Beach Water Testing Comparative Analysis

Introduction

Background

Ottawa has five City of Ottawa supervised beaches: Britannia, Westboro, Mooney's Bay, Petrie East Bay, and Petrie River. The Ontario Public Health Standards identify the minimum expectations for public health programs and services for which Boards of Health are accountable. The Recreational Water Protocol, under these standards, provides direction to Boards of Health on the delivery of local, comprehensive recreational water programs, which includes the surveillance and inspection of public beaches, investigations and response to complaints and promoting the awareness and safe use of public beach facilities.

Ottawa's supervised beaches are all located on rivers which means the water is constantly being replaced at varying rates. Water sample results provide a snapshot of water quality at the time the sample is collected. From 2016 to 2024, during the beach season (June to August), Ottawa Public Health (OPH) collected beach water samples daily (Monday to Sunday) and tested for *E. coli* levels.[i] Water sample results take 18 to 24 hours to process in the laboratory, and as such, results were posted the following day and "swim" and "no-swim" recommendations were based on results from the previous day.

The presence of *E. coli* in water samples is an indicator of possible fecal contamination and elevated risk of gastrointestinal illness[1]. OPH would issue a one-day "no-swim" recommendation if bacterial levels for the previous day were over 200 *E. coli* per 100mL of water, per provincial guidelines[2]. "No-swim" recommendations were also issued after significant rainfall, regardless of bacterial levels, because rainfall is known to have negative impacts on water quality[3]. As a result, the recommendation may not have always accurately reflected the water quality on the same day, as conditions may have changed from one day to the next.

In 2025, samples are being collected once a week on Wednesdays and posted the following day to monitor long-term water quality trends at the five beaches. "Swim" and "no-swim" recommendations are no longer issued and public health education

[i] A minimum of five water samples were collected at each of the five City of Ottawa beaches to average the bacterial levels of *E. coli*. A geometric mean is calculated as per the provincial Operational Approaches for Recreational Water Guideline. Geometric mean is an averaging method used to reduce the effect of a single high reading.

emphasizes real-time environmental indicators of water quality like rainfall, wind, wildlife activity and water clarity, while still sharing the most recent and historical *E. coli* results to enable beachgoers to make an informed decision. However, many beachgoers became familiar with reviewing the water quality test results and basing their decision to swim on the previous day's result and now use the weekly results when deciding to swim or not on any given day at a particular beach. As such, the change in testing frequency and associated recommendations prompted the OPH Board of Health to question whether weekly testing would be as accurate when assessing water quality as daily testing.

Descriptive Analysis

Historically (2016-2024), the City of Ottawa supervised beaches met the water quality standard 86% of the time (**Figure 1**), had an average annual mean of 151 *E. coli* or less per 100mL (**Figure 2**), and had "no-swim" recommendations 20% of the time (**Table 1**).

Figure 1 shows that between 2016 and 2024, on average the beaches combined ("Total") met the water quality standard 86% of the time. There was variation by beach and by year, from a low of 48% of assessments meeting the standard at Petrie East Bay in 2020 to a high of 100% at Britannia beach in 2016. In 2024, overall, 78% of the beach assessments met the standard.

