

Assessment of the presence of heavy metals in municipal wastewater in Aotearoa New Zealand

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EXECUTIVE SUMMARY

Municipal wastewaters contain a wide range of contaminants that may pose a hazard to human health where there is exposure to untreated or partially treated effluents (eg, during flooding events), or where these contaminants are not fully removed by treatment processes. Previous reports prepared for the Ministry of Health have identified several classes of contaminants of particular concern for human health present in municipal and industrial wastewaters, based largely on international data. The aim of this report is to provide an overview of what is known about the presence of contaminants from one of these classes, heavy metals, in effluents from municipal wastewater treatment plants (WWTPs) in New Zealand.

Heavy metals are metallic elements characterised by their high atomic weight and density. These elements are generally highly toxic, and many have been classified as known carcinogens. In this report, data primarily from wastewater treatment plant compliance monitoring reports was examined to identify effluent concentrations, consent limits and monitoring requirements for seven heavy metals of the most concern for human health based on published literature - arsenic, cadmium, chromium, lead, mercury, nickel and zinc.

Effluent concentration data was obtained for several WWTPs across New Zealand, including Blenheim, Christchurch, Hastings, Hāwera, Porirua and Wellington (both Moa Point and Seaview). Information on consent limits was not available for all locations, but for those sites with reported consent limits these often varied considerably between WWTPs. Similarly, the frequency of monitoring varied between different WWTPs with required monitoring periods for some heavy metals ranging from fortnightly to annually. Compliance requirements for heavy metals are currently regulated through the resource consenting process. Heavy metals are not included in the proposed new wastewater environmental performance standards set by the Water Service Authority – Taumata Arowai. However, they have noted that future wastewater standards will address heavy metals and until such time they will continue to be regulated through the resource consent process.

To determine whether the presence of the target heavy metals in municipal WWTP effluents are likely to pose a health risk during recreational usage of wastewater-impacted waterways, an exposure tool developed by Cressey (2023) was employed. Using the maximum effluent concentrations identified for the target heavy metals, with the exclusion of lead, it was estimated that the risk posed during a range of different water-based recreational activities (swimming, surfing, canoeing/kayaking, rowing, sailing and fishing) was within the tolerable, or acceptable, range. No risk estimation was able to be conducted for lead as no safe exposure level has been established.

The presence of heavy metals in effluents from municipal WWTPs in New Zealand indicates that the currently employed treatment processes are not removing all of these contaminants. Over 70% of the New Zealand population is serviced by WWTPs employing conventional activated sludge treatment processes. International data has shown that removal of heavy metals by these processes is highly variable. Several advanced treatment technologies for removal of heavy metals from wastewater exist but adoption of these technologies would require considerable prior assessment as many are still in their infancy.

1. INTRODUCTION

1.1 BACKGROUND

Municipal wastewaters contain a wide variety of chemical and biological contaminants, many of which may pose a potential hazard to human health. Exposure to these contaminants can occur through contact with untreated wastewaters (eg, during flooding events) or contaminated receiving environments (eg, surface waters, or land to which biosolids are applied) due to the contaminant being insufficiently removed by treatment processes.

Two recent reports prepared for the Ministry of Health highlighted the presence of several different classes of contaminants that may pose a hazard to human health in untreated municipal (Coxon & Eaton, 2023) and industrial wastewaters (Eaton, 2022) internationally. Based on these reports, certain classes were selected for in-depth analysis of their presence in, and removal from, municipal wastewater in New Zealand. The focus of this in-depth assessment is heavy metals, a group of potentially toxic elements which have been associated with a variety of adverse human health effects.

1.2 HEAVY METALS AS PRIORITY CONTAMINANTS

Heavy metals are naturally occurring metallic elements with high atomic weight and a density at least five times that of water (Tchounwou et al., 2012). These elements are found throughout the environment including in the air, water and soil (Tchounwou et al., 2012). There are two main routes by which heavy metals enter aquatic environments – naturally via sediment erosion and volcanic eruptions, and anthropogenically via mining, stormwater runoff and industrial effluents (Zia et al., 2020). Sources contributing to the presence of heavy metals in stormwater are discussed Coxon and Eaton (2023), and industries whose effluents have been associated with heavy metal contamination internationally are discussed in Eaton (2022).

Heavy metals have been associated with a range of adverse human health effects, and many have been classified by the International Agency for Research on Cancer (IARC) as “probable” or “known” carcinogens (Tchounwou et al., 2012). Heavy metals exert their toxic effects in a variety of ways including damage of cellular organelles, interference with enzyme function and induction of DNA damage (Tchounwou et al., 2012). The exact health effects of exposure vary depending on the metal. The reports of Eaton (2022) and Coxon and Eaton (2023) provide in-depth assessments of the potential human health impacts for a subset of heavy metals of the most concern for human health.

Heavy metals selected for inclusion in this report were those known to be of most concern for human health, as guided by Eaton (2022) and Coxon and Eaton (2023), and include arsenic (strictly a metalloid rather than a metal), cadmium, chromium, lead, mercury, nickel and zinc.

1.3 APPROACH AND SCOPE

The aim of this report is to assess the presence of the subset of heavy metals named above in municipal wastewater in New Zealand, and to provide an overview of what is known about the removal of these contaminants from wastewater by treatment processes currently employed in New Zealand.

This report will cover the following aspects:

- a) A review of grey and published literature (eg, scientific publications, technical reports, monitoring or consent-related sampling data) to identify information on the presence of the target heavy metals in effluents from municipal wastewater treatment plants (WWTPs) in New Zealand.
- b) Estimation of potential human health risks arising from recreational usage of aquatic environments to which municipal wastewater effluents are discharged, based on concentrations identified in a) and the exposure tool developed by Cressey (2023).
- c) A review of literature on the efficacy of conventional wastewater treatment processes in removal of the target heavy metals and brief overview of advanced treatment processes.

The following considerations are outside of the scope of the current review:

- The focus of this report is solely on the presence of heavy metals in municipal WWTP effluents discharged to aquatic receiving environments. There will be no specific consideration of industrial effluents, biosolids or land application of effluents.

2. HEAVY METALS IN MUNICIPAL WASTEWATER IN NEW ZEALAND

Municipal wastewaters are not noted to be a major source of heavy metals into aquatic environments in New Zealand (Zia et al., 2020). However, as some territorial authorities in New Zealand permit discharge of industrial effluents to the municipal wastewater network as trade waste, there is the potential for elevated heavy metal concentrations, which if not removed sufficiently by treatment processes may be discharged to aquatic receiving environments. Maximum permissible concentrations for heavy metals in trade waste are specified in the New Zealand Model General Bylaw Standard (NZS 9201:Part 23:2004) (Standards New Zealand, 2004). However, there are currently no standard consent limits for heavy metals in municipal wastewater in New Zealand. As such, acceptable concentration limits and monitoring requirements vary between different WWTPs. The new Water Services Authority, Taumata Arowai, has noted that heavy metals are not covered in their proposed new wastewater environmental performance standards and “will continue to be regulated through the existing resource consenting process, pending future wastewater standards that address them”¹.

2.1 APPROACH

To identify information on heavy metal concentrations in municipal wastewater in New Zealand, a series of approaches were employed to screen grey and published literature. Initially, the web of science database was screened using the key words “wastewater heavy metals New Zealand”. However, this failed to identify any suitable information. The same key words were then used in an online search for any relevant publicly available data. This identified some useful information, but it was mostly of a qualitative nature, with the exception of consent monitoring reports for the Diamond Harbour (Kaser, 2021b) and Akaroa wastewater treatment plants (Kaser, 2021a). Due to resource constraints, it was not possible to directly contact individual territorial authorities to directly obtain consent or monitoring data.

To identify information on heavy metal concentrations in treated wastewater from specific WWTPs in New Zealand, a more direct approach was taken. Firstly, the Water Services Authority Public Register of Wastewater Networks² was screened to identify all municipal networks servicing populations of 5,000 or greater. These are listed in the appendix, based on information available as of 17 March 2025. An iterative approach was then undertaken, whereby an online search of publicly available data with “[treatment plant name] wastewater treatment plant consent monitoring report” or “[treatment plant name] wastewater treatment plant compliance monitoring report” was performed. Results were then manually parsed to

¹ <https://www.taumataarowai.govt.nz/assets/Uploads/Wastewater-consultation/Discussion-document-National-wastewater-environmental-performance-standards-FINAL.pdf?vid=3> Accessed 17 March 2025

² <https://hinekorako.taumataarowai.govt.nz/publicregister/wastewater/> Accessed 24 March 2025

identify any relevant information on heavy metal concentrations in treated wastewater, consent limits and/or required monitoring periods. Information obtained is summarised in Tables 1 – 7.

In many cases, the form in which a given metal was quantified differs between different WWTPs, making it difficult to directly compare reported concentrations and limits. The different forms include “dissolved”, “acid soluble” and “total”, where dissolved refers to the amount of a given heavy metal ‘in solution’ in the wastewater sample and is measured from filtered samples³; acid soluble refers to the amount of heavy metal which can be measured after acid extraction of the wastewater sample (Kim et al., 2006); and total refers to all forms present in the sample – dissolved, acid soluble and acid insoluble forms.

2.2 ARSENIC

Based on the search parameters described above, arsenic concentrations in treated municipal wastewater were identified for 12 WWTPs across New Zealand, as summarised in Table 1. Consent limits were identified for four WWTPs – Moa Point (Cacnio, 2023), Nelson (Tasman District Council, 2020), Porirua (Vachova, 2024b) and Seaview (Villada, 2023). For Nelson, Moa Point and Porirua, limits were for total arsenic and ranged from 0.023 – 1.98 mg/l. For the Seaview WWTP the reported consent limit is 0.115 mg/l for dissolved arsenic. Required monitoring periods ranged from monthly to annually (Table 1). The highest reported concentration was 0.023 mg/l in wastewater from the Katikati WWTP (Brown, 2016).

2.3 CADMIUM

Using the approach detailed above, cadmium concentrations in treated effluents were identified for 14 municipal WWTPs across New Zealand (Table 2). Consent limits were reported for six WWTPs - Hastings (Wang & Cameron, 2022), Moa Point (Cacnio, 2023), Nelson (Tasman District Council, 2020), New Plymouth (Taranaki Regional Council, 2020a), Porirua (Vachova, 2024b) and Seaview (Villada, 2023). For Moa Point, Nelson and Porirua WWTPs, limits ranged from 0.039 – 0.08 mg/l for total cadmium. For Hastings and New Plymouth limits ranged from 0.04 – 0.07 mg/l for acid soluble cadmium. For Seaview WWTP, dissolved cadmium was measured, with a limit of 0.035 mg/l. Required monitoring periods ranged from monthly to annually. The highest reported concentration was 0.019 mg/l in treated effluent from the Akaroa WWTP in 2017 (Kaser, 2021a). The monitored form (eg, dissolved, acid soluble or total cadmium) was not specified.

³ <https://www.flowlink.ca/post/2018/12/15/dissolved-total-metals-whats-the-difference-and-why-it-matters> Accessed 24 March 2025

Table 1 Arsenic concentrations detected in treated municipal wastewater from selected wastewater treatment plants in New Zealand

Location	Required monitoring period	Consent limit (mg/l)	Sample date	Concentration (mg/l)	Form	Reference
Blenheim	Annually		Jan 2020	0.004	Total	Jenner (2022)
			Jan 2021	0.006		
			Jan 2022	< 0.021		
Christchurch	Six monthly		July 2022	0.0000026		Huang and Irvine (2023)
			Oct 2022	0.000003		
			Jan 2023	0.0000053		
			April 2023	0.000002		
			July 2023	0.0000026		
Diamond Harbour	Annually		Jan 2016	< 0.0015		Kaser (2021b)
			Jan 2017	0.001		
			Jan 2018	0.0015		
			Jan 2019	0.0013		
			Jan 2020	0.0012		
			Jan 2021	< 0.001		

Location	Required monitoring period	Consent limit (mg/l)	Sample date	Concentration (mg/l)	Form	Reference
Dunedin (Tahuna)	Six monthly ^a		Aug 2013 – Feb 2016 (n = 6)	< 0.001 – 0.003		Golder Associates (2016)
Hastings (East Clive)	Quarterly: acid soluble Annually: total, dissolved and acid soluble		May 2022	0.0023 – 0.0025	Dissolved	Wang and Cameron (2022)
				0.0022 – 0.003	Acid soluble	
				0.005 – 0.0052	Total	
			Aug 2022	0.003	Acid soluble	Mothelesi (2023)
			Oct 2022	0.005		
			Feb/Mar 2023	0.009		
			May 2023	0.003		
Hāwera	Twice annually		Sep 2019	< 0.0011		Taranaki Regional Council (2021)
			Mar 2020	< 0.0011		
			Oct 2021	< 0.0011		Taranaki Regional Council (2023a)
			Mar 2022	< 0.0011		
			Sep 2022	< 0.011		Taranaki Regional Council (2024b)
			Apr 2023	< 0.011		

Location	Required monitoring period	Consent limit (mg/l)	Sample date	Concentration (mg/l)	Form	Reference
Katikati	Quarterly		2010 – 2015	< 0.005 – 0.023		Brown (2016)
Māngere			Aug 2021	0.0017		Hurrisunker (2022)
Moa Point	Quarterly	0.26	July 2022	0.0017	Total	Cacnio (2023)
			Oct 2022	0.001		
			Jan 2023	0.002		
			Apr 2023	0.002		Shuttleworth (2024)
			Jan 2024	0.002		
			July 2024	0.002		
			Oct 2024	0.002		
Nelson	Annually	1.98			Total	Tasman District Council (2020)
Porirua	Monthly	0.023	Jan 2024	0.002	Total	Vachova (2024b)
			Feb 2024	0.002		
			Mar 2024	0.002		

Location	Required monitoring period	Consent limit (mg/l)	Sample date	Concentration (mg/l)	Form	Reference
Porirua	Monthly	0.023	Apr 2024	0.002	Total	Vachova (2024a)
			May 2024	0.002		
			June 2024	0.002		
			July 2024	0.002		Murphy (2024)
			Aug 2024	0.004		
			Sep 2024	0.002		
			Oct 2024	0.002		Murphy (2025b)
			Nov 2024	0.002		
			Dec 2024	0.002		
Rosedale			2016 – 2020	0.0018 (average)		Hurrisunker (2022)
Seaview	Monthly	0.115	Jan 2023	0.0017	Dissolved	Villada (2023)
			Feb 2023	0.002		
			Mar 2023	0.002		

^aRecommended to be removed from schedule by Golder Associates (2016). Grey shading indicates data not identified. All values converted to mg/l.



