Do meteorological conditions and sample chemistry influence the efficacy of wastewater SARS-CoV-2 surveillance for COVID-19 case and mortality prediction?

UNIVERSITY OF MIAMI
MILLER SCHOOL of MEDICINE

Samantha Abelson[1], Johnathon Penso[1], Shelja Kumar[1], Bader Alsuliman[1], Kristina Babler[2], Mark Sharkey[3], George Grills[3], Helena Solo-Gabrielle[2], Naresh Kumar[1]

1.Department of Public Health, University of Miami Miller School of Medicine, Miami, Florida.
2. Department of Chemical, Environmental, and Materials Engineering, College of Engineering, University of Miami, Coral Gables, Florida
3. Department of Medicine, Miller School of Medicine, University of Miami, Miami, FL, US

INTRODUCTION

Wastewater monitoring has emerged as a cost-effective and non-invasive tool for infectious disease surveillance during the COVID-19 pandemic (Fig. 1)[1]. However, the efficacy of this surveillance can be influenced the quality of infectious agent retrieval in the wastewater samples. The objectives of this research are to:

- assess whether meteorological conditions and sample chemistry affect the detection of SARS-CoV-2 in wastewater.
- evaluate the efficacy of wastewater SARS-CoV-2 for COVID-19 surveillance, adjusting for meteorological conditions.

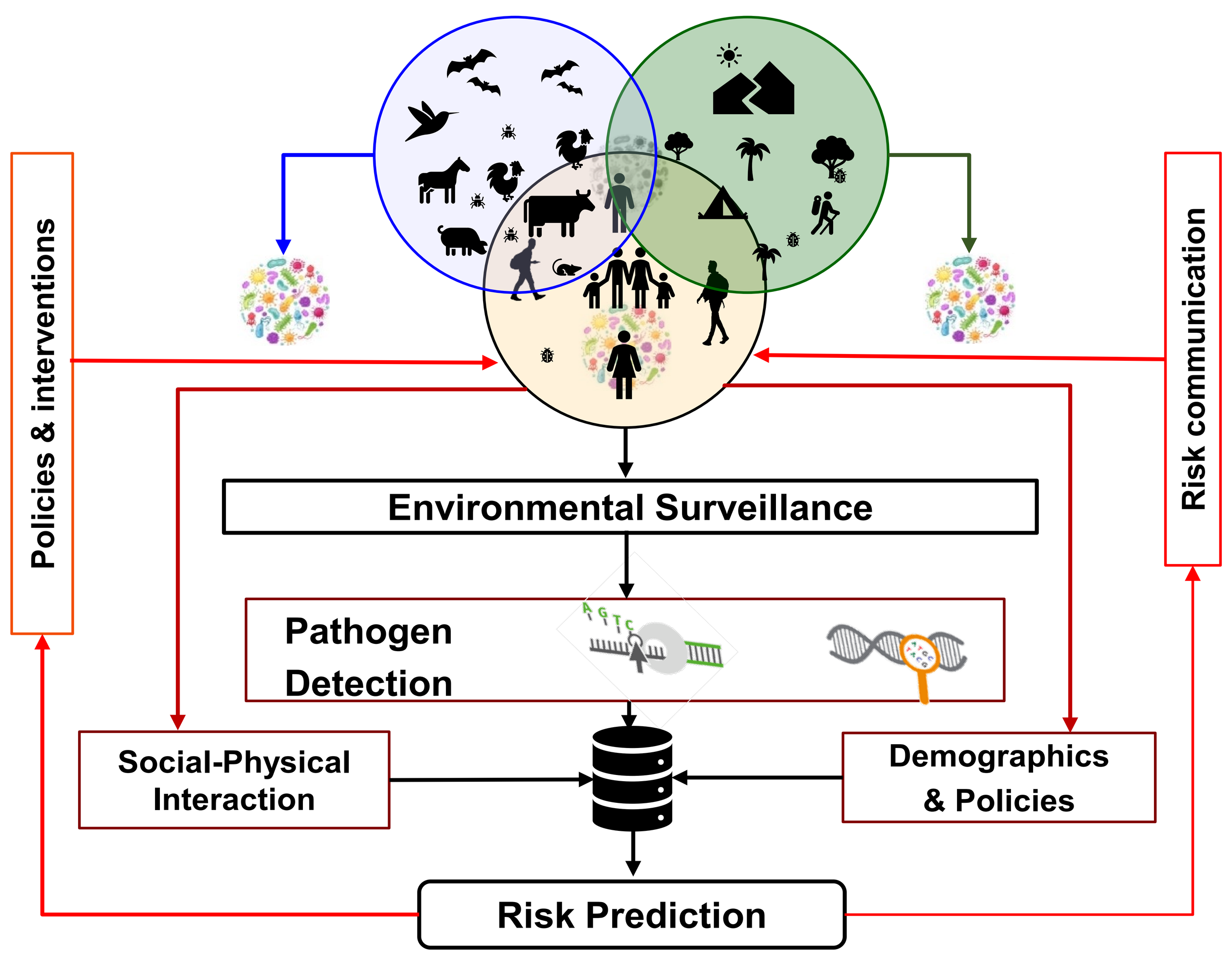

Fig. 1: A conceptual framework of environmental surveillance of infectious agent(s) and risk prediction.

