Title

Wastewater-Based Epidemiology: Global Collaborative to Maximize Contributions in the Fight Against COVID-19

Journal

Environmental Science and Technology, 54(13)

ISSN

0013-936X

Authors

Bivins, Aaron
North, Devin
Ahmad, Arslan
et al.

Publication Date

2020-07-07

DOI

10.1021/acs.est.0c02388

Peer reviewed

Environmental Science & Technology

pubs.acs.org/est

Viewpoint

Wastewater-Based Epidemiology: Global Collaborative to Maximize Contributions in the Fight Against COVID-19

Aaron Bivins, Devin North, Arslan Ahmad, Warish Ahmed, Eric Alm, Frederic Been, Prosun Bhattacharya, Lubertus Bijlsma, Alexandria B. Boehm, Joe Brown, Gianluigi Buttiglieri, Vincenza Calabro, Annalaura Carducci, Sara Castiglioni, Zeynep Cetecioglu Gurol, Sudip Chakraborty, Federico Costa, Stefano Curcio, Francis L. de los Reyes, III, Jeseth Delgado Vela, Kata Farkas, Xavier Fernandez-Casi, Charles Gerba, Daniel Gerrity, Rosina Girones, Raul Gonzalez, Eiji Haramoto, Angela Harris, Patricia A. Holden, Md. Tahmidul Islam, Davey L. Jones, Barbara Kasprzyk-Hordern, Masaaki Kitajima, Nadine Kotlarz, Manish Kumar, Keisuke Kuroda, Giuseppina La Rosa, Francesca Malpei, Mariana Mautus, Sandra L. McLellan, Gertjan Medema, John Scott Meschke, Jochen Mueller, Ryan J. Newton, David Nilsson, Rachel T. Noble, Alexander van Nuijs, Jordan Peccia, T. Alex Perkins, Amy J. Pickering, Joan Rose, Gloria Sanchez, Adam Smith, Lauren Stadler, Christine Stauber, Kevin Thomas, Tom van der Voorn, Krista Wigginton, Kevin Zhu, and Kyle Bibby*

Cite This: https://dx.doi.org/10.1021/acs.est.0c02388

Read Online

ACCESS | Metrics & More | Article Recommendations

Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), a novel member of the *Coronaviridae* family, has been identified as the etiologic agent of an ongoing pandemic of severe pneumonia known as COVID-19.[1] To date there have been millions of cases of COVID-19 diagnosed in 184 countries with case fatality rates ranging from 1.8% in Germany to 12.5% in Italy.[2] Limited diagnostic testing capacity and asymptomatic and oligosymptomatic infections result in significant uncertainty in the estimated extent of SARS-CoV-2 infection.[3] Recent reports have documented that infection with SARS-CoV-2 is accompanied by persistent shedding of virus RNA in feces in 27%[4] to 89% of patients at densities from 0.8 to 7.5 $\log_{10}$ gene copies per gram.[5] The presence of SARS-CoV-2 RNA in feces raises the potential to survey sewage for virus RNA to inform epidemiological monitoring of COVID-19, which we refer to as wastewater-based epidemiology (WBE),[6] but is also known as environmental surveillance.[7]

Several studies have reported the detection of SARS-CoV-2 RNA in wastewater in the early stages of local outbreaks, further supporting the technical viability of WBE.[8−10] WBE could be especially informative given that asymptomatic and oligosymptomatic infections are unlikely to be detected during clinical surveillance. In such instances, WBE can be used to determine the burden of undiagnosed infections at the population level, which is critical to refining estimates of case-fatality rates. Additionally, wastewater offers an aggregate sample from an entire community that is more easily accessible than pooled clinical samples.[11] Along with clinical data and other technological approaches, such as contact tracing, WBE could provide critical monitoring of SARS-CoV-2 transmission within a community including the beginning, tapering, or re-emergence of an epidemic (Figure 1). This approach mirrors previous efforts in environmental monitoring, for example

