# Wastewater analysis as an early warning system for COVID-19 at population level. Summary of national and international research and ongoing activities in Norway

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Norwegian Institute for Water Research

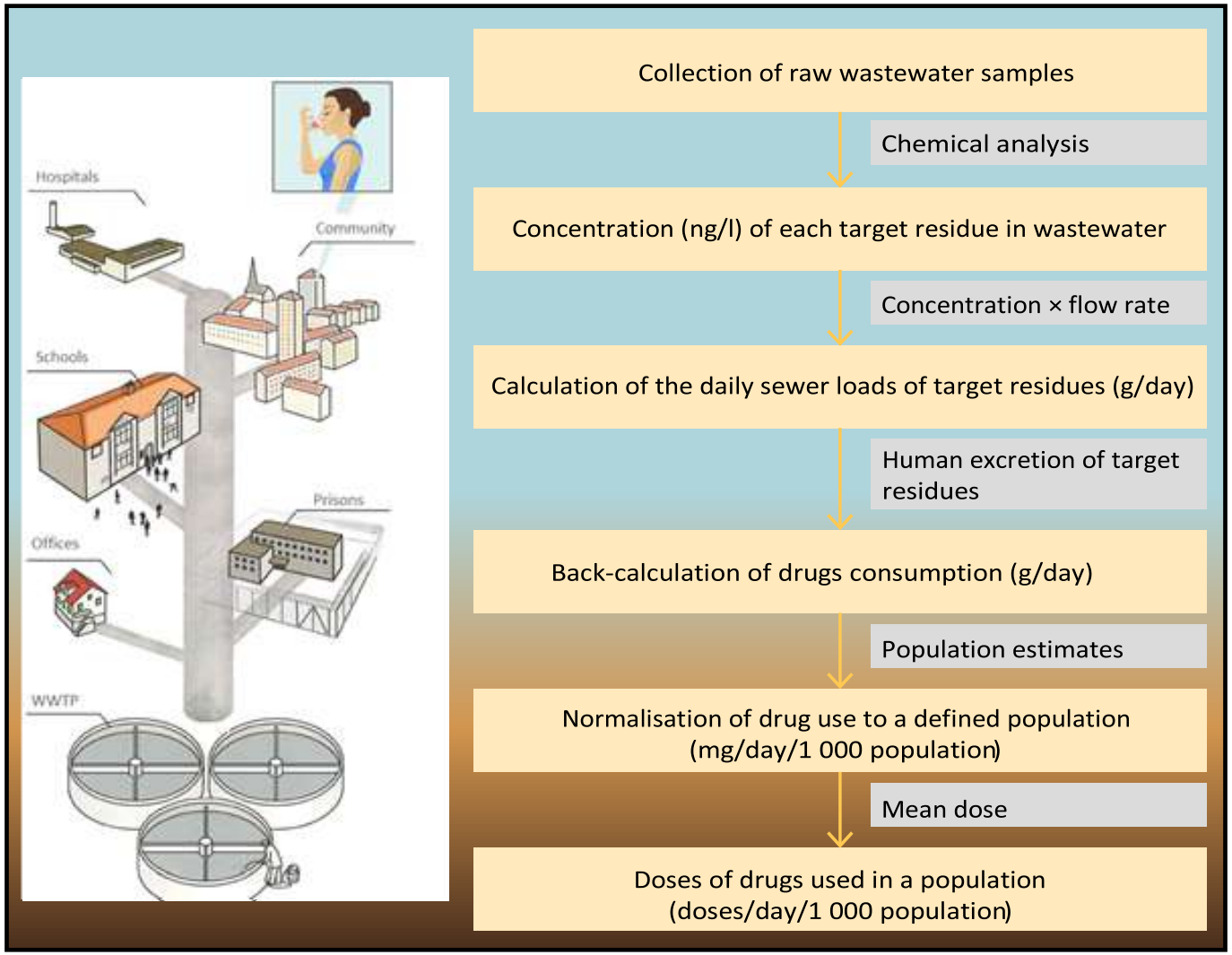
18 January 2021

Koronavirussmitte og vann

# Outline

- Wastewater-based Epidemiology
- SARS-CoV-2 in wastewater
- International and national research
- National activities
- Conclusions

