Wastewater-based epidemiology: Latest updates and potential application to LMICs

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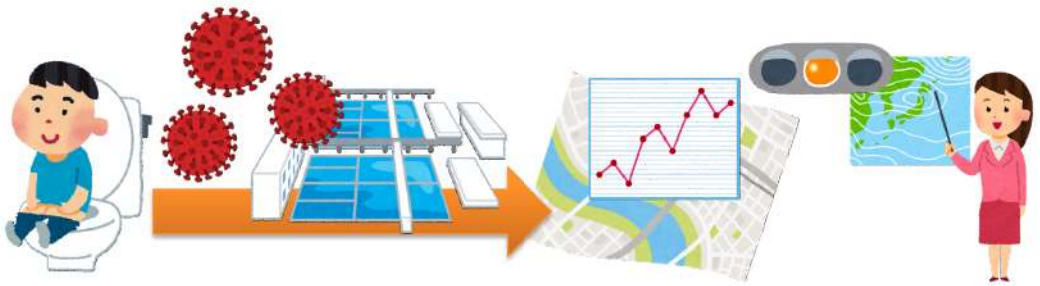

Public benefits and ethical issues in WBE for COVID-19

Data Sci. J. 2021, 20 (27), 1–6. https://doi.org/10.5334/dsj-2021-027.

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

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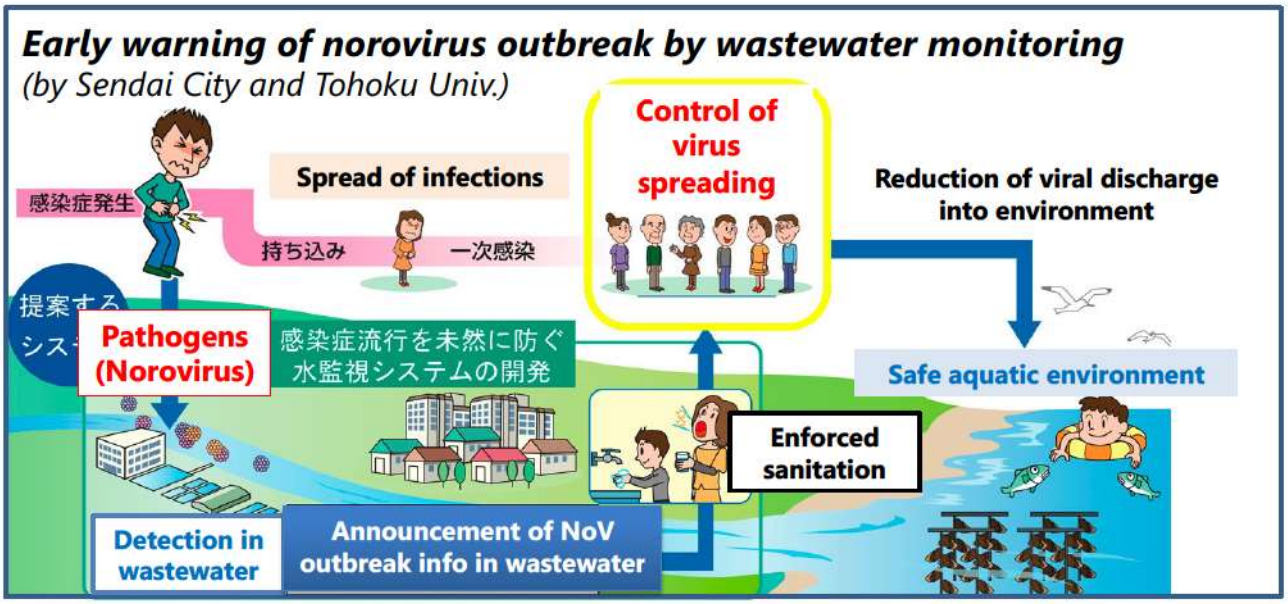
ESSAY

ubiquity press

 * Data Science Journal is published by CODATA – International Science Council

Wastewater-based epidemiology (WBE)

- A wastewater treatment plant collects night soils of people in the sewer catchment.
- Monitoring of wastewater enables to monitor epidemic situation of infectious diseases.
  - e.g. SARS-CoV-2, norovirus, poliovirus, illicit drugs



3 (Translated and modified from website by Sendai City and Tohoku Univ. https://novinsewage.com/)

Wastewater-based epidemiology for norovirus

AMERICAN SOCIETY FOR MICROBIOLOGY | Applied and Environmental Microbiology®

Environmental Surveillance of Norovirus Genogroups I and II for Sensitive Detection of Epidemic Variants

Shinobu Kazama,[a] Takayuki Miura,[a] Yoshifumi Masago,[b] Yoshimitsu Konta,[a] Kentaro Tohma,[c] Takafumi Manaka,[c] Xiaofang Liu,[c] Daisuke Nakayama,[d] Takashi Tanno,[e] Mayuko Saito,[c] Hitoshi Oshitani,[c] Tatsuo Omura[a]

Outbreak trend could be detected before reporting in clinical surveillance.

