Appendix N:

Ecological Risk Assessment of Emerging Organic Contaminants in Poverty Bay

Ecological risk assessment of emerging organic contaminants in Poverty Bay from wastewater overflows

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Executive Summary

In Gisborne, wet weather wastewater overflows result from excessive inflow of stormwater into the wastewater network, causing the capacity of the network to be exceeded and surcharging to occur. While the Gisborne wastewater network is sized to cater for 4 to 6 times the average (dry weather) wastewater flow, stormwater inflow to the network can be significant during heavy rainfall events. Currently the wastewater network overflows on average approximately 2.5 times per year and Gisborne District Council (GDC) is implementing a programme (Drainwise) that aims to reduce stormwater inflow and infiltration so that overflows occur on average less than once every two years. Similarly, following the successful implementation of the Drainwise programme, overflow volume in a 10-year Annual Recurrence Interval (ARI) event is predicted to reduce from 17,849 m^3 to 1,545 m^3 (12-fold reduction) and 25,782 m^3 to 8,010 m^3 (3-fold reduction) for the major Wainui and Peel Street overflows, respectively.

Wastewater overflows can release untreated sewage into the receiving environment, leading to adverse environmental effects caused by contaminants contained within the untreated sewage.

Emerging organic contaminants (EOCs) are any synthetic or naturally occurring organic chemical that is not commonly monitored in the environment but has the potential to enter the environment and cause known or suspected adverse ecological and (or) human health effects. Major sources of EOCs include treated wastewater discharges, wastewater overflows, stormwater and landfill leachate.

EOCs encompass a large variety of chemicals. These include human and animal medicines (pharmaceuticals), antimicrobial disinfectants in soaps/shampoos, UV-filters in sunscreens, fragrances, pesticides, and those chemicals associated with industry (plasticisers, corrosion inhibitors, surfactants, flame retardants).

Wastewater overflows from the Gisborne network may lead to ecological effects from EOCs in the marine receiving environment of Poverty Bay and estuarine areas of the city. To address this, Gisborne District Council (GDC) has contracted Streamlined Environmental Ltd (SEL) to undertake a risk assessment of EOCs in wastewater overflows.

Data on EOC concentrations in untreated influent (after pre-screening) from the Gisborne wastewater treatment plant (WWTP) were used to prioritise the most at-risk EOCs in the influent. The ecological "predicted no effects concentration" (PNEC) was obtained for each prioritised EOC. Risk quotients (EOC influent concentration/PNEC) under normal (mean EOC influent concentration) and worst-case (maximum EOC influent concentration) scenarios were calculated.

EOCs present in overflows of untreated Gisborne wastewater have the potential to elicit adverse ecological effects in the marine receiving environment. The majority (18) of the prioritised EOCs exhibit a potential ecological risk from untreated wastewater overflows (risk quotient >1). Risk quotients of up to 2,460 (17 α -ethynylestradiol, maximum concentration) were calculated.

MetOcean Solutions undertook a numerical investigation into the fate of wastewater discharged from four overflow discharge locations under different forcing conditions (rivers, initial tidal states and wind), discharge rates, and 2- and 10-year ARI overflow discharge scour events for the existing situation and following improvements (implemented through GDC's Drainwise programme).

Time series dilution data at 14 sites identified for each modelled scenario were supplied by MetOcean Solutions. Minimum, median and maximum dilutions at each site for all scenarios were calculated 6 hours, 24 hours and 48 hours post wastewater discharge. A worst-case scenario of EOC concentrations at each of the 14 receiving environment sites was calculated based on minimum dilutions at each site under all scenarios, minimum time (6 hours) post wastewater discharge, and risk quotient for maximum EOC influent concentrations.

Under this worst-case scenario, dilution by receiving environment water reduces the risk quotients of all EOCs to <1 within 6 hours of discharge, suggesting negligible effects. Furthermore, greater dilutions 24 hours and 48 hours after discharge will further reduce risk quotients, and associated potential for adverse effects.

However, there is still potential for bioaccumulation of some EOCs in marine species. Bioaccumulation concentration factors (BCF) may be used to estimate potential bioaccumulation of EOCs in biota, with a value >1,000 indicative of potential for bioaccumulation. Six EOCs have a BCF value above 1,000 and so are expected to bioaccumulate: technical nonylphenol (26,580); galaxolide (19,002); tonalide (13,834); methyl-triclosan (9,161); triclosan (4,270); and mestranol (1,059). Sixteen EOCs are not expected to bioaccumulate, with BCF < 1,000.

It is noted that while there is an ongoing risk of bioaccumulation, GDC's implementation of the Drainwise programme will reduce both the frequency and volume of wet weather overflows substantially. This programme aims to reduce overflow frequency, which is currently an average of 2.5 times per year, to less than once every two years. Similarly, overflow volume in a 10-year event is predicted to reduce from 17,849 m^3 to 1,545 m^3 and 25,782 m^3 to 8,010 m^3 for the Wainui and Peel Street overflows respectively. So, while an overflow event will result in EOCs being discharged, and hence the potential for bioaccumulation to occur, the load of EOCs discharged via overflows will be reduced substantially and will significantly reduce the rate at which any bioaccumulation occurs.

Even though some EOCs are expected to bioaccumulate there are not established analytical methods to measure them in biota and, there is a large knowledge gap of potential human health effects of EOCs in biota from which to establish whether there is a risk from consumption of these species.

EOCs present in drinking water are a potential human health risk. However, with a coastal discharge, drinking water is not of relevance to this study.

