Technical Documentation

Methods for creating interpretable and actionable description of neighborhood-level COVID-19 wastewater levels and trends for routine reporting

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BOSTON PUBLIC HEALTH COMMISSION

Contents:

Summary

The concentration of SARS-CoV-2 in wastewater approximates community transmission and burden of COVID-19. Starting in October 2022, the Boston Public Health Commission (BPHC) began testing wastewater for COVID-19 at 11 neighborhood sampling sites to help better understand COVID-19 epidemiology across the city of Boston. Using data from the first year of the program, BPHC aimed to develop methods to be incorporated into routine wastewater reporting, with the goal of making wastewater SARS-CoV-2 concentration levels and trends more interpretable and actionable.

To develop methods for routine reporting, we followed four general steps: 1) smoothing raw values; 2) classifying current COVID-19 wastewater levels; 3) classifying current 2-week trends; and 4) reporting and visualizing results. In addition, we compare wastewater results to clinical indicators to assess how wastewater levels and trends relate to other more readily interpretable COVID-19 metrics such as reported COVID-19 cases, hospitalizations, and deaths.

We categorized wastewater concentrations into five levels (i.e., very high, high, moderate, low, very low) and these levels reflect time periods of known low and high SARS-CoV-2 concentration, with 'very high' levels observed during winter months and lowest observed during summer months. These wastewater level categories correspond with lagged clinical indicators, with 'Very High' wastewater levels generally coinciding with peak levels of COVID-19 hospital admissions, inpatient hospitalizations, and deaths observed during winter surges. Alongside COVID-19 levels, we also report 2-week trends, also in 5 categories (large increase, increase, stable, decrease, and large decrease). Using these five categories allowed us to distinguish between large increases observed at the start of respiratory disease season and smaller, steadier increases observed during other times. These methods were incorporated into twice weekly routine reporting of wastewater results both at a citywide level and results specific to each neighborhood with accompanying text to convey information interpreting levels and trends for each neighborhood. This information is linked to recommendations and resources based on the current COVID-19 wastewater level in that neighborhood.

COVID-19 trends, including the emergence of new variants and population immunity through vaccination and SARS-CoV-2 infection, are constantly evolving. As such, we will revisit this methodology every six months, and update levels and trends methodology as needed. In addition to SARS-CoV-2, BPHC began monitoring wastewater for several other respiratory pathogens – Influenza A & B, and Respiratory Syncytial Virus (RSV) – starting in October 2023. The methods described herein will be extended to these pathogens when there is sufficient data to do so.

Background/Rationale

People infected with SARS-CoV-2 can shed virus in their feces with and without symptoms. Measuring concentration levels of SARS-CoV-2 virus in wastewater can serve as a proxy for levels of community transmission and burden of COVID-19.[1–3] Viral wastewater concentrations, measured in units of RNA copies/mL, represent pooled results from individuals who live in the wastewater sampling area.

Currently, there is no widely adopted practice to translate wastewater concentration values into numbers that are more readily interpretable such as the number of people infected or number of expected hospitalizations in that community. In part, this is because the relationship between wastewater levels and COVID-19 clinical indicators (i.e., number of cases, hospitalizations, deaths) is complex and expected to vary based on multiple factors that may change over time or be different across settings.[4–7] For example, these may include:

- Environmental factors: sewerage infrastructure, wastewater travel time/viral degradation and rainfall
- Variation in sampled population: population mobility, differences in amount of viral shedding per case (e.g., variant/strain, host immunologic profile and demographics), COVID-19 case detection rates and testing practices (e.g., unreported at-home test results, factors related to clinical severity including population immunity via vaccination or prior infection, age and other sociodemographic characteristics of persons infected, and availability of treatment.

Because of this, we present viral wastewater concentrations and trends as they are observed rather than trying to estimate number of people infected, but additional details are often needed to contextualize and interpret these values.

Starting in October 2022, the Boston Public Health Commission (BPHC) began testing wastewater for COVID-19 at 11 neighborhood sampling sites to better understand COVID-19 epidemiology across the city of Boston.[8] Results from the first year of this program demonstrated different levels and trends across Boston neighborhoods and are reported routinely on the BPHC website. Building on learnings from the first year of the program, BPHC, in collaboration with academic partners, aimed to develop methods to be incorporated into routine reporting with the goal of making wastewater concentration levels and trends more interpretable and actionable.

Approach and Methods

In this technical document, we describe our approach to develop methods to categorize and describe both **current levels** and **trends** over time in SARS-CoV-2 wastewater concentrations across Boston neighborhoods. In developing methods, we aimed for an approach that balanced methodological rigor with simplicity and interpretability. In addition, we compare wastewater results to clinical indicators to assess how wastewater levels and trends relate to other more readily interpretable COVID-19 metrics, such as reported COVID-19 cases, hospitalizations, and deaths.

To produce routinely reported description of levels and trends, we followed four general steps, each described in further detail below: 1) smoothing raw values; 2) classifying current COVID-19 wastewater levels; 3) classifying current trends; and 4) reporting and visualizing results.

Step 1: Smoothing

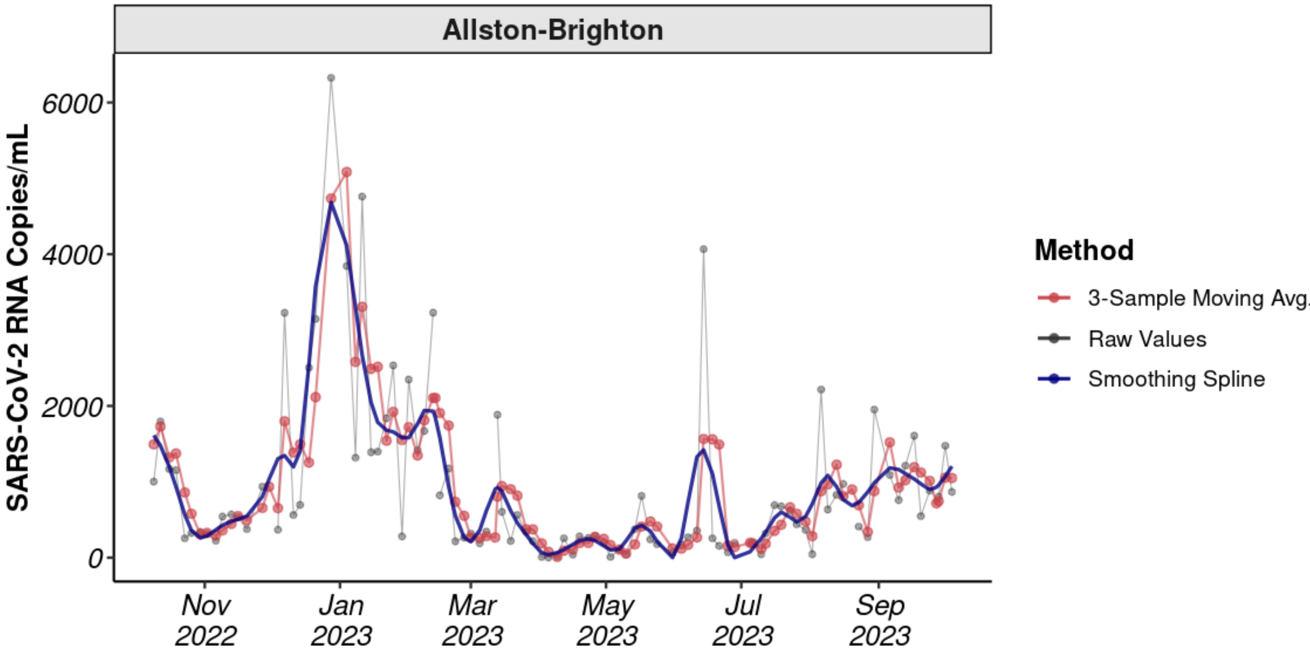
Neighborhood wastewater sampling takes place upstream of the wastewater treatment plant and covers smaller populations than those served by the treatment plant. BPHC's 11 neighborhood wastewater sampling sites vary in size of population covered, from <1,500 people at the smallest site (Hyde Park) to ~35,000 people at the largest (Dorchester). Compared to results from wastewater treatment plants, values observed at neighborhood wastewater sampling sites are more variable, with variability increasing as the size of the population covered decreases. This statistical noise obscures trends, especially for the smallest sites. Because of this, values from single wastewater samples are often smoothed to help with interpretation of these values (e.g., through moving averages).