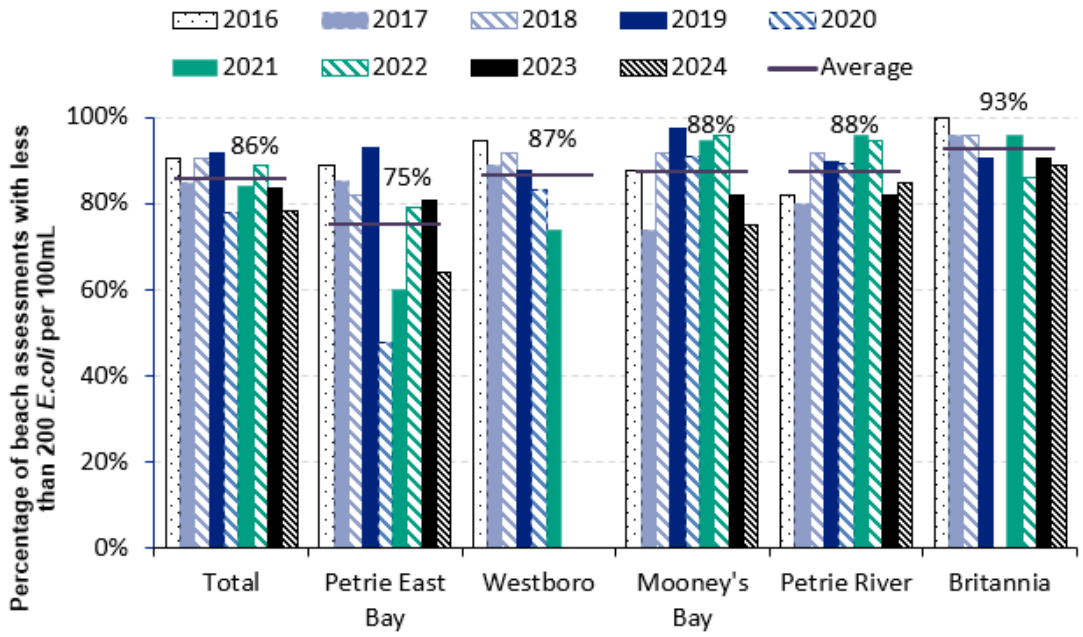

Figure 1. Annual percentage of beach assessments that met the standard of less than 200 *E. coli* per 100mL at the five City of Ottawa supervised beaches, 2016 to 2024

Note: Britannia beach was temporarily closed in 2020 and Westboro beach was closed from 2022 to 2024.

Figure 2 shows that between 2016 and 2024, the beaches combined ("Total") had an annual average of daily water quality sampling results of 151 *E. coli* or less per 100mL, meeting the standard of less than 200 *E. coli* per 100mL. All but three beach-years had an annual average that met water quality standards. In 2020, Petrie East Bay beach had an annual average greater than 200 *E. coli* per 100mL and in 2021, Petrie East Bay and Westboro beaches had an annual average greater than 200 *E. coli* per 100mL.

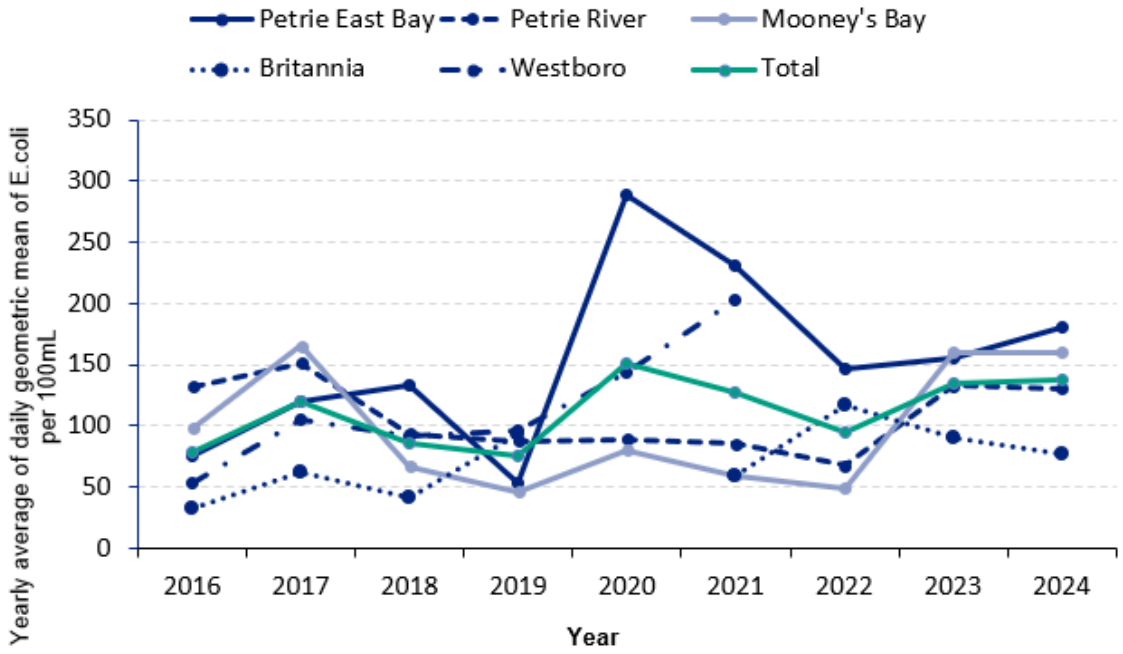

Figure 2. Average annual *E. coli* mean at the five City of Ottawa supervised beaches, 2016 to 2024

Note: Britannia beach was temporarily closed in 2020 and Westboro beach was closed from 2022 to 2024.

