however, took shape with a rather militarized emphasis on biosecurity²⁴. The Bush administration foregrounded concerns about bioweapons, while propagating dual use for drug development and pandemic preparedness²⁵. Infectious disease transformed from a minor theme, dealt with by agencies such as the US Center for Disease Control (CDC), into a national priority, with the prospect of the additional purpose of developing antiviral drugs. The same Dr Fauci that is today widely known as a key public figure of anti-COVID-19 measures advising the US government had then been in charge of building a biosecurity program and biomedical surveillance infrastructure as their core mission, aligned with counterterror programs²⁶. Reconfigured as bioterrorism preparedness, public health institutions encountered the first SARS epidemic, with a response infrastructure focusing on bioweapons²⁷.

While US public health was reframed as matters of national security, the international agencies, such as the WHO had few funding at their dis-

²² This takes up studies that take infrastructure from sanitary or transport infrastructure and knowledge infrastructure to other societal realms, where the work of infrastructuring takes place. See C. Howe *et al.*, *Paradoxical Infrastructures*, cit.; M. Murphy, *Alterlife and Decolonial Chemical Relations*, cit.

²³ See for example S.L. Greer, H. Jarman, R. Baeten, *The New Political Economy of Health Care in the European Union: The Impact of Fiscal Governance*, “International Journal of Health Services”, 46, 2, 2016, pp. 262-282.

²⁴ C. Caduff, *The Pandemic Perhaps. Dramatic Events in a Public Culture of Danger*, University of California Press, Oakland CA 2015.

²⁵ See J. Masco, *The Theater of Operations. National Security Affect from the Cold War to the War on Terror*, Duke University Press, Durham-London 2014.

²⁶ Ivi, pp. 160-161.

²⁷ Ivi, p. 159.

posals and were weakened during the transition from international health to global health²⁸. The latest modifications of thresholds to declaring health emergencies and pandemic situations had again become controversial. When the WHO declared the swine flu pandemic in 2009 and recommended preparations for large-scale vaccine contracting, reviews issued by the Council of Europe and European Parliament criticized this as overreacting and providing unjustified benefits to the pharmaceutical industry²⁹. In addition to decreasing impact of international agencies in a post-Cold War era, the pandemic has cracked open the extent to which state public health systems have lost resources. Global health programs emerged outside of the UN and international agencies, run largely by philanthropic foundations and privately funded initiatives such as the Gates Foundation or the Poverty Action Lab³⁰. These programs are directed to eradicate certain diseases, imposing a strict performance evaluation program and randomized trial evaluation methods. Critics of this mode of global health research have stressed that the focus on quick results visible in performance indicators, often comes at the expense of public health ground work. This prioritizes efficiency of interventions over the less spectacular everyday labour that maintaining community health infrastructures require.

With poor public health infrastructures after years of austerity, calls for digital innovations proliferate and are expected to make up for this lack of funding. Monitoring and scoring systems building on intensified data sourcing for more fine-grained real-time tracking. Given the rapid changes in data practices with digitalization, it is important to understand the relational work of calculative devices, including intensified data sourcing and emergent 'capture-all' technologies. Drawing attention to the social stratification effects in these techniques, this paper takes a closer look at the modes of compartmentalizing that continue to shape the calculative infrastructures and modes of aggregating in epidemiology.

²⁸ T.M. Brown, M. Cueto, E. Fee, *The World Health Organization and the transition from "international" to "global" public health*, "American Journal of Public Health", 96, 1, 2006, pp. 62-72.

²⁹ See D. Cohen, P. Carter, *WHO and the pandemic flu "conspiracies"*, "British Medical Journal", 2010, 340:c2912.

³⁰ For the Boston-based Poverty-Action Lab (J-PAL), see <https://www.povertyactionlab.org/about-j-pal>

3. *Compartmentalization: Aggregating and enacting liquid population*

A basic epistemic grid is ubiquitous throughout epidemiology to the extent that it is difficult to grasp analytically: the concept of ‘population’. As used in epidemiology, the concept of ‘population’ is concerned less with population growth or the politics of reproduction, but pervasively enacted as part of its epistemic infrastructures. Indeed, the concept of ‘population’ has been holding together the discipline in terms of its ‘population-based’ quantitative study designs, as opposed to ‘individual’ medicine. Having become part of epidemiology’s methodological infrastructure, ‘population’ is not a neutral tool, but entangled with phantasies of population improvement or control and with intervening and governing at the level of population and subpopulations³¹.

At the same time, ‘population’, in certain settings of clinical epidemiology, is used to point to the social dimensions for medical communities working in individual medicine, including ‘critical population health’ research³². Within health sciences epistemic infrastructure, it seems unthinkable to advocate for social medicine without relying on the concept of ‘population’. However, ‘population’ continues to enact a particular mode of biopolitics through aggregations that render masses and crowds manageable. As integral part of the epistemic infrastructure in the social sciences and health policy making, ‘population’ seems available or simply there as pertinent container for knowledge making – and for worries about health matters³³. Deeply entrenched in the methods of epidemiology, ‘population’ is an effect of the epistemic infrastructures and brings about a particular dichotomization of individual/population, which has become perceived as neutral. ‘Population’ has also been mobilized to align with notions of collectives and politics of justice, for instance in formulating a critical population health research³⁴. This, however, does not undo, but continues to enact the concept of ‘population’ and pertinent biopolitical technologies, dichotomizing individual/mass, while affording particular dividual³⁵ – aggregate

³¹ See M. Murphy, *Against Population, Towards Alterlife*, in A. Clarke, D. Haraway (eds.), *Making Kin, Not Population*, Prickly Paradigm Press, Chicago IL 2018.

³² R. Labonte, M. Polyani, N. Muhajarine, T. MacIntish, A. Williams, *Beyond the Divides. Toward Critical Population Health Research*, “Critical Public Health”, 15, 1, 2005, pp. 5-17.