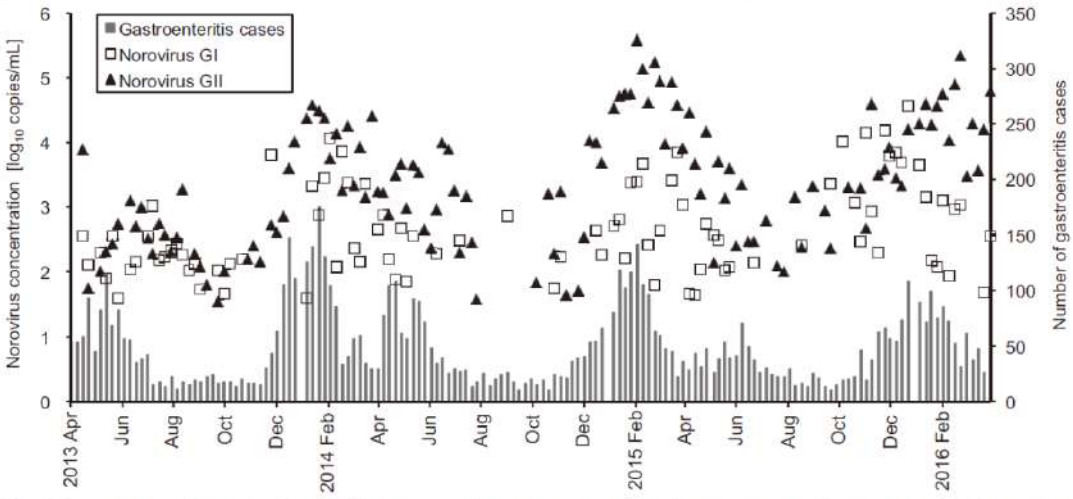


FIG 1 Concentrations of norovirus GI and GII in sewage and numbers of gastroenteritis cases reported in the study area. The norovirus GI and GII detection limits are 1.5 and 1.6 $\log_{10}$ copies/ml, respectively.

4 Kazama et al. 2017 Appl. Environ. Microbiol. 83. https://doi.org/10.1128/AEM.03406-16

Correlation of SARS-CoV-2 in wastewater with COVID-19 cases

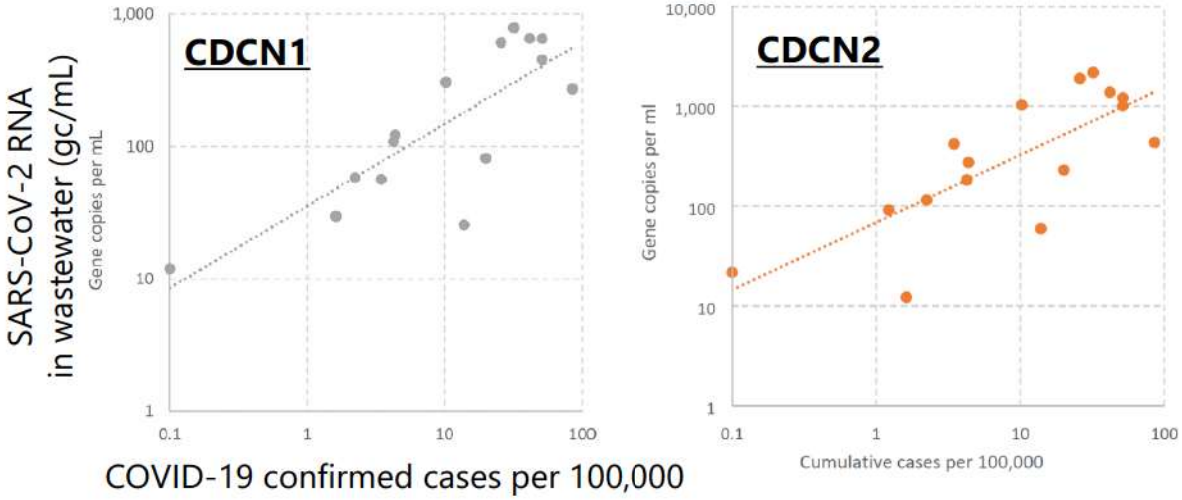
Environmental Science & Technology Letters

pubs.acs.org/journal/estlcu

Letter

Presence of SARS-Coronavirus-2 RNA in Sewage and Correlation with Reported COVID-19 Prevalence in the Early Stage of the Epidemic in The Netherlands

Gertjan Medema,* Leo Heijnen, Goffe Elsinga, Ronald Italiaander, and Anke Brouwer



[1] Medema et al. Environ. Sci. Technol. Lett. https://doi.org/10.1021/acs.estlett.0c00357