We considered several different methods for smoothing neighborhood wastewater values, with the goal of selecting a methodology that approximated a weekly average. This would allow for comparison between wastewater values publicly available in the greater-Boston area[1] and with other COVID-19 clinical indicators, often reported as 7-day trailing averages. In addition, in our original reports (available on the BPHC Wastewater Monitoring website under 2023 Wastewater Reports), BPHC used a three-sample moving average (8-days) to report neighborhood wastewater values.

As inputs for each smoothing method, we used SARS-CoV-2 effective concentrations normalized by the human fecal biomarker pepper mild mottle virus (PMMoV) measured in each sample. We compared simple moving averages (2-sample, 3-sample, 4-sample, and 5-sample moving averages) to several other smoothing methods: exponentially weighted moving averages (EWMA), LOESS smoothing with varying spans, smoothing splines with varying degrees of freedom and knots, and penalized generalized additive regression models (GAM). From these approaches, we selected smoothing splines with parameters chosen to approximate 3-sample trailing average values. Smoothing splines offered several advantages over simple moving averages, including improved temporality (i.e., smoothing splines do not lag as much as trailing averages) and increased sensitivity/higher weight to more recent values. See **Figure 1** below shows an example of comparison of raw, 3-sample moving average, and smoothing spline values for the Allston-Brighton neighborhood.

[1] Data from the Metropolitan Water Resource Authority (MWRA) https://www.mwra.com/biobot/biobotdata.htm

Figure 1. *Example of trends in SARS-CoV-2 concentrations comparing unsmoothed single-sample values (grey), smoothed 3-sample moving average (red), and smoothing spline methods (blue) for the Allston-Brighton neighborhood sampling site*



Unlike trailing averages that only use past data points, smoothing splines use observations from both sides of a given point (i.e., past and future observations) to generate smoothed estimates. Because of this, smoothing spline estimates at the end of the time series (i.e., the most recent observations) may be less reliable than those earlier in the time series and are subject to change as subsequent data points are added. Because of this, smoothed estimates for the most recent data points are considered preliminary and are suppressed or qualified until enough subsequent observations are available to ensure reliability. To determine the appropriate lag time to balance timeliness and reliability (i.e., how long to suppress preliminary estimates to improve reliability without overriding the timeliness of recent data), we compared preliminary estimates (i.e., estimates for the most recent data point estimated using only data to date) and estimates using increasing numbers of future observations to smoothing spline estimates using the entire time series (i.e., final estimates, gold standard).

Figure 2 shows an example of smoothing spline estimates using different reporting lags compared to the smoothing spline estimates using the entire time series for the Allston-Brighton neighborhood. We observed large differences between smoothing spline estimates reported without a lag (**Figure 2A**) and smoothing spline estimates using the entire time series – on average, preliminary estimates not lagged differed from final estimates by an average of 199.4 copies/mL, with 70.2% of estimates resulting in the correct COVID-19 level (706/1,006) (**Table 3**). Reporting samples with a 1-sample lag improved estimates over non-lagged samples (average difference from final estimates: 62.4 copies/mL, 88% correct COVID-19 level [885/1,006]) (**Figure 2B, Table 3**). Differences from final smoothing spline estimates for reporting lags of ≥2 days were similar to those lagged by 1 sample (**Figure 2C-D**), and therefore, we chose to suppress only the result for the most recent sample (i.e., lagged 1 sample).

Figure 2. *Example comparison of smoothing spline estimation for the Allston-Brighton sampling site using different reporting lags (red) compared to final smoothing spline estimates using the full time series (dark blue) – (A) smoothing spline estimates reported with no lag, (B) estimates suppressed until one subsequent sample available (1-sample lag); (C) estimates suppressed until two subsequent samples available (2-sample lag); (D) estimates suppressed until three subsequent samples available (3-sample lag);*

