Derivation of Class 3 and 4 Landfill Waste Acceptance Criteria

Prepared for

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PATTLE DELAMORE PARTNERS LTD
Level 4, 111 Customhouse Quay,
Wellington 6011
PO Box 6136, Wellington 6141, New Zealand

Tel +64 4 **471 4130** Fax +64 4 **471 4131**
Website **http://www.pdp.co.nz**
Auckland Tauranga **Wellington** Christchurch

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Prepared by

SIGNATURE

Graeme Proffitt and Natalie Webster

Reviewed by

SIGNATURE

Erin Weightman

Approved by

Graeme Proffitt

Limitations:

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Table of Contents

Table of Tables

1.0 Introduction

This report sets out new waste acceptance criteria (WAC) for Class 3 (Managed) fills and revised WAC for Class 4 (Controlled) fills for incorporation into a revised version of the WasteMINZ draft document *Technical Guidelines for Disposal to Land* (WasteMINZ, 2018) (henceforth, 'the Guidelines').

This report is based on three technical memoranda prepared for the Ministry for the Environment (MfE), which were in turn passed on to the WasteMINZ/MfE Technical Guidelines for Disposal to Land Reference Group (the Reference Group) for consideration. These memoranda proposed revised derivations for a suite of eight common metal contaminants (arsenic, cadmium, chromium, copper, lead, mercury, nickel and zinc), seven organic compounds (benzene, ethylbenzene, toluene, xylene, benzo(a)pyrene, dieldrin and DDT), and two total petroleum hydrocarbon (TPH) fractions, respectively. Decisions from the Reference Group have resulted in the final values presented in Table 1 below.

This report concentrates on the derivation of Class 3 WAC, which were not presented in WasteMINZ (2018). The WAC for a given contaminant in soil deposited in a Class 3 fill is the lowest (most conservative) of the values protective of a nearby groundwater drinking-water source or protective of a nearby surface water aquatic environment. The risk to these two receptors arises via the soil leaching to groundwater pathway, and for the aquatic environment, subsequent discharge of ground water to the surface water body.

It is convenient and more economical to have Class 3 acceptance criteria in terms of total recoverable concentrations (in mg/kg), even though it is leaching that is critical in the landfill, as the waste soil will often already have laboratory results for total concentrations as part of contaminated site investigations. It is therefore necessary to convert leaching criteria (as estimated by synthetic precipitation leaching procedure (SPLP) analysis) to total concentration criteria. The calculated total concentration WAC are intended to provide waste disposers and Class 3 facility operators generic values which can be relied on to not produce unacceptable leaching to a groundwater users or aquatic environment after disposal.

However, should a soil exceed a total concentration WAC, it is still possible to carry out leachability testing using the SPLP test to determine whether the soil complies with the limiting SPLP concentrations on which the various total recoverable WAC are based. If a soil complies with the relevant SPLP limits, the soil would be acceptable for disposal. The intention is that the more complicated (and expensive) leachability testing provides a fallback option for soil acceptance assessment.

The two leaching pathways to groundwater and to an aquatic environment were also considered in the derivation of the Class 4 WAC presented in Appendix C of

WasteMINZ (2018). The original intention was to replicate the leaching pathway derivations for the Class 3 scenario. However, the leaching pathway derivations in that document for the metal contaminants used generic soil partitioning coefficients (Kd) that vary by orders of magnitude, depending on soil properties such as pH and mineralogy. This variability created uncertainty about whether the earlier derived values were valid. It was therefore decided to use soil-leachate partitioning relationships developed from a large New Zealand dataset of laboratory testing results in place of the generic coefficients. This derivation method is described in Section 2.

For the organic compounds, the same approach used in Appendix C was adopted except that the organic carbon – water partition coefficients (Koc) previously used were examined and updated as considered necessary. This is described in Section 3.

Previously, there were no leaching pathway derivations for the two TPH fractions considered in the Guidelines as there are no drinking water or aquatic environment protection values for hydrocarbon mixtures. A proxy compound approach was employed using a large dataset of laboratory results to get around this problem. This is described in Section 4.

While this report does not focus on Class 4 WAC, in some cases the new Class 3 derivations affect Class 4 values. Following Appendix C of WasteMINZ (2018), the adopted Class 4 WAC are the lowest (most conservative) of values protective of soil ecology, human health, drinking water or an aquatic environment. Typically, the soil ecology or human health value is the lowest for Class 4. However, in the case where one or other of the leaching pathways is critical for a contaminant, this becomes the Class 4 WAC with the same value also being the Class 3 WAC. For some contaminants, the new Class 3 derivations resulted in a change to the Class 4 WAC.

In addition, the opportunity was taken while re-examining the Class 4 WAC to review more recently derived soil ecology protection values (eco-soil guideline values or eco-SGV). In some cases, the revised eco-SGVs, taken from Landcare (2019), are the limiting values. These changes have been included in Table 1. For some contaminants revised eco-SGVs were not available and the original values from Cavanagh and O'Halloran (2006) and Cavanagh (2006) remain.

It is noted that in some localities, natural background concentrations of contaminants in soils may be higher than the Class 4 WAC. Where this is the case, the natural background concentration should prevail as the WAC, so as not to prevent virgin / natural soils from being disposed of to a Class 4 site.

The assistance of the members of the Technical Guidelines for Disposal to Land Reference Group is acknowledged. In addition, the assistance of Analytica Laboratories Limited and R J Hill Laboratories Limited in freely providing data to assist with deriving the WAC for the metals and total petroleum hydrocarbons is

acknowledged. The assistance provide by Jane Sherrard of Hill Laboratories was particularly valuable.

Table 1: Class 3 (Managed Fill) and Class 4 (Controlled Fill) WAC Criteria (mg/kg)

Contaminant	Class 3	Class 4
Arsenic	140[1]	17[2]
Cadmium	10[3]	0.8
Chromium	150[4]	150
Copper	280	220[5]
Lead	460	160
Mercury	3[3]	0.7
Nickel	320[6]	35[7]
Zinc	1,200[8]	190[7]
TPH $C_7 - C_9$	200[9]	110
TPH $C_{10} - C_{14}$	600[10]	58
Benzene	0.11	0.11
Ethylbenzene	10	10
Toluene	19	19
Total Xylene	25	25
Benzo(a)pyrene (eq)[11]	125	2.8
Dieldrin	0.10	0.10
Total DDTs[12]	2	2[13]

Notes:

1. *Blue shading indicates the drinking-water pathway is limiting.*
2. *Grey shading indicates human health agricultural land use or rural residential land use is limiting.*
3. *Not calculated. Based on SPLP – total concentration dataset and likely source site concentrations.*
4. *Green shading indicates aquatic pathway is limiting.*
5. *Orange shading indicates soil quality for protection of ecological receptors (minimal risk / protective of agricultural land use) is limiting.*
6. *Not calculated. Based on SPLP – total concentration dataset and ensuring not below possible local background concentrations.*
7. *WAC may be lower than natural background concentrations for soils in some localities. Where this is the case, the natural background concentration should prevail.*
8. *Calculated based on the aquatic pathway being limiting but WAC set to be above possible background concentrations.*
9. *Based on TPH – BTEX dataset comparison, using BTEX compounds as proxies*
10. *Based on TPH – PAH dataset, using naphthalene as proxy.*
11. *Equivalent benzo(a)pyrene concentrations calculated as a toxicity-weighted sum of the nine carcinogenic PAHs in the standard PAH analytical suite.*
12. *Sum of the concentrations of the six DDT, DDD and DDE isomers.*
13. *WAC to protect aquatic species via the leaching pathway is similar to the limiting eco-SGV for DDT from Cavanagh and Ohalloran (2006) of 1.9 mg/kg. To avoid confusion over a minor difference in the Class 3 and Class 4 WAC values, the WAC for both has been set at 2 mg/kg.*

2.0 Waste Acceptance Criteria for Metal Contaminants

2.1 Background

This section is based on a technical memorandum describing the derivation of WAC for a suite of eight common metal contaminants being arsenic, cadmium, chromium, copper, lead, mercury, nickel and zinc (PDP, 2020a). This followed an earlier discussion provided in PDP (2019), which pointed out the difficulties of developing WAC to be protective of groundwater and surface water via leaching using distribution coefficient (Kd) values. An alternative approach is to use the synthetic precipitation leaching procedure (SPLP) to simulate leaching and use this test to determine whether a waste is acceptable. However, as noted above, this approach is less convenient and the laboratory analysis more expensive than using simple total recoverable concentrations (TRC). It is advantageous to both the waste disposal facility operators and the facility users to be able to infer the suitability of a waste soil for disposal from the TRC values obtained during the investigation of a source site, and/or from verification sampling undertaken once waste has arrived at a disposal facility.

The PDP (2019) memorandum therefore proposed using existing SPLP data available from testing laboratories to attempt to come up with SPLP-TRC relationships for each of the elements within the commonly used heavy metal suite (eight elements) in order to arrive at total concentration WAC. This section presents the development of such relationships. This process has been carried out for a range of common metal contaminants but not for organic contaminants. This is because the review of the WAC derivation process that is described in PDP (2019) found that the partition coefficients used for derivation of the WAC for organics did not show the same variability as for the metals (which vary over orders of magnitude, depending on soil properties).

To achieve WAC that would ensure that leachate from Class 3 fill sites would not pose a significant risk to nearby groundwater users and aquatic environments, TRC and corresponding SPLP data pairs from a variety of soil types and from around the country were compared to a calculated target values for contaminants of concern. Several hundred and in some cases more than a thousand data pairs were available for this exercise. Further details on the analysis methodology are provided in the next section.

2.2 Analysis Methodology

2.2.1 SPLP-TRC Dataset

Class 3 WAC have been derived for eight metal contaminants of concern (arsenic, cadmium, chromium, copper, lead, mercury, nickel and zinc). The combined SPLP-TRC dataset provided by two New Zealand based laboratories (Hill Laboratories and Analytica Laboratories) used in this derivation is summarised in

Table 2 below. It is expected that these two laboratories carry out the majority of SPLP analyses in New Zealand. The data represents up to ten years of analysis results, which is the length of time for which data was readily available when obtained in December 2019.

Table 2: Metal Contaminant Dataset Summary

Contaminant	Total Number of Data Pairs (TRC and SPLP)	Range	
		Total Recoverable Concentration (mg/kg)	SPLP Concentration (mg/L)
Arsenic	1,259	<0.2 – 111,101	<0.0011 – 305
Cadmium	721	<0.01 – 1,005	<0.000053 – 0.081
Chromium	981	0.12 – 7,629	<0.00053 – 0.99
Copper	1,141	<0.2 – 101,309	<0.005 – 3.68
Lead	930	0.29 – 42,379	<0.00011 – 21.47
Mercury	366	<0.01 – 161	<0.00008 – 0.011
Nickel	861	0.16 – 37,029	<0.00053 – 0.229
Zinc	979	0.0759 – 42,107	<0.0011 – 10.476

2.2.2 Calculating SPLP Target Values

To determine if contaminant concentrations pose a risk to the receiving environment, target SPLP values were derived for each contaminant. These target values are the lower (more conservative) of either the *Drinking Water Standards for New Zealand* (DWSNZ) (MoH, 2018) Maximum Acceptable Values (MAV) for the protection of groundwater as a drinking-water source; or the web-based *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*[1] (ANZG, 2018) for the protection of 95% of species in a freshwater aquatic environment, after multiplying by a dilution and attenuation factor (DAF). The ANZG (2018) water guideline superseded the ANZECC 2000 water quality guidelines used for the WasteMINZ (2018) derivations, although the numerical values for most of the contaminants did not change.

