CONTAMINANTS WITHIN URBAN WATERWAYS SEDIMENT AND THE IMPLICATIONS FOR FLOOD PROTECTION PROJECTS

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ABSTRACT (500 WORDS MAXIMUM)

Urban waterways throughout the world are often neglected and underappreciated stretches of land which receive untreated urban run-off from a variety of land uses. They once were a valued source of food for Iwi, but now due to our increased understanding of urban contaminants and how they may impact on the food cycle, this tradition is often prevented from occurring. Increasingly we see pollution warning signs due to transient biological pollutants but residing in the sediment on the bed of our urban rivers, several other contaminants, which have been accumulating for well over a century, present other issues to the health of our waterways and a financial burden for those looking to remove the sediment.

Following the Canterbury earthquake sequence in 2010-2011, the land in several areas of Christchurch dropped in elevation and combined with an influx of liquefaction derived sand and silt together with damaged stormwater drains all resulted in several significant flooding events along the Ōpāwaho Heathcote River. Christchurch City Council (CCC) have completed several initial flood protection works along the Heathcote River including dredging and reprofiling of the Woolston Cut.

The paper describes sediment assessments undertaken in 2017-2018, the assessment methodology and the analytical results with regards to the National Environmental Standards (NES) Regulations and also the Asbestos Regulations (2016). Due to the presence of elevated concentrations of asbestos, heavy metals and polycyclic aromatic hydrocarbons within the sediment additional controls were required during the dredging works. This paper outlines the contaminants identified in the sediment along an approximately 3 km stretch of the Heathcote River and the potential impact on the aquatic ecosystem and human health of those in contact with it. It also discusses the elutriation analytical technique designed to assess the release of contaminants into the water column due to sediment disturbance. Site management implications and cost implications on the CCC dredging programme are also discussed as is the need for an urban ambient asbestos concentration in soil.

KEYWORDS

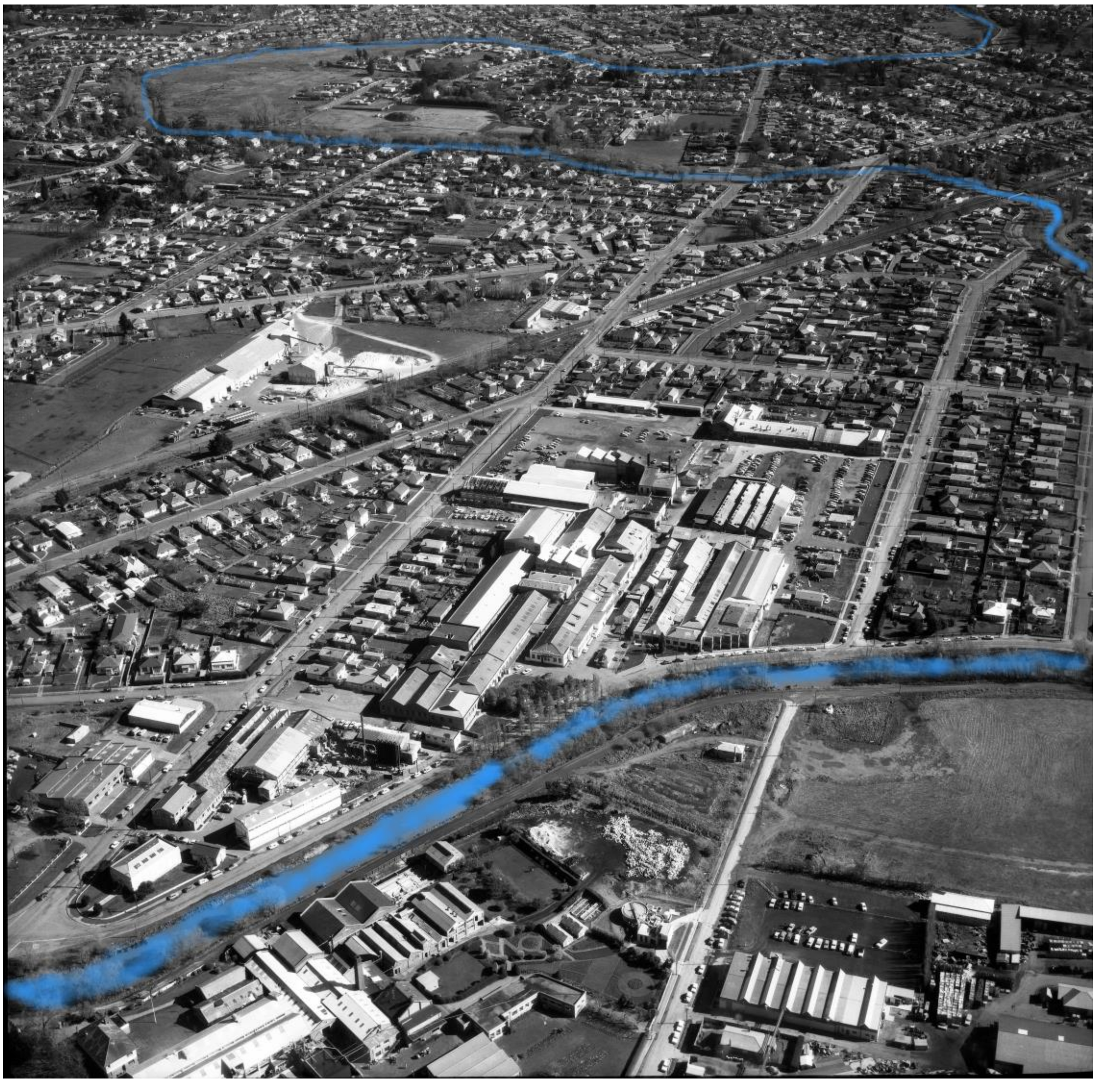
Urban sediment contaminants, dredging, asbestos, heavy metals, polycyclic aromatic hydrocarbons.

PRESENTER PROFILE

Gareth Oddy is an environmental Scientist with over 15 years' experience in the investigation, assessment and remediation of contaminated sites. Gareth is a Certified Environmental Practitioner and has a Master of Science in Contaminant Hydrogeology specialising in the remediation of hydrocarbon plumes via bioremediation.

1 INTRODUCTION

Urban waterways throughout the world are often neglected and underappreciated stretches of land which receive untreated urban run-off from a variety of land uses. They once were a valued source of food for Iwi and but now due to our increased understanding of urban contaminants and how they may impact on the food cycle, this tradition is often prevented from occurring. Increasingly we see pollution warning signs due to transient biological pollutants but residing in the sediment on the bed of our urban rivers, are several other contaminants which have been accumulating for well over a century. These other contaminants present longer term challenges to the health of our rivers and often a financial burden for those looking to remove the sediment.



Photograph 1: Aerial photograph of the Heathcote River, Looking to Opawa from above Woolston, 1970. Credit VC Browne.

Urban stormwater run-off and the primary contaminants of concern to ecological life, copper, lead and zinc have been well studied over the last three decades (Williamson, 1993, J.N. Brown, B.M. Peake, 2006, Charters et al, 2016). However other contaminants which are present in the built environment, can find their way into the stormwater system and eventually the sediment within watercourses.

Following the Canterbury earthquake sequence in 2010-2011, the land in several areas of Christchurch dropped in elevation and combined with an influx of liquefaction derived sand and silt and damaged stormwater drains, several significant flooding events along the Ōpāwaho Heathcote River occurred. To resolve this and to provide future resilience to the area, Christchurch City Council (CCC) has commenced constructing several stormwater retention basins and constructed wetlands in the Southwest of the City together with dredging of existing parts of the network including the Wigram retention basin and the Heathcote River to enable greater storage capacity.

