BEFORE THE TASMAN DISTRICT COUNCIL

Under	the Resource Management Act 1991
In the matter of	of an application by **THE NELSON REGIONAL SEWERAGE BUSINESS UNIT** for the resource consents to continue applying biosolids to land on Moturoa / Rabbit Island.

STATEMENT OF EVIDENCE OF NEALE ALAN HUDSON

FOR THE NELSON REGIONAL SEWERAGE BUSINESS UNIT

11 MAY 2022

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STATEMENT OF EVIDENCE OF NEALE ALAN HUDSON

Introduction

1 My full name is Neale Alan Hudson. I am an Environmental Chemist at the National Institute of Water and Atmospheric Research Limited, where I currently hold the position Manager – Freshwater.

2 I have a PhD in Environmental Chemistry from Queensland University of Technology, and more than 20 years' experience in the areas of emission processes, waste management, environmental management, water quality, and assessments of environmental effects, including health risk assessments.

3 I was engaged to assess the human health risk associated with the application of treated biosolids from the Bell Island wastewater treatment plant (**WWTP**) to land at Moturoa /Rabbit Island. The outcomes of that assessment were summarised in a technical report – "Moturoa/Rabbit Island: Application of biosolids to land" (Hudson 2020) which accompanied the application submitted to the Tasman District Council in August 2020. The assessment of health risks considered potential:

3.1 local effects arising from exposure to potentially pathogenic microbes through inhalation of aerosols and contact with runoff from biosolids applied to land at Moturoa/Rabbit Island; and

3.2 health risks to recreational water users on beaches on Moturoa/Rabbit Island, as well as at beaches in the Waimea Inlet and southern Tasman Bay.

4 Previous involvement with the assessment of human health risk effects arising from discharge of treated wastewater from the Bell Island WWTP (McBride 2017), and an assessment of health risk effects related to aberrational discharges from the sewer network that conveys untreated sewage to the Bell Island WWTP (Hudson and McBride 2017; Hudson and Wadhwa 2017) provided valuable background knowledge regarding the sources and fates of pathogens in the southern Tasman Bay, and resulting health risks.

5 While this is a Council-level hearing, I acknowledge that I have read and am familiar with the Code of Conduct for Expert Witnesses contained in the Environment Court Practice Note 2014, and that I agree to comply with it. I confirm that this evidence is within my area of expertise, except where I state that this evidence is given in reliance on another person's evidence. I have considered all material facts that are known to me that might alter or detract from the opinions I express in this evidence.

Scope of Evidence

6 In my evidence I will outline the following:

6.1 An assessment of measured pathogen concentrations in treated biosolids, including comparison of measured concentrations within the NZWWA "Guidelines for the safe application of biosolids to land in New Zealand 2003" (NZWWA 2003) (**the NZ Biosolids Guidelines**).

6.2 The health risk assessment process.

6.3 Use of recreational water quality monitoring results to assess risks to water users at more distant locations.

6.4 Potential health risks associated with inhalation of airborne contaminants.

6.5 Potential health risks arising from exposure to groundwater.

6.6 Comments on Council Officer's Report.

6.7 Summary.

Treatment of biosolids and effect on microbial contaminants

Autothermal Thermophilic Aerobic Digestion

7 Treatment of wastewater at the Bell Island WWTP utilises an Autothermal Thermophilic Aerobic Digestion (**ATAD**) process. This involves heating and maintaining the sludge generated in the wastewater treatment process in a series of tanks at between 50 and 65 °C for approximately 19 days.

8 Although these conditions do not constitute pasteurisation in the sense used in the NZ Biosolids Guidelines, which specifies heating the sludge to a temperature of 70–80 °C for approximately 30 minutes, the earlier technical report (Berry 2020) and evidence of Dr Berry (Berry 2022) indicates that the resulting biosolids are considered to meet the requirements for Grade Ab biosolids stabilisation.

9 The prolonged resident time that biosolids are held in the ATAD tanks produces biosolids of a reasonably uniform composition – this is evident from the reasonably consistent concentrations of several pathogens and indicator bacteria over time.

Microbial contaminant concentrations in biosolids

10 Samples of biosolids derived from the ATAD process are routinely submitted for laboratory analysis to determine the concentrations of several pathogens and indicator bacteria. Available results of analysis are summarised in Table 1 below.

Table 1: Compliance with microbial guideline values. Data were available for the period November 2014 through November 2021 inclusive.

From Table 4.1 (NZWWA 2003). Rows shaded blue indicate additional pathogens for which guideline values do not exist. "N/S" indicates not sampled, "N/A" indicates not applicable. "Unknown" indicates compliance cannot be estimated because the analytical method is insufficiently sensitive.

Microbial contaminant	Guideline concentration	No. compliant samples	Proportion of compliant samples
E. coli	<100 MPN/g	22/24	92%
Campylobacter	<1/25 g (<0.04/g)	N/S	N/S
Salmonella	<1/25 g (<0.04/g)	0/24	0
Enteric viruses	<1 pfu/4 g	24/24	100%
Helminth ova	<1/4 g	16/24	67%
Adeno viruses	N/A	–	–
Faecal coliforms	N/A	–	–
Total coliforms	N/A	–	–
Confirmed *Cryptosporidium*	N/A	–	–
Confirmed *Giardia*	N/A	–	–

11 These results indicate full compliance with microbial guideline values for enteric viruses, and high level of compliance (92%) with the *E. coli* guideline value.

12 Approximately two-thirds of samples comply with the helminth ova guideline value.

12.1 Enumeration of helminth ova is a multistep process requiring extraction and concentration of eggs from a slurry of sludge, followed by microscopic enumeration.

12.2 This method is acknowledged to provide variable results, which in turn has spurred investigation of molecular methods (Rocha et al. 2016; Amoah et al. 2017). Jaromin-Gleń et al. (2017) highlight the importance of determining the efficiency of egg recovery in order to reduce the variability in quantification of oocysts.

12.3 I have confirmed with the laboratory service provider that recovery tests are not undertaken for helminth ova tests.[1] The recovery tests allow results to be normalised and reduce variability associated with the efficiency of the extraction, concentration and visual inspection process to be accounted for. Absence of this "normalisation"

[1] Email from Marina, Team Leader Microbiology, Watercare Services Limited laboratory, Auckland. Tuesday, 10 May 2022 09:07. "***Helminth**: We prep the sample using graduated pore size sieves and then centrifuge the rinsate to concentrate the sample, use density gradients to isolate helminth from other debris and then examine via microscopy. The recovery efficiency is not included in the analysis.*"

procedure does not make the tests ineffective but increases the likelihood that results will be variable over time, as is evident.