Early detection of COVID-19 by wastewater surveillance

nature biotechnology

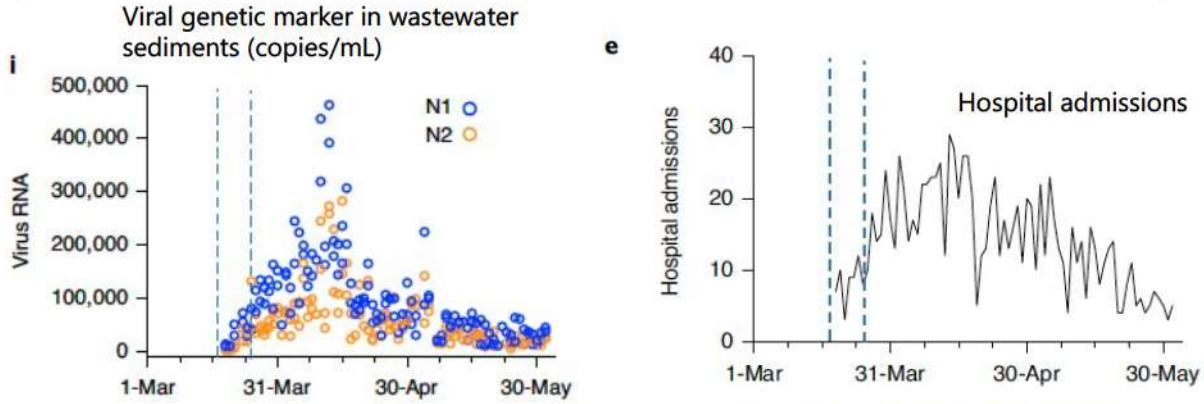
LETTERS

https://doi.org/10.1038/s41587-020-0684-z

Check for updates

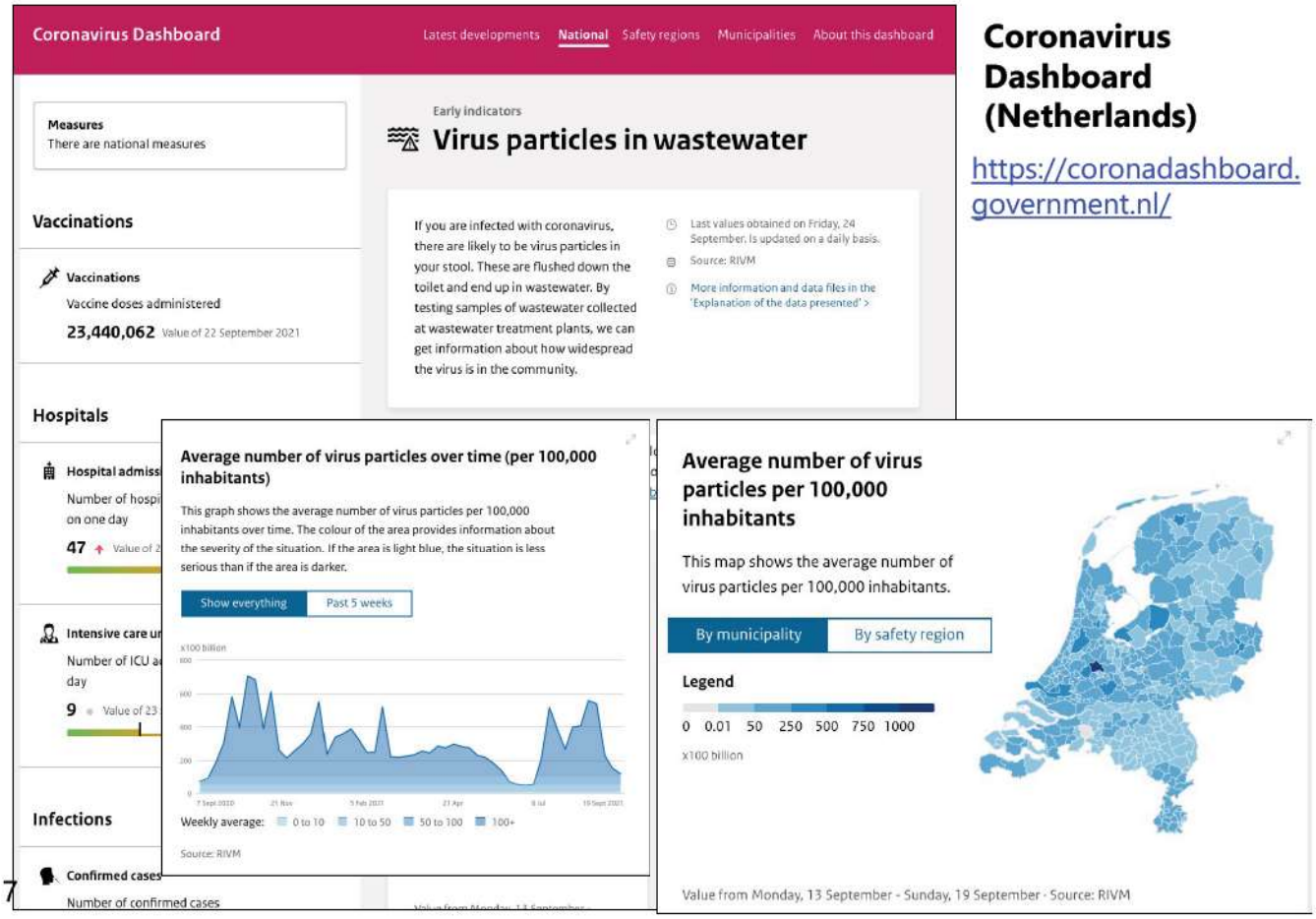
Measurement of SARS-CoV-2 RNA in wastewater tracks community infection dynamics