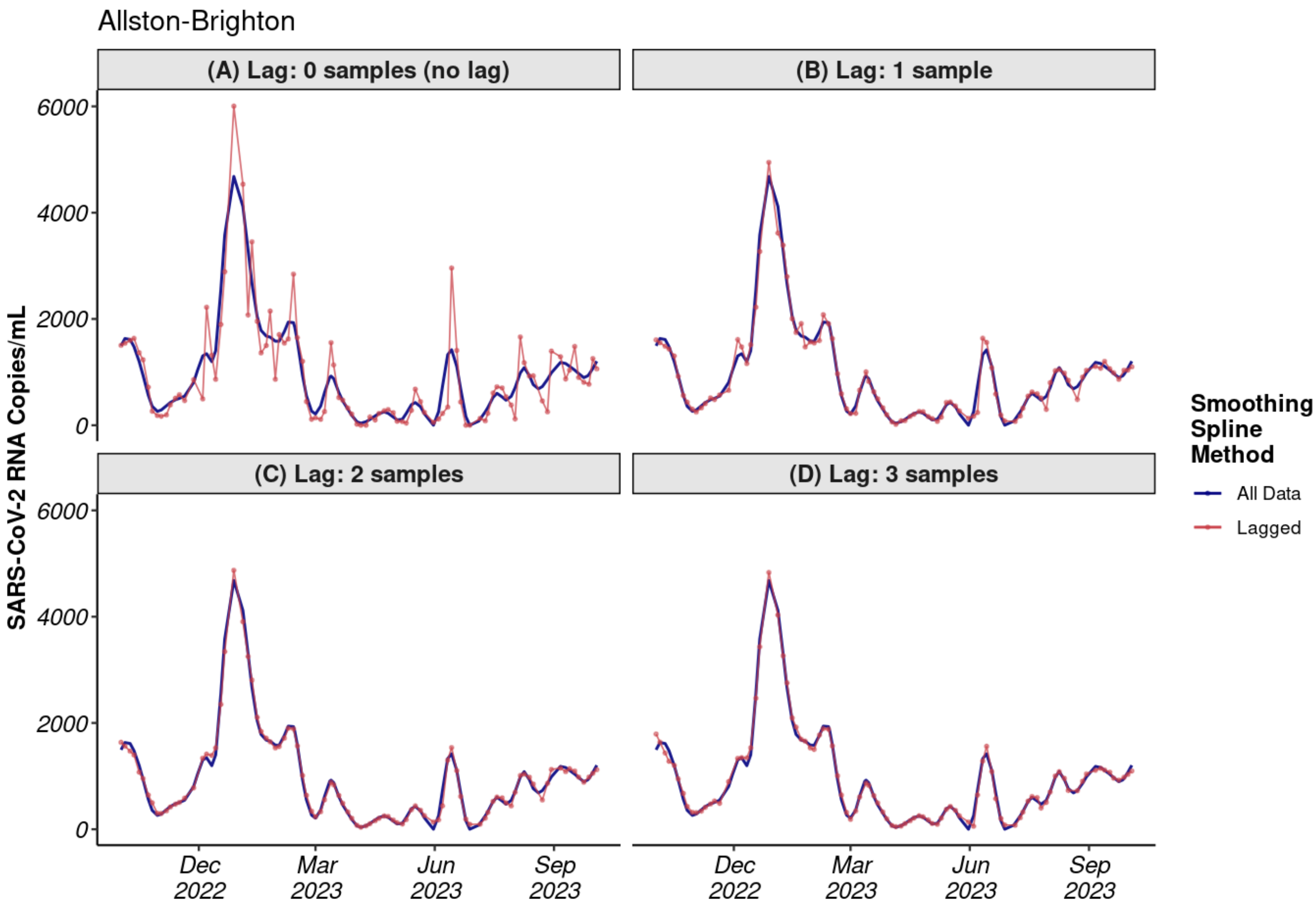


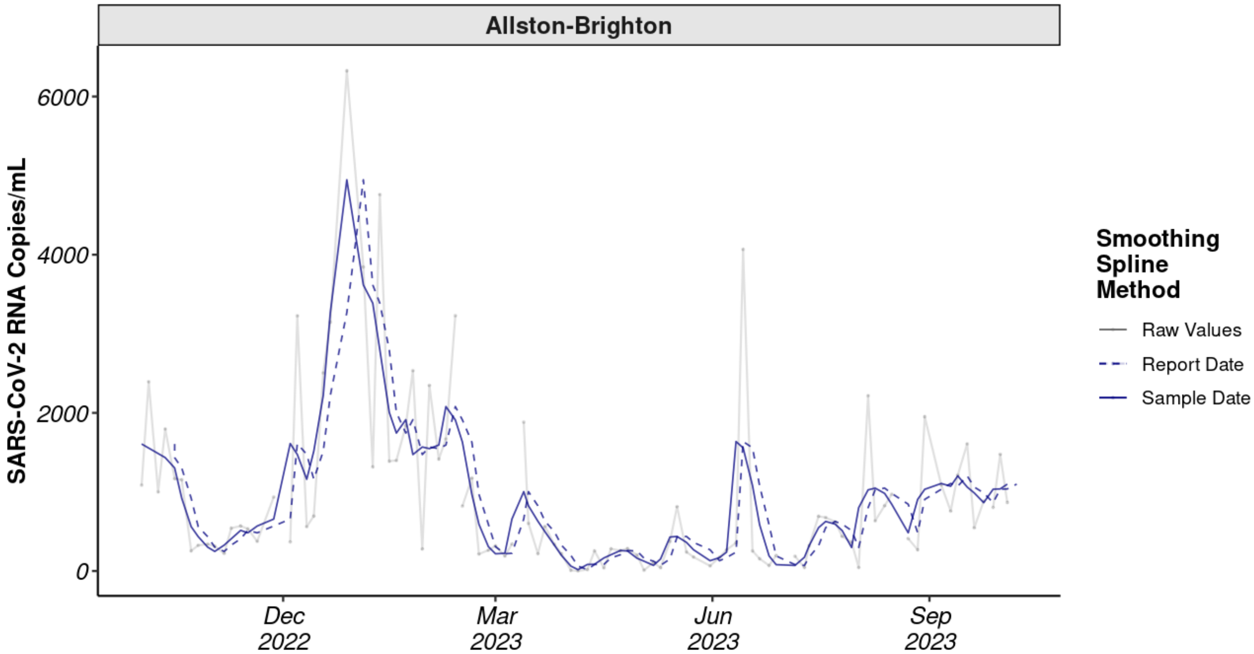
Table 3. *Differences in estimated smoothing spline values using different reporting lags (0 days to 10 days) compared to final estimates using the entire time series.*

Reporting Lag (n Samples)	n	Avg. Absolute Diff. (copies/mL)	n Level Correct	% Level Correct
0*	1,006	199.4	706	70.2%
1	1,006	62.4	885	88.0%
2	1,006	41.5	926	92.0%
3	1,006	38.7	927	92.1%
4	1,007	34.1	945	93.8%
5	1,007	33.6	943	93.6%
6	1,007	32.9	946	93.9%
7	1,007	31.6	953	94.6%
8	1,007	31.3	952	94.5%
9	1,007	31.1	949	94.2%
10	1,007	30.1	952	94.5%

*No Lag

Suppressing preliminary estimates and reporting results with a 1-sample lag results in slightly decreased temporality (**Figure 4**). The resulting spline-smoothed estimates reported with a 1-sample lag exhibit similar timeliness but results in smoothing improvements over 3-sample moving average, and timeliness improvements over 5-sample moving averages.

Figure 4. *Example of trends in SARS-CoV-2 concentrations comparing unsmoothed single-sample values (grey), smoothing spline estimated lagged 1-day shown by sample date (blue solid line) smoothing spline estimated lagged 1-day shown by reporting date (blue dotted line) for the Allston-Brighton neighborhood sampling site*



Step 2: COVID-19 Wastewater Levels Classification

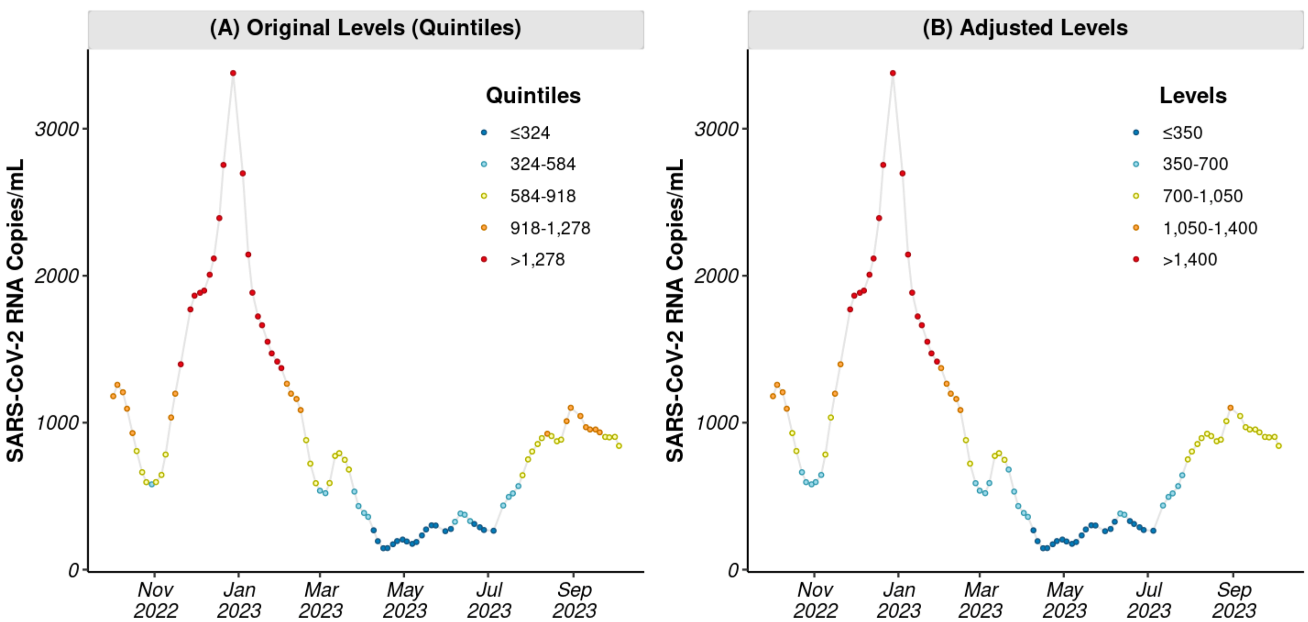
After smoothing, we next aimed to categorize wastewater concentration values into qualitative levels to help with interpretation (e.g., Very High, High, Moderate, Low, and Very low). Because there is no established set of values/cut points used to define these levels across jurisdictions, we established cut points for these levels using the distribution of values observed at the city-level over the first year of the program (i.e., citywide values from October 2022 – September 2023). Unlike in prior years where more consistent levels of SARS-CoV-2 infections were sustained over long periods, COVID-19 rates over the first year of the wastewater program varied widely, with periods of very low transmission (e.g., summer) and high levels of hospitalizations during winter peak resulting in a wide range of values observed during the first year of the program. In addition, BPHC's citywide wastewater values over the first year closely track with trends observed in regional wastewater data for the greater-Boston area (MWRA) and are also strongly correlated with subsequent trends in clinical indicators with varying lead-times over the first year of the program (described in further detail below).

As starting values for cut points between levels, we used quintiles observed over the first year citywide (see **Table 5** below). We then adjusted these quintile cut points slightly so that there was equal distance between levels to preserve interpretation/context of levels relative to each other. In general, these adjusted levels reflect time periods of known low and high SARS-CoV-2 concentration, with highest levels observed during winter months and lowest observed during May/June (see **Figure 6** and **Table 5** below).