13 Samples are not analysed for *Campylobacter* concentrations (as this is not a requirement of the existing consent conditions), and the detection limit of the test used for *Salmonella* analysis is insufficiently sensitive to measure compliance with the relevant guideline value.

14 Results for several microbial contaminants are summarised graphically in Figure 3 through Figure 6. Concentrations tend to be consistent over time, with relatively infrequent elevated values. These results indicate that the ATAD process produces biosolids with consistent microbial characteristics, i.e., relatively constant means that health risk potential may be understood over time. Although the concentrations of helminth ova, and protozoan contaminants - cryptosporidium and Giardia, appear to vary more than other microbial contaminants, as noted in paragraph 12 (including the footnote), the nature of the test procedure is likely to provide variable results. However, there is little evidence of a trend over time across helminths, Giardia or cryptosporidium, suggesting the ATAD treatment process is able to consistently reduce the numbers of these species and oocysts.

15 During 2021 a series of samples were collected from the inflow to the ATAD system, as well as from the outflow from each of the three treatment units. These samples were analysed for six representative microbial indicator organisms. The results of these analyses are included in Figure 4, and are summarised separately in Figure 7. These results indicate consistent pathogen removal over time – at least 80-fold and 4,000-fold reduction in concentrations of adenovirus and enterovirus respectively, between 5 and 7 $\log_{10}$ reduction in faecal indicator bacteria (i.e., from 100,000 to 10,000,000 times reduction), and at least ten-fold reduction in *Salmonella* concentrations.

15.1 I recommended the above sampling in my 2020 technical report (as a discrete survey) to provide clarification of the effectiveness of the ATAD process. It is pleasing to see that the NRSBU adopted this work programme, which has confirmed consistent performance over a representative period of time.

16 The biosolids treatment process appears to reduce concentrations of four of the five microbial test species sufficiently to meet the NZ Biosolids Guidelines (all except salmonella).

17 The limit of quantification of the *Salmonella* test currently used is inadequate to demonstrate compliance with the guideline value for Grade A biosolids - the detection limit for the method has varied over time from 0.38 MPN/g to 0.52 MPN/g. As a result, of the 37 samples available, 32 are reported as “less than detection limit”. The detection limits are all approximately an order of magnitude greater than the Biosolids Guideline value (0.04 MPN/g). None of the samples were compliant with the standard.

17.1 It would be advisable for NRSBU to seek guidance about use of alternate methods of analysis. Lower detection limits have been achieved, e.g., Krzyzanowski et al. (2014), reported values from 0.006 MPN/g total solids (the detection limit) to 12 MPN/g total solids, using an EPA method (EPA 2006).

17.2 However, the reported EPA method has a nominal detection limit of 0.0067 MPN/mL, which translates to a detection limit of 0.28 MPN/4 g, or 0.07 MPN/g, which is approximately 40% larger than the Biosolids Guideline value.

17.3 Although it was not clear from the work of Krzyzanowski et al. (2014) how they modified the basic EPA method to achieve the lower detection limit, further investigation by a suitable laboratory may demonstrate how the required detection limit may be achieved.

The risk assessment process

18 Risk assessment is a widely applied process. In the case of human health risks arising from exposure to microbial contaminants, it is necessary to consider the relationship between a **hazard** (anything with potential to cause harm) and the **probability** that someone may be harmed by the hazard.

19 Assessment of risk is expanded to include other factors, for example: **risk** = **chance** + **hazard** + **exposure** + **consequence** One definition defines risk as "*the likelihood of identified hazards causing harm in exposed populations in a specified time frame, including the severity of the consequences*".[2]

20 In a circumstance where discharge of treated wastewater to water occurs, such as for the Bell Island WWTP, the discharge is immediate, and the flux of contaminants (number of pathogens per unit time) may be estimated directly, and the fate of contaminants predicted using a calibrated hydrodynamic model.

20.1 Health risks were estimated for the Bell Island WWTP using a Quantitative Microbial Risk Assessment (**QMRA**) process, which accounts for the likely ranges of pathogen concentrations, the dilution and advection of pathogens discharged to the ocean, from which the concentration of pathogens in waters to which recreational users are exposed may be estimated. The QMRA also considers the duration of exposure (e.g., a range of "swimming time" values), the volume of highly diluted treated wastewater that is likely to be ingested (e.g., a range "swallowed seawater" estimates), for typical adult or child recreational users.

20.2 QMRA is a probabilistic modelling process that represents many tens of thousands of "circumstances" (e.g., bathing events) during which many individuals might be at the

[2] E.g., http://qmrawiki.canr.msu.edu/index.php/Quantitative_Microbial_Risk_Assessment and https://en.wikipedia.org/wiki/Risk#Risk_assessment

beach. The process generates tables of Individual Illness Risks (**IILLR**) for that might apply to any individual involved in a particular form of recreation at a specified location on any day who is exposed to wastewater subject to a defined level of treatment. These risks are expressed in terms that indicate the proportion of individuals who might get ill, e.g., "the risk of gastrointestinal illness (IILLR) would be below 1% (less than 1 case per 100 people) for 95% of exposures when the level of treatment reduced the concentration of pathogens 10,000 times".

20.3 In the situation where materials containing pathogens are applied to land, it is difficult to directly assess risk because the **chance** and **exposure** components are difficult to quantify. For example,

20.3.1 The mechanisms whereby residual pathogens in treated biosolids that are applied to land and subsequently enter water are largely determined by antecedent soil conditions (principally soil moisture), rainfall intensity and total depth of rainfall in an event, and surface water runoff (**runoff**) duration and volume. All these factors are variable over time, and with the exception of rainfall, are currently not measured.

20.3.2 The concentration of pathogens in runoff have not been measured, and no information exists regarding the likely volume of runoff during any event, or where potentially contaminated runoff may be discharged to the coastal marine environment. Consequently, it is impossible to estimate the numbers of pathogens per unit time that enter coastal waters, where exposure to receptors during recreation could potentially occur.

20.4 The limited information available regarding the fate of biosolids (and constituent materials) makes direct estimation of risk impossible, and it is necessary to undertake an indirect assessment of health risk, using information collected for other purposes.

Estimating risk using recreational water quality monitoring data

21 Coastal recreational water quality is assessed by Tasman District Council and Nelson City Council during the summer bathing period according to the New Zealand Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas (MfE/MoH 2003).

22 Samples are collected weekly and analysed to determine the concentration of enterococci, one of several potential faecal indicator bacteria (**FIB**). Monitoring recreational water quality generally relies on use of FIB – enterococci is favoured in saline waters. Sample results are graded using a traffic light system, and when an upper concentration threshold is exceeded, additional samples are collected. In the event of persistent contamination, a beach may be closed, warning signs erected, and investigation initiated to determine the source of contamination.