1. Introduction

In Gisborne, wet weather wastewater overflows result from excessive ingress of stormwater into the wastewater network, causing the capacity of the network to be exceeded and surcharging to occur. While the Gisborne wastewater network is sized to cater for 4 to 6 times the average (dry weather) wastewater flow, stormwater inflow to the network can be significant during heavy rainfall events. Currently the wastewater network overflows on average approximately 2.5 times per year and Council is implementing a programme (Drainwise) that aims to reduce stormwater inflow so that the network does not overflow in a 50% Annual Exceedance Probability rainfall event.[1] Similarly, following the successful implementation of the Drainwise programme, overflow volume in a 10-year ARI event is predicted to reduce from 17,849 m^3 to 1,545 m^3 (12-fold reduction) and 25,782 m^3 to 8,010 m^3 (3-fold reduction) for the major Wainui and Peel Street overflows, respectively. Drainwise is primarily targeted at reducing stormwater inflow and infiltration from private property and involves upgrades to both private and public wastewater and stormwater networks.

Wastewater overflows can release untreated sewage into the receiving environment, leading to adverse environmental effects caused by contaminants contained within the untreated sewage.

Contaminants of concern can be microbiological (e.g. bacteria, viruses, protozoa) physical (e.g. suspended sediment, pH, temperature) and chemical (e.g. metal and organic contaminants). This report focusses on the risk from a subset of organic contaminants, coined “emerging organic contaminants” (EOCs).

EOCs are defined as:

> "any synthetic or naturally occurring organic chemical that is not commonly monitored in the environment but has the potential to enter the environment and cause known or suspected adverse ecological and (or) human health effects”.[2]

There is global concern that the presence of EOCs in the environment may cause adverse effects on human and ecological health. Some EOCs (endocrine disrupting chemicals: EDCs) are implicated in affecting male and female reproduction, juvenile development and certain cancers by disrupting endocrine (hormonal) systems in many species (WHO/UNEP, 2012). Antimicrobial resistance – resistance of a microorganism to an antimicrobial drug that was originally effective for treatment of infections caused by it – is an increasing threat to global public health. The use and misuse of antimicrobial drugs accelerates the emergence of drug-resistant strains (WHO, 2015).

EOCs encompass a large variety of chemicals. These include human and animal medicines (pharmaceuticals), antimicrobial disinfectants in soaps/shampoos, UV-filters in sunscreens, fragrances, pesticides, and those chemicals associated with industry (plasticisers, corrosion inhibitors, surfactants, flame retardants).

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[1] A rainfall event that has a 50% probability of occurring in any year – this is equivalent to a rainfall event that occurs, on long term average, once every two years.
[2] modified from http://toxics.usgs.gov/regional/emc/

Major sources of EOCs to the environment include treated wastewater discharges, wastewater overflows, stormwater and landfill leachate. Furthermore, there is considerable overlap of EOCs from these sources (Stewart et al., 2016).

Wastewater overflows from the Gisborne network may lead to ecological effects from EOCs in the marine receiving environment of Poverty Bay. To address this, Gisborne District Council (GDC) has contracted Streamlined Environmental Ltd (SEL) to undertake a risk assessment of EOCs from wastewater overflows[3]. Central to this risk assessment are data from two reports:

1. EOC concentrations in untreated influent (after pre-screening) from the Gisborne wastewater treatment plant (WWTP) (Northcott, 2017), and;
2. Hydrodynamic modelling of the fate of wastewater discharged from four overflow discharge locations under various wind and tidal conditions to provide dilutions at specified sites in Poverty Bay (MetOcean Solutions, 2019).

The four overflow discharge locations and 14 sites used to assess potential ecological effects from EOCs in Poverty Bay are shown in Figure 1.

The risk assessment follows the process:

- Prioritisation of EOCs (Section 2.1);
- Ecological effects of EOCs (Section 2.2);
- Ecological risk of prioritised EOCs in untreated Gisborne wastewater (Section 2.3);
- Modelled dilutions of wastewater at receiving environment sites (Section 2.4);
- Ecological risk of prioritised EOCs in untreated wastewater overflows to receiving environment sites (Section 2.5).

Not covered in the risk assessment is risk to human health. EOCs present in drinking water are a potential human health risk. However, with a coastal discharge, drinking water is not of relevance to this study.

[3] GDC has also commissioned an assessment of ecological effects associated with other contaminants carried in wastewater.