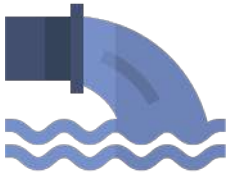
# Wastewater-based Epidemiology



# Wastewater-based Epidemiology

Societal Health

Sustainability



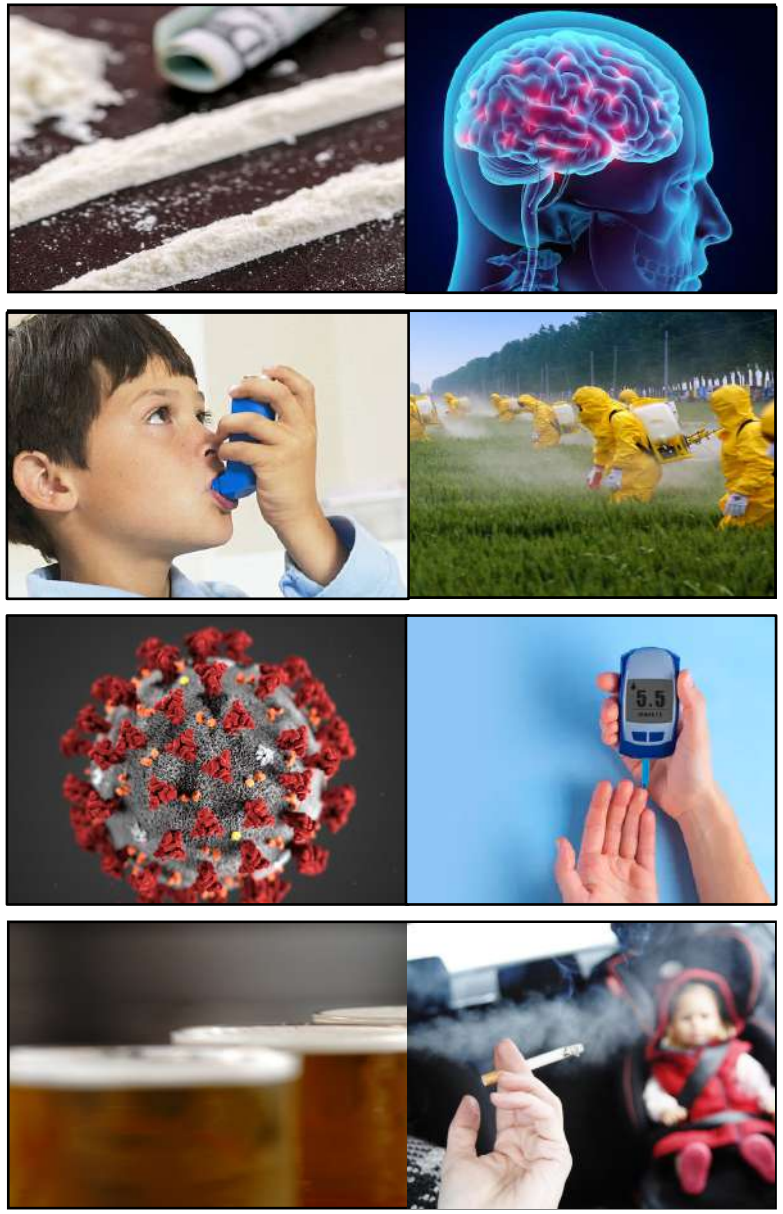
Environment

Sewage Data Mining

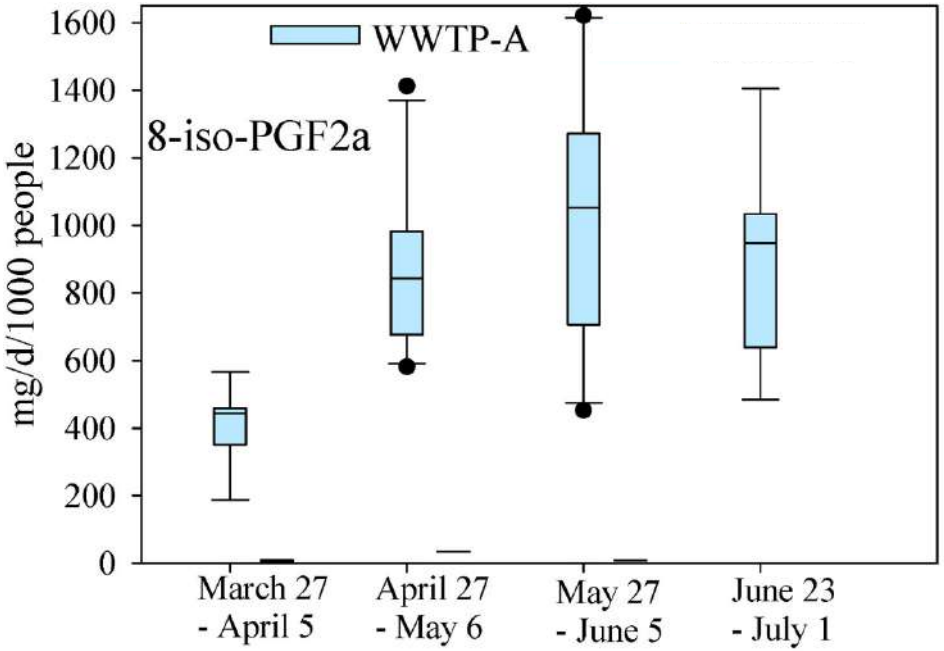
Circular Economy

Sewage Monitoring

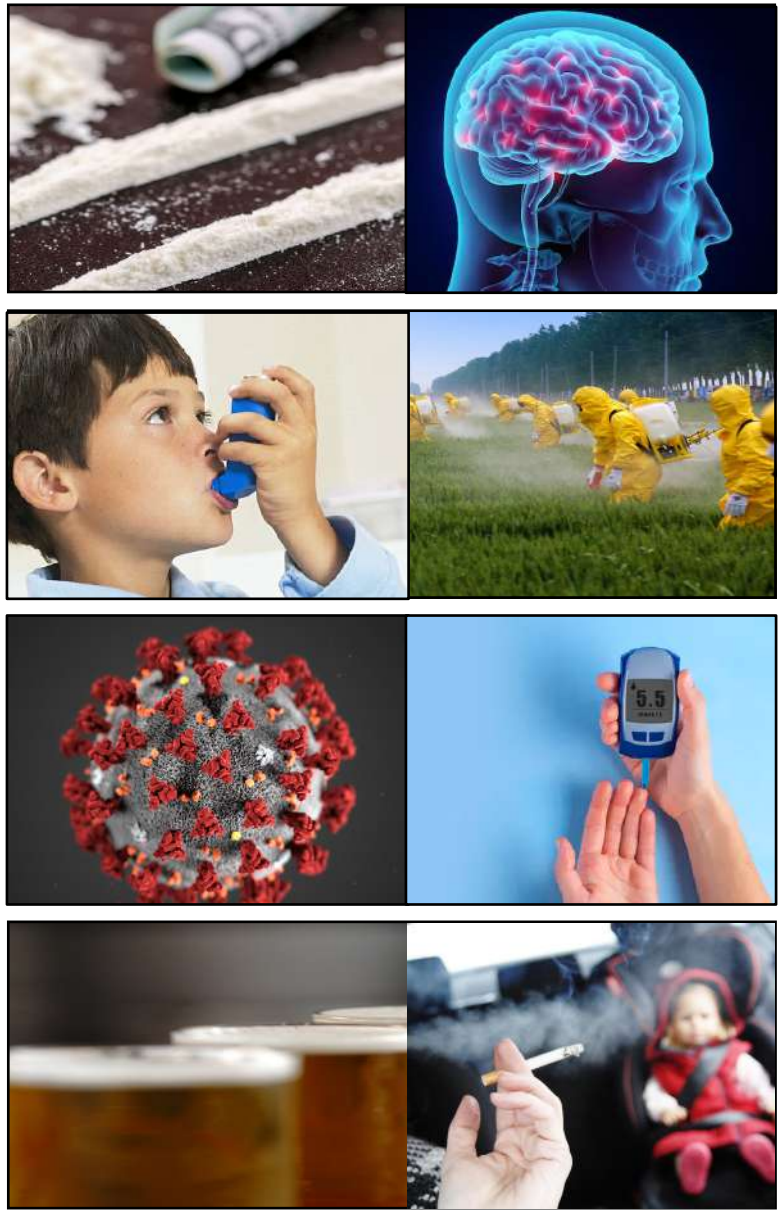
# Wastewater-based Epidemiology



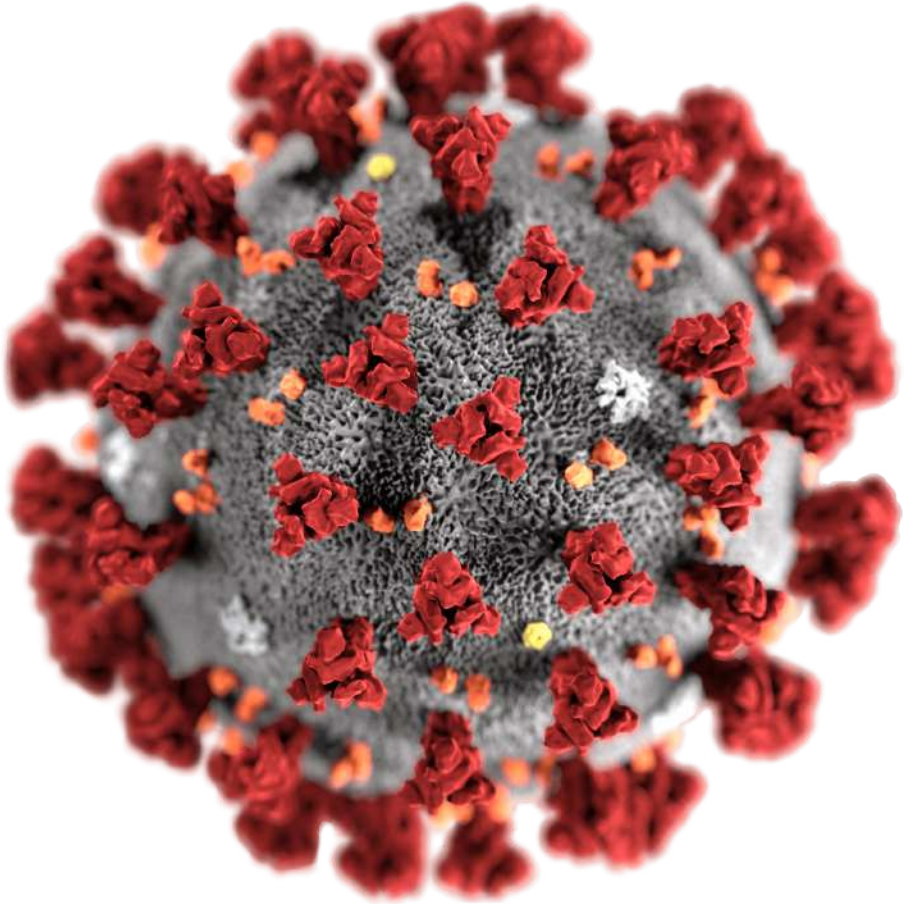
# Wastewater-based Epidemiology




Bowers, I. et al. Isoprostanes in Wastewater as Biomarkers of Oxidative Stress During COVID-19 Pandemic. Chemosphere, 129489.