Table 5. *Original cut points for wastewater COVID-19 levels created from quintiles of the citywide distribution over the first year of the program compared to cut points after adjustment for equal breaks across levels*

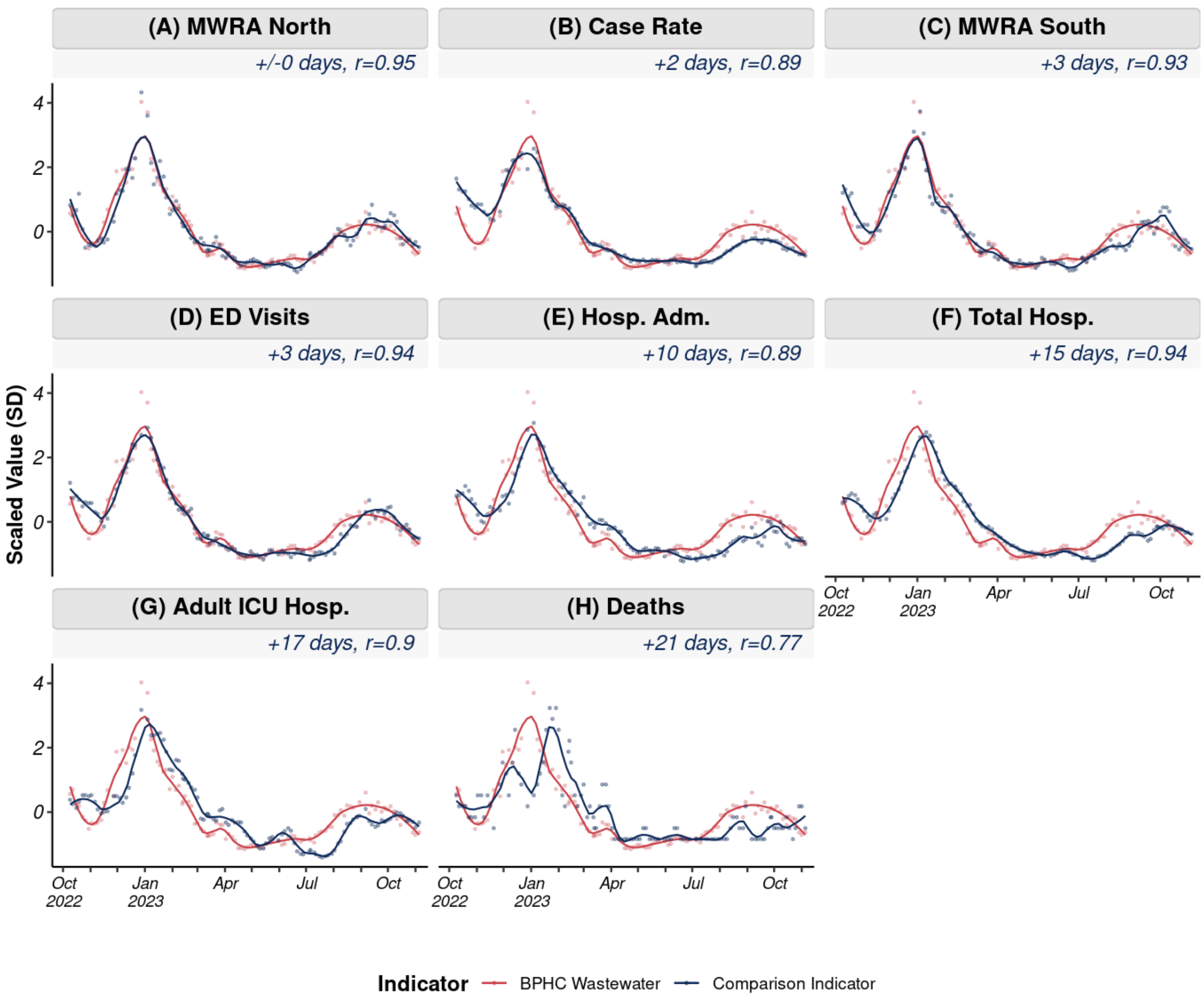
Percentile	Original Cutpoint (Quintiles)	Adjusted Cutpoint (Levels)
0% (lowest)	140	-
20%	324	350
40%	584	700
60%	918	1,050
80%	1,231	1,400
100% (highest)	3,367	-

Figure 6. *Wastewater SARS-CoV-2 concentrations observed over the first year of the program colored by (A) wastewater COVID-19 levels using original quintile cut points compared to (B) COVID-19 levels after adjusting cut points to have equal breaks across levels. Values shown represent smoothed citywide population-weighted average effective concentration across 11 neighborhood sites.*



Next, to assess whether levels observed in wastewater corresponded with lagging clinical indicators, we compared BPHC's citywide wastewater concentration values to various COVID-19 indicators including regional wastewater concentrations in the greater-Boston area, reported COVID-19 case rates and deaths in the city of Boston, and COVID-19 hospital admissions, total COVID-19 hospitalizations, and adult ICU hospitalizations from Boston hospitals. Citywide wastewater values correspond well to lagging clinical indicators, preceding clinical indicators from a range of 2 days for case rates to 23 days for COVID-19 deaths (see **Figure 7** below).[2]

Figure 7. *Trends in citywide population-weighted average SARS-CoV-2 concentration observed across BPHC sampling sites (red line in all panels) compared to COVID-19 indicators including Boston-area regional wastewater concentrations from Metropolitan Regional Wastewater Authority's (A) Northern location (MWRA North)1 and (C) Southern location (MWRA South) (B) Reported COVID-19 Case Rates; (D) COVID-19 emergency department visits, (E) new COVID-19 hospital admissions; (F) total inpatient hospitalizations; (G) total ICU hospitalizations; (H) COVID-19 deaths. All indicators are scaled and centered, with mean zero and units in standard deviations from the mean and shown with a loess smoothing line with a span of 0.15. Indicators are ordered by shortest lead time (MWRA North, 0 days) to longest lead time (COVID-19 deaths, +21 days).*

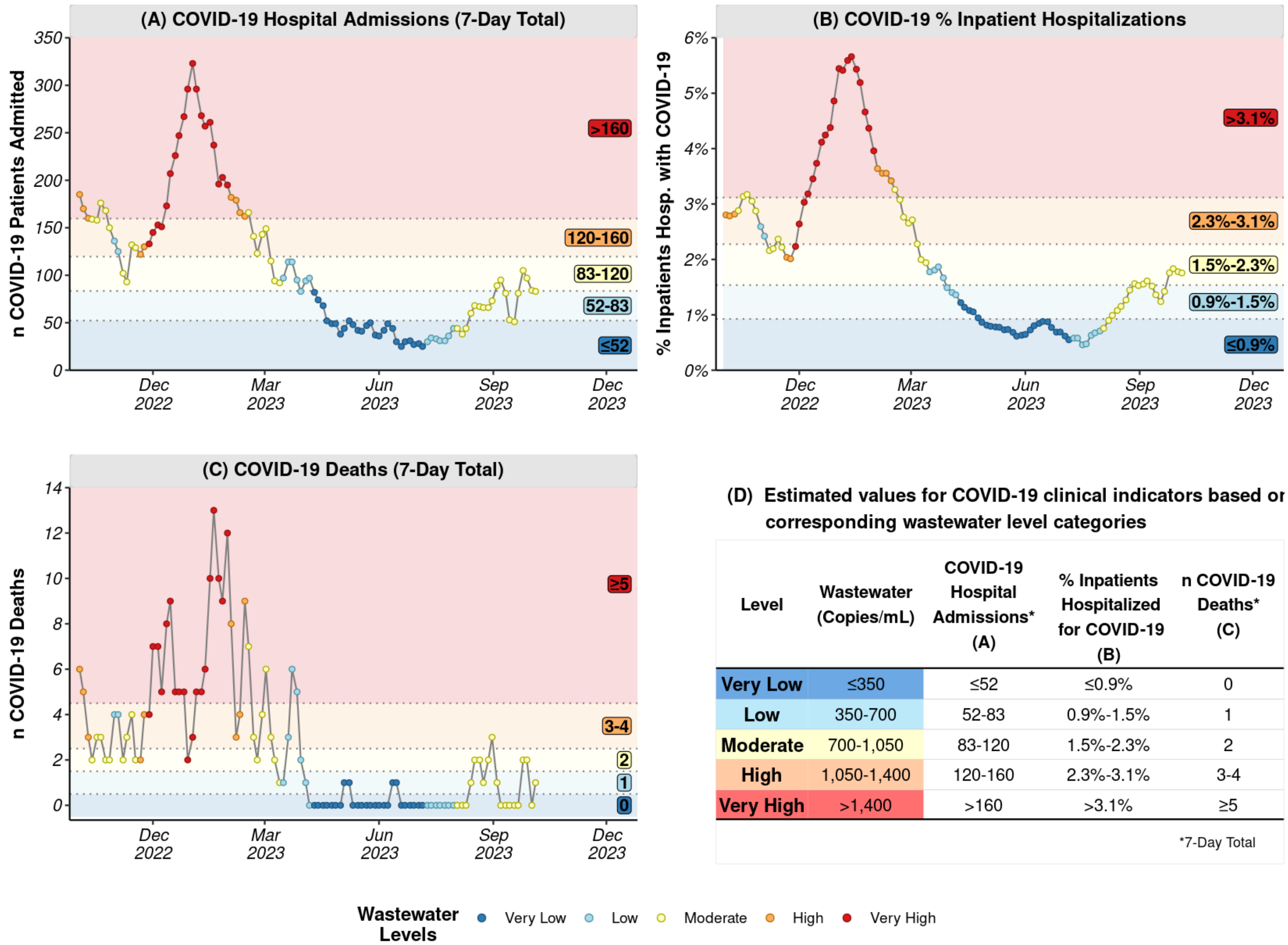


[2] Results from this analysis including **Figure 7** included here are described in further detail in a research manuscript currently undergoing peer review and will be made available upon publication.

