PUBLIC HEALTH COMMUNICATION CENTRE AOTEAROA

More wastewater testing could guide optimal Covid-19 control on the path back to elimination

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This blog briefly considers the issue of wastewater testing as part of Covid-19 control in Aotearoa NZ. Our analysis suggests that wastewater testing is much more effective in determining if a population is very likely to be Covid-19 free, when compared to typical levels of community testing. It also achieves these better results at perhaps only 1% of the cost of community testing. Even though there are large benefits in maximising the use of wastewater testing, community testing does still have a critical role to play, especially if cases are actually present.

On 26 August, ESR was reported to be testing wastewater for the pandemic virus (SARS-CoV-2) at 97 sites across the country, with this covering cities and towns with around 3.8 million New Zealanders (Prime Minister's 1pm Briefing). This testing now covers 75% of the total NZ population and over 90% of the population connected to wastewater systems. There are now a total of 28 sites in the South Island.[1] Nevertheless, not all of these sites will have daily testing – with some having weekly or twice weekly testing [Personal Communication, Dr Brent Gilpin, ESR]. Sampling methods also vary by site, with continuous sampling over 24-hour periods being the ideal.

According to the Chief Scientist at ESR, Dr Brett Cowan, wastewater testing in NZ can typically detect 5-6 people infected with SARS-CoV-2 in a population of 100,000.[2] Even higher detection sensitivity has been reported internationally, equivalent to detecting one case out of populations ranging from 29,000 to 290,000.[3] As such, wastewater can allow "for early detection of infections at three different scales (lot, suburb, and city)."[3]

Another particular advantage of wastewater testing is in terms of early detection. One review reported that SARS-CoV-2 signals in wastewater "appear 4-5 days earlier in comparison to clinical testing".[4] This is because some people never develop symptoms, are infectious before developing symptoms, there can be delays getting tested, and also delays with the testing process (especially during high demand during outbreaks).

In NZ's current outbreak situation, a potential advantage of wastewater testing may be to assist (along with high levels of community-based testing), in determining if a region is Covid-19-free to a high level of probability. This finding would then allow for that particular region to move down Alert Levels more quickly than other regions. To inform thinking about scaling up of wastewater testing (eg, to cover even more sites and to move from twice weekly to daily testing in more areas) we have made some comparisons with community testing in the table below in terms of effectiveness and cost.

Table 1: Estimated probability of detecting people with SARS-CoV-2 infection in the community with wastewater testing vs community testing in a community of 100,000 people with 15 infectious cases and with 5 continuous days of daily testing

Method	Cumulative probability of detecting any SARS-CoV-2 infections in a community of 100,000 people when there are 15 continuously infectious cases present for a continuous 5-day period	Estimated cost of testing (excluding time costs for people waiting for testing)
Wastewater testing	**Assumptions:** One test per day over 5 days. We used the estimate that 10% of the NZ population use septic tanks[5] and so are not connected to the sewerage system (so their infections can never be detected via wastewater – although this will be slightly inaccurate as some people will use such a system when visiting urban areas for work and recreation etc). Also we assumed that 20% of infected cases who have households connected to the sewerage system never excrete virus into wastewater (via faeces or respiratory secretions in the shower/washed clothing*). We note however, that this 20% figure could be too large given that the Delta variant is reported to be causing much higher viral loads than earlier variants.[6] Detection sensitivity for wastewater testing was assumed to be that advised by ESR of around 10 cases per 100,000 (when assuming this is at the 100% level, rather than the approximate 50% level for detecting 5 to 6 cases per 100,000 population). **Results:** Cumulative probability of detection of any case after 5 days = 93%. The reason for this not being 100% is substantially due to some people in homes that are not on the sewerage grid or if so, not shedding into wastewater.	**Assumption:** Cost per test is guesstimated at 10 times that of a community based PCR test** **Result:** 1 test per day for 5 days at $1380 per test = $6900
Community testing (random sampling) [Scenario A]	**Assumption:** Just random sampling and resampling at 100 tests per 100,000 population per day in the community (ie, with 0.5% of the population ultimately being tested). **Result:** Cumulative probability of detection of any case after 5 days = 7%. (At this level of testing, no detection would give a 95% confidence interval for the prevalence of infection of [0%, 0.6%] (or between 0 and 600 cases.)	**Result:** 100 tests per day for 5 days at $138 per test = $69,000
As directly above but with 10 times more testing [Scenario B]	**Assumption:** As directly above but for 1000 tests per day (ie, with 5% of the population ultimately being tested). **Result:** Cumulative probability of detection of any case after 5 days = 54%	**Result:** 1000 tests per day for 5 days at $138 per test = $690,000

