



Public Health Benefits and Ethical Aspects in the Collection and Open Sharing of Wastewater-Based Epidemic Data on COVID-19

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ABSTRACT

Collection and open sharing of wastewater-based epidemic data potentially provide immense public health benefits during outbreak of infectious diseases such as COVID-19. By early detection and localization of unidentified infections, wastewater surveillance is expected to enable early and targeted containment of the local outbreak. Wastewater surveillance renders potentially high public health benefits when a small catchment is targeted; however, it possibly leads to stigmatization and discrimination against the targeted group. Therefore, public commitment is crucial for the collection and open sharing of wastewater-based epidemic data. With respect to the sharing of wastewater-based epidemic data, technical limitations and uncertainty of collected data also should be simultaneously shared on the basis of scientific communication. Useful application of wastewater-based epidemic data is to complement clinical epidemic data, which is possibly biased and overlooks unidentified infections. To acquire public commitment toward the collection and open sharing of wastewater-based epidemic data, stakeholders need to reach a consensus on possible options of restrictive measures taken with respect to the collected data as well as appropriate handling of the collected data to prevent stigmatization and discrimination.

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1. BENEFITS OF WASTEWATER SURVEILLANCE FOR THE INVESTIGATION OF A LOCAL EPIDEMIC SITUATION

Wastewater monitoring is an effective strategy to obtain information about an epidemic situation of infectious diseases. In some infectious diseases, pathogens are shed in feces of patients, which are then detected in the wastewater collected from the sewer catchment area in which patients are present. Such wastewater surveillance, referred to as wastewater-based epidemiology, has been practically applied to investigate the epidemic situation of norovirus and poliovirus. In some countries, wastewater-based epidemiology also has been applied to investigate illicit drug use. Recently, wastewater-based epidemiology is popularly known for its potential application for the early detection of the COVID-19 outbreak. As genetic markers of SARS-CoV-2 are shed in feces of people infected by COVID-19, these genetic markers can be detected in wastewater when infected people are present in the sewer catchment area. Notably, the viral genetic marker in wastewater was reportedly detected as early as 5–7 days ahead of clinical surveillance reports and 0–2 days ahead of specimen collection (Peccia et al., 2020). Moreover, the viral genetic marker concentration reflects the infected population of the sewer catchment in a highly prevalent area of COVID-19 infection (Medema et al., 2020; Peccia et al., 2020). Regarding these potential benefits as a regional epidemic indicator, the monitoring of genetic signals of SARS-CoV-2 in wastewater has been reportedly conducted in several countries such as the USA and EU. In the Netherlands, monitored data of the genetic signal in wastewater is openly shared and updated weekly on a website developed by a governmental authority, in addition to other epidemic indicators, such as confirmed COVID-19 cases and hospital admissions, etc. (Ministry of Health, Welfare and Sport, 2021) Recently, the genotyping of SARS-CoV-2 in wastewater has been reported by reading viral genome sequences (Crits-Christoph et al., 2021; Nemudryi et al., 2020). Wastewater surveillance is possibly applicable for the early detection of newly emerged (or imported) variants and tracking of the temporal and geographical spread of the virus variant.

Key benefits of wastewater-based epidemiology for COVID-19 include enabling population-scale epidemic investigation or group diagnosis with a small number of tests, including unidentified infections. The critical difficulty in controlling the COVID-19 outbreak is the abundance of asymptomatic and pre-symptomatic infections. Among all COVID-19 infections, 40–60% of the infections were reported to be asymptomatic (He et al., 2021; Lavezzo et al., 2020; Nishiura et al., 2020). A large portion of asymptotically infected people remain unidentified, possibly causing secondary infections. According to serological surveys in California in April 2020, 30–80 times of the larger population had history of infection as indicated by SARS-CoV-2 antibodies than the confirmed COVID-19 cases (Bendavid et al., 2021; Sood et al., 2020). Notably, asymptomatic and pre-symptomatic infections were estimated to be the major transmission source of COVID-19 (Emery et al., 2020; Ferretti et al., 2020). Regarding the abundance of asymptomatic infections, a large number of polymerase chain reaction (PCR) diagnostic tests are currently performed daily in several countries, targeting people not only with suspicious symptoms but also without apparent symptoms. Drawbacks of such massive individual testing include (i) requirement of substantial costs as well as labor resources, (ii) reporting time lag for data aggregation, and (iii) possible bias by clinical diagnostic situations, such as the scale of testing (i.e., more PCR tests reveal more infections) and selection of target persons (e.g., due to accessibility to medical services). Meanwhile, epidemic data obtained by wastewater surveillance are ready-to-use without data aggregation as a single wastewater sample reflects the presence of infections in the catchment. Wastewater surveillance potentially enables to acquire a warning signal of the outbreak or an epidemic trend for lower efforts and costs, with a less time lag and lower bias of diagnostic situations. In addition, these features are beneficial to investigate epidemic situations of people in rural areas of developing countries and urban poverty area who have limited access to medical services.