Using the strong relationship with lagged clinical indicators described above, we next estimated the number of corresponding hospital admissions, total inpatient hospitalizations, and COVID-19 deaths for each wastewater level. To do so, we fit separate generalized additive models with thin plate regression splines to account for any non-linearities between wastewater concentration values (predictors) and of each lagged clinical indicator of COVID-19 severity (outcomes) – weekly COVID-19 hospital admissions (lagged 10 days), percent of inpatients hospitalized with COVID-19 (lagged 15 days) and number of weekly COVID-19 deaths (lagged 21 days, quasipoisson model for count data). We used these models to translate wastewater level cut points into corresponding categories for each lagged clinical indicator and plotted the time series of each clinical indicator using these categories (see **Figure 8**). This allowed us to compare whether wastewater levels were consistent with levels observed across clinical indicators (e.g., whether periods of 'very high' COVID-19 wastewater levels occurred prior to and during winter peaks in COVID-19 hospitalizations).

Wastewater level categories showed good correspondence with lagged clinical indicators, with 'Very High' wastewater levels generally coinciding with peak levels of COVID-19 hospital admissions, inpatient hospitalizations, and deaths observed during winter surges (**Figure 8A-C**). 'Very High' COVID-19 wastewater levels (>1,400 copies/mL) translated into an estimated >161 new COVID-19 hospital admissions per week, >3.1% of inpatients hospitalized with COVID-19 and ≥5 COVID-19 deaths per week (**Figure 8D**). In contrast, 'very low' wastewater concentration levels of <350 copies/mL corresponded to an estimated <52 new COVID-19 hospital admissions per week, <0.9% of inpatients hospitalized with COVID-19 and zero COVID-19 deaths per week.

Figure 8. *Trends in citywide COVID-19 clinical indicators over time (A) 7-day total COVID-19 hospital admissions; (B) total percent of inpatients hospitalized for COVID-19; and (C) COVID-19 deaths. For each time series (A-C), the color of the dot represents COVID-19 wastewater level and the horizontal shaded areas separated by dotted lines represent the translated level of the clinical indicator that corresponds to the wastewater level – estimated values for each clinical indicator that correspond to the COVID-19 wastewater levels are shown in panel (D), and as labels to the right of each panel.*



(D) Estimated values for COVID-19 clinical indicators based on corresponding wastewater level categories

Level	Wastewater (Copies/mL)	COVID-19 Hospital Admissions* (A)	% Inpatients Hospitalized for COVID-19 (B)	n COVID-19 Deaths* (C)
Very Low	≤350	≤52	≤0.9%	0
Low	350-700	52-83	0.9%-1.5%	1
Moderate	700-1,050	83-120	1.5%-2.3%	2
High	1,050-1,400	120-160	2.3%-3.1%	3-4
Very High	>1,400	>160	>3.1%	≥5

*7-Day Total

Step 3: Trends Classification

After smoothing and classifying COVID-19 wastewater concentrations into levels, we aimed to describe current trends in COVID-19 wastewater concentrations citywide at each neighborhood site. The goal of classifying trends was to describe the magnitude and direction of change in wastewater concentrations over the past 4 weeks to be incorporated into routine reports rather than to predict future trends. As such, we prioritized methods that could be easily understood and interpreted and calculated the difference between current values and the value observed 14 days ago using smoothed estimates described in Step 1.

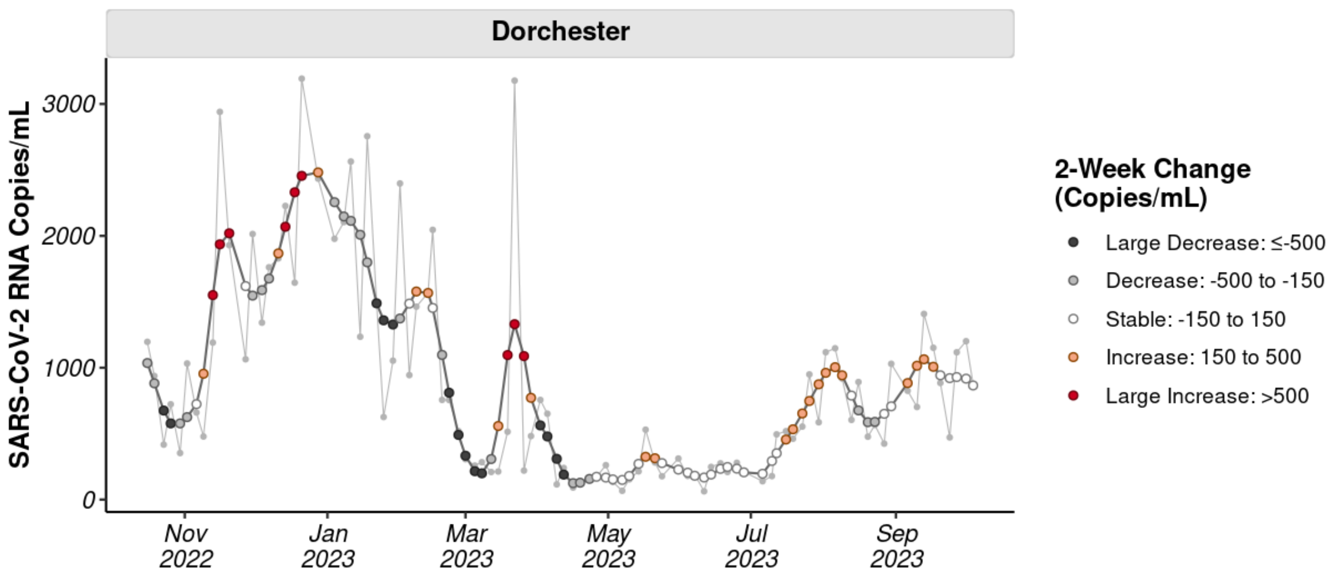
After calculating 14-day change at each site, we categorized these changes to describe the magnitude and direction of trend across each site. For routine reporting of results, we include values for both absolute change in copies/mL and percentage change but chose to focus on the absolute change for characterizing trends since the interpretation simpler and does not depend on baseline values. This decision was further supported by the linear relationship between wastewater concentrations and lagged clinical indicators described in Step 2 above.

Using data from the first year of the program (October 2022-September 2023), we visualized absolute changes compared to 2 weeks prior across neighborhood sites throughout the first year of the program. We categorized 14-day differences into five categories compared to values observed 14-days prior:

- Large Increase: ≥ +500 copies/mL
- Increase: +150 to +500 copies/mL
- Stable: -150 to +150 copies/mL
- Decrease: -500 to -150 copies/mL
- Large Decrease: < -500 copies/mL

These categories allowed us to distinguish between large increases observed at the start of respiratory disease season and smaller, steadier increases observed during other times (e.g., late summer/back-to-school season). **Figure 9** below depicts an example of these 2-week trend categories for the Dorchester neighborhood sampling site.