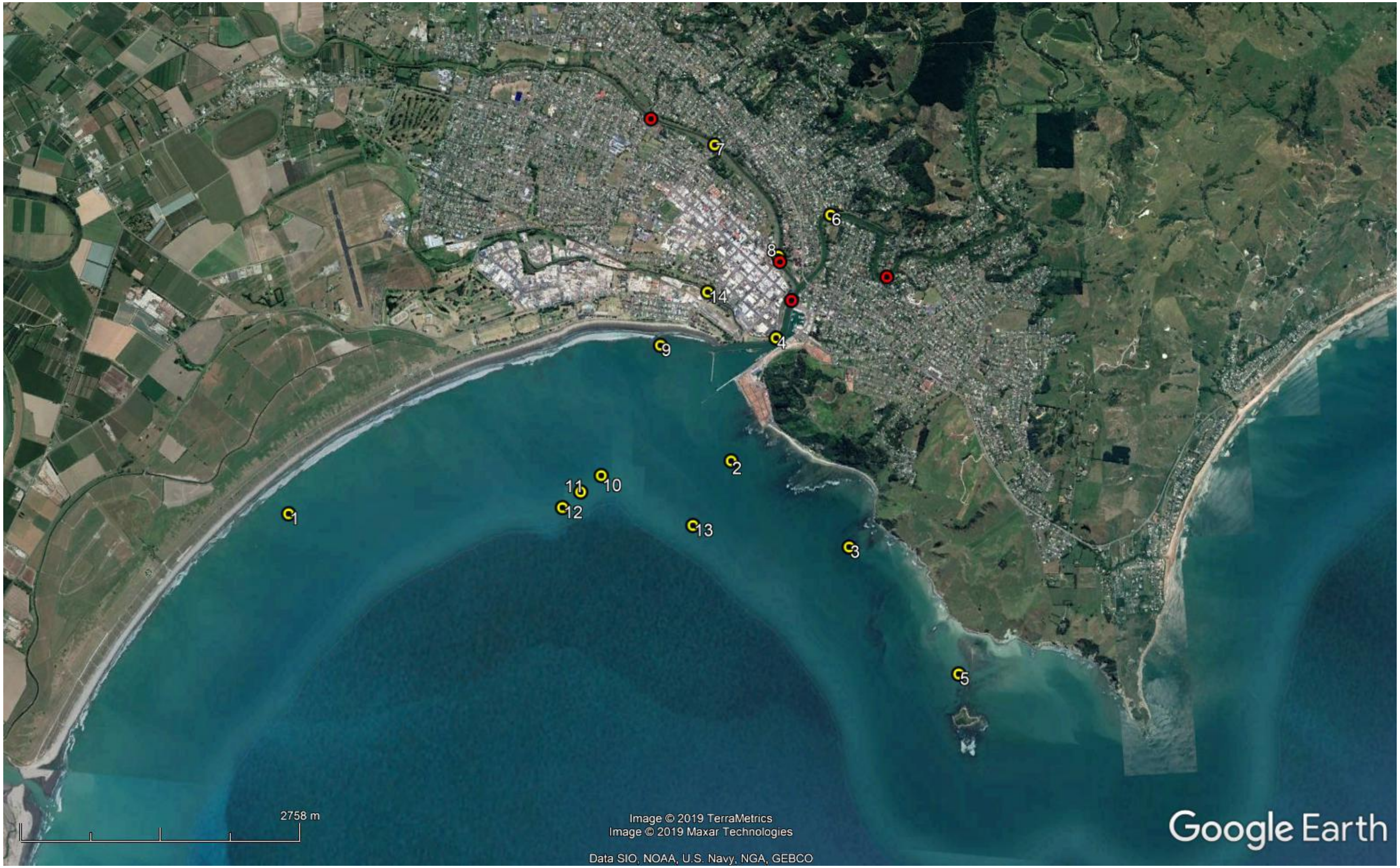

Figure 1. Receiving environment sites used for assessment (numbered and yellow) with 4 discharge locations (not numbered and red).

2. Risk Assessment

2.1 Prioritisation of EOCs

Northcott (2017) measured a total of 81 individual EOCs representing ten different classes, namely:

- Alkylphosphate flame retardants (11 compounds)
- Industrial alkylphenols (7 compounds)
- Insect repellents (3 compounds)
- Nitro- and polycyclic musk fragrances (10 compounds)
- Paraben preservatives (5 compounds)
- Pharmaceuticals (10 compounds)
- Phenolic antimicrobials (five compounds)
- Phthalate esters and plasticisers (13 compounds)
- Steroid hormones (16 compounds)
- UV filter (1 compound)

Other specific analyses were for:

- Polycyclic aromatic hydrocarbons (59 compounds)
- the herbicide terbuthylazine.

Bioassays were used to measure biological activity – described in a previous report (Northcott and Tremblay, 2015) – namely:

- TCDD EQ = tetrachlorodibenzodioxin equivalents, measured as arylhydrocarbon response (AhR)
- EEQ = estrogen equivalents measured as the relative potency against 17β-estradiol
- TMX EQ = anti-estrogen activity measured as the relative potency against tamoxfen
- DHT EQ = androgen equivalents measured as the relative potency against dihydroxy testosterone
- CypAc EQ = anti-androgen activity measured as the relative potency against cyproterone acetate.

Of the 81 individual EOCs analysed, 22 were identified by Northcott (2017) as priority EOCs. Of the biological endpoints, dioxin-like activity was identified as a priority. The identified priority EOCs, their chemical class and CAS # are displayed in Table 1.

Table 1. Priority EOCs identified by Northcott (2017).

Priority EOC	Chemical class	CAS #
TCEP[1]	Alkylphosphate flame retardant	115-96-8
TCPP[2]	Alkylphosphate flame retardant	13674-84-5
TDCP[3]	Alkylphosphate flame retardant	13674-87-8
TBEP[4]	Alkylphosphate flame retardant	78-51-3
Triclosan	Anti-microbial	3380-34-5
Methyl-triclosan	Anti-microbial	4640-01-1
Technical nonylphenol	Alkyl phenol	84852-15-3
DEET	Insect repellent	134-62-3
Carbamazepine	Pharmaceutical	298-46-4
Diclofenac	Pharmaceutical	15307-86-5
Ibuprofen	Pharmaceutical	51146-56-6
Ketoprofen	Pharmaceutical	22071-15-4
Meclofenamic acid	Pharmaceutical	644-62-2
Naproxen	Pharmaceutical	22204-53-1
Monoethyl phthalate acid ester	Plasticiser metabolite	2306-33-4
Monobutyl phthalate acid ester	Plasticiser metabolite	131-70-4
Monoethylhexyl phthalate acid ester	Plasticiser metabolite	4376-20-9
Galaxolide	Polycyclic musk fragrance	1222-05-5
Tonalide	Polycyclic musk fragrance	21145-77-7
Estrone	Steroid hormone	53-16-7
Mestranol	Steroid hormone	72-33-3
17α-ethynylestradiol	Steroid hormone	57-63-6
Dioxin like activity	Dioxin-like chemicals(?)	1746-01-6 (2,3,7,8-TCDD)

[1] TCEP= Tris(2-chloroethyl) phosphate, [2] TCPP = Tris (1-chloro-2-propyl) phosphate, [3] TDCP = Tris[2-chloro-1-(chloromethyl)ethyl]phosphate, [4] TBEP = Tris-(2-butoxyethyl)-phosphate.