Assessment of the presence of heavy metals in municipal wastewater in Aotearoa New Zealand

Table 2 Cadmium concentrations detected in treated municipal wastewater from selected wastewater treatment plants in New Zealand

Location	Required monitoring period	Consent limit (mg/l)	Sample date	Concentration (mg/l)	Form	Reference
Akaroa	Annually		Jan 2016	< 0.0002		Kaser (2021a)
			Jan 2017	0.019		
			Jan 2018	0.001		
			Jan 2019	< 0.001		
			Jan 2020	< 0.001		
			Jan 2021	< 0.001		
Blenheim	Annually		Jan 2020	0.00005	Total	Jenner (2022)
			Jan 2021	Not detected		
			Jan 2022	< 0.0011		
Christchurch	Six monthly		July 2022	< 0.000001		Huang and Irvine (2023)
			Oct 2022	< 0.000001		
			Jan 2023	< 0.000001		
			April 2023	< 0.000001		
			July 2023	< 0.000001		

Location	Required monitoring period	Consent limit (mg/l)	Sample date	Concentration (mg/l)	Form	Reference
Diamond Harbour	Annually		Jan 2016	< 0.0002		Kaser (2021b)
			Jan 2017	< 0.01		
			Jan 2018	< 0.01		
			Jan 2019	< 0.01		
			Jan 2020	< 0.01		
			Jan 2021	< 0.01		
Hastings (East Clive)		0.07	May 2022	0.000049	Dissolved	Wang and Cameron (2022)
				0.00006	Acid soluble	
				0.000084 – 0.00012	Total	
			Aug 2022	< 0.01	Acid soluble	Mothelesi (2023)
			Oct 2022	< 0.01		
			Feb/Mar 2023	< 0.01		
			May 2023	< 0.01		

Location	Required monitoring period	Consent limit (mg/l)	Sample date	Concentration (mg/l)	Form	Reference
Hawera	Twice annually		Sep 2019	< 0.001		Taranaki Regional Council (2021)
			Mar 2020	< 0.001		
			Oct 2021	< 0.001		Taranaki Regional Council (2023a)
			Mar 2022	< 0.001		
			Sep 2022	< 0.001		Taranaki Regional Council (2024b)
			Apr 2023	< 0.001		
Katikati	Quarterly		2010 – 2015	< 0.001 – < 0.002		Brown (2016)
Māngere			Aug 2021	< 0.00005		Hurrisunker (2022)
Moa Point	Quarterly	0.08	July 2022	0.0001	Total	Cacnio (2023)
			Oct 2022	0.00025		
			Jan 2023	0.001		
			Apr 2023	0.001		
			Jan 2024	0.001		Shuttleworth (2024)
			July 2024	0.001		Murphy and La Riviere (2024)
			Oct 2024	0.001		Murphy (2025a)

Location	Required monitoring period	Consent limit (mg/l)	Sample date	Concentration (mg/l)	Form	Reference
Nelson	Annually	0.039			Total	Tasman District Council (2020)
New Plymouth	Biannually	0.04	Dec 2019	< 0.001	Acid soluble	Taranaki Regional Council (2020a)
			Jun 2020	< 0.001		
			Dec 2022	< 0.001		Taranaki Regional Council (2024a)
			Mar 2023	< 0.001		
Porirua	Monthly	0.055	Jan 2024	0.001	Total	Vachova (2024b)
			Feb 2024	0.001		
			Mar 2024	0.001		
			Apr 2024	0.001		Vachova (2024a)
			May 2024	0.001		
			June 2024	0.001		
			July 2024	0.001		
			Aug 2024	0.001		
			Sep 2024	0.001		Murphy (2024)

Location	Required monitoring period	Consent limit (mg/l)	Sample date	Concentration (mg/l)	Form	Reference
Porirua	Monthly	0.055	Oct 2024	0.001	Total	Murphy (2025b)
			Nov 2024	0.001		
			Dec 2024	0.001		
Rosedale			2016 – 2020	0.00022 (average)		Hurrisunker (2022)
Seaview	Monthly	0.035	Jan 2023	0.0002	Dissolved	Villada (2023)
			Feb 2023	0.0002		
			Mar 2023	0.0002		
Stratford	Annually		2009 - 2017	< 0.005 – 0.005	Acid soluble	Taranaki Regional Council (2018)
			Mar 2018	< 0.005		
			Jan 2019	< 0.001		Taranaki Regional Council (2020b)
			Feb 2021	< 0.001		Taranaki Regional Council (2022)
			Jan 2022	< 0.001		Taranaki Regional Council (2023b)
			Feb 2023	< 0.001		Taranaki Regional Council (2024c)
			Jan 2024	< 0.001		Taranaki Regional Council (2025)

Grey shading indicates data not identified. All values converted to mg/l.

2.4 CHROMIUM

Using the iterative search approach detailed above, chromium concentrations in treated wastewater were identified for 13 WWTPs across New Zealand (Table 3). Concentration limits were noted for five WWTPs – Hastings (Mothelesi, 2023; Wang & Cameron, 2022), Moa Point (Cacnio, 2023), Nelson (Tasman District Council, 2020), New Plymouth (Taranaki Regional Council, 2020a), Porirua (Vachova, 2024b) and Seaview (Villada, 2023). For the Hastings WWTP, separate limits exist for acid soluble chromium (III) (2.74 mg/l) and chromium (VI) (0.44 mg/l) (Mothelesi, 2023). For New Plymouth WWTP, there is a maximum permissible limit of 0.15 mg/l for acid soluble chromium. For Moa Point, Nelson and Porirua WWTPs, the consent limits are 0.48, 0.24 and 0.044 mg/l total chromium respectively. For Seaview WWTP, the reported concentration limit is 0.22 mg/l for dissolved chromium. Required monitoring periods range from fortnightly to annually. The highest concentration reported was 0.0167 mg/l acid soluble chromium in treated effluent from the Hastings WWTP in 2022. With respect to the two main oxidation states of chromium, chromium (III) levels were highest in treated effluents from the Hastings WWTP in 2023 and chromium (VI) levels were highest in effluents from the same WWTP in 2022 (0.098 and 0.009 mg/l acid soluble chromium respectively).

2.5 LEAD

Lead concentrations in treated municipal WWTP effluents were identified for 13 WWTPs across NZ (Table 4). Concentration limits were reported for six sites – Nelson (Tasman District Council, 2020), Hastings (Mothelesi, 2023), Moa Point (Cacnio, 2023), New Plymouth (Taranaki Regional Council, 2020a), Porirua (Vachova, 2024b) and Seaview (Villada, 2023) WWTPs. With respect to total lead, limits of 0.044, 0.24 and 0.48 mg/l were reported for Porirua, Nelson and Moa Point WWTPs respectively. In contrast, New Plymouth and Hastings WWTPs have limits for acid soluble lead of 0.1 and 0.44 mg/l respectively. For Seaview WWTP, there is a maximum permitted concentration of dissolved lead of 0.22 mg/l.

The maximum concentration identified was in effluent from the New Plymouth WWTP in 2019, with a concentration of 0.02 mg/l acid soluble lead (Taranaki Regional Council, 2020a).

Table 3 Chromium concentrations detected in treated municipal wastewater from selected wastewater treatment plants in New Zealand

Location	Required monitoring period	Consent limit (mg/l)	Sample date	Concentration (mg/l)	Form	Reference
Akaroa	Annually		Jan 2016	< 0.001		Kaser (2021a)
			Jan 2017	0.0024		
			Jan 2018	0.001		
			Jan 2019	< 0.001		
			Jan 2020	< 0.001		
			Jan 2021	< 0.001		
Blenheim	Annually		Jan 2020	0.003	Total	Jenner (2022)
			Jan 2021	0.003		
			Jan 2022	< 0.011		
Christchurch	Six monthly		July 2022	0.000002		Huang and Irvine (2023)
			Oct 2022	0.0000022		
			Jan 2023	0.000003		
			April 2023	0.0000028		
			July 2023	0.0000051		

Location	Required monitoring period	Consent limit (mg/l)	Sample date	Concentration (mg/l)	Form	Reference
Diamond Harbour	Annually		Jan 2016	< 0.001		Kaser (2021b)
			Jan 2017	< 0.001		
			Jan 2018	< 0.001		
			Jan 2019	< 0.001		
			Jan 2020	0.0013		
			Jan 2021	< 0.001		
Dunedin	Fortnightly ^a Cr (VI); Cr (III) measured but no values given		2012-2016	Not detected		Golder Associates (2016)
Hastings (East Clive)	Quarterly: acid soluble Annually: total, dissolved and acid soluble	Cr (III): 2.74 Cr (VI): 0.44	May 2022	0.0062 – 0.0093	Dissolved	Wang and Cameron (2022)
				0.0093 – 0.0167	Acid soluble	
				0.029 – 0.057	Total	
				0.009	Cr (VI)	
		2.74	Aug 2022	0.038	Acid soluble Cr (III)	Mothelesi (2023)
			Oct 2022	0.066		
			Feb/Mar 2023	0.026		
			May 2023	0.098		

Location	Required monitoring period	Consent limit (mg/l)	Sample date	Concentration (mg/l)	Form	Reference
Hastings (East Clive)	Quarterly: acid soluble Annually: total, dissolved and acid soluble	0.44	Aug 2022	< 0.001	Acid soluble Cr (VI)	Mothelesi (2023)
			Oct 2022	< 0.001		
			Feb/Mar 2023	< 0.001		
			May 2023	0.01		
Hāwera	Twice annually		Sep 2019	< 0.01		Taranaki Regional Council (2021)
			Mar 2020	< 0.01		
			Oct 2021	< 0.01		Taranaki Regional Council (2023a)
			Mar 2022	< 0.01		
			Sep 2022	< 0.01		Taranaki Regional Council (2024b)
			Apr 2023	< 0.01		
Katikati	Quarterly		2010 – 2015	< 0.001 – 0.002		Brown (2016)

Location	Required monitoring period	Consent limit (mg/l)	Sample date	Concentration (mg/l)	Form	Reference
Moa Point	Quarterly	0.48	July 2022	0.001	Total	Cacnio (2023)
			Oct 2022	0.0025		
			Jan 2023	0.001		
			Apr 2023	0.001		Shuttleworth (2024) Murphy and La Riviere (2024) Murphy (2025a)
			Jan 2024	0.002		
			July 2024	0.001		
			Oct 2024	0.001		
Nelson	Annually	0.24			Total	Tasman District Council (2020)
New Plymouth	Biannually	0.15	Dec 2019	< 0.01	Acid soluble	Taranaki Regional Council (2020a)
			Jun 2020	< 0.005		
			Dec 2022	< 0.005		Taranaki Regional Council (2024a)
			Mar 2023	< 0.005		

Location	Required monitoring period	Consent limit (mg/l)	Sample date	Concentration (mg/l)	Form	Reference
Porirua	Monthly	0.044	Jan 2024	0.001	Total	Vachova (2024b)
			Feb 2024	0.001		
			Mar 2024	0.002		
			Apr 2024	0.001		Vachova (2024a)
			May 2024	0.001		
			June 2024	0.001		
			July 2024	0.002	Total	Murphy (2024)
			Aug 2024	0.002		
			Sep 2024	0.002		
			Oct 2024	0.002		Murphy (2025b)
			Nov 2024	0.001		
			Dec 2024	0.002		
Seaview	Monthly	0.22	Jan 2023	0.001	Dissolved	Villada (2023)
			Feb 2023	0.002		
			Mar 2023	0.001		

Location	Required monitoring period	Consent limit (mg/l)	Sample date	Concentration (mg/l)	Form	Reference
Stratford	Annually		2009 - 2017	< 0.03 – 0.03	Acid soluble	Taranaki Regional Council (2018)
			Mar 2018	< 0.03		
			Jan 2019	< 0.01		Taranaki Regional Council (2020b)
			Feb 2021	< 0.01		Taranaki Regional Council (2022)
			Jan 2022	< 0.01		Taranaki Regional Council (2023b)
			Feb 2023	< 0.01		Taranaki Regional Council (2024c)
			Jan 2024	< 0.01		Taranaki Regional Council (2025)

^aRecommended by Golder Associates (2016) to measure total chromium. Grey shading indicates data not identified. All values converted to mg/l.