Figure 9. *Example of trends in SARS-CoV-2 concentrations where colors of the points represent 2-week trend category for the Dorchester neighborhood sampling site*



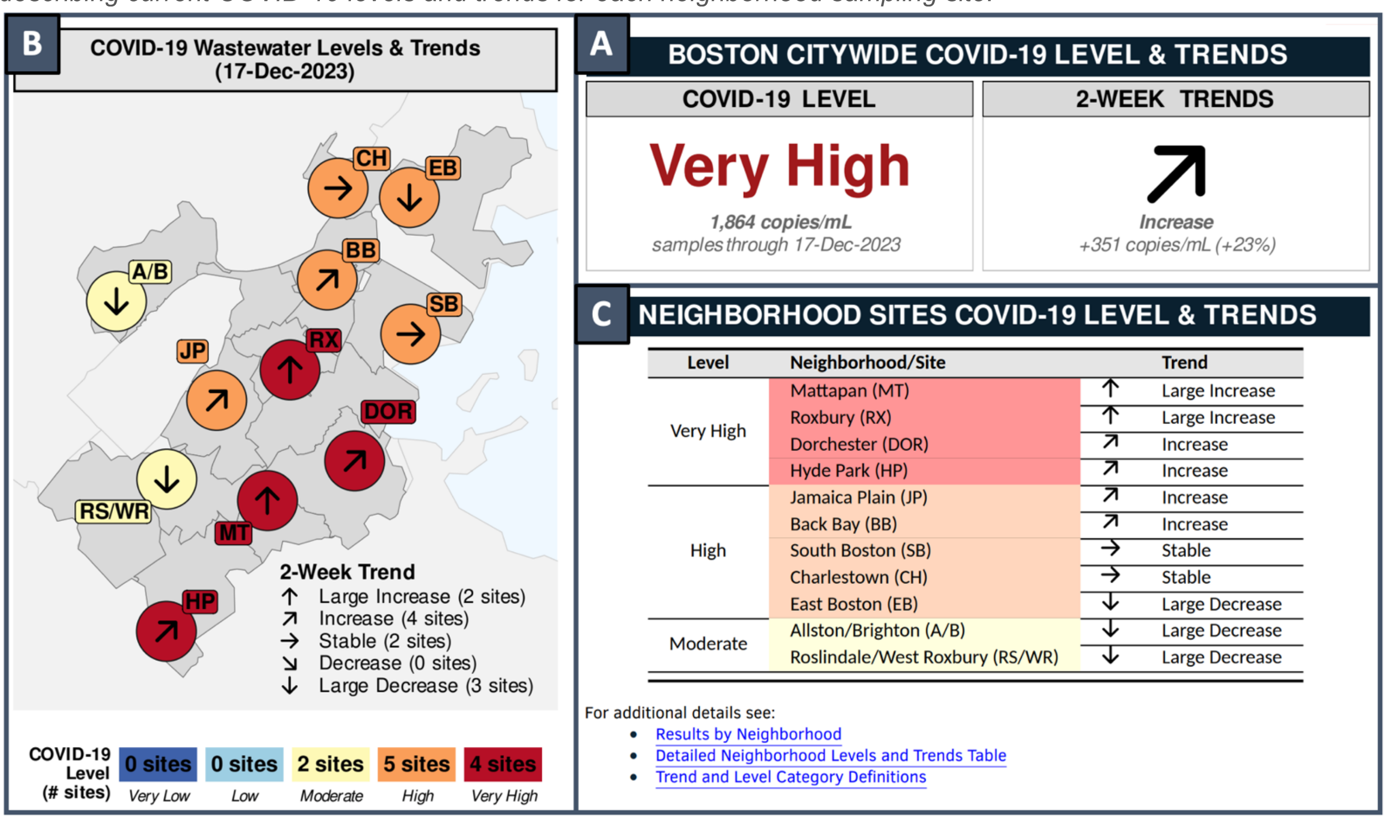
Step 4: Data Reporting, Visualization and Communication

After levels and trends were developed as described above, we aimed to incorporate these results into routine reporting of updated results as new data arrive. As a first step, these results were incorporated into the twice weekly PDF reports posted to the BPHC website, and subsequently added as an interactive data visualization on BPHC's wastewater epidemiology program specific webpage.[9] Additionally, these results will be be incorporated into a PowerBI respiratory illness dashboard .

Unlike many wastewater epidemiology programs that measure viral concentration at the wastewater treatment plant, including MWRA's Boston-area wastewater data, BPHC's wastewater levels are measured at the neighborhood level across 11 neighborhoods sites. As such, we aimed to report and communicate results not only at a citywide level but also at the neighborhood-level emphasizing neighborhood-specific levels and trends.

In the first iteration of our updated reporting, we presented current wastewater COVID-19 level and 2-week trends citywide (i.e., the population weighted average across sites). In this description (**Figure 10A**), we emphasize the qualitative description of the level and direction of trend for quick interpretation (e.g., Level: "very high"; 2-week trend: increase), but also include quantitative results for each (e.g., Level: 1,864 copies/mL; 2-week trend: +351 copies/mL [+23%]). We present citywide results alongside a map and table depicting levels and trends at each of the neighborhood sites. In the levels and trends map (**Figure 10B**), each neighborhood site is depicted as a circle placed at the centroid of each catchment area, with the most recent COVID-19 wastewater level depicted by the color of the circle, and the 2-week trend shown as an arrow icon within the circle. An accompanying table (**Figure 10C**) lists each neighborhood ordered from highest to lowest COVID-19 concentration and shows the corresponding level and trend in that neighborhood consistent with the map in **Figure 10B**.

Figure 10. *Example of first iteration of updated COVID-19 wastewater levels and trends report including [A] Boston citywide COVID-19 level and 2-week trend across all 11 neighborhood sites; [B] map and [C] table describing current COVID-19 levels and trends for each neighborhood sampling site.*

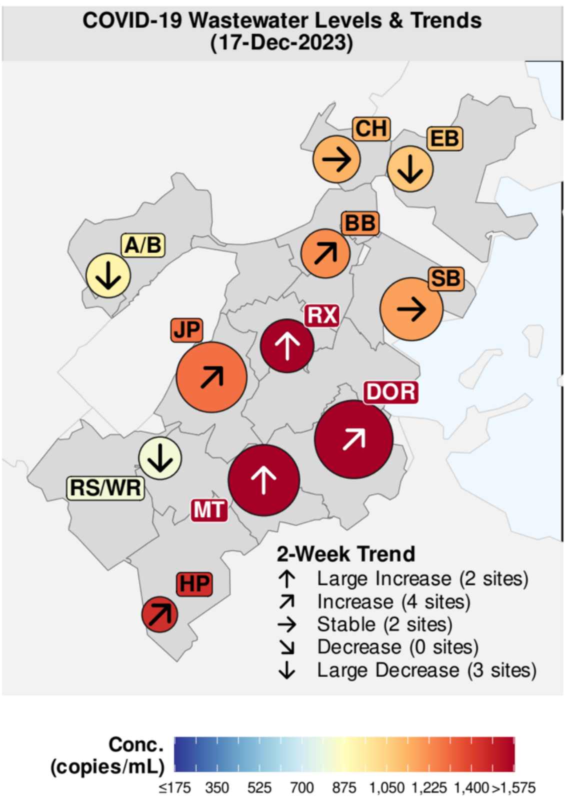


Level	Neighborhood/Site	Trend
Very High	Mattapan (MT)	Large Increase
	Roxbury (RX)	Large Increase
	Dorchester (DOR)	Increase
	Hyde Park (HP)	Increase
High	Jamaica Plain (JP)	Increase
	Back Bay (BB)	Increase
	South Boston (SB)	Stable
	Charlestown (CH)	Stable
	East Boston (EB)	Large Decrease
Moderate	Allston/Brighton (A/B)	Large Decrease
	Roslindale/West Roxbury (RS/WR)	Large Decrease

For simplicity of interpretation, the detailed quantitative results for the level and trend in each neighborhood are not now shown in favor of presenting the more interpretable qualitative information.

Because of this, the report also includes a more detailed map and table showing further quantifications of the levels and trends (**Figure 11**). Key differences between the detailed results and the simplified results in **Figure 10** above are 1) the map uses a continuous color scale to depict the current concentration at each neighborhood site rather than a discrete color scale representing the five levels. In this color scale, the colors are roughly mapped to correspond to the colors used in the discrete scale, but to convey additional information; 2) the accompanying table includes corresponding quantitative values for both the current COVID-19 level and 2-week trend; and 3) the dots are proportionally sized relative to population coverage.