CCC hold a global resource consent from Canterbury Regional Council, CRC121582, to remove earthquake derived sediments from Christchurch's surface water bodies. The consented works includes disturbance of river beds by dredging and the associated sediment discharge. A Consent condition requires that samples are collected for every 250 m^3 of material dredged and analysed for contaminants of concern.

ENGEO Ltd, for whom the paper author is employed with as an environmental scientist was engaged by Christchurch City Council to complete an assessment of the sediment. The objective of the assessment was to assess the sediment present at four distinct sites for the presence of potential contaminants of concern and to provide disposal recommendations and site management procedures.

This paper focuses on the contaminants identified at the sites, the assessment approach, findings and relevance of this work to other stormwater projects in towns and cities throughout New Zealand.

2 SITE ASSESSMENT

2.1 ASSESSMENT OBJECTIVES

Testing undertaken as part of this investigation aimed to assess whether sediment within the three watercourses contained contaminants and to what degree. The assessment has been completed to assess impacts from TPH, heavy metals, organochlorine pesticides (OCPs) and asbestos in the sediment sampled and evaluate their distribution within the three separate sites. Figure 1 indicates the location of the site and three specific project areas.

2.2 SITE LOCATIONS

CCC is currently in the process of constructing new flood protection schemes and modifying existing networks to increase the storage capacity of the network and simultaneously improving stormwater quality.

The four watercourses assessed and discussed in this paper are the Curletts Stream, Heathcote River and the Paparua Stream (commonly referred to as the Haytons Drain) and Wigram Retention Pond. All four watercourses were being modified in some way and required removal of sediment during the works.

Figure 1: Sampling locations Curletts Stream, Heathcote River, Paparua Stream and the Wigram Retention Pond

2.2.1 CURLETTS STREAM

A section of the Curletts Stream that runs south of the Southern Motorway to Curletts Road was to be re-routed to allow for a constructed wetland to be built. The stream was assessed at seven locations over approximately 1km.

2.2.2 PAPARUA STREAM AND WIGRAM RETENTION POND

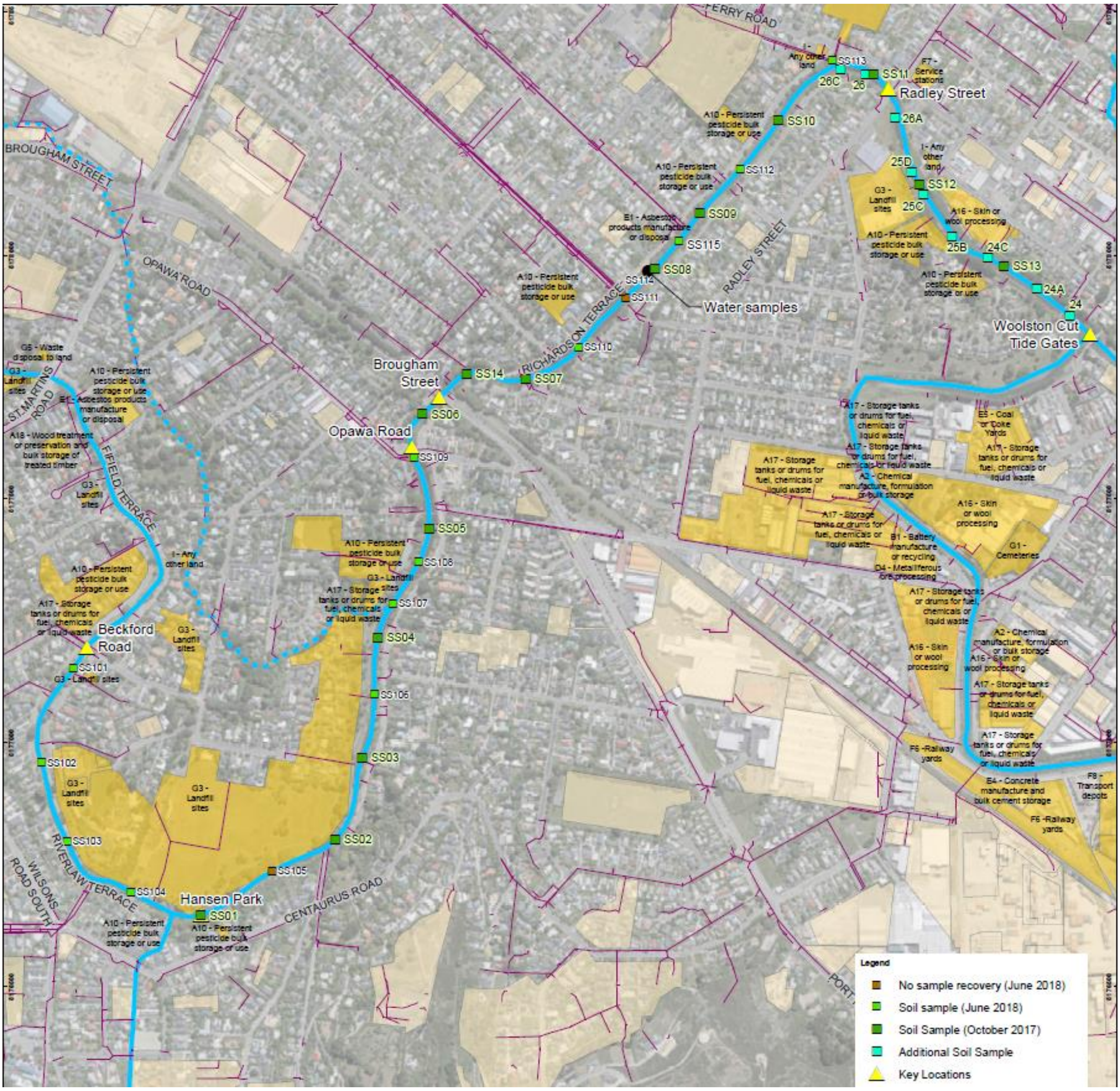
The Wigram Retention Pond and possibly some of the Paparua Stream were to be dredged as part of ongoing maintenance of the Pond. Water from the Wigram Retention Pond and Curletts Stream discharges at two points into the Heathcote River. Due to the industrial nature of the catchment of both the Paparua Stream and the Curletts Stream, elevated concentrations of contaminants, principally metals such as zinc and lead, have been historically identified by CCC and Environment Canterbury (ECan). Sediment data provided by CCC from city wide sampling conducted in 2003 / 2004 indicated that zinc levels upstream of the Curletts Stream were at least 2-3 times higher than other waterways in the city at 1240 mg/kg. Although zinc discharges from roofs would contribute to an ‘ambient urban’ contaminant loading, other industrial point sources may increase the loading further including potentially several industrial facilities in the catchment including an electroplaters specialising in zinc plating.

2.2.3 HEATHCOTE RIVER ŌPĀWAHO

Two stretches of the Heathcote River were assessed. The first section was in the upper stretches of the Heatchote in the suburbs of Wigram and Hillmorton starting from the outlet from the Wigram Retention Pond, including the convergence with Curletts Stream and south through Spreydon, ceasing prior to the Heathcote meeting the Cashmere Stream. The stretch of the Heathcote River assessed was approximately 4.25km long and included nine sampling locations. Although dredging was not proposed at present for this stretch of the Heathcote River, information on the contaminant concentrations in sediment up and down stream of the Paparua Stream and Curletts discharge points was important for future decision making regarding improving water quality long term.