Jordan Peccia[1,10] ✉, Alessandro Zulli[1,10], Doug E. Brackney[2,10], Nathan D. Grubaugh[3], Edward H. Kaplan[1,4,5], Arnau Casanovas-Massana[3], Albert I. Ko[3], Amyn A. Malik[6,7], Dennis Wang[6], Mike Wang[6], Joshua L. Warren[8], Daniel M. Weinberger[3], Wyatt Arnold[1] and Saad B. Omer[3,6,7,9] ✉



[2] Peccia et al. Nature Biotechnol. https://doi.org/10.1038/s41587-020-0684-z

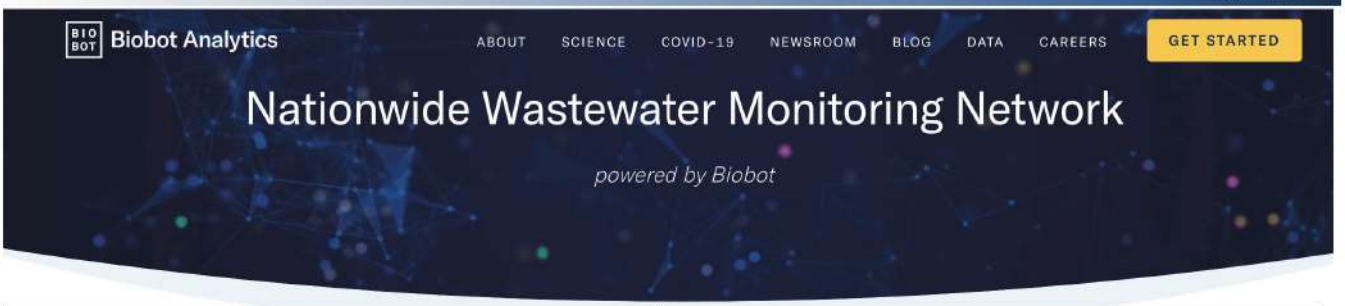
Nation-wide surveillance of SARS-CoV-2 in wastewater in Netherlands

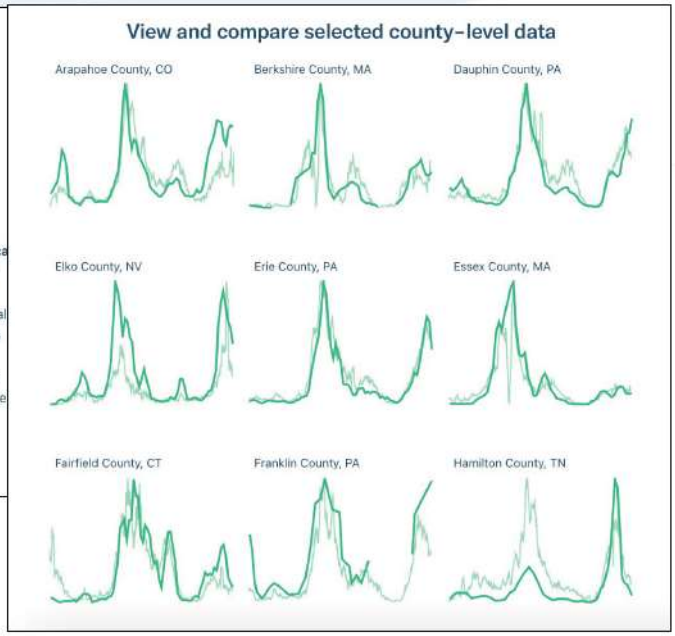


Coronavirus Dashboard (Netherlands)

https://coronadashboard.government.nl/

Nation-wide surveillance of SARS-CoV-2 in wastewater in USA





https://biobot.io/data/

Limitation of clinical surveillance and benefit of WBE on COVID-19

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◆Presence of unrecognized infections

- ✓ **40-60%** of infections are **asymptomatic** [1-4],
- ✓ Asymptomatic and pre-symptomatic infections estimated to contribute to **70% of total transmissions**.

Many infected people remains undiagnosed.

Massive PCR testings are being conducted

- Regardless of apparent symptoms
- Information for quarantine and policy making

Labor and cost intensive

◆Benefits of wastewater surveillance

- ✓ Able to take a snapshot of epidemic situation of a group with the single test
- ✓ Able to find undiagnosed infections from a group

[1] Lavezzo et al. Nature 10.1038/s41586-020-2488–1. ; [2] Mizumoto et al. Eurosurveillance 25, 1–5; [3] Expert Taskforce COVID-19 Cruise Ship Outbreak, Emerg. Infect. Dis 10.3201/eid2611.201165. [4] H. Nishiura, et al. Int. J. Infect. Dis. 10.1016/j.ijid.2020.03.020. [5] 厚生労働省 https://www.mhlw.go.jp/content/000689773.pdf [6] Emery et al. Elife 10.7554/eLife.58699. [7] Sood et al. JAMA, 323(23), 2425. https://doi.org/10.1001/jama.2020.8279, [8] Bendavid et al). *MedRxiv*, 2020.04.14.20062463. https://doi.org/10.1101/2020.04.14.20062463

Application of WBE for COVID-19 outbreak detection

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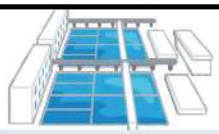
Regional ⟷ **Local**

WWTP catchment	Small sewer catchment	Building
		
Influent wastewater of WWTP	**Manholes Pumping stations**	**Building effluent**
		
➢ **Forecasting epidemic trend** ➢ **Early detection of outbreak**	➢ **Identifying community outbreak**	➢ **Early detection of group infections & infected persons**