# SARS-CoV-2 in wastewater



# SARS-CoV-2 in wastewater:

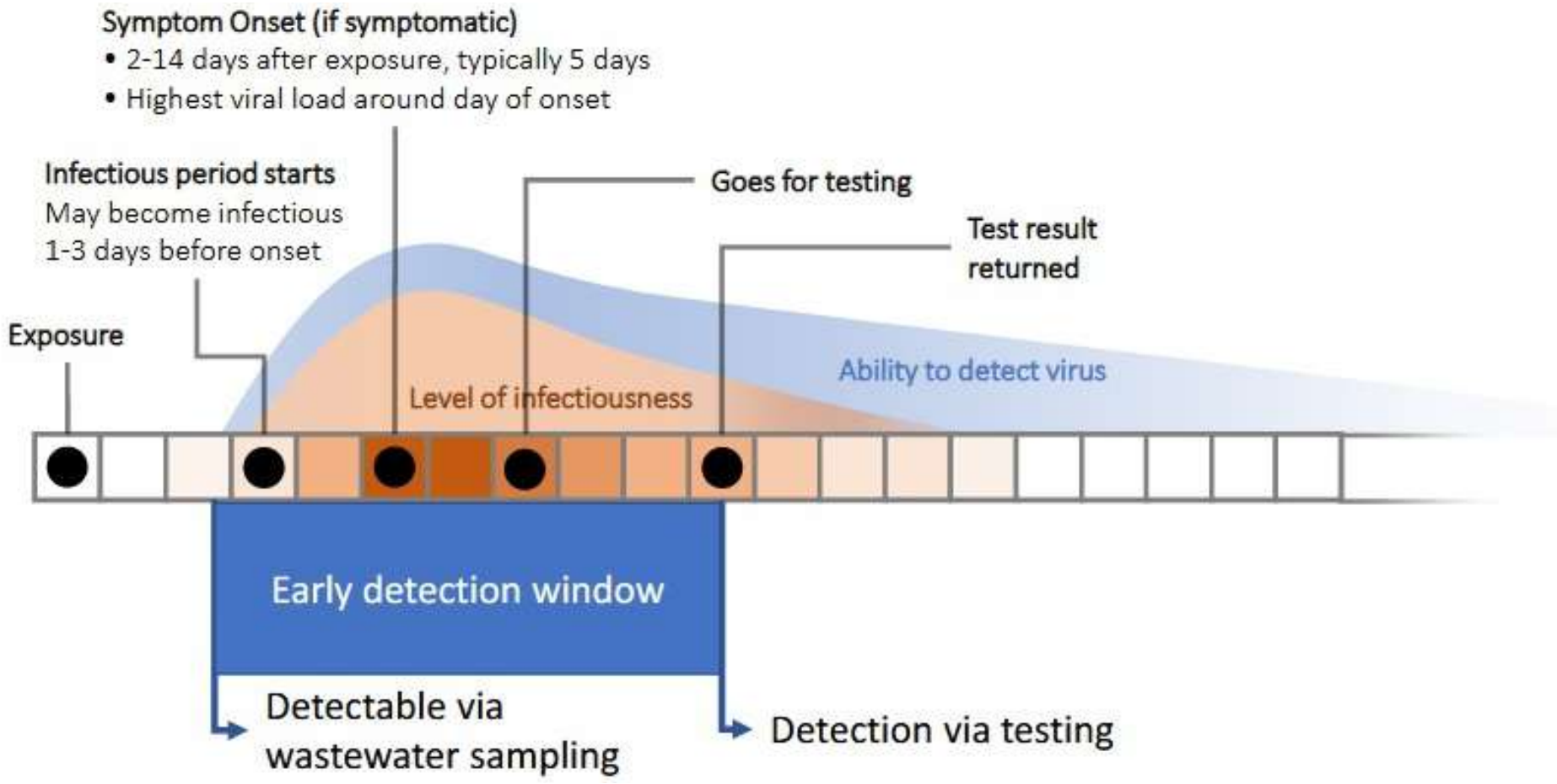
1 - Potential use cases

2 - Considerations for implementation

3 - Research needs

# SARS-CoV-2 in wastewater. 1) Potential use cases

## Early Warning System



# SARS-CoV-2 in wastewater. 1) Potential use cases

## Early Warning System

## Location with limited clinical surveillance

Marginalized population

Crowded and extremely low-resources

No test capacity

Issue: non-sewered sanitation systems

Science of the Total Environment 743 (2020) 140719

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

### Wastewater surveillance for Covid-19: An African perspective

Renée Street[a,b,*], Shirley Malema[a], Nomfundo Mahlangeni[a], Angela Mathee[a,c,d]

[a] Environment & Health Research Unit, South African Medical Research Council, South Africa
[b] School of Nursing and Public Health, Discipline of Occupational and Environmental Health, University of KwaZulu Natal, South Africa
[c] Environmental Health Department, University of Johannesburg, South Africa
[d] School of Public Health, University of the Witwatersrand, South Africa

HIGHLIGHTS

- Wastewater surveillance could play a key role in management of the COVID-19 pandemic.
- Unlike well-resourced countries, there is high reliance on non-sewered sanitation systems in resource-constrained regions.
- In sub-Saharan Africa, locally relevant alternatives to sampling from wastewater treatment plants are required.

GRAPHICAL ABSTRACT

Street, Renée, et al. "Wastewater surveillance for Covid-19: an African perspective." Science of The Total Environment 743 (2020): 140719.

# SARS-CoV-2 in wastewater. 1) Potential use cases

National Environment Agency
Safeguard · Nurture · Cherish

Early Warning System

Location with limited clinical surveillance

**Potential hotspots**

NEA-led programme at migrant worker dorms could detect spread of coronavirus through wastewater testing

The programme is part of the Government's gradual clearance of dormitories of Covid-19. PHOTO: ST FILE

Wastewater testing to support dedicated efforts at workers 'dormitories in Singapore

# SARS-CoV-2 in wastewater. 1) Potential use cases

Early Warning System

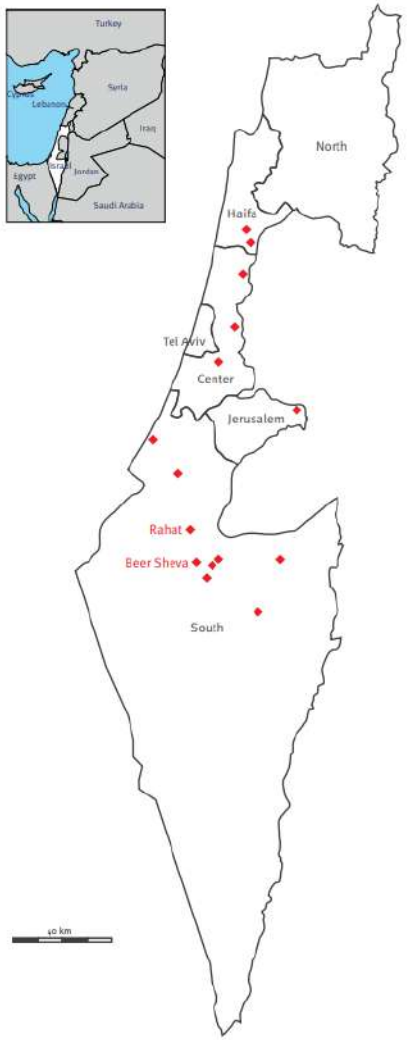
Location with limited clinical surveillance

Potential hotspots

**Monitoring circulation of SARS-CoV-2**

**FIGURE**

Locations of sewage samples positive for wild poliovirus type 1 identified through environmental surveillance, Israel, by district, 3 February–12 September 2013




defined as 'hot' cases (i.e. lacking a complete series of routine childhood IPV immunisation due to young age or parental objection) [13]. The estimated annual AFP incidence in 2013, based on cases detected so far, is 1.15 cases per 100,000 population <15 years of age. All 45 AFP cases tested negative for WPV1.