A DAF of x20 was applied to the DWSNZ MAVs and x100 for ANZG (2018) guidelines to account for the reduction in contaminant concentrations during

[1] Available https://www.waterquality.gov.au/anz-guidelines/guideline-values/default/water-quality-toxicants/search - accessed May 2021.

leachate migration between the waste site and nearby receptors[2]. These DAF are the same as used in Appendix C.4 of WasteMINZ (2018). The target SPLP values are presented in Table 3 below.

Table 3: Target SPLP Values for Deriving WAC[1]

Contaminant	Groundwater as Drinking-water		Aquatic Protection	
	DWSNZ MAV[2]	Target Concentration = MAV x 20 = SPLP Limit	ANZG 95%[3]	Target Concentration = ANZG x 100 = SPLP Limit
Arsenic	0.01	**0.2**	0.013	1.3
Cadmium	0.004	0.08	0.0002	**0.02**
Hexavalent Chromium	0.05	1	0.001	**0.1**
Trivalent Chromium	0.05	1	0.0033[4]	**0.33**
Copper	2	40	0.0014	**0.14**
Lead	0.01	**0.2**	0.0034	0.34
Mercury	0.007	0.14	0.0006	**0.06**
Nickel	0.08	1.6	0.011	**1.1**
Zinc	1.5	30	0.008	**0.8**

Notes:

1. *All values in mg/litre*
2. *Drinking Water Standards for New Zealand – Maximum Acceptable Values (MoH, 2018).*
3. *Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG, 2018) for the protection of 95% of species.*
4. *Low quality guideline based on data for few species.*

BOLD *denotes the lower of the two values and therefore the applied target SPLP value.*

Two target SPLP values are provided for chromium, one each for trivalent and hexavalent forms. Both hexavalent chromium (Cr(VI)) and trivalent chromium (Cr(III)) forms can occur in the environment, but trivalent forms are more common in the soil environment as hexavalent chromium in soil is generally rapidly reduced to trivalent forms by organic material in the soil. Therefore, trivalent chromium (Cr(III)) is considered to be the more relevant form of

[2] The dilution factor is based on sorption, absorption and attenuation of a contaminant during its migration from source (waste facility) to receptor (groundwater and/or surface water) as well as dilution with cleaner soils and/or water sources during the migration process.

chromium, although hexavalent chromium (Cr(VI)) is more toxic to both people and the aquatic environment.

2.2.3 Calculating TRC WAC

To determine an appropriate WAC based on TRC, the SPLP results were plotted against their respective TRC concentrations to establish if there was a TRC below which there could be a reasonable level of confidence that the SPLP concentration would comply with the calculated target value.

For most of the contaminants there were a few high SPLP results for low TRCs, which meant that it was not possible to have all SPLP results below some WAC without having the WAC being unreasonably low. To get around this, a trial approach was taken, selecting a WAC and then calculating the percentage of SPLP results exceeding the target SPLP. This was repeated for a range of potential WAC (refer to Section 2.3 for detail) with percentage exceedances calculated for each trial up to about 3% SPLP target exceedances. The percentages were calculated relative to the total dataset.

As a matter of judgement, the WAC can then be selected so as not to have too many SPLP exceedances. The acceptable percentage of instances in which an exceedance of the target SPLP would occur for a given WAC is discussed further below. However, the philosophy is that some small number of SPLP exceedances can be tolerated on the basis that, on average, all soil would comply if it were to be mixed (not a practical proposition given that soil arrives at different times); and even if a slightly more leachable parcel of soil was to be disposed of, it would be co-disposed with or on top of other less leachable soil so that by the time leachate from various parcels of soil reached the water table it would, on average, be compliant.

The question then becomes, what (low) proportion of exceedances can be tolerated while maintaining confidence that the bulk of emplaced soil will not result in discharges that could cause adverse effects to drinking water or aquatic receptors? It should also be borne in mind that the SPLP test is conservative as an estimate for leachability, as are the DAFs used in the derivation of the leachate target.

2.3 WAC Derivations

A range of potential WAC values and associated percentage of samples exceeding the target SPLP values are presented in the following sections for each contaminant of concern. Greater detail is provided for arsenic, to illustrate the process, but a similar process was worked through for all contaminants. For cadmium, mercury and nickel the leachability was found to be low. In these cases, the trial approach was not necessary, as is explained in the relevant sections below. Further detail is provided in PDP (2020a).

It was found that there was no consistency between the various contaminants with respect to percentage exceeding the SPLP targets and the percentage of the dataset that these values represent. The choice of WAC values is therefore necessarily a matter of judgement. To assist this judgement, a decision-making hierarchy was developed, taking into account factors such as the prevention of unacceptable adverse effects and practical considerations (e.g., ensuring where possible that there is differentiation between Class 3 and 4 landfills; ensuring the ability of a Class 3 landfill to dispose of waste soils from sites where it may most commonly be generated). The decision-making hierarchy was:

1. The WAC must be above the background concentration.
2. The WAC should preferably be above the residential human-health soil contaminants standard (SCS) on the basis that residential development will be the source of much waste soil and avoiding excessive SPLP testing for this common source is preferable.
3. As a matter of judgement, where percentages exceeding the SPLP target could be calculated, a WAC in the range 2 to 3% should be chosen as giving reasonable values while ensuring adequate protection of the environment.
4. Given the scatter in the SPLP versus TRC plots at high TRC values and, in some cases, extreme values still being within the SPLP targets, as a matter of judgement the WAC should not exceed the 95th percentile and preferably not exceed the 90th percentile of the respective datasets.
5. As a "nice to have", the WAC should not exceed the ANZG "high" sediment guideline, with the effect that a non-compliance of stormwater sediment controls would be less significant, if poorly treated stormwater runoff reaches an aquatic environment. It should be noted that engineered controls to prevent significant sediment reaching an aquatic environment with the primary goal to prevent smothering effects should also avoid contaminant effects.
6. Existing consented landfill WAC have not been considered, as these have many site-specific and regional plan issues factored in.

2.3.1 Arsenic

The applicable SPLP target value for arsenic is 0.2 mg/L from the DWSNZ MAV (indicated by the horizontal red line on the graph below). For clarity of presentation in the plot a maximum TRC value of 300 mg/kg has been used (i.e., all TRC values greater than 300 mg/kg are not presented). Approximately 96% of the laboratory-supplied dataset is <300 mg/kg.

The plot shows that only a relatively small number of arsenic results exceed the SPLP target value of 0.2 mg/kg where TRC <300 mg/kg, suggesting that in the majority of cases, the leachable portion of the total recoverable arsenic is low. There is a weak correlation of increasing TRC to increasing SPLP, however, there are also many instances where similar TRC values result in quite different SPLP values (and vice versa. For example, in one sample a TRC of arsenic of 122 mg/kg produced an SPLP <0.001 mg/L, while in another sample a TRC of 142 mg/kg produced an SPLP of 0.98 mg/L (almost five times the target value).

Because of the scatter, it is not possible to establish a TRC WAC for arsenic with no SPLP exceedances above the 0.2 mg/L screening value without the WAC being very low. For the current dataset, this value would be about 25 mg/kg, which is only a little higher than the residential soil contaminant standard from MfE (2011a) and would mean most waste soils with elevated arsenic would require SPLP testing. This reduces the usefulness of a TRC WAC. However, it is clear from the plot that most soil would comply with the SPLP screening value at much higher TRC values.

Adopting the trial TRC approach as described above, the proportion of the total dataset that exceeded the SPLP target was calculated. The different trial TRC concentrations are also shown on the plot below, with the exceedances visually represented by the dots above the SPLP target and to the left of the various trial TRC WAC values (the vertical lines).

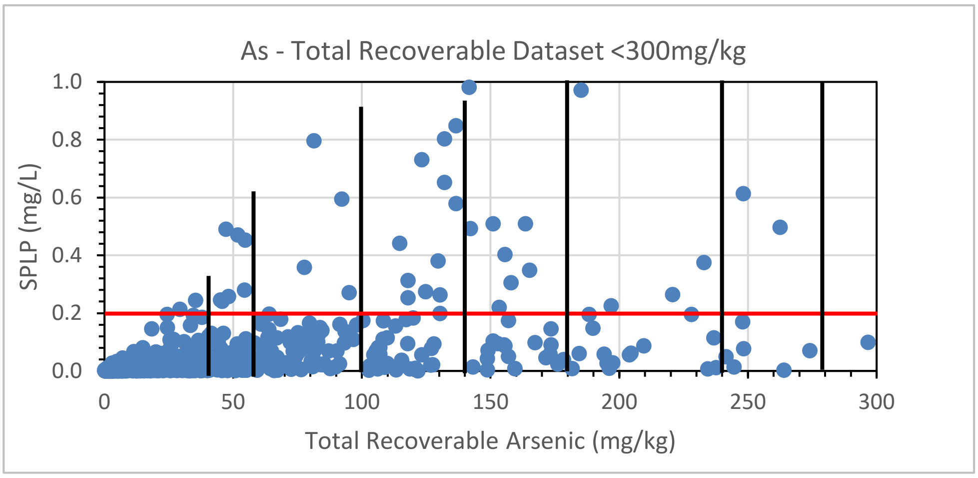
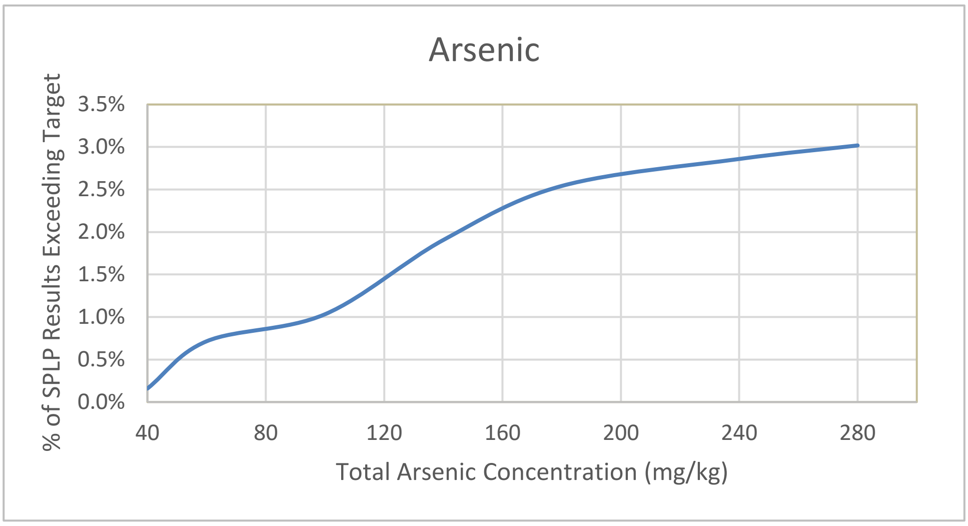


Table 4 below presents a range of trial WAC and the associated SPLP exceedance percentages up to about 3%, with the plot further below on the next page showing a graphical representation. As can be seen in the table and plot, the percentage exceedance increased only slightly above 3% from about 270 mg/kg.