The second stretch of the Heathcote River assessed was the stretch from Beckford Road in Opawa east to the Woolston Cut tidal gates in Woolston (Refer to Figure 2). This stretch of the River covering a distance of 4.5km was proposed to be dredged and approximately 80,000 tonnes of sediment to be removed from the River Bed.

Figure 2: Heathcote River, Beckford to Woolston Cut.



Photograph 2: The Heathcote River, view from Radley Street Bridge East, March 2018, prior to the dredging and bank reprofiling works

2.3 Assessment Methodology

2.3.1 SAMPLE COLLECTION METHODOLOGY

Sediment samples were collected with a core sampler which were advanced to approximately one metre below the bed surface, or until met with refusal.

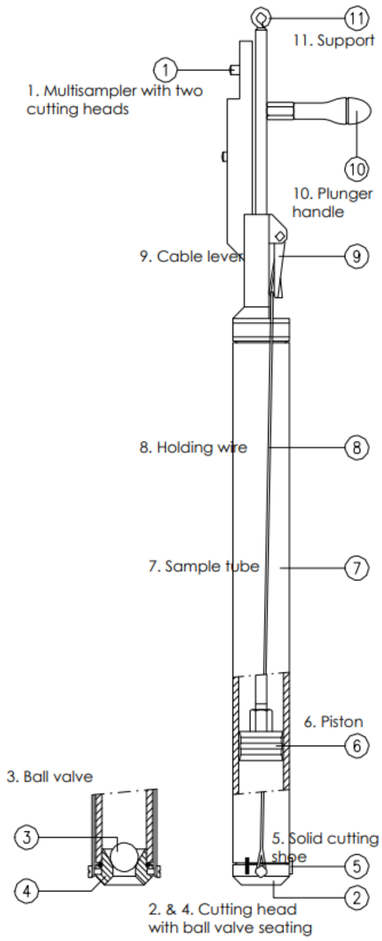
Soil samples were collected from each sampling location from depths where sufficient sample was recovered and typically between 0.0 - 0.3 m bgl which is considered to represent the most recently deposited sediment and the sediment with the most interaction with aquatic receptors.

Sediment core samples were collected using a Multi Sampler. The entire length of the sample barrel of the Multi Sampler (approx. 1.0 m long, diameter 40 mm, volume > 1 litre) was progressed until refusal.

All soil samples collected for chemical analysis were placed in laboratory-supplied glass and plastic containers, which were then sealed, labelled with a unique identifier and placed in chilled containers prior to transportation to the laboratory.

Samples for asbestos analysis were placed into 200 µm plastic zip lock bags labelled and double bagged and also submitted to an IANZ accredited Laboratory.

To reduce the potential for cross contamination, each sample was collected directly from the Multi Sampler using disposable nitrile gloves that were discarded following the collection of each



sample. After collection of each sample, the sampling equipment was decontaminated by rinsing with a solution of Decon90 and rinsing with tap water followed by deionised water.

Photograph 3: ENGEO Environmental Scientist, Sean Freeman, sediment sampling in the Heathcote River in October 2017.

2.3.2 POTENTIAL CONTAMINANTS OF CONCERN

Given the wide number of potential sources, both point and diffuse, of contaminants our initial analysis schedule was comprehensive and was refined to the key contaminants of concern following several rounds of tests.

The following contaminants of potential concern were analysed for:

- Polycyclic Aromatic Hydrocarbons (PAHs)
- Organochlorine Pesticides (OCPs)
- Total Petroleum Hydrocarbons (TPH)
- Benzene, toluene, ethylbenzene and xylenes (BTEX)
- Phenols
- Polychlorinated Biphenyls (PCBs)
- Metals (aluminium, antimony, arsenic, barium, beryllium, bismuth, boron, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, molybdenum, nickel, selenium, silver, thallium, tin, titanium, uranium, vanadium and zinc); and,
- Asbestos (semi-quantitative).

Although information on the presence of asbestos in river sediment has not currently been the focus of research based on current understanding that it is only a hazard to human health when airborne, to ensure all disposal options were evaluated a comprehensive sampling regime for asbestos was initiated.

2.3.3 LABORATORY ANALYSIS

Samples over the yearlong assessment were submitted to two commercial IANZ accredited laboratories and analysed for the following tests summarised in Table 1.

Table 1: Sediment samples and scheduled analysis

Contaminants of potential concern	**No. of samples analysed from each site**				
	Heathcote River (Beckford to Woolston Cut)	Heathcote River (Wigram to Rose St)	Curletts Stream	Paparua Stream (Haytons Drain)	Wigram Retention Pond
Asbestos	34	9	7	2	5
Heavy Metals	32	9	7	2	5
OCPs	14	2	2	-	-
PAHs	34	2	2	-	-
PCBs	14	2	2	-	-
Phenols	14	2	2	-	-
TPH & BTEX	14	2	2	-	-
Cyanide	14	2	1	-	2

3 ASSESSMENT CRITERIA

The sediment analytical results were evaluated against several assessment criteria including disposal waste acceptance criteria and those protective of human health and ecological receptors.

3.1 DISPOSAL CRITERIA

In Canterbury during the completion of this project, five disposal options existed for the sediment. A summary of disposal options available for the proposed 40,000 tonnes of sediment to be dredged from the Heathcote River between Brougham Street and the Woolston Cut stages of the project is presented in Table 2. The approximate cost per tonne and total for each option based on an initial 40,000 tonnes is also provided in Table 2.

Table 2: Summary of Disposal Facility Acceptance Criteria

Disposal Option	**Contaminants of concern**	**Disposal Criteria**	**Disposal Cost ($/tonne)**
Re-use on CCC owned recreational land	All	Meet recreational land use criteria. Asbestos below 0.001% w/w.	Free
Cleanfill	Metals, PAHs, TPH	Below background	$5

	Asbestos	Non-detect	($200,000)
Managed Fill (CCC Burwood Landfill)	Metals, PAHs, TPH	Below human health – recreational guideline values (MfE, 2012)	$20 ($800,000)
	Asbestos	Non-detect	
Managed Fill with asbestos (Frews Hororata)	Metals, TPH, PAHs	Below Frews-specific acceptance criteria based on Residential land use values.	$95 ($3.8 million)
	Asbestos AF and FA	Below all site uses / residential guideline values (0.001% w/w) and no bulk ACM.	
Kate Valley Landfill (Class A)	Metals, PAHs, TPH	Below Kate Valley-specific acceptance criteria, based on leachability testing.	$150 ($6 million)
	Asbestos	Any amount is acceptable	

3.1.1 ASBESTOS ASSESSMENT CRITERIA

The Building Research Association New Zealand (BRANZ) released the New Zealand Guidelines for Assessing and Managing Asbestos in Soil on 6 November 2017. The BRANZ Guideline asbestos investigation criteria are presented in Table 3. The BRANZ guideline criteria were adopted as investigation criteria for this assessment.

Table 3: Asbestos Assessment Criteria

Form of asbestos	Soil guideline values for asbestos (w/w)			
	Residential	High-density residential	Recreational	Commercial and Industrial
ACM (bonded)	0.01%	0.04%	0.02%	0.05%
FA and/or AF[5]	0.001%			

ACM: Asbestos-containing material i.e. asbestos bound in a matrix; material that cannot pass through a 7 mm x 7 mm sieve. **FA:** Fibrous asbestos. Encompasses friable asbestos material, such as severely weathered ACM, and asbestos in the form of loose fibrous material such as insulation products. Friable asbestos is defined here as asbestos material that is in a degraded condition, such that it can be broken or crumbled by hand pressure. **AF:** Asbestos fines. It includes free fibres of asbestos, small fibre bundles and also ACM fragments that pass through a 7 mm x 7 mm sieve.