No case of paralytic polio has been detected to date in Israel.

### Start of aseptic meningitis surveillance

National aseptic meningitis surveillance was also initiated in June 2013. As of 28 August 2013, a total of 156 cases of aseptic meningitis were reported nationally: none was positive for poliovirus; 65 cases (42%) were positive for other non-polio enteroviruses.

### Ongoing national supplementary immunisation activity

A supplementary immunisation activity using bivalent OPV [14,15] was initiated in the Southern district on 5 August 2013 and has been expanded nationally since 18 August, with the objective of rapidly interrupting WPV1 transmission across the country, particularly in children previously vaccinated according to the IPV-only programme, by inducing effective intestinal immunity [16,17].

All children born after 1 January 2004, who have received at least one dose of IPV in the past, were considered vaccine candidates. This approach is in accordance with that used in the routine national immunisation schedule during 1990 to 2004, which has a formidable international safety profile [18]. Vaccine candidates who have immunodeficiency conditions or those living with immunocompromised household contacts are not vaccinated with bivalent OPV.

As of 15 September 2013, approximately 750,000 of about 1,200,000 eligible bivalent OPV candidates (63%, inter-district range: 45–83%) were vaccinated nationwide (Table 2).

The Israeli response to the finding of WPV1 has been fully coordinated with leading local epidemiology, infection disease and paediatric experts, as well as WHO and the US CDC. A joint WHO/CDC mission visited Israel in June 2013 and its experts have been consulted at every stage of the outbreak response.

### Discussion

The last widespread circulation of wild poliovirus in Israel was 25 years ago, resulting in a national outbreak with cases of permanent paralytic polio [3]. The major difference between the 1988 outbreak in Israel and other outbreaks of wild poliovirus infection in recent years in other developed countries [19,20] that used an IPV-only routine vaccination schedule, is the early detection of silent virus circulation through an existing early warning system, involving national environmental

Anis E, et al. Insidious reintroduction of wild poliovirus into Israel, 2013. Euro Surveill. 2013;18(38)

# SARS-CoV-2 in wastewater. 1) Potential use cases

Early Warning System

Location with limited clinical surveillance

Potential hotspots

Monitoring circulation of SARS-CoV-2

**Research**

## Detection of SARS-CoV-2 variants in Switzerland by genomic analysis of wastewater samples

Katharina Jahn[1,2,*], David Dreifuss[1,2,*], Ivan Topolsky[1,2,*], Anina Kull[3], Pravin Ganesanandamoorthy[3], Xavier Fernandez-Cassi[4], Carola Bänziger[3], Elyse Stachler[3], Lara Fuhrmann[1,2], Kim Philipp Jablonski[1,2], Chaoran Chen[1,2], Catharine Aquino[5], Tanja Stadler[1,2], Christoph Ort[3], Tamar Kohn[4], Timothy R. Julian[3], Niko Beerenwinkel[1,2,+]

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[3]Eawag, Swiss Federal Institute of Aquatic Science and Technology, 8600 Dübendorf, Switzerland;
[4]Laboratory of Environmental Chemistry, School of Architecture, Civil and Environmental Engineering, École Polytechnique Fédérale de Lausanne (EPFL), CH-1015 Lausanne, Switzerland;
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### Abstract

The SARS-CoV-2 lineages B.1.1.7 and 501.V2, which were first detected in the United Kingdom and South Africa, respectively, are spreading rapidly in the human population. Thus, there is an increased need for genomic and epidemiological surveillance in order to detect the strains and estimate their abundances. Here, we report a genomic analysis of SARS-CoV-2 in 48 raw wastewater samples collected from three wastewater treatment plants in Switzerland between July 9 and December 21, 2020. We find evidence for the presence of several mutations that define the B.1.1.7 and 501.V2 lineages in some of the samples, including co-occurrences of up to three B.1.1.7 signature mutations on the same amplicon in four samples from Lausanne and one sample from a Swiss ski resort dated December 9 - 21. These findings suggest that the B.1.1.7 strain could be detected by mid December, two weeks before its first verification in a patient sample from Switzerland. We conclude that sequencing SARS-CoV-2 in community wastewater samples may help detect and monitor the circulation of diverse lineages.

Jahn, Katharina, et al. "Detection of SARS-CoV-2 variants in Switzerland by genomic analysis of wastewater samples." medRxiv: 2021-01