Table 4: Arsenic Total Concentrations Versus Percentage of Dataset Exceeding SPLP Target Value								
Trial WAC (mg/kg)	40	60	100	140	180	240	280	300
% Results Exceeding SPLP Target Value (0.2 mg/L)	0.16	0.71	1.03	1.91	2.54	2.86	3.02	3.02



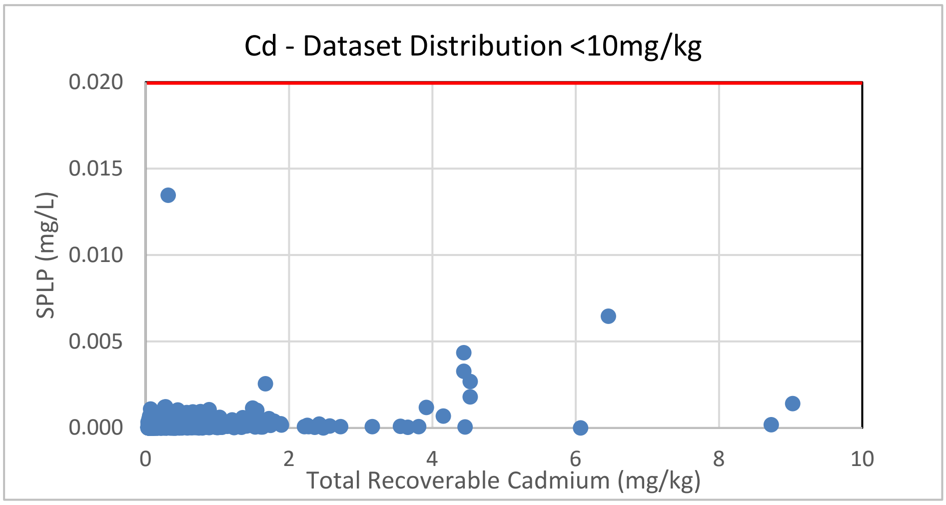
What constitutes an acceptable percentage of relatively more leachable soil is subjective and may vary between contaminants. If 1% is deemed to be an acceptable level of non-compliance, then the WAC for arsenic could be set at 100 mg/kg (nearest round number) but this may not be suitable for certain localities where the natural background concentration of arsenic (e.g. for some volcanic soils) may make such soils unacceptable for disposal at Class 3 waste facilities without SPLP testing. If 2% were chosen, then the arsenic WAC would be around 140 mg/kg, at 2.5% the arsenic WAC would be around 180 mg/kg, and at 3% it would be about 280 mg/kg.

A WAC value of 140 mg/kg has been agreed by the Reference Group, which is the 2% exceeding value. This is the equivalent to the 92nd percentile of the dataset, which is in the middle of the 90th to 95th percentile guideline. It is not possible to stay within the ANZG sediment guideline.

2.3.2 Cadmium

The graph below presents the distribution of the cadmium dataset. For the purpose of data presentation, a TRC cut-off of value of 10 mg/kg has been applied (i.e. the 17 values greater than 10 mg/kg are not shown; equating to approximately 97.6% of the total dataset being shown).

The target SPLP value for cadmium is 0.02 mg/L derived from the DWSNZ MAV (indicated by the red line on the graph). Of the 721 data pairs in the cadmium dataset, only one SPLP value (0.08 mg/L from a TRC of 11.45 mg/kg) exceeds this target (this value is not shown on the graph below as the TRC is above the displayed values). This suggests that the likelihood of cadmium contaminated soils generating a leachate that exceeds the target SPLP is low. Further, the leachability of cadmium appears to be variable with weak correlation with total concentration. For example, the two highest SPLP values (0.08 and 0.01 mg/L) were derived from TRC values of 11.45 and 0.32 mg/kg cadmium, respectively.



Given the low leachability, calculating the percentage of SPLP values exceeding the target concentration for different WAC values is of no benefit. Instead, a WAC must be selected as a matter of judgement. Any value up to the maximum dataset value of approximately 1,000 mg/kg could be chosen, with the one value that exceeds the target being only 0.14% of all values. If the maximum value as displayed of 10 mg/kg was chosen as the TRC WAC, with soil with concentrations greater than this requiring SPLP testing, of the 17 values within the dataset above this value, approximately 94% of instances (16 out of 17) of the SPLP results would still comply with the target value.

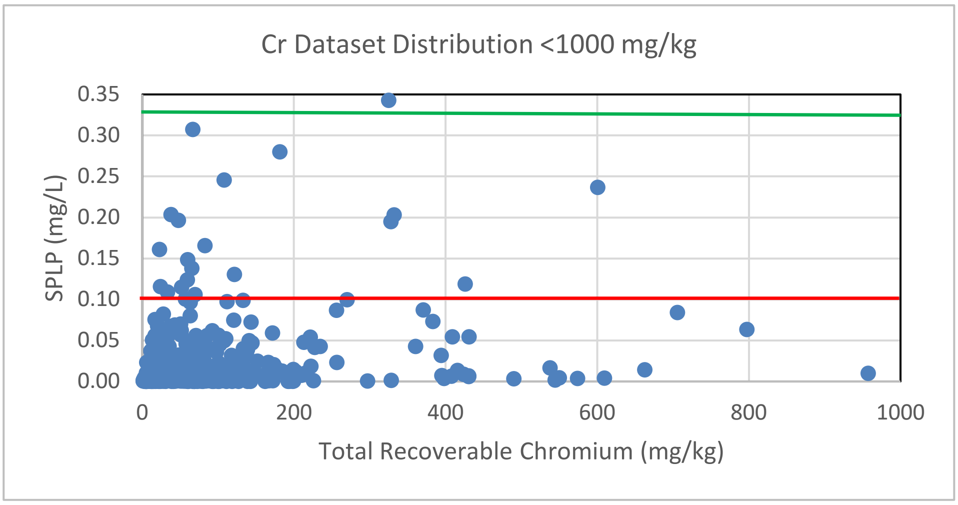
A value of 10 mg/kg has therefore been adopted as a matter of judgement. This represents the 98th percentile of the data set, which is higher than the dataset percentage guideline range, but given the low leachability of cadmium at higher concentrations, this is not considered a significant issue. Coincidentally, the value is the same as the ANZG (2018) high sediment value and has the advantage of being an easily remembered round value.

2.3.3 Chromium

As noted previously the target SPLP value for chromium may be calculated two ways, depending on whether the trivalent or hexavalent form is used. The TRC and SPLP results, reported as total chromium, do not differentiate between the forms of chromium. Depending on what form is present, the two targets may be conservative or unconservative.

In general, the trivalent form is expected to be the main form present in soil, which means using the hexavalent target would be conservative by a factor of 3.3. Given this, the trivalent target would generally be recommended. However, if the source of waste soil is an industrial site where hexavalent chromium could be present, for example a timber treatment site using the CCA treatment process, hexavalent chromium may be more appropriate.

The data for chromium is presented below, with a cut-off value 1000 mg/kg for display purposes. This cut-off value incorporates approximately 98% of the dataset of 981 values. The target SPLP value for hexavalent chromium is 0.1 mg/L derived from the ANZG (2018) for the protection of 95% species (indicated by the red line on the graph below). The target SPLP value for trivalent chromium is 0.33 mg/L (indicate by the green line on the graph below), based on a low-quality value from ANZG (2018), as insufficient data were available to develop values for different levels of protection.



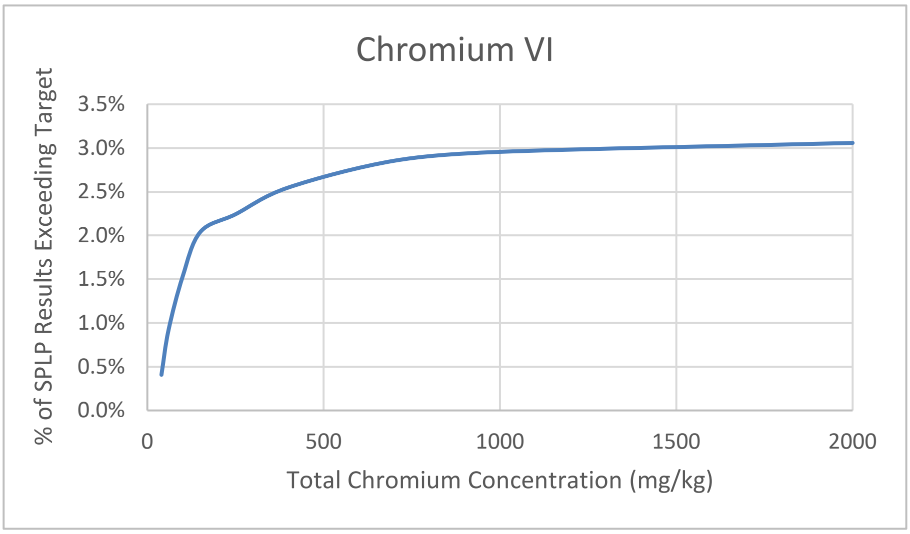
Below approximately 22 mg/kg there are no exceedances of the SPLP target value for Cr(VI). Above this there is greater scatter in the dataset and exceedances begin to occur. For Cr(III) there are few exceedances of the target, the first occurring at about 325 mg/kg.

The number of exceedances within the dataset is low overall suggesting that the chromium generally has low leachability. There is a weak correlation of increasing TRC to increasing SPLP value between approximately 50 mg/kg and 300 mg/kg, but this tends to break down toward the higher values within the dataset, which may be reflective of the low number of values in the dataset that reported high TRC. As with the other contaminants, there are a number of instances where a low TRC and a very high TRC have very similar SPLP values (e.g. 0.04 mg/L SPLP and 0.037 mg/L SPLP from 7,629 mg/kg and 10.9 mg/kg respectively).

Table 5 below presents a range of trial WAC and the associated exceedance percentages for Cr(VI) (if the assumption is made that the data is representative of Cr(VI). These are plotted on the graph further below.