³³ M. Murphy, *Against Population, Towards Alterlife*, cit., pp. 106-107.

³⁴ R. Labonte *et al.*, *Beyond the Divides*, cit.

³⁵ See G. Deleuze, *Postscript on the Societies of Control*, October, 59, 1992, pp. 3-7.

mixtures, amenable to various forms of governance in the tradition of political arithmetic³⁶.

Contemporary epidemiology operates with an epistemic infrastructure shaped by the legacies of colonial public health and Cold War biomedicine and the concept of ‘population’ has been both an effect and foundational category for the discipline. Its basic methodological devices are entrenched in these legacies and actualize them; they containerize health and disease in a specific way, enacting populationalized modes of acting on matters of health and disease³⁷. In this compartmentalization, epidemiology’s apparatus of observation generates a range of measures of disease occurrence and enumeration practices, then uses these measures for purposes of comparison. Disease surveillance and risk assessment evolved through layers of history, and multiply retrofitted and repurposed infrastructure, in terms of data collection techniques, categories, and classifications³⁸. Data sourcing and processing works through compartmentalization into different groups and subgroups, defined by a grid of routinized categories derived from demography. The making of ‘population’ involves aggregation and enclosures, exclusions, and inclusions. Doing this categorization involves meticulous assembling of variables from various sources (health sector, administration, environmental data, socioeconomic registers) and attending to their data structure and interrelations. As new modes of routine pandemic surveillance, these decisions in design and population subgrouping and boundary drawing used in the epidemiological dataset also later contribute to shaping policies and publics.

Like other infrastructure, epistemic infrastructure needs labour and care to be maintained³⁹. This involves shared routines within the discipline of epidemiology in terms of a community of shared practices. An

³⁶ For statistics as political technology, see A. Desrosières, *The politics of large numbers: A history of statistical reasoning*, Harvard University Press, Cambridge MA 1998; T.M. Porter, *Trust in numbers: The pursuit of objectivity in science and public life*, Princeton University Press, Princeton NJ 1995.

³⁷ On classification and containing, G. Bowker, S.L. Star, *Sorting Things Out. Classification and its Consequences*, MIT Press, Cambridge MA 1999; S. Bauer, M. Schlünder, M. Rentetzi, *Boxes. A Field Guide*, Mattering Press, Manchester 2020. On ‘populationalization’, see C. Holmberg, C. Bischof, S. Bauer, *Making predictions: computing populations*, “Science, Technology & Human Values”, 38, 3, 2013, pp. 398-420.

³⁸ G.C. Bowker, Geoffrey C., S.L. Star, *Sorting Things Out. Classification and Its Consequences*, cit.

³⁹ S.L. Star, *Ethnography of Infrastructure*, “American Behavioral Scientist”, 43, 1998, pp. 377-391.

analysis of models and their visualizations featuring in textbook exercises, can help us understand epidemiological thinking and practice. In order to teach and habituate modes of compartmentalizing, health sciences explicate and operationalize ‘population’ through visual analogies. One popular teaching device has been the “bath model”, used to convey and explain measures of disease frequency, especially incidence and prevalence (Fig. 1)⁴⁰. This ‘bath model’ of population, with its input and output streams is different from the ‘urn model’ often used in statistics textbooks to introduce probability theory. The epidemiological analogy of a ‘liquid population’ is more flexible, in terms of changing through input and output flows. It is aimed to deal with a dynamic population, with disease events within a reference population that is not fixed. With a temporal dynamic added in the reservoir model, distinguishing between new (incident) cases and prevalent cases as well as transmission within a dynamic population is habituated, which is important for learning and practicing how to model infectious disease.

Population, here, is enacted as something that can be steered and channelled, managed and governed; despite or rather through its ‘liquid’ character, its data aggregation serves to model and steer a ‘crowd’ by measures steering the flow of data and people. The ‘bath model’ enacts population as an entity that needs to be contained and enclosed. The means of enclosure here focus on the dynamics, on the input and output streams, on what is being added, on treating the population ‘as a whole’ and on making it into an epistemic entity, for which statistical laws can be described and manipulated using an analogy to hydraulics. This mode of thinking taught in epidemiology – and keeping the field together as a discipline – has significant repercussions as to how public health measures are conceptualized. It is a ‘container model’ that underlies and mediates modes of ‘epistemic enclosure’ through study design and numerical abstracting.

Like hydraulic economic models of money flow emerging at about the same time, these analogues enact particular connections and characteristics – streams of data, capital, and people can be brought in analogy using sociotechnical imaginaries of corresponding ducts⁴¹. Through epidemiology’s ‘bath model’, social engineering is designed following hydraulics im-

⁴⁰ R.S. Bhopal, *Concepts of Epidemiology*, Oxford University Press, Oxford 2002, p. 186.

⁴¹ M.S. Morgan, M. Boumans, *Secrets Hidden by Two-Dimensionality: The Economy as a Hydraulic Machine*, in S. de Chadarevian, N. Hopwood (eds.), *Models. The Third Dimension of Science*, Stanford University Press, Stanford 2004, pp. 369-401.

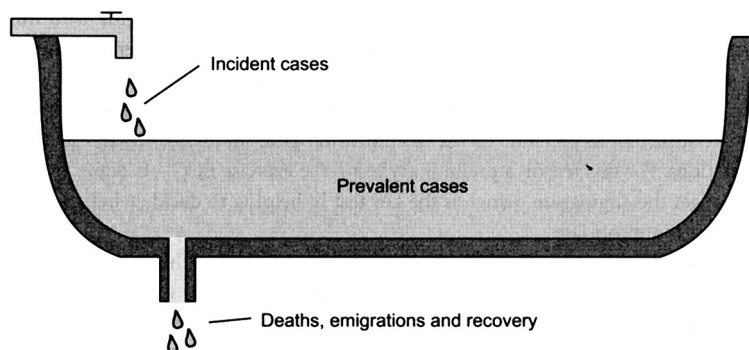


Fig. 7.6 Incidence, prevalence, and the bath model of disease (Adapted from a figure provided by Howel, see Permissions).