Wastewater surveillance primarily targets a regional-scale population in the catchment of a wastewater treatment plant. Catchments of wastewater treatment plants often cover populated areas and divide a municipality into several smaller areas. Therefore, the monitoring of wastewater at a wastewater treatment plant can efficiently specify the area in which COVID-19 infections are abundant irrespective of the situation of clinical diagnoses. Notably, wastewater surveillance can target an even smaller group of the population by monitoring a manhole of a sewer network or a building unit. It is technically possible to identify the location

of an emerged infection via the tracking of viral genetic markers in a sewer pipeline (Larson et al., 2020). At a student dormitory in the University of Arizona, the detection of SARS-CoV-2 genetic signals in wastewater led to individual clinical testing of all residents (n = 311) and identification of three infected persons, including two asymptomatic infections (Betancourt et al, 2021). Political decisions on the COVID-19 outbreak control are often made in reference to epidemic indicators, e.g., clinically confirmed cases, that are aggregated on the basis of administrative municipal boundaries. Therefore, mass quarantine, such as stay-at-home orders and business closures, typically restricts the movement of the entire population in the corresponding municipal boundaries. As wastewater-based epidemiology can efficiently investigate the epidemic situation of small areas, it enables the implementation of outbreak control measures that target a more specific area or a small population. From the viewpoint of disease outbreak control, it is effective to detect a group infection in the early stage and prevent the spread of infection to the larger population. In addition, the targeted implementation of quarantine measures in a limited area or community can mitigate adverse impact on economic activities.

2. ETHICAL ASPECTS IN OPEN SHARING OF WASTEWATER-BASED EPIDEMIC DATA

Foundation for the open sharing of wastewater-based epidemic data is the public nature of a sewer and wastewater treatment system. Sewer and wastewater treatment systems are often operated as public service. Hence, wastewater-based epidemic surveillance is often conducted by the public authority, which is financially supported by tax expenditure or sewer service fee. When the wastewater surveillance is conducted by the public authority (or the organization commissioned by the public authority), it is reasonable to consider that the public or people served by the sewer system have the right to access the collected data. The monitoring of viral genetic markers at a wastewater treatment plant for the collection of COVID-19 epidemic data is possibly accepted in several cases however, clear public commitment to open the collected data to the public has not been established thus far in most cases. At a wastewater treatment plant, water quality indicators such as organic matter and nutrients, etc. are regularly analyzed as a part of its operation service. Collection of such water quality data is considered to have public commitment as it is crucial to achieve the prescribed service of the wastewater treatment system, namely the removal of pollutants from wastewater before discharge into the environment. On the other hand, the collection of wastewater-based epidemic data has not been explicitly prescribed as the service of a sewer system in most cases thus far. Clinical surveillance requires consent by the tested individuals. Collection and use of wastewater-based epidemic data by public authorities is likely to have implicit public commitment as long as it is used for investigation of regional epidemic situations and for better resource allocation to mitigate health impact. However, wastewater surveillance may cause ethical concerns if the collected data is used without explicit public commitment to target individuals or groups for restriction orders, such as stay-at-home order or business closure. Open discussion on social benefits and ethical aspects is crucial to acquire public commitment toward the collection and open sharing of wastewater-based epidemic data.