Table 5: Hexavalent Chromium Total Concentrations Versus % of Dataset Exceeding SPLP Target

Trial WAC (mg/kg)	40	100	150	250	400	700	1,000	2,000
% Results Exceeding SPLP Target Value (0.1 mg/L)	0.41	1.53	2.04	2.24	2.55	2.85	2.96	3.06

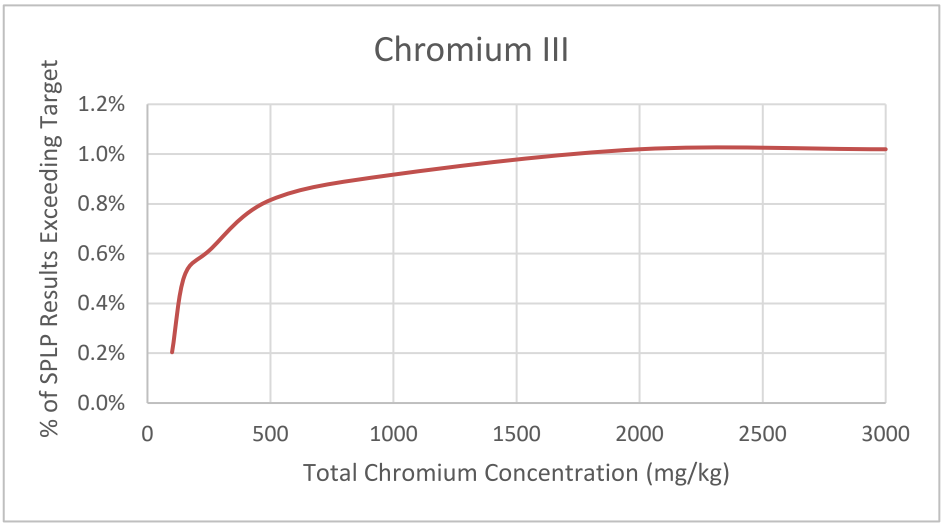


At 60 mg/kg (75% of the total dataset) approximately 1% of the SPLP results exceed the target value. However, a WAC of 60 mg/kg may be restrictive for some naturally occurring soils e.g., volcanic origin materials. At 2% exceedances the WAC would be close to 150 mg/kg (95% of the total dataset). Past this concentration the number of SPLP exceedances decreases significantly with 3% exceedances equating to a very high value of about 1,500 mg/kg and 97.8% of the dataset.

Table 6 below presents a range of trial WAC and the associated exceedance percentages for Cr(III) (if the assumption is made that the data is representative of Cr(III)). These are plotted on the graph further below.

Table 6: Trivalent Chromium Total Concentrations Versus % of Dataset Exceeding SPLP Target							
Trial WAC (mg/kg)	100	150	250	500	1,000	2,000	3,000
% Results Exceeding SPLP Target Value (0.33 mg/L)	0.20	0.51	0.61	0.82	0.92	1.02	1.02

The same rapid "flattening" of the curve as occurs with Cr(VI) also occurs with Cr(III) but because of the higher SPLP target, at lower concentrations. This results in 1% exceedance of the SPLP target occurring at about 1,800 mg/kg (99% of the dataset) with so few higher values in the dataset that it is not possible to calculate a percentage exceeding higher than 1.02%.

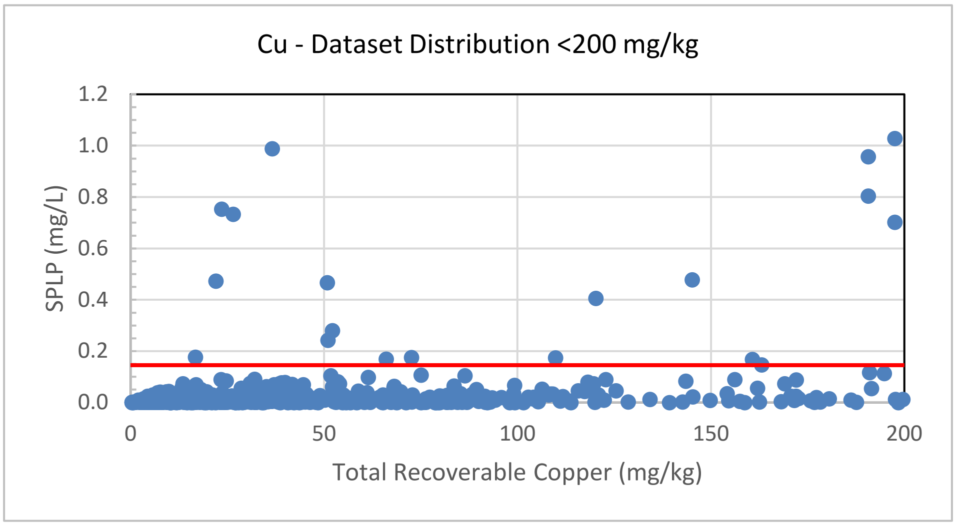


While, as noted earlier, Cr(III) is more commonly encountered and should provide the better SPLP target, the low leachability as measured by total chromium suggests having a single WAC defined by Cr(VI) for both Cr(VI) and CR(III) is expedient (and conservative), rather than using a high Cr(III) WAC.

The 2% exceeding value for Cr(VI) of 150 mg/kg represents the 95th percentile of the dataset, which is the top of the decision-making hierarchy range, and has therefore been chosen as the WAC. It falls comfortably below the ANZG high sediment guideline.

2.3.4 Copper

The target SPLP value for copper is 0.14 mg/L derived from ANZG (2018) for the protection of 95% species (indicated by the horizontal red line on the graph below). A TRC cut-off of value of 200 mg/kg has been used for presentation purposes on the graph. This incorporates approximately 87% of the dataset of 1,141 data pairs.



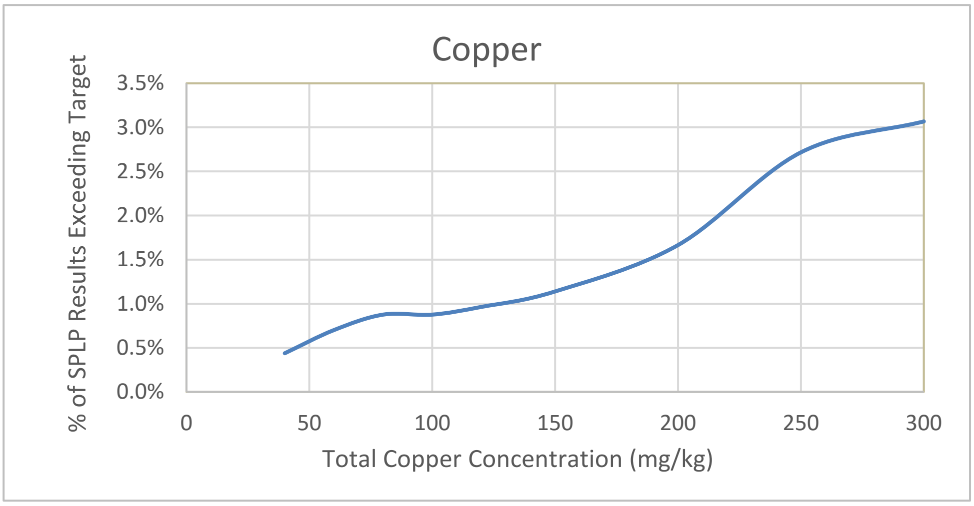
The scatter in the plot shows little if any correlation between increasing TRC and SPLP concentration, suggesting that a wide range of TRC values can have a significant leachable proportion. To achieve zero instances of target SPLP value exceedance within the dataset, a WAC of <16mg/kg would be required. This is below background concentration for many soils.

While there are exceedances of the target SPLP for a range of TRC values, they are relatively infrequent in the context of the total dataset (i.e., of the 1,141 data pairs only 75 (6.6%) reported SPLP values above the target value). Table 7 on the next page presents the range of trial WAC and the associated exceedance percentages up to 3% exceedance. This is illustrated on the graph below the table.

At 130 mg/kg (83% of the total dataset) about 1% of the SPLP results exceeded the target value. Above approximately 1% the percentage exceedance increases rapidly for relatively small increases in TRC with 2% exceedance occurring at about 220 mg/kg (88% of the dataset) and 3% occurring at about 280 mg/kg (91% of the dataset).

Table 7: Copper Total Concentrations Versus % of Dataset Exceeding SPLP Target Value

Trial WAC (mg/kg)	40	60	80	100	150	200	250	300
% Results Exceeding SPLP Target Value (0.14 mg/L)	0.44	0.70	0.88	0.88	1.14	1.67	2.72	3.07

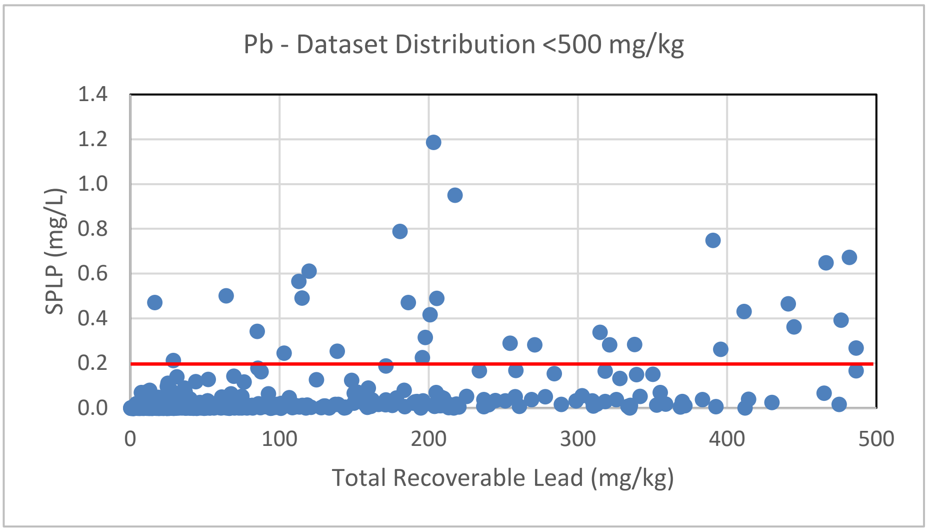


The adopted WAC for copper is 280 mg/kg. This is the 3% exceeding value, and represents 91% of the dataset, at the top and towards the bottom of the respective decision-making hierarchy ranges for these values. The value is slightly above the ANZG high sediment guideline.

2.3.5 Lead

The target SPLP value for lead is 0.2 mg/L derived from the DWSNZ MAV (indicated by the red line on the plot on the next page. A cut-off of value of 500 mg/kg has been used for presentation purposes in then plot below. This incorporates approximately 84% of the 930 pairs in the dataset.

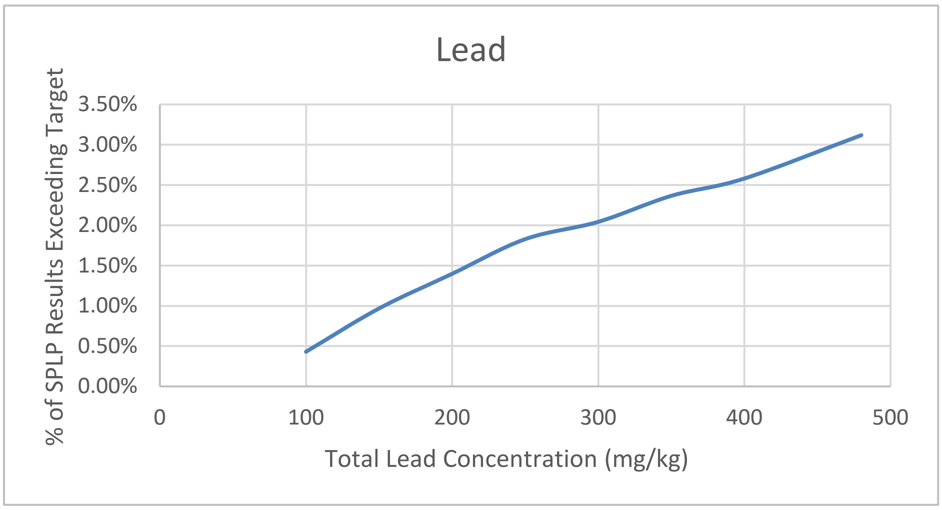
The plot shows a weak correlation of increasing TRC to increasing SPLP target value exceedance. There are also some notable anomalous results where a low TRC corresponds to a high SPLP value e.g., a TRC of 16.4 mg/kg with a corresponding SPLP concentration of 0.47 mg/L. These occurrences are the exception and are likely to be represent a small volume of the soil which may be accepted into a landfill facility. Below a TRC of approximately 100 mg/kg there is a very low instance of SPLP target value exceedance. Exceedances increase above approximately 180 mg/kg. In the context of the total dataset the number of SPLP exceedances is low (approximately 89% of the SPLP results are below the target value).