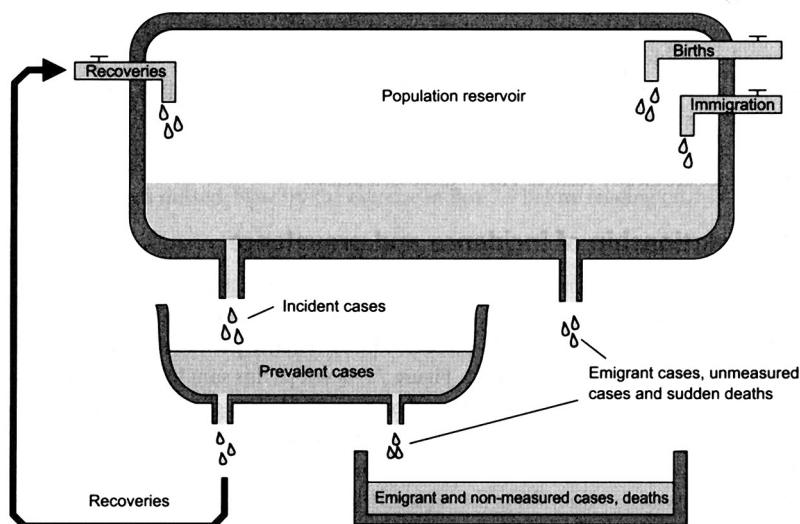


Fig. 7.7 Incidence, prevalence in a natural population: the population reservoir.

Fig. 1. Liquid population. Epidemiology textbook's "bath model", explaining the difference of prevalence and incidence and habituating population thinking (source: Bhopal 2002, see note 40).

aginaries. How statistical relations materialize is dependent on data collecting, routinized categories, and modes of compartmentalization. Key

categories activated when these models are put to use for tracking pandemic developments are (nation) state systems of reporting and assessing, which afford specific national responses. The model affords manipulations to the system, for instance in response to a pandemic, in terms of modifying enclosures and as tinkering with the categorization of groups and the model's input and output streams.

Take the models used in infectious disease epidemiology, referred to as "SIR model", which operationalize 'population' as a totality, made up of three different compartments: susceptible, infectious, and recovered. Based on this compartmentalization, the mathematical model describes and predicts the movement in and out of these compartments, with rates assumed to be constant or estimated⁴². To be validated with data, infectious disease modellers also translate these tools to guide policy making, to predict and compare effects of particular intervention measures (including vaccination strategies), based on current data of prevalence, transmission, and immunization rates. Compartmental models are a key epistemic infrastructure, developed for studies of smallpox and pandemic strains of influenza A.

Such model traditions and compartmentalization at epidemiology's disposal have been mobilized and activated in today's knowledge base to address the COVID-19 pandemic. Containers and compartmentalization were also activated in the epidemiological responses to the COVID-19 pandemic. This included those sociotechnical imaginaries of engineering the economy in a stratified mode, using immunity-status to protect elites and assign citizens to maintain certain sectors or receive privileges. From the early phase of the pandemic – even in the absence of vaccines – ideas of "immunity passports" were proposed, which prompted controversy as they incentivized infection and reinforced divisive relations of "immuno-privilege"⁴³.

⁴² M. Kretzschmar, *Infectious Disease Modeling*, in K. Heggenhougen, S. Quah (eds.), *International Encyclopedia of Public Health*, 3, Academic Press, San Diego 2008, pp. 569-576.

⁴³ For a discussion of 'immunity passports' and 'vaccine passports' respectively, see for instance R.C.H. Brown, J. Savulescu, B. Williams *et al.*, *Passport to Freedom? Immunity Passports for COVID-19*, "Journal of Medical Ethics", 46, 2020, pp. 652-659; T. Osama, M.S. Razai, A. Majeed, *COVID-19 Vaccine Passports: Access, Equity, and Ethics*, "British Medical Journal", 2021; 373, 2021, n861 doi:10.1136/bmj.n861; C.H. Liew, G.T. Flaherty, *Immunity Passports to Travel during the COVID-19 Pandemic: Controversies and Public Health Risks*, "Journal of Public Health (Oxf)", 43, 1, 2021, e135-e136; J. Liz, *COVID-19, Immunoprivilege and Structural Inequalities*, "History and Philosophy of the Life Sciences", F43, 1, 2021, 19; B. Ajana, *Immunitarianism: Defence and Sacrifice in the Politics of COVID-19*, "History and Philosophy of the Life Sciences", 2021 Feb. 22;43(1):25.

As the visual model reprinted in Fig.1 conveys to the students of epidemiology, there are ‘bottlenecks’ and other steering options that can be used to control incident cases, which then, almost as a reflex, is translated into the measure of preventing ‘inflow’ through means of border closing. In the COVID-19 pandemic, this was exacerbated, especially given the lack of a joint EU response in the early phase of the public health responses before testing and tracing was established. Despite a certain public health rhetoric, infrastructural work does not necessarily foster solidarity, but evokes and prompts border closings, reinforcing the “us versus them” rhetoric, inclusion, and exclusion. Solidarity also becomes compartmentalized, and restricted to those within national borders.

In the era of digitalization and the expectation of digital solutions, new devices participate in compartmentalization. Online dashboards have become important interfaces for epidemiological monitoring, tracking and visualizing numbers of infections. Taking the cue from Verran’s notion of “decomposing numbers” and engaging with the realm of indexing⁴⁴, the next section begins to diffract and decompose three instances of apparatus: online dashboards, database recombination, and sewage epidemiology.