23 Several sites are monitored in South Tasman Bay which are relevant to the disposal of treated biosolids to Moturoa/Rabbit Island. The locations of these sites are indicated in Figure 1. This figure also indicates the direction of the plume of treated wastewater arising from the Bell Island WWTP and sites of several monitored freshwater inflows to the Waimea Inlet.

23.1 This is relevant because the movement of contaminants is generally from west to east, driven by large-scale forcing factors (principally winds and currents).

23.2 The predicted plume direction also indicates that shoreline concentrations of FIB along the south Tasman Bay beaches are most likely to be impacted by the Bell Island discharge.

23.3 Multiple river and stream inflows may impact the microbiological water quality of the Waimea Inlet. This is important as it allows the relative effects of the biosolids activity to be considered within the context of FIB contamination arising from non-wastewater sources.

24 The results from the five most recent recreation seasons for which data were available are summarised in Figure 2. Each bar represents the 95th percentile concentration for the recreation period, (generally derived from approximately 20 samples collected at weekly frequency over the season). These data indicate:

24.1 Generally good recreational water quality exists at these representative sites in the Nelson/Tasman region.

24.2 Recreational water quality is best at the Rabbit Island Main Beach site, and health risks to recreational users has been below the no-observed-adverse-effect level (**NOAEL**) which denotes “the level of exposure of an organism, found by experiment or observation, at which there is no biologically or statistically significant increase in the frequency or severity of any adverse effects of the tested protocol” (Wikipedia 2022).

24.3 When water quality was poorest at the Rabbit Island Main Beach site (2017/18 season), recreational water quality was poor at all sites, suggesting that large scale or regional factors were responsible.

25 Although recreational water quality data were not collected as part of a programme intended to specifically assess the effects of applying biosolids to Moturoa/Rabbit Island, these data do not suggest that treated biosolids exert an adverse effect on shoreline concentrations of enterococci, and therefore does not increase human health risks to recreational users locally or further afield.

Health risks associated with inhalation of airborne microbial contaminants

26 Hudson (2020) described the biosolids applied to the forest as having a low solids content (typically 4%), amenable to application using relatively low-pressure nozzles that produced a coarse spray.

26.1 Although the discharge pressure is sufficient to allow the biosolids to travel up to approximately 20 m, and the application method is not considered capable of generating a substantial proportion of aerosols (addressed in the evidence of Mr Clarke), the formation of aerosols cannot be eliminated.

26.2 Formation of a substantial proportion of aerosols is necessary to increase the risk of illness to human receptors: aerosols are able to travel further than coarse droplets under the influence of prevailing winds, and the size of aerosols allow them (and associated microbial contaminants) to enter the respiratory tract, where infection may occur.

27 The exposure of human receptors to aerosols (and associated microbial contaminants) is mitigated by several factors:

27.1 Areas to which biosolids are applied are closed to the public by use of buffer zones and physical barriers, and signage is erected to discourage recreational use of these areas.

27.2 Buffer zones contain tree shelter belts. These form porous barriers that reduce the velocity of the prevailing wind, impede transport of droplets and aerosols through the vegetation by creating tortuous flow paths. The high surface area of the vegetative barrier increases the likelihood that a droplet or aerosol will impinge on a surface. Vegetative barriers produce volatile organic compounds that include oils and other “sticky” compounds that encourage trapping or adsorption of particles such as dust and aerosols.

27.3 The evidence of Mr Heveldt (Heveldt 2020) noted that removal of vegetative buffers may increase odour impact. This view is supported in the evidence of Dr Bender, who notes that turbulence created by forested application areas will dilute odorous air and reduce odour impacts. The same factors are likely to reduce the concentrations of pathogens downwind of disposal areas.

28 The Best Management Practices for applying biosolids to forest plantations in New Zealand (Scion 2010) recommend several practices likely to reduce human health risk, including:

28.1 ensuring adequate physical separation exists between application areas and receptors;

28.2 adequate disinfection of biosolids prior to disposal;

28.3 use of equipment that minimises aerosol formation;

28.4 avoiding application of biosolids when conditions are excessively windy; and

28.5 maintaining adequate buffers, using vegetation to reduce the potential for transport of aerosols.

29 Dr Bender supports these practices, noting “the primary mitigation of adverse odour effects remains the large separation distance from the biosolids spraying areas to the sensitive residential areas”.

30 It is my opinion that the method of application of biosolids, coupled with adherence to practices recommended in appropriate guidelines is likely to reduce risks to public health to less than minor.

Health risks arising from exposure to groundwater

31 The hydrogeology of Moturoa/Rabbit Island was described by Tonkin & Taylor (2020). Using groundwater level data from monitoring wells and interpolation procedures, a groundwater gradient was defined that suggests that contaminants applied to the soil surface are likely to move in a northeast to southwest direction, should they enter the groundwater.

32 Although no information is available regarding concentrations of pathogens or FIB[3] in groundwater underlying the disposal areas, in my opinion these concentrations are likely to be low:

32.1 Biosolids operational data indicates that pathogens and FIB occur in low to moderate concentrations in biosolids applied to land.

32.2 Several processes are likely to further reduce concentrations of pathogens following application to land, including: interception of materials on vegetation and soil surfaces, prompting inactivation after desiccation or following exposure to solar UV radiation, adsorption to soil organic material, or minerals within the soil profile.

32.3 Hydrogeological assessment indicates that groundwater tends to move in a northeast to southwest direction. As detailed above, indicate that all sources of FIB appear to have less than minor effect on shoreline FIB at the Moturoa/Rabbit Island Main Beach site, and less than minor to minor effect at Moturoa/Rabbit Island Back Beach site.

32.4 I conclude that residual FIB and pathogens in shallow groundwater pose negligible risk of illness to recreational water users on Moturoa/Rabbit Island or further afield.

[3] I note that the NRSBU proposed consent conditions include a requirement at [27(a)] to take three-monthly representative samples from at least two piezometers for FIB.

Council Officer's Report

33 In preparing my evidence I have reviewed the Council Officer's s42A Report which briefly discusses 'Public health' at paragraphs 7.29 and 7.30.

33.1 In my opinion the treatment process reduces the health risk associated with land disposal of biosolids substantially, but I do not consider that the risk is "eliminated". There will always be the potential for risk, but consider the risk is less than minor.

33.2 Maintaining a low level of risk depends on consistent biosolids treatment, applying well-treated biosolids to areas from which the public are excluded, and minimising aerosol production.

33.3 Maintaining an effective forested screen at all times, and minimising land application during windy periods will also minimise risk.

33.4 Although odour may be objectionable, and may cause annoyance, these effects are largely due to psychosocial factors, which will affect some members of a community more than others. I do not consider these factors pose an illness risk.

