ON-SITE WASTEWATER SYSTEMS – RISKS AND INSIGHTS INTO THEIR FUNCTION

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ABSTRACT

On-site wastewater management systems (OWMS) release chemical and microbial contaminants into the environment, potentially posing risks to surface water, groundwater, and human health. Although OWMS effluent quality has been characterised internationally, in Aotearoa (New Zealand), the chemical and microbial quality of effluent is poorly characterised. Thus, water regulators and engineers for OWMS manufacturers typically rely on international data to inform policy and estimate risks to receiving environments and human health. However, international data is unrepresentative of the OWMS designs typically present in Aotearoa and therefore may differ in treatment capacities and discharge quality. To address this knowledge gap, we present effluent quality data from three sources sampled within Waitaha/Canterbury:

- Long-term field-scale OWMS research site in North Canterbury
- Composite samples (taken across 4-5 days) from a primary and secondary treatment OWMS
- 30 discrete samples from a mix of primary and secondary treatment OWMS across Canterbury

Results from the 30 OWMS discrete sample locations include *Escherichia. coli* (*E. coli*) concentrations that ranged between 5.4 x 10^3 and 2.4 x10^7 MPN/100mL for primary treatment systems and between 2 x10^2 and 9.8 x10^6 MPN/100mL for secondary treatment systems. The mean *E. coli* results for primary and secondary treatment systems were 2.9 x10^6 and 8 x10^5, respectively. Total phosphorous concentrations ranged from 7 – 91 mg/L and 2 – 20 mg/L for primary and secondary treatment systems, respectively. Mean total phosphorous concentrations for primary and secondary treatment systems were 17 and 12 mg/L, respectively. Total Kjeldahl Nitrogen (TKN) concentrations ranged from 35 – 300 mg/L and 2 – 98 mg/L for primary and secondary treatment systems, respectively. The mean TKN concentrations for primary and secondary treatment systems were 98 and 23 mg/L, respectively.

This OWMS effluent quality data contributes to the understanding of the composition of effluent entering the receiving environment. The composition of this discharge from OWMS in Aotearoa is relatively unresearched in a New Zealand context, therefore, this research provides critical information to decision-makers concerned with the impact of OWMS on water quality. Additional insights can be achieved by coupling chemical and microbial loading rates with OWMS location

information to estimate the significance of the contaminant contribution to the environment to direct policy, estimate impacts on catchment and regional scales, and inform wastewater infrastructure decisions.

KEYWORDS

On-site wastewater, chemical and microbial contaminants, risks

PRESENTER PROFILE

For the past 12 years, Bronwyn Humphries has worked for ESR as a research scientist. Her research focuses on the fate and transport of chemical and microbiological contaminants within groundwater and the implications for human and environmental health.

INTRODUCTION

Centralised and reticulated wastewater services (i.e., municipal wastewater treatment plants) serve approximately 75% of New Zealand's population (GHD, 2020). The remaining population (~1.25 million people), primarily in rural and peri-urban areas, dispose of wastewater via on-site wastewater management systems (OWMS).

OWMS primarily serve individual homes but are also used by schools, marae, and farming facilities. Well-functioning OWMS can provide a high degree of domestic waste treatment (Robertson et al., 2019), yet, in areas with high densities of even well-functioning OWMS, the release of contaminants could pose risks to receiving waters (Pang et al., 2006). However, the greatest environmental and public health risks are associated with inadequate treatment, typically relating to unsuitable land application systems, or when the OWMS is ageing, improperly serviced, or not regularly maintained (Rakhimbekova et al., 2021; Spoelstra et al., 2020; Yang et al., 2017). Many OWMS users may be unaware that the system requires careful management to ensure it remains healthy and well-functioning. For example, some common household products (e.g., bleach, antimicrobial cleaning products) can alter microbiological activity within the system, negatively impacting its treatment efficiency (Chen & Roberts, 2021; MfE, 2008). In addition, maintenance checks on OWMS are required to ensure the systems are functioning adequately. Maintenance checks involve filter cleaning, pump maintenance and the removal of solid waste by a wastewater removal company approximately every 3 years (Chen & Roberts, 2021; MfE, 2008). However, the maintenance of OWMS is not regulated in many parts of Aotearoa (including Canterbury), therefore, some systems are likely to be improperly maintained.

