Memorandum

To:	Peter Cressey	**Date:**	8 July 2025
From:	Hayden Porter	**Our Ref:**	3250504-1956028608-577
Copy:	Garrett Hall	**:**	
Subject:	Kaikohe WWTP MBR Upgrade Virus Evaluation		

Introduction

Pathogen reduction is a key objective of wastewater treatment plants to protect public health. In the case of Kaikohe WWTP the impact of the current and potential future discharges to the Wairoro Stream are being reviewed through a Quantitative Microbial Risk Assessment (QMRA). This memo sets out the estimated virus removal/inactivation performance of the existing treatment plant and of the upgraded plant following the planned upgrade to a membrane bioreactor-based process.

The current wastewater treatment process is made up of an anaerobic pond, large oxidation pond and constructed wetland. FNDC has facilitated a Best Practicable Option selection process from which the preferred upgrade using a membrane bioreactor (MBR) process with UV disinfection has been selected.

Existing Plant Process Virus Removal/Inactivation

Virus removal and inactivation mechanisms in waste stabilisation ponds are achieved through a variety of mechanisms dominated by UV exposure but also including adsorption, sedimentation, microbial predation among others. Pond system performance is inherently linked to climatic conditions and therefore can vary significantly.

An analysis of literature from a range of treatment pond systems reviewed the correlation of virus removal with hydraulic retention time (HRT, a key design parameter for ponds systems) (Verbyla & Mihelcic, 2015). Figure 1 shows a summary of findings for the log reduction of virus plotted against the HRT. The authors note that the correlation is only weak to moderate, the red lines in the figure have been added to show a range between 1 log reduction per 50days HRT and 1 log reduction per 20 days HRT. These are more conservative than the published correlations referenced by the authors.

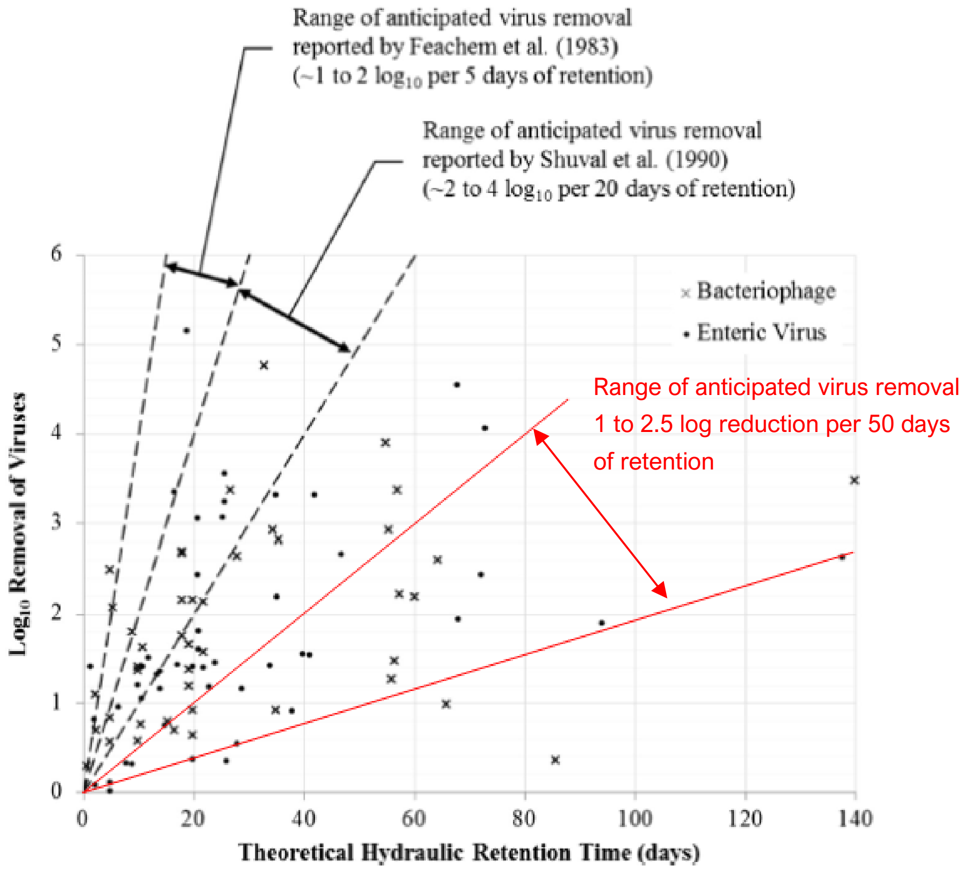

Figure 1 Theoretical hydraulic retention time versus mean log removal of viruses developed from literature Fig. 4 from (Verbyla & Mihelcic, 2015)

The primary treatment process unit at the Kaikohe WWTP is the oxidation pond which has a volume of 70,110m3 and an annual average daily flow rate (2003-2025) of 1,916m3/d giving a theoretical HRT of just over 36 days. Typically, wetlands such as the constructed wetland at Kaikohe WWTP would be considered to provide additional virus reduction – literature varies on the performance of wetlands for virus removal. A review of international wetland viral removal found typical removal rates between 95-99% removal (i.e. up to 2 log removal) however this included one site which was identified with no planting with a removal rate of only 61.5% (Gerba, Kitajima, & Iker, 2013). The current wetland is in a poor state of planting and wetland functionality.