3.2 ECOLOGICAL ASSESSMENT CRITERIA

The Australian and New Zealand Environment and Conservation Council (ANZECC) interim sediment quality guideline (ISQG) values were utilised to assess the potential impact of contaminants within sediment to ecological receptors in the River. The ISQG low and high values correspond to the effects range of low and –median effect on ecological receptors.

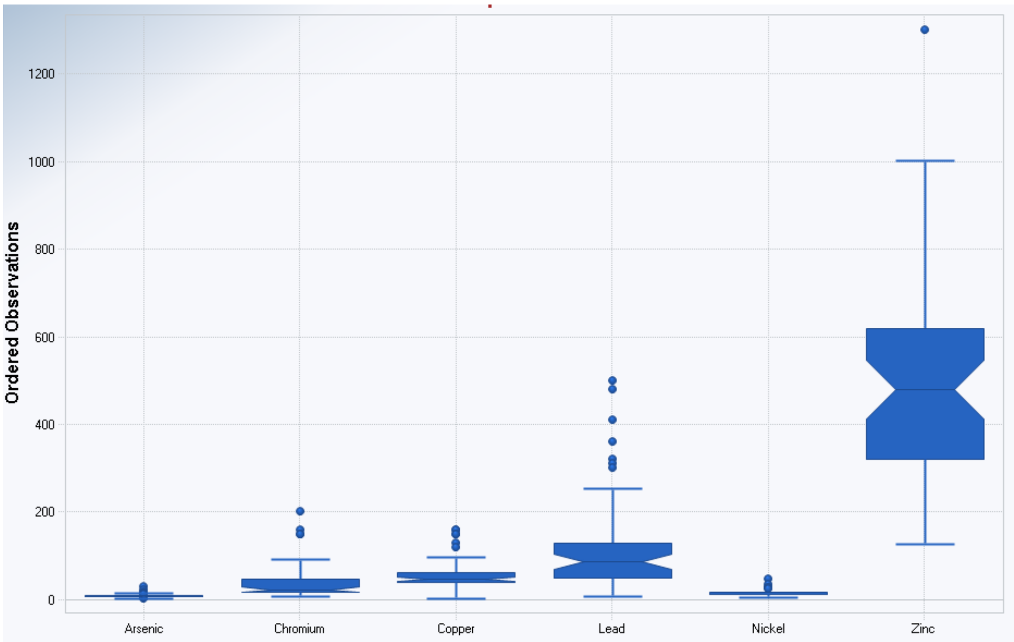
4 RESULTS

4.1 HEAVY METALS – THE USUAL SUSPECTS

Copper (from vehicle brake pads) and zinc (from tyre wear and roofing) are the usual contamination suspects in urban river sediment. The constant supply of these metals to our roads and the conveyance of roof rain water untreated to the stormwater network means copper and zinc concentrations do not appear to be reducing in their frequency or scale. An initial comparison has been made of these sediment results with previous sediment assessments completed for the Heathcote River by NIWA (2015). The heavy metal and PAH contaminant concentrations previously identified in 2015 are within the same range.

During this assessment several heavy metals in sediment exceeded the regional background soil concentrations, with zinc significantly above these criteria in the majority of samples. The average for lead, mercury and zinc also exceeded the ANZECC ISQG indicating that these trace elements are elevated throughout the river sediment and above ecological guideline criteria. The UCL 95% were above the ecological guideline criteria for lead, mercury, silver and zinc. The box plots for several of the trace elements are presented in Figure 3.

Figure 3: Box Plots displaying arsenic, chromium, copper, lead, nickel and zinc sediment concentrations (mg/kg)



Several outliers for lead were noted and these tended to be located further down river in the Heathcote and located in the more industrialised areas suggesting other point sources may also be important local sources of contamination.

The average concentrations of arsenic and nickel were below background soil concentrations suggesting these trace elements are not contaminants of concern. Cadmium, chromium and copper were identified in the sediment above background soil concentrations but on average below ANZECC ISQG-Low. The concentrations of lead, mercury and zinc were reported to be above the background criteria and ANZECC ISQG-Low. A summary of some of the results is presented in Table 4 and 5.

Table 4: Heavy Metals, Radley Street Bridge to Woolston Cut

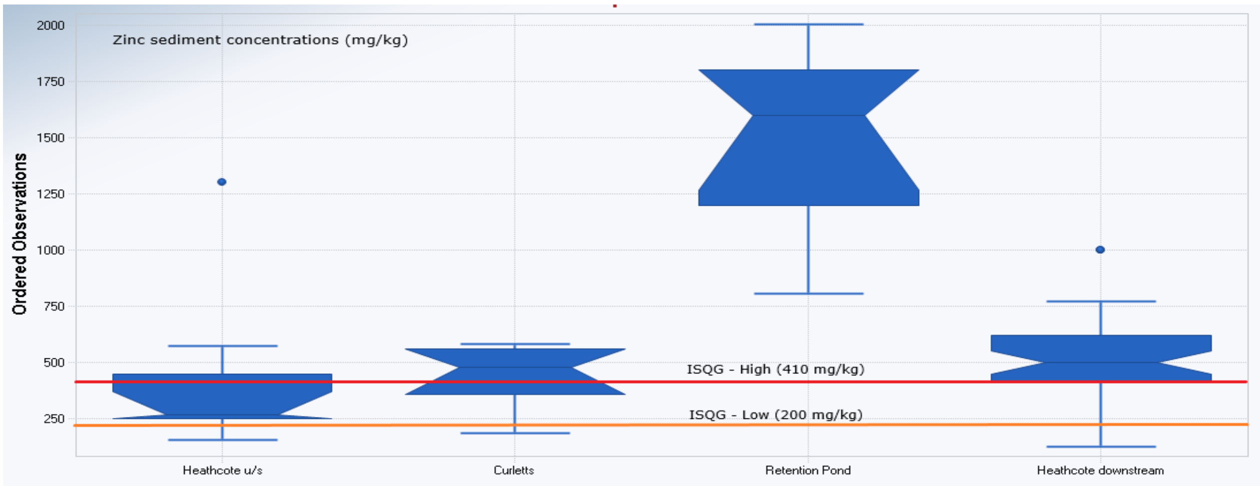
Heathcote 14417	**Sample Details**												**Sediment Quality Guidelines**	
ENGEO Sample	**24 SS1**	**24 SS2**	**24 SS3**	**24C SS1**	**24C SS2**	**24C SS3**	**25C SS1**	**25C SS2**	**25C SS3**	**26C SS1**	**26C SS2**	**26C SS3**	**ANZECC ISQG - Low**	**ANZECC ISQG - High**
Aluminium	22,000	22,000	26,000	27,000	21,000	23,000	24,000	33,000	33,000	23,000	24,000	21,000	-	-
Arsenic	8.3	11	13	22	6.7	7.5	**29**	15	16	7.4	7	6.6	20	70
Beryllium	< 2	< 2	2.1	< 2	< 2	< 2	< 2	2.4	2.4	< 2	< 2	< 2	-	-
Boron	< 10	< 10	< 10	21	10	15	15	18	17	< 10	< 10	< 10	-	-
Cadmium	0.6	0.8	1	1.2	0.5	0.6	1.6	1.3	1.3	0.6	0.5	0.5	1.5	10
Chromium	55	72	90	160	44	47	150	200	150	33	40	44	80	370
Cobalt	13	13	15	27	10	11	26	21	21	15	14	12	-	-
Copper	48	63	120	150	33	43	160	150	160	53	52	48	65	270
Lead	110	200	180	**300**	74	100	**310**	**480**	**410**	86	93	92	50	220
Manganese	410	460	490	540	360	350	380	600	580	430	490	360	-	-
Mercury	0.1	0.2	0.2	0.3	< 0.1	0.1	0.7	0.4	0.6	< 0.1	< 0.1	0.1	0.15	1
Molybdenum	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	-	-
Nickel	17	18	17	48	14	15	35	28	28	14	16	13	21	52
Selenium	< 2	< 2	< 2	< 2	< 2	< 2	2	< 2	< 2	< 2	< 2	< 2	-	-
Silver	1.1	1.1	1.5	4.6	1	0.9	5.5	2.6	2	0.8	0.7	1	1	3.7
Tin	< 10	< 10	< 10	16	< 10	< 10	21	15	14	< 10	< 10	< 10	-	-
Vanadium	48	52	60	54	41	43	47	64	63	44	46	40	-	-
Zinc	430	660	680	660	280	410	770	670	640	600	540	500	200	410

