Tracking COVID-19 employing waste waters: a reliable indicator for supporting the prevention and management of the pandemic

Main Messages

In light of the progression of the pandemic and the emergence of a second wave in several countries, tracking the presence of the virus in wastewater is highly recommended, as a relatively cheap and reliable way of gathering essential information. It should be used in conjunction with other public health indicators and can be very useful to establish and adjust public health management strategies. The tool also appears useful in providing targeted ad hoc support in less favoured countries where epidemiological data are not available.

- Information gathered so far show **a direct correlation between the quantities of the Covid19 virus found in wastewaters and the number of persons infected** in the corresponding area.
- Waste water surveillance can be effectively used as:
  - **preventive or early warning tool** – as soon as the virus is detected, this should be taken as a signal of a possible (re)emergence of the pandemic;
  - **management tool** – absence of the virus in wastewater could indicate that the corresponding zone can be considered as of low risk;
  - **safety net** – if the virus is detected in wastewater but the testing of the resident population is negative, investigations of undetected infection sources should be undertaken.
- Data from wastewater surveillance should always be used as a **complement to epidemiological data**. Where no such epidemiological data are available, information on the presence of the virus in wastewater can help in designing the **most effective assistance strategies to the benefit of less-favoured countries and social categories**.
- **Tracking wastewater is a cost-effective** preparedness and resilience **tool**: securing effective surveillance of 1 treatment plant requires ca**. 25 000 €/year.**[1]
- Tracking viruses' presence at regular interval in wastewaters can also be useful **to anticipate possible new pandemics**[2] **–** next to future 'waves' of the current one.

Since the emergence of the COVID-19 pandemic, wastewater has been investigated as a means to identify the virus presence in the community, both within the EU and internationally. Data gathered so far indicate that surveillance of wastewater is a cheap and reliable tool to track the virus presence. This should be done in conjunction with the information collected on the prevalence of the virus from other sources such as swab testing, blood test, tracing apps[3]. **The purpose of this short memo** is to (1) synthetize the main results obtained so far; and (2) draw first conclusions and recommendations. This memo is expected to be regularly updated as science and research is rapidly evolving.[4]

[1] Average cost based on two analysis per week – valuable for large waste water treatments (up to 1M inhabitants). For comparison: the development of the CORONA warn app in Germany costed 22.7 Mio € plus an estimated of 2.5 – 3.5 Mio € of monthly running costs

[2] This risk was recently highlighted in a IPBES publication – see: https://ipbes.net/pandemics

[3] https://www.who.int/publications/i/item/water-sanitation-hygiene-and-waste-management-for-covid-19; https://doi.org/10.1016/j.coesh.2020.09.006; https://doi.org/10.1016/j.scitotenv.2020.139076

[4] Most of the results are extracted from the JRC/ENV project https://ec.europa.eu/jrc/en/science-update/call-notice-feasibility-assessment-eu-wide-wastewater-monitoring-system-sars-cov-2-surveillance

Why is the virus SARS-CoV-2 present in wastewaters? How reliable are the results?

COVID-19 (Corona Virus Disease 2019) – is caused by the virus SARS-CoV-2. The virus is present in the stools of persons infected by COVID-19[5], regardless of whether they show typical symptoms of the diseases. Also SARS-CoV-2 RNA from urine[6] and respiratory secretions (from handwashing, showering, nasal lavages, tissues, sputum) may contribute to the load of SARS-CoV-2 into the sewer system, as indicated by the detection of SARS-CoV-2 RNA in washbasin and shower siphons[7].

Stools and other viral material (sputum, urine, washing water, etc.) are then transported to waste water treatment facilities, via the local wastewater collecting (sewerage) system. To date, no infectious SARS-CoV2 virus has been recovered from untreated or treated sewage[8] and hence, the virus is understood to be inactive in raw wastewater, although its genetic presence can nonetheless be detected at the entry of wastewater treatment plants.

Wastewater treatment is known to lessen the signal of the (inactive genetic) virus material, therefore samples are usually taken at the inlet to the plant. It is typical practice at wastewater treatment plants to take samples of incoming sewage, and the plants are designed to do so in a safe and efficient manner[9]. Samples of waste water can also be collected directly from the collecting system[8], for instance at a pumping station, or at a suspected virus 'hotspot' such as a hospital[10, 11], dormitories[12] , a residential district or other confined places such cruise ships or passenger aircrafts[13].