Unique to the Northcott (2017) study was the measurement of EOCs in both dissolved and particulate phases of the influent and effluent. He argued that most studies of EOCs in wastewater concentrated on the dissolved phase only, neglecting material that binds to suspended solids in the wastewater stream. This may under-estimate the concentration of EOCs in the wastewater, especially where suspended solids are a significant component of the total wastewater.

Using a conservative approach, the ranking of the prioritised list of EOCs for risk assessment was undertaken based on the TOTAL concentration of EOCs in the influent, i.e. BOTH the dissolved and particulate concentrations. It is acknowledged that this may potentially over-estimate the risk of some EOCs when comparing concentrations against ecological guidelines as some may be strongly bound to particulate material and therefore not bioavailable. Hence, this is a more conservative approach than assessing against dissolved EOC concentrations only.

2.2 Ecological effects

The lowest available marine[4] predicted no effects concentration (PNEC) for each of the priority EOCs was obtained from the NORMAN[5] Ecotoxicology Database.[6] Lowest PNECs were either predicted by Quantitative Structure Activity Relationship (QSAR) or obtained experimentally and voted on by NORMAN ecotoxicology experts. Lowest PNECs are used primarily for prioritisation purposes. NORMAN states that most of the lowest PNECs have been derived for freshwater. Unless there is an experimental value for other matrices, the lowest PNEC for marine water is calculated by lowest PNEC for freshwater/10. The PNECs used for the prioritised EOCs, along with method (predicted or experimental) and justification of marine PNEC are summarised in Table 2.

Table 2. Lowest Predicted No Effects Concentrations (PNEC) for priority EOCs.

Priority EOC	NORMAN Lowest Marine PNEC (ng/L)	PNEC ID[1]	Justification[2]
TCEP	400	Predicted	FW/10
TCPP	3.9	Predicted	FW/10
TDCP	110	Predicted	FW/10
TBEP	14	Predicted	FW/10
Triclosan	2.0	Predicted	FW PNEC Chronic/10
Methyl-triclosan	6.8	Predicted	FW/10
Technical nonylphenol	25	Predicted	FW/10
DEET	8,800	Predicted	FW/10
Carbamazepine	5.0	Predicted	FW PNEC Chronic/10
Diclofenac	5.0	Predicted	FW/10
Ibuprofen	100	Predicted	FW/10
Ketoprofen	210	Predicted	FW/10
Meclofenamic acid	9.7	Predicted	FW/10
Naproxen	170	Predicted	FW/10
Monoethyl phthalate acid ester	620	Predicted	FW/10
Monobutyl phthalate acid ester	231	Predicted	FW/10
Monoethylhexyl phthalate acid ester	19	Predicted	FW/10
Galaxolide	700	Predicted	FW/10
Tonalide	ND[3]	ND	ND
Estrone	0.36	Predicted	FW/10
Mestranol	0.170	Predicted	FW/10
17α-ethynylestradiol	0.0035	Predicted	FW/10
Dioxin like activity (TCDD EQ)	0.90	Predicted	FW/10

[1] Predicted or experimental.
[2] FW = freshwater value. For triclosan and carbamazepine marine PNEC were based specifically on chronic FW PNEC (lowest presented).
[3] ND = No data.

[4] Although discharges may be into a stream, the ultimate receiving environment sites are predominantly marine.
[5] NORMAN is a network of reference laboratories, research centres and related organisations for monitoring of emerging environmental substances. NORMAN has a membership of more than 70 leading laboratories and authorities across Europe and North America.
[6] https://www.norman-network.com/nds/ecotox/lowestPnecIndex.php

2.3 Ecological risk of prioritised EOCs in untreated Gisborne wastewater

To estimate the ecological risk of the prioritised EOCs to the marine receiving environment, hazard risk quotients were calculated for both mean and maximum influent EOC concentrations. The risk quotient is calculated by EOC concentration/PNEC concentration, with a value >1 indicating a potential ecological effect. In simplistic terms, the risk quotient is the dilution required to provide negligible ecological effects in the receiving environment. Mean and maximum wastewater overflow concentrations[7] and associated risk quotients have been ranked from highest to lowest risk and summarised in Table 3.

As summarised in Table 3, the majority (18) of the prioritised EOCs exhibit a potential ecological risk from untreated wastewater overflows (risk quotient >1). Risk quotients of up to 2460 (17α-ethynylestradiol, maximum concentration) have been calculated. The top 10 highest risk EOCs have risk quotients >100 (based on maximum concentration). Mean and median risk quotients of 229 and 58 were calculated, based on maximum concentration (Table 3).

These results suggest that EOCs in untreated (and undiluted)[8] wastewater from Gisborne's wastewater network – that are discharged via wastewater overflows – are a significant risk to the immediate receiving environment with up to orders of magnitude dilution required to reduce their concentrations to below ecological effects levels.

Table 3. Summary of mean and maximum (undiluted) wastewater overflow concentrations and associated risk quotients.