33.5 At paragraphs 7.102 – 7.104 the Council Officer discusses the importance of monitoring and reporting. I agree that monitoring is critical in ensuring that the NRSBU continues to produce Grade Ab biosolids to minimise adverse effects, including those to public health. I have identified that investigation of methods available for determination of salmonella concentrations in biosolids are warranted. Although the existing method indicates that the treatment process delivers consistent concentrations of salmonella in biosolids applied to land, the inability to determine compliance with Biosolids Guideline values means that the risk associated with residual concentrations of salmonella cannot be quantified at this time.

Comments on Submissions

34 I have reviewed the submissions received on the application. None of the submissions raised health risks associated with land disposal of biosolids as an issue of concern.

Summary

35 I consider the land disposal of biosolids to forested areas of Moturoa/Rabbit Island a pragmatic aspect of management of a potentially hazardous by product of the wastewater treatment process.

36 The ATAD process is well-run, producing biosolids with consistent characteristics, including concentrations of pathogens and faecal indicator bacteria that are largely consistent over time.

37 Application of the biosolids to land in forest using moderate pressure sprays, to areas where public access is minimised, signage is erected, and buffer zones are maintained, minimises exposure of humans to air-borne contaminants, including pathogens.

38 Hydrogeological assessment has not identified that pathogens are entering the shallow groundwater, evidenced by low concentrations of FIB such as *E. coli* or enterococci. FIB are present in higher concentrations in the treated biosolids than pathogens, so I conclude that concentrations of pathogens in shallow groundwater are likely to be negligible.

39 Shoreline concentrations of FIB (enterococci) on Moturoa/Rabbit Island are consistently lowest of those measured across southern Tasman Bay, indicating that the application of well-treated biosolids to land is not having a deleterious effect on recreational water quality, and constitutes negligible risk to recreational water users.

40 Ensuring health risks to recreational water users and public health risk on Moturoa/Rabbit Island is less than minor requires consistent treatment of biosolids to a high standard. The NRSBU is advised to identify laboratory service providers who are able to quantify salmonella at concentrations able to demonstrate compliance with the NZ Biosolids Guidelines.

Neale Hudson
11 May 2022

Amoah, et al. (2017) Detection and quantification of soil-transmitted helminths in environmental samples: A review of current state-of-the-art and future perspectives. *Acta Tropica*, 169: 187-201. https://doi.org/10.1016/j.actatropica.2017.02.014.

Berry (2020) Moturoa / Rabbit Island Consent Application - Biosolids Process Alternatives Assessment. Prepared for Nelson Regional Sewerage Business Unit (NRSBU) by Beca Limited3257053-355743471-17, 37 pp.

Berry (2022) Statement of evidence of NICHOLAS DAVID BERRY for Nelson Regional Sewerage Business Unit (NRSBU) by Beca Limited: 17.

EPA (2006) Salmonella in Sewage Sludge (Biosolids) Modified Semisolid Rappaport-Vassiliadis (MSRV).EPA-821-R-06-14pp.

Heveldt (2020) Discharges to Air from Moturoa /Rabbit Island Biosolids Disposal. Draft report preared for NRSBUIn prep.pp.

Hudson (2020) Moturoa/Rabbit Island: Application of biosolids to land: Appendix J: Public health risks. NIWA client report repared for Nelson Regional Sewerage Business Unit2020113HN, 41 pp.

Hudson, McBride (2017) Quantitative Microbial Risk Assessment for Waimea Inlet, Nelson: Sewer pump station overflows. Prepared for Nelson City Council. October 20172017348HN, 76 pp.

Hudson, Wadhwa (2017) Quantitative microbial risk assessment for Waimea Inlet, Nelson. Spatial assessment of risk2017348HN, 79 pp.

Jaromin-Gleń, et al. (2017) Division of methods for counting helminths' eggs and the problem of efficiency of these methods. *Annals of Agricultural and Environmental Medicine*, 24(1): 1-7. 10.5604/12321966.1233891.

Krzyzanowski, et al. (2014) Quantification and characterization of Salmonella spp. isolates in sewage sludge with potential usage in agriculture. *BMC microbiology*, 14: 263-263. 10.1186/s12866-014-0263-x.

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Scion (2010) Best management guidelines for applying biosolids to forest plantations in New Zealand45869, 42 pp.

Tonkin & Taylor (2020) Moturoa/ Rabbit Island Biosolids Application Facility: Groundwater assessment. Client report prepared for Nelson Regional Sewerage Business Unit1012787.0203, 31 pp.

Wikipedia (2022) No-observed-adverse-effect level. Wikipedia.