Table 4 Lead concentrations detected in treated municipal wastewater from selected wastewater treatment plants in New Zealand

Location	Required monitoring period	Consent limit (mg/l)	Sample date	Concentration (mg/l)	Form	Reference
Akaroa	Annually		Jan 2016	< 0.0015		Kaser (2021a)
			Jan 2017	0.0033		
			Jan 2018	0.001		
			Jan 2019	0.001		
			Jan 2020	< 0.001		
			Jan 2021	< 0.001		
Blenheim	Annually		Jan 2020	0.00057	Total	Jenner (2022)
			Jan 2021	0.0004		
			Jan 2022	< 0.0021		
Christchurch	Six monthly		July 2022	< 0.000001		Huang and Irvine (2023)
			Oct 2022	< 0.000001		
			Jan 2023	< 0.000001		
			April 2023	< 0.000001		
			July 2023	< 0.000001		

Location	Required monitoring period	Consent limit (mg/l)	Sample date	Concentration (mg/l)	Form	Reference
Diamond Harbour	Annually		Jan 2016	< 0.0015		Kaser (2021b)
			Jan 2017	< 0.001		
			Jan 2018	< 0.001		
			Jan 2019	< 0.001		
			Jan 2020	0.0014		
			Jan 2021	< 0.001		
Hastings (East Clive)	Quarterly: acid soluble Annually: total, dissolved and acid soluble	0.44	May 2022	0.00015 – 0.00045	Dissolved	Wang and Cameron (2022)
				0.00158 – 0.0017	Acid soluble	
				0.0024 – 0.0026	Total	
			Aug 2022	0.0028	Acid soluble	Mothelesi (2023)
			Oct 2022	0.0019		
			Feb/Mar 2023	0.003		
			May 2023	0.0027		

Location	Required monitoring period	Consent limit (mg/l)	Sample date	Concentration (mg/l)	Form	Reference
Hāwera	Twice annually		Sep 2019	< 0.002		Taranaki Regional Council (2021)
			Mar 2020	< 0.002		
			Oct 2021	< 0.002		Taranaki Regional Council (2023a)
			Mar 2022	< 0.002		
			Sep 2022	< 0.002		Taranaki Regional Council (2024b)
			Apr 2023	< 0.002		
Katikati	Quarterly		2010–2015	< 0.001 – < 0.002		Brown (2016)
Māngere			Aug 2021	0.00028		Hurrisunker (2022)
Moa Point	Quarterly	0.48	July 2022	0.00042	Total	Cacnio (2023)
			Oct 2022	0.00081		
			Jan 2023	0.001		
			Apr 2023	0.001		
			Jan 2024	0.001		Shuttleworth (2024)
			July 2024	0.001		Murphy and La Riviere (2024)
			Oct 2024	0.001		Murphy (2025a)

Location	Required monitoring period	Consent limit (mg/l)	Sample date	Concentration (mg/l)	Form	Reference
Nelson	Annually	0.24			Total	Tasman District Council (2020)
New Plymouth	Biannually	0.1	Dec 2019	0.02	Acid soluble	Taranaki Regional Council (2020a)
			Jun 2020	< 0.002		
			Dec 2022	< 0.002		Taranaki Regional Council (2024a)
			Mar 2023	0.002		
Porirua	Monthly	0.044	Jan 2024	0.001	Total	Vachova (2024b)
			Feb 2024	0.001		
			Mar 2024	0.001		
			Apr 2024	0.001		
			May 2024	0.001		Vachova (2024a)
			June 2024	0.001		
			July 2024	0.001		
			Aug 2024	0.001		
			Sep 2024	0.001		Murphy (2024)

Location	Required monitoring period	Consent limit (mg/l)	Sample date	Concentration (mg/l)	Form	Reference
Porirua	Monthly	0.044	Oct 2024	0.001	Total	Murphy (2025b)
			Nov 2024	0.001		
			Dec 2024	0.001		
Rosedale			2016–2020	0.00044 (average)		Hurrisunker (2022)
Seaview	Monthly	0.22	Jan 2023	0.0013	Dissolved	Villada (2023)
			Feb 2023	0.0013		
			Mar 2023	0.0008		

Grey shading indicates data not identified. All values converted to mg/l.

2.6 MERCURY

Mercury concentrations in treated municipal WWTP effluents were identified for nine sites across New Zealand (Table 5). Concentration limits were identified for six sites – Hastings (Mothelesi, 2023), Moa Point (Cacnio, 2023), Nelson (Tasman District Council, 2020), New Plymouth (Taranaki Regional Council, 2024a), Porirua (Vachova, 2024b) and Seaview (Villada, 2023) WWTPs. For Moa Point and Porirua WWTPs, the limits were for total mercury and were set at 0.01 and 0.001 mg/l respectively. For Hastings and New Plymouth WWTPs limits were for acid soluble mercury and were set at 0.01 and 0.002 mg/l respectively. For Seaview WWTP the maximum permissible concentration of mercury in treated effluents was 0.005 mg/l dissolved mercury. For Nelson the limit was set at 0.006 mg/l for inorganic mercury (Tasman District Council, 2020). Required monitoring periods ranged from monthly to annually. The maximum reported concentration of mercury in treated WWTP effluents was 0.001 mg/l which was reported for several of the WWTPs.

2.7 NICKEL

Nickel concentrations in treated municipal WWTP effluents were identified for 12 sites across New Zealand (Table 6). Concentration limits were identified for six sites – Hastings (Mothelesi, 2023), Moa Point (Cacnio, 2023), Nelson (Tasman District Council, 2020), New Plymouth (Taranaki Regional Council, 2024a), Porirua (Vachova, 2024b) and Seaview (Villada, 2023) WWTPs. For Moa Point, Nelson and Porirua WWTPs, the limits were for total nickel and were set at 0.77, 0.39 and 0.07 mg/l respectively. For Hastings and New Plymouth WWTPs limits were for acid soluble nickel and were set at 0.7 and 0.15 mg/l respectively. For Seaview WWTP, the limit is set at 0.35 mg/l dissolved nickel. Required monitoring periods ranged from monthly to annually. The maximum reported concentration of nickel in treated WWTP effluents was 0.02 mg/l total nickel detected in treated effluent from the Porirua WWTP in 2024 (Vachova, 2024b).

Table 5 Mercury concentrations detected in treated municipal wastewater from selected wastewater treatment plants in New Zealand

Location	Required monitoring period	Consent limit (mg/l)	Sample date	Concentration (mg/l)	Form	Reference
Christchurch	Six monthly		July 2022	< 0.00000005		Huang and Irvine (2023)
			Oct 2022	< 0.00000005		
			Jan 2023	< 0.00000005		
			April 2023	< 0.00000005		
			July 2023	< 0.00000005		
Dunedin	Six monthly		Aug 2013 – Feb 2016	< 0.00008 – 0.00013		Golder Associates (2016)
Hastings (East Clive)	Quarterly: acid soluble Annually: total, dissolved and acid soluble	0.01	May 2022	0.000079	Dissolved	Wang and Cameron (2022)
				0.000079	Acid soluble	
				0.000079	Total	
			Aug 2022	< 0.00008	Acid soluble	Mothelesi (2023)
			Oct 2022	< 0.00008		
			Feb/Mar 2023	< 0.00008		
			May 2023	< 0.00008		

Location	Required monitoring period	Consent limit (mg/l)	Sample date	Concentration (mg/l)	Form	Reference
Hāwera	Twice annually		Sep 2019	< 0.0008		Taranaki Regional Council (2021)
			Mar 2020	< 0.0008		
			Oct 2021	< 0.00008		Taranaki Regional Council (2023a)
			Mar 2022	< 0.00008		
			Sep 2022	0.0002		Taranaki Regional Council (2024b)
			Apr 2023	< 0.00008		
Katikati	Quarterly		2010 – 2015	< 0.001		Brown (2016)
Moa Point	Quarterly	0.01	July 2022	0.0001	Total	Cacnio (2023)
			Oct 2022	0.00025		
			Jan 2023	0.001		
			Apr 2023	0.001		
			Jan 2024	0.001		Shuttleworth (2024)
			July 2024	0.001		Murphy and La Riviere (2024)
			Oct 2024	0.001		Murphy (2025a)

Location	Required monitoring period	Consent limit (mg/l)	Sample date	Concentration (mg/l)	Form	Reference
Nelson	Annually	0.006			Inorganic mercury	Tasman District Council (2020)
New Plymouth	Biannually	0.002	Dec 2019	< 0.00008	Acid soluble	Taranaki Regional Council (2020a)
			Jun 2020	< 0.00008		
			Dec 2022	< 0.00008		Taranaki Regional Council (2024a)
			Mar 2023	< 0.00008		
Porirua	Monthly	0.001	Jan 2024	0.001	Total	Vachova (2024b)
			Feb 2024	0.001		
			Mar 2024	0.001		
			Apr 2024	0.001		Vachova (2024a)
			May 2024	0.001		
			June 2024	0.001		
			July 2024	0.001		
			Aug 2024	0.001		Murphy (2024)
			Sep 2024	0.001		

Location	Required monitoring period	Consent limit (mg/l)	Sample date	Concentration (mg/l)	Form	Reference
Porirua	Monthly	0.001	Oct 2024	0.001	Total	Murphy (2025b)
			Nov 2024	0.001		
			Dec 2024	0.0001		
Seaview	Monthly	0.005	Jan 2023	0.0005	Dissolved	Villada (2023)
			Feb 2023	0.0005		
			Mar 2023	0.0005		

Grey shading indicates data not identified. All values converted to mg/l.

Table 6 Nickel concentrations detected in treated municipal wastewater from selected wastewater treatment plants in New Zealand

Location	Required monitoring period	Consent limit (mg/l)	Sample date	Concentration (mg/l)	Form	Reference
Blenheim	Annually		Jan 2020	0.002	Total	Jenner (2022)
			Jan 2021	0.002		
			Jan 2022	< 0.011		
Christchurch	Six monthly		July 2022	0.000002		Huang and Irvine (2023)
			Oct 2022	0.0000043		
			Jan 2023	0.000035		
			April 2023	0.000014		
			July 2023	0.000002		
Diamond Harbour	Annually		Jan 2016	< 0.0025		Kaser (2021b)
			Jan 2017	< 0.001		
			Jan 2018	0.0012		
			Jan 2019	< 0.001		
			Jan 2020	0.0015		
			Jan 2021	0.0011		

Location	Required monitoring period	Consent limit (mg/l)	Sample date	Concentration (mg/l)	Form	Reference
Hastings (East Clive)	Quarterly: acid soluble Annually: total, dissolved and acid soluble	0.7	May 2022	0.0036 – 0.0039	Dissolved	Wang and Cameron (2022)
				0.0055 – 0.0059	Acid soluble	
				0.0069 – 0.008	Total	
			Aug 2022	0.005	Acid soluble	Mothelesi (2023)
			Oct 2022	0.005		
			Feb/Mar 2023	0.0045		
			May 2023	0.0052		
Hāwera	Twice annually		Sep 2019	< 0.01		Taranaki Regional Council (2021)
			Mar 2020	< 0.01		Taranaki Regional Council (2023a)
			Oct 2021	< 0.01		
			Mar 2022	< 0.01		
			Sep 2022	< 0.01		Taranaki Regional Council (2024b)
			Apr 2023	< 0.01		
Katikati	Quarterly		2010 – 2015	< 0.001 – 0.006		Brown (2016)

Location	Required monitoring period	Consent limit (mg/l)	Sample date	Concentration (mg/l)	Form	Reference
Māngere			Aug 2021	0.0078		Hurrisunker (2022)
Moa Point	Quarterly	0.77	July 2022	0.0011	Total	Cacnio (2023)
			Oct 2022	0.0005		
			Jan 2023	0.001		
			Apr 2023	0.001		Shuttleworth (2024) Murphy and La Riviere (2024) Murphy (2025a)
			Jan 2024	0.002		
			July 2024	0.001		
			Oct 2024	0.001		
Nelson	Annually	0.39			Total	Tasman District Council (2020)
New Plymouth	Biannually	0.15	Dec 2019	< 0.01	Acid soluble	Taranaki Regional Council (2020a)
			Jun 2020	< 0.005		
			Dec 2022	< 0.005		Taranaki Regional Council (2024a)
			Mar 2023	< 0.005		

Location	Required monitoring period	Consent limit (mg/l)	Sample date	Concentration (mg/l)	Form	Reference
Porirua	Monthly	0.07	Jan 2024	0.018	Total	Vachova (2024b)
			Feb 2024	0.02		
			Mar 2024	0.001		
			Apr 2024	0.001		Vachova (2024a)
			May 2024	0.001		
			June 2024	0.001		
			July 2024	0.001		Murphy (2024)
			Aug 2024	0.001		
			Sep 2024	0.001		
			Oct 2024	0.001		Murphy (2025b)
			Nov 2024	0.001		
			Dec 2024	0.001		

Location	Required monitoring period	Consent limit (mg/l)	Sample date	Concentration (mg/l)	Form	Reference
Rosedale			2016–2020	0.0037 (average)		Hurrisunker (2022)
Seaview	Monthly	0.35	Jan 2023	0.012	Dissolved	Villada (2023)
			Feb 2023	0.012		
			Mar 2023	0.007		

Grey shading indicates data not identified. Values converted to mg/l.