Priority EOC	Mean Concentration (ng/L)	Maximum Concentration (ng/L)	Risk Quotient (Mean)	Risk Quotient (Maximum)	Rank[1]
17α-ethynylestradiol	5.5	8.6	1562	2460	1
Triclosan	648.8	993.0	324	497	2
Estrone	51.0	135.0	142	375	3
Monoethylhexyl phthalate acid ester	3279.0	5832.0	173	307	4
Technical nonylphenol	4329.5	6921.0	173	277	5
TCPP	918.5	1071.0	236	275	6
Diclofenac	1070.5	1157.0	214	231	7
Ibuprofen	12677.0	16882.0	127	169	8
Carbamazepine	666.3	794.0	133	159	9
TBEP	1351.5	1963.0	97	140	10
Naproxen	8908.0	11824.0	52	70	11
Mestranol	4.3	7.7	25	46	12
Galaxolide	4996.0	6433.0	7.1	9.2	13
Dioxin like activity (TCDD EQ)	3.2	4.1	3.6	4.6	14
TDCP	329.5	468.0	3.0	4.3	15
Methyl-triclosan	12.5	27.1	1.8	4.0	16
Monobutyl phthalate acid ester	677.3	881.0	2.9	3.8	17

[7] Mean and maximum EOC concentrations calculated from 4 separate monitoring events (Northcott, 2017).
[8] Overflows that occur during wet weather in Gisborne result from excessive stormwater inflow to the wastewater network. Hence, wet weather overflows are substantially diluted by stormwater prior to discharge via an overflow point.

Priority EOC	Mean Concentration (ng/L)	Maximum Concentration (ng/L)	Risk Quotient (Mean)	Risk Quotient (Maximum)	Rank[1]
Meclofenamic acid	15.7	18.5	1.6	1.9	18
Monoethyl phthalate acid ester	389.5	513.0	0.6	0.8	19
Ketoprofen	123.3	168.0	0.6	0.8	20
TCEP	182.8	214.0	0.5	0.5	21
DEET	1223.5	1697.0	0.1	0.2	22
Tonalide	279.0	353.0	NA[2]	NA	NA
Mean			**149**	**229**	
Median			**39**	**58**	

[1] Rank based on maximum concentration risk quotient.
[2] Not applicable as PNEC could not be sourced.

2.4 Modelled dilutions of wastewater at receiving environment sites

MetOcean Solutions (2019) undertook a numerical investigation into the expected discharge characteristics from different overflow discharge locations (Figure 1) for both the existing discharge scenarios for the 2- and 10-year ARI events and future (following implementation of GDC's Drainwise programme) discharge scenarios for the 10-year ARI event[9].

Although wet weather wastewater overflow discharges are unplanned, and result from very heavy rainfall events, hydrodynamic conditions under different forcing conditions can be modelled, therefore allowing the general geographical dispersion of the discharges to be determined.

MetOcean Solutions (2019) modelled a range of scenarios in order to describe the expected dispersion and dilution characteristics of stormwater discharges from the outfalls in the event of a discharge. Each of the simulations is unique in terms of the initial tidal state, forcing conditions (rivers, initial tidal states and wind) and discharge rates, and represents 2- and 10-year ARI discharge scour events for the existing and 10-year ARI future discharge scenarios.

Time series dilution data at the 14 sites identified (Figure 1) were supplied by MetOcean Solutions. Minimum, median and maximum dilutions at each site for all scenarios under current 2-year ARI, current 10-year ARI and future 10-year ARI were calculated 6 hours, 24 hours and 48 hours post wastewater discharge. These statistics are summarised in Table 4 (6-hours post discharge), Table 5 (24-hours post discharge), Table 6 (48-hours post discharge). Minimum dilutions only at each site under all scenarios and 6 hours, 24 hours and 48 hours post wastewater discharge were used for a worst-case scenario of EOC receiving environment calculations and are summarised in Table 7.

[9] No overflows are predicted to occur in a 2-year ARI event following improvements implemented through GDC's Drainwise programme, hence this scenario was not modelled.

Table 4. Minimum, median, and maximum dilutions of wastewater overflow plume at selected sites 6-hours post discharge and under all scenarios modelled.[1]

Descriptor	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8	Site 9	Site 10	Site 11	Site 12	Site 13	Site 14
Current 2yr ARI														
Minimum	11,400	0	0	5,310	0	30,700	0	0	6,840	32,483	26,202	19,491	36,577	0
Median	2.8E+24	4.0E+04	5.1E+04	6.4E+03	4.2E+04	3.2E+04	0	0	8.4E+03	4.3E+08	2.0E+06	1.2E+06	6.1E+07	0
Maximum	2.3E+27	4.7E+16	4.1E+22	7.3E+03	3.1E+35	3.3E+04	0	0	2.3E+24	9.2E+13	4.6E+12	7.3E+09	1.5E+15	0
Current 10yr ARI														
Minimum	7,970	15,200	44,100	3,190	0	44,100	10,000	10,100	5,450	21,400	14,200	9,840	19,600	0
Median	3.7E+06	2.1E+06	1.2E+17	4.4E+03	1.1E+05	4.5E+04	1.0E+04	1.0E+04	7.3E+03	1.1E+05	7.5E+04	9.2E+04	4.8E+05	0
Maximum	2.7E+22	1.1E+14	4.6E+24	5.6E+03	4.3E+35	4.7E+04	1.1E+04	1.1E+04	4.5E+05	1.4E+06	3.2E+05	2.2E+05	1.5E+07	0
Future 10yr ARI														
Minimum	22,400	44,300	128,000	7,920	0	0	0	0	14,600	55,000	37,100	27,100	55,700	0
Median	4.6E+07	1.0E+07	7.4E+17	1.2E+04	3.8E+05	0	0	0	2.3E+04	3.3E+05	2.3E+05	2.7E+05	1.7E+06	0
Maximum	4.5E+22	1.8E+14	1.0E+25	1.6E+04	9.8E+35	0	0	0	5.4E+05	3.7E+06	1.2E+06	6.1E+05	5.2E+07	0

[1] A value of 0 means the wastewater plume did not reach this site.