Table 1 shows that between 2016 and 2024, the five City of Ottawa supervised beaches had “no-swim” recommendations 20% of the days during the season, ranging from a low of 12% at Brittania beach to 30% at Petrie East Bay beach. This includes recommendations based on the previous day’s *E.coli* levels, significant rainfall, or both.

Table 1. Number of “no-swim” recommendations by reason for recommendation, 2016 to 2024 combined, five City of Ottawa beaches

Beach	Number of “no-swim” days due to *E. coli* previous day	Number of “no-swim” days due to rainfall	Number of “no-swim” days due to high *E. coli* and rainfall	Total number “no-swim” days*	Total number of days tested	% days beach had “no-swim” recommendation
Britannia	44	26	0	70	576	12.2%
Mooney’s Bay	92	26	3	121	641	18.9%
Petrie East Bay	154	29	4	187	622	30.1%
Petrie River	85	41	1	127	620	20.5%
Westboro	61	21	0	82	425	19.3%
Total	**436**	**143**	**8**	**587**	**2884**	**20.4%**

Note: Britannia beach was temporarily closed in 2020 and Westboro beach was closed from 2022 to 2024. * “No-swim” days in the columns preceding are mutually exclusive.

Objective

The objective of the comparative analysis was to compare the historical accuracy of using OPH’s daily versus weekly water quality test results to assess the following day(s) water quality at the five City of Ottawa supervised beaches.

Methods

Results from testing *E. coli* levels in beach water and “swim” and “no-swim” recommendations (excluding those based solely on rainfall) from 2016 to 2024 for the five City of Ottawa beaches were included in the analyses and are publicly available from Beach Water Sampling | Open Ottawa, where the *E. coli* results shown are from the previous day's sample. To meet the objective, we determined the number of false positives, true positives, false negatives and true negatives in the relationship between beach water sampling results and “swim” and “no-swim” recommendations (**Table 2**). These values were used to calculate the accuracy, positive predictive value and negative predictive value of daily versus weekly testing for each beach, overall and by

year. Accuracy, positive predictive value, and negative predictive value are measures frequently used in clinical epidemiology to understand the accuracy of diagnostic tests, with values approaching 100% indicating a better test.[4] Data were analyzed using StataSE 17 (64-bit) and Microsoft Excel.

Some beaches were not open during part of the analysis period and testing was not completed during closures. Westboro beach was closed from 2022 to 2024 for infrastructure renovations. Britannia beach was closed in 2020 for dredging and water deepening. Both Petrie River and Petrie East Bay were closed in June 2017 and June 2019. “No-swim” recommendations based solely on the previous day’s rainwater will not be included in the comparative analysis because these recommendations have not changed. Water safety and drowning were outside the scope of this report.

Because the recommendation for a given day was based on the results from a water sample taken on a previous day[ii], it is possible for the recommendation to be discordant with the current water quality. When this happened, there was a “swim” recommendation on a day with poor water quality or a “no-swim” recommendation on a day with acceptable water quality. As a result, there are four scenarios that describe the relationship between the current recommendation and the current water quality (**Table 2**).

Table 2. The relationship between the current recommendation and the current water quality

		Beach water sampling result	
		E. coli count does not meet standards (>200 *E. coli* per 100 mL)	*E. coli* count meets standards (≤200 *E. coli* per 100 mL)
Recommendation	“No-swim”	True Positive	False Positive
	“Swim”	False Negative	True Negative

1. **True Positive**: A “no-swim” recommendation for the current day was issued based on *E. coli* counts from the previous day which did not meet standards. *E. coli* counts for the current day also do not meet standards. Since *E. coli* counts from the previous and current day both do not meet standards, the recommendation was correct.
2. **True Negative**: A swim recommendation for the current day was issued based on *E. coli* counts from the previous day which met standards. *E. coli* counts for the current

[ii] The previous day is one day before in the case of daily testing, and one to seven days before in the case of weekly testing.

day also meet standards. Since *E. coli* counts from the previous and current day both meet standards, the recommendation was correct.