Through extensive knowledge sharing internationally, sampling and analysis methods have achieved good level of harmonisation and are considered reliable. They are based on proven methods (PCR) used in medicine for the patient testing (swab tests or blood analyses). Competent laboratories are available in all Member States.

Is it possible to detect the virus in wastewaters in anticipation of the pandemic?

Investigations have shown that the virus can be detected within hours in human stool in case of an infection, independent of the patient showing no, mild or strong symptoms of COVID-19. Consequently, the presence of the virus has been detected in some wastewater treatment facilities before the virus was understood to have spread in the population and before medical symptoms were detected by the medical community. The time between the appearance of the virus in untreated wastewater and the appearance of increased numbers of symptomatic patients oscillates between few days and few weeks.

This was demonstrated for instance in Amsterdam, Milan or Barcelona. As shown in the table below, in Amsterdam the virus was already detected on the 6th of February, i.e. **3 weeks before the first Dutch**

[5] https://doi.org/10.1016/j.ebiom.2020.102916
[6] https://doi.org/10.1007/s00345-020-03246-4
[7] https://doi.org/10.1101/2020.05.28.20114041
[8] https://www.who.int/publications/i/item/water-sanitation-hygiene-and-waste-management-for-the-covid-19-virus-interim-guidance
[9] https://doi.org/10.1016/j.scitotenv.2020.140444
[10] https://doi.org/10.1007/s00103-020-03118-7
[11] https://doi.org/10.1016/j.ijid.2020.04.024
[12] https://www.washingtonpost.com/nation/2020/08/28/arizona-coronavirus-wastewater-testing/
[13] https://doi.org/10.1093/jtm/taaa116

case was reported and 5 weeks before the decision to establish a lock-down[14]. In Barcelona, while the first case was reported on the 25th of February 2020, the virus resulted in samples of wastewater in the area taken on the 25th of January, i.e. **41 days before the first case** was confirmed. In Italy, the first case was reported on February 21, while the virus presence could be seen in wastewater already in December 18th in Milan and Turin and then on the January 29th in Bologna, i.e. **64 and 23 days**, respectively, **before the first cases**.

	Confirmed presence in waste waters	First reported cases	Date of National Lockdown Measures	Days between detection and lockdown	National casualties between first case and lockdown	National casualties x days after lockdown
Amsterdam (NL)	Feb 6, 2020	Feb 27, 2020	Mar 15, 2020	21 days	20	15/04/2020: 3134 (21 days after lockdown)
Barcelona (ES)	Jan 25, 2019	Feb 25, 2020	Mar 14, 2020	31 days	292	14/04/2020: 18276 (31 days after lockdown)
Milan (IT)	Dec, 18, 2019	Feb 21, 2020	Mar 9, 2020	65 days	1809	13/05/2020: 31106 (65 days after lock down)

This early-warning function was confirmed in the meantime: in a first example, the re-appearance of SARS-CoV-2 was anticipated in a research project in A Coruña (Spain), where the virus load started to increase on July 14th, 2020[15]. In the US successful applications have been reported from Arizona, preventing an outbreak at the university campus[16].

The use of tracking viruses in wastewater is well established and has previously been deployed successfully to monitor, for instance, the polio virus[17] or enteric bacteria[18]. Tracking the virus' presence at regular interval in waste waters could therefore be useful to anticipate a possible pandemic and/or possible new 'waves' of the pandemic.

Is it possible to quantify the presence of the virus in the population on the basis of waste water surveillance?

First results obtained from the JRC / ENV project as well as the information gathered so far show a correlation between the number of person infected in a zone and the quantities of virus found in the waste waters. Results reported in literature (articles cited here) show also that the viral load in the sewage increases, before the number of infected persons increase. Therefore, the number of people infected in an area could in principle be roughly estimated based on quantities of virus found in the wastewaters.

[14] https://www.medrxiv.org/content/10.1101/2020.03.29.20045880v2
[15] https://www.medrxiv.org/content/10.1101/2020.07.02.20144865v2.full.pdf and personal communication, still under moratorium due to IPR
[16] https://www.washingtonpost.com/nation/2020/08/28/arizona-coronavirus-wastewater-testing/
[17] https://doi.org/10.1017/S095026881000316X
[18] https://www.nature.com/articles/s41467-019-08853-3

These remain rough estimates to be cross-checked with other sources of information. There are different reason for this: first, the testing strategies of each country differ and provide different numbers in terms of persons infected. Secondly, wastewater does not lie about the virus presence, but it is not clear if the virus load stems from residents or for instance commuting work forces or tourists. Wastewater surveillance is hence most powerful in combination with patient oriented testing.