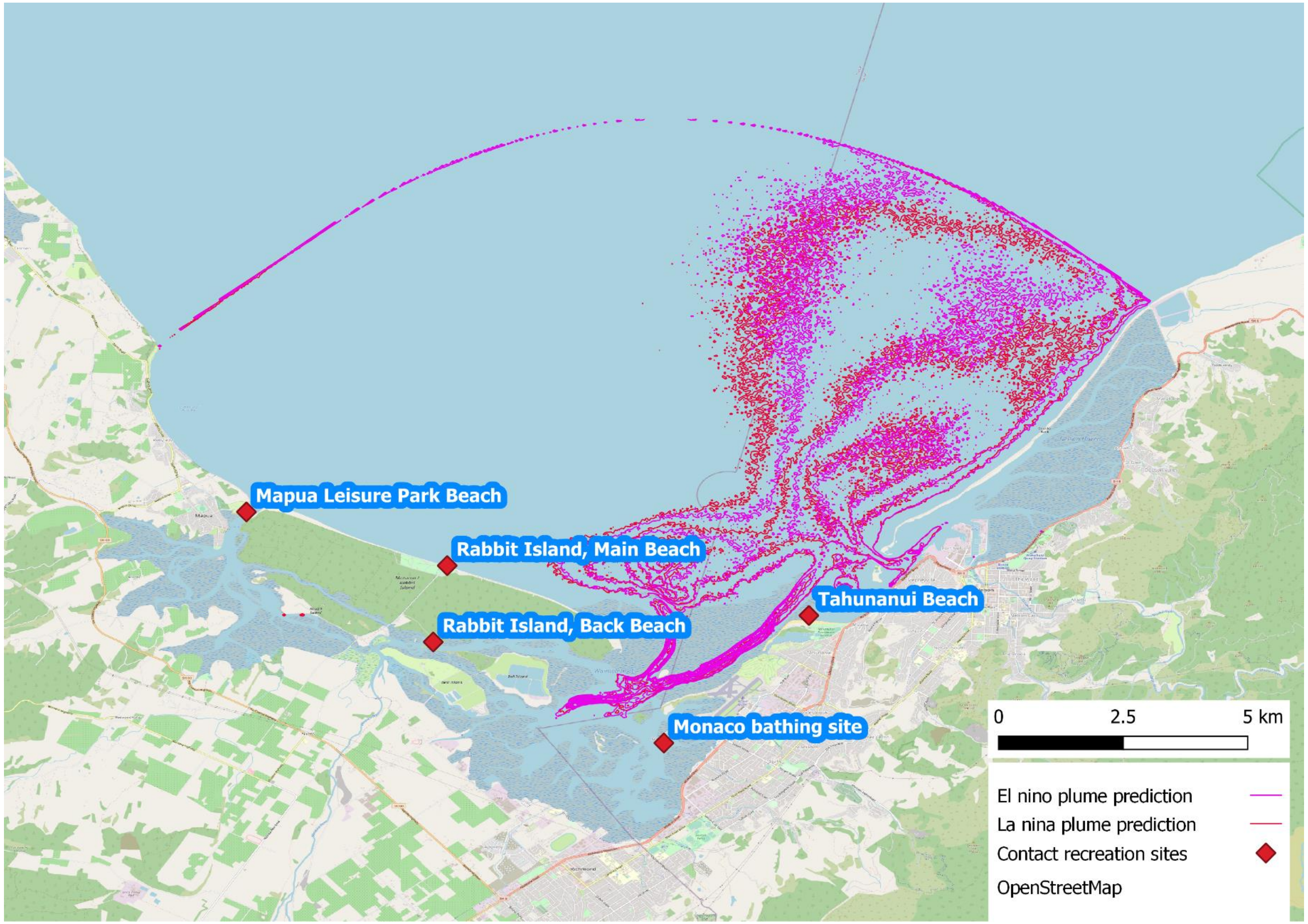

Figure 1: Recreational water quality monitoring sites and typical direction of plume of treated wastewater discharged from Bell Island. The semicircle of magenta dots indicates the extent of the model domain.

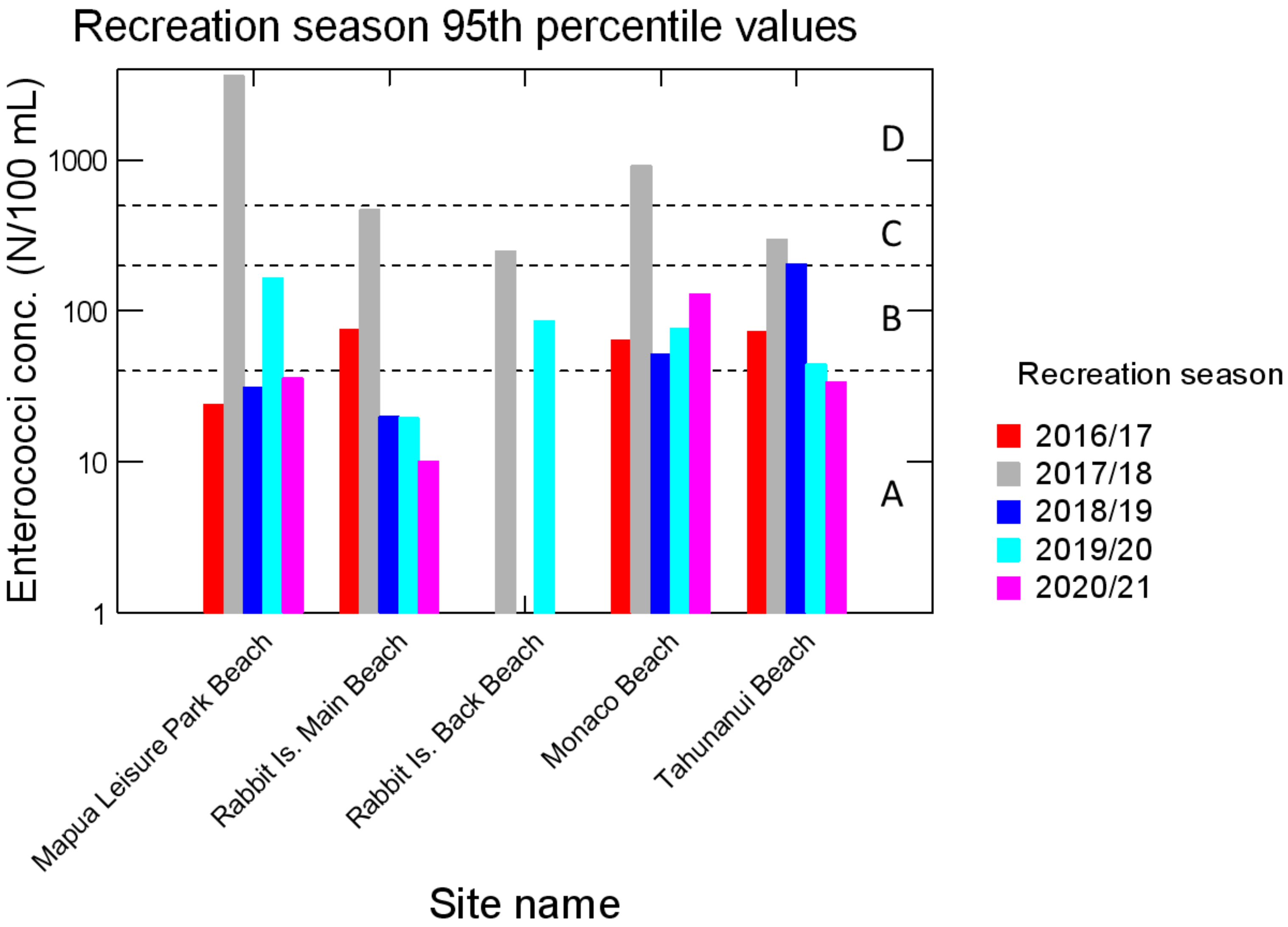

Figure 2: Recreation season ninety-fifth percentile enterococci values. The broken horizontal lines represent the 40 enterococci/100 mL, 200 enterococci/100 mL and 500 enterococci/100 mL concentration thresholds that define health risk categories A, B, C and D respectively (see Table 2 for explanation of these categories)