Figure 11. *Example of detailed map and table included in the first iteration of updated COVID-19 wastewater levels and trends report*



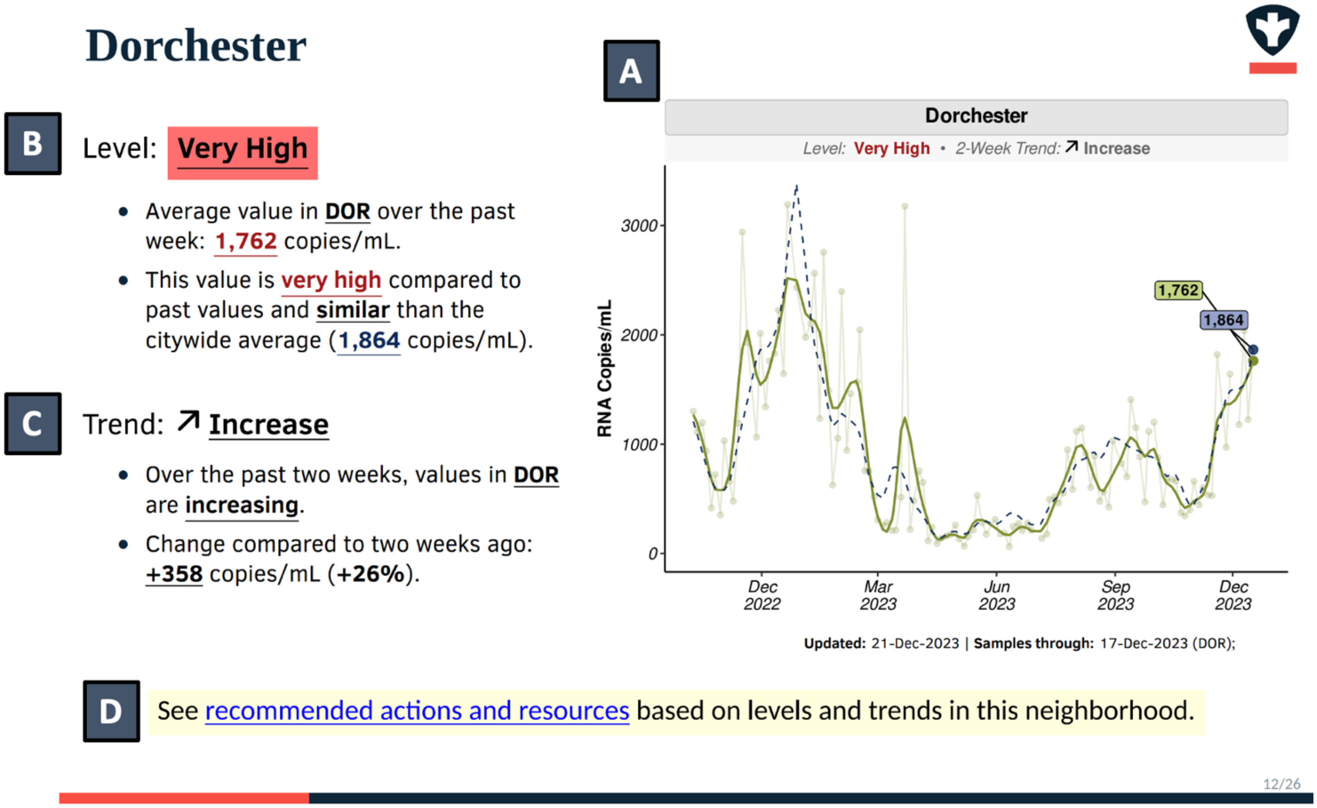
	COVID-19 Wastewater Levels		2-Week Trends		
NH	Conc. (copies/mL)	Level	Trend	Diff. (copies/mL)	% Change
BOSTON	**1,864**	**Very High**	**Increase**	**+351**	**+23%**
MT	3,278	Very High	Large Increase	+1,104	+51%
RX	2,769	Very High	Large Increase	+1,062	+62%
DOR	1,762	Very High	Increase	+358	+26%
HP	1,447	Very High	Increase	+281	+24%
JP	1,292	High	Increase	+416	+47%
BB	1,220	High	Increase	+323	+36%
SB	1,182	High	Stable	-44	-4%
CH	1,139	High	Stable	-10	-1%
EB	1,085	High	Large Decrease	-1,588	-59%
A/B	929	Moderate	Large Decrease	-1,587	-63%
RS/WR	814	Moderate	Large Decrease	-2,224	-73%

Concentration Levels: Very High: >1,400 copies/mL; High: 1,050-1,400 copies/mL; Moderate: 700-1,050 copies/mL; Low: 350-700 copies/mL; Very Low: ≤350 copies/mL

2-Week Trend Categories: Large Increase: >+500 copies/mL; Increase: +150 to +500 copies/mL; Stable: -150 to +150 copies/mL; Decrease: -500 to -150 copies/mL; Large Decrease: ≤-500 copies/mL

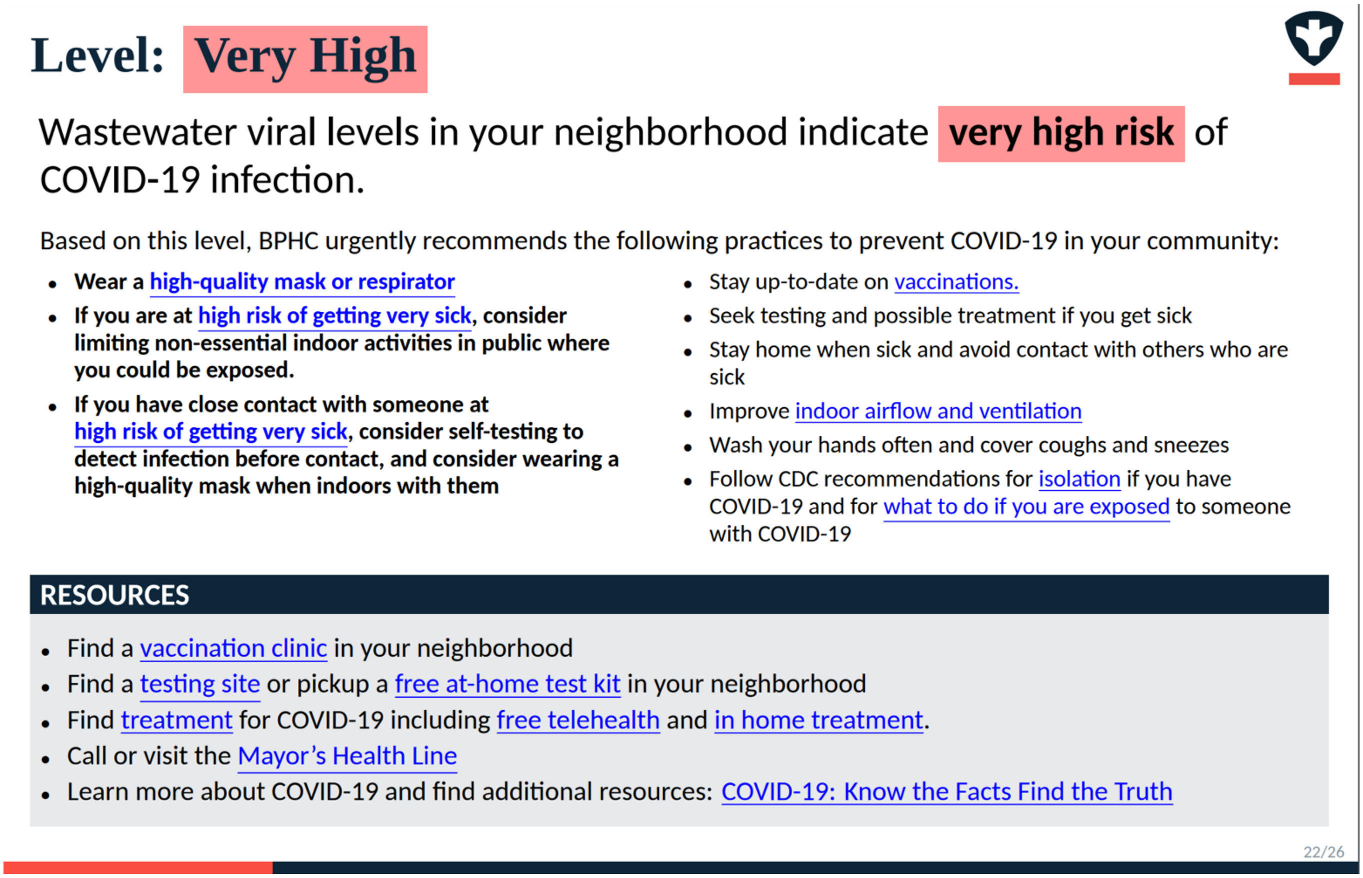
Because BPHC's wastewater program emphasizes neighborhood-specific results, we outline results for each neighborhood and provide accompanying text to help interpret levels and trends in that neighborhood (**Figure 12**). Furthermore, for each neighborhood, we overlay the raw sample values with the smoothed time series with the citywide average trends included in each plot for reference (**Figure 12A**). Alongside the time series, we show the COVID-19 level, smoothed concentration value, a comparison to the current citywide level to identify whether the neighborhood is higher, similar, or lower to the citywide average (**Figure 12B**) and the interpretation of the current 2-week trend as a percentage and as an absolute change of the current value compared to 2 weeks prior (**Figure 12C**).