METHODS

On-site wastewater effluent samples were collected from three sources in Canterbury from December 2022 to June 2023:

- Field-scale OWMS research site
- Composite samples (taken across 4 days) from a primary and secondary treatment OWMS
- 30 discrete samples from a mix of primary (17) and secondary (13) treatment OWMS

The on-site wastewater samples were analysed for 28 analytes (Table 1).

Table 1: List of 28 analytes used in the on-site wastewater effluent analysis.

Analyte	Unit
Total Coliforms	MPN/100mL
E. coli	MPN/100mL
pH	pH units
Total Alkalinity	mg/L as $CaCO_3$
Electrical Conductivity	mS/m
Total Suspended Solids	mg/L
Total Dissolved Solids	mg/L
Dissolved Barium	mg/L
Dissolved Boron	mg/L
Dissolved Calcium	mg/L
Dissolved iron	mg/L
Dissolved Magnesium	mg/L
Dissolved Manganese	mg/L
Dissolved Potassium	mg/L
Dissolved Sodium	mg/L
Dissolved Zinc	mg/L
Chloride	mg/L
Total Ammoniacal-N	mg/L
Nitrite-N	mg/L
Nitrate-N	mg/L
Nitrate-N + Nitrite-N	mg/L
Total Kjeldahl Nitrogen	mg/L
Dissolved Reactive Phosphorus (trace)	mg/L
Phosphate from DRP	mg/L
Total Phosphorus	mg/L
Total Biochemical Oxygen Demand (TBOD)	g O_2/m^3
Dissolved Non-Purgeable Organic Carbon (DNPOC)	mg/L
Non-Purgeable Organic Carbon (NPOC)	mg/L

RESULTS AND DISCUSSION

Results from the 30 OWMS discrete sample locations include *E. coli* concentrations that ranged between 5.4 x 10^3 and 2.4 x10^7 MPN/100mL for primary treatment systems and between 2 x10^2 and 9.8 x10^6 MPN/100mL for secondary treatment systems (Figure 1). The mean *E. coli* results for primary and secondary treatment systems were 2.9 x10^6 and 8 x10^5 respectively. There was no statistically significant difference between primary and secondary treatment systems for the *E. coli* concentrations encountered.

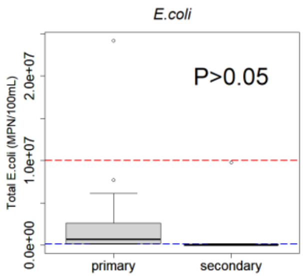

Figure 1: E. coli concentrations for primary (range: 5.4 x 10^3 and 2.4 x10^7 MPN/100mL) *and secondary (*2 x10^2 and 9.8 x10^6 MPN/100mL) *on-site wastewater treatment systems.*

Total phosphorous concentrations ranged from 7 – 91 mg/L and 2 – 20 mg/L for primary and secondary treatment systems respectively (Figure 2). Mean total phosphorous concentrations for primary and secondary treatment systems were 17 and 12 mg/L respectively. There was no statistically significant difference between primary and secondary treatment systems for total phosphorus concentrations.