One obvious lesson of the results gained so far is that if the virus is not present in the wastewaters from an area it means that this area is relatively safe.

How the information provided by wastewater can be used?

Information on the presence of the virus in wastewaters could be used in three main ways:

1. As a **preventive or early warning tool** – clearly when the virus is detected it should be taken as a signal of a possible (re)emergence of the pandemic;
2. As a **management tool** – the absence of the virus in wastewater from a particular zone could indicate that the corresponding zone can be considered as of low risk at the time the sample was taken. If the virus is presence is low and stable or decreasing quantities, this could mean that the pandemic is under control and that measures taken are efficient. On the contrary if the quantities of virus increase that would mean that additional measures are necessary to stop the spreading of the virus. This application requires frequent sampling of wastewater, close coordination with health authorities to understood measures in place and the expected time lag between implementing a measure and a change in the progression of the disease. Where the detection of the virus is carried out in the collecting system (sewerage) of different districts of a city or an area, it could provide additional fine tuned geographical information.
3. As a **safety net** – if testing of resident population is negative, but the virus is detected in wastewater, investigations of undetected infection sources should be initiated. Such a system, can also help to re-establish public trust in accessing, cruise ships, touristic facilities or other well defined areas with a controlled sewer system.

It is important to stress that this information should always be used as a complement to epidemiologic data when available. In absence of such reliable data, information on presence of the virus in wastewater might be the only reliable indicator of the pandemic extension, and can help for instance in the assistance of situations of less-favoured conditions and countries.

This is confirmed in a recent publication of WHO[19] but also by the French Académie de Médécine [20]identifying that the tracking of the virus can be used for early warning, detection of the virus in areas with limited clinical capacity, monitoring the circulation of the virus, further research. The document advantages of this approach including cost-effectiveness, whilst emphasising the importance of close coordination of laboratories, utilities, and public health authorities to deliver the needs of the public health services.

[19] "*Status of environmental surveillance for SARS-CoV-2 virus*" https://www.who.int/news-room/commentaries/detail/status-of-environmental-surveillance-for-sars-cov-2-virus

[20] http://www.academie-medecine.fr/communique-de-lacademie-covid-19-surveillance-de-la-circulation-du-sars-cov-2-dans-les-eaux-usees-indicateur-simple-de-suivi-de-la-pandemie-de-covid-19/

What are the most advanced experience in using this indicator?

Several countries in Europe and beyond are now tracking virus presence in their wastewater as an additional means by which to manage the pandemic.

The **Netherlands** introduced a national programme, commencing September 2020. The Netherlands Ministry of Health announced on June 23rd that **all 352 Dutch WWTPs** are to be sampled **on a daily basis** for the presence of the virus, with the data fed into the National Dashboard (decision support tool for pandemic measures). [21] In **Austria**, the Region of Tyrol has also introduced a systematic surveillance programme. All 43 WWTPs in the Region covering 99 % of the population are regularly tested[22]. Other countries, among which **Luxembourg[23], France[24][25], Germany[26], Belgium[27], Italy[28], Spain[29], Portugal[30], Czech Republic[31], Cyprus[32]** and **Finland[33]** have set up national reference studies and seek to mobilize funding for upscaling. **Australia[34]** introduced a country-wide deployment as of June 10th and also **Turkey[35]** conducted a full country assessment of its major cities.

What are the costs?

In order better estimates the costs for a rollout, the JRC has published an EU Survey. A total of 13 replies were obtained with information from 8 countries, i.e. from Belgium, Hungary, Italy, Luxembourg, Portugal, Spain, the Netherlands and the UK. The participants were asked about the costs for sampling, shipment, laboratory tests, their estimate for costs compared to what they would charge as a service.