4. *Dashboards: Tracking devices and epidemic indexing*

Since early on in the COVID-19 pandemic, online dashboards appeared in the public sphere⁴⁵. These tracking and reporting devices, built on geographic information systems (GIS) technologies, are continuously updated by recording, counting, and storing information on cases from defined sources, with the goal of getting as close to real-time numbers as possible. During the pandemic, millions of people looked at these semi-automated maps, checking numbers every day. What kind of orderings, compartmentalization, and densities do these public health surveillance devices enact?

The term ‘dashboard’ has gained currency with digitalization and smart city projects, while its genealogy takes us to control units for cars, but also to cockpits and control rooms of reactors, large water management sys-

⁴⁴ H. Verran, *The Changing Lives of Measures and Values: From Centre-Stage in the Fading ‘Disciplinary’ Society to Pervasive Background Instrument in the Emerging ‘Control’ Society*, “The Sociological Review”, 58, S2, 2012, pp. 60-72; Id., *Decomposing numbers*, “HAU: Journal of Ethnographic Theory”, 8, 1-2, 2018, pp. 23-26.

⁴⁵ See the one by Johns Hopkins University, published first on 22 January, see Lancet 20 correspondence E. Dong *et al.*, *An Interactive Web-Based Dashboard...*, cit., pp. 533-534.

tems, or industrial processes. Dashboards are means for data gathering and evidence-based policy-making. They function as data-driven public steering practices and they are able to render public relations otherwise invisible⁴⁶. At the beginning of the pandemic, coronavirus dashboards were often an immediate response, partly initiated in academia by schools of public health, then international agencies, and later on also by regions and municipalities. With diverse funding from research organizations, philanthropy, government, and charities, these dashboards collect and visualize data on COVID-19 cases, deaths, tests, hospitalizations, and more recently, vaccinations, with the goal to “help the public, policymakers, and healthcare professionals worldwide respond to the pandemic”⁴⁷.

Widespread datafication, number-making, tracking, and visualizing through dashboard, recently also led to the emergence of ‘data journalism’, which is reporting on and producing enumerative online tools. Initiatives like the Oxford-based “Our World in Data” list COVID-19 statistics, as part of a much larger effort of sharing data and statistics openly. WHO, as part of health surveillance, collates COVID-19 data or the frequently cited Johns Hopkins University (JHU) coronavirus dashboard (Fig. 2)⁴⁸. In addition, news agencies and media have established their own data sourcing and reporting schemes. That WHO numbers are but one data source within scientific and public debates over policy recommendations points to an increasing number of actors, much beyond UN agencies. With increasingly distributed infrastructures in data science and calculative platforms, close studies of apparatus seem even more important. Visual and numerical renderings generated through dashboards – inscriptions as products of apparatus – are reassembled⁴⁹. This specific apparatus of observation is not contained in one lab or fully standardized research infrastructure, but mostly heterogeneous, contingent and distributed. To examine this further, we will take a closer look at the JHU online dashboard.

As a counting device, the JHU coronavirus dashboard⁵⁰ brings together numbers from different sources on one screen. Comparability of num-

⁴⁶ A. Desrosières, *The Politics of Large Numbers*, cit.

⁴⁷ JHU Coronavirus Resource Center. <https://coronavirus.jhu.edu/about>

⁴⁸ *Ibidem*.

⁴⁹ B. Latour, S. Woolgar, *Laboratory Life*, Princeton University Press, Princeton NJ 1987; K. Barad *Meeting the Universe Halfway*, cit.

⁵⁰ E. Dong *et al.*, *An Interactive Web-Based Dashboard...*, cit., pp. 533-534. The platform aggregates data from multiple sources from different countries and their agencies. There are a number of international websites giving global numbers, such as WHO, “the world in data”, world in numbers and diverse press agencies drawing on data science and data journalism as emerging professional fields in journalism, some reporting slightly different kinds of summary statistics.

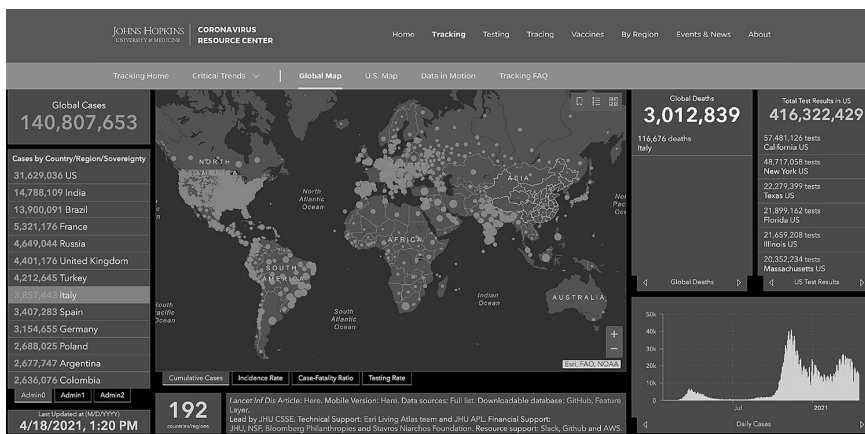


Fig. 2. Global COVID-19 tracking. Semiautomatic pandemic data streams (source: Johns Hopkins University (JHU) Coronavirus Resource Center; screenshot of the JHU COVID-19 Dashboard, April 5, 2021).

bers within tables and visualizations is limited due to differences in resources and administrative routines, resulting in a heterogeneous morphology of reporting. In its global tracking version, the dashboard lists absolute numbers, for incidence and mortality. The JHU dashboard also features visual maps (Fig. 2). The map displays how the SARS-CoV-2 virus and the pandemic's epicenters, as several epidemic surges, described as 'waves', move from within Asia to Europe, North America, South America, and by May 2021 to India. The dashboard's main world map builds on the Mercator projection, a colonial era mapping technique in marine navigation which depicts areas far from the equator, like North America and Europe, as much larger in relation to equatorial countries, often truncating parts of the southern hemisphere. Initially, dots denoting case numbers appeared on more and more places and allowed to track the global spread of disease from region to region; once the pandemic has spread globally, with growing numbers and overlapping visual icons, those maps provide little information.