Because of the scatter, a TRC WAC for lead with no SPLP exceedances above the 0.2 mg/L screening value would equate to approximately 16 mg/kg, which is below natural background levels for many soils and therefore not useful. Larger trial WAC values and the associated percentage of SPLP exceedances are presented in Table 8 and the plot below. There is a reasonably linear trend of increasing TRC value to increasing percentage of SPLP exceedances.

Table 8: Lead Total Concentrations Versus % of Dataset Exceeding SPLP Target Value

Trial WAC (mg/kg)	100	150	200	250	300	350	400	480
% Results Exceeding SPLP Target Value (0.2 mg/L)	0.43	0.97	1.40	1.83	2.04	2.37	2.58	3.12



Lead is frequently the driver for soil remediation during redevelopment of older residential suburbs and therefore much of the soil requiring disposal will exceed the residential human health SCS of 210 mg/kg (MfE, 2011a). The plot demonstrates the acceptability of most soil well in excess of 210 mg/kg.

A WAC of 460 mg/kg for lead has therefore been adopted. This is the 3% exceeding value but represents only the 83rd percentile of the dataset. This value has been chosen to avoid an unnecessarily high percentage of waste soil needing to undergo SPLP testing. The WAC is above the ANZG high sediment guideline, but relatively less so than arsenic.

2.3.6 Mercury

The target SPLP value for mercury is 0.06 mg/L derived from ANZG (2018) for the protection of 95% of species. No exceedances of this target concentration were identified within the dataset of 366 values. Mercury had a low number of data pairs relative to the other contaminants and the low TRC generally encountered (92% of the dataset was < 2 mg/kg and only 12 values – 3% of the dataset – exceeded 10 mg/kg) suggest that mercury is not a commonly encountered contaminant. In addition, when encountered, it is at generally low concentrations.

At the encountered concentrations mercury had low leachability. The highest SPLP concentration in the dataset (0.01 mg/L) was only 18% of the target value suggesting that an exceedance of the target value is highly unlikely for soils arising from a 'typical' site, as represented by the dataset.

In the absence of any exceedances, it was not possible to calculate a TRC WAC using the methodology described in Section 2.2. Instead, a TRC WAC must be selected as a matter of judgement. For the dataset this suggests any value up to 160 mg/kg, and even higher, could be used. As a comparison, the residential SCS for mercury is 310 mg/kg.

A value of 3 mg/kg was adopted, which is the 93rd percentile of the dataset. This is in the middle of the dataset percentile range recommended in the decision-making hierarchy.

2.3.7 Nickel

The target SPLP value for nickel is 1.1 mg/L derived from ANZG (2018) for the protection of 95% of species. No exceedances of this target concentration exist within the dataset of 861 values. If the laboratory-supplied dataset is representative of the range of nickel found in contaminated soils in New Zealand, the absence of SPLP exceedances and that 95% of the TRC values are below 100 mg/kg, suggest that nickel is rarely encountered in high and/or highly leachable concentrations in New Zealand.

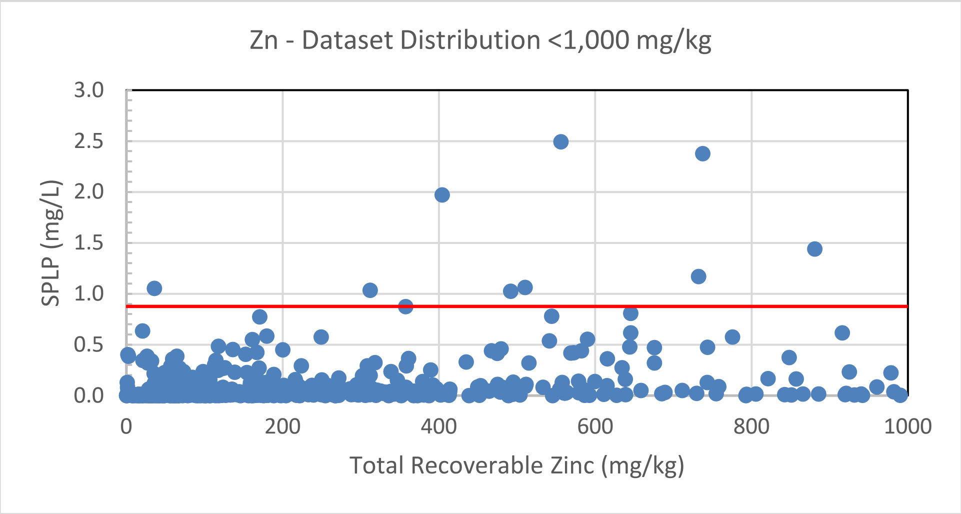
The highest SPLP concentration encountered (0.23 mg/L, associated with a TRC of 61 mg/kg, was only 21% of the target value. Even the highest concentrations of nickel in the dataset (approximately 37,000 mg/kg and 6,900 mg/kg) produced SPLP concentrations below the target value (0.05 mg/L and 0.09 mg/L, respectively). This suggests that an exceedance of the target value is highly unlikely under most circumstances.

In the absence of any exceedances, it was not possible to calculate a TRC WAC using the methodology described in Section 2.2 and judgement must be used.

The 95th percentile of the dataset is 100 mg/kg, which is below background concentration for some soils. The WAC should be set at a value that will not prevent the disposal of natural soils. Volcanic soils in Auckland can be up to 320 mg/kg, and this value has been adopted. Approximately 98% of the dataset falls below this value.

2.3.8 Zinc

The target SPLP value for zinc is 0.8 mg/L derived from the ANZG (2018) for the protection of 95% of species (indicated by the red line on the graph below). A cut-off value of 1,000 mg/kg has been used for presentation purposes. This incorporates approximately 88% of the dataset of 979 values.

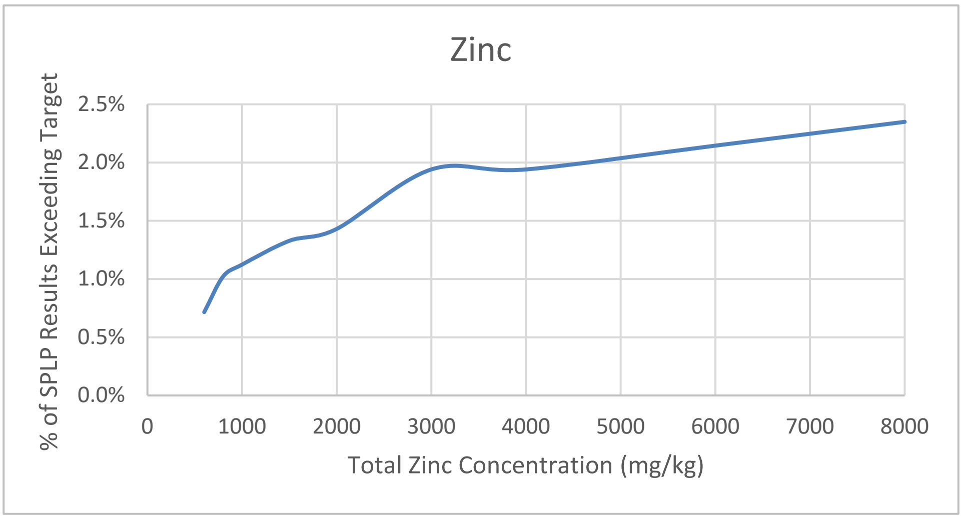


The plot shows that there is a weak correlation of increasing TRC to increasing SPLP, however, there are also some notable anomalous results where a low TRC corresponds to an SPLP value exceeding the target concentration e.g., 36 mg/kg TRC with 1.05 mg/L SPLP.

A TRC WAC for zinc with no SPLP exceedances above the 0.8 mg/L target would equate to about 35 mg/kg, which is significantly below natural background levels for many soils. Using greater trial WAC, the associated percentage of SPLP exceedances are presented in Table 9 below, with the results plotted further below.

Table 9: Zinc Total Concentrations Versus % of Dataset Exceeding SPLP Target Value

Trial WAC (mg/kg)	600	800	1,000	1,500	2,000	3,000	4,000	6,000	8,000
% Results Exceeding SPLP Target (0.8 mg/L)	0.72	1.02	1.12	1.33	1.43	1.94	1.94	2.15	2.35



There is a reasonably linear trend of increasing SPLP exceedances with increasing TRC for TRC values between 800 and 3,000 mg/kg, with the percentage changing little above 3,000 mg/kg. It was not possible to calculate a 3% exceedance, with the maximum value being 2.35% at a TRC of about 7,300 mg/kg.

A WAC for zinc of 1,200 mg/kg has been adopted. This is the dataset's 88th percentile and represents approximately 1.2% of the results exceeding the SPLP target. The value has been selected in consultation with the Reference Group to avoid accepting high zinc concentrations but allow soils with naturally moderately high concentrations – as can occur in volcanic settings in Auckland and possibly elsewhere – to be disposed of to Class 3 fills.

2.4 Heavy Metal Summary

The adopted WAC for heavy metals are summarised in Table 10 below. In general, the proportion of SPLP target exceedances between 2 – 3% has been considered appropriate, with the added criteria of the selected WAC falling within the 90th to 95th percentiles of the respective datasets. While there are obvious risks associated with allowing too many exceedances of the SPLP target value, the conservative nature of the SPLP test and the WAC derivation means this risk is generally small. On the other hand, it is appropriate to not go too high within a dataset, as it becomes increasingly uncertain how representative high values of TRC are of the "real world".

Table 10: Adopted Class 3 Waste Acceptance Criteria for Metal Contaminants

Contaminant	TRC WAC[1]	Percentage of Exceedances[2]
Arsenic	140	2%
Cadmium	10	N/A[3]
Chromium	150	2%
Copper	280	3%
Lead	460	2%
Mercury	3	N/A[3]
Nickel	320	N/A[3]
Zinc	1,200	1.7%

Notes:

1. *All values in mg/kg.*
2. *Percentage of samples that would still exceed the target SPLP value based on the current dataset.*
3. *Due to a low number or absence of SPLP values exceeding the target value it was not possible to calculate the likely percentage of samples that would exceed the target SPLP value.*

While some of the WAC values appear high, it should be borne in mind that there is an averaging effect within a landfill, with soil being physically mixed, leachate mixing in the ground and being adsorbed within other soil in the landfill, and further mixing within groundwater. This means that occasional SPLP exceedances will not eventuate in a risk to drinking water or an aquatic environment.

For cadmium, mercury and nickel, very few or no exceedances of the SPLP target value existed within the laboratory dataset and, as such, the data indicate that these elements are unlikely to leach at concentrations posing a risk to groundwater and/or surface water receptors (apart from unusual contamination conditions). Further, the low volume of soils that do exceed the SPLP target value for these elements are likely to be mitigated by the far greater volume of low SPLP value soils.