3. **False Positive**: A “no-swim” recommendation for the current day was issued based on *E. coli* counts from the previous day which did not meet standards. However, *E. coli* counts for the current day met standards. Since *E. coli* counts from the previous day did not meet standards but counts from the current day meet standards, the recommendation was incorrect.
4. **False Negative**: A swim recommendation for the current day was issued based on *E. coli* counts from the previous day which met standards. However, *E. coli* counts for the current day do not meet standards. Since *E. coli* counts from the previous day met standards but counts from the current day do not meet standards, the recommendation was incorrect.

Using beach water sampling results and recommendations issued from 2016 to 2024, the frequency of each of these scenarios for each of the five City of Ottawa beaches was calculated. From this information, the accuracy, positive predictive value (PPV), and negative predictive values (NPV) were calculated:

1. **Accuracy** = (True Positives + True Negatives) / Total number of sampling results
    - Accuracy refers to the ability to correctly issue a “swim” or “no-swim” recommendation based on the water sampling results.
2. **Positive Predictive Value** = True Positives / (True Positives + False Positives)
    - PPV represents the probability that the *E. coli* count did not meet standards and a “no-swim” recommendation was issued. It answers the question: "Of all “no-swim” recommendations, what are the chances that the *E. coli* count did not meet standards?”.
3. **Negative Predictive Value** = True Negatives / (True Negatives + False Negatives)
    - NPV represents the probability that the *E. coli* count met standards when there was a “swim” recommendation issued. It answers the question: "Of all “swim” recommendations, what are the chances that the *E. coli* count met standards?”.

For the first part of the analysis, daily “swim” or “no-swim” recommendations based on the previous day’s sample (Day0) were compared to the water sampling results from the same day (Day1). Each water sample result is based on the geometric mean of five *E. coli* culture results taken at the same beach on the same day and time.

To compare daily versus weekly water testing, we considered a scenario of one recommendation per week which occurs when water samples are collected once a week. The results of water sampling for one day in the week (Day0) were used to

assign the recommendation for the entire week (Day1 through Day7). Weekly "swim" and "no-swim" recommendations were compared to daily water sampling results. For ease of interpretation, Tuesday testing was selected to demonstrate the rate of true and false positives and negatives. However, the comparison for accuracy, PPV and NPV was performed seven times to avoid biasing results by choosing only one specific day of the week, each time considering a different sample collection day during the week upon which to base the weekly recommendation (i.e. Monday, Tuesday, Wednesday, Thursday, Friday, Saturday, Sunday). The results were averaged using the median.

Results

A total of 2884 water sample *E. coli* culture results (each representing the geometric mean of five samples taken the same day) from five beaches collected from 2016 to 2024 were included in the analysis.

Daily testing

As summarized in **Table 3**, most recommendations were true positives (5.3%) or true negatives (77%) where the Day1 recommendation based on Day0 results correctly aligned with the Day1 results. The majority (82.3%) of recommendations were correct based on daily testing.

Table 3. Number of true positives, true negatives, false positives, and false negatives for daily samples, 2016 to 2024 combined, five City of Ottawa beaches

Beach	Number of true positives *"No-swim" recommendation and E. coli count does not meet standards*	Number of true negatives *"Swim" recommendation and E. coli count meets standards*	Number of false positives *"No-swim" recommendation but E. coli count meets standards*	Number of false negatives *"Swim" recommendation but E. coli count does not meet standards*	Total number of days sampled
Britannia	5	499	36	36	576
Mooney's Bay	31	512	49	49	641
Petrie East	73	389	80	80	622
Petrie River	28	496	48	48	620
Westboro	16	326	41	42	425
All combined	**153 (5.3%)**	**2222 (77.0%)**	**254 (8.8%)**	**255 (8.8%)**	**2884**

Table 4 presents the accuracy, PPV and NPV of daily testing calculated based on the values in **Table 3**. Values vary by beach. The overall accuracy ranged from 74.3% at Petrie East to 87.5% at Britannia beach. The NPVs are higher than the PPVs at all beaches.