2.8 ZINC

Zinc concentrations in treated municipal WWTP effluents were identified for 15 sites across New Zealand (Table 7). Concentration limits were identified for six sites – Hastings (Mothelesi, 2023), Moa Point (Cacnio, 2023), Nelson (Tasman District Council, 2020), New Plymouth (Taranaki Regional Council, 2024a), Porirua (Vachova, 2024b) and Seaview (Villada, 2023) WWTPs. For Moa Point, Nelson and Porirua WWTPs, the limits were for total zinc and were set at 1.65, 0.83 and 0.08 mg/l respectively. For Hastings and New Plymouth WWTPs limits were for acid soluble zinc and were set at 1.5 and 0.2 mg/l respectively. For Seaview WWTP, the limit is set at 0.75 mg/l dissolved zinc. Required monitoring periods ranged from fortnightly to annually. The maximum reported concentration of zinc in treated WWTP effluents was 0.42 mg/l acid soluble zinc detected in treated effluent from the Hastings WWTP in 2023 (Mothelesi, 2023).

Table 7 Zinc concentrations detected in treated municipal wastewater from selected wastewater treatment plants in New Zealand

Location	Required monitoring period	Consent limit (mg/l)	Sample date	Concentration (mg/l)	Form	Reference
Akaroa	Annually		Jan 2016	0.045		Kaser (2021a)
			Jan 2017	0.095		
			Jan 2018	0.042		
			Jan 2019	0.063		
			Jan 2020	0.048		
			Jan 2021	0.057		
Blenheim	Annually		Jan 2020	0.007	Total	Jenner (2022)
			Jan 2021	0.005		
			Jan 2022	< 0.021		
Christchurch	Six monthly		July 2022	0.000031		Huang and Irvine (2023)
			Oct 2022	0.000014		
			Jan 2023	0.000013		
			April 2023	0.000009		
			July 2023	0.000017		
Diamond Harbour	Annually		Jan 2016	0.025		Kaser (2021b)
			Jan 2017	0.02		
			Jan 2018	0.047		
			Jan 2019	0.025		
			Jan 2020	0.069		

Location	Required monitoring period	Consent limit (mg/l)	Sample date	Concentration (mg/l)	Form	Reference
Diamond Harbour	Annually		Jan 2021	0.031		Kaser (2021b)
Dunedin (Tahuna)	Fortnightly		2012 – 2016 (n = 90)	0.0015 – 0.81		Golder Associates (2016)
Hastings (East Clive)	Quarterly: acid soluble Annually: total, dissolved and acid soluble	1.5	May 2022	0.021 – 0.043	Dissolved	Wang and Cameron (2022)
				0.11 – 0.12	Acid soluble	
				0.176 – 0.18	Total	
			Aug 2022	0.099	Acid soluble	Mothelesi (2023)
			Oct 2022	0.159		
			Feb/Mar 2023	0.115		
			May 2023	0.42		
Hāwera	Twice annually		Sep 2019	0.02		Taranaki Regional Council (2021)
			Mar 2020	0.03		Taranaki Regional Council (2023a)
			Oct 2021	0.04		
			Mar 2022	0.03		Taranaki Regional Council (2024b)
			Sep 2022	0.02		
			Apr 2023	0.02		
Katikati	Quarterly		2010 – 2015	< 0.005 – 0.023		Brown (2016)
Māngere			Aug 2021	0.051		Hurrisunker (2022)

Location	Required monitoring period	Consent limit (mg/l)	Sample date	Concentration (mg/l)	Form	Reference
Moa Point	Quarterly	1.65	July 2022	0.029	Total	Cacnio (2023)
			Oct 2022	0.03		
			Jan 2023	0.029		
			Apr 2023	0.02		
			Jan 2024	0.027		Shuttleworth (2024)
			July 2024	0.02		Murphy and La Riviere (2024)
			Oct 2024	0.022		Murphy (2025a)
Nelson	Annually	0.83			Total	Tasman District Council (2020)
New Plymouth	Biannually	0.2	Dec 2019	0.05	Acid soluble	Taranaki Regional Council (2020a)
			Jun 2020	0.04		
			Dec 2022	0.02		Taranaki Regional Council (2024a)
			Mar 2023	< 0.05		

Location	Required monitoring period	Consent limit (mg/l)	Sample date	Concentration (mg/l)	Form	Reference
Porirua	Monthly	0.08	Jan 2024	0.001	Total	Vachova (2024b)
			Feb 2024	0.001		
			Mar 2024	0.021		
			Apr 2024	0.019		Vachova (2024a)
			May 2024	0.019		
			June 2024	0.016		
			July 2024	0.023		Murphy (2024)
			Aug 2024	0.016		
			Sep 2024	0.005		
			Oct 2024	0.016		Murphy (2025b)
			Nov 2024	0.016		
			Dec 2024	0.017		
Rosedale			2016 – 2020	0.030 (average)		Hurrisunker (2022)
Seaview	Monthly	0.75	Jan 2023	0.0005	Dissolved	Villada (2023)
			Feb 2023	0.0005		
			Mar 2023	0.0005		

Location	Required monitoring period	Consent limit (mg/l)	Sample date	Concentration (mg/l)	Form	Reference
Stratford	Annually		2009 - 2017	0.008 – 0.035	Acid soluble	Taranaki Regional Council (2018)
			Mar 2018	0.007		
			Jan 2019	< 0.02		Taranaki Regional Council (2020b)
			Feb 2021	< 0.02		Taranaki Regional Council (2022)
			Jan 2022	< 0.02		Taranaki Regional Council (2023b)
			Feb 2023	0.02		Taranaki Regional Council (2024c)
			Jan 2024	< 0.02		Taranaki Regional Council (2025)

Grey shading indicates data not identified. All values converted to mg/l.

3. RISK ESTIMATION

The presence of heavy metals in WWTP effluents (or the discharge of untreated/incompletely treated wastewater) will ultimately lead to the presence of these chemicals in receiving environments (eg, rivers, marine environments, land to which effluents are applied). Whether or not this poses a hazard to human health depends on several different factors, including the concentration of the heavy metal in the receiving environment (affected by the amount discharged and the dilution factor), route and length of exposure, recommended exposure limits (eg, health-based guidance values (HBGVs)) for the contaminant, and human behaviours (eg, children generally ingest more water during recreational water usage than adults).

To estimate the health risks posed by the presence of the target heavy metals in aquatic environments during different water-based recreational activities, an exposure tool developed by Cressey (2023) was employed. This tool contains health-based information for a range of common contaminants, including the target heavy metals. Information on the environmental concentration of the contaminant is entered, a HBGV (eg, reference dose (RfD), tolerable daily intake (TDI)) is selected (or manually entered for chemicals not already included in the tool), and a factor relating to dilution in the receiving environment is entered. This is then used to estimate the sum of oral and dermal exposure during various contact recreational activities (swimming, surfing, canoeing/kayaking, rowing, sailing and fishing) in wastewater-affected aquatic receiving environments (freshwater and marine). This tool also calculates hazard/risk indices, where exposure is expressed as a proportion of a HBGV. Where this risk index is less than 1 (ie, exposure < HBGV) the exposure is considered tolerable/acceptable, with the lower the risk index the lower the risk.

Results of this analysis can be considered a 'tier 1' or 'screening-level' risk assessment which can be used to determine if more detailed investigation is warranted.

3.1 APPLICATION OF THE CRESSEY (2023) EXPOSURE TOOL

In using the exposure tool of Cressey (2023) for the target heavy metals, some initial decisions were made to facilitate its usage. Firstly, the value used for the concentration of the heavy metal in wastewater was set at the maximum concentration detected in wastewater effluents in studies assessed during preparation of this report. Secondly, where multiple HBGVs were available, the RfD was chosen for consistency as this was the sole option available for arsenic, chromium and zinc. No HBGVs are available for lead as international assessments have failed to establish a safe exposure level (FSANZ, 2019). As such, no risk estimation was conducted for lead. Lastly, as no information was available on the dilution of the target heavy metals in receiving environments, a conservative approach was taken with the value set at 1, indicating no dilution of effluents prior to exposure.

For chromium, the exposure tool contains separate options for chromium (III) and (VI) due to differences in toxicity of these two oxidation states. As such, risk estimation was conducted for both forms. Results of the risk estimation for all target heavy metals, excluding lead, are shown in Table 8. None of the calculated risk indices were greater than 1, with the highest value being 0.54 for exposure to arsenic during surfing. For 38 of the 63 estimates (60%), the risk index was 0. This indicates that the results of the tier 1 risk assessment for the target heavy metals, with the exclusion of lead, show that the risk is tolerable/acceptable (based on concentration data identified during preparation of this report). However, it should be noted that as detailed in the introduction, heavy metals are also known to be present in aquatic environments due to a range of other non-wastewater sources (eg, volcanic activity, sediment erosion, mining), and as such concentrations may be higher in certain locations, leading to elevated risk.

Table 8 Summary of exposure risk estimates and hazard indices for target heavy metals detected in effluents from municipal WWTPs in New Zealand

Heavy metal	Wastewater effluent concentration* (ng/L)	HBGV (mg/kg/day)	Total exposure (mg/kg bw/day) (top value) and hazard index (bottom value)								
			Swimming (FW, child)	Swimming (FW, adult)	Swimming (M, child)	Swimming (M, adult)	Surfing	Canoeing/ kayaking	Rowing	Sailing	Fishing
Arsenic (inorganic)	23,000	0.0003	7.6 x10 ⁻⁶ 0.03	5.1 x10 ⁻⁷ 0.00	9.3 x10 ⁻⁶ 0.03	6.0 x10 ⁻⁷ 0.00	6.2 x10 ⁻⁵ 0.21	7.8 x10 ⁻⁷ 0.00	1.2 x10 ⁻⁶ 0.00	4.9 x10 ⁻⁶ 0.02	5.6 x10 ⁻⁷ 0.00
Cadmium	19,000	0.0005	2.8 x10 ⁻⁵ 0.06	5.5 x10 ⁻⁶ 0.01	3.4 x10 ⁻⁵ 0.07	6.5 x10 ⁻⁶ 0.01	8.8 x10 ⁻⁵ 0.18	2.9 x10 ⁻⁶ 0.01	1.1 x10 ⁻⁵ 0.02	7.3 x10 ⁻⁵ 0.15	3.1 x10 ⁻⁶ 0.01
Chromium (III)	16,700	1.5	8.1 x10 ⁻⁵ 0.00	1.8 x10 ⁻⁵ 0.00	9.8 x10 ⁻⁵ 0.00	2.1 x10 ⁻⁵ 0.00	1.7 x10 ⁻⁴ 0.00	8.3 x10 ⁻⁶ 0.00	3.6 x10 ⁻⁵ 0.00	2.5 x10 ⁻⁴ 0.00	9.8 x10 ⁻⁶ 0.00
Chromium (VI)	16,700	0.003	8.4 x10 ⁻⁵ 0.03	1.9 x10 ⁻⁵ 0.01	1.0 x10 ⁻⁴ 0.03	2.2 x10 ⁻⁵ 0.01	1.8 x10 ⁻⁴ 0.06	8.6 x10 ⁻⁶ 0.00	3.8 x10 ⁻⁵ 0.01	2.6 x10 ⁻⁴ 0.09	1.0 x10 ⁻⁵ 0.00
Mercury	1,000	0.0003	1.1 x10 ⁻⁶ 0.00	2.1 x10 ⁻⁷ 0.00	1.4 x10 ⁻⁶ 0.00	2.5 x10 ⁻⁷ 0.00	4.0 x10 ⁻⁶ 0.01	1.2 x10 ⁻⁷ 0.00	4.2 x10 ⁻⁷ 0.00	2.8 x10 ⁻⁶ 0.01	1.2 x10 ⁻⁷ 0.00
Nickel	20,000	0.02	1.1 x10 ⁻⁵ 0.00	1.6 x10 ⁻⁶ 0.00	1.4 x10 ⁻⁵ 0.00	1.9 x10 ⁻⁶ 0.00	6.2 x10 ⁻⁵ 0.00	1.2 x10 ⁻⁶ 0.00	3.2 x10 ⁻⁶ 0.00	2.0 x10 ⁻⁵ 0.00	1.1 x10 ⁻⁶ 0.00
Zinc	420,000	0.3	1.3 x10 ⁻⁴ 0.00	7.0 x10 ⁻⁶ 0.00	1.6 x10 ⁻⁴ 0.00	8.2 x10 ⁻⁶ 0.00	1.1 x10 ⁻³ 0.00	1.3 x10 ⁻⁵ 0.00	1.7 x10 ⁻⁵ 0.00	5.8 x10 ⁻⁵ 0.00	9.0 x10 ⁻⁶ 0.00

*Based on highest concentration reported in studies assessed during preparation of this report. FW, freshwater; M, marine water. Calculated using the exposure tool developed by Cressey (2023).