3.0 Organic Waste Acceptance Criteria Except TPH

3.1 Background

This section sets out the derivations of WAC for the organic compounds for Class 3 fills and revisions to the WAC for Class 4 fills except for the two TPH factions in WasteMINZ (2018). As the C_7-C_9 and C_{10}-C_{14} TPH fractions do not have drinking-water standards and aquatic protection guidelines, it is not possible to derive Class 3 WAC in the same way as in the WasteMINZ (2018). The TPH derivations are described separately in Section 4.0.

This section is based on PDP (2019) and PDP (2020b). There was no intention originally to change the derivations of the Class 4 WAC for other organic compounds but as pointed out in PDP (2020b) an error was discovered in the original derivation for the Class 4 WAC for xylene. This prompted a review of all the calculations for the Class 4 organic WAC. As some of the Class 3 WAC will be the same as the Class 4 WAC for situations where one of the leaching pathways is critical for Class 4, this review affected both Class 3 and 4 organic WAC values.

The results of the review are new organic WAC values for Class 3 and Class 4 fills.

3.2 Basis for Class 3 Organic WAC Derivations

As discussed in PDP (2019), the Class 3 WAC for organic compounds need only consider the groundwater use and aquatic environment leaching pathways. The calculations are the same for these pathways for Class 4 fills, but for Class 4, other pathways (e.g., residential land use or ecological protection) may be the limiting pathways and become the WAC.

As for the heavy metals, the leaching pathway calculations start with an estimate of leachate concentrations. To obtain a soil concentration-based WAC it is necessary to relate the leachate concentration to the soil concentration. Appendix C in the Guidelines uses a partitioning relationship. In addition, as described above for the metals, Appendix C uses DAFs to allow for attenuation of the contaminants between the waste and a hypothetical drinking-water abstraction point at the downgradient boundary of the waste or to a small stream at the downgradient boundary of the waste. The same DAFs as used the metals are used for the organic compounds.

The derivation process is the same as WasteMINZ (2018), but the drinking-water and aquatic protection guideline values have been checked and more up-to-date ecological protection values for the Class 4 derivations have been used, where available. In addition, the parameters used in the partitioning relationship have been checked and, as necessary, updated.

The partitioning relationship is expressed in its simplest form as:

Soil contaminant concentration (mg/kg) = Kd (ml/g) x Equilibrium pore water concentration (mg/L)

where Kd is the distribution coefficient (or partition coefficient) for the contaminant.

For organic compounds, Kd values can be calculated from an organic carbon-water partitioning coefficient (Koc) for a given fraction of organic carbon (foc) within the soil. The Kd value is simply the Koc value for the contaminant multiplied by the foc. While Kd values for heavy metals vary by orders of magnitude between varying soil types, measured Koc values for organic compounds vary much less from soil to soil than Kd values for heavy metals and are typically reported as averaged fixed values.

For the Class 4 derivations an foc of 1% has been assumed in the Guidelines. This is a reasonable (and conservative) value for most New Zealand soils, but may not be conservative for sandy or other granular soils with low organic carbon content. However, if it is assumed that most waste soil will have at least 1% foc, then even if some of the soil is sandy, on average the waste mass will have an foc of 1% or more.

3.3 Revised Derivations

The Class 4 derivations covered a range of organic compounds typically found at low levels on many contaminated sites. These include the BTEX compounds (benzene, toluene, ethylbenzene and xylenes) found in petrol and diesel; two persistent pesticides, DDT and dieldrin; and a polycyclic aromatic hydrocarbon (PAH) compound, benzo(a)pyrene (BaP). Benzo(a)pyrene is associated with petroleum hydrocarbons but is also a by-product of incomplete combustion and is often found as soil contamination in urban and industrial environments. Class 3 WAC have been derived for the same organic compounds.

Only some compounds had aquatic guidelines in the ANZECC 2000 document used for the original Class 4 derivations. The updated ANZG (2018) has 95% species protection values for all the organic contaminants. This means that both leaching pathways can now be assessed, whereas previously only the drinking-water pathway was able to be checked for some compounds.

In addition, it is apparent that the aquatic guideline previously used for the total xylenes aquatic pathway derivation was in error. There are three xylene isomers, o-, m- and p-xylene. Each have different aquatic guidelines. The WasteMINZ (2018) xylene calculations used 0.55 mg/L as the 95% species protection value, which appears to be the sum of the 95% protection guidelines for the o- and p-xylene isomers. A summation approach does not seem correct, as this would result in a higher (less conservative) WAC than would seem to be appropriate for a mixture of isomers with a range of toxicity. Instead, using an average guideline value seems more appropriate. An averaging approach for total xylenes has been used here.

Finding the error in the xylene WAC prompted a review of all the earlier calculations, including reviewing the Koc values used for the various organic compounds. The source of the Koc values is not reported in Appendix C of the 2018 Guidelines, however, from back-calculations it is apparent that the source for some of the values was the MfE *Petroleum Guidelines* (MfE, 2011b). These values were compiled in the mid-1990s when the *Petroleum Guidelines* were first developed. The availability of more recent values was therefore assessed. In addition, as the source of the Koc values for DDT and dieldrin is not clear in WasteMINZ (2018), these were also examined. It was found from a brief review of literature values that the previously used Koc values for dieldrin and DDT were too high, in one case by a factor of more than 10.

A non-exhaustive review of the literature has resulted in revised Koc values for all the organic compounds being sourced from the United States Environmental Protection Agency's (US EPA) online 'Chemical Dashboard[3]. This is regarded as an authoritative source. The database provides a range of measured, average measured and modelled values. Average measured values were used in the revised WAC derivations.

Table 11 on the next page shows the original and revised values of Koc and water quality guideline values used in the derivations.

For the Class 4 WAC, ecological values protecting plants and soil biota may be limiting. Landcare Research Limited has developed more up-to-date values than were used in the 2018 Guidelines for some of the organic compounds (Landcare, 2019). In the revised Class 4 derivations these values have been used where they are different from the original ecological values. Revised ecological guidelines were used for BaP and DDT. Ecological values were not available from the Landcare report for the BTEX group of hydrocarbons and dieldrin.

[3] Available https://comptox.epa.gov/dashboard/, accessed July 2020.

Table 11: Koc and Guideline Values for Class 3 and 4 Organic Compound Derivations

Contaminant	Koc (L/kg)		Drinking-water MAV[2] (mg/L)	95% Aquatic Guideline	
	Original	Revised[1]		Original	Revised[3]
Benzene	83	56.2	0.01	0.95	0.95
Ethylbenzene	1100	170	0.3	-	0.08
Toluene	302	117	0.8	-	0.18
Total Xylene	240	204[4]	0.6	0.55	0.21[4]
BaP	389,000	891,000	0.0007	-	0.0002
Dieldrin	21,380	12,000	0.00004	-	0.00001
Total DDT[5]	2,630,000	204,000	0.001	0.00001	0.00001

Notes:

1. *All values from US EPA Chemicals Dashboard: https://comptox.epa.gov/dashboard/ except as shown.*
2. *From MoH New Zealand Drinking-water Standards 2005 (Revised 2018): https://www.health.govt.nz/publication/drinking-water-standards-new-zealand-2005-revised-2018.*
3. *From Australia and New Zealand Guidelines for Fresh and Marine Water Quality 2018: https://www.waterquality.gov.au/anz-guidelines/guideline-values/default/water-quality-toxicants/search.*
4. *Mean value for o-, m- and p-isomers*
5. *Total DDT is the six o,p'- and p,p'- isomers of DDT, DDD and DDE.*

3.4 Revised WAC Values

The revised organic compound WAC for Class 3 and Class 4 are shown in Table 12 below, compared with the values currently in the Guidelines for Class 4 and what would have been derived for Class 3 using the parameters in the current Guidelines. All the Class 4 WAC are different, mainly lower, although slightly increased values were obtained for BaP and DDT. Five of the seven values have leaching pathways as limiting for Class 4 (four drinking-water and one aquatic value), which means the same values apply to Class 3.

Of the seven Class 3 WAC, five have the drinking-water pathway as limiting and two have the aquatic pathway as limiting.

The DDT WAC for Class 3 of 2 mg/kg based on aquatic protection, is only slightly different from the soil ecological guideline of 1.9 mg/kg from Cavanagh and O'Halloran (2006) that would have applied as the limiting value for Class 4. However, to avoid having only a small difference between the two classes it was decided to use 2 mg/kg for both.

Table 12: Adopted Class 3 and 4 WAC for Organic Compounds compared with (mg/kg)

	Class 3 using 2018 Class 4 Derivation[5]	Adopted Class 3 using Revised Parameters	Class 4 from 2018 Guideline	Adopted Class 4 using Revised Parameters
Benzene	0.2	0.11	0.2	0.11
Ethylbenzene	66	10	59	10
Toluene	50	19	50	19
Total Xylene	29	25	30	25
Benzo(a)pyrene (equivalent)[7]	54	125	Interim based on soil background = 2	2.8[6]
Dieldrin	0.2	0.10	0.2	0.10
Total DDTs[8]	26	2	0.7	2[9]

Notes:

1. *Blue shading indicates drinking water pathway is limiting.*
2. *Green shading indicates aquatic pathway is limiting.*
3. *Grey shading indicates human health agricultural land use or rural residential land use is limiting.*
4. *Orange shading indicates soil quality for protection of ecological receptors (minimal risk / protective of agricultural land use) is limiting.*
5. *Derived using Koc values in WasteMINZ (2018) Guidelines.*
6. *Landcare (2019).*
7. *Equivalent benzo(a)pyrene concentrations calculated as a toxicity-weighted sum of the nine carcinogenic PAHs in the standard PAH analytical suite.*
8. *Sum of the concentrations of the six DDT, DDD and DDE isomers.*
9. *WAC to protect aquatic species via the leaching pathway is similar to the limiting eco-SGV for DDT from Cavanagh and Ohalloran (2006) of 1.9 mg/kg. To avoid confusion over a minor difference in the Class 3 and Class 4 WAC values, the WAC for both has been set at 2 mg/kg.*

4.0 TPH Waste Acceptance Criteria

4.1 Background

This section describes the derivation process for the two TPH fractions in the Guidelines and is based on PDP (2021).

As was pointed out above, it is not possible to derive WAC for the two TPH fractions considered in WasteMINZ (2018) using the approach for the other organic compounds, because drinking-water guidelines and aquatic environment protection values do not exist for these petroleum mixtures. Following consultation with the Reference Group it was decided to explore a proxy compound approach. This is based on the expectation that if TPH concentrations are elevated then one or more of the BTEX compounds or a PAH compound, for which a WAC could be derived, could be used as proxies.

The BTEX compounds can be used as proxies for C_7-C_9 TPH and a lighter PAH can be used as proxy for C_{10}-C_{14} TPH. To do this, a large, anonymised dataset of TPH, BTEX and PAH results for the same soil samples was obtained from Hill Laboratories.