Table 4. Overall accuracy, PPV, and NPV of daily beach water quality testing, 2016 to 2024 combined, five City of Ottawa beaches

Beach	Accuracy *The ability to correctly issue a "swim" or "no-swim" recommendation based on the water sampling results*	Positive predictive value (PPV) *Of all "no-swim" recommendations, what are the chances that the E. coli count did not meet standards?*	Negative predictive value (NPV) *Of all "swim" recommendations, what are the chances that the E. coli count met standards?*
Britannia	87.5%	12.2%	93.3%
Mooney's Bay	84.7%	38.8%	91.3%
Petrie East	74.3%	47.7%	82.9%
Petrie River	84.5%	36.8%	91.2%
Westboro	80.5%	28.1%	88.6%

Weekly testing

As summarized in **Table 5**, most recommendations were true positives (4.8%) or true negatives (74.1%) where the Day1 recommendation based on Day0 results correctly aligned with the Day1 through Day7 results. The majority (78.9%) of recommendations were correct based on weekly testing.

Table 5. Number of true positives, true negatives, false positives, and false negatives were sampling done once per week on Tuesdays (and reported out on Wednesdays), 2016 to 2024, five City of Ottawa beaches

Beach	Number of true positives *"No-swim" recommendation and E. coli count does not meet standards*	Number of true negatives *"Swim" recommendation and E. coli count meets standards*	Number of false positives *"No-swim" recommendation but E. coli count meets standards*	Number of false negatives *"Swim" recommendation but E. coli count does not meet standards*	Total number of days sampled (total days)
Britannia	7	494	37	34	80 (572)
Mooney's Bay	29	476	85	51	89 (641)
Petrie East	72	356	113	81	86 (622)
Petrie River	20	467	77	56	86 (620)
Westboro	9	341	26	48	59 (424)
All combined	**137 (4.8%)**	**2134 (74.1%)**	**338 (11.7%)**	**270 (9.4%)**	**400 (2879)**

Notes: Tuesday was selected as an example because results do not vary widely by day; subsequent analysis uses a median average of all days of the week.

Table 6 presents the accuracy, PPV and NPV of weekly testing calculated based on the values in **Table 5**. Values vary by beach. The overall accuracy ranged from 69.9% at Petrie East to 87.0% at Britannia beach. The NPVs are higher than the PPVs at all beaches. An "All combined" row is not included in **Table 6** because it is displayed in Table 7 using a median average rather than an arithmetic mean.

Table 6. Overall accuracy, PPV, and NPV of weekly beach water quality testing, 2016 to 2024 combined, five City of Ottawa beaches

Beach	Accuracy ***The ability to correctly issue a "swim" or "no-swim" recommendation based on the water sampling results***	Positive predictive value (PPV) ***Of all "no-swim" recommendations, what are the chances that the E. coli count did not meet standards?***	Negative predictive value (NPV) ***Of all "swim" recommendations, what are the chances that the E. coli count met standards?***
Britannia	87.0%	5.7%	92.7%
Mooney's Bay	81.0%	25.4%	89.0%
Petrie East	69.9%	38.9%	80.3%
Petrie River	78.5%	12.5%	87.8%
Westboro	77.6%	20.0%	87.4%

Note: The accuracy, PPV and NPV shown are the median averages of these values were weekly sampling carried out on each day of the week.

Daily versus weekly testing

Table 7 compares the overall accuracy, PPV and NPV of daily versus weekly samples. Overall accuracy and NPV were similar for daily and weekly testing, while the PPV was 23.4% lower for weekly testing (20.0%) than daily testing (43.4%).

Table 7. Accuracy, PPV and NPV of daily beach water quality testing, daily or weekly testing, five City of Ottawa beaches combined, and all years combined (2016 to 2024)

Frequency of sampling	Accuracy *The ability to correctly issue a "swim" or "no-swim" recommendation based on the water sampling results*	Positive predictive value (PPV) *Of all "no-swim" recommendations, what are the chances that the E. coli count did not meet standards?*	Negative predictive value (NPV) *Of all "swim" recommendations, what are the chances that the E. coli count met standards?*
Daily	80.3%	43.4%	88.0%
Weekly	78.5%	20.0%	87.8%
Absolute Difference	**1.8%**	**23.4%**	**0.2%**

Notes: The daily accuracy, PPV and NPV shown are median averages across the 5 beaches. The accuracy, PPV and NPV shown for weekly sampling are the median averages of the values calculated for each day of the week.

Table 8 shows that the absolute difference between the daily vs weekly test accuracy varies by beach, from a low of 0.5% at Britannia beach to a high of 6.0% at Petrie River beach.