4. REMOVAL OF HEAVY METALS FROM WASTEWATER

Heavy metals are non-biodegradable, and as such if not removed by wastewater treatment processes will contaminate receiving environments (Qasem et al., 2021). However, not all treatment processes are efficient at removing heavy metals from wastewater. This section will provide an overview of what is known about removal of the target heavy metals by conventional wastewater treatment processes and will highlight some of the advanced approaches being developed to remove these contaminants from wastewater, particularly in industrial settings.

4.1 REMOVAL BY CONVENTIONAL TREATMENT PROCESSES USED IN NEW ZEALAND

No information specifically addressing removal of heavy metals from municipal wastewater in New Zealand was identified during preparation of this report. As such, information from international studies conducted in WWTPs with similar treatment processes to those used in New Zealand will be drawn on in this section.

In New Zealand, the main wastewater treatment processes employed are activated sludge (types 1-3), trickling filters (type 4.1 and 4.2) and ponds and lagoons (type 5.1 and 5.2), as shown in Figure 1 and Table 9.

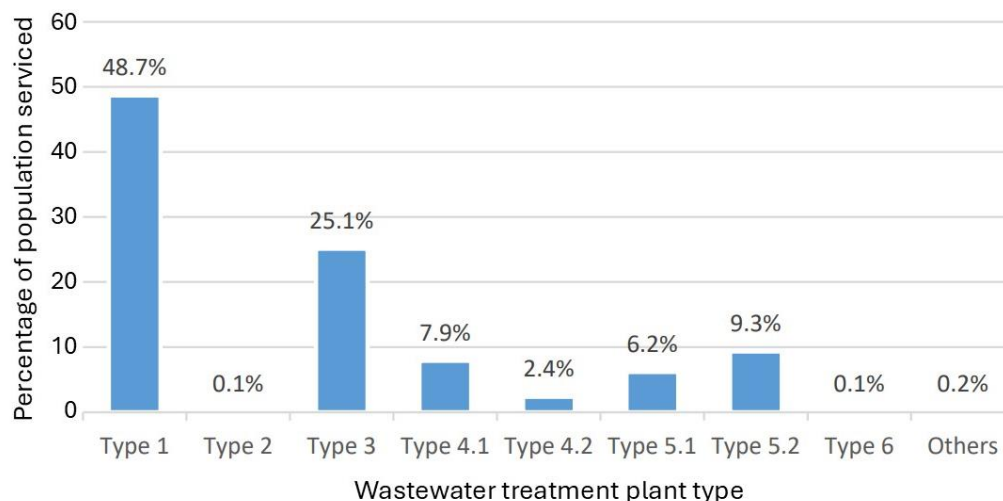


Figure 1 Wastewater treatment plants in New Zealand ordered by population serviced

Reproduced from Ho et al. (2020). See Table 9 for definitions of treatment types.

Table 9 Overview of wastewater treatment plant technology employed in New Zealand

Treatment	Water Services Association of Australia group	Classification	No. of facilities	% by No.	% by population
Activated sludge	Type 1	Activated sludge process with primary treatment, digesters and onsite co-generation	5	2	49
	Type 2	Activated sludge process with primary treatment, digesters and no onsite co-generation	1	0.3	0.1
	Type 3	Activated sludge process with process with no primary treatment or anaerobic digesters	51	16	25
Trickling filters	Type 4.1	Trickling filters	22	8	11
	Type 4.2	Trickling filters combined with activated sludge process	4		
Ponds and lagoons	Type 5.1	Aerated lagoons and oxidation ponds with high intensity aeration	37	64	15
	Type 5.2	Facultative ponds and wetlands	168		
Others	Type 6	Recirculating filters	17	5	0
	Others	Septic tanks, Imhoff Tanks, worm farms	16	5	0

Data from Ho et al. (2020)

Activated sludge is the most common treatment process employed in New Zealand, with around 74% of the population serviced by treatment plants employing a variation of activated sludge treatment (type 1, 2 or 3) (Ho et al., 2020).

A study conducted at an activated sludge treatment plant in Thessaloniki, Greece found that concentrations of cadmium were reduced by around 55% after primary and secondary sedimentation, chromium levels were reduced by around 58%, nickel around 44%, lead around 31%, and zinc around 43% (Karvelas et al., 2003). For cadmium, chromium, lead and zinc, most of the metal present in effluents after secondary sedimentation was in the particulate phase (~ 70 – 90%), whereas most of the nickel was in the dissolved phase (~ 90%). A study conducted at two conventional municipal WWTPs in New Jersey, USA which employ biological treatment processes, found that less than 30% of the arsenic load reaching the treatment plant was removed (Ge et al., 2020). In another study conducted at an activated sludge-based WWTP in Jiaozuo, China more than 80% of total mercury reaching the treatment plant was found to end up in the sludge (Mao et al., 2016).

In 2015, Yang et al. investigated the removal of arsenic, chromium, nickel, lead and zinc by 17 WWTPs in Beijing, China. These WWTPs employ four different types of activated sludge processes – conventional activated sludge (three plants), oxidation ditch (OD, six plants), anaerobic-anoxic-oxic process (A²-O, four plants) and sequencing batch reactor (SBR, four plants). For arsenic, conventional activated sludge processes only removed around 39% of the arsenic load, compared to around 45% for SBR, 57% for A²-O, and 70% for OD. In contrast, for chromium, conventional activated sludge processes removed around 92% of the chromium load, compared to 88% for SBR, 63% for A²-O and 85% for OD. Removal rates for nickel were considerably lower, with around 32% removed by conventional activated sludge processes, 17% by SBR, 19% by A²-O and 41% for OD. Conventional activated sludge, A²-O and OD processes were relatively efficient at removing lead (74, 71 and 78% removal respectively), compared to SBR which only removed around 19% of the lead load. For zinc, removal by OD, SBR and A²-O processes was considerably more efficient (72, 85 and 77% removal rates) than conventional activated sludge processes (51%) (Yang et al., 2015).

4.2 ADVANCED METHODS FOR REMOVAL OF HEAVY METALS FROM WASTEWATER

As can be seen from the studies discussed above, heavy metal removal by conventional treatment processes can be highly variable. A wide variety of advanced treatment processes have been developed, or are in development, for the removal of heavy metals from wastewater. This section provides a brief overview of the five main classes of advanced treatments – adsorption, membrane, chemical, electric and photocatalytic. Within each of these classes, there are a variety of implementations, each with advantages and limitations. The costs associated with these advanced treatments can be considerable. It is beyond the scope of this document to undertake a full assessment of these advanced treatments, particularly in light of the low concentrations of heavy metals identified in this report. Should a situation arise where advanced treatment to removal heavy metals was necessary, then detailed assessment should be undertaken.

4.2.1 Adsorption approaches

These approaches rely on the adherence of heavy metals to some kind of adsorbent, allowing them to be separated out from the wastewater stream (Figure 2). The ability of the heavy metal to adhere to the adsorbent is determined by chemical properties of the adsorbent, heavy metal concentration and process conditions such as temperature, pH and time allowed for adsorption (Qasem et al., 2021). A wide variety of different adsorbents can be utilised including carbon- and chitosan-based adsorbents, mineral and magnetic adsorbents, biosorbents and metal-organic framework adsorbents (Qasem et al., 2021). These approaches are generally cheap, efficient and easy to implement.

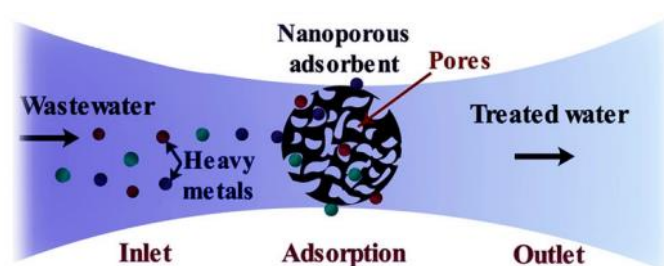


Figure 2 Schematic showing removal of heavy metals from wastewater by adsorption

Reproduced from Qasem et al. (2021).

4.2.2 Membrane approaches

These approaches involve filtration of wastewater through a membrane to separate out the heavy metal contaminants. Options include microfiltration, where micron-sized particles are removed by a microporous membrane (generally this results in low removal of heavy metals as most pass through the pores); ultrafiltration, where additives may be bonded to the heavy metal ions to make them large enough so that they cannot pass through the pores; nanofiltration, where particles > 0.2 Da (around $0.0005 - 0.007 \mu\text{m}$) are removed; and reverse osmosis, where a semi-permeable membrane with pores $0.5 - 1.5$ nm is used in a pressure-driven process by which the small heavy metal ions pass through the membrane whilst larger molecules cannot (Qasem et al., 2021) (Figure 3).

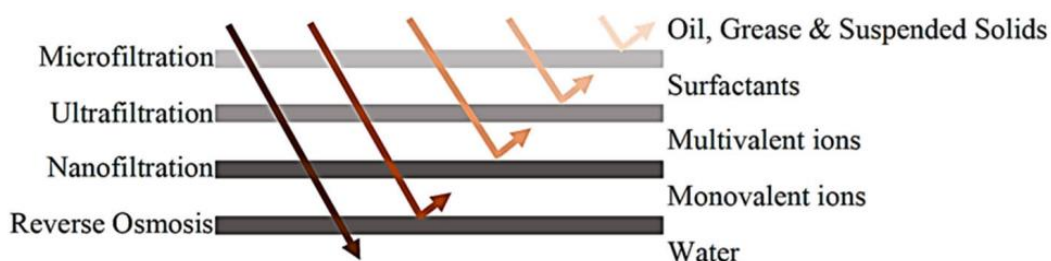


Figure 3 Schematic showing membrane-based methods for removal of pollutants from wastewater

Reproduced from Qasem et al. (2021).

4.2.3 Chemical approaches

Chemical-based approaches for removal of heavy metals from wastewater generally involve precipitation, coagulation-flocculation or flotation. Precipitation approaches are some of the most effective and involve addition of a chemical which interacts with the heavy metal ions causing them to coagulate into solid particles which are then removed by sedimentation (Figure 4). Hydroxides such as calcium hydroxide are commonly used as they react with the heavy metal ions to form insoluble metal hydroxide precipitates (Qasem et al., 2021).

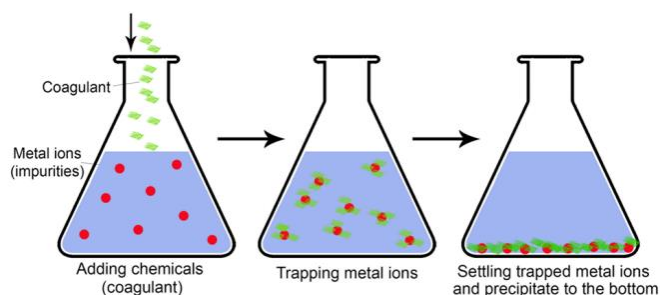


Figure 4 Schematic showing removal of heavy metal ions by chemical coagulation

Reproduced from Qasem et al. (2021).

In coagulation-flocculation, a chemical is added to the wastewater, neutralising the forces keeping the metal ions apart and causing them to coagulate. A flocculant is then added which causes the coagulated particles to accumulate and form large agglomerates which are removed by sedimentation, filtration or other methods (Qasem et al., 2021) (Figure 5).