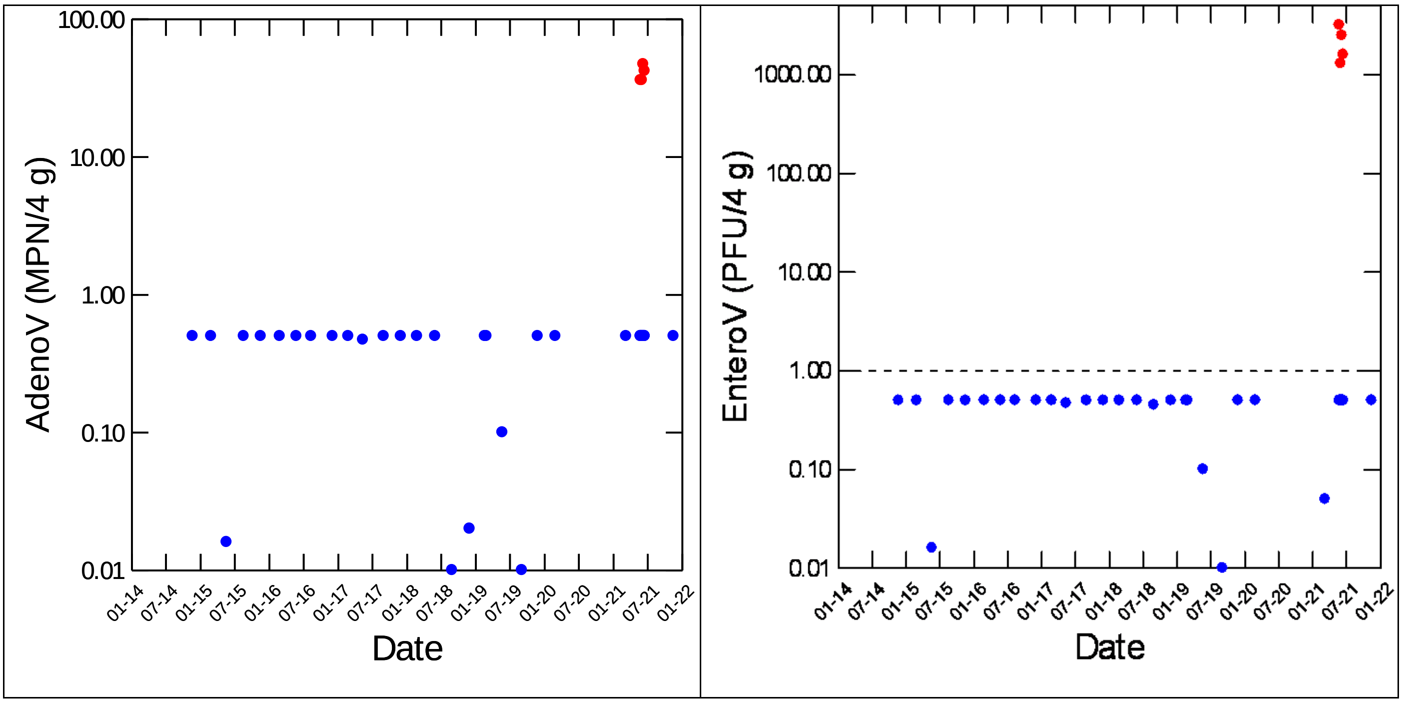

Figure 3: Concentrations of viral contaminants in treated biosolids. The horizontal dashed line indicates the guideline value for enteric viruses (1 pfu/4 g; pfu = plaque forming unit) (Table 4.1, NZWWA 2003). No NZ biosolids Guideline value exists for adenoviruses.

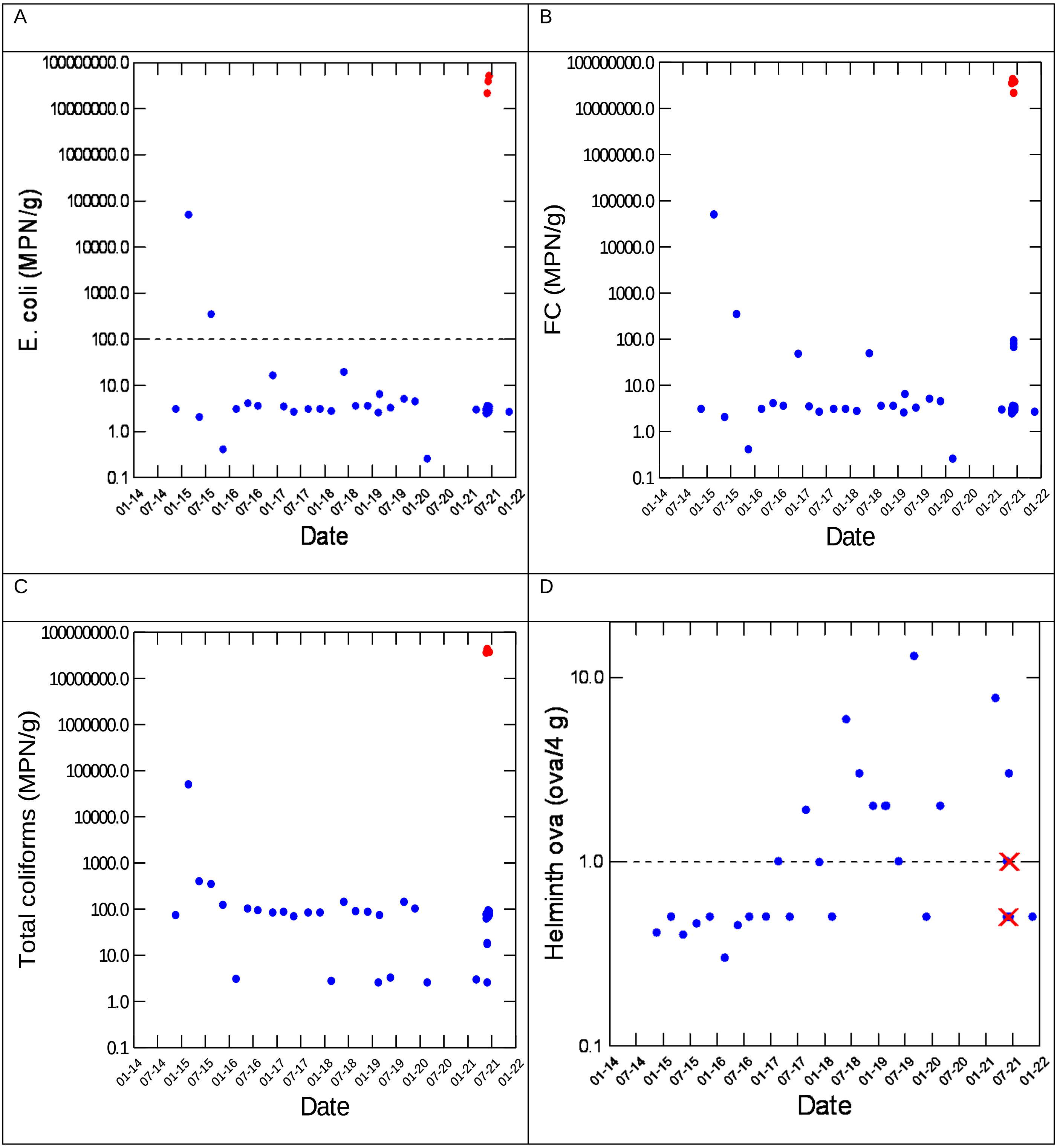

Figure 4: Concentrations of bacterial contaminants in processed biosolids. The horizontal dashed lines indicate relevant guideline value for E. coli (100/4 g) and helminth ova (1/4 g) (Table 4.1, NZWWA 2003). No Guideline value exists for faecal coliforms or total coliforms.