The first column on the left of the dashboard lists its main category: "cases by countries, regions, sovereignty" – which functions as a main organizing grid within the dashboard's enumerations. Mainly composed of states, underreporting and overwhelmed public health systems have been

an issue for countries of the global south⁵¹. Over time, the main compartmentalization enacted is the universalized grid of the nation state, territorializing the pandemic in a particular way⁵². The compartmentalization affords national aggregations and stratified population governance. Indeed, the pandemic surge goes together with a surge of the nation state, a compartmentalization of the pandemic, with national-level response and vaccination strategies and border regimes.

The list to the left-hand side is continuously updated and ranked by absolute numbers for confirmed infection cases. This number, however, is not suited for country comparisons, since it is not reported in terms of incidence rates per 100.000 residents. Therefore, countries with smaller numbers of inhabitants, but high incidence would not feature at the top. Absolute numbers are still highly relevant for public health systems, in terms of cases healthcare systems need to provide contact tracing, and hospital care. In addition, for country comparisons of mortality, mortality rates (numbers per 100.000) need to be searched for in another section of the dashboard, under the rubric “data visualizations” and “critical trends”⁵³. In public reporting throughout the pandemic though, when referring to the JHU website, the focus has been on large absolute numbers, often out of context in rather sensational reporting for countries with large population numbers.

A key aspect of generating valid epidemiological disease counts, like the ones displayed in an online dashboard, is case ascertainment. This refers to standardized procedures of what counts as COVID-19, in testing, diagnosis and recording mortality. What are the diagnostic criteria and what documentation is needed to count a case as case for this dashboard? How do testing rates modify the numbers? In her 2020 discussion of the JHU dashboard, historian of science Ilana Löwy reminds us of the myriad of decisions involved in diagnosing a case and how this is not just a count, but an outcome of a complex apparatus of observation and measurement procedures within a diagnostic procedure⁵⁴. Even once a standardized

⁵¹ While in mid-2021 India reported a surge in incidence and mortality, Turkmenistan never reported data, as it claimed to be unaffected by Covid-19 and others paused or stopped their counts. For instance, Tanzania a few months into the pandemic, stopped reporting numbers, with case numbers just remaining at 509 since.

⁵² Some non-state entities also feature in the list – these are Diamond Princess and MS Zaandam, the cruising vessels affected in the early phase of the pandemic, but remaining in the list, as extraterritorial entities.

⁵³ <https://coronavirus.jhu.edu/data/mortality>

⁵⁴ I. Löwy, *Ludwik Fleck Where Are You Now That We Need You*, “Somatosphere. Science, Medicine, and Anthropology”, 16 October 2020.

methodology emerges from a collective effort in research, there may still be disagreement both within and between thought collectives. The work of selecting the indicators, establishing and visualizing them is key to calibration of a test. Here, calibration can refer to any single testing technology and indicator or visualization, but is also highly relevant for the dashboard as a whole. Fleck's work, as Löwy explicates for the case of PCR diagnosis, opens up for a more nuanced account, in terms of following the linkages a test technology enacts, foregrounds, gives up on, or plays down.

Dashboards are a powerful apparatus of observation in two ways, as they participate in world making, machine-mediated diagnosis, and affective economies: First, as they are ordering the social in evidence-based governance and, second, as they become infrastructural as decision-support tools. The data visualizations provided inform collective sense making and getting accustomed to case numbers: With calls to "flatten the curve", a 'terrible number' on one side of the curve can be met as 'quite a relief' on the other side of the curve. Reports of rising mortality (known to increase 2-4 weeks after incidence peaks) are met with resignation and fatalism, or just routinized. Within Europe, for example, already from the start of the pandemic, the ways in which it was met in different ways. Some governments' first concerns were how to secure equipment and expand intensive care infrastructures – other governments' primary concern was *who* should get available resources and, consequently, in a biopolitic or necropolitic of who must die⁵⁵. During Europe's second wave of COVID-19 in late 2020, politicians rushed, often under pressure of upcoming elections, to relieve restrictions as soon as incidence rates began to stop growing exponentially. Once case numbers became routinized, the formerly preventable deaths, as they occur with a time lag after a rise in incidence numbers, began to appear unavoidable. Meanwhile, on the longer term, new SARS-CoV-2 mutations require modifications to the model predictions, as well as provide experimental opportunities for new data platforms. "Machine diagnosis"⁵⁶, as visual cultures scholar Ramon Amaro uses the concept in his genealogy of calculus and government forecasting, as one informed by political arithmetic, indeed applies at more-than-individual level.

Different from political arithmetic, online dashboards bring statistical data into the public realm, changing the configuration of the epidemio-

⁵⁵ A. Mbembe, *Necropolitics*, Duke University Press, Durham 2019.

⁵⁶ R. Amaro, *Machine diagnosis*, cit.

logical gaze into a more synoptic⁵⁷ control room, for both professionals and for the broad public. Asking whether this works toward democratization of expertise and broader public deliberation might miss the point of infrastructural agency in these techniques. What the extension of institutional transparency assembles, rather seems similar to ‘control room publics’, affirming a universalizing apparatus in heterogeneous worlds. As dashboards become more permanent interfaces, they configure the ways in which policymakers navigate the pandemic, limiting what indicators are available and deemed relevant. While there is heterogeneity in case ascertainment and completeness of records and data processing, these universalized reporting machineries and their numbers and visuals bear agency, especially as they work in the sense of quasi-‘capture all’ formations. While a virus prompted the making of dashboards, the pandemic as a phenomenon also gets ‘techno-digested’ as it enters and travels through human-made infrastructures, such as data repositories.