Collection and open sharing of wastewater-based epidemic data is mostly accepted as long as it targets a large population. One advantage of wastewater-based epidemiology in data collection and sharing is having low privacy and stigmatization issues (Murakami et al., 2020). A sewer catchment of a wastewater treatment plant often covers thousands to millions of people. When wastewater is monitored at a wastewater treatment plant, surveillance data represent a large population in the sewer catchment. Wastewater surveillance data are linked to temporal and geographical information, albeit without specifying infected individuals. On the contrary, clinical surveillance data collected by individual testing needs to be made anonymous by data aggregation before sharing the data with the public. Currently, a large number of COVID-19 diagnoses by individual PCR assays are conducted for the purpose of quarantine and epidemic data collection rather than diagnosis for clinical treatment. Infected people, or those diagnosed with a false-positive result, are potentially harmed by stigma and social isolation (Zhai & Du, 2020). In principle, the sharing of wastewater-based epidemic data would not cause stigmatization and discrimination against individuals. However, it possibly leads to stigmatization and discrimination against specific groups when it targets a small catchment or

building. The collected data should be carefully handled especially in case of income disparity in the target catchment or it is characterized by a race or a religious culture. Open sharing of wastewater surveillance data collected from a small catchment may promote stigmatization and discrimination against the targeted group. The liability to the potential harm might be enhanced when the wastewater surveillance targets a smaller group.

Targeted wastewater surveillance is beneficial as it enables the public health authority to locate unidentified infections early and take control measures in a more targeted manner. The open sharing of targeted wastewater surveillance data possibly encourages (i) preventive actions against the disease, e.g., face covering and hand sanitization, etc., and (ii) social understanding on the restrictive measures targeting the specific area, e.g., group quarantine and business closures, etc., by providing local epidemic information to people in the targeted catchment. These early and targeted actions can enable the effective containment of an outbreak. Achievement of early containment benefits people not only in the targeted area but also in the broader area, which is potentially affected by the local outbreak. However, ethical issues might arise from the collection of wastewater-based epidemic data when the information is used for restrictive measures such as group quarantine or business closure in the targeted area (Gable et al., 2020). Debates on ethical concerns of targeted wastewater surveillance have been conducted for the monitoring of illicit drug use (Hall et al., 2012; Prichard et al., 2014). According to these debates, wastewater surveillance for illicit drug use does not raise major ethical concerns mostly when targeting large populations (e.g. the entire catchment of a wastewater treatment plant) without the identification of individuals. Also, there have been debates on ethical issues in public health surveillance. For example, in the context of HIV/AIDS, data collection strategies targeting certain vulnerable groups or public release of data identifying high-risk groups might lead to discrimination and stigmatization (Klingler et al., 2017). WHO (2017) published ethical guidelines in public health surveillance, in which the public authority holding the surveillance data is required to safeguard the privacy and other interest of the individuals and communities concerned. In wastewater-based epidemic surveillance, it is recommended to develop ethical guidelines when potential harm such as stigmatization is expected by targeting a small area. The important point of this debate is a reasonable balance between public health benefits and the potential harm to affected people.

In wastewater-based epidemiology for infectious diseases, targeting a small group would increase public health benefits of effective containment due to the more precise localization of infected people, while it may also increase potential social harm to the targeted people. Currently, science underlying wastewater-based epidemiology for COVID-19 is still developing. A positive detection of the genetic marker of SARS-CoV-2 in wastewater certainly indicates the presence of infected people in the catchment; however, it is quite unreliable for the negative detection of the genetic marker to indicate the absence of infection. According to the sensitivity of the genetic marker detection in wastewater by the popularly used assay (Hata & Honda, 2020), the early detection of infection is more likely to demonstrate promise for a small group of population than a population-based surveillance for a large sewer catchment. Meanwhile, the detection of viral markers is less certain in a small catchment due to the increased fluctuation by the timing of fecal discharge and large variance of viral shedding by the infected people in the catchment. Thus far, wastewater-based epidemic data alone is not feasible to account for the epidemic situation of the targeted population. It is expected to be useful to complement clinical epidemic data, which is possibly biased and overlooks unidentified infections. In addition, technical limitations and uncertainty should be well explained when wastewater-based epidemic data are shared to the public. For public commitment to the open sharing of wastewater-based epidemic data, the potential ethical issues and technical limitations should be presented, as well as the expected public health benefits.

3. CONCLUSIONS

By the early detection and localization of unidentified infections, wastewater surveillance is expected to enable early and targeted containment of the local outbreak. However, ethical issues possibly arise from restrictive measures, stigmatization, and discrimination against the targeted group. Regarding technical limitations and potential ethical issues, public commitment is crucial for the collection and open sharing of wastewater-based epidemic data. To acquire

public commitment, stakeholders need to reach a consensus on possible options of restrictive measures taken according to the collected data as well as the appropriate handling of the collected data to prevent stigmatization and discrimination.

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COMPETING INTERESTS

The authors have no competing interests to declare.

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