Table 5: Statistical analysis of heavy metal sediment concentrations

Analyte	**No. of samples >LOD**	**Min**	**Mean**	**Median**	**Max**	**UCL 95%**	**Background**	**ANZECC ISQG - Low**
		All concentrations expressed as mg/kg						
Arsenic	32	2.4	7.66	7.5	14	8.27	16.3	20
Cadmium	23	0.4	0.69	0.6	1.3	0.78	0.2	1.5
Chromium	32	11	29.03	21.5	69	34.72	20.1	80
Copper	32	9	53	50	**130**	61.23	19.5	65
Lead	32	14	**105.2**	**87.5**	**500**	**132.1**	128.8	50
Mercury	9	0.1	**0.2**	**0.2**	**0.4**	**0.254**	0.1	0.15
Nickel	32	8.8	13.6	13	26	14.85	18	21
Silver	30	0.2	0.643	0.4	**5.1**	**1.352**	-	1
Zinc	32	130	**490.6**	**495**	**1000**	**547.9**	166.8	200

Zinc concentrations were identified to be significantly higher in the Wigram retention pond than the other watercourses (Refer to Figure 4). This may be due to its proximity to the Wigram industrial estate and several zinc electroplaters in the catchment and the ponds inherent ability to reduce flow rates and allow suspended solids to deposit and zincs strong affinity for attaching to suspended solids.

Figure 4: Zinc sediment concentrations at varying stretches of study area



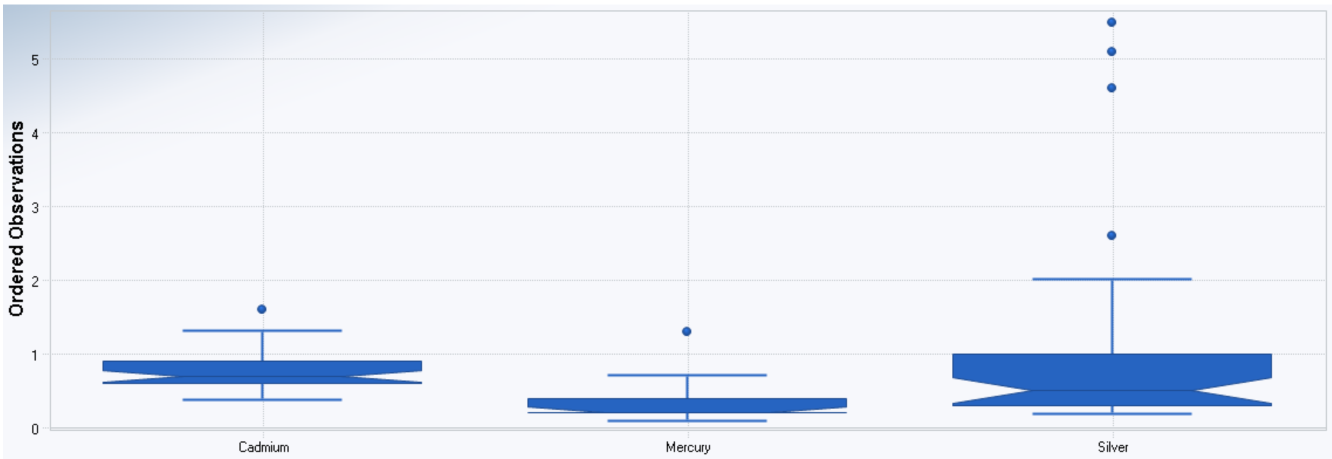
4.2 THE UNUSUAL SUSPECTS

Concentrations of heavy metals, copper, lead and zinc in urban run-off in New Zealand has been well established since the initial works of Williamson (1993) and the production of the Urban Run-off Data Book. As our industry and consumer demands change so too does the potential for other contaminants to enter our waterways from urban run-off and contaminated sites. Although our assessment included a wide range of potential contaminants, it did not asses for other emerging contaminants such as Per-and polyfluoroalkyl substances (PFAS), Brominated Flame Retardants, Dioxins and Furans or the numerous unregulated chemicals used daily. Further assessment of these other potential persistent pollutants in urban river sediment is required to aid our understanding of the distribution and impact of these chemicals in the environment.

4.2.1 SILVER

The concentrations of silver in the sediment were elevated particularly in the Radley Street to Woolston Cut stretch where the surrounding land use becomes more industrialised. The silver concentrations exceeded the ISQG-low in the majority of samples and exceeded the ISQG-high at two locations. The concentrations of silver were more frequently detected and at concentrations of concern more often than other metals which are commonly considered a potential urban pollutant such as cadmium and mercury (Refer to Figure 5). Silver sources in the environment include emissions from smelting operations, manufacture and disposal of certain photographic and electrical supplies and coal combustion are some of the common anthropogenic sources of silver.

Figure 5: Cadmium, mercury and silver concentrations



4.2.2 ALUMINIUM

Aluminum is naturally occurring in soil with range typically between 10,000 – 300,000 mg/kg. However the MfE landfill waste acceptance criteria for a class A landfill is only 800mg/kg, while for Class B it is just 80 mg/kg. We identified aluminium in sediment at concentrations ranging between 7,900 – 33,000 mg/kg considerably above the class A and B WAC. It appears the WAC for aluminium and potentially others do not take into account the background concentration of these trace elements.

4.3 POLYCYCLIC AROMATIC HYDROCARBONS (PAHS)

Numerous polycyclic aromatic hydrocarbons were identified in the sediment at concentrations exceeding the urban background concentration. Concentrations of both low and molecular weight PAHs exceed the ANZECC (2000) ISQG-low criteria in the majority of locations. Individual PAHs also exceeded the ANZEEC ISQG – low criteria where values have been established. The concentrations in several sample locations from the Radley Street bridge east to the Woolston Cut contained PAHs which exceeded ANZECC (2000) ISQG-high criteria for several PAHs. Benzo(a)pyrene equivalent concentrations were elevated at several locations and most notably SS101, SS02 and SS113.