# SARS-CoV-2 in wastewater. 2) Considerations for implementation

Representativeness

Coordination

Cost-effectiveness

Ethical and legal considerations

Quality assurance

# SARS-CoV-2 in wastewater. 3) Research needs

Biologic

Epidemiologic

Technical

Economic

# SARS-CoV-2 in wastewater. 3) Research needs

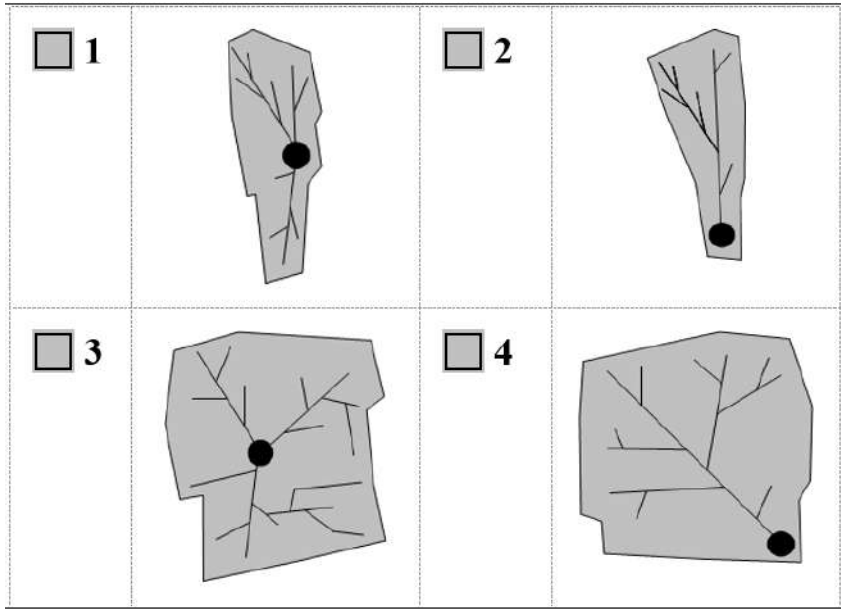
Biologic

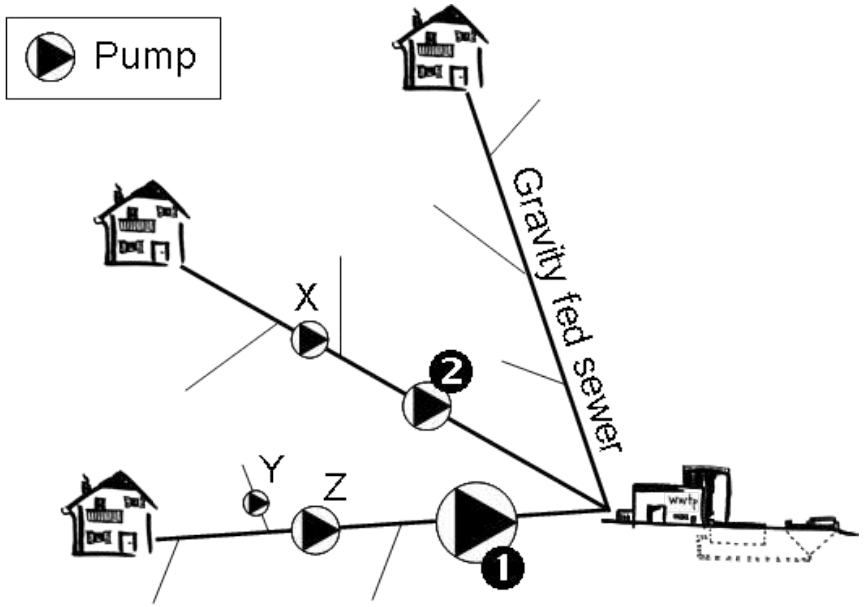
Epidemiologic

Technical

Economic

- **Hydraulic**
- Biological
- Physico-chemical



# SARS-CoV-2 in wastewater. 3) Research needs

Biologic

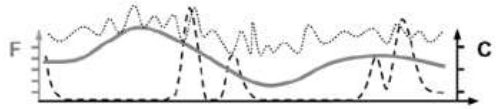
Epidemiologic

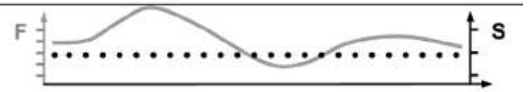
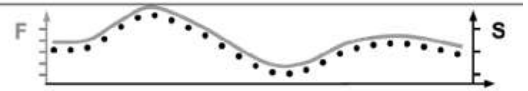
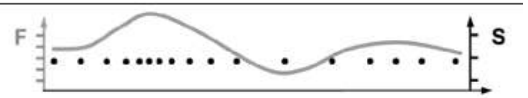
Technical

Economic

- **Hydraulic**
- Biological
- Physico-chemical

**Conceptual example**




| Sampling mode | | Short description (see "Sampling guide" to find out which sampling mode is suitable in which situation). | Illustration (F=Flow in sewer, S=sampling volume) |
|---|---|---|---|
| **Continuous** | **flow-proportional** | Divert a side stream, proportional to the flow in the sewer |  |
| | **constant** | Divert a constant side stream from the sewer |  |
| **Discrete** | **T:** time-proportional | Take a constant sample volume at constant time intervals |  |
| | **F:** flow-proportional | Make sample volume proportional to the flow in the sewer taking them at constant time intervals |  |
| | **V:** volume-proportional | Take a constant sample volume at variable time intervals, after a certain volume of wastewater has passed the sampling point |  |
| | **g:** grab sample | Take one (or a number of) grab sample |  |

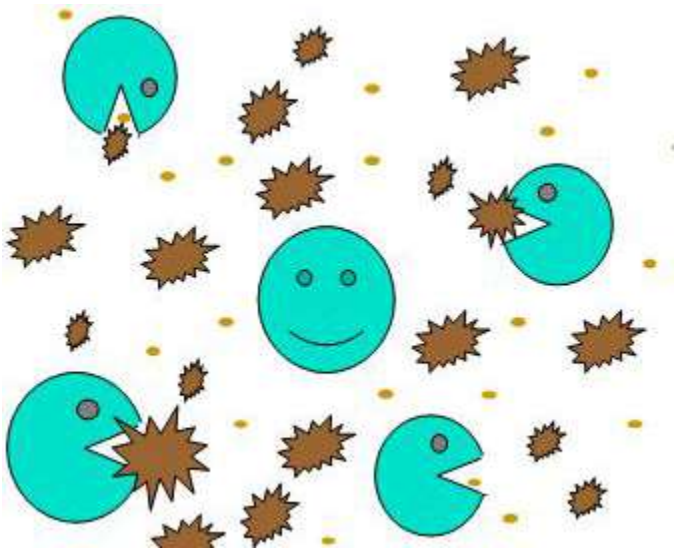
# SARS-CoV-2 in wastewater. 3) Research needs

Biologic

Epidemiologic

Technical

Economic



- Hydraulic
- **Biological**
- **Physico-chemical**

| Parameter | BT | AT |
|---|---|---|
| pH | 7.73 ± 0.24 | 7.88 ± 0.56 |
| Turbidity (NTU) | 128 ± 1.12 | 24.0 ± 0.84 |
| SS ($mgL^{-1}$) | 201 ± 1.40 | 89.0 ± 1.23 |
| Nitrate ($mgL^{-1}$) | 8.40 ± 0.27 | 2.40 ± 0.72 |
| COD ($mgL^{-1}$) | 1360 ± 1.74 | 467 ± 1.32 |
| BOD ($mgL^{-1}$) | 49.20 ± 0.18 | 17.92 ± 0.64 |

Values are expressed as means ± standard deviation of triplicate determinations
*NTU* Nephelometric turbidity units
*COD* Chemical oxygen demand
*BOD* Biological oxygen demand
*SS* Suspended solids
*BT* Before treatment
*AT* After treatment

# SARS-CoV-2 in wastewater. 3) Research needs

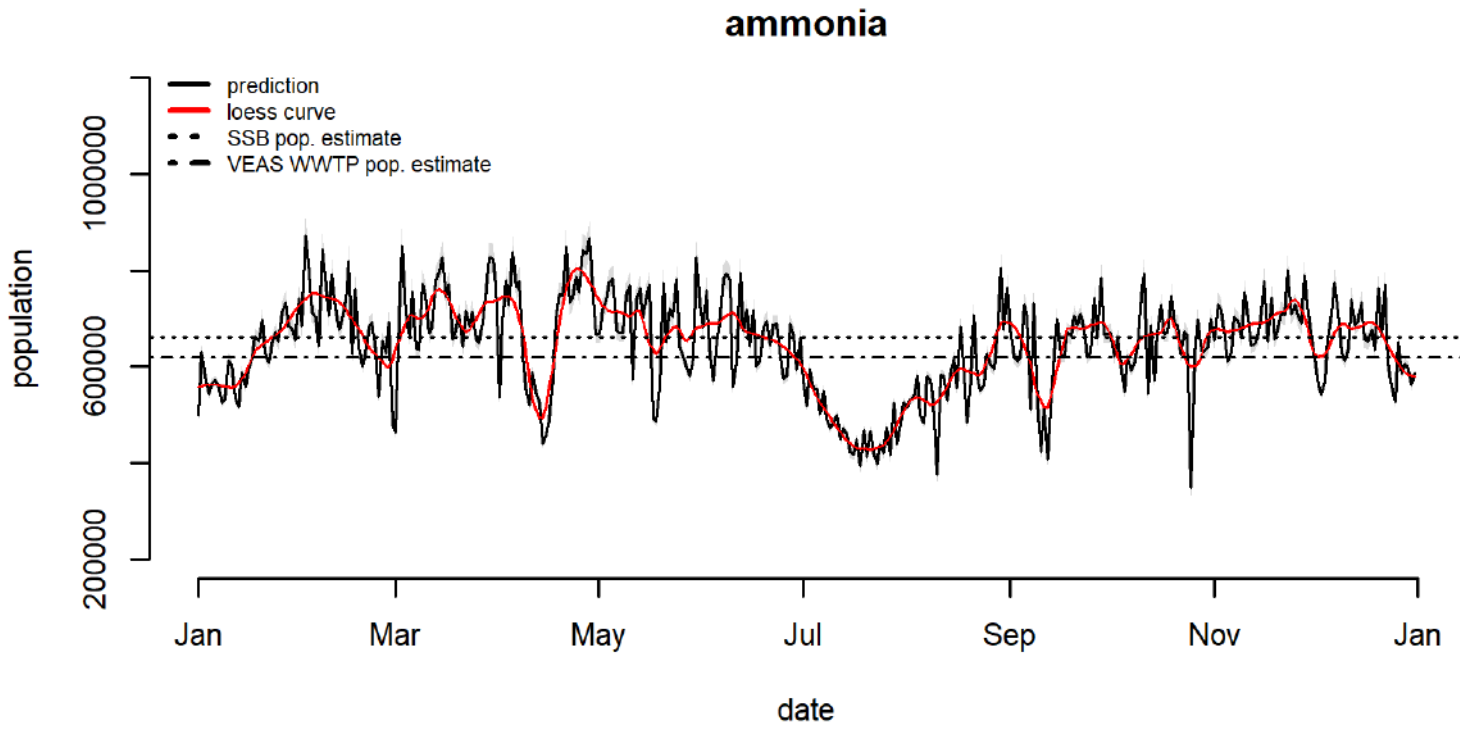
Biologic

Epidemiologic

Technical

Economic

- Population dynamics
- Excretion rates
- In-sewer stability




Baz-Lomba, J.A., et al. "Assessing alternative population size proxies in a wastewater catchment area using mobile device data." Environmental science & technology 53.4 (2019): 1994-2001.