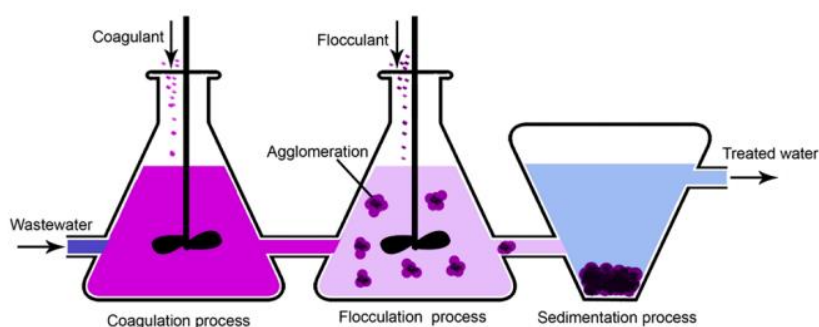


Figure 5 Schematic showing removal of heavy metal ions by coagulation-flocculation

Reproduced from Qasem et al. (2021).

In flotation approaches, added chemicals interact with the heavy metals causing them to adhere to air bubbles pumped into the system and float to the liquid surface from which they can be removed (Qasem et al., 2021) (Figure 6).

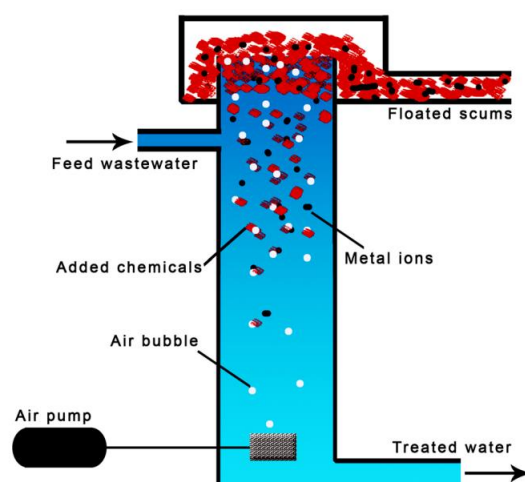


Figure 6 Schematic showing removal of heavy metal ions by flotation

Reproduced from Qasem et al. (2021).

4.2.4 Electric approaches

Electric approaches utilise electricity to facilitate the removal of heavy metals from wastewater and include electrochemical reduction, electroflotation, electrocoagulation, electrooxidation and ion exchange. The fundamentals of these different approaches has been comprehensively reviewed by Qasem et al. (2021), and are summarised in Figure 7.

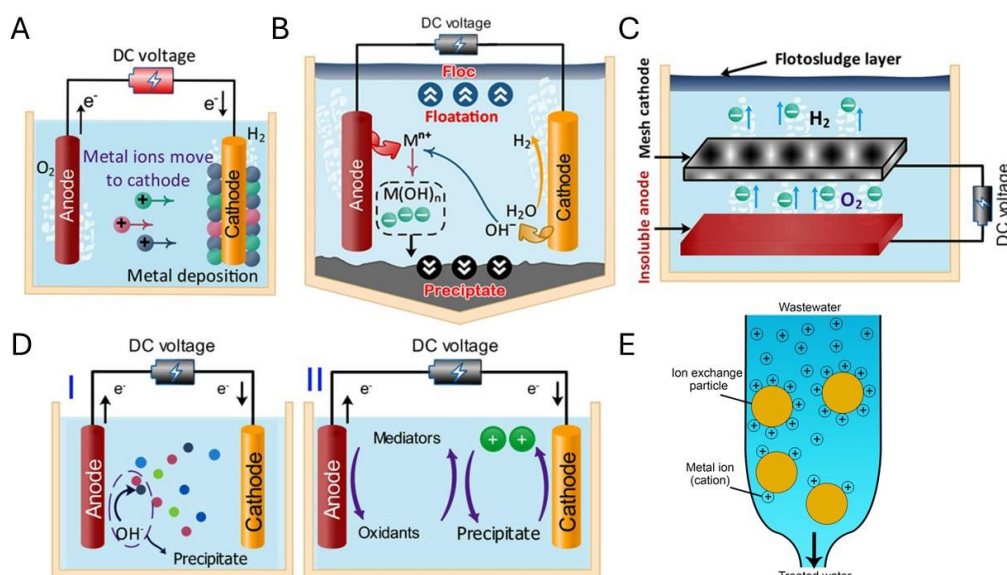


Figure 7 Schematic showing removal of heavy metal ions by electrochemical methods

Modified from Qasem et al. (2021). A, electrochemical reduction; B, electrocoagulation; C, electroflotation; D, direct (I) and indirect (II) electrochemical oxidation; E, ion exchange.

4.2.5 Photocatalytic approaches

As the name suggests, photocatalytic approaches utilise light together with a semiconductor such as titanium oxide (TiO_2) to facilitate the removal of heavy metals from wastewater (reviewed in Qasem et al. (2021)). Whilst these approaches are environmentally friendly, they are still in their relative infancy compared to other methods such as chemical and membrane-based approaches.

5. SUMMARY

Wastewater is known to contain a wide variety of contaminants of potential concern for human health. One group of contaminants of particular concern are the heavy metals, a class of metallic elements of high atomic weight and density which are generally highly toxic and have been associated with a range of adverse human health conditions. Previous reports prepared for the Ministry of Health identified potential sources of these contaminants in municipal and industrial wastewaters (trade wastes) based on international data. The aim of this review was to assess what is known about the presence of these contaminants in municipal wastewater in New Zealand. Specific focus was placed on a subset of heavy metals of most concern for human health – arsenic, cadmium, chromium, lead, mercury, nickel and zinc. Information on the concentrations of these contaminants detected in wastewater effluents in New Zealand was then used as inputs for the Cressey (2023) exposure tool to estimate health risks associated with recreational usage of wastewater-impacted aquatic receiving environments.

Although monitoring data was obtained for multiple different treatment plants for any given heavy metal, in many cases the form in which the metal was quantified varied between the different treatment plants (eg, dissolved, acid soluble, total) making comparisons difficult. If new standards relating to heavy metals in wastewater are developed, it would be preferable if a standardised approach could be used, allowing for easier comparison.

Monitoring data relating to the presence of arsenic in WWTP effluents was identified for 12 WWTPs across New Zealand, with the highest reported concentration being 0.023 mg/l total arsenic. Consent limits were identified for four WWTPs, with the highest limit being 1.98 mg/l for total arsenic. The lowest limit for total arsenic identified was 0.023 mg/l, meaning an 86-fold difference in allowable concentrations between two WWTPs. Monitoring periods also varied considerably between different sites, with some requiring monthly monitoring for arsenic, some quarterly, some six-monthly and others only annual monitoring. Application of the Cressey (2023) exposure tool, using the maximum concentration identified of 0.023 mg/l, indicated that the recreational activity with the highest risk was surfing. However, the hazard index was only 0.21 indicating that the risk is tolerable/acceptable based on a HBGV of 0.0003 mg/kg/day.

For cadmium, information on concentrations in municipal WWTP effluents was identified for 14 WWTPs across New Zealand, with the highest reported concentration being 0.019 mg/l. Consent limits were identified for six WWTPs, with the highest limit being 0.08 mg/l for total cadmium. Required monitoring periods ranged from monthly to annually. Application of the Cressey (2023) exposure tool, using the maximum concentration identified of 0.019 mg/l, again indicated that the recreational activity with the highest risk was surfing, with a hazard index of 0.18. However, as this value is below 1, the risk is considered tolerable/acceptable, based on a HBGV of 0.0005 mg/kg/day.

For chromium, information on concentrations in municipal WWTP effluents was identified for 13 WWTPs across New Zealand, with the highest reported concentration being 0.0167 mg/l acid soluble chromium, and 0.009 mg/l for highly toxic chromium (VI). Consent limits were identified for six WWTPs, with the highest limit being 0.48 mg/l for total chromium, 2.74 for

the low toxicity chromium (III), and 0.44 for chromium (VI). Required monitoring periods ranged from fortnightly to annually. For estimation of potential health risks using the Cressey (2023) exposure tool, separate risks were calculated for chromium (III) and (VI) due to the considerable differences in toxicity of these two oxidation states. Using a concentration of 0.0167 mg/l, all risk estimates for chromium (III) were 0. For chromium (VI), the highest risk was during sailing with a hazard index of 0.09, indicating that the risk is again tolerable/acceptable.

For lead, information on concentrations in municipal WWTP effluents was identified for 13 WWTPs, with the highest reported concentration being 0.02 mg/l. Consent limits were identified for six WWTPs, with the highest limit being 0.48 mg/l for total lead. The lowest limit identified for total lead was 0.044 mg/l, equating to an 11-fold difference in allowable concentrations between the two WWTPs. Required monitoring periods also varied, ranging from monthly to annually. Exposure risks could not be estimated as there are no HBGVs for lead as international assessments have failed to establish a safe exposure level.

For mercury, information on concentrations in municipal WWTP effluents was identified for 9 WWTPs across New Zealand, with the highest reported concentration being 0.001 mg/l total mercury. Consent limits were identified for six WWTPs, with the highest limit being 0.01 mg/l for total mercury. Required monitoring periods ranged from monthly to annually. Application of the Cressey (2023) exposure tool, using the maximum concentration identified of 0.001 mg/l, indicated that the recreational activities with the highest estimated risk were surfing and sailing, both with hazard indices of 0.01, whilst for the rest of the activities the value was 0. As these values are well below 1, the risk is considered tolerable/acceptable, based on a HBGV of 0.0003 mg/kg/day.

For nickel, information on concentrations in municipal WWTP effluents was identified for 12 WWTPs across New Zealand, with the highest reported concentration being 0.02 mg/l total nickel. Consent limits were identified for six WWTPs, with the highest limit being 0.77 mg/l for total nickel. Required monitoring periods ranged from monthly to annually. When the Cressey (2023) exposure tool was applied, using the maximum concentration identified of 0.02 mg/l, all risk estimates were 0, based on a HBGV of 0.02 mg/kg/day.

For zinc, information on concentrations in municipal WWTP effluents was identified for 15 WWTPs across New Zealand, with the highest reported concentration being 0.42 mg/l for acid soluble zinc. Consent limits were identified for six WWTPs, with the highest limit being 1.65 mg/l for total zinc. In contrast, the lowest limit identified was 0.08 mg/l total zinc, a difference of 20-fold between the two WWTPs. Required monitoring periods ranged from fortnightly to annually. When the Cressey (2023) exposure tool was applied, using the maximum concentration identified of 0.42 mg/l, all risk estimates were 0, based on a HBGV of 0.3 mg/kg/day.

The presence of heavy metals in effluents from municipal WWTPs indicates that not all these contaminants are removed by treatment processes. According to the New Zealand Wastewater Sector Review published in 2020, 74% of the population is serviced by WWTPs employing activated sludge treatment processes. A review of recent literature found that removal of heavy metals by conventional activated sludge processes is highly variable. For example, in two studies of removal of chromium one reported a removal rate of 58% whilst another reported removal of 92% of the chromium load. Similarly, for lead removal rates

varied from 31% to 74%; for nickel removal rates ranged from 32 – 44%; and for zinc rates ranged from 43 – 51%. For arsenic, two different studies reported removal rates of <30% and 39%. For cadmium, only one study addressing removal rates by conventional activated sludge processes was identified, with an estimated removal rate of 55%. For mercury, a single study found that more than 80% of the mercury load ended up in the sewage sludge. There are a range of advanced treatment processes which could be employed to more efficiently remove heavy metals from wastewater. However, careful consideration would need to be given to selection of advanced technologies as they are not all technically mature, and some may not be cost-effective or environmentally friendly.