METHODS AND MATERIALS

- Daily 24 h composite wastewater samples were collected from the Miami-Dade Central District Wastewater Treatment Plant from August 23, 2021 to August 31, 2022.
- Wastewater samples were concentrated and RNA was extracted and purified.
- The extracted RNA was analyzed for SARS-CoV-2 genomic copies using our novel qPCR methods as detailed in Sharkey et al. 2022[2].
- Samples were spiked with OC43 and quantified as a measure of RNA recovery.
- COVID-19 case incidence and mortality data from March 2020 to August 2022 were acquired from CDC.
- The association of SARS-CoV-2 in wastewater samples with meteorological conditions and samples chemistry were examined using log-linear regression.
- COVID-19 case incidence and mortality were modelled with respect to time-lagged wastewater SARS-CoV-2 adjusting for ambient temperature and SARS-CoV-2 RNA recovery using instrumental autoregressive models.

RESULTS

- Temperature, dew point, pH values and % OC43 recovery showed significant associations with SARS-CoV-2 in wastewater samples (Table 1).

Covariates	$\log_e$(SARS-CoV-2)	$\log_e$(SARS-CoV-2$^{\alpha}$)
pH	-4.250***	-2.102**
	(-7.268 - -1.233)	(-3.743 - -0.460)
Dew point (° C)	0.307***	0.075***
	(0.209 - 0.405)	(0.019 - 0.132)
$\log_e$(precipitation mm)	0.006	-0.068
	(-0.244 - 0.257)	(-0.199 - 0.063)
$\log_e$(% OC43 recovery)	2.137***	0.845***
	(1.610 - 2.665)	(0.557 - 1.134)
Observations	371	271
R^2	0.217	0.141

*** p<0.01, ** p<0.05, * p<0.1; 95% CI in parentheses;
$^{\alpha}$ excluding samples with SARS-CoV-2 below the detection limit

Table 1. Relationship between SARS-CoV-2 in wastewater samples and meteorological conditions, sample chemistry and RNA recovery.

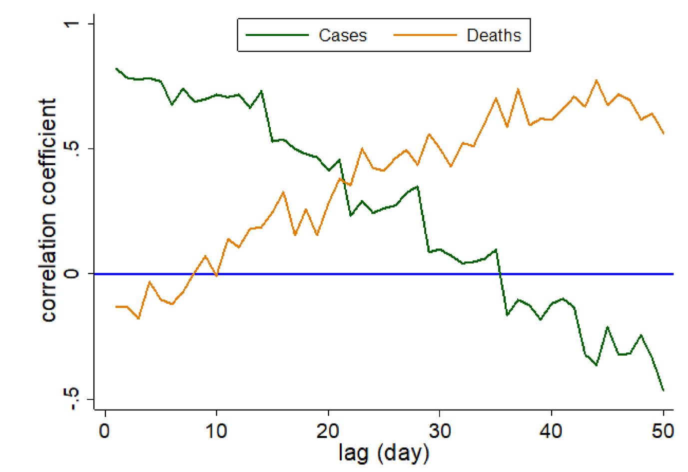

Fig. 2: Coefficient of correlation between time-lagged SARS-CoV-2 in wastewater samples and COVID-19 cases and mortality rate in Miami-Dade, August 2021 to August 2022.

- There was a strong association between time-lagged SARS-CoV-2 in wastewater samples and COVID-19 cases and mortality (Fig. 2). The COVID-19 cases peaked 35 to 45 days prior to the peak of COVID-19 mortality rate (Fig. 3).
- COVID-19 case incidence and mortality rates showed the strongest association with SARS-CoV-2 in wastewater samples 1 day and 37 days prior, respectively (Fig. 4A and 4B).
- RNA recovery, measured by OC43 spike, can greatly influence SARS-CoV-2 concentration in the sample (β ~ 0.47; 95% CI = 0.29 – 0.64; p < 0.001; n = 37) (Table 1).
- A 0.37% change in the seven days moving average of COVID-19 case incidence rate was associated with a 1% change the seven days moving average of SARS-CoV-2 in wastewater (β ~ 0.37; 95% CI = 0.33 – 0.44; p < 0.001; n = 343) (Table 2A).
- 28-day lag in ambient temperature showed the strongest association with COVID-19 case incidence rate (β ~ -0.045; 95% CI = -0.072 – 0.019; p < 0.001; n = 343) (Table 2A).