It is worth noting that petroleum hydrocarbons found on typical hydrocarbon-contaminated sites are measured using three TPH fractions, including a heavier C_{15}-C_{36} TPH fraction. The Guidelines have not considered the heavier hydrocarbons. This is acceptable because, in general, the aliphatic[4] components of the heavy hydrocarbons in fuels are not particularly toxic (they are typically solids such as waxes, when not dissolved in the lighter hydrocarbons) and have low leachability. Calculation of a WAC would result in a high value (tens of thousands of mg/kg) which would be greater than would be found on real-world sites. In effect there is no limit to the allowable concentration of heavy aliphatic hydrocarbons in a waste soil. The more toxic heavy hydrocarbons are typically the PAHs, which are represented by BaP (which in turn is used to represent several toxic PAHs as an equivalent BaP value (BAP_{eq}) calculated as a toxicity-weighted sum of the concentrations of the several PAHs).

4.2 C_7-C_9 TPH

The purpose of the TPH C_7-C_9 – BTEX data pairs comparison was to determine if there was a concentration for TPH in the C_7-C_9 range which, if set as a Class 3 WAC, would ensure that BTEX compounds would not exceed the individual BTEX WAC.

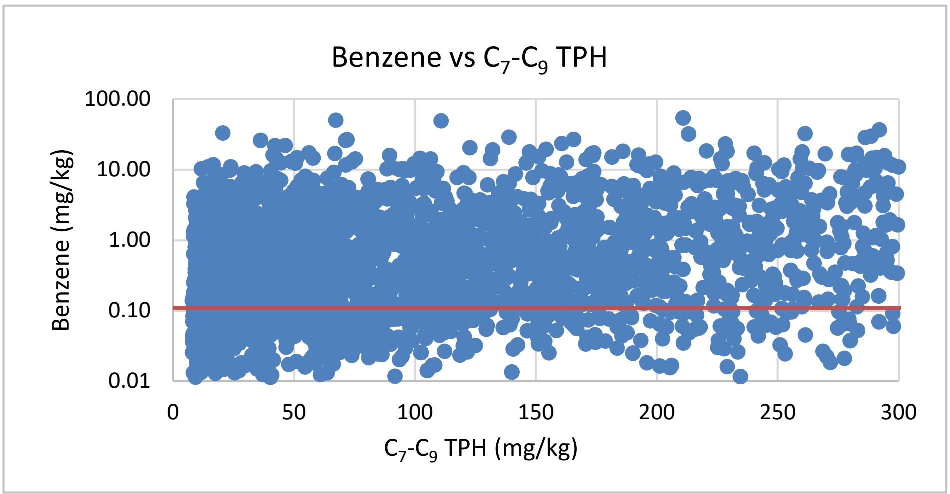
[4] Aliphatic hydrocarbons have carbon and hydrogen atoms in straight chains, branched chains or non-aromatic rings. This is distinct from aromatic hydrocarbons that typically (but not always) have single or multiple six-carbon benzene rings.

Using the individual BTEX compounds as the proxy for TPH in the C_7-C_9 carbon range is a reasonable (if conservative) approach as, although there are other hydrocarbons present in the C_7-C_9 range which are measured by the TPH test, the monoaromatic (ring-shaped) BTEX hydrocarbons are similarly or more toxic than the light, volatile aliphatic (straight chain and branched) hydrocarbons such as hexane and octane.

As noted above, the Class 3 and Class 4 WAC for all the BTEX compounds are the same. This is because the leaching pathway is limiting for these compounds. Therefore, whatever TPH WAC is derived must aim to prevent the leaching of BTEX compounds at concentrations which would exceed either the drinking water or aquatic guidelines, whichever is the applicable limiting guideline value (once the DAF has been taken into account to model the attenuation between the contaminant in the landfill and the groundwater use or aquatic environment receptor).

A data set for nearly 7,000 soil samples was obtained from the laboratory. Plotting the relationship between TPH C_7-C_9 and each of the BTEX data found that even low concentrations of TPH in the C_7-C_9 range could result in concentrations of BTEX compounds in excess of the WAC for those compounds. This means that the low TPH could theoretically produce leachate that would exceed the applied guideline values.

As an example, the plot of C_7-C_9 TPH against benzene is shown below, limited to TPH less than 300 mg/kg (which represents only a small part of the dataset; the maximum TPH measured was 77,000 mg/kg) with benzene on a logarithmic scale. There are many results above the red line showing the benzene WAC of 0.11 mg/kg. In fact, soils which contain TPH in the C_7-C_9 range as low as 9 mg/kg can contain concentrations of benzene exceeding the benzene WAC.



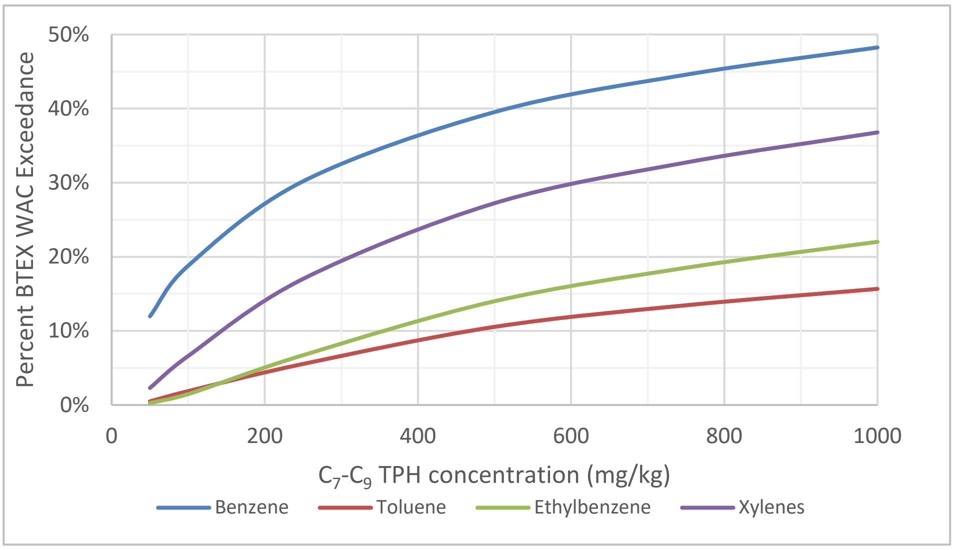
The same process was caried out with the other BTEX compounds. For toluene, TPH as low as 18 mg/kg may exceed the toluene WAC of 19 mg/kg. For ethylbenzene, TPH as low as 23 mg/kg may exceed the ethylbenzene WAC of 10 mg/kg; and for total xylenes, TPH as low as 12 mg/kg may exceed the total xylenes WAC of 25 mg/kg. This means setting a C_7-C_9 TPH WAC that would prevent all soils which contain BTEX concentrations above the BTEX WAC from being placed in a Class 3 facility would result in an impractically low TPH WAC (particularly as natural TPH could be higher than these concentrations).

On this basis, and in a similar way as was done as part of the derivation of WAC for inorganic elements using SPLP / total concentration data pairs, the data was assessed to determine the percentage of BTEX exceedances that may occur at nominated TPH concentrations. The following table summarises this analysis for a range of C_7-C_9 TPH between 50 and 750 mg/kg.

Table 13: Percent Exceedance Over Respective WAC

C_7-C_9 TPH (mg/kg)	Benzene	Toluene	Ethylbenzene	Total Xylenes
50	11.97%	0.49%	0.27%	2.30%
100	18.80%	1.88%	1.48%	6.62%
250	30.19%	5.54%	6.72%	17.02%
500	39.53%	10.55%	14.01%	27.23%
750	44.57%	13.46%	18.52%	32.72%
1000	48.25%	15.67%	22.02%	36.78%

A plot of this data is shown below:



As can be seen from the table and plot, the BTEX WAC which are exceeded the most frequently are benzene and total xylenes. For benzene, even at a TPH concentration of 50 mg/kg, approximately 12% of samples will contain benzene at concentrations which exceed the benzene WAC. At a TPH concentration of 100 mg/kg, approximately 19% of samples will contain benzene at concentrations which exceed the benzene WAC, and 6% of samples will contain total xylenes at concentrations which exceed the total xylenes WAC (25 mg/kg).

As discussed above, setting a TPH WAC at a low enough concentration to prevent a reasonably high percentage of the soils for disposal from exceeding the benzene WAC (in particular) will result in an impractically low TPH WAC.

It is also worth noting that the C_7-C_9 TPH WAC for Class 4 landfills (110 mg/kg) has been set at a concentration which is protective of ecological receptors in soils for agricultural land use; but which according to the TPH/BTEX data received from the laboratory, would result in soils being disposed of into Class 4 landfills which exceed the BTEX WAC (which are the same for both Class 3 and 4 landfills).

However, mitigating factors exist when considering BTEX compounds and the likelihood of soils containing these chemicals to cause a discharge to either drinking water or ecological receptors. All BTEX compounds are highly volatile and will volatilise to some degree on exposure to air. In addition, all the BTEX compounds, particularly benzene, will biodegrade relatively quickly under aerobic conditions. A study by Landcare Research[5] showed that for soil samples individually spiked with 2,000 mg/kg of xylene, ethylbenzene and toluene, the following losses were recorded with time in an open test vessel:

- Xylene: up to 50% loss after 30 minutes, up to 89% loss after six hours.
- Ethylbenzene: up to 65% loss after 30 minutes, up to 98% loss after six hours.
- Toluene: up to 83% loss after 30 minutes, up to 99% loss after six hours.

The action of excavating soils containing BTEX compounds from the source site, loading them into trucks, then unloading them at the landfill is expected to encourage attenuation through volatilisation and biodegradation; and further attenuation will occur if deposited soils are placed in a location with aerobic conditions at the landfill.

Taking the various mitigating factors into account, a reasonably high percentage of exceedances for benzene and total xylenes can be tolerated. On that basis, the Reference Group accepted a concentration of 200 mg/kg for C_7-C_9 TPH would represent an acceptable WAC. The following factors were considered:

[5] https://contamsites.landcareresearch.co.nz/btex_details.htm

- 200 mg/kg represents a reasonable increase from the Class 4 WAC (110 mg/kg), consistent with the general application of higher WAC for other contaminants for Class 3 landfills.
- At 200 mg/kg TPH the lab results indicate that approximately:
  - 27% of benzene results may exceed the benzene WAC
  - 4% of toluene results may exceed the toluene WAC
  - 5% of ethylbenzene results may exceed the ethylbenzene WAC
  - 14% of total xylenes results may exceed the total xylenes WAC
- This level of potential exceedances is acceptable in the context of the volatility and biodegradability of BTEX compounds, with both processes expected to reduce the concentration of the various BTEX compounds in the soil when it is disposed of in a landfill.
- Not all of the soil received into the landfill will be contaminated with petroleum hydrocarbons, so the actual BTEX-leaching potential of the deposited soils will be much less than has been assumed in the derivation (e.g. soil mixing with non-TPH/BTEX contaminated soils will result in lower concentrations and lower leaching potential).
- There are likely to be other procedures in place at the landfill, and / or consent conditions, that will aid in preventing the acceptance of soils which contain unacceptable concentrations of BTEX compounds, such as waste acceptance procedures that preclude the acceptance of stained or odorous soils.