Table 6: Summary of PAH concentrations in sediment

Analyte	No. of samples >LOD	Min	Mean	Median	Max	UCL 95%	Background	ANZECC ISQG - Low
		All concentrations expressed as mg/kg						
Benzo(a)pyrene	32	0.04	**0.814**	0.39	**4.9**	**1.343**	0.595	0.43
Benzo(a)pyrene TEQ	33	0.07	1.16	0.57	7.1	1.695	-	-
Low Molecular Weight PAHs	34	0.04	**3.127**	**0.758**	**36.77**	**8.289**	-	0.552
High Molecular Weight PAHs	34	0.18	**5.459**	**2.59**	**36.21**	**9.842**	-	1.7

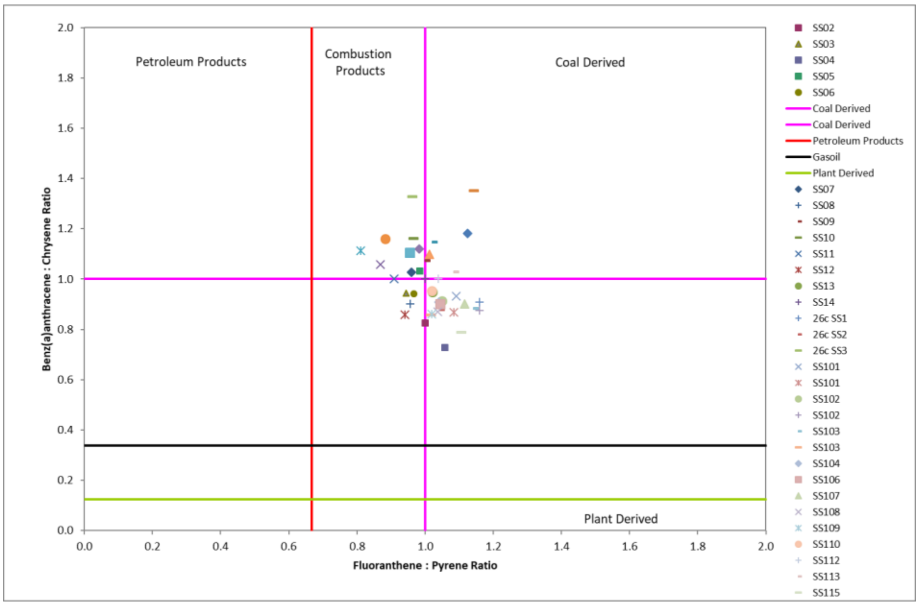
4.4 IDENTIFYING THE SOURCE OF PAHS

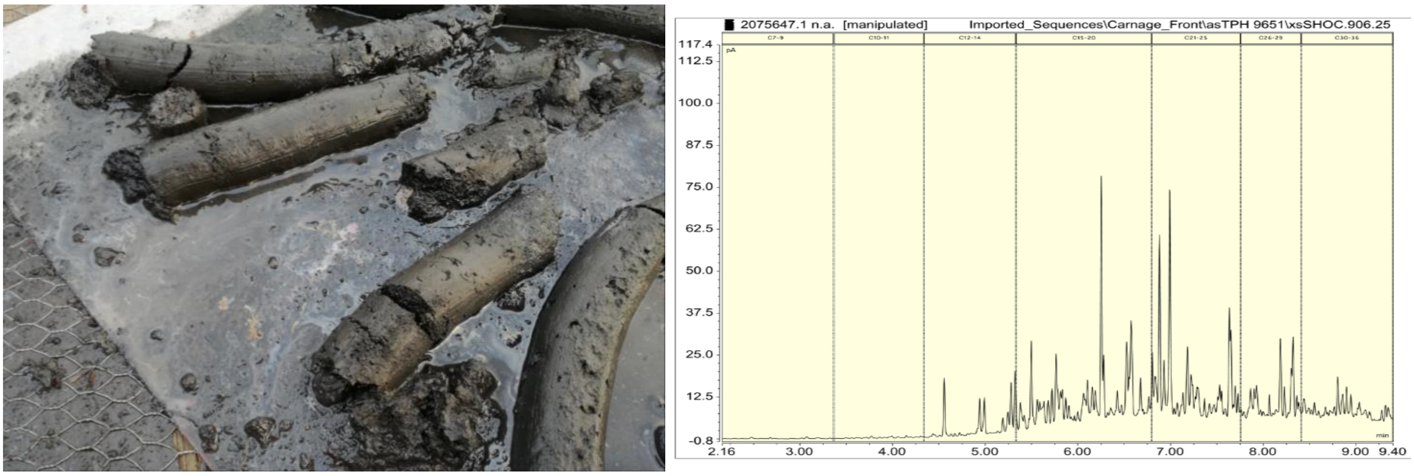
Polycyclic aromatic hydrocarbons (PAHs) are the result of incomplete combustion or pyrolysis of organic material containing hydrogen and carbon. There are numerous natural and anthropogenic sources. PAHs can be produced naturally through biogenic and petrogenic processes or be generated through combustion mechanisms (pyrogenic). These different mechanisms of formation result in distinct distribution of individual PAHs. These differences can be used to determine the source.

A method to assess the potential sources of PAH contaminants has been developed by M.B. Yunker et al. (2002) and others by utilising ratios of individual PAHs to allow the type of source to be identified. An assessment of PAH ratios was completed to assist with evaluating a source of the PAHs.

The PAHs appear to be related to the combustion of coal with a gas works influence present in the sediment as concluded from a review of the laboratory chromatogram and PAH ratio plots (Refer to Figure 6). A former gas works site located on Moorhouse Avenue in the south east of the city closed in the 1980's with stormwater from this site likely to have entered the Heathcote River via streams and drains along Ferry Road. Gas works waste has also been identified in uncontrolled fill in land adjacent to the River.

Figure 6: Heathcote Sediment PAH Ratio Sources





Photograph 3: PAH impacted sediment from the Heathcote River, near Radley Street Bridge and the corresponding GC MS – Chromatogram for sample obtained in the Heathcote River with typical gasworks contaminant signature.

4.5 ASBESTOS

In total 32 sediment samples have been analysed for asbestos with 12 samples identified as containing asbestos with concentrations ranging between 0.000034 – 0.0046% w/w. Three samples were reported at concentrations in excess of recreational guideline values. The mean of all 32 samples was calculated to be 0.00031% w/w and the 95% upper confidence level to be 0.00102% w/w (95% Chebyshev UCL).

The source of asbestos in the sediment is likely to be urban stormwater run-off containing asbestos fibres from the weathering and erosion of asbestos containing building materials.

Three sediment samples were found to have contained asbestos concentrations that were above the Building Research Association New Zealand (BRANZ) Guidelines for Assessing and Managing Asbestos in Soil (November 2017). A summary of the asbestos concentrations detected in sediment is presented in Table 7.

Table 7: Asbestos concentrations in the Heathcote River Sediment

Sample name	Asbestos Type Detected	Description of Asbestos Form	AF and FA as % w/w of Total Sample
SS01	**Chrysotile**	**Weathered fibre cement fragments**	**FA = 0.0011% w/w**
SS08	**Chrysotile, amosite and crocidolite**	**Loose fibre bundles**	**AF = 0.0046% w/w**
SS09	Chrysotile	Loose fibre bundles	AF = 0.000046% w/w
26	Chrysotile and amosite	loose fibre bundles	AF = 0.00022% w/w
26C SS1			AF = 0.00021% w/w
26C SS2			AF = 0.0001% w/w
26C SS3			AF = 0.00011% w/w
SS102	Chrysotile	loose fibre bundles	AF = 0.000074% w/w
SS103	Chrysotile	loose fibre bundles	AF = 0.000034% w/w
SS112	Chrysotile, amosite and crocidolite	loose fibre bundles	AF = 0.00055% w/w
SS113	**Chrysotile, amosite and crocidolite**	**loose fibre bundles**	**AF = 0.0026% w/w**
SS115	Chrysotile and amosite	loose fibre bundles	AF = 0.00027% w/w

4.6 ELUTRIATION

The elutriation test was conducted on the sediment sample obtained from S113 which appeared to be impacted with potential gas works waste. The elutriation analysis would therefore provide a worst case assessment of potential mobilisation of contaminants during the dredging in the river.