Table 1 – Cost estimates retrieved from an EU Survey

Cost element	Average	Range

[21] https://coronadashboard.government.nl/landelijk/rioolwater
[22] https://www.osttirol-heute.at/politik/covid-19-abwasser-monitoring-als-warnsystem-fuer-zusaetzliche-sicherheit/
[23] https://www.list.lu/en/news/presence-of-sars-cov-2-in-waste-water-first-conclusive-results-of-the-coronastep-study/
[24] https://sciences.sorbonne-universite.fr/actualites/obepine-un-observatoire-unique-pour-surveiller-la-circulation-du-sars-cov2-dans-les-eaux
[25] https://www.sciencemag.org/news/2020/04/coronavirus-found-paris-sewage-points-early-warning-system
[26] https://www.helmholtz.de/gesundheit/fruehwarnsystem-durch-abwasseranalysen/
[27] https://www.brusselstimes.com/news/belgium-all-news/health/134304/belgium-coronavirus-waste-water-sciensano-pandemic/
[28] https://www.iss.it/coronavirus/-/asset_publisher/1SRKHcCJJQ7E/content/id/5344257
[29] https://www.businesswire.com/news/home/20200813005853/en/
[30] https://tecnico.ulisboa.pt/en/news/covidetect-an-early-warning-system-that-can-make-the-difference-in-the-fight-against-the-pandemic/
[31] https://www.mdpi.com/784760
[32] https://doi.org/10.1016/j.jece.2020.104306
[33] https://yle.fi/uutiset/osasto/news/thl_to_track_coronavirus_in_waste_water/11315440
[34] https://www.waterra.com.au/research/communities-of-interest/covid-19/
[35] https://doi.org/10.1101/2020.05.03.20089417

Shipment	88 €	20 -400 €
Sampling and field work	140 €	50 -450 €
Estimate for 1 test	176 €	50-550 €
Charged cost*	238 €	80-750 €
Cost estimate by lab	236 €	60-550 €
Annual running budget for 1 WWTP (twice controls per weak)	+/- 25 000 €	

*value retained for further calculations

On average, the laboratories are able to survey ca 20 wastewater treatment plants, but a vast range of situation was encountered with one laboratory running 80 or more plant surveillances. If one takes these costs estimates and assumes two controls per week (104 measurements per year) laboratories equipped with the necessary instrumentation **require ca. 25 000 € running cost for the annual surveillance of 1 treatment plant.** Differences exist of course due to differences in over-head cost motels and salaries for laboratory staff across the EU. Currently, the Netherlands operate a surveillance programme for all of its 300 treatment plants.

A parallel investigation in the US State of Utah estimated the cost per inhabitants to be 0.10 USD for rural areas (higher shipment) to less than 0.01 USD per inhabitants for urbanised areas[15].

Based on the information gathered so far, upscaling costs for national rollouts are estimated to amount to 1-3 Mio € per Member State, depending on the number of the WWTPs to be included in Surveillance Program. The current costs entailed by the EU Umbrella run by the JRC confirmed these figures. For comparison: the development of the CORONA warn app in Germany costed 22.7 Mio € plus an estimated of 2.5 – 3.5 Mio € per months running cost[36,37].

Is it dangerous for wastewater operators to work in the vicinity of the virus?

Wastewater contain, at any time, a number of pathogens (whether viruses or bacteria), and the risks to all personnel who may come into contact with waste water are well understood. All such work environments should have in place adequate safety procedures in line with the requirements of national authorities, best practice and advice available. Nevertheless, evidence to-date demonstrated that the infectious properties are destroyed during the wastewater treatment processes. Exposure to the virus is therefore considered as negligible compared to direct contacts between humans.

What is done at EU level ? And what are the next steps?

Since the beginning of the pandemic, the European Commission, through its Joint Research Centre with the support of DG ENV and the involvement of DG SANTE, has launched an initiative to jointly

[36] https://fragdenstaat.de/anfrage/vertragsdokumente-zur-corona-app-mit-der-telekom-und-sap/513354/anhang/Vertrag%20Telekom.pdf
[37] https://www.rnd.de/digital/corona-warn-app-vertrag-veroffentlicht-app-kostet-25-bis-35-millionen-euro-monatlich-J6TEZB3ZJBBPBANPCT4A7EQ4ZQ.html

assess wastewater samples and collect data from Member States, to make additional standardised sampling and analysis, to disseminate first results and to favour exchange of information and best practices. Three open webinars[38] were organised with the participation of several EU and non-EU countries, including the WHO and UNEP.

A first scientific review of the results obtained is to be published before end 2020. Practical guidelines for wastewater operators are also in preparation, as well as a comparative exercise of sampling and analysis methods. The added value of imposing regular influent sampling for pathogens at the wastewater treatment facilities will be assessed within the ongoing review of the Urban Waste Water Treatment Directive.[39]

[38] Temporary access to the webinar can be provided in the coming weeks

[39] Additional information is available from https://ec.europa.eu/environment/water/water-urbanwaste/index_en.html