Method	Cumulative probability of detecting any SARS-CoV-2 infections in a community of 100,000 people when there are 15 continuously infectious cases present for a continuous 5-day period	Estimated cost of testing (excluding time costs for people waiting for testing)
Community testing (more selective sampling) [Scenario C]	**Assumption:** Self-selection of those who go to get tested so that all the 15 infected people in the community are in the 25% of the population eligible for testing (ie, they have respiratory symptoms or have some possible association with cases in other regions). That is the 15 infected people are assumed to be just concentrated in the 25,000 of the population being sampled. **Result:** Cumulative probability of detection of any case after 5 days = 26%.	**Result:** 100 tests per day for 5 days at $138 per test = $69,000
As directly above but with 10 times more testing [Scenario D]	**Assumption:** As directly above but for 1000 tests per day (ie, with 5% of the population ultimately being tested – an extremely high level of testing for the NZ setting). **Result:** Cumulative probability of detection of any case after 5 days = 96%.	**Result:** 1000 tests per day for 5 days at $138 per test = $690,000

Notes:

* Kumblathan et al 2021[7] reports that studies have estimated that SARS-CoV-2 sheds into the faeces in 27 to 89% of infected patients. But also domestic wastewater contains bath, shower, and laundry wastewater, meaning that respiratory secretions will also be present (ie, when a person touches their face or coughs on their hands – then virus will be washed off their skin into the wastewater system when they have a shower or wash their hands). Given this background, we assumed that 80% of infected people would excrete some virus into the wastewater system on a daily basis and 20% of individuals would never excrete virus.

** A media report states that “figures released under the Official Information Act reveal it costs $75 to collect each [nasopharyngeal] swab and $63 for each test result, a total cost of $138 per test…”.[8] We used 10 times this value as a crude approximation that was supported by consultation with ESR. In reality the true marginal cost of a test is very difficult to determine since there will be economies of scale as testing is scaled up – but also for remoter locations the transport cost will disproportionately increase.

Interpretation of results

These approximate calculations in Table 1 suggest that wastewater testing is more effective and more cost-effective in determining if a population is likely to be Covid-19-free, when compared to typical levels of community testing. It gives more valuable results (eg, at

least 93% assurance of detecting a small number of cases vs 54% for community testing [Scenario B in Table 1] at only around 1% of the cost). Only when community testing is at an extremely high level (ie, 5% of the population being tested) does community testing begin to out-perform wastewater testing (ie, 96% vs 93% assurance of detecting a small number of cases [Scenario D in Table 1]). Wastewater testing can also be particularly effective in building assurance that small towns are Covid-19-free (see Appendix).

Furthermore, if wastewater testing is positive for a locality – then it can allow health authorities to focus on community testing at such a locality so as to accelerate the identification of cases (to allow for contact tracing and isolation and quarantine). Indeed, we have specifically studied the value of community testing in the NZ context[9] – although this was before wastewater testing was so well developed. Ideally, however, both forms of testing need to continue to be used extensively in NZ – but ideally with a much greater emphasis on wastewater testing.

Our analysis has used some simplifying assumptions and we hope to improve on it in the near future (eg, accounting for uncertainty in various parameters and better estimates of costs). Also of note is that the use of pooled samples for community testing would greatly lower the costs, as would probably the use of saliva testing (which would also be more acceptable to the public and speed up flows at testing centres). Furthermore, a large neglected cost is the time and travel cost for people to attend community testing (especially if wait times are increased during outbreak situations).

Limitations of wastewater testing

As noted, one limitation of wastewater testing is that it cannot detect cases who are living in homes that are not connected to sewage treatment plants (eg, septic tanks), or are connected to small systems that are not sampled. It is hard to estimate the impact of homes off the sewerage system grid since people (eg, essential workers) will often travel daily to workplaces that are on the grid.