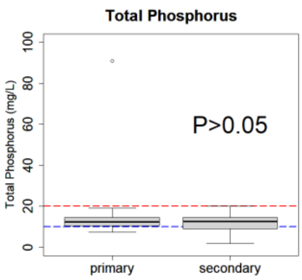

Figure 2: Total Phosphorus concentrations for primary (range: 7 – 91 mg/L) *and secondary (*2 – 20 mg/L) *on-site wastewater treatment systems.*

The Nitrate-N concentrations ranged from <0.02 – 20 and <0.02 – 98 mg/L for primary and secondary treatment systems respectively (Figure 3). The Total Ammoniacal-N concentrations ranged from 36 – 250 and 0.08 – 102 mg/L for primary and secondary treatment systems respectively. Total Kjeldahl Nitrogen (TKN) concentrations ranged from 35 – 300 mg/L and 2 – 98 mg/L for primary and secondary treatment systems respectively. The Total Nitrogen concentrations ranged from 35 – 302 and 8.7 – 123 mg/L for primary and secondary treatment systems respectively.

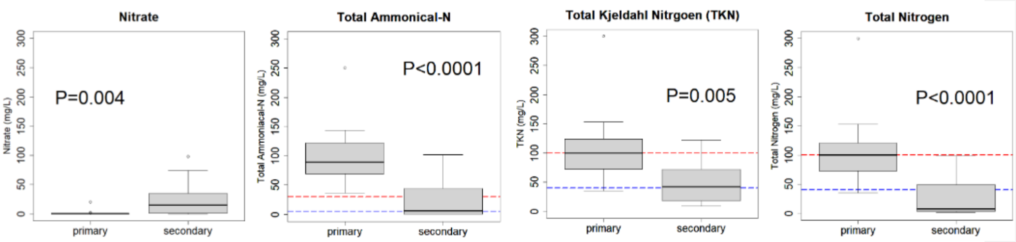

Figure 3: Concentration ranges for primary and secondary treatment systems respectively: Nitrate-N (<0.02 – 20 mg/L and <0.02 – 98 mg/L), Total Ammoniacal-N (36 – 250 mg/L and 0.08 – 102 mg/L), Total Kjeldahl Nitrogen (35 – 300 mg/L and 2 – 98 mg/L) and Total Nitrogen (35 – 302 mg/L and 8.7 – 123 mg/L).

The *E. coli* and Total Phosphorus results fall within the expected ranges for primary and secondary treatment systems. The results for the various nitrogen species agreed with the current literature also (Robertson, 2021) in that effluent from the primary systems contained higher concentrations of Total Kjeldahl Nitrogen (mean 104 mg/L), Total Ammoniacal-N (mean 99 mg/L) and Total Nitrogen (mean 106 mg/L) compared with secondary systems (mean concentrations of 27 mg/L, 22 mg/L, and 52 mg/L, respectively). Ammonium (NH_4^+) is the largest proportion of nitrogen in effluent from primary systems. However, when ammonium-rich effluent enters the vadose zone or oxic aquifers, such as those in Canterbury, the ammonium is likely to be nitrified to nitrate.

Although the mean Total Nitrogen concentration in primary effluent was twice the value of secondary effluent, nitrate concentrations were much higher in secondary systems (mean 29 mg/L) compared to primary systems (mean 1.5 mg/L). Higher nitrate concentrations are expected in secondary systems, as dissolved and particulate organic matter are removed in the first chamber, and a secondary aeration chamber promotes nitrification of Ammoniacal-N (Gill et al., 2009, Richards et.al, 2017). Thus, although nitrate concentrations were higher in secondary effluent, the lower Total Nitrogen concentrations in secondary effluent showed better treatment performance compared to primary systems.

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CONCLUSIONS

There is value in characterising OWMS effluent quality for a New Zealand context in that it provides evidence to support a targeted response by regional councils and central government. While the results show that there is no significant difference between primary and secondary OWMS effluent for *E. coli* and Total Phosphorus, the results for the various nitrogen species confirm that greater treatment of nitrogen is achieved by secondary treatment. This research highlights the potential to target the performance, operation and maintenance of primary systems as a priority alongside highlighting the need to explore modifications and upgrading of primary OWMS throughout New Zealand.

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