5. *Recombinatory sense making: Repurposing genetic databases*

Making sense of the COVID-19 pandemic in the era of digitalization is not restricted to online dashboards; it mobilizes a broad range of life sciences techniques. The virus moves through epistemic infrastructures, technological batteries and data repositories at hand. The COVID-19 pandemic provides opportunities to showcase relevance to some of those data repositories established during the promissory era of genomics⁵⁸.

On September 30, 2020, a preview of a Nature article boldly claiming that “The major genetic risk factor for severe COVID-19 is inherited from Neanderthals”⁵⁹. The presented research ventured into the exploration of genetic risk factors for the differential disease response to the virus by different groups of people. For their paper researchers used available databases in order to investigate risk genetic factors for severe COVID-19, after early studies had already identified certain genetic regions on

⁵⁷ Building on Michel Foucault’s work, surveillance studies scholars have coined the terms oligopticon and synopticon to describe the changing surveillant gaze. On the notion of synopticon, see: T. Mathiesen, *The Viewer Society: Michel Foucault’s Panopticon” Revisited*, “Theoretical Criminology”, 1, 2, 1997, pp. 215-234.

⁵⁸ M. Fortun, *Promising Genomics. Iceland and deCODE Genetics in a World of Speculation*, University of California Press, Berkeley 2008.

⁵⁹ H. Zeberg, S. Pääbo, *The major genetic risk factor for severe COVID-19 is inherited from Neanderthals*, “Nature”, online 30 September 2020, doi: 10.1038/s41586-020-2818-3.

the genome to be associated with COVID-19. Based on studying haplotypes, combinations of genetic variation, are examined with respect of whether carriers of certain haplotypes (a combination of genetic variations) are potentially at increased risk for severe COVID-19. What emerged as possible markers, were some regions on chromosome 9 that determine the ABO blood groups as well as haplotypes on chromosome 3 also known from previous studies to be found in genetic material from Neanderthals. The study looked into the known haplotype characteristic in ancient DNA as well as in different population groups, genetically mapped and known from those infrastructure projects human genetic diversity scientists work with, for example the HapMap Project.

Genomic databases, such as the HapMap Project and the 1000 Genomes Project were projects of data collection and inventory. Repurposed during the COVID-19 pandemic, scientists now interrogated those databases to find genetic risk factors for severe COVID-19, as a means to speak to prevention and health care provision by identifying potentially vulnerable groups research questions about risk factors for severe COVID-19, with the goal of improving prevention and health care provision by identifying and targeting vulnerable groups. Techniques such as genome-wide association studies and computational biology were put to use, linked up and recombined with other information, stockpiled in these digital information repositories. Through linkage analysis, scientists determine in which of the studied groups (as categorized in their databases) and where “risk haplotypes” (particular variations on the genome shared by patients with severe COVID-19) correspond to haplotypes found in Neanderthal samples and, according to the scientists, this group was found most closely linked with the Croatia Vindija Neanderthal⁶⁰. This is interpreted as pointing to the group possibly at a higher statistical risk than others, as there is geographic variation in the proportion of humans carrying this haplotype. The authors estimate these proportions at 50% in South Asia and 16% in Europe today, simultaneously bringing COVID-19 risk characteristics in connection with alleged genetic clues to ancient human migration history. In these knowledge-building practices, haplotypes function as entities that draw together COVID-19 patients, ancient samples from Southern Europe (Croatia) and Southern Siberia (Altai Mountains)⁶¹.

For these studies, comprehensive projects, such as the Human Genetic Diversity Project, the HapMap Project, the 1000 Genomes Project, and

⁶⁰ *Ibidem.*

⁶¹ *Ibidem.*

similar stock taking initiatives, including the databases and biobanks make up the current knowledge base of genomics. Their digital and material repositories have become infrastructural to what postgenomic biosciences are and how they are being put to action and made relevant as a cutting-edge resource to speak to the scientific sense-making of the COVID-19 pandemic. Evolutionary biologists and geneticists identify some of these databases as available means to scientifically tackle a problem. This refers also to issues of monitoring and available battery of tools for sense-making. Sensemaking hence is always related to infrastructures, methods, toolboxes, empirical strategies, databases and study designs. Take the example of omics technologies, a term for the set of technologies developed from and reaching far beyond the human genome project. The latter once was designed to sequence the human genome, then turned into studies of genetic differences, such as single nucleotide polymorphisms, as markers that could be mapped for disease susceptibility as well as to make conclusions about human origins, migration histories.

This mode of knowing and sense making works through mining and reshuffling previous scientific infrastructures and categories. This mode of repurposing could be referred to as a retrofitted “epidemic of signification” of its own, another voice in response to the pandemic, in a sound science speculative move, using genomics databases at hand⁶². A speculative mode of science on the one hand or, turned the other way around, the virus SARS-CoV-2 meandering through and aligning with existing epistemic infrastructures.

6. *Passive sampling: Sewage-based epidemiology*

Water and sanitation systems have played a key role in epidemiological research, from the textbook case and seminal work by 19th century epidemiologist John Snow on cholera and the Broad Street pump supplying water to the district⁶³. New analytic techniques have rendered sanitation systems – here sewage systems – and the human excretions they contain – as a promising source of information on public health and epidemic surveillance. In studying excretions contained in wastewater and present in

⁶² For the notion of “epidemic of signification”, see P.A. Treichler, *AIDS, homophobia and biomedical discourse*, cit.; S. Bauer, *Indexing, Coding, Scoring*, cit.

⁶³ J. Snow, *Cholera and the Water Supply in the South Districts of London in 1854*, “Journal of Public Health and Sanitary Review”, 2, 7, 1856, pp. 239-257.

sewage systems, epidemiologists take advantage of this access to human biological materials through sanitation systems, establishing an entirely new field: sewage-based epidemiology.