Received: April 16, 2020

poliovirus RNA, to inform mechanistic models of pathogen transmission dynamics.[12]

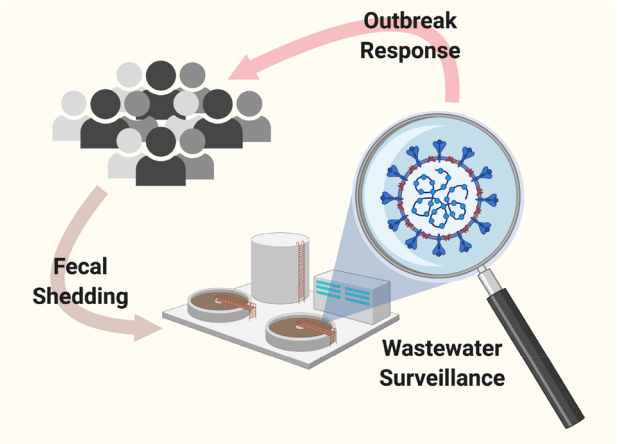

Figure 1. In wastewater-based epidemiology (WBE), the prevalence of SARS-CoV-2 infections in a community could be estimated by enumerating the virus RNA in that community's sewage and performing mass balances on virus shedding using population and sewage flow rate data. Such information can then inform public health responses to the outbreak.

The ongoing pandemic provides a meaningful opportunity to field-test the hypothesis that WBE can be used to detect and manage infectious disease transmission in communities. Many research groups across the globe are mobilizing to monitor wastewater for SARS-CoV-2 RNA for this purpose. However, the quantitative relationship between RNA densities in sewage and human infection prevalence is dependent on many spatial and temporal variables. Importantly, these relationships must be examined in both urban settings with centralized wastewater facilities and rural and low-income settings with decentralized wastewater infrastructure. Assessing variation and uncertainty across such diverse settings requires the systematic harmonization and validation of methodologies across research groups. Therefore, to maximize the potential of the diverse WBE efforts underway, we propose a global effort to coordinate methodologies and data-sharing to maximize the yields of WBE for the current and future outbreaks of disease. The community will also benefit from including appropriate quantitative controls and standards as described previously by Bustin et al.[13] to ensure cross laboratory comparability and data defensibility. Efficient harmonization of sampling, quality control, and analysis methods in the near term and, in the future, widespread dissemination of the resulting data sets and publications will help to ensure a high-quality evaluation of WBE.

In partnership with the Sewage Analysis CORe group Europe (SCORE) network and the Global Water Pathogen Project, we have launched the COVID-19 WBE Collaborative (https://www.covid19wbec.org/) as a hub to coordinate and promote the efforts of research groups undertaking WBE for COVID-19. The Web site will include content such as press releases, commentaries, and media content for public outreach and will be used to solicit participation in the collaborative and advertise events relevant to WBE. In the future, the site could also be used to host data sets and promulgate publications and presentations that result from the COVID-19 WBE Collaborative. We are pleased to invite our colleagues to join this effort at a level commensurate with their discretion.

The Web site also links to two important platforms for ongoing collaboration. The first is a protocols.io workshare platform for methodological coordination. Research groups currently undertaking wastewater surveillance for SARS-CoV-2 RNA are invited to share their protocols to help produce comparable results across geographies and time scales. Important details include, but are not limited to, the timing, frequency, location, and volume of sampling, relevant metadata, sample storage, means of concentration, extraction, and quantification of nucleic acids and observed processing recoveries. As previously mentioned, harmonization in the execution, or at a minimum, the reporting of relevant details, will greatly enhance the robustness of resulting data sets for analyzing transmission dynamics at various spatial and temporal levels. The second platform linked through the Web site is a Slack workspace for informal communication regarding COVID-19 WBE. The ongoing COVID-19 pandemic continues to evolve rapidly; therefore, any collaborative effort must include a platform for rapid communication.