For the current treatment system, we estimate that:

- The shorter retention time anaerobic pond provides minimal virus reduction.
- The oxidation pond provides approximately 1 log reduction in virus.
- The constructed wetland may provide some additional virus removal assumed to be approximately 0.5 log.

Total virus reduction in the existing plant is estimated to be approximately 1.5 log.

Upgraded Plant Virus Removal/Inactivation

The estimated virus removal/inactivation of the upgraded plant has been broken down into the two key process units which will impact its performance, the MBR, and the UV.

The mechanisms for virus removal in MBR systems are dominated by size exclusion. However, this is not solely reliant on the membrane pore size to exclude virus, biological processes contribute to the removal including aggregation/biosorption on the activated sludge floc and biofilm development on membrane surface. Predation and biological and chemical removal also contribute to removal rates (Zaman, Nelson, Moores, & Hai, 2015).

The Kaikohe WWTP MBR upgrade will specify hollow-fibre PVDF membranes with a pore size of 0.04 micron. Contributing biological factors will be assumed to follow standard design practice.

In the reported literature for full-scale virus removal rates in MBR care must be taken of the published log removals. In a state-of-the-art review paper (O'Brien & Xagoraraki, 2020) seven papers provided log removal values for Norovirus (type 1 or 2 or both). Of these, one was not a typical MBR process arrangement (Prado, A. de Castro Bruni, Garcia, & L. Z. Moreno, 2019). A review of the 4 most recent papers show that most had very few effluent samples with detectable concentrations of norovirus in the MBR permeate, see Table 1**Error! Reference source not found.**. In these cases, typically the limit of detection was used for the effluent concentrations, while for the qPCR method used this is typically low (10s of gene copies per mL i.e. in the order of 10^1) if the influent virus concentration is lower than 10^5 this can limit the log reduction which can be reported.

The paper with the most positive effluent results was also the paper with the highest reported log removal of 4.6 to 5.7 (Chaudhry, Nelson, & Drewes, 2015).

Table 1 Published Norovirus Removal Rates in Full-Scale MBR WWTP

Site	Membrane Pore Size (micron)	Influent Conc.	Reported Log Removal	Reference	Comment
American Canyon, CA	0.04	10^5	4.6-5.7	(Chaudhry, Nelson, & Drewes, 2015)	5 of 17 effluent samples below limit of quantification or non-detect.
Traverse City, MI	0.1	10^5	3.5-4.8	(Simmons, Kuo, & Xagoraraki, 2011)	Norovirus non-detect in all effluent samples.

Site	Membrane Pore Size (micron)	Influent Conc.	Reported Log Removal	Reference	Comment
Northern OH	0.4	10^2-10^4	1.51-3.32 (limited by influent concentrations)	(Francy, et al., 2012)	All but 2 MBR effluent samples had non-detectable norovirus
Northwest France	0.4	6log	3.0 (single measured effluent concentration used and not the detection limit)	(Miura, Schaeffer, Saux, Mehaute, & Guyader, 2018)	1 of 15 effluent samples were non-detect.

We estimate that the typically achieved virus removal by the MBR for the upgraded plant is 4log removal.

Measurement of the effectiveness of UV for the inactivation of norovirus is a challenging as it can't be cultured and gene counting methods such as qPCR measure viable, non-viable and fragmented genetic material. In the case of post-MBR combined effluent, as seen in the section above, the virus concentrations in the MBR are so low that the effect of the UV is not seen as it is either already below the limits of detection or close to it.

To estimate the performance of UV disinfection the response of surrogate virus' to UV can be reviewed. (Park, Linden, & Sobsey, 2011) noted "A UV dose of c. 30 mJ cm^2 was able to achieve a 4-log_{10} reduction of three mammalian NoV surrogates. Thus, it is likely that human NoV could be effectively controlled by 40 mJ cm^2, which is the UV disinfection practice for drinking water (ANSI/ NSF, 2002)."

The Kaikohe WWTP upgrade UV disinfection unit is yet to be designed. We would expect a typical dose range of 20-40 mWs/cm^2. We estimate that the UV disinfection will provide approximately 2-log iinactivation. Given the high performance of the MBR (refer previous section) there will likely be low concentrations of virus in the permeate as such, we have only added 1-log virus inactivation to the total plant virus removal/inactivation.

The total estimated log reduction/inactivation for norovirus via the MBR and UV process units is approximately 5-log.

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Hayden Porter

Associate Wastewater Process Engineer

Email: Hayden.Porter@beca.com