MATTERS ARISING

OPEN

Discussion on “Potential discharge, attenuation and exposure risk of SARS-CoV-2 in natural water bodies receiving treated wastewater”

Charles N. Haas¹ , Aaron Bivins², Warish Ahmed³ , Kerry A. Hamilton⁴ and Stuart J. Khan⁵

ARISING FROM Kumar, M. et al. *npj Clean Water* <https://doi.org/10.1038/s41545-021-00098-2> (2021)

npj Clean Water (2021)4:32; <https://doi.org/10.1038/s41545-021-00123-4>

The challenges posed by COVID-19 require many diverse fields of research engagement to address. Understanding risks relating to exposure of the infectious agent, SARS-CoV-2, is key among them. Kumar et al. have assembled relevant literature with the aim of developing a risk assessment for recreators using bodies of natural water. However, the authors have introduced a number of shortcomings into their analysis, which in our opinion results in a substantial overestimate of the underlying risks of exposure and infection. We briefly discuss them below.

Despite prolonged SARS-CoV-2 RNA detection in the stool of infected and convalescent patients¹, observations of intact virions² and evidence of virion infectivity in stool are sparse³. In nasopharyngeal clinical specimens, RNA is found to be more persistent (median duration 34 days) compared to culturable virus⁴ (median duration 7 days), thus establishing that observations of SARS-CoV-2 RNA alone are not sufficient to confirm the presence of infectious virus.

As noted by Kumar et al., SARS-CoV-2 RNA has been detected in untreated (or “raw”) wastewater throughout the world. Circumstantial epidemiological evidence has linked untreated sewage⁵ and sewage aerosols⁶ with local clusters of SARS-CoV-2 infection, but culturable SARS-CoV-2 has not yet been reported in untreated sewage, even that originating from a hospital isolation ward for SARS-CoV-2 patients⁷ or surface waters contaminated with untreated sewage⁸. While SARS-CoV-2 RNA has been observed in secondary treated effluent^{9,10}, which Kumar et al. describe as “treated wastewater”, detections of SARS-CoV-2 RNA at low concentrations in treated final effluent, or in river water receiving final effluent¹⁰ remain rare.

Critically, the isolation of infectious SARS-CoV-2 from sewage of any kind, including untreated or final treated effluent, or from environmental waters has not been reported. A study of infectious SARS-CoV-2 seeded into primary municipal wastewater and dechlorinated tap water found that SARS-CoV-2, an enveloped coronavirus, is not as persistent in aquatic environments as common fecal-oral pathogens¹¹. Together these observations suggest that the risk of SARS-CoV-2 transmission via ingestion of environmental water during recreation is very low. Quantitative microbial risk assessment (QMRA) is a useful framework for estimating such risks, but the plausibility of the risk characterization is dependent upon a reasonable model of the chain of events leading to exposure and the resulting dose.

In the exposure scenario the authors describe, the effects of the dilution of treated or untreated wastewater with surface water and

the decay of the infectious agent during transport must be considered. While the authors acknowledge the occurrence of both dilution and decay in their survey of the literature, they account for neither in estimating the dose expected from recreational contact.

To quantify the dose, the authors assume that each gene copy of SARS-CoV-2 RNA, the unit reported in wastewater studies, is equivalent to an infectious plaque-forming unit (pfu) of viable virus, the unit of the dose-response model. Given the evidence described above, this is a potentially large overestimate of the presence of infectious virus. While we are unaware of studies describing the expected ratio of SARS-CoV-2 RNA gene copies to infectious virions in environmental samples, meta-analyses of clinical data in hospitalized patients suggest the absence of viable virus below 10⁶ RNA gene copies³. From a study investigating laboratory persistence of SARS-CoV-2 in primary wastewater effluent and dechlorinated tap water, this ratio varied from 10 to more than 10,000 over 7 days of observation¹¹. Logically, these ratios will increase (fewer infectious viruses per gene copy) as discharge and transport into the environment occurs.

The authors use volume per event values of 2 mL ingestion for fishing and 6 mL for swimming. While these are reasonable, they then assume that “all the ingestion dose reaches the nasal cavity”. This is not reasonable since accidental ingestion during swimming is conventionally understood to occur by swallowing water from the mouth. The assumption regarding the nasal cavity is applied to justify the use of a previously reported dose-response model for the related SARS-CoV, reported by Watanabe et al.⁵. However, the establishment of that model was based on data pertaining to inhalation exposure, not oral ingestion of water, and infectious virus (PFU or TCID₅₀ was the dose metric). Dose-response relationships from these two exposure routes vary markedly, since inhalation exposure transfers virions to the respiratory system, whereas oral ingestion of water occurs primarily via the digestive system. Thus, the application of this dose-response relationship—even as a rough estimate—is not appropriate in this case and harmonization of factors is needed. We are not aware of reliable data on accidental inhalation during recreational water activities, but it is almost certainly only a small fraction of the ingested volume¹². In one of the only QMRA’s for inhalation from recreational water (in splash parks) a substantially reduced exposure volume was assumed¹³.