As we work to sample sewage in the midst of this pandemic, biosafety remains paramount. Beyond protocols for sample analysis, we encourage all interested parties to work together to ensure appropriate biosafety measures while conducting this important work. Additionally, we ask funding agencies and the wastewater industry to consider funding for collaborative research related to COVID-19 WBE. The ongoing COVID-19 pandemic requires engineers and scientists to collaborate with population-based scientists, including epidemiologists, mathematical modelers and public health agencies. A multidisciplinary approach on a global scale is required for timely and high impact results to help society. To that end, we have established the COVID-19 WBE Collaborative to facilitate such collaboration and we encourage all interested parties to join us.

AUTHOR INFORMATION

Corresponding Author

Kyle Bibby − *Department of Civil and Environmental Engineering and Earth Sciences, University of Notre Dame, Notre Dame, Indiana 46556, United States;* orcid.org/0000-0003-3142-6090; Email: kbibby@nd.edu

Authors

Aaron Bivins − *Department of Civil and Environmental Engineering and Earth Sciences, University of Notre Dame, Notre Dame, Indiana 46556, United States*

Devin North − *Department of Civil and Environmental Engineering and Earth Sciences, University of Notre Dame, Notre Dame, Indiana 46556, United States*

Arslan Ahmad − *Department of Sustainable Development, Environmental Science and Engineering, KTH Royal Institute of Technology, SE-10044 Stockholm, Sweden; KWR Water Research Institute, 3433 PE Nieuwegein, The Netherlands*

Warish Ahmed − *CSIRO Land and Water, Ecosciences Precinct, Dutton Park, Queensland 4102, Australia*

Eric Alm − *Department of Biological Engineering, Massachusetts Institute of Technology, Cambridge, Massachusetts 02142, United States*

Frederic Been − *KWR Water Research Institute, Water Quality and Heath, 3433 PE Nieuwegein, The Netherlands*

https://dx.doi.org/10.1021/acs.est.0c02388
Environ. Sci. Technol. XXXX, XXX, XXX−XXX