APPENDIX

Table 10 Summary of New Zealand wastewater treatment plants servicing populations of 5,000 or more with consent to discharge to aquatic environments

	WWTP name	Population serviced	Consent type	Consent ID	Reference number	Expiry	Receiving environment	Discharge point
Northland	Mangawhai	13,500	Coastal permit	CON-00001835	AUT.014969.07.02	30/09/2042		
	Paihia	5,000					River, Stream or Creek	Waitangi Wetlands
	Whangārei	56,120	Discharge to water	CON-00002164	AUT.004352.01.06	30/04/2022	River, Stream or Creek	Limeburners Creek
			Discharge to water	CON-00002165	AUT.004352.02.03	30/04/2022		
Auckland	Army Bay	62,990	Coastal permit	CON-00001018	CST60083182	17/06/2049	Marine Coastal	Army Bay WWTP Outfall
			Coastal permit	CON-00001045	DIS60331146	19/12/2054		
			Coastal permit	CON-00001656	REG/2013/3738	13/06/2049		
			Coastal permit	CON-00001657	REG/2013/3739	14/06/2049		
			Coastal permit	CON-00001658	REG/2013/3740	15/06/2049		
			Coastal permit	CON-00001659	REG/2013/3741	16/06/2049		
			Coastal permit	CON-00001660	REG/2013/3742	17/06/2049		

	WWTP name	Population serviced	Consent type	Consent ID	Reference number	Expiry	Receiving environment	Discharge point
Auckland	Army Bay	62,990	Coastal permit	CON-00001661	REG/2013/3743	18/06/2049	Marine Coastal	Army Bay WWTP Outfall
			Coastal permit	CON-00001662	REG/2013/3744	19/06/2049		
			Coastal permit	CON-00001663	REG/2013/3745	20/06/2049		
			Coastal permit	CON-00001664	REG/2013/3746	21/06/2049		
			Coastal permit	CON-00001665	REG/2013/3747	22/06/2049		
			Coastal permit	CON-00001666	REG/2013/3748	23/06/2049		
			Coastal permit	CON-00001667	REG/2013/3749	24/06/2049		
			Coastal permit	CON-00001668	REG/2013/3750	25/06/2049		
			Coastal permit	CON-00001669	REG/2013/3751	26/06/2049		
			Coastal permit	CON-00001670	REG/2013/3752	27/06/2049		
			Coastal permit	CON-00001671	REG/2013/3753	28/06/2049		
			Coastal permit	CON-00001672	REG/2013/3754	29/06/2049		
			Coastal permit	CON-00001673	REG/2013/3755	30/06/2049		
			Discharge to water	CON-00001781	DIS60331146	19/12/2054		

	WWTP name	Population serviced	Consent type	Consent ID	Reference number	Expiry	Receiving environment	Discharge point
Auckland	Māngere	1,423,900	Coastal permit	CON-00001053	CST60083182	17/06/2049	Marine Harbour	Māngere foreshore discharge
			Coastal permit	CON-00001057	CST60083186	05/06/2049		
			Coastal permit	CON-00001068	CST80294146	31/12/2032		
			Coastal permit	CON-00001548	REG/2013/3738	13/06/2049		
			Coastal permit	CON-00001549	REG/2013/3739	14/06/2049		
			Coastal permit	CON-00001550	REG/2013/3740	15/06/2049		
			Coastal permit	CON-00001551	REG/2013/3741	16/06/2049		
			Coastal permit	CON-00001552	REG/2013/3742	17/06/2049		
			Coastal permit	CON-00001553	REG/2013/3743	18/06/2049		
			Coastal permit	CON-00001554	REG/2013/3744	19/06/2049		
			Coastal permit	CON-00001555	REG/2013/3745	20/06/2049		
			Coastal permit	CON-00001556	REG/2013/3746	21/06/2049		
			Coastal permit	CON-00001557	REG/2013/3747	22/06/2049		
			Coastal permit	CON-00001558	REG/2013/3748	23/06/2049		
			Coastal permit	CON-00001559	REG/2013/3749	24/06/2049		

	WWTP name	Population serviced	Consent type	Consent ID	Reference number	Expiry	Receiving environment	Discharge point
Auckland	Māngere	1,423,900	Coastal permit	CON-00001560	REG/2013/3750	25/06/2049	Marine Harbour	Māngere foreshore discharge
			Coastal permit	CON-00001561	REG/2013/3751	26/06/2049		
			Coastal permit	CON-00001562	REG/2013/3752	27/06/2049		
			Coastal permit	CON-00001563	REG/2013/3753	28/06/2049		
			Coastal permit	CON-00001564	REG/2013/3754	29/06/2049		
			Coastal permit	CON-00001565	REG/2013/3755	30/06/2049		
			Coastal permit	CON-00001768	DIS60266760	30/09/2050		
			Coastal permit	CON-00001769	DIS60083293	30/06/2049		
			Discharge to water	CON-00001773	DIS60267345	15/05/2047		
			Discharge to water	CON-00001774	DIS60264164	16/02/2042		
			Discharge to water	CON-00001775	DIS60264024	01/02/2042		
			Discharge to water	CON-00001793	DIS60263635	31/12/2032		

	WWTP name	Population serviced	Consent type	Consent ID	Reference number	Expiry	Receiving environment	Discharge point
Auckland	Pukekohe	51,900	Coastal permit	CON-00001006	CST60083182	17/06/2049	River, Stream or Creek	Parker Lane Stream
			Discharge to water	CON-00001071	AUTH137406.01.02	26/10/2052		
			Coastal permit	CON-00001188	REG/2013/3738	13/06/2049		
			Coastal permit	CON-00001189	REG/2013/3739	14/06/2049		
			Coastal permit	CON-00001190	REG/2013/3740	15/06/2049		
			Coastal permit	CON-00001191	REG/2013/3741	16/06/2049		
			Coastal permit	CON-00001192	REG/2013/3742	17/06/2049		
			Coastal permit	CON-00001193	REG/2013/3743	18/06/2049		
			Coastal permit	CON-00001194	REG/2013/3744	19/06/2049		
			Coastal permit	CON-00001195	REG/2013/3745	20/06/2049		
			Coastal permit	CON-00001196	REG/2013/3746	21/06/2049		
			Coastal permit	CON-00001197	REG/2013/3747	22/06/2049		
			Coastal permit	CON-00001198	REG/2013/3748	23/06/2049		
			Coastal permit	CON-00001199	REG/2013/3749	24/06/2049		
			Coastal permit	CON-00001200	REG/2013/3750	25/06/2049		

	WWTP name	Population serviced	Consent type	Consent ID	Reference number	Expiry	Receiving environment	Discharge point
Auckland	Pukekohe	51,900	Coastal permit	CON-00001201	REG/2013/3751	26/06/2049	River, Stream or Creek	Parker Lane Stream
			Coastal permit	CON-00001202	REG/2013/3752	27/06/2049		
			Coastal permit	CON-00001203	REG/2013/3753	28/06/2049		
			Coastal permit	CON-00001204	REG/2013/3754	29/06/2049		
			Coastal permit	CON-00001205	REG/2013/3755	30/06/2049		
	Rosedale	277,690	Coastal permit	CON-00001016	CST60083182	17/06/2049	Marine Coastal	Rosedale WWTP Outfall
			Coastal permit	CON-00001037	CST60260647	31/12/2030		
			Coastal permit	CON-00001584	REG/2013/3738	13/06/2049		
			Coastal permit	CON-00001585	REG/2013/3739	14/06/2049		
			Coastal permit	CON-00001586	REG/2013/3740	15/06/2049		
			Coastal permit	CON-00001587	REG/2013/3741	16/06/2049		
			Coastal permit	CON-00001588	REG/2013/3742	17/06/2049		
			Coastal permit	CON-00001589	REG/2013/3743	18/06/2049		
			Coastal permit	CON-00001590	REG/2013/3744	19/06/2049		
			Coastal permit	CON-00001591	REG/2013/3745	20/06/2049		

	WWTP name	Population serviced	Consent type	Consent ID	Reference number	Expiry	Receiving environment	Discharge point
Auckland	Rosedale	277,690	Coastal permit	CON-00001592	REG/2013/3746	21/06/2049	Marine Coastal	Rosedale WWTP Outfall
			Coastal permit	CON-00001593	REG/2013/3747	22/06/2049		
			Coastal permit	CON-00001594	REG/2013/3748	23/06/2049		
			Coastal permit	CON-00001595	REG/2013/3749	24/06/2049		
			Coastal permit	CON-00001596	REG/2013/3750	25/06/2049		
			Coastal permit	CON-00001597	REG/2013/3751	26/06/2049		
			Coastal permit	CON-00001598	REG/2013/3752	27/06/2049		
			Coastal permit	CON-00001599	REG/2013/3753	28/06/2049		
			Coastal permit	CON-00001560	REG/2013/3754	29/06/2049		
			Coastal permit	CON-00001561	REG/2013/3755	30/06/2049		
			Coastal permit	CON-00001764	CST60262535	16/07/2047		
			Discharge to water	CON-00001798	CST60260652	31/12/2030		
			Coastal permit	CON-00001806	CST60260652	31/12/2030		

	WWTP name	Population serviced	Consent type	Consent ID	Reference number	Expiry	Receiving environment	Discharge point
Auckland	Snells Beach	5,200	Discharge to water	CON-00001002	DIS60050020	30/03/2052	Marine Coastal	Martins Bay Outfall
			Coastal permit	CON-00001019	CST60083182	17/06/2049		
			Coastal permit	CON-00001072	DIS60069253-B	21/03/2052		
			Coastal permit	CON-00001692	REG/2013/3738	13/06/2049		
			Coastal permit	CON-00001693	REG/2013/3739	14/06/2049		
			Coastal permit	CON-00001694	REG/2013/3740	15/06/2049		
			Coastal permit	CON-00001695	REG/2013/3741	16/06/2049		
			Coastal permit	CON-00001696	REG/2013/3742	17/06/2049		
			Coastal permit	CON-00001697	REG/2013/3743	18/06/2049		
			Coastal permit	CON-00001698	REG/2013/3744	19/06/2049		
			Coastal permit	CON-00001699	REG/2013/3745	20/06/2049		
			Coastal permit	CON-00001700	REG/2013/3746	21/06/2049		
			Coastal permit	CON-00001701	REG/2013/3747	22/06/2049		
			Coastal permit	CON-00001702	REG/2013/3748	23/06/2049		
			Coastal permit	CON-00001703	REG/2013/3749	24/06/2049		

	WWTP name	Population serviced	Consent type	Consent ID	Reference number	Expiry	Receiving environment	Discharge point
Auckland	Snells Beach	5,200	Coastal permit	CON-00001704	REG/2013/3750	25/06/2049	Marine Coastal	Martins Bay Outfall
			Coastal permit	CON-00001705	REG/2013/3751	26/06/2049		
			Coastal permit	CON-00001706	REG/2013/3752	27/06/2049		
			Coastal permit	CON-00001707	REG/2013/3753	28/06/2049		
			Coastal permit	CON-00001708	REG/2013/3754	29/06/2049		
			Coastal permit	CON-00001709	REG/2013/3755	30/06/2049		
			Discharge to water	CON-00001776	DIS60050020	30/03/2052		
			Discharge to water	CON-00001799	DIS60069253-B	31/03/2025		
			Coastal permit	CON-00001800	REG-67911	21/03/2052		
	Waiuku	9,540	Coastal permit	CON-00001013	CST60083182	17/06/2049	Marine Harbour	Waiuku River
			Discharge to water	CON-00001044	DIS60334129	15/06/2027		
			Coastal permit	CON-00001440	REG/2013/3738	13/06/2049		
			Coastal permit	CON-00001441	REG/2013/3739	14/06/2049		
			Coastal permit	CON-00001442	REG/2013/3740	15/06/2049		
			Coastal permit	CON-00001443	REG/2013/3741	16/06/2049		

	WWTP name	Population serviced	Consent type	Consent ID	Reference number	Expiry	Receiving environment	Discharge point
Auckland	Waiuku	9,540	Coastal permit	CON-00001444	REG/2013/3742	17/06/2049	Marine Harbour	Waiuku River
			Coastal permit	CON-00001445	REG/2013/3743	18/06/2049		
			Coastal permit	CON-00001446	REG/2013/3744	19/06/2049		
			Coastal permit	CON-00001447	REG/2013/3745	20/06/2049		
			Coastal permit	CON-00001448	REG/2013/3746	21/06/2049		
			Coastal permit	CON-00001449	REG/2013/3747	22/06/2049		
			Coastal permit	CON-00001450	REG/2013/3748	23/06/2049		
			Coastal permit	CON-00001451	REG/2013/3749	24/06/2049		
			Coastal permit	CON-00001452	REG/2013/3750	25/06/2049		
			Coastal permit	CON-00001453	REG/2013/3751	26/06/2049		
			Coastal permit	CON-00001454	REG/2013/3752	27/06/2049		
			Coastal permit	CON-00001455	REG/2013/3753	28/06/2049		
			Coastal permit	CON-00001456	REG/2013/3754	29/06/2049		
			Coastal permit	CON-00001457	REG/2013/3755	30/06/2049		
			Coastal permit	CON-00001801	DIS60334129	15/06/2027		

	WWTP name	Population serviced	Consent type	Consent ID	Reference number	Expiry	Receiving environment	Discharge point
Auckland	Warkworth	5,800	Discharge to water	CON-00001003	DIS60050020	30/03/2052	Marine Harbour	Mahurangi River
			Coastal permit	CON-00001017	CST60083182	17/06/2049		
			Discharge to water	CON-00001074	DIS603386349	03/03/2025		
			Coastal permit	CON-00001620	REG/2013/3738	13/06/2049		
			Coastal permit	CON-00001621	REG/2013/3739	14/06/2049		
			Coastal permit	CON-00001622	REG/2013/3740	15/06/2049		
			Coastal permit	CON-00001623	REG/2013/3741	16/06/2049		
			Coastal permit	CON-00001624	REG/2013/3742	17/06/2049		
			Coastal permit	CON-00001625	REG/2013/3743	18/06/2049		
			Coastal permit	CON-00001626	REG/2013/3744	19/06/2049		
			Coastal permit	CON-00001627	REG/2013/3745	20/06/2049		
			Coastal permit	CON-00001628	REG/2013/3746	21/06/2049		
			Coastal permit	CON-00001629	REG/2013/3747	22/06/2049		
			Coastal permit	CON-00001630	REG/2013/3748	23/06/2049		
			Coastal permit	CON-00001631	REG/2013/3749	24/06/2049		