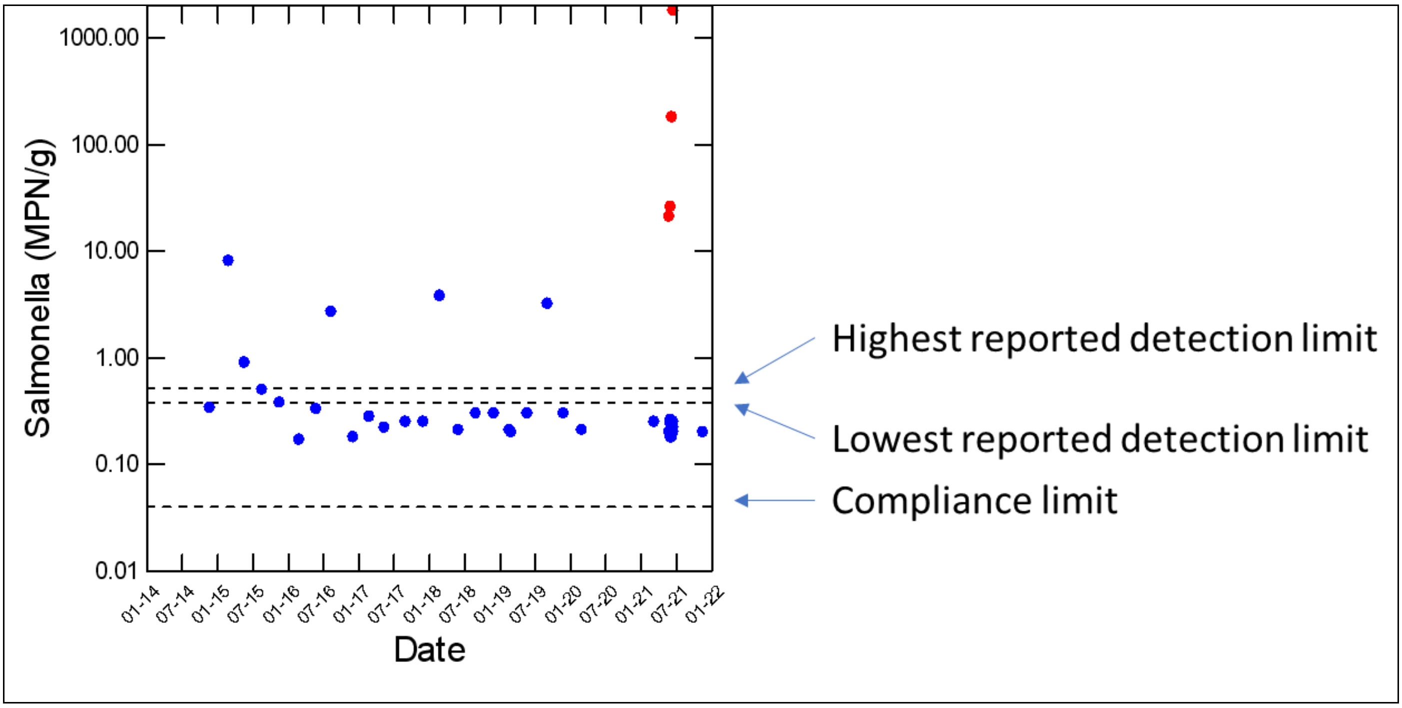

Figure 5: Results of analysis for helminth ova in processed biosolids. The horizontal dashed lines indicates the highest and lowest analytical detection limits, and the Guideline value for helminth ova (one per 4 g). (Table 6.2, NZWWA 2003).

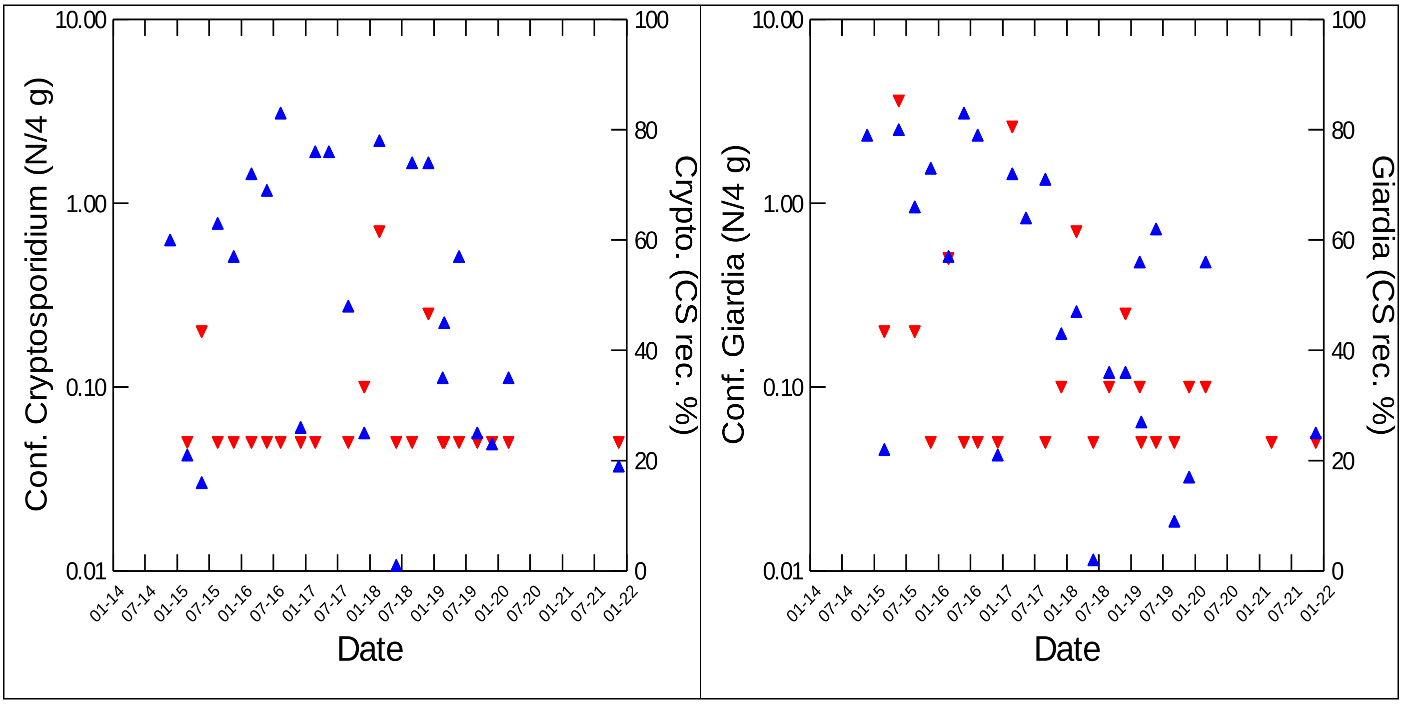

Figure 6: Results of analysis for protozoan contaminants in processed biosolids. The blue symbols indicate percent recovery of a labelled inactivated organism (Color Seed®, CS), used for quality assurance purposes. ColorSeed recovery that exceeds 20% suggests that the method of analysis is likely to provide useful data.