4.3 TPH C_{10}-C_{14}

The purpose of the TPH C_{10}-C_{14}/PAH data pairs comparison was to determine if there was a concentration for TPH in the C_{10}-C_{14} range which, if set as a Class 3 WAC, would ensure that PAH compounds would not cause an unacceptable discharge via leaching. Naphthalene was selected as the key compound for comparison because it is the most soluble of the PAH compounds and therefore poses the greatest risk of leaching from a waste soil that contains a mixture of PAHs.

Both the aquatic protection pathway (for which an Australian and New Zealand freshwater 95% species protection guideline is available) and the drinking water pathway need to be considered. An ANZ (2018) aquatic protection value exists but no New Zealand or World Health Organization (WHO) drinking-water guideline exists, and a search of other jurisdictions failed to find a value. Given this, as an intermediate step, a naphthalene WAC must be calculated. There is no intention to implement a new naphthalene WAC, but it provides a means of checking both the drinking-water and aquatic protection pathways.

Deriving a notional drinking-water guideline requires a tolerable daily intake value. Two tolerable daily intake (or oral reference dose – RfD_o) values were sourced from the United States Environmental Protection Agency (US EPA, 1998, 2008), which results in a drinking-water guideline range of 0.07 – 0.7 mg/L using the World Health Organisation calculation methodology (WHO, 2017). The Ministry of Health (MoH) follows the WHO methodology with an adjustment for a heavier body weight[6]. The lowest of the calculated notional drinking-water guidelines is based on what US EPA (1998) describes as a low quality oral RfD. Given this, the more recent US EPA RfD (USEPA, 2008) is probably preferable.

At the lower end of the calculated drinking-water value range the drinking-water pathway proves to be critical with the calculated naphthalene WAC being 13 mg/kg, compared with 15 mg/kg for the aquatic protection pathway. However, if any of the three other calculated drinking-water values[7] are chosen, the aquatic protection pathway is critical. Given the lowest drinking-water value uses a low quality RfD and a percentage of TDI assigned to water no longer recommended by the WHO, it is appropriate to select the aquatic protection pathway as critical. However, whether the lowest drinking water pathway or the aquatic pathway is used gives essentially the same result when all the uncertainties in the derivation method are taken into account.

A dataset of approximately 1,350 TPH and PAH sample results was obtained from Hill Laboratories. A comparison between the C_{10}-C_{14} TPH and naphthalene results shows that a significant proportion of the naphthalene results (i.e. approximately 85%) are below the naphthalene WAC. A plot of the data for naphthalene concentrations less than 1,000 mg/kg is presented on the next page.

In a similar way to the C_7-C_9 TPH derivation, some naphthalene WAC exceedances occurred at low C_{10}-C_{14} TPH concentrations. Again, the sample dataset was assessed to determine the percentage of exceedances that occurred at nominated TPH concentrations. Table 14 shows the results of this analysis for a range of C_{10}-C_{14} TPH from 100 to 1000 mg/kg.

[6] The MoH follows the WHO calculation method except uses a 70 kg body weight and by default assigns 10% of the TDI to water whereas WHO has more recently changed to using 20% of the TDI assigned to water, advising 10% is too conservative. The calculated range uses both 10 and 20%.
[7] Total of four calculated values, from two RfD/TDI values and two percentages of these values assigned to water.

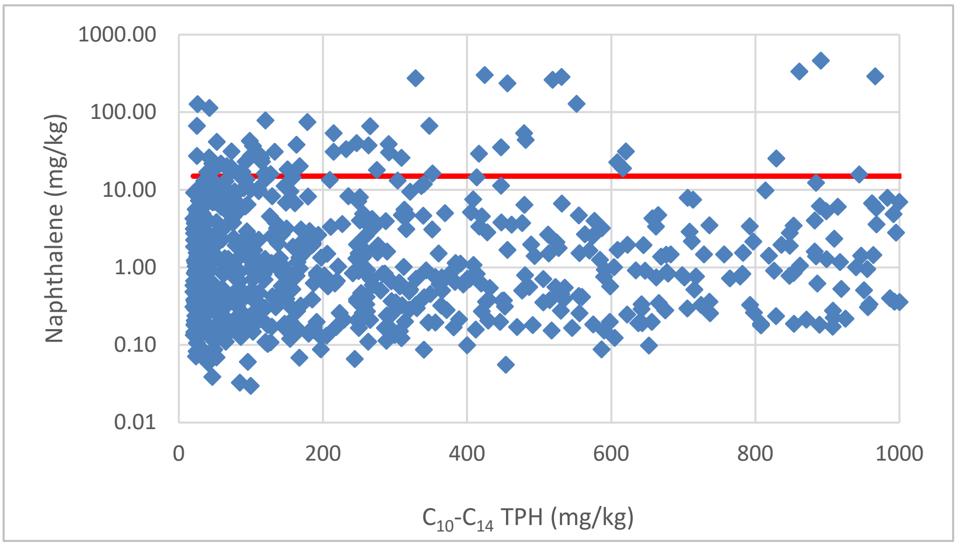
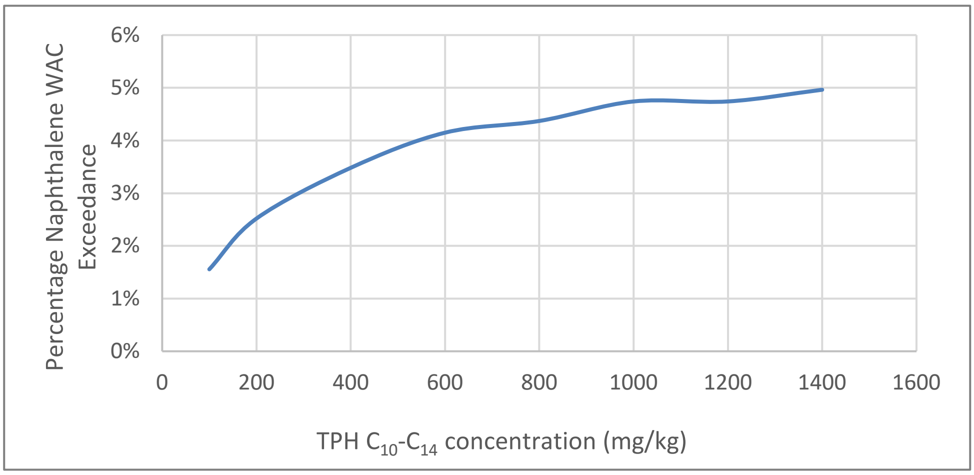


Table 14: Percent Exceedance Over Naphthalene WAC						
Trial WAC (mg/kg)	100	200	600	1,500	800	1000
% Results Exceeding SPLP Target (0.8 mg/L)	1.6	2.5	3.5	4.1	4.4	4.7

A plot of Table 14 is shown below.



It is apparent the WAC for naphthalene is not frequently exceeded even at relatively high concentrations of TPH in the C_{10}-C_{14} range. This finding, along with the knowledge that all PAH compounds are relatively insoluble in soils, leads to the conclusion that a C_{10}-C_{14} TPH WAC could be set at a concentration of up to, nominally, 800 mg/kg without creating a significant risk from the leaching of PAHs. However, this concentration represents a significant increase in comparison to the Class 4 WAC of 58 mg/kg and it was decided to adopt a concentration of 600 mg/kg.

The adopted TPH values compared with earlier values are shown in Table 15 below.

Table 15: Class 3 and 4 WAC as per 2018 Guidelines and Revised Adopted (mg/kg)

Contaminant	Class 3 using Guideline Class 4 Derivation	Revised Adopted Class 3	Class 4 from Guidelines	Revised Adopted Class 4
TPH $C_7 - C_9$	No Practical Limit[5]	200[6]	120	110
TPH $C_{10} - C_{14}$	No Practical Limit[5]	600[7]	58	58

Notes:

1. *Blue shading indicates that the drinking water pathway is limiting for the benzene WAC on which the TPH C_7-C_9 WAC is based.*
2. *Green shading indicates that the aquatic pathway is limiting for the nominal naphthalene WAC on which the TPH C_{10}-C_{14} WAC is based.*
3. *Grey shading indicates human health agricultural land use or rural residential land use is limiting.*
4. *Orange shading indicates protection of ecological receptors (minimal risk / protective of agricultural land use) is limiting.*
5. *Not calculated in the Guidelines but if calculated using the Guidelines parameters, value very large and unlikely to be encountered on real world sites (no practical limit).*
6. *Based on TPH – BTEX dataset comparison.*
7. *Based on TPH – Naphthalene dataset comparison.*

5.0 Summary

Table 16 below summarises the derived waste acceptance criteria compared with the original Guidelines derivations.

Table 16: Class 3 and 4 WAC as per Guidelines and Revised (mg/kg)

Contaminant	Class 3 using Guideline Class 4 Derivation	Adopted Class 3	Class 4 from Guidelines	Adopted Class 4
Arsenic	310[1]	140	17[2]	17
Cadmium	10[3]	10[4]	0.8	0.8
Chromium	630	150	290	150
Copper	>44 or soil background	280	>44 or soil background	220[5]
Lead	1,000	460	>60 or soil background	160
Mercury	160	3[4]	0.7	0.7
Nickel	310	320[6]	310	35[7]
Zinc	400	1,200[8]	400	190[7]
TPH $C_7 – C_9$	No Practical Limit[9]	200[10]	120	110
TPH $C_{10} – C_{14}$	No Practical Limit[9]	600[11]	58	58
Benzene	0.2	0.11	0.2	0.11
Ethylbenzene	66	10	59	10
Toluene	50	19	50	19
Total Xylene	29	25	30	25
Benzo(a)pyrene (eq)[12]	54	125	Interim based on soil background = 2	2.8
Dieldrin	0.2	0.10	0.2	0.10
Total DDTs[13]	26	2	0.7	2[14]

Notes:

1. *Blue shading indicates drinking water pathway is limiting.*
2. *Grey shading indicates human health agricultural land use or rural residential land use is limiting.*
3. *Green shading indicates aquatic pathway is limiting.*
4. *Not calculated. Based on SPLP – total concentration dataset and likely source site concentrations.*
5. *Orange shading indicates ecological receptors (minimal risk / protective of agricultural land use) is limiting.*
6. *Not calculated. Based on SPLP – total concentration dataset and ensuring not below possible local background concentrations.*
7. *WAC may be lower than natural background concentrations for soils in some localities. Where this is the case, the background concentration should prevail.*
8. *Calculated based on the aquatic pathway being limiting but WAC set to be above possible background concentrations.*
9. *Not calculated in the Guidelines but if calculated using the Guidelines parameters, value very large and unlikely to be encountered on real world sites (no practical limit).*
10. *Based on TPH – BTEX dataset comparison, using BTEX compounds as proxies.*
11. *Based on TPH – PAH dataset comparison, using naphthalene as proxy..*
12. *Equivalent benzo(a)pyrene concentrations calculated as a toxicity-weighted sum of the nine carcinogenic PAHs in the standard PAH analytical suite.*
13. *Sum of the concentrations of the six DDT, DDD and DDE isomers.*
14. *WAC to protect aquatic species via the leaching pathway is similar to the limiting eco-SGV for DDT from Cavanagh and Ohalloran (2006) of 1.9 mg/kg. To avoid confusion over a minor difference in the Class 3 and Class 4 WAC values, the WAC for both has been set at 2 mg/kg.*

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