Table 8. Overall accuracy of daily versus weekly beach water quality testing, 2016 to 2024 combined, five City of Ottawa beaches

Beach	Daily Test Accuracy *The ability to correctly issue a "swim" or "no-swim" recommendation based on the water sampling results taken daily*	Weekly Test Accuracy *The ability to correctly issue a "swim" or "no-swim" recommendation based on the water sampling results taken once a week*	Absolute Difference *Daily - weekly*
Britannia	87.5%	87.0%	0.5%
Mooney's Bay	84.7%	81.0%	3.7%
Petrie East	74.3%	69.9%	4.4%
Petrie River	84.5%	78.5%	6.0%
Westboro	80.5%	77.6%	2.9%

Notes: The weekly accuracy are the median averages of the values calculated for each day of the week.

Table 9 shows that the daily accuracy varies from a low of 76.7% in 2024 to a high of 87.8% in 2016, while the weekly accuracy varies from a low of 70.8% in 2024 to a high of 85.8% in 2022. The absolute difference between the daily versus weekly test accuracy is small and varies by year, from a low of -0.6% in 2019 (weekly testing was more accurate on average) to a high of 5.9% in 2024 (daily testing was more accurate on average).

Table 9. Accuracy of daily versus weekly beach water quality testing by year, 2016 to 2024, five City of Ottawa beaches combined

Year	Daily Test Accuracy *The ability to correctly issue a "swim" or "no-swim" recommendation based on the water sampling results taken daily*	Weekly Test Accuracy *The ability to correctly issue a "swim" or "no-swim" recommendation based on the water sampling results taken once a week*	Absolute Difference *Daily - weekly*
2016	87.8%	84.6%	3.1%
2017	79.9%	76.4%	3.4%
2018	86.1%	82.5%	3.6%
2019	84.3%	84.9%	-0.6%
2020	77.7%	75.0%	2.7%
2021	82.5%	77.7%	4.8%
2022	85.4%	85.8%	-0.3%
2023	78.1%	73.3%	4.9%
2024	76.7%	70.8%	5.9%

Notes: The weekly accuracy percentages are the median average of the values calculated for each day of the week.

Discussion

Accuracy, PPV, and NPV were calculated to compare weekly versus daily beach water testing at five City of Ottawa supervised beaches. The accuracy was high for both weekly testing and daily testing (78.5% vs. 80.3%, respectively), and varied by beach and year. PPV, or the chances that the *E. coli* count did not meet standards out of all "no-swim" recommendations, was low regardless of weekly or daily testing (20.0% and 43.4%). NPV, or the chances that the *E. coli* count met the standards out of all "swim" recommendations, was high for both weekly and daily testing (87.8% vs. 88.0%). Results of the comparative analysis suggest that differences between weekly and daily water testing are not meaningful.

When "no-swim" was recommended, Day0 results triggered unnecessary "no-swim" recommendations on Day1 8.8% of the time ("false positive") even with daily testing, and the PPV was low at 43.4%. When relying on weekly testing, the false positive rate increased slightly to 11.7% and the PPV dropped to 20.0%. Thus, when the Day0 test result does not meet standard at the City of Ottawa supervised beaches, it is not a good predictor of current day's water quality with either daily or weekly testing and should not be relied on exclusively when deciding to swim at a beach. Critically, with daily testing, on 8.8% of the beach-days Day0 culture results would have resulted in a "false negative" on Day1, when a "no-swim" recommendation was needed based on Day1 results not meeting the standard but was not issued. The false negatives increased to 11.4% with weekly testing. These corresponded with daily and weekly NPVs of 88.0% and 87.8%, respectively, indicating that in either scenario when the previous test result met the standard, it was a good predictor of current day's water quality. This supports the continuation of weekly testing and the promotion of assessment of other real-time indicators of water quality alongside *E. coli* results.

It is understood that the percentage of tests that do not meet the standard at each beach affects PPV and NPV[4]. When not meeting standards is more prevalent, the test is better at 'ruling in' the "no-swim" (PPV) and worse at 'ruling it out' (NPV), as can be noted in the results for Petrie East Bay which on average experiences a higher percentage (25%) of tests exceeding 200 *E. coli* per 100mL than the other beaches and also shows the highest PPV of any beach (47.7% for daily testing), while still being a relatively low PPV. Based on this understanding and the historical data summarized in the descriptive analysis, it can be concluded that Ottawa's generally high-quality beach water makes the PPV lower and NPV higher. This is true for daily or weekly testing. Canadian research has shown that the previous *E. coli* level is the most important predictor of current *E. coli* levels when modelling recreational water quality using environmental predictors[3].