Table 5. Minimum, median, and maximum dilutions of wastewater overflow plume at selected sites 24-hours post discharge and under all scenarios modelled.[1]

Descriptor	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8	Site 9	Site 10	Site 11	Site 12	Site 13	Site 14
Current 2yr ARI														
Minimum	9,290	30,000	37,072	6,287	36,300	0	0	0	8,290	29,100	27,300	22,448	41,257	0
Median	1.5E+06	5.3E+04	1.4E+05	7.9E+03	2.1E+07	0	0	0	1.0E+04	4.5E+04	3.3E+04	2.9E+04	2.2E+05	0
Maximum	4.8E+07	1.6E+07	4.4E+07	9.3E+03	1.1E+35	0	0	0	4.3E+06	7.0E+06	1.5E+06	1.3E+06	7.5E+06	0
Current 10yr ARI														
Minimum	8,130	13,600	28,200	3,170	24,500	44,800	10,000	10,100	5,390	19,700	12,900	10,700	17,300	0
Median	6.3E+04	4.6E+04	9.0E+04	4.5E+03	1.6E+05	4.6E+04	1.0E+04	1.0E+04	7.5E+03	2.7E+04	3.2E+04	2.6E+04	3.6E+04	0
Maximum	5.3E+06	1.2E+05	1.3E+07	5.7E+03	3.8E+09	4.7E+04	1.1E+04	1.1E+04	2.5E+05	6.2E+04	1.0E+05	1.7E+05	8.5E+04	0
Future 10yr ARI														
Minimum	22,600	38,000	79,200	7,930	68,900	0	0	0	14,500	53,700	35,200	29,800	47,300	0
Median	2.1E+05	1.4E+05	2.8E+05	1.2E+04	5.5E+05	0	0	0	2.3E+04	8.0E+04	1.0E+05	7.8E+04	1.1E+05	0
Maximum	1.4E+07	3.8E+05	3.6E+07	1.6E+04	1.1E+10	0	0	0	5.0E+05	2.0E+05	1.6E+05	4.5E+05	2.9E+05	0

[1] A value of 0 means the wastewater plume did not reach this site.

Table 6. Minimum, median, and maximum dilutions of wastewater overflow plume at selected sites 48-hours post discharge and under all scenarios modelled.[1]

Descriptor	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8	Site 9	Site 10	Site 11	Site 12	Site 13	Site 14
Current 2yr ARI														
Minimum	11,700	51,000	40,956	0	40,457	0	0	0	35,621	30,100	28,900	27,500	40,600	0
Median	1.1E+06	1.9E+05	9.6E+04	0	1.4E+05	0	0	0	3.3E+05	1.6E+05	7.3E+04	3.4E+04	9.7E+04	0
Maximum	9.8E+06	2.3E+06	5.3E+06	0	2.3E+07	0	0	0	2.1E+06	1.4E+06	1.2E+06	1.2E+06	1.3E+06	0
Current 10yr ARI														
Minimum	8,650	31,000	24,700	9,030	23,100	0	0	0	13,600	21,000	16,900	14,200	24,900	0
Median	5.9E+04	4.2E+04	6.6E+04	3.7E+06	8.8E+04	0	0	0	6.9E+04	4.5E+04	3.3E+04	2.7E+04	4.4E+04	0
Maximum	4.6E+06	9.0E+04	9.7E+04	5.9E+06	5.9E+08	0	0	0	2.7E+05	9.0E+04	6.1E+04	3.8E+04	8.9E+04	0
Future 10yr ARI														
Minimum	281,000	150,000	233,000	0	391,000	0	0	0	1,600,000	138,000	141,000	143,000	146,000	0
Median	1.6E+06	1.4E+06	1.3E+06	0	2.4E+06	0	0	0	1.4E+07	2.8E+06	2.9E+06	2.1E+06	1.8E+06	0
Maximum	2.1E+07	4.1E+06	2.9E+06	5.7E+09	1.7E+09	0	0	0	7.3E+07	9.2E+06	7.2E+06	6.5E+06	8.3E+06	0

Table 7. Minimum dilutions of wastewater overflow plume at selected sites under all scenarios modelled for current 2-year and 10-year ARI and future 10-year ARI. [1]

Descriptor	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8	Site 9	Site 10	Site 11	Site 12	Site 13	Site 14
Current 2yr ARI														
6 hours all scenarios	11,400	0	0	5,310	0	30,700	0	0	6,840	32,483	26,202	19,491	36,577	0
24 hours all scenarios	9,290	30,000	37,072	6,287	36,300	0	0	0	8,290	29,100	27,300	22,448	41,257	0
48 hours all scenarios	11,700	51,000	40,956	0	40,457	0	0	0	35,621	30,100	28,900	27,500	40,600	0
Current 10yr ARI														
6 hours all scenarios	7,970	15,200	44,100	3,190	0	44,100	10,000	10,100	5,450	21,400	14,200	9,840	19,600	0
24 hours all scenarios	8,130	13,600	28,200	3,170	24,500	44,800	10,000	10,100	5,390	19,700	12,900	10,700	17,300	0
48 hours all scenarios	281,000	150,000	233,000	0	391,000	0	0	0	1.6E+06	138,000	141,000	143,000	146,000	0
Future 10yr ARI														
6 hours all scenarios	22,400	44,300	128,000	7,920	0	0	0	0	14,600	55,000	37,100	27,100	55,700	0
24 hours all scenarios	22,600	38,000	79,200	7,930	68,900	0	0	0	14,500	53,700	35,200	29,800	47,300	0
48 hours all scenarios	281,000	150,000	233,000	0	391,000	0	0	0	1.6E+06	138,000	141,000	143,000	146,000	0

[1] A value of 0 means the wastewater plume did not reach this site.

2.5 Ecological risk of prioritised EOCs in untreated wastewater overflows to receiving environment sites

The risk quotient from priority EOCs (Table 1) to the marine receiving environment was calculated. Risk quotients were calculated for the current wastewater situation (i.e. before implementation of Drainwise) and the future wastewater situation (i.e. after implementation of Drainwise).