	WWTP name	Population serviced	Consent type	Consent ID	Reference number	Expiry	Receiving environment	Discharge point
Auckland	Warkworth	5,800	Coastal permit	CON-00001632	REG/2013/3750	25/06/2049	Marine Harbour	Mahurangi River
			Coastal permit	CON-00001633	REG/2013/3751	26/06/2049		
			Coastal permit	CON-00001634	REG/2013/3752	27/06/2049		
			Coastal permit	CON-00001635	REG/2013/3753	28/06/2049		
			Coastal permit	CON-00001636	REG/2013/3754	29/06/2049		
			Coastal permit	CON-00001637	REG/2013/3755	30/06/2049		
			Discharge to water	CON-00001777	DIS60050020	30/03/2052		
			Discharge to water	CON-00001803	DIS603386349	03/03/2025		
Waikato	Huntly	9,618	Discharge to water	CON-00002265	119647	31/03/2029	River, Stream or Creek	Waikato River; Kimihia Stream
			Discharge to water	CON-00002266	119650	31/03/2029		
			Discharge to water	CON-00002267	119651	31/03/2029		
	Matamata	9,050	Discharge to water	CON-00002203	AUTH110031.01.03	08/06/2024	River, Stream or Creek	Mangawhero Stream

	WWTP name	Population serviced	Consent type	Consent ID	Reference number	Expiry	Receiving environment	Discharge point
Waikato	Morrinsville	5,800	Discharge to water	CON-00002235	AUTH118885.01.02	17/12/2024	River, Stream or Creek	Totara Gully (Piako River tributary)
			Discharge to water	CON-00002236	AUTH119563.01.01	17/12/2024		
			Discharge to water	CON-00002237	AUTH118886.01.01	17/12/2024		
	Ngāruawāhia	7,641	Discharge to water	CON-00002282	119642	31/03/2029	River, Stream or Creek	Waikato River
			Discharge to water	CON-00002283	119646	31/03/2029		
	Paeroa	5,009	Discharge to water	CON-00002099	AUTH141634.01.01	20/12/2026	River, Stream or Creek	Waihou River
	Pukete	160,911	Discharge to water	CON-00002207	114674	18/09/2027	River, Stream or Creek	Waikato River
			Discharge to water	CON-00002210	134278	02/02/2039		
	Te Awamutu	14,000	Discharge to water	CON-00002153	AUTH135108.01.02	30/06/2043	River, Stream or Creek	Te Awamutu WW Discharge - via Rock Filter
	Te Kauwhata	5,917	Discharge to water	CON-00002284	117991	07/04/2028	Lake	Lake Waikare
	Thames	7,883	Discharge to water	CON-00002231	AUTH140148.01.01	31/01/2041	River, Stream or Creek	Waihou River

	WWTP name	Population serviced	Consent type	Consent ID	Reference number	Expiry	Receiving environment	Discharge point
Waikato	Tokoroa	12,243	Discharge to water	CON-00002156	AUTH140055.01.01	01/09/2056	River, Stream or Creek	
	Waihi	5,740					River, Stream or Creek	Ohinemuri River tributary
	Whitianga	6,545	Discharge to water	CON-00002234	AUTH121318.01.01	28/02/2041	River, Stream or Creek	Ngārahutunoa Stream
Bay of Plenty	Chapel Street (Tauranga)	66,000	Discharge to water	CON-00002356	RC62878	30/04/2040	Marine Coastal; Marine Harbour	Combined Ocean Outfall; Emergency Overflow
			Discharge to water	CON-00002357	RC62882	30/04/2040		
	Katikati	5,741	Coastal permit	CON-00002030	RM16-0206-DC.02+	31/07/2038	Marine Coastal	Katikati Ocean Outfall
	Te Maunga	81,000	Discharge to water	CON-00002358	RC62878	30/04/2040	Marine Coastal; Marine Harbour	Combined Ocean Outfall; Emergency Overflow; Oxidation Pond Seepages
			Discharge to water	CON-00002359	RC62881	30/04/2040		
			Discharge to water	CON-00002360	RC62885	30/04/2040		
	Whakatāne	16,500	Discharge to water	CON-00001938	20368.0.01-DC+	01/10/2026	Marine Coastal	

	WWTP name	Population serviced	Consent type	Consent ID	Reference number	Expiry	Receiving environment	Discharge point
Gisborne	Gisborne	35,000	Coastal permit	CON-00002387	CD-2005-1202-00	02/07/2042	Marine Coastal	Outfall Pipe
			Coastal permit	CON-00002388	CD-2005-1203-00	02/07/2042		
			Coastal permit	CON-00002389	CD-2005-1204-00	02/07/2042		
			Coastal permit	CON-00002390	CD-2005-1205-00	02/07/2042		
			Coastal permit	CON-00002391	CD-2005-1206-00	02/07/2042		
			Coastal permit	CON-00002392	CD-2005-1207-00	02/07/2042		
			Coastal permit	CON-00002393	CD-2005-1208-00	02/07/2042		
			Coastal permit	CON-00002394	CD-2005-1209-00	02/07/2042		
			Coastal permit	CON-00002395	CD-2005-1210-00	02/07/2042		
			Discharge to water	CON-00002396	DW-1997-1702-00	31/01/2032		
Hawke's Bay	Hastings (East Clive)	62,118	Discharge to water	CON-00002401	AUTH-120712-01	31/05/2049	Marine Coastal	Long Ocean Outfall
			Coastal permit	CON-00002402	CL050429C	31/05/2040		
			Coastal permit	CON-00002403	CL150256C	31/05/2049		
			Discharge to water	CON-00002404	CD130272W	31/05/2049		
			Discharge to water	CON-00002405	CD130271W	31/05/2049		

	WWTP name	Population serviced	Consent type	Consent ID	Reference number	Expiry	Receiving environment	Discharge point
Hawke's Bay	Hastings (East Clive)	62,118	Coastal permit	CON-00002406	CL150305O	31/05/2049	Marine Coastal	Long Ocean Outfall
			Coastal permit	CON-00002407	CL150176a CL150177Ea CL150178Ca	31/05/2049		
	Napier	60374	Coastal permit	CON-00002209	AUTH-118503-02	07/11/2036	Marine Coastal	Awatoto WWTP Marine Outfall
Taranaki	Hāwera	9,790	Coastal permit	CON-00001833	5079-2.0	01/06/2052	Other	Tasman Sea
			Discharge to water	CON-00002167	7520-1	01/06/2027	River, Stream or Creek	Unnamed stream 22
	New Plymouth	74,598	Coastal permit	CON-00001834	0882-4.1	01/06/2041	Marine Coastal ⁴	Tasman Sea
	Stratford	5,740	Discharge to water	CON-00002157	R2/0196-5.0	02/06/2034	River, Stream or Creek	Pātea River
Manawatu-Whanganui	Dannevirke	6,000	Discharge to water	CON-00002296	ATH-2003008378.00	9/12/2027	River, Stream or Creek	Mangatera Stream
	Feilding	6,369	Discharge to water	CON-00002182	106948	26/11/2026	River, Stream or Creek	Oroua River

⁴ <https://www.trc.govt.nz/assets/Documents/Environment/Monitoring-wastewater/2019onwards/MR20-NPWWTP.pdf> Accessed 19 March 2025

	WWTP name	Population serviced	Consent type	Consent ID	Reference number	Expiry	Receiving environment	Discharge point
Manawatu-Whanganui	Totara Rd (Palmerston North)	84,639	Discharge to water	CON-00001048	ATH-2003009337.03	16/05/2028	River, Stream or Creek	Manawatū River
			Discharge to water	CON-00001049	ATH-2003009340.00	16/05/2028		
	Whanganui Urban	47,300	Coastal permit	CON-00002174	105288	01/07/2026	Marine Coastal	South Beach Outfall
			Coastal permit	CON-00002175	101706	01/07/2026		
Wellington	Carterton	5,840	Discharge to water	CON-00002119	WAR160341	17/01/2052	River, Stream or Creek	Reservoir Outfall; emergency discharge weir
	Homebush (Masterton)	20,000	Discharge to water	CON-00002069	WAR090066 34491, 34492	08/12/2034	River, Stream or Creek	Ruamahanga River
	Moa Point	178,000	Coastal permit	CON-00002361	WGN080003 [31505]	11/05/2034	Marine Coastal	Moa Point WWTP Long and Short Outfalls
			Coastal permit	CON-00002362	WGN080003 [35047]	11/05/2034		
	Paraparaumu	48,010	Discharge to water	CON-00002249	WGN970255 [2565] ⁵	22/03/2022	River, Stream or Creek	Mazengarb Drain

⁵ <https://www.kapiticoast.govt.nz/media/p44g4gt1/pwwtp-q4-fy2023-final-1.pdf> Accessed 17 March 2025

	WWTP name	Population serviced	Consent type	Consent ID	Reference number	Expiry	Receiving environment	Discharge point
Wellington	Porirua	96,000	Coastal permit	CON-00002369	WGN200229 [36816]	21/06/2041	Marine Coastal	Porirua WWTP Main Outfall
	Seaview	163,461	Coastal permit	CON-00002363	WGN050359 [24539]	25/08/2031	Marine Coastal	Seaview WWTP Main Outfall
			Coastal permit	CON-00002364	WGN120142 [33407]	25/08/2031	River, Stream or Creek	Waiwhetū Stream Short Outfall
	Western	14,000	Coastal permit	CON-00002365	WGN060283 [35255]	28/07/2035	Marine Coastal; River, Stream or Creek	Western WWTP Long and Short Outfalls
			Coastal permit	CON-00002366	WGN060283 [25227]	28/07/2035		
Tasman	Motueka	14,000	Discharge to water	CON-00002287	RM141088	15/10/2035	River, Stream or Creek	WWTP Motueka Discharge Point
			Coastal permit	CON-00002319	RM141092	15/10/2035		
Nelson	Nelson	30,000	Coastal permit	CON-00002254	RM025169	1/12/2024	Marine Coastal	Tasman Bay
	Nelson Regional Sewerage Scheme (Bell Island)	56,000	Coastal permit	CON-00002259	RM171238	20/03/2040	Marine Harbour	Waimea Inlet

	WWTP name	Population serviced	Consent type	Consent ID	Reference number	Expiry	Receiving environment	Discharge point
Marlborough	Blenheim	30,860	Coastal permit	CON-00002043	U071181.06	3/10/2025	Marine Coastal	Blenheim WWTP - Wetlands Outlet
Canterbury	Christchurch	355,379	Discharge to water	CON-00002112	CRC051724	16/05/2041	Marine Coastal	CWTP Ocean Outfall
	Timaru domestic	36,800	Coastal permit	CON-00002382	CRC242247 ⁶	26/11/2045	Marine Coastal	Timaru Ocean Outfall
Otago	Alexandra	6,010	Discharge to water	CON-00001911	RM12.517.02.V1	8/01/2038	River, Stream or Creek	Clutha River/Mata-au
	Cromwell	7,855	Discharge to water	CON-00001912	RM13.233.02.V3	26/02/2049	Lake	Lake Dunstan
	Green Island	34,220	Coastal permit	CON-00002293	97530.V1	30/06/2032	Marine Coastal	Green Island Outfall
			Coastal permit	CON-00002294	97550	30/06/2032		
			Coastal permit	CON-00002295	97551	30/06/2032		
	Oamaru	14,828	Discharge to water	CON-00002339	2002.655	30/04/2038	River, Stream or Creek	Landon Creek

⁶ <https://www.ecan.govt.nz/data/consent-search/consentdetails/CRC242247> Accessed 17 March 2025

	WWTP name	Population serviced	Consent type	Consent ID	Reference number	Expiry	Receiving environment	Discharge point
Otago	Tahuna – Ōtepoti	84,447	Coastal permit	CON-00002309	2002.623	30/06/2032	Marine Coastal	Tahuna Outfall; Lawyers Head Outfall
			Coastal permit	CON-00002310	2006.534	30/06/2032		
			Coastal permit	CON-00002311	2002.621	22/10/2039		
			Coastal permit	CON-00002312	2002.624	30/06/2032		
Southland	Clifton	51,000	Discharge to water	CON-00002053	200749	30/06/2029	Marine Coastal; River, Stream or Creek	Clifton Discharge to New River Estuary; Station Road Biosolids Stormwater and Leachate
			Discharge to water	CON-00002054	200750	30/06/2029		
			Discharge to water	CON-00002058	20136275-01-V2	30/06/2029		
	Gore	7,911	Discharge to water	CON-00001805	203595	31/12/2023	River, Stream or Creek	Gore WWTP Outfall and Gore WWTP overflow

Data obtained from the Taumata Arowai Public Register of Wastewater Networks accessed 13 March 2025

(<https://hinekorako.taumataarowai.govt.nz/publicregister/wastewater/>). Ashburton was removed as data on the Environment Canterbury website (ecan.govt.nz) identified that the consents were not strictly for discharge to water. Red text indicates those permits which are expired.

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