Another limitation with wastewater testing, that has already been seen in the NZ situation, is that people who were infected cases might still excrete viral fragments for some time after becoming non-infectious. This problem of ‘false positives’ can be somewhat ameliorated by health authorities keeping track of the location of people who were cases for a couple of weeks after they leave a MIQ facility (or after they get a negative test if being managed at home). The actual total volume of viral fragments in the wastewater may also give some clues as to identifying a post-infection viral fragment shedding situation. Genomic analysis of the wastewater results can even sometimes also identify links with other cases – as recently shown with results for Warkworth.[10]

A further source of ‘false positives’ can be MIQ facilities themselves when they are housing infected people, particularly facilities dedicated to isolating infected cases, such as the Jet Park Hotel in Auckland. This problem can be managed in some cases by sampling upstream of facility, or in different parts of the network.

APPENDIX: Some relevant estimates for wastewater testing in different sized towns and cities

Table A1: Minimum number of SARS-CoV-2 cases in the community for wastewater testing to give a >95% probability of detection after 5 continuous days of testing (and as per Table 1, assuming 20% of cases shedding no viral fragments)*

Catchment population for towns and cities with wastewater testing	Minimum number of cases in the community for >95% probability of detection after 5 continuous days of testing
300	2
1000	2
3000	2
10,000	3
30,000	6
100,000	16
300,000	44

* This analysis does not account for likely variability in the wastewater systems by size eg, large cities may have the wastewater more diluted by discharges from factories. Some older systems also have stormwater mixing with the wastewater – which would also increase dilution effects. Also some towns and cities will have households on their edges that are not connected to the wastewater system grid (ie, are using septic tanks).

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References

1. Jamieson D, Louren M. Covid-19: Getting South Island to alert level 3 ‘not as simple as no positive cases’. Stuff 2021;(25 August). https://www.stuff.co.nz/national/health/coronavirus/126163186/covid19-getting-south-island-to-alert-level-3-not-as-simple-as-no-positive-cases.
2. Radio New Zealand. ESR says wastewater testing one tool in kit to detect Covid-19. Radio New Zealand 2021;(20 August). https://www.rnz.co.nz/news/national/449602/esr-says-wastewater-testing-one-tool-in-kit-to-detect-covid-19.
3. Schang C, Crosbie ND, Nolan M, Poon R, Wang M, Jex A, John N, Baker L, Scales P, Schmidt J, Thorley BR, Hill K, Zamyadi A, Tseng CW, Henry R, Kolotelo P, Langeveld J, Schilperoort R, Shi B, Einsiedel S, Thomas M, Black J, Wilson S, McCarthy DT. Passive Sampling of SARS-CoV-2 for Wastewater Surveillance. *Environmental science & technology* 2021;55:10432-41.
4. Morvan M, Jacomo A, Souque C, Wade M, Hoffmann T, Pouwels K, Singer A, Bunce J, Engeli A, Grimsley J, O’Reilly K, Danon L. Estimating SARS-CoV-2 prevalence from large-scale wastewater surveillance: insights from combined analysis of 44 sites in England. Report. (Undated). https://assets.researchsquare.com/files/rs-770963/v1_covered.pdf?c=1627928008.
5. BECA GHD Boffa Miskell. The New Zealand Wastewater Sector. Report Prepared for the Ministry of the Environment. October 2020.

https://www.orc.govt.nz/managing-our-environment/waste-and-hazardous-substances/septic-tanks.
6. Reardon S. How the Delta variant achieves its ultrafast spread. Nature 2021;(21 July). https://www.nature.com/articles/d41586-021-01986-w.
7. Kumblathan T, Liu Y, Uppal G, Hrudey S, Li X-F. Wastewater-Based Epidemiology for Community Monitoring of SARS-CoV-2: Progress and Challenges. ACS Environmental 2021; https://doi.org/10.1021/acsenvironau.1c00015.
8. Fonseka D. Slow saliva testing roll-out hurting New Zealand's ability to get on top of outbreak: Scientist. Stuff 2021;(24 August). https://www.stuff.co.nz/business/126151636/slow-saliva-testing-rollout-hurting-new-zealands-ability-to-get-on-top-of-outbreak-scientist.
9. Wilson N, Schwehm M, Verrall AJ, Parry M, Baker MG, Eichner M. Detecting the re-emergent COVID-19 pandemic after elimination: modelling study of combined primary care and hospital surveillance. *N Z Med J* 2020;133:28-39.
10. Ministry of Health. 62 additional community cases of COVID-19; one new case in managed isolation facilities; record 80,000 vaccinations yesterday. (Media release). Ministry of Health 2021;(25 August). https://www.health.govt.nz/news-media/media-releases/62-additional-community-cases-covid-19-one-new-case-managed-isolation-facilities-record-80000.

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