The elutriation analysis indicated that PAHs, specifically anthracene, benzo(a)pyrene, fluranthene, naphthalene and phenanthrene could be liberated from the sediment and increase water concentrations by one to two orders of magnitude in the water column during dredging near SS113. The analysis indicates that the concentrations of PAHs would be in excess of the available ANZECC criteria and DWSNZ.

The elutriation analysis which simulates sediment dredging and disturbance indicates that PAH contaminants will become mobilised into the water column during the proposed works. All PAHs were not detectable in the water sampled from the river water but all were detectable at low concentrations in the elutriation extract.

There are limited ANZECC guideline criteria for PAHs in water, and the majority provided are classed as 'low reliability' criteria established from a limited dataset. anthracene, benzo(a)pyrene, fluranthene, naphthalene and phenanthrene were all detected in the elutriation extract above the ANZECC trigger values for freshwater.

The elutriation analysis for heavy metals indicated that metals would likely bind to sediment and not be available in the water column, with the majority of concentrations higher in the initial pretest water analysis than after disturbance and analysis of the elutriation extract. The pretest water sample contained concentrations of total chromium, copper and zinc in the water above the ANZECC trigger values while the extract met all ANZECC criteria but contained an arsenic concentration marginally above the NZDWS (2008).

5 DISCUSSION

5.1 ASBESTOS RISK

Asbestos is a naturally occurring mineral that has been mined in New Zealand and many countries around the world due to its many beneficial properties when it is added to building materials. Asbestos is a hazardous material and its harmful effects are well known and well documented.

Asbestos causes cancer in a dose-dependent manner (WHO 2000a). The Ministry of Health (2017) has stated; 'the greater the exposure, and the longer the time of exposure, the greater the risk of contracting an asbestos-related disease' and therefore the dose appears to be important for asbestos related disease but no threshold has been identified below which no carcinogenic effect will occur.

Due to recent research (Swartjes and Tromp, 2008) and an increase in the awareness and understanding of asbestos in soil risk assessment within the environmental science industry over the last decade, the risk low levels of asbestos in soil pose is now better understood. Prior to 2009 and the introduction of the Western Australian Department of Health (WADOH) Asbestos in soil guidelines, the assessment of asbestos in soil was qualitative and one fibre would result in the soil being catergorised as contaminated. The aforementioned advances have now allowed a quantitative approach to the risk to be made and the introduction of the BRANZ (2017) Guidelines for assessing and managing asbestos in soil. The BRANZ guidelines have affectively provided a quantity of asbestos fines and fibrous asbestos in soil which would not result in an unacceptable risk to the health of the occupants and land users.

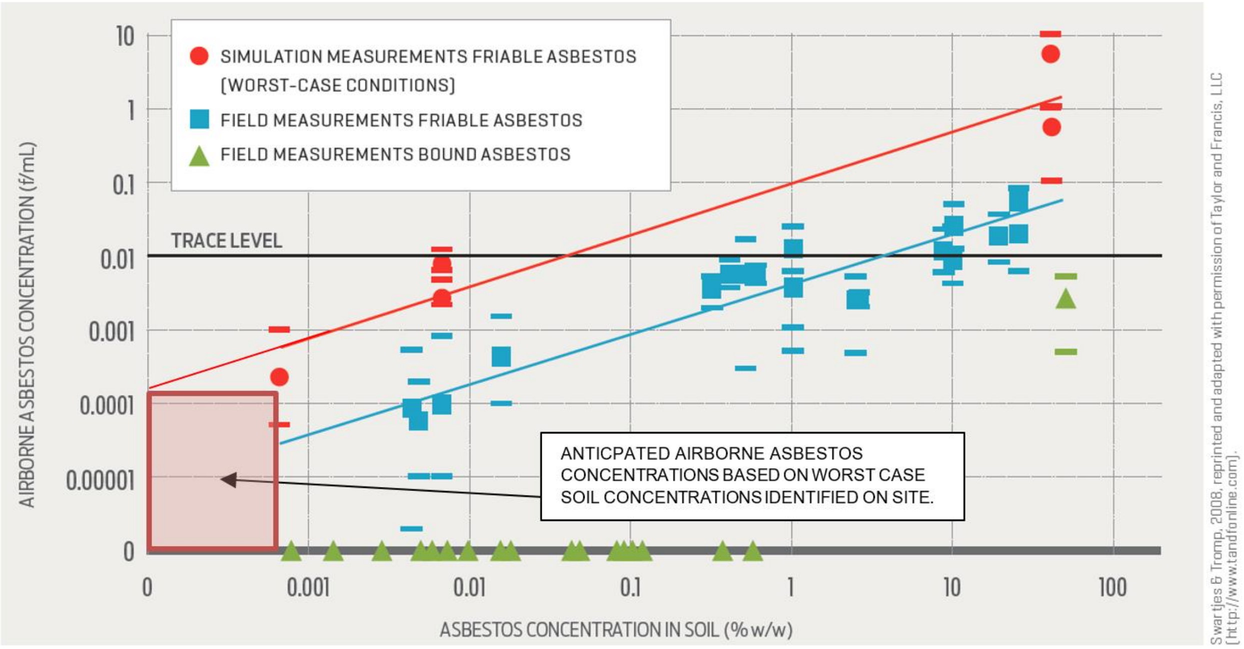
5.1.1 EXPOSURE PATHWAYS

Asbestos typically becomes a potential risk to health when the fibres are liberated from the matrix (building material, parent rock or soil) and become airborne in a significant concentration, with the risk of adverse effects increasing with repeated exposures and higher doses. The majority of asbestos human health risk assessments have concentrated on the indoor built environment with few studies assessing asbestos in soil.

Two important studies, Addison et al 1988 and Swartjes and Tromp, 2008 have evaluated the potential for airborne concentrations of asbestos fibres from various types and degrees of asbestos contaminated soil. Although there are several gaps in the literature and research which are still to be completed, the data currently indicates that significant soil contamination in excess of the BRANZ guideline are required to exceed regulatory control limits for air.

The Swartjes & Tromp (2008) study evaluated the concentration present in soil and the airborne concentration under several scenarios. Their study data is presented in Figure 7 and includes field and modelled data. The study concluded that airborne asbestos concentrations were unlikely to exceed 0.01 fibres / milliliter (f/ml) of air, while soil concentrations were at 0.01 % w/w. Sediment samples from the watercourses in this assessment were one to two orders of magnitude below this and with a considerable difference in moisture content.

Figure 7: Correlation between asbestos soil concentrations v's airborne (Source: Modified from BRANZ (2017)).



5.2 WORKING WITH ASBESTOS

In accordance with the Approved Code of Practice (2016) and BRANZ (2017) Guidelines for the management and removal of asbestos, work involving soil containing asbestos is permitted as asbestos-related work if it does not contain ACM or friable asbestos in a quantity likely to lead to airborne contamination above trace level during the work. Trace level is defined in the ACOP as an average concentration over any eight-hour period of less than 0.01 asbestos fibres per millilitre of air (< 0.01 f/ml).

Given the low concentrations of asbestos fibres detected in the sediment, the soil type being predominately silt, the inherent high moisture content of the sediment and the proposed activities, we anticipated that fibre concentrations within air were highly unlikely to exceed trace levels if basic site management controls were applied. A pilot study was completed with air monitoring for asbestos to confirm this with all results below the trace level.

5.3 URBAN RIVER BEDS AS HAIL SITES?

The NES Regulations apply to sites that have previously or currently have a hazardous activity or industrial land use associated with them. The undertaking of an activity such as dredging and the likely presence of contaminants above background soil concentrations would trigger the requirements of an environmental assessment and potentially for a resource consent prior to the works.