Large ⟷ Small — Target population

Quantitative ⟷ Qualitative — Detection methodology

Regional-scale application – Forecasting epidemic trend

Funabashi City, Japan

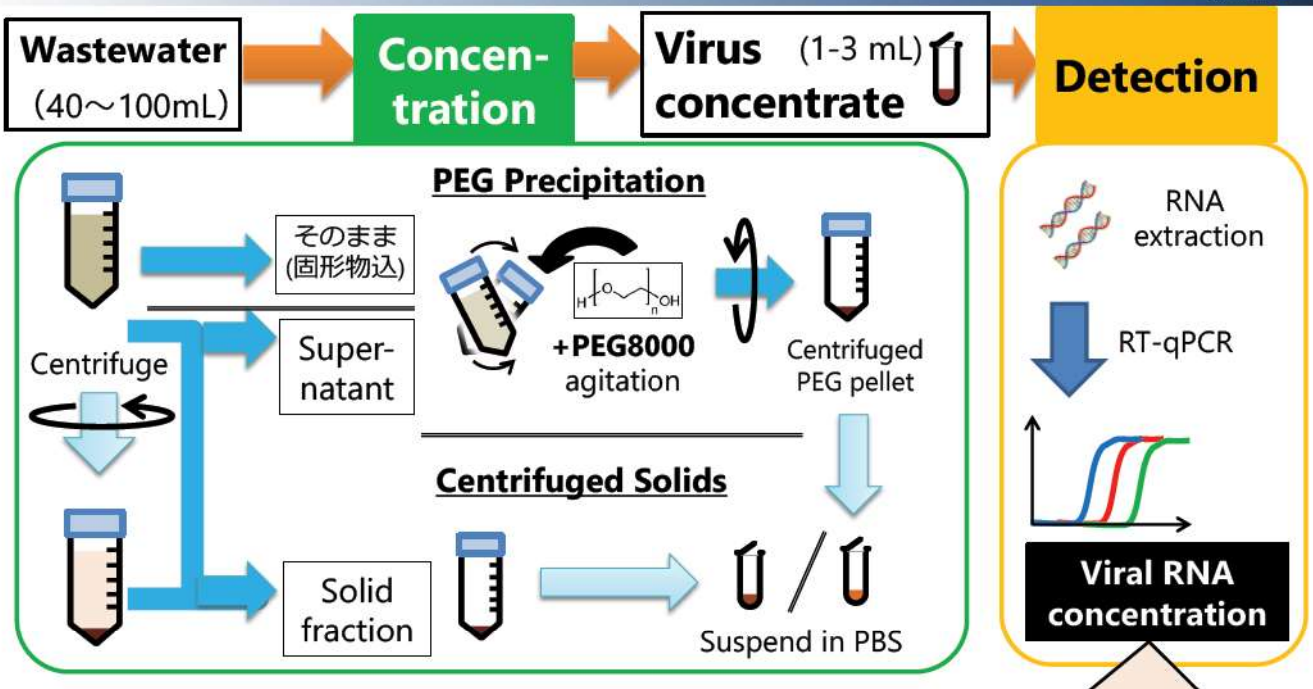
- Population: 640,000
- Total confirmed cases: 12,700人 (as of 2021.9.15)

WWTP	Sewer	Coverage area (ha)	Population coverage
Takase	Combined	339 ha	**48,000**
	Sanitary	1,731 ha	**207,000**
Nishiura	Combined	805 ha	**108,000**
	Sanitary	181 ha	6,000

(as of R2.4.1)

Funabashi City locates 30 km-east of Tokyo

Detection of SARS-CoV-2 RNA in wastewater



Necessary time until quantification
PEG precipitation： approx. 1.5 day (next day)
Centrifuged solids：approx. 1 day

Handling techniques Not difficult if experienced with qPCR.