Figure 12. *Example of neighborhood specific results and interpretation included in the first iteration of updated COVID-19 wastewater levels and trends report for the Dorchester neighborhood sampling site*



Finally, in order to make results from our neighborhood wastewater epidemiology program actionable, for each neighborhood, we also provide a link to recommendations and resources based on the current level in that neighborhood (**Figure 12D**, above). For each of the five levels, we include information on recommended actions adapted from CDC, Massachusetts Department of Public Health (MA DPH) and internal Boston Public Health commission guidance as well as links to resources for finding vaccination, testing, treatment information and educational materials (**Figure 13**).

Figure 13. *Example of recommendations and resources based on COVID-19 level included in the first iteration of updated COVID-19 wastewater levels and trends report; Results shown are for the 'very high' level*



Level: Very High

Wastewater viral levels in your neighborhood indicate **very high risk** of COVID-19 infection.

Based on this level, BPHC urgently recommends the following practices to prevent COVID-19 in your community:

- **Wear a high-quality mask or respirator**
- **If you are at high risk of getting very sick, consider limiting non-essential indoor activities in public where you could be exposed.**
- **If you have close contact with someone at high risk of getting very sick, consider self-testing to detect infection before contact, and consider wearing a high-quality mask when indoors with them**
- Stay up-to-date on vaccinations.
- Seek testing and possible treatment if you get sick
- Stay home when sick and avoid contact with others who are sick
- Improve indoor airflow and ventilation
- Wash your hands often and cover coughs and sneezes
- Follow CDC recommendations for isolation if you have COVID-19 and for what to do if you are exposed to someone with COVID-19

RESOURCES

- Find a vaccination clinic in your neighborhood
- Find a testing site or pickup a free at-home test kit in your neighborhood
- Find treatment for COVID-19 including free telehealth and in home treatment.
- Call or visit the Mayor's Health Line
- Learn more about COVID-19 and find additional resources: COVID-19: Know the Facts Find the Truth

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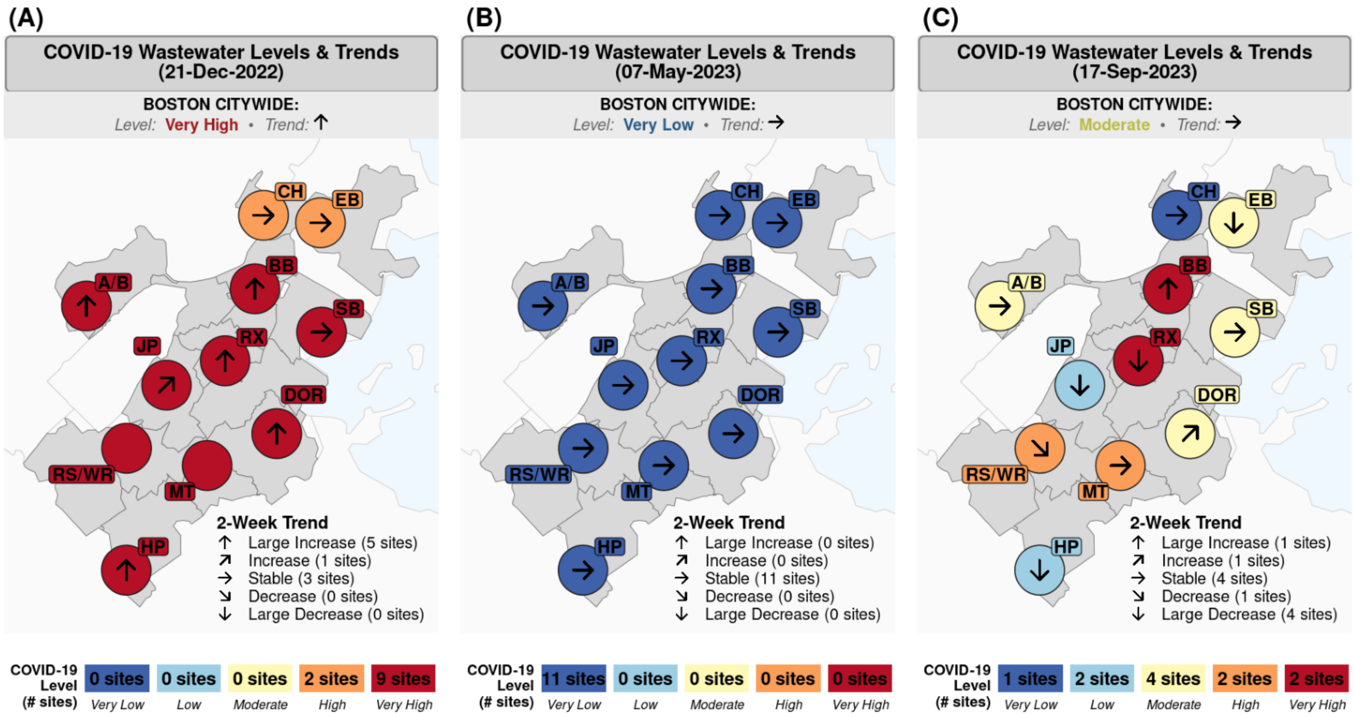
Results and Future Directions

Levels and Trends Over Time

In general, neighborhood levels and trends varied both across neighborhoods and over time. When citywide and regional wastewater SARS-CoV-2 concentrations were highest (December/January) and lowest (May/June), levels and trends observed across sites were relatively consistent (**Figure 14**). For example, on 21-December-2023, Boston citywide COVID-19 wastewater levels were very high, with a large increase 2-week trend, wastewater levels were 'very high' or 'high' across all 11 sites, and the majority of sites had increasing trends (**Figure 14A**). Similarly, on 7-May-2023 COVID-19 levels were 'very low' with 'stable' trends across all 11 sites, consistent with the Boston citywide wastewater level and trend (**Figure 14B)**. In contrast, during periods where citywide and regional levels were not at their highest and lowest, there was more variation in COVID-19 levels and trends observed across neighborhood sites (**Figure 14C**).

Figure 14. *COVID-19 wastewater levels and 2-week trends across sites at three selected timepoints – (A) 21-December-2022 (citywide level: very high, citywide trend: large increase), (B) 07-May-2023 (citywide level: very low, citywide trend: stable), and (C) 17-September-2023 (citywide level: moderate, citywide trend: stable)*[3]



Next Steps and Future Directions

BPHC is collaborating with academic partners to prepare more detailed results and further discussion of COVID-19 levels and trends methodology for publication in an academic journal. As described above, the levels and trends methodology developed for routine reporting used data from the first year of the program (October 2022-September 2023). COVID-19 trends, including emergence of new variants and population immunity through vaccination and SARS-CoV-2 infection, are constantly evolving. As such, we will revisit this methodology every six months, and update levels and trends methodology as needed.

In addition to SARS-CoV-2, BPHC began monitoring wastewater for several other respiratory pathogens – Influenza A & B, and Respiratory Syncytial Virus (RSV) – starting in October 2023. The methods described herein will be extended to these pathogens when there is sufficient data to do so.

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[3] On 21-December-2023, Roslindale/West Roxbury (RS/WR) and Mattapan (MT) neighborhood sampling sites had just begun sample collection and therefore did not have 2-week trend information available.

References & Additional Details

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