Based on the data reviewed for the Heathcote River and other three water courses, all contain contaminants in sediment above background concentrations and the NES Regulations should therefore be considered for large scale works.

5.4 AMBIENT LEVELS OF ASBESTOS

Identifying the source of asbestos fibres in river sediment is fraught with difficulties due to the extensive number of uses of asbestos and the prevalence of asbestos containing materials. Historically, vehicle brake pads contained asbestos and this would enter the stormwater system via the roading network.

Adjacent to the Heathcote River are a number of residential areas built and modified during the period (1940 – 1990) when asbestos containing materials were extensively used in residential properties. Again, weathering and erosion of these materials such as Super Six asbestos cement roofing can lead to asbestos fibres being released into stormwater. In addition to this, there is an extensive network of aging asbestos cement pipework within Christchurch which may also be a source of trace amounts of asbestos fibres in the urban environment.

Studies on the deterioration of asbestos containing building material due to weathering and erosion by Bornemann & Hildebrandt 1986 and Brown 1998 have estimated that asbestos sheet thickness can decrease by 0.01 to 0.02 mm per year. Additional studies (Spurny, 1989) estimate that 20% of the liberated asbestos is released into the air while the remaining 80% is removed by rain.

A study by the WHO (1998) undertaken in Canada, Italy, Japan, the Slovak Republic, Switzerland, the United Kingdom and the USA showed means and medians of asbestos fibres between 0.00005 to 0.02 f/ml in outdoor air in urban areas. Airborne asbestos fibres that deposit on hard standing will eventually enter the stormwater system and our urban rivers.

6 CONCLUSIONS

This paper summarises perhaps the first assessment of asbestos in river bed sediment in New Zealand. Often considered irrelevant to the ecological and human receptors in question, the need to test for it was lacking from a toxicological or water quality viewpoint. Due to improved analytical techniques and an increased awareness of the risk assessment process, assessors of contaminated land have increasingly over the past ten years identified asbestos at trace levels on residential, commercial and industrial sites. Due to the dredging of the Heathcote River, the sediment disposal options were required to be assessed and the presence of asbestos to be evaluated.

This paper has looked extensively at the sediment in four watercourses in the south of Christchurch only, all of which have a long history of receiving urban run-off and industrial discharges. Asbestos was identified frequently in the sediment along stretches of the Heathcote River at predominately trace concentrations. Asbestos was detected less frequently in the Wigram retention pond, Curletts and the upper stretches of the Heathcote river. The Wigram retention pond was created in the late 1980’s with a large percentage of the industrial premises in the Wigram/ Middleton area also built post 1980 and the peak asbestos usage era of the 1970’s. The lower stretches of the Heathcote River on the other hand have been developed with residential properties adjacent to the

River since at least 1940 and has received stormwater from industrial parts of the City's south east prior to this date.

The risk posed by the asbestos to human health during excavation and handling is considered low, however controls including personal protective equipment, fencing and signage should be employed to ensure the requirements of the Asbestos Regulations are met.

Zinc concentrations continue to be significantly elevated in the catchment with the Wigram Retention pond containing the highest concentrations in the study area. Concentrations in the Heathcote River appear to increase with distance along the River but this may also be due to the river bed composition changing from a sandy gravelly bed to one containing greater proportions of finer silt sediment.

The heavy metal and polycyclic aromatic hydrocarbon (PAH) concentrations in the sediment are elevated with regards to regional background concentrations and were therefore not suitable for disposal at clean fill locations. The concentrations meet the CCC Burwood Landfill criteria which are based on recreational land use criteria. The source of the PAHs appears to be related to coal combustion.

The sediment in our urban rivers continues to contain contaminants that are above ecological guideline criteria indicating that aquatic life may be impacted. Efforts to improve the biodiversity and value of our rivers may need to target not only the incoming stormwater quality but the level of contamination in the sediment. The cost to dispose of sediment from urban rivers may be a significant cost to a project due to the likely presence of metals above background concentrations and potentially asbestos depending upon the catchment. Environmental assessments of the sediment should be conducted to determine the most appropriate disposal location and to inform budget decision making.

Catchment management is essential for managing the health of our urban rivers. The increase in the use of rain gardens and other sustainable urban drainage designs will be essential together with other remedial work to ensure our rivers can maintain their biodiversity and provide aesthetic and recreational benefits.

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REFERENCES

Addison J, Davies LST, Robertson A, Willey RJ (1988). The release of dispersed asbestos fibres from soils, Institute of Occupational Medicine, Report No. TM/88/14.

ANZECC (2000). Australian and New Zealand guidelines for fresh and marine water quality. Volume 1: The guidelines. Australian and New Zealand Environment and Conservation Council, ANZECC, and Agriculture and Resource Management Council of Australia and New Zealand, ARMCANZ, Artarmon, New South Wales.

Bornemann P and Hildebrandt U., (1986). The question of environmental pollution by material removed from asbestos cement by weathering. Staub Reinhalt der Luft, 41(11), 486–489.

Brown J.N., Peake B.M., (2006). Sources of heavy metals and polycyclic aromatic hydrocarbons in urban stormwater runoff. Science of the Total Environment 359, 145–155.

Brown S.K., (1998). Physical properties of asbestos-cement roof sheeting after longterm exposure. J. Occup. Health Safety-AustNZ 14(2), 129-134.

Charters, F.J., Cochrane, T.A. & O'Sullivan, (2016). Predicting sediment and heavy metal loads in stormwater runoff from individual surfaces, 2016 New Zealand Stormwater Conference, Nelson.

ENGEO (2018). Detailed Environmental Site Investigation, Ōpāwaho Heathcote River - Beckford Road to Radley Street. Project Reference 14417. Dated 05.09.2018.

Hickey, C., Buckland, S., Hannah, D. et al. Bull. Environ. Contam. Toxicol. (1997) 59: 106. Polychlorinated Biphenyls and Organochlorine Pesticides in the Freshwater Mussel Hyridella menziesi from the Waikato River, New Zealand

NES-CS - Resource Management (National Environmental Standard for Assessing and Managing Contaminants in Soil to Protect Human Health) Regulations 2011.

NIWA (2015). Sediment Quality Survey for Heathcote River Catchment, City Outfall Drain and Estuary Drain. Prepared for CCC. NIWA CLIENT REPORT No: AKL-2015-021.

Spurny K.R., 1989. Asbestos Fibre Release by Corroded and Weathered Asbestos-Cement Products. IARC Sci Publ 1989;(90): 367-371.

Swartjes F.A., Tromp P.C., (2008). A Tiered Approach for the Assessment of the Human Health Risks of Asbestos in Soils. Soil & Sediment Contamination, 17:137–149.

Tonkin and Taylor, (2006). Background concentrations of selected trace elements Canterbury soils. Prepared for Environment Canterbury. Environment Canterbury Report No. R07/1, Christchurch. July 2006.

Tonkin and Taylor, (2007). Background concentrations of selected trace elements Canterbury soils. Addendum 1: Additional samples and Timaru specific background levels. Prepared for Environment Canterbury. Environment Canterbury Report No. R07/1/2, Christchurch. February 2007.

M.B. Yunker et al., PAHs in the Fraser River basin: a critical appraisal of PAH ratios as indicators of PAH source and composition. Organic Geochemistry, Volume 33, Issue 4, April 2002, Pages 489-515.

World Health Organization, (1998). Environmental Health Criteria 203 – Chrysotile Asbestos. ISBN 92 4 157203 5.