Notably, other jurisdictions use different *E. coli* thresholds for safe recreational water use, though risk of enteric illness exists at any threshold. For example, the Environmental Protection Agency in the United States suggests notifying beachgoers if test values are above 235 or 190 *E. coli* per 100mL, depending on the state's preference[5]. In contrast, the European Union suggests 500 *E. coli* or lower per 100mL would be deemed excellent quality for inland waters[6]. In Ontario, prior to 2018, the threshold was 100 *E. coli* per 100mL[7]. Although the relationship between *E. coli* counts and recreational water illness (particularly skin, ear and eye infections) is sometimes weak[8,9] and can vary depending on the unique contamination sources and factors of the specific beach[3], research substantiates a dose-response with enteric illness[8]. This underscores the importance of personal mitigation of risk at all beaches.

As provincial technology evolves, we expect the provincial government might adopt qPCR testing for beach water quality. qPCR testing has been shown to be more precise, accurate, and timely than testing using *E. coli* culture which is currently being used and takes 18 to 24 hours to process[10]. However, any test is limited in reflecting the water quality in real-time as test samples are taken from a snapshot in time. We also await the results of the Canadian Beach Cohort Study, which promises to make predictive modelling tools more easily accessible through a free web app[11].

A limitation of this analysis is that we did not perform any statistical tests (e.g., Cohen's Kappa) to ascertain how much of the accuracy between the Day 0 results and the Day1 results can be explained by chance. We expect that if the water quality declines at City of Ottawa supervised beaches in future years, the accuracy of *E. coli* testing will also decline.

Climate change is expected to lead to more days with hot weather and heavy rainfall, both of which will likely increase *E. coli* and other pathogen levels at a time when beach use is likely to increase as residents and visitors to Ottawa seek ways to cool off and the Ottawa population grows[12].The launch of the City's Combined Sewage Storage Tunnel (CSST) in November 2020 has significantly reduced the frequency and amount of combined sewage overflow during heavy rainfall; however, overflow of a combination of untreated sewage and storm water into the Ottawa River does still occur[13]. Five of the six beaches are on the Ottawa river, and Petrie Island beaches are located downstream of overflow sites. Weekly testing will help monitor the climate-related impacts on our beaches, but enhanced beach monitoring might be needed in response to extreme weather events as a part of climate change preparedness.

Regardless of potential improvements in testing or modelling, it will remain important for beachgoers to the City of Ottawa's supervised beaches to consider the previous water quality results, assess the environmental factors due to the constantly changing nature

of river water, and take steps to prevent illness (e.g., avoid ingestion of water, shower and towel-dry immediately afterwards if possible, always wash hands before handling food or eating). Risk of gastrointestinal illness from recreational use of beaches may exist regardless of whether water quality standards based on *E. coli* levels are met. Studies have shown that children and youth are at higher risk of recreational water illness than adults because they spend more time in water, ingest more water while swimming, and have developing immune and digestive systems[14]. There are many physical and psychological benefits to recreating at our local beaches (e.g., cooling, exercise), and the generally high-quality of Ottawa's beach water should be promoted to encourage public access, while providing information on water quality and recreational water illness risk prevention measures.

Conclusion

From 2016 to 2024, the five City of Ottawa supervised beaches met the water quality standard 86% of the time and had an average annual mean of 151 *E. coli* or less per 100mL. Weekly testing and long-term trends at each beach can support a decision to swim owing to good accuracy and high NPV. When the last result does not meet the standard, it is especially important for beachgoers to assess real-time environmental indicators of water quality because the PPV of the last result is low. Weekly surveillance of *E. coli* levels at City of Ottawa supervised beaches will ensure trends throughout the season and between seasons can be monitored and additional beach-specific action can be taken to protect public health if needed. Ongoing engagement with partners can improve the accessibility and ease of interpretation of the available beach water quality information, and help determine what actions might be warranted should a beach consistently fail to meet the water quality standard, for example. However, risk of gastrointestinal and other illness from recreational use of beaches may exist regardless of whether water quality standards based on *E. coli* levels are met, and measures to prevent illness should be consistently promoted particularly to those at higher risk of illness, such as families with young children.

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