Human biological samples are usually taken in medical institutions and as part of biomedical research or healthcare provision, where individual human biological material is a scarce resource stored and taken care of in biobanks under ethics protocols and strict governance regimes. Viral loads can not only be measured through testing for citizens or in medical settings, but also in more mundane, less individual-level modes, within sewage in residential areas, containing excrements of entire neighbourhoods. Environmental health researchers and epidemiologists have developed techniques that take advantage of the biological materials available in cities' sewage systems. These practices take part in reassembling inscription devices and surveillance techniques for viral monitoring, tracing viral infections through bodily excretions by sanitation infrastructure in residential areas. This mode of mapping enables remote surveillance in a 'capture all' sampling approach and puts to work a spatial grid used for governance and delineating measures as well as informing public health responses⁶⁴.

Wastewater-based epidemiology gained momentum, as it was used to estimate COVID-19 infection without enrolling individuals into medical testing or screening in population studies⁶⁵. To enable comprehensive sewage-based biosurveillance, researchers organize collaborative work to develop standardized methods, digital collaborative tools and platforms for pandemic monitoring⁶⁶. Previously, this epidemiological approach, referred to as "wastewater fingerprinting" has been applied to track medications, health status as well as pathogens and antimicrobial resistance⁶⁷. As "Sewage Biological and Chemical Information Mining", such ap-

⁶⁴ T. Prado, T.M. Fumian, C.F. Mannarino, P.C. Resende, F.C. Motta, A.L.F. Eppinghaus, V.H. Chagas do Vale, R.M.S. Braz, J.D.S.R. de Andrade, A.G. Maranhão, M.P. Miagostovich, *Wastewater-Based Epidemiology as a Useful Tool to Track Sars-Cov-2 and Support Public Health Policies at Municipal Level in Brazil*, "Water Res.", 2021, 191:116810.

⁶⁵ G. Orive, U. Lertxundi, D. Barcelo, *Early Sars-Cov-2 Outbreak Detection by Sewage-Based Epidemiology*, "Science of the Total Environment", 2020, 732:139298; S. Agrawal, L. Orschler, S. Lackner, *Long-Term Monitoring of Sars-Cov-2 Rna in Wastewater of the Frankfurt Metropolitan Area in Southern Germany*, "Nature Scientific Reports", 11, 1, 2021, 5372.

⁶⁶ A. Bivins, D. North, A. Ahmad *et al.*, *Wastewater-Based Epidemiology: Global Collaborative to Maximize Contributions in the Fight Against COVID-19*, "Environmental Science & Technology", 54, 2020, pp. 7754-7757.

⁶⁷ M. Lorenzo, Y. Picó, *Wastewater-Based Epidemiology: Current Status and Future Prospects*, "Environmental Science and Health", 9, 2019, pp. 77-84.

proaches have been used for sampling for community-based SARS-CoV-2 analyses⁶⁸. With faster techniques for PCR-based analyses available, this mode of biosensing has been promoted as non-invasive sampling approach, and early warning system⁶⁹. Work on standardization is ongoing, in order to tackle issues of comparability of measurements, establish sampling logistics, manage the temporalities, and assess conditions of dilution and persistence of the virus outside living organisms and which adaptations analytic techniques may need. Standardized and workable procedures for sampling and analysis are worked on and calibrated, since current test kits were developed for the purpose of medical diagnostics and not for measurements in environmental samples.

As a mode of passive sampling, sewage-based real-time monitoring may reshape stratified urban spaces and the momentum of community surveillance. A technique developed for environmental surveillance of toxic pollutants and envisioned as predictive tool where population studies are too difficult, it is used to complement the toolbox of environmental health monitoring. At the same time, this mode of community biosurveillance nurtures capture-all-in-real-time imaginaries, aligning well with current trends in intense datafication. As “multi-omics” vision, these efforts envision surveillance of the microbiome and the metabolome for “residential catchment” areas⁷⁰. Sewage-based epidemiology has been used to estimate “the collective illicit drug use in a community”, for instance in relation to the opioid epidemic in the US⁷¹. Scientific practitioners, aware that this kind of surveillance produces ethical dilemmas, have developed guidelines on how to account for “ethical risk factors” and prevent stigmatization, for instance in site-based studies including schools, prisons, and workplaces⁷². Delineating the sites and catchment areas for capture-all monitoring and aligning wastewater infrastructures with health monitoring may set off a broader reshuffling, often reinforcing social stratification. Aware that, in the case of drug biosurveillance such practices can stigmatize entire neighbourhoods, researchers propose communication

⁶⁸ S. Mallapaty, *How Sewage Could Reveal True Scale of Coronavirus Outbreak*, “Nature”, 2020, 580(7802), pp. 176-177.

⁶⁹ G. Orive *et al.*, *Early SARS-CoV-2...*, cit.

⁷⁰ Matus M. *et al.* 2019. 24-hour multi-omics analysis of residential sewage reflects human activity and informs public health, bioRxiv preprint doi: <https://doi.org/10.1101/728022>.

⁷¹ S. Salvatore, J.G. Bramness, M.J. Reid, J. Malcolm, K.V. Thomas; Harman, P. Christopher, J. Roislien, *Wastewater-Based Epidemiology of Stimulant Drugs: Functional Data Analysis Compared to Traditional Statistical Methods*, “PLOS ONE”, 10, 9.

⁷² <https://score-cost.eu/ethical-guidelines-for-wbe/>

strategies about goals and purpose of the studies, as well as community stakeholder dialogue, and protection of anonymity. Quests for comprehensive biosurveillance epitomize the simultaneity of care and control in public health. In a transnational take, how the virus moves through bodies and sewage is already socially stratified and so are the available public health resources. Calls for more biosurveillance leave both societal and environmental inequities where they were, if not amplifying how the SARS-CoV-2 inequitably affects different groups.