Current wastewater situation (pre-Drainwise)

By following conservative principles, a worst-case scenario was followed: maximum EOC concentration and minimum dilution of the wastewater plume at any site (see Table 7). For the current wastewater situation, the lowest dilution was 3,170, at site 4, 24-hours after discharge.[10] The receiving environment risk quotients for the current worst-case scenario are summarised in Table 8, which shows that risk quotients in the marine receiving environment for the most at-risk site (i.e. with minimum dilution of wastewater – in this case site 4) ranged from 0.0001 (DEET) to 0.8 (EE2). A risk quotient of <1 suggests negligible ecological effects from each individual EOC.

Most sites had dilution of the wastewater plume after 6 hours >10,000, so providing greater dilution (and less risk) to the most at-risk site. Furthermore, generally after 24 and 48 hours, the minimum dilution at all sites is either static or increases (Table 7). Therefore, risks from wastewater overflows would generally be further reduced after 24 and 48 hours.

[10] I note the dilution at this site 6-hours post discharge was 3,190.

Table 8. Summary of worst-case scenario risk quotients for EOCs from wastewater overflows into the marine receiving environment for the current wastewater situation (pre-Drainwise).

Priority EOC	Risk Quotient based on maximum influent concentration	Minimum wastewater dilution at any site	Greatest calculated risk quotient in the marine receiving environment
17α-ethynylestradiol (EE2)	2460.0	3170	0.8
Triclosan	496.5	3170	0.2
Estrone	375.0	3170	0.12
Monoethylhexyl phthalate acid ester	306.9	3170	0.10
Technical nonylphenol	276.8	3170	0.09
TCPP	274.6	3170	0.09
Diclofenac	231.4	3170	0.07
Ibuprofen	168.8	3170	0.05
Carbamazepine	158.8	3170	0.05
TBEP	140.2	3170	0.04
Naproxen	69.6	3170	0.02
Mestranol	45.5	3170	0.01
Galaxolide	9.2	3170	0.003
Dioxin like activity (TCDD EQ)	4.6	3170	0.001
TDCP	4.3	3170	0.001
Methyl-triclosan	4.0	3170	0.001
Monobutyl phthalate acid ester	3.8	3170	0.001
Meclofenamic acid	1.9	3170	0.001
Monoethyl phthalate acid ester	0.8	3170	0.0003
Ketoprofen	0.8	3170	0.0003
TCEP	0.5	3170	0.0002
DEET	0.2	3170	0.0001
Tonalide	NA	NA	NA

Future wastewater situation (post-Drainwise)

By following conservative principles, a worst-case scenario was followed: maximum EOC concentration and minimum dilution of the wastewater plume at any site (see Table 7). For the future wastewater situation, the lowest dilution was 7,920 at site 4, 6-hours post-discharge. The receiving environment risk quotients for the future worst-case scenario are summarised in Table 9, which shows that risk quotients in the marine receiving environment for the most at-risk site (i.e. with minimum dilution of wastewater – in this case site 4) ranged from 0.00002 (DEET) to 0.3 (EE2).

Table 9. Summary of worst-case scenario risk quotients for EOCs from wastewater overflows into the marine receiving environment for the future wastewater situation (post-Drainwise).

Priority EOC	Risk Quotient Max Influent	Minimum dilution at any site	Risk quotient marine receiving environment	Rank
17α-ethynylestradiol	2460.0	7920	0.3	1
Triclosan	496.5	7920	0.1	2
Estrone	375.0	7920	0.05	3
Monoethylhexyl phthalate acid ester	306.9	7920	0.04	4
Technical nonylphenol	276.8	7920	0.03	5
TCPP	274.6	7920	0.03	6
Diclofenac	231.4	7920	0.03	7
Ibuprofen	168.8	7920	0.02	8
Carbamazepine	158.8	7920	0.02	9
TBEP	140.2	7920	0.02	10
Naproxen	69.6	7920	0.01	11
Mestranol	45.5	7920	0.01	12
Galaxolide	9.2	7920	0.001	13
Dioxin like activity (TCDD EQ)	4.6	7920	0.001	14
TDCP	4.3	7920	0.001	15
Methyl-triclosan	4.0	7920	0.001	16
Monobutyl phthalate acid ester	3.8	7920	0.0005	17
Meclofenamic acid	1.9	7920	0.0002	18
Monoethyl phthalate acid ester	0.8	7920	0.0001	19
Ketoprofen	0.8	7920	0.0001	20
TCEP	0.5	7920	0.0001	21
DEET	0.2	7920	0.00002	22
Tonalide	NA	NA	NA	NA

3. Discussion

3.1 Potential for bioaccumulation

Although the risk assessment for EOCs in Section 2 suggests negligible ecological effects from each individual EOC to the marine receiving environment, there is still potential for bioaccumulation of some EOCs in marine species. However, the risk assessment is based on a conservative worst-case approach, using the minimum receiving environment dilution at any site.

A complication of assessing bioaccumulation of EOCs is that there is even less known about distribution of EOCs in biota than water and sediment. There are only a couple of EOC classes for which there are several reported analytical methods for measuring their concentrations in biota (Barceló, 2012). Methods have been reported for brominated flame retardants (BDEs) in fish, crab, mussels and oysters (Gao et al., 2009; Mizukawa et al., 2009; Xu et al., 2009). Methods have also been reported for per- and poly-fluoroalkyl substances (PFAS) in fish, mussels, oysters and macroalgae (Berger et al., 2009; Llorca et al., 2009; Schuetze et al., 2010; So et al., 2006; Taniyasu et al., 2003).

In New Zealand, capability for BDE and PFAS analysis in biota is provided by AsureQuality.