The authors use the exponential dose-response relationship from Watanabe et al.⁵. They then, somewhat confusingly, apply a Poisson distribution to the dose, which is already a population average. The

¹Drexel University, Philadelphia, PA, USA. ²University of Notre Dame, Notre Dame, IN, USA. ³CSIRO, Brisbane, Australia. ⁴Arizona State University, Tempe, AZ, USA. ⁵University of New South Wales, Sydney, Australia. ✉email: haas@drexel.edu

authors seemingly ignore the basis for the derivation of the exponential dose–response function, which includes an assumption of Poisson distribution in doses between individuals⁶. Thus, there is no need for the imposition of another Poisson function. If there is hypervariability with respect to the Poisson, alternative computational frameworks exist¹⁴.

Considering these shortcomings, it is likely that the risks of SARS-CoV-2 infection associated with recreational exposures to waters under the influence of treated wastewater (if any) are orders of magnitude below those estimated by Kumar et al. despite their assertion that “the estimated chance of infection for COVID-19 in this study could be underestimated.” Thus, it is unsurprising that, to our knowledge, no cases of COVID-19 have been linked to such exposures. We would also note that further work is needed in the contexts of unsewered areas, lower and middle income countries with uncontrolled waste management, and open defecation⁷.

Received: 6 February 2021; Accepted: 21 May 2021;

Published online: 15 June 2021

REFERENCES

- Wu, Y. et al. Prolonged presence of SARS-CoV-2 viral RNA in faecal samples. *Lancet Gastroenterol. Hepatol.* **5**, 434–435 (2020).
- Zhang, Y., Chen, C. & Zhu, S. Isolation of 2019-nCoV from a stool specimen of a laboratory-confirmed case of the coronavirus disease 2019 (COVID-19). *China CDC Wkly.* **2**, 123–124 (2020).
- Xiao, F. et al. Infectious SARS-CoV-2 in feces of patient with severe COVID-19. *Emerg. Infect. Dis.* **26**, 1920–1922 (2020).
- Kim, M.-C. et al. Duration of culturable SARS-CoV-2 in hospitalized patients with Covid-19. *N. Engl. J. Med.* <https://doi.org/10.1056/NEJMc2027040> (2021).
- Yuan, J. et al. Sewage as a possible transmission vehicle during a coronavirus disease 2019 outbreak in a densely populated community: Guangzhou, China, April 2020. *Clin. Infect. Dis.* <https://doi.org/10.1093/cid/ciaa1494> (2020).
- Kang, M. et al. Probable evidence of fecal aerosol transmission of SARS-CoV-2 in a high-rise building. *Ann. Intern. Med.* <https://doi.org/10.7326/M20-0928> (2020).
- Wang, J. et al. SARS-CoV-2 RNA detection of hospital isolation wards hygiene monitoring during the Coronavirus Disease 2019 outbreak in a Chinese hospital. *Int. J. Infect. Dis.* **94**, 103–106 (2020).
- Rimoldi, S. G. et al. Presence and infectivity of SARS-CoV-2 virus in wastewaters and rivers. *Sci. Total Environ.* **744**, 140911 (2020).
- Randazzo, W. et al. SARS-CoV-2 RNA in wastewater anticipated COVID-19 occurrence in a low prevalence area. *Water Res.* **181**, 115942 (2020).
- Haramoto, E., Malla, B., Thakali, O. & Kitajima, M. First environmental surveillance for the presence of SARS-CoV-2 RNA in wastewater and river water in Japan. *Sci. Total Environ.* **737**, 140405 (2020).
- Bivins, A. et al. Persistence of SARS-CoV-2 in Water and Wastewater. *Environ. Sci. Technol. Lett.* <https://doi.org/10.1021/acs.estlett.0c00730> (2020).
- Dufour, A. P., Behymer, T. D., Cantu, R., Magnuson, M. & Wymer, L. J. Ingestion of swimming pool water by recreational swimmers. *J. Water Health* **15**, 429–437 (2017).
- de Man, H. et al. Health risk assessment for splash parks that use rainwater as source water. *Water Res.* <https://doi.org/10.1016/j.watres.2014.02.010> (2014).
- Haas, C. N. Conditional dose-response relationships for microorganisms: development and application. *Risk Anal.* **22**, 455–463 (2002).

AUTHOR CONTRIBUTIONS

The authors contributed equally to this submission.

COMPETING INTERESTS

The authors declare no competing interests.

ADDITIONAL INFORMATION

Correspondence and requests for materials should be addressed to C.N.H.

Reprints and permission information is available at <http://www.nature.com/reprints>

Publisher's note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Open Access This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license, and indicate if changes were made. The images or other third party material in this article are included in the article's Creative Commons license, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons license and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this license, visit <http://creativecommons.org/licenses/by/4.0/>.

© The Author(s) 2021