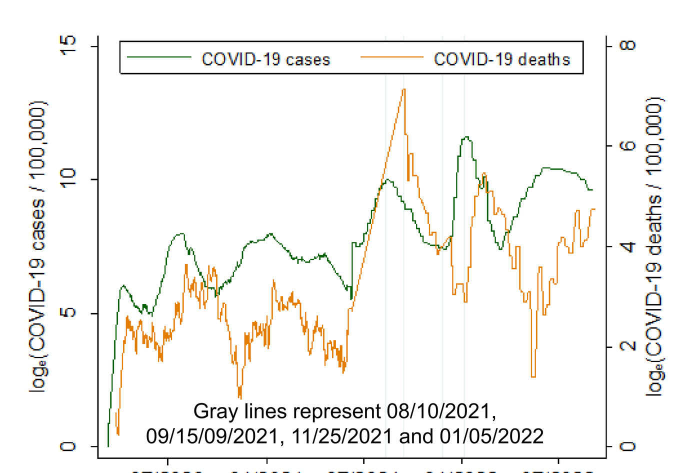

Fig. 3: COVID-19 case incidence and mortality rates in Miami-Dade County, 2020 to 2022.

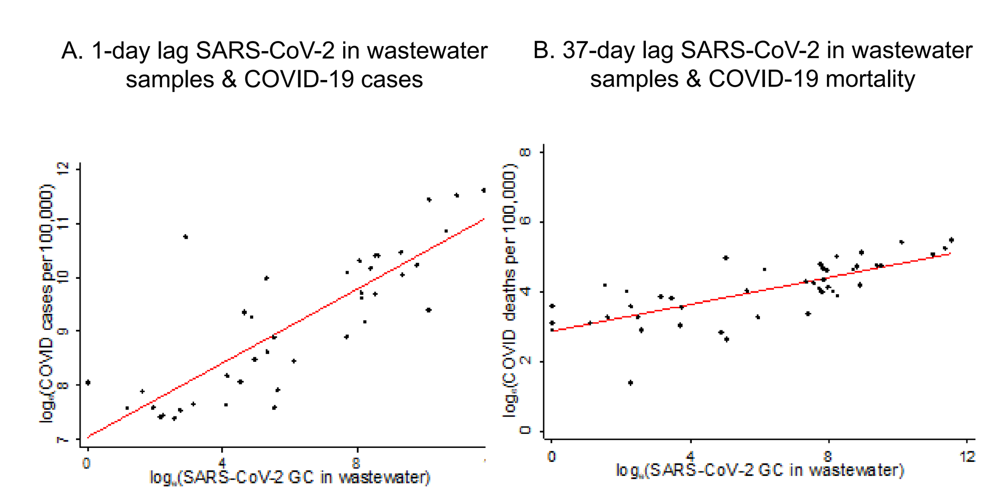

Fig. 4: COVID-19 case incidence and mortality rates & time lagged SARS-CoV-2 in wastewater samples in Miami-Dade, 2021-2022.

	A. $\log_e$(COVID-19 cases / 100,000 population)			B. $\log_e$(COVID-19 deaths / 100,000 population)		
Variable name	Time lag = 0 (or same day) day^{ø}	Instrumented on % OC 43 recovery: lag = 0 day	Instrumented on % OC 43 recovery: ± 7 day moving average	37 days lag	Instrumented on % OC 43 recovery: 37 day lag	Instrumented on % OC 43 recovery: 44 day lag
Time lagged $\log_e$ (SARS-Cov-2 GC/L in wastewater)	0.218***	0.465***	0.372***	0.163***	0.089**	0.125***
	(0.142 - 0.294)	(0.290 - 0.640)	(0.303 - 0.441)	(0.144 - 0.183)	(0.015 - 0.163)	(0.062 - 0.187)
28 day lagged ambient temperature (° C)		-0.074	-0.045***	-0.065***	-0.055***	-0.069***
		(-0.178 - 0.029)	(-0.072 - - 0.019)	(-0.085 - -0.045)	(-0.079 - -0.031)	(-0.090 - -0.048)
# Observation ^{ø}	41	37	343	328	328	321
R-squared	0.464	0.796	0.741	0.469	0.378	0.528

*** p<0.01, ** p<0.05, * p<0.1; 95% CI in parenthesis; ^{ø} for 0 day lag, analysis was restricted when weekly COVID-19 cases were reported.

Table 2. Relationship between SARS-CoV-2 in wastewater samples and COVID19 case incidence rate [A] and mortality rate [B] in Miami-Dade, 2021-2022.