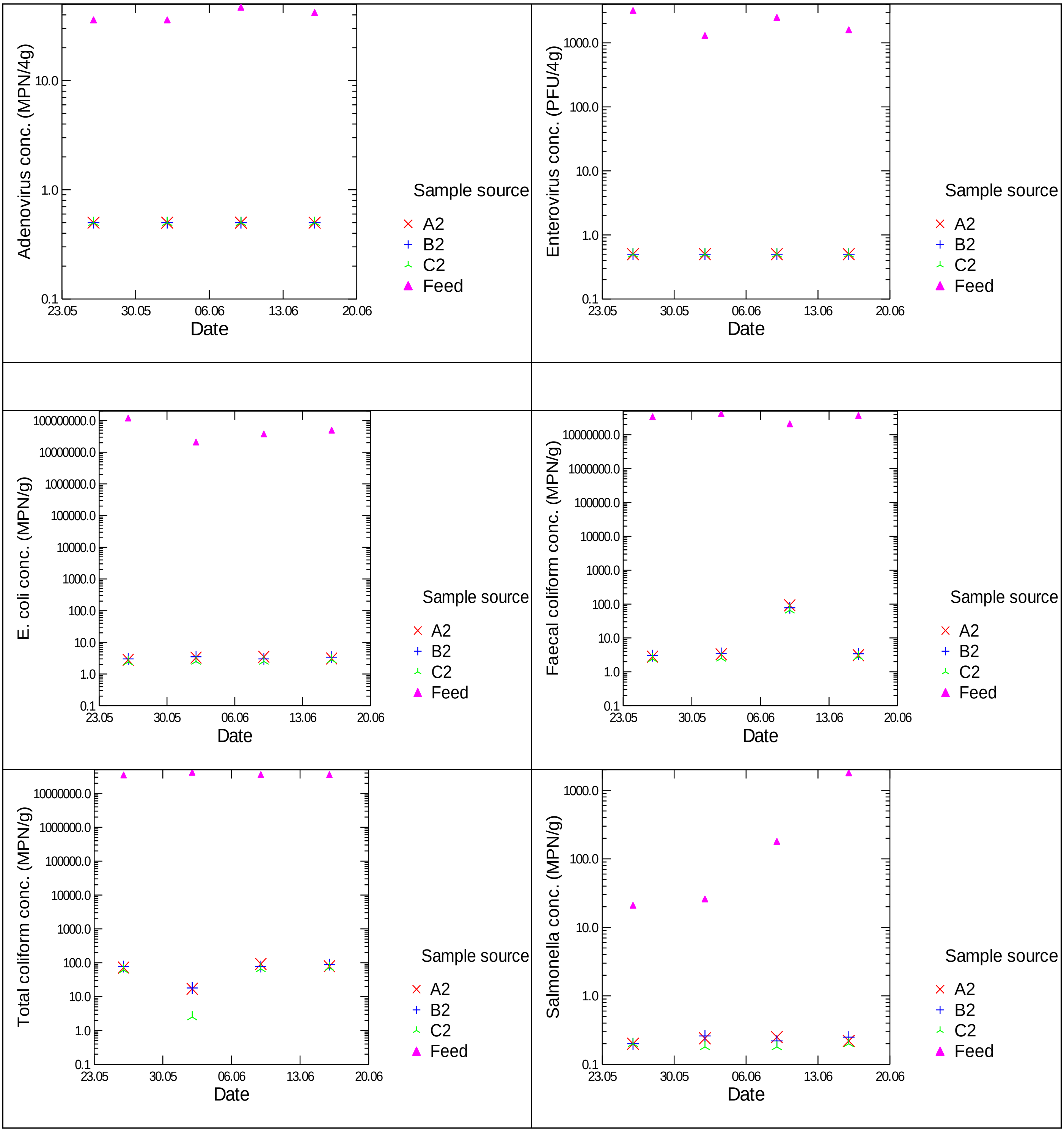

Figure 7: Comparison of concentrations of microbial contaminants in the inflow and outflow of the three ATAD units used to process biosolids. "Feed" = samples from the common inflow to the ATAD system. A2, B2 and C2 = output samples from three individual treatment units.

Table 2: Extended table H1 of the New Zealand recreational water quality guidelines. (MfE/MoH 2003). The grading is applied to measured data in Figure 2. GI is gastrointestinal illness risk, AFRI is acute febrile respiratory illness risk, NOAEL is "no observable adverse effects level", LOAEL is "low observable adverse effects level".

Grade	95th percentile value (enterococci/100 mL)	Basis of derivation	Estimated risk
A	≤ 40	This value is below the NOAEL in most epidemiological studies.	**< 1% GI illness risk, < 0.3% AFRI risk.** This relates to an excess illness of less than one incidence in every 100 exposures. The AFRI burden would be negligible.
B	41–200	The 200/100 mL value is above the threshold of illness transmission reported in most epidemiological studies that have attempted to define a NOAEL or LOAEL for GI illness and AFRI.	**1–5% GI illness risk, 0.3–< 1.9% AFRI illness risk.** The upper 95th percentile value of 200 relates to an average probability of one case of gastroenteritis in 20 exposures. The AFRI illness rate at this water quality would be 19 per 1000 exposures, or approximately 1 in 50 exposures.
C	201–500	This level represents a substantial elevation in the probability of all adverse health outcomes for which dose–response data is available.	**5–10% GI illness risk, 1.9–3.9% AFRI illness risk.** This range of 95th percentiles represents a probability of 1 in 10 to 1 in 20 of gastroenteritis for a single exposure. Exposures in this category also suggest a risk of AFRI in the range of 19–39 per 1000 exposures, or a range of approximately 1 in 50 to 1 in 25 exposures.
D	> 500	Above this level there may be a significant risk of high levels of minor illness transmission.	**> 10% GI illness risk, > 3.9% AFRI illness risk.** There is a greater than 10% chance of illness per single exposure. The AFRI illness rate at the 95th percentile point of 500 enterococci per 100 mL would be 39 per 1000 exposures, or approximately 1 in 25 exposures.