Prosun Bhattacharya − *Department of Sustainable Development, Environmental Science and Engineering, KTH Royal Institute of Technology, SE-10044 Stockholm, Sweden; KWR Water Research Institute, 3433 PE Nieuwegein, The Netherlands;* orcid.org/0000-0003-4350-9950
Lubertus Bijlsma − *Analytical Chemistry in Public Health and the Environment, University Jaume I, 12071 Castellón de la Plana, Spain;* orcid.org/0000-0001-7005-8775
Alexandria B. Boehm − *Department of Civil and Environmental Engineering, Stanford University, Stanford, California 94305, United States*
Joe Brown − *School of Civil and Environmental Engineering, Georgia Institute of Technology, Atlanta, Georgia 30332, United States;* orcid.org/0000-0002-5200-4148
Gianluigi Buttiglieri − *Catalan Institute for Water Research (ICRA), E-17003 Girona, Spain*
Vincenza Calabro − *Laboratory of Transport Phenomena & Biotechnology, Department of Computer Engineering, Modeling, Electronics and Systems, University of Calabria, 87036 Rende, Cosenza, Italy*
Annalaura Carducci − *Department of Biology, University of Pisa, 56126 Pisa, Italy*
Sara Castiglioni − *Department of Environmental Health Sciences, Instituto di Richerche Farmacologiche Mario Negri IRCCS, 20156 Milan, Italy*
Zeynep Cetecioglu Gurol − *Department of Chemical Engineering, KTH Royal Institute of Technology, SE-11428 Stockholm, Sweden*
Sudip Chakraborty − *Laboratory of Transport Phenomena & Biotechnology, Department of Computer Engineering, Modeling, Electronics and Systems, University of Calabria, 87036 Rende, Cosenza, Italy*
Federico Costa − *Instituto de Saúde Coletiva, Universidade Federal da Bahia, Salvador, Bahia, Brazil 40110-040*
Stefano Curcio − *Laboratory of Transport Phenomena & Biotechnology, Department of Computer Engineering, Modeling, Electronics and Systems, University of Calabria, 87036 Rende, Cosenza, Italy*
Francis L. de los Reyes, III − *Department of Civil, Construction, and Environmental Engineering, North Carolina State University, Raleigh, North Carolina 27607, United States;* orcid.org/0000-0002-3593-0932
Jeseth Delgado Vela − *Department of Civil and Environmental Engineering, Howard University, Washington, D.C. 20059, United States;* orcid.org/0000-0001-6171-4400
Kata Farkas − *School of Ocean Sciences, Bangor University, Anglesey LL59 5AB, U.K.*
Xavier Fernandez-Casi − *Laboratory of Environmental Chemistry, School of Architecture, Civil and Environmental Engineering (ENAC), École Polytechnique Fédérale de Lausanne (EPFL), CH-1015 Lausanne, Switzerland*
Charles Gerba − *Department of Environmental Science, University of Arizona, Tucson, Arizona 85745, United States*
Daniel Gerrity − *Applied Research and Development Center, Southern Nevada Water Authority, Las Vegas, Nevada 89106, United States*
Rosina Girones − *Department of Genetics, Microbiology and Statistics, University of Barcelona, 08028 Barcelona, Spain*
Raul Gonzalez − *Hampton Roads Sanitation District, Virginia Beach, Virginia 23455, United States;* orcid.org/0000-0002-8115-7709
Eiji Haramoto − *Interdisciplinary Center for River Basin Environment, University of Yamanashi, Kofu, Yamanashi 400-8511, Japan;* orcid.org/0000-0002-0126-0651
Angela Harris − *Department of Civil, Construction, and Environmental Engineering, North Carolina State University, Raleigh, North Carolina 27607, United States*
Patricia A. Holden − *Bren School of Environmental Science & Management, University of California, Santa Barbara, California 93106, United States;* orcid.org/0000-0002-6777-5359
Md. Tahmidul Islam − *Department of Sustainable Development, Environmental Science and Engineering, KTH Royal Institute of Technology, SE-10044 Stockholm, Sweden*
Davey L. Jones − *School of Natural Sciences, Bangor University, Gwynedd, Wales LL57 2UW, United Kingdom*
Barbara Kasprzyk-Hordern − *Department of Chemistry, University of Bath, Claverton Down Bath BA2 7AY, United Kingdom;* orcid.org/0000-0002-6809-2875
Masaaki Kitajima − *Division of Environmental Engineering, Hokkaido University, Kita-ku, Sapporo, Hokkaido 060-8628, Japan;* orcid.org/0000-0002-8142-511X
Nadine Kotlarz − *Department of Biological Sciences, North Carolina State University, Raleigh, North Carolina 27695, United States;* orcid.org/0000-0002-7302-9176
Manish Kumar − *Discipline of Earth Science, Indian Institute of Technology, Gandhinagar, Gujarat 382 355, India;* orcid.org/0000-0002-3351-7298
Keisuke Kuroda − *Department of Environmental & Civil Engineering, Toyama Prefectural University, Imizu-city, Toyama 9390398, Japan*
Giuseppina La Rosa − *Department of Environment and Health, Italian National Institute of Health, 00161 Roma RM, Italy*
Francesca Malpei − *Dipartimento di Ingegneria Civile e Ambientale, Politecnico di Milano, 20133 Milano MI, Italy*
Mariana Mautus − *Biobot Analytics, LLC, Somerville, Massachusetts 02143, United States;* orcid.org/0000-0002-2880-0339
Sandra L. McLellan − *School of Freshwater Sciences, University of Wisconsin-Milwaukee, Milwaukee, Wisconsin 53204, United States;* orcid.org/0000-0003-3283-1151
Gertjan Medema − *KWR Water Research Institute, Water Quality and Heath, 3433 PE Nieuwegein, The Netherlands; Delft University of Technology, 2628 CN Delft, The Netherlands; Michigan State University, Natural Resources, East Lansing, Michigan 48823, United States;* orcid.org/0000-0003-0475-6465
John Scott Meschke − *Dept. Environmental and Occupational Health Sciences, School of Public Health, University of Washington, Seattle, Washington 98105-6099, United States*
Jochen Mueller − *Queensland Alliance for Environmental Health Sciences (QAEHS), University of Queensland, Brisbane, Queensland 4102, Australia*
Ryan J. Newton − *School of Freshwater Sciences, University of Wisconsin-Milwaukee, Milwaukee, Wisconsin 53204, United States;* orcid.org/0000-0001-8946-0035
David Nilsson − *Department of Sustainable Development, Environmental Science and Engineering, KTH Royal Institute of Technology, SE-10044 Stockholm, Sweden*
Rachel T. Noble − *UNC Chapel Hill Institute of Marine Sciences, Morehead City, North Carolina 28557, United States*
Alexander van Nuijs − *Toxicological Centre, University of Antwerp, 2610 Wilrijk, België*