Primer/Probe for SARS-CoV-2
- CDCN1, CDCN2

Process control
- PMMoV, F-phage+MNV

Forecasting epidemic trend by wastewater surveillance

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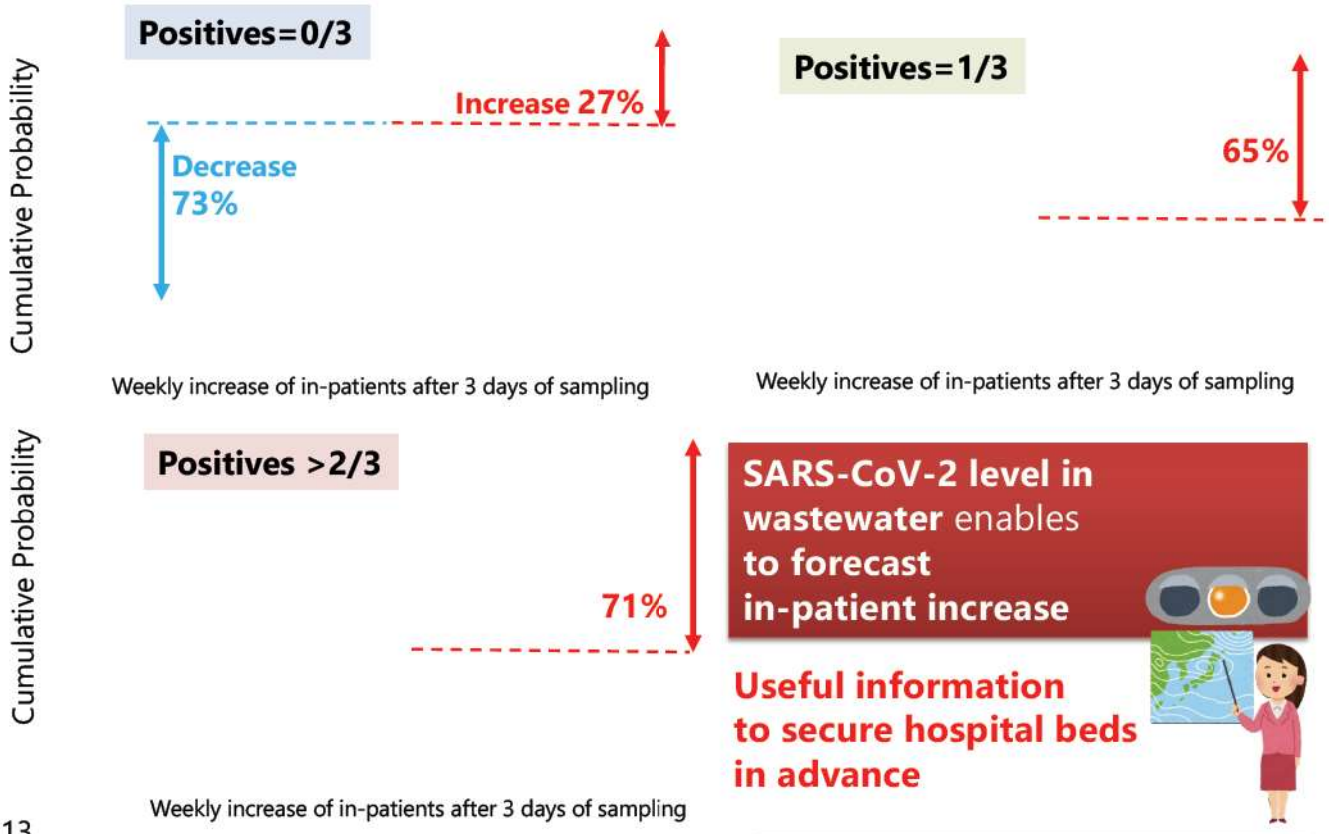
Probability of in-patient increase by SARS-CoV-2 level in wastewater



SARS-CoV-2 level in wastewater enables **to forecast in-patient increase**

Useful information to secure hospital beds in advance

(Honda, unpublished)

【Supporters】 Funabashi City, CTI Inc., ER&S Inc.

Forecasting epidemic trend by wastewater surveillance

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No. Positives /Tests	Observation 2021.4-7			Forecasted probability
	(A) Data points	(B) Patients increased	Proportion of increase(B/A)	From data 2020.7-2021.3
All case	[redacted]		44%	-
0/3			**28%**	**27%**
1/3			**60%**	**65%**
2/3			100%	-
3/3			100%	-
>2/3			**100%**	**71%**

Trends could be forecasted well.

Forecasting from wastewater surveillance by machine-learning model

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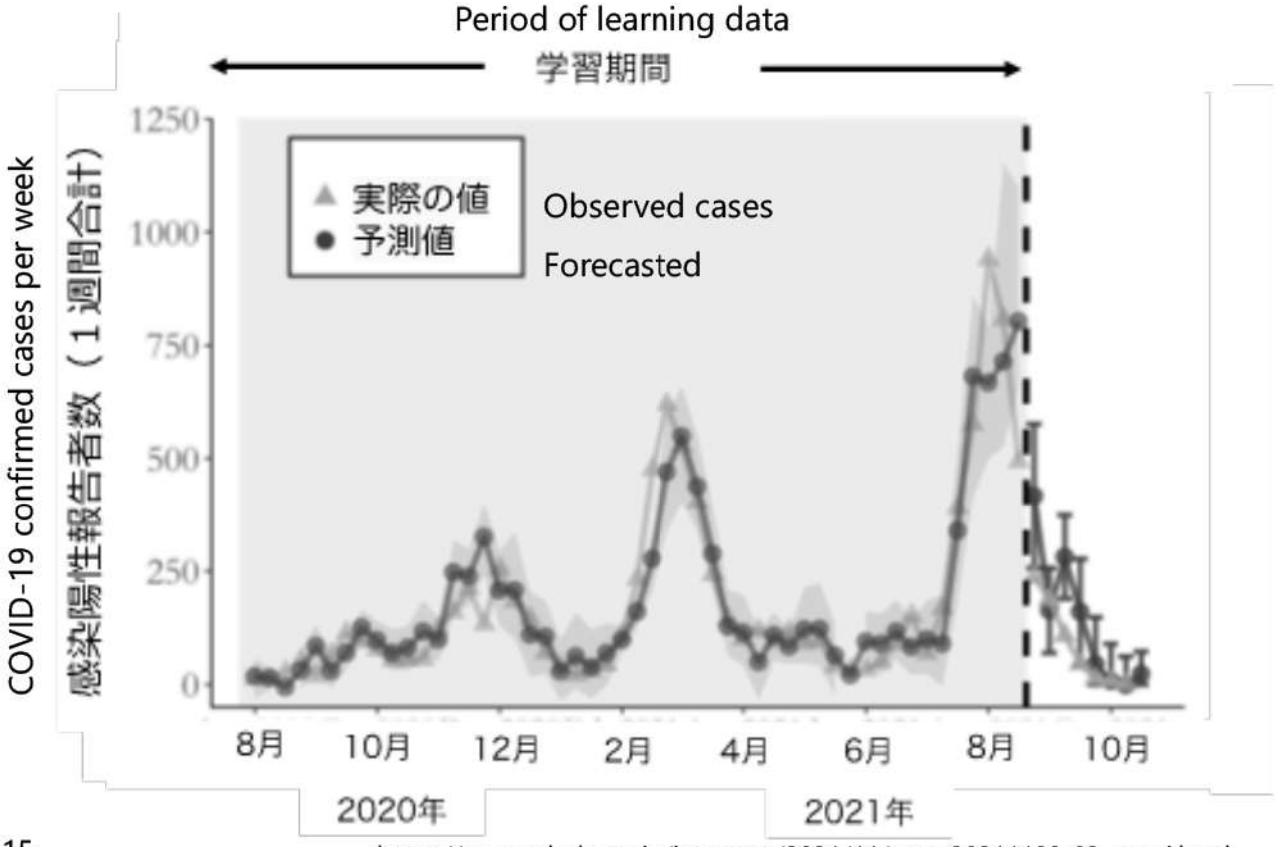
Forecasting COVID-19 cases from wastewater SARS-CoV-2 data in Sendai