RESULTS (Cont.)

- COVID-19 mortality rate showed the strongest association with SARS-CoV-2 in wastewater 44 days prior (β ~ 0.125; 95% CI = 0.062 - 0.187; p < 0.001; n = 321) (Table 2B).
- A 7% change in COVID-19 mortality rate was associated with a unit change in ambient temperature 28 days prior (β ~ -0.069; 95% CI = -0.090 - -0.048; p < 0.001; 321)
- A strong seasonal pattern was observed in the distribution of COVID-19 case incidence and mortality rates (Fig. 5A and 5B).

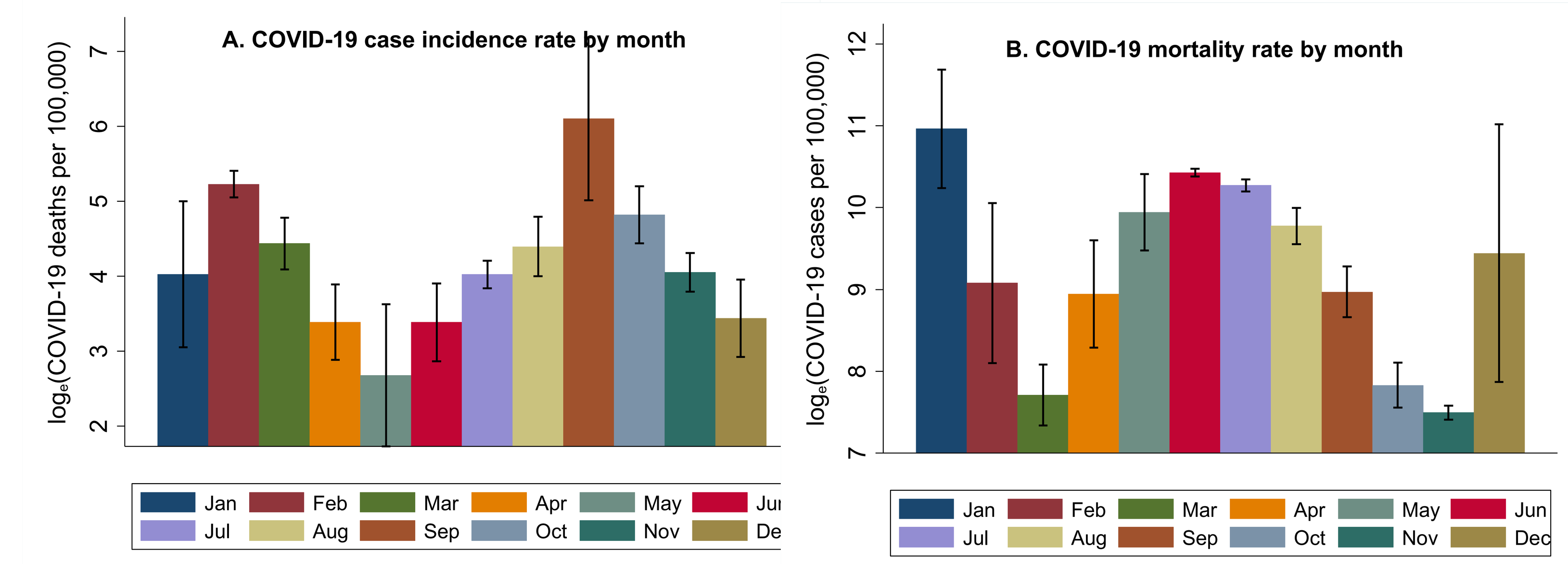

Fig. 5: COVID-19 case incidence and mortality rates in Miami-Dade, March 2020 to August 2022.

CONCLUSION

- The COVID-19 mortality peaked 35 to 45 days after the peak of COVID-19 cases.
- The efficacy of SARS-CoV-2 in the wastewater samples to predict COVID-19 cases and mortality can be influenced by RNA recovery from the samples.
- SARS-CoV-2 in wastewater adjusted for RNA recovery and time-lagged meteorological conditions have about 80% power to predict COVID-19 cases.
- Time lagged SARS-CoV-2 and ambient temperature together had 52% efficiency to predict COVID-19 mortality rate.

LIMITATIONS

- COVID-19 case and mortality data were reported weekly, we had to use weekly moving averages to derive daily estimates.
- Results were not adjusted for socio-demographic characteristics, as COVID-19 data were not available at finer spatial resolution.
- Models lacked adjustment for the existing COVID-19 cases, a measure infectious disease diffusion / transmission.

REFERENCES & ACKNOWLEDGEMENT

Acknowledgement

We are grateful to the staff members of Miami-Dade Wastewater Treatment Plant for allowing us to collect daily wastewater samples.
This work was supported by NIH (U01DA053941).

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