https://dx.doi.org/10.1021/acs.est.0c02388
Environ. Sci. Technol. XXXX, XXX, XXX−XXX

Jordan Peccia − *Department of Chemical and Environmental Engineering, Yale University, New Haven, Connecticut 06520-8292, United States;* orcid.org/0000-0002-6482-2084
T. Alex Perkins − *Department of Biological Sciences and Eck Institute for Global Health, University of Notre Dame, Notre Dame, Indiana 46556, United States*
Amy J. Pickering − *Civil and Environmental Engineering, Tufts University, Medford, Massachusetts 02155, United States;* orcid.org/0000-0001-6193-2221
Joan Rose − *Department of Fisheries and Wildlife, Michigan State University, East Lansing, Michigan 48824, United States*
Gloria Sanchez − *Institute of Agrochemistry and Food Technology (IATA-CSIC), 46980 Paterna − Valencia, Spain*
Adam Smith − *Astani Department of Civil and Environmental Engineering, University of Southern California, Los Angeles, California 90089, United States;* orcid.org/0000-0002-3964-7544
Lauren Stadler − *Department of Civil and Environmental Engineering, Rice University, Houston, Texas 77005, United States;* orcid.org/0000-0001-7469-1981
Christine Stauber − *School of Public Health, Georgia State University, NE Atlanta, Georgia 30302, United States*
Kevin Thomas − *Queensland Alliance for Environmental Health Sciences (QAEHS), University of Queensland, Brisbane, Queensland 4102, Australia;* orcid.org/0000-0002-2155-100X
Tom van der Voorn − *Institute of Environmental Systems Research, University of Osnabrück, D49069 Osnabrück, Germany*
Krista Wigginton − *Department of Civil and Environmental Engineering, University of Michigan, Ann Arbor, Michigan 48109-2125, United States;* orcid.org/0000-0001-6665-5112
Kevin Zhu − *School of Civil and Environmental Engineering, Georgia Institute of Technology, Atlanta, Georgia 30332, United States*

Complete contact information is available at: https://pubs.acs.org/10.1021/acs.est.0c02388

Notes

The authors declare no competing financial interest.