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https://www.tohoku.ac.jp/japanese/2021/11/press20211108-03-gesui.html

Local-scale application – Early detection of infection in buldings

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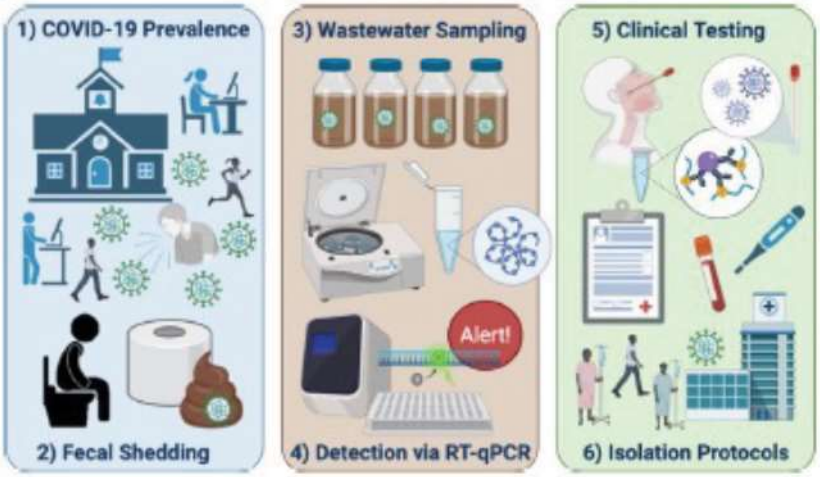
Wastewater surveillance in student dormitories of Arizona University, USA



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Early detection and isolation of infected persons

Betancourt et al.. *Sci. Total Environ.* **2021**, *779*, 146408.

Dorm A (311 residents)
Grab sampling at manholes

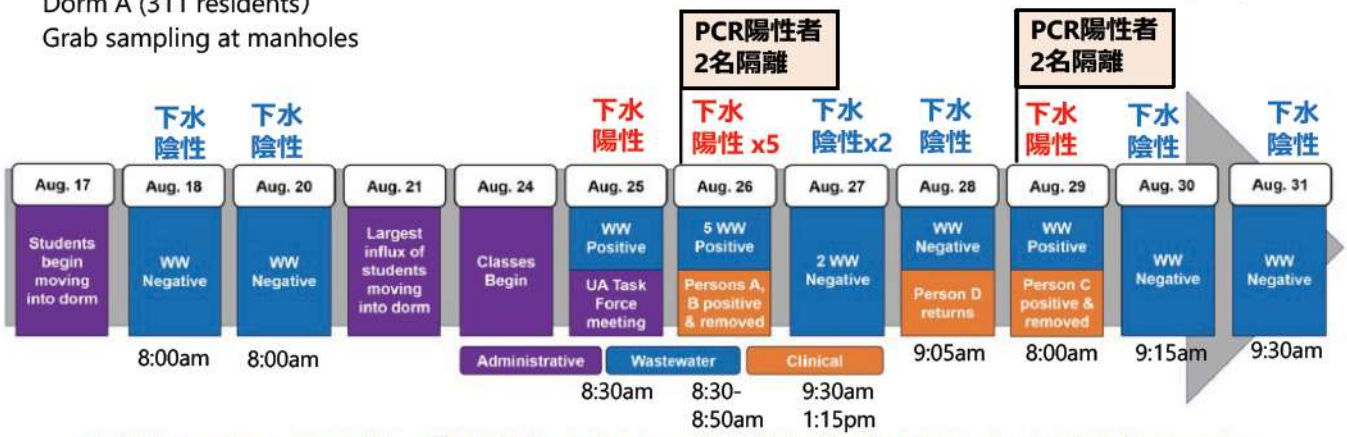

Fig. 1. Timeline of events at Dorm A. Legend: Dates (left to right) and events (top to bottom) are listed in chronological order. WW = wastewater.