7. Conclusions

More than a year into the global COVID-19 pandemic, a virus and its mutations have shaken up everyday lives, with unequal and highly stratified consequences. Epidemiological models and numbers circulate in the public domain to an unprecedented extent. Models are more than just scientific struggles over representation of the best or the most workable depiction of reality. They actualize epistemic legacies and enact particular modes of ordering. This paper has been concerned with examples of calculative devices mobilized to feed into pandemic response, which mediate and co-shape truth speaking and policy responses. Crafting public health response uses digital technologies, such as dashboards, database recombination, and wastewater surveillance, prompting a host of rather invisible shifts. The focus on apparatus has been an attempt to better understand some of the lynchpins driving pandemic response and shaping future epidemiological infrastructures.

From 'container models' and population compartmentalization to semi-automated dashboards for tracking cases, this paper has examined the application of capture-all monitoring and sense making of the pandemic. While epidemiological models of liquid population historically mobilized hydraulics as guiding vision for engineering, they continue to shape epidemiology's mode of compartmentalizing. This includes optimization techniques that continue to rely on the concept of 'population' that has been pervasive from social medicine to eugenics and from medical geography to population health and technologies of the self. More than mere metaphors, these model exercises habituate the thinking and the ways in which societies act on the pandemic. Conceived as container for liquid population, tracking devices enact the 'nation state'. Deploying the options offered by the model, governments prioritize border closing as a first measure over transnationally or regionally coordinated responses – even when variations

within countries exceeded variations between countries. During the covid-19 pandemic, new developments every single day make it difficult to contain an analysis. Rather they render visible more layers of inequity in global health, regarding access to testing, vaccine nationalism in the global north, pursuing vaccine diplomacy merely as an add on.

As virus and pandemic travel through existing infrastructures, the very categories of compartmentalization prompt societies to respond in specific ways. New research in automation, metabolomics, and digital epidemiology are reconfiguring epidemiological research practices. In efforts toward transparency and to establish trust, governments and scientific institutions make available data to the public. Yet, epistemically, epidemiology's imagined publics continue to be conceptualized as passive subjects in public health, enacting collectives as populationalized remote object of health surveillance. For the sake of controlled knowledge regimes and fixed designs, citizens feature as blinded individuals in large numbers, which has been solidified into the very epistemic infrastructure of expert public health knowledge for response and prevention.

Attempts to initiate epidemiology from below have remained marginalized, by its very epistemic framework that put study participants in a position of methodologically sanctioned atomized individuals within a population statistic. Working toward "infrastructure literacy", as has been proposed in the case of data processing and social media⁷³, may be key to make room for a broader deliberation on technologies such as pandemic tracking devices. Instead of these exclusions, which amplify societal divides, such efforts could work to reformulate a more "participatory epidemiology"⁷⁴. Decentring epistemic infrastructure and reconfiguring the technoscience apparatus of epidemiology could mean to make room for interventions and reconfigurations into scientific practices toward an epidemiology of commons.

Compared to the climate crisis, the COVID-19 pandemic brought about sudden disruptions and unprecedented 'acuteness', changing mobility patterns and adding new segmentations upon existing ones. The scale of pandemic disruption of everyday life may be new to the recent public memory of western citizens. However, post-Cold War societies, postcolonial societies, and indigenous communities have long had to deal with more severe disruption – be it 'transitioning' from late socialism to

⁷³ J. Gray, C. Gerlitz, L. Bounegru, *Data Infrastructure Literacy*, "Big Data & Society", July 2018. doi:10.1177/2053951718786316.

⁷⁴ P. Brown, *Popular Epidemiology Revisited*, "Current Sociology", 1997, 45, 3, pp. 137-156.

neoliberalism, living with austerity measures or under structural adaptation programs, and the long aftermath of colonialism and settler colonialism. Different from infectious diseases like tuberculosis, malaria, or Ebola epidemics in the global south, COVID-19 pandemic and avoidable death toll hitting also Europe and North America, prompted unprecedented response in terms of protection measures and economic backing. The COVID-19 pandemic also reassembled epidemiology, its calculative devices and pertinent policy responses – now that a virus moved both through epidemiology’s quasi-experimental infrastructures and reached unprecedented public presence. A collective surveillant gaze and infection numbers out in the public – with everyone watching everyone – has replaced the clinical gaze and the panopticon of surveillance medicine has transmogrified into a “synopticon” of epidemiological monitoring⁷⁵.

With the current pandemic, we have witnessed how something that has long been evoked as a vague prediction by global health researchers: the return of infectious disease, showing how a viral pandemic exacerbates health inequities and societal divides. In addition to assertions that “nobody is safe until everyone is,” decolonial scholarship has long reminded us that, many indigenous people already live in a postapocalyptic state caused by modernization projects⁷⁶. The COVID-19 crisis exposes the inequitable positioning in the technoscientific labour to cope with the pandemic, unequal geographic distribution of experimental labour by vaccine trial subjects and actual beneficiaries of trial results. The global pandemic results in specific containments, leading to new societal stratification and segmentation, adding just another layer of disparity. Much is at stake regarding future calculative infrastructuring, stratification effects in modes of accounting, and accountability. Focusing on pandemic apparatus may help us counteract and intervene in the violent stratifications that have been a part of epidemiology’s colonial and Cold War legacies. Moreover, this makes room for engaging differently and more symmetrically with inequitable public health matters and for decomposing and eventually recomposing the ways of knowing in public health.

⁷⁵ See: T. Mathiesen, *The Viewer Society: Michel Foucault’s “Panopticon” Revisited*, “Theoretical Criminology”, 1, 2, 1997, pp. 215-234.

⁷⁶ See, for instance, K.P. Whyte, *Our Ancestors’ Dystopia Now: Indigenous Conservation and the Anthropocene*, in U.K. Heise, J. Christensen (eds.), *The Routledge Companion to the Environmental Humanities*, Routledge, New York 2017, pp. 206-215; K. TallBear, *Caretaking Relations, Not American Dreaming*, “Kalfou: A Journal of Comparative and Relational Ethnic Studies”, 6, 1, 2019.