REFERENCES

(1) Zhou, P.; Yang, X. Lou; Wang, X. G.; Hu, B.; Zhang, L.; Zhang, W.; Si, H. R.; Zhu, Y.; Li, B.; Huang, C. L.; et al. A Pneumonia Outbreak Associated with a New Coronavirus of Probable Bat Origin. *Nature* **2020**, *579* (7798), 270−273.
(2) Dong, E.; Du, H.; Gardner, L. An Interactive Web-Based Dashboard to Track COVID-19 in Real Time. *Lancet Infect. Dis.* **2020**, *3099* (20), 19−20.
(3) Li, R.; Pei, S.; Chen, B.; Song, Y.; Zhang, T.; Yang, W.; Shaman, J. Substantial Undocumented Infection Facilitates the Rapid Dissemination of Novel Coronavirus (SARS-CoV2). *Science (Washington, DC, U. S.)* **2020**, *3221* (January), eabb3221.
(4) Zhang, W.; Du, R. H.; Li, B.; Zheng, X. S.; Yang, X. Lou; Hu, B.; Wang, Y. Y.; Xiao, G. F.; Yan, B.; Shi, Z. L.; et al. Molecular and Serological Investigation of 2019-NCoV Infected Patients: Implication of Multiple Shedding Routes. *Emerging Microbes Infect.* **2020**, *9* (1), 386−389.
(5) Wölfel, R.; Corman, V. M.; Guggemos, W.; Seilmaier, M.; Zange, S.; Müller, M. A.; Niemeyer, D.; Jones, T. C.; Vollmar, P.; Rothe, C.; et al. *Nature* **2020**, *581*, 465.
(6) Sims, N.; Kasprzyk-hordern, B. Future Perspectives of Wastewater-Based Epidemiology: Monitoring Infectious Disease Spread and Resistance to the Community Level. *Environ. Int.* **2020**, *139*, 105689.
(7) Zhou, N. A.; Fagnant-Sperati, C. S.; Komen, E.; Mwangi, B.; Mukubi, J.; Nyangao, J.; Hassan, J.; Chepkurui, A.; Maina, C.; van Zyl, W. B.; et al. Feasibility of the Bag-Mediated Filtration System for Environmental Surveillance of Poliovirus in Kenya. *Food Environ. Virol.* **2020**, *12* (1), 35−47.
(8) Medema, G.; Heijnen, L.; Elsinga, G.; Italiaander, R.; Brouwer, A. Presence of SARS-Coronavirus-2 in Sewage. *medRxiv*. DOI: 10.1101/2020.03.29.20045880.
(9) Wu, F.; Xiao, A.; Zhang, J.; Gu, X.; Lee, W.; Kauffman, K.; Hanage, W.; Matus, M.; Ghaeli, N.; Endo, N.; et al. SARS-CoV-2 Titers in Wastewater Are Higher than Expected from Clinically Confirmed Cases. *medRxiv* **2020**, No. No. February 2019, 1−13.
(10) Ahmed, W.; Angel, N.; Edson, J.; Bibby, K.; Bivins, A.; O'Brien, J. W.; Choi, P. M.; Kitajima, M.; Simpson, S. L.; Li, J.; et al. First Confirmed Detection of SARS-CoV-2 in Untreated Wastewater in Australia: A Proof of Concept for the Wastewater Surveillance of COVID-19 in the Community. *Sci. Total Environ.* **2020**, *728*, 138764.
(11) Murakami, M.; Hata, A.; Honda, R.; Watanabe, T. Letter to the Editor: Wastewater-Based Epidemiology Can Overcome Representativeness and Stigma Issues Related to COVID-19. *Environ. Sci. Technol.* **2020**, 20045880.
(12) Manor, Y.; Handsher, R.; Halmut, T.; Neuman, M.; Abramovitz, B.; Mates, A.; Mendelson, E. A Double-Selective Tissue Culture System for Isolation of Wild-Type Poliovirus from Sewage Applied in a Long-Term Environmental Surveillance. *Appl. Environ. Microbiol.* **1999**, *65* (4), 1794−1797.
(13) Bustin, S. A.; Benes, V.; Garson, J. A.; Hellemans, J.; Huggett, J.; Kubista, M.; Mueller, R.; Nolan, T.; Pfaffl, M. W.; Shipley, G. L.; et al. The MIQE Guidelines: Minimum Information for Publication of Quantitative Real-Time PCR Experiments. *Clin. Chem.* **2009**, *55* (4), 611−622.