# SARS-CoV-2 in wastewater

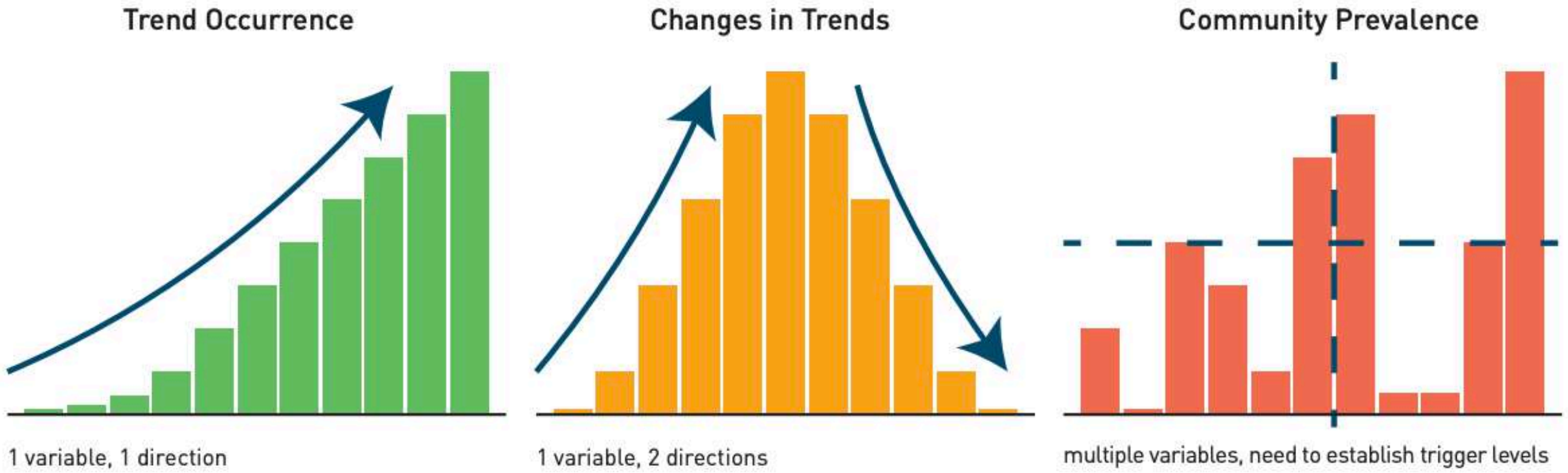
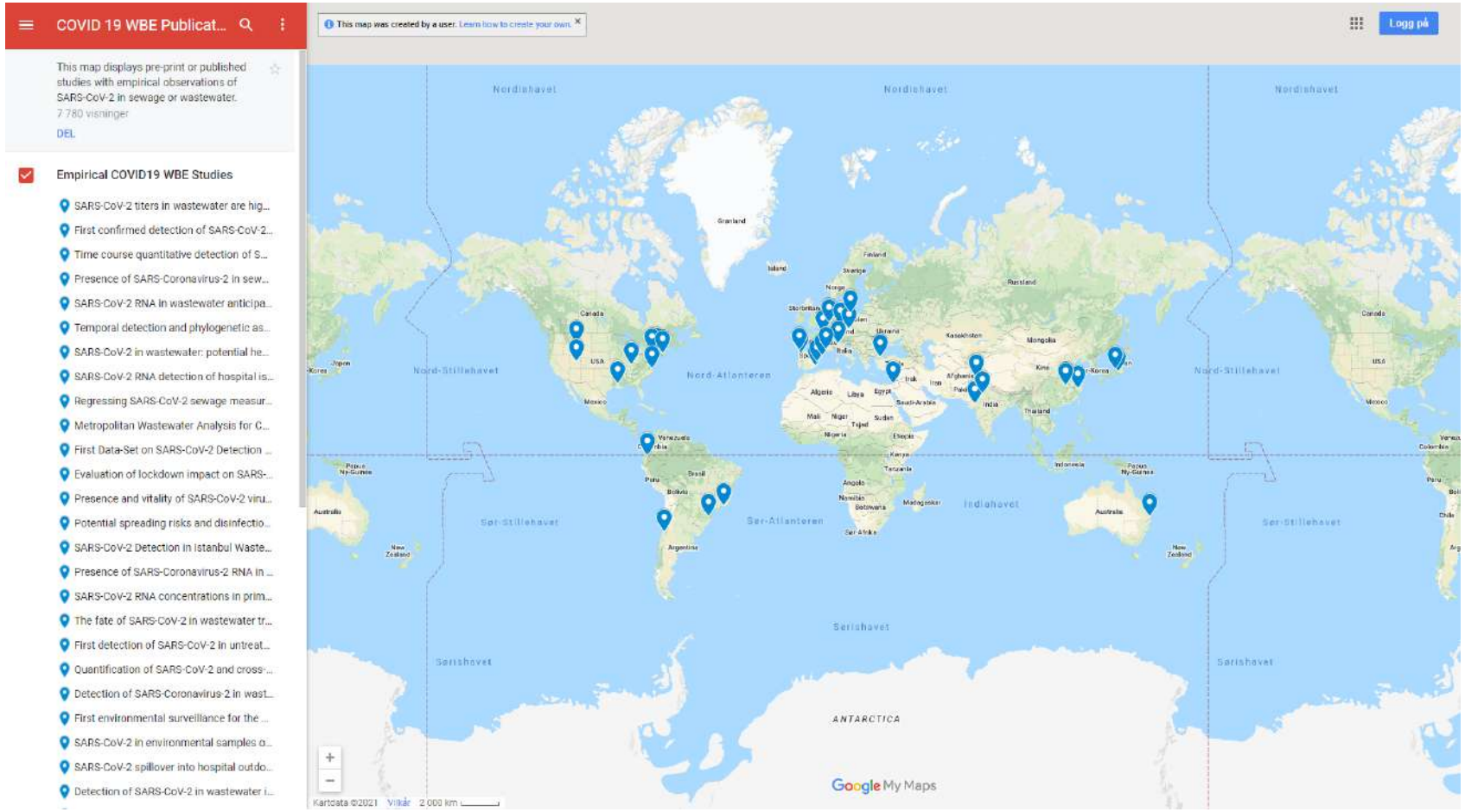



**Figure 1. Increasing complexity for wastewater surveillance applications**

The Water Research Foundation. Wastewater Surveillance of the COVID-19 Genetic Signal is Sewersheds