Table 3
WBE accuracy as an early-warning diagnostic for new cases of COVID-19.

		Clinical 医療検査	
		Positive 陽性	Negative 陰性
Wastewater 下水検査	Positive 陽性	79	20
	Negative 陰性	25	195
Sensitivity (76.0%).		感度：76%	特異度：91%
Specificity (90.7%).			
Positive predictive value (79.8%).			
Negative predictive value (88.6%).			

陽性的中率：80%
陰性的中率：89%

＊採水方法の
最適化で改善する余地あり

(Note by Honda)
Better prediction is possible by improving sampling.

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Benefits of WBE for COVID-19

◆Population-scale WBE at WWTP

- **[FAST]** Earlier detection of regional epidemic situation with less reporting time lag.
- **[EFFICIENT]** Small no. of testing enables population-based epidemic situation. (Frequent testing is feasible.)
- **[LESS BIAS]** Regional-scale epidemic situations including undiagnosed infections. (Clinically reported cases is affected by no. of testing.)

◆Local-scale WBE for buildings/community

- Early detection of group infection is enabled.
- Frequent testing is feasible than testing of every individual.
- Highly sensitive to detect the single infected person. Also effective to confirm no presence of infection.
- Positive detection in wastewater can trigger individual testing for earlier identification and quarantine of infected persons.

Prevent group infection in the community

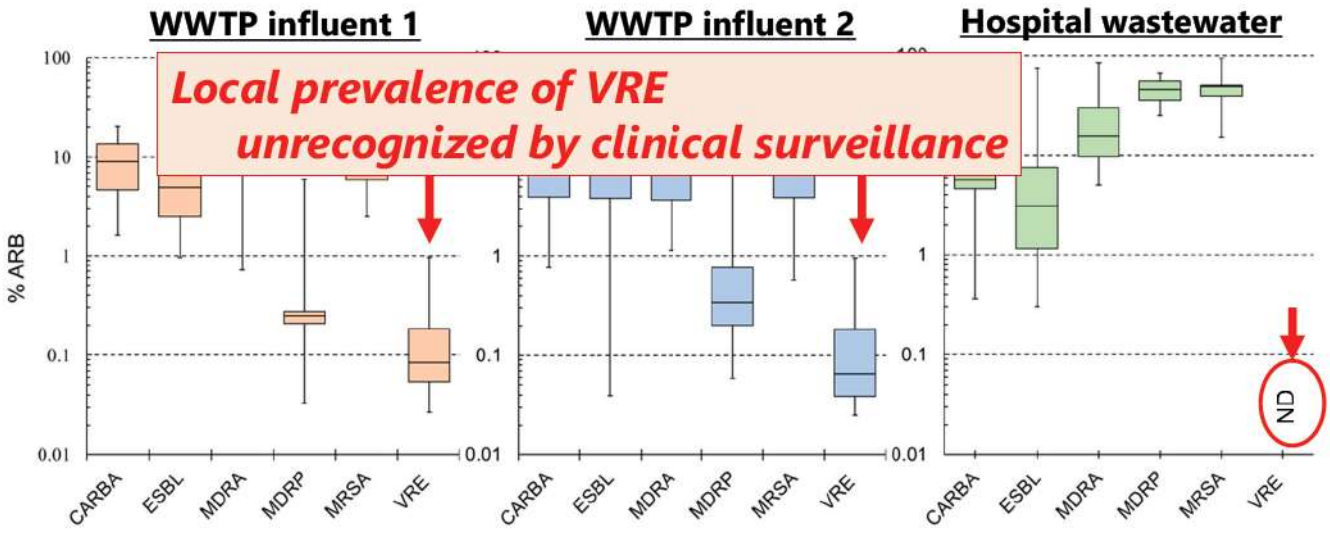
Wastewater-based epidemic survey for antimicrobial resistance

antibiotics

Article

Prevalence of Antibiotic-Resistant Bacteria ESKAPE among Healthy People Estimated by Monitoring of Municipal Wastewater

Masateru Nishiyama [1,*], Susan Praise [1], Keiichi Tsurumaki [1], Hiroaki Baba [2], Hajime Kanamori [2] and Toru Watanabe [1,*]



Nishiyama et al.. Antibiotics 10, 495. doi:10.3390/antibiotics10050495

Benefits in application of WBE to developing countries

Detection of unrecognized disease outbreak

- ✓ Able to know infections overlooked by clinics/hospitals.
- ✓ Applicable to various diseases
  - ➢ SARS-CoV-2, norovirus, polioviurs, influenza
  - ➢ Cholera, typhoid, Shigella dysentery
  - ➢ Antibiotic resistant bacteria

Benefits in application to developing countries

- ✓ Applicable to various tropical diseases
- ✓ **Early etection and surveillance of disease outbreak among people with limited access to medical services**
  - ➢ Rural area
  - ➢ Urban poverty area/community