Bioaccumulation concentration factors (BCF) may be used to <u>estimate</u> potential bioaccumulation of EOCs in biota. US EPA[11] define a chemical with BCF <1000 as having a low bioconcentration potential. ECHA[12] define a chemical as fulfilling the bioaccumulation criterion when BCF >2000. Following the most conservative approach, a BCF >1000 was used to indicated potential for bioaccumulation in this assessment.

BCF for each priority EOC assessed in this report is provided in Table 10. Six EOCs have a BCF[13] value above the US EPA guide of 1,000 and so are expected to bioaccumulate: technical nonylphenol (26,580); galaxolide (19,002); tonalide (13,834); methyl-triclosan (9,161); triclosan (4,270); and mestranol (1,059). Sixteen EOCs are not expected to bioaccumulate, with BCF ranging from 1 to 515.

The potential for some EOCs to bioaccumulate highlights the importance of reducing the frequency of wastewater overflow events. As stated earlier, GDC's implementation of the Drainwise programme will reduce both the frequency (by around 5-fold) and volume (by between 3-fold and 12-fold at major Wainui and Peel Street overflows) of wet weather overflows substantially. Therefore, the proposed Drainwise programme will provide for reduced potential for bioaccumulation of EOCs from the current situation.

[11] US EPA Sustainable Futures / P2 Framework Manual 2012 EPA-748-B12-001 Chapter 5. Estimating Physical / Chemical and Environmental Fate Properties with EPI Suite™.

[12] ECHA Report. Guidance on Information Requirements and Chemical Safety Assessment Part C: PBT/vPvB assessment Version 3.0 June 2017.

[13] BCF is calculated at pH 5.5 and 7.4. pH 7.4 values were used here as these are closer to the pH of seawater.

Table 10. Estimated bioaccumulation concentration factor for priority EOCs

Priority EOC	BCF at pH 7.4	Greatest RQ (see Table 6)
Technical nonylphenol	26,580	0.09
Galaxolide	19,002	0.003
Tonalide	13,834	NA
Methyl-triclosan	9,161	0.001
Triclosan	4,270	0.2
Mestranol	1,059	0.01
17α-ethynylestradiol	515	0.8
TBEP	251	0.04
Estrone	216	0.1
TDCP	176	0.001
TCPP	34	0.09
DEET	29	0.0001
Meclofenamic acid	19	0.0006
TCEP	7	0.0002
Monoethylhexyl phthalate acid ester	2	0.10
Diclofenac	1.2	0.07
Naproxen	1.0	0.02
Ibuprofen	1.0	0.05
Ketoprofen	1.0	0.0003
Carbamazepine	1.0	0.05
Monoethyl phthalate acid ester	1.0	0.001
Monobutyl phthalate acid ester	1.0	0.0003

3.2 Human health risk

Human health risk of EOCs that are discharged to the receiving environment from wastewater can include consumption of aquatic species (where bioaccumulation of EOCs has occurred) and through ingestion of water contaminated with EOCs. These are discussed below.

3.2.1 Consumption of aquatic species

As stated in Section 3.1, some EOCs have the potential to accumulate in biota. However, for most of these there are not established analytical methods to measure them in biota. Furthermore, there is a large knowledge gap of potential human health effects of EOCs in biota from which to establish whether there is a risk from consumption of these species.

3.2.2 Drinking water

EOCs present in drinking water are a potential human health risk. However, these are largely agricultural derived pesticides. The National Survey of Pesticides in Groundwater has been running since 1990, with the recent survey (2018) including EOCs for the first time (Close and

Humphries, 2019). There were 279 wells sampled for a range of pesticides, with none exceeding applicable drinking water maximum acceptable values (MAV).

For wastewater derived EOCs in this report that may be present in drinking water, there are currently no World Health Organisation (WHO) drinking water guidelines (WHO, 2017).

As the wastewater discharge is to a coastal environment, drinking water aspects are not relevant. Furthermore, ingestion of water from contact recreation is likely a low risk due to the low volume of saline water that can be ingested.

4. Summary

Emerging organic contaminants (EOCs) present in overflows of untreated Gisborne wastewater have the potential to elicit adverse ecological effects in the marine receiving environment. The majority (18) of the prioritised EOCs exhibit a potential ecological risk from untreated wastewater overflows (risk quotient >1). Risk quotients of up to 2460 (17α-ethynylestradiol, maximum concentration) were calculated.

However, dilution by receiving environment water reduces the risk quotients of all EOCs to <1 within 6 hours of discharge, suggesting negligible effects. Furthermore, greater dilutions 24 hours and 48 hours after discharge will further reduce risk quotients, and associated risk.

However, there is still potential for bioaccumulation of some EOCs in marine species. Bioaccumulation concentration factors (BCF) may be used to estimate potential bioaccumulation of EOCs in biota, with a value >1,000 indicative of potential for bioaccumulation. Six EOCs have a BCF value above 1,000 and so are expected to bioaccumulate: technical nonylphenol (26,580); galaxolide (19,002); tonalide (13,834); methyl-triclosan (9,161); triclosan (4,270); and mestranol (1,059). Sixteen EOCs are not expected to bioaccumulate, with BCF < 1,000.

The potential for some EOCs to bioaccumulate highlights the importance of reducing the frequency and volume (around 3-fold to 12-fold) of wastewater overflow events. Therefore, the proposed Drainwise programme will provide for reduced potential for bioaccumulation of EOCs.

Even though some EOCs are expected to bioaccumulate there are no established analytical methods to measure them in biota and, there is a large knowledge gap of potential human health effects of EOCs in biota from which to establish whether there is a risk from consumption of these species.

EOCs present in drinking water are a potential human health risk. However, with a coastal discharge, drinking water is not of relevance to this study.

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