# International and national research




https://www.covid19wbec.org/publication-map

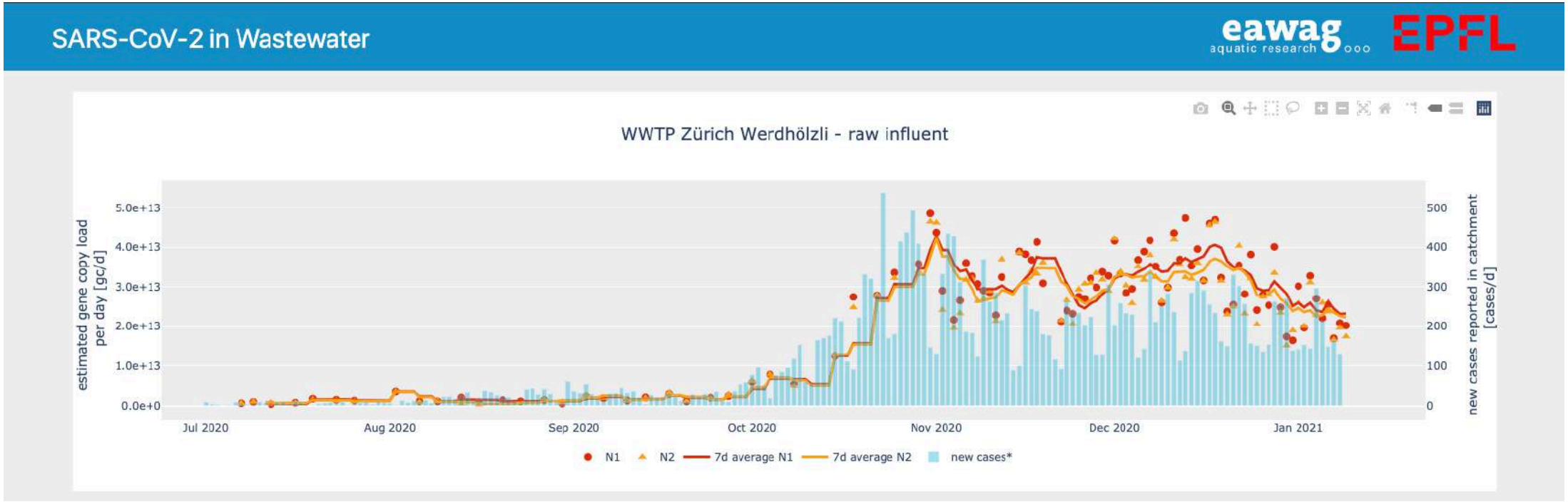
PUBLICATIONS

# International and national research. Resources


https://www.covid19wbec.org/covidpoops19

INTERNATIONAL EFFORTS

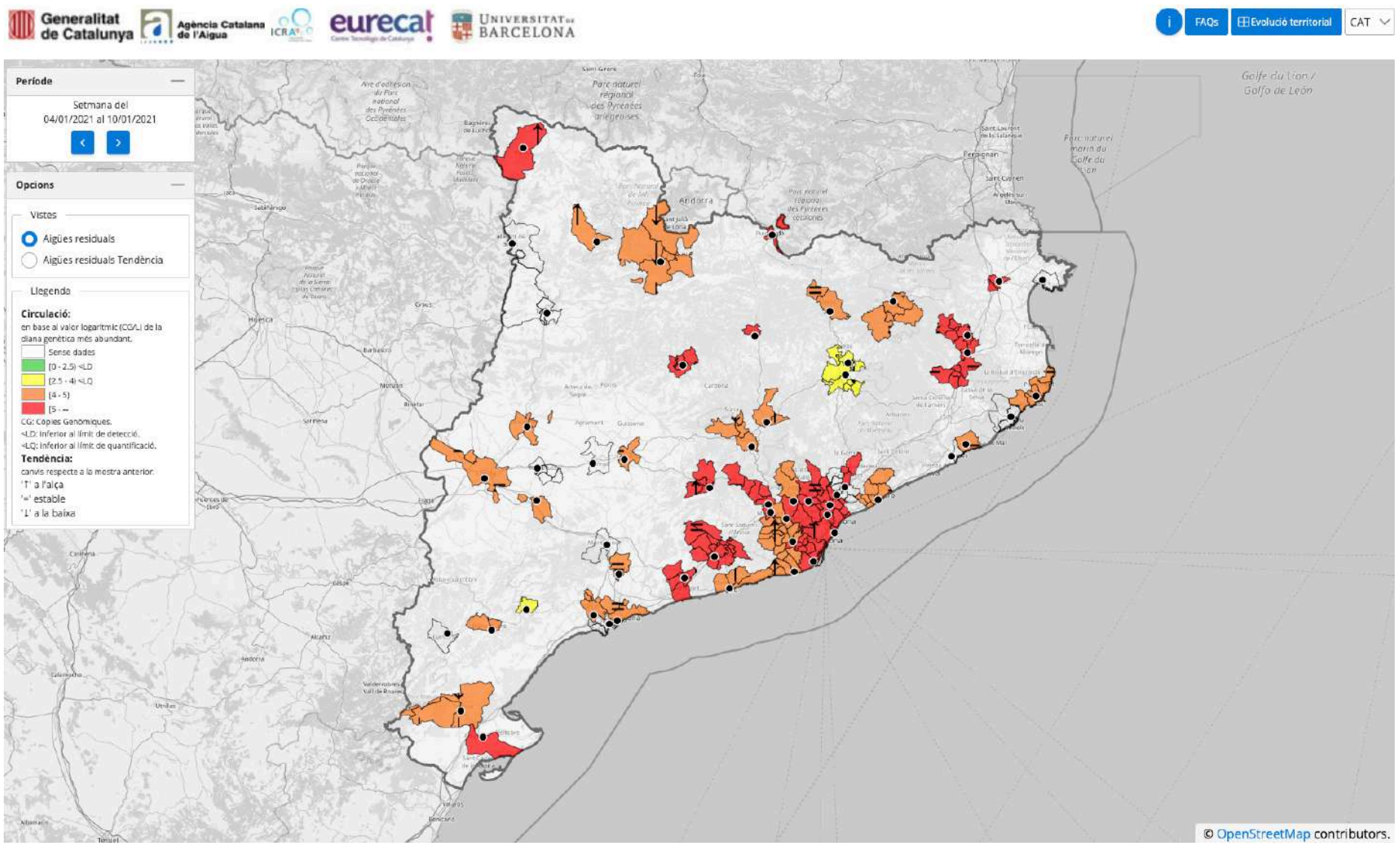
# International and national research. Resources: dashboards



# International and national research. Resources: dashboards


Rijksinstituut voor Volksgezondheid en Milieu
*Ministerie van Volksgezondheid, Welzijn en Sport*

# International and national research. Resources: dashboards



# National activities

| Application | Leading Institution | Status |
| --- | --- | --- |
| ENVIRION: Sewage screening, early warning and environmental persistence of SARS-CoV-2 | | |

# Sites

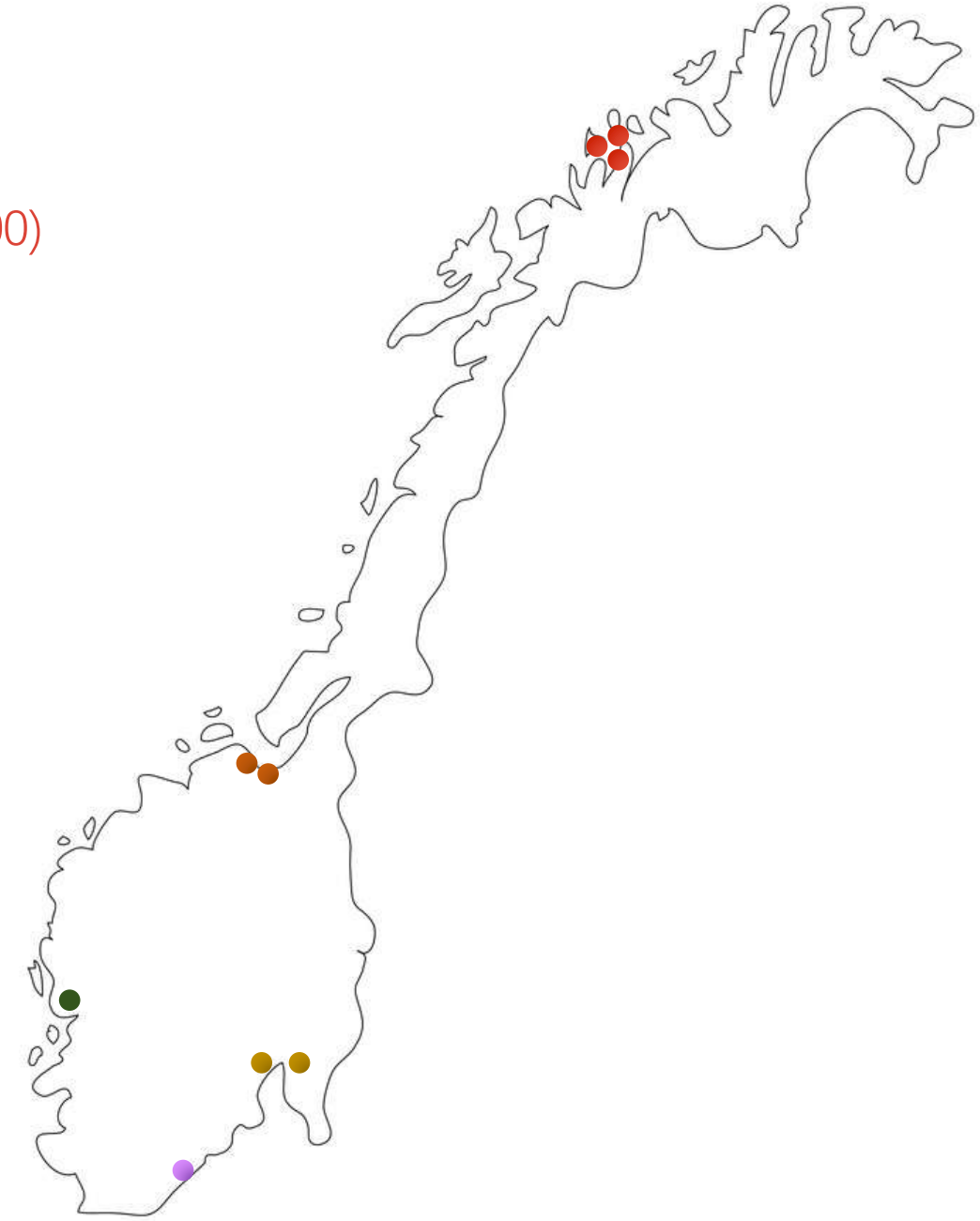
Tromsø (18 000, 20 000 and 17 000)

Trondheim (122 000 and 170 000)

Bergen (71 000)

Oslo (624 000 and 320 000)

Grimstad (600)



# 2020

| | M | T | W | T | F | S | S | M | T | W | T | F | S | S | M | T | W | T | F | S | S | M | T | W | T | F | S | S | M | T | W | T | F | S | S | M | T |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **JANUARY** | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | | | | | |
| **FEBRUARY** | | | | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | | | | |
| **MARCH** | | | | | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 |
| **APRIL** | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | | | | | |
| **MAY** | | | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | | |
| **JUNE** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | | | | | | | |
| **JULY** | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | | | | |
| **AUGUST** | | | | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | |
| **SEPTEMBER** | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | | | | | | |
| **OCTOBER** | | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | | | |
| **NOVEMBER** | | | | | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | |
| **DECEMBER** | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | | | | | |

# National activities

Forskningsrådet

| Application | Leading Institution | Status |
| --- | --- | --- |
| ENVIRION: Sewage screening, early warning and environmental persistence of SARS-CoV-2 | NMBU | ✗ |

# National activities

Forskningsrådet

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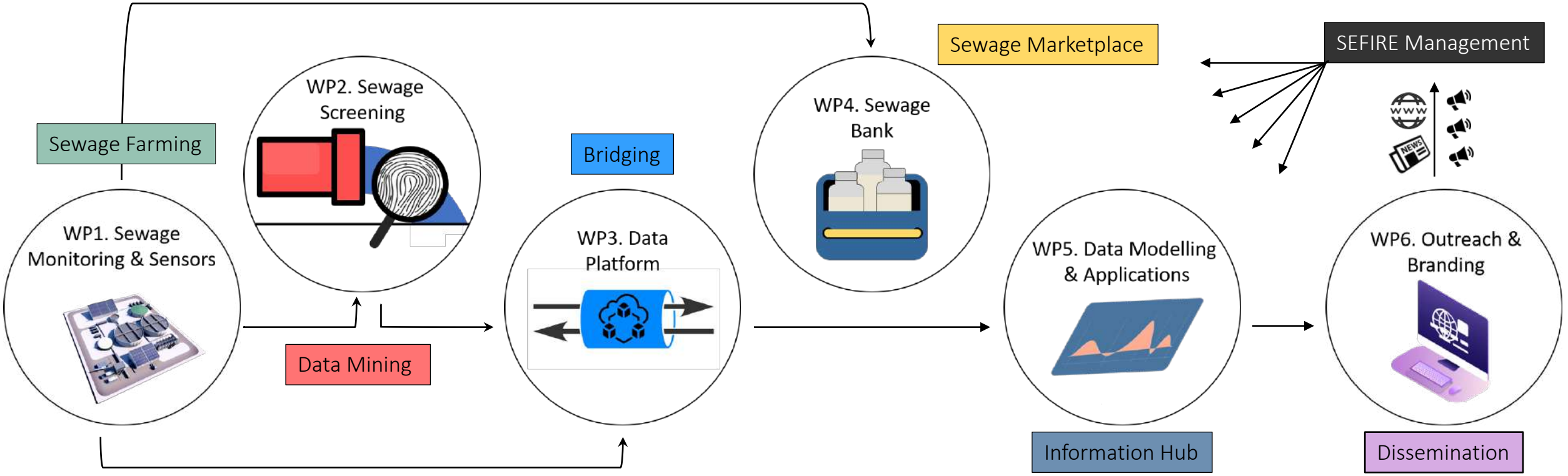
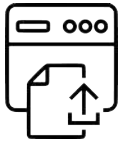
| SEFIRE: Research infrastructure for knowledge-building on societal health, security and sustainability | NIVA | ◌ |


Sewage Farming
WP1. Sewage Monitoring & Sensors
WP2. Sewage Screening
Data Mining
Bridging
WP3. Data Platform
WP4. Sewage Bank
Sewage Marketplace
SEFIRE Management
WP5. Data Modelling & Applications
Information Hub
WP6. Outreach & Branding
Dissemination

# National activities

| Application | Leading Institution | Status |
| --- | --- | --- |
| ENVIRION: Sewage screening, early warning and environmental persistence of SARS-CoV-2 | NMBU | ✗ |
| SEFIRE: Research infrastructure for knowledge-building on societal health, security and sustainability | NIVA | ◌ |
| Integrated Sentinel Surveillance of infectious agents such as SARS-CoV-2 detected in wastewater in Norway | FHI Folkehelseinstituttet |  |

# Conclusions

- WBE is a rapid, (relative) low-cost and potentially robust tool for tracking SARS-CoV-2. WBE is well positioned to inform and improve local decision-making process.
- Whereas WBE cannot replace clinical testing, it can serve to alert emergency response teams to the presence of infected individuals in specific sites (Early Warning System).
- WBE also appears to constitute the only viable means of enabling large-scale population-wide testing globally, particularly in resource poor regions.
- WBE has gained rapidly popularity, but there are still various limitations and challenges to be addressed in the analytical protocols and overall estimations for community prevalence.

# Thank you for your attention

## Acknowledgements

VEAS

REGIONALE FORSKNINGSFOND HOVEDSTADEN

NMBU NTNU SINTEF FHI Folkehelseinstituttet åpenhet GA Genetic Analysis