NZ TRANSPORT AGENCY
WAKA KOTAHI

Auckland Motorways

Road Derived Sediments (RDS) and Vegetative Material Reuse Feasibility Study

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Quality Assurance Statement

Project Manager: Peter Mitchell – Stormwater Asset Manager

Prepared by:

Angela Mayson, Senior Environmental Consultant

Dr Craig Depree, Environmental Chemist

Dr Robyn Simcock, Environmental Scientist

Reviewed by:

Peter Mitchell – Stormwater Asset Manager

Angela Mayson - Senior Environmental Consultant

Dr Craig Depree - Environmental Chemist

Dr Robyn Simcock - Environmental Scientist

Approved for issue by:

Peter Mitchell – Stormwater Asset Manager

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Executive Summary

The New Zealand Transport Agency (NZTA) manages the Auckland motorway network, from the Bombay Hills in the south to Pokeno in the North, through the Auckland Motorway Alliance (AMA). The AMA is responsible for the operations and maintenance of the network which includes:

- road sweeping,
- catch pit clearing
- maintenance of stormwater treatment devices
- landscaping and weeding

These activities generate significant amounts of sediment (termed road derived sediment or RDS) that require disposal to landfill. Over 3000 tonnes of RDS is disposed of annually from the Auckland motorway network at a cost of approximately $450,000 for landfill disposal. In addition, landscaping and weeding maintenance generates significant vegetative material.

International research and management of RDS has resulted in significant advances in opportunities for reuse of the material.

International Perspective for RDS reuse

A literature review found that:

- RDS is known to contain elevated levels of hydrocarbons and the heavy metals, copper, lead and zinc
- regulations and guidelines allow for disposal of RDS to land, usually with some form of pre-treatment to minimise potential effects on the environment
- composting of RDS may treat and dilute RDS to levels where it can be reused as a soil conditioner or compost
- where necessary, or just best practice, the heavy metals in the composted RDS material can be immobilised to a greater extent via the addition of suitable stabilisers.

Current Disposal Options for RDS

The potential disposal options for RDS reuse in Auckland are limited to landfill disposal. RDS cannot be disposed of as cleanfill or to managed fill due to its contaminant levels. Currently there are no compost producers who can accept RDS as part of their composting operations due to resource consent restraints.

New Zealand Regulations and Guidelines

A review of national New Zealand regulations and guidelines found that:

- RDS is not specifically mentioned with regard to reuse.

- RDS typically has only moderate contaminant levels when compared to contaminant guidelines . These guidelines include:

  - Guidelines for the Safe application of Biosolids to Land, MfE (NZWWA 2003)
  - New Zealand Standard 4454:2005 Composts, Soil Conditioners and Mulches
  - Proposed National Environmental Standard for Assessing and Managing Contaminants in Soil
  - Proposed Auckland Regional Plan: Air Land and Water (2001)

- for copper, lead, zinc, TPH and PAH's in RDS are typically above background soil limits when compared to TP 153, Background Concentrations of Inorganic Elements in Soils from the Auckland Region

RDS Analysis

Sampling and analysis of RDS from the AMA network showed that:

- RDS from the AMA contains moderate levels of contaminants including copper, lead, zinc, TPH and PAH's

- RDS from the AMA has contaminants that exceed TP 153, Background Concentrations of Inorganic Elements in Soils from the Auckland Region and as such is required to be treated as a contaminated material

- the limiting contaminant in RDS is zinc.

AMA Vegetative Material

A review of vegetative material produced from the AMA network showed that:

- there is enough vegetative material available from the AMA to compost RDS although the exact quantities required to obtain acceptable treatment levels are not available at this stage

- compost produced from RDS and vegetative material could be reused on the AMA

Composting

An investigation of composting processes and plants showed that:

- There are a number of options available for composting facilities

- There is potential for significant cost savings for NZTA if RDS can be composted and reused as a resource

- RDS on the AMA network has levels of contaminants (particularly copper, lead, zinc, TPH and PAH's) that are above Auckland background soil levels. As such it is likely that application of the untreated RDS to land without resource consent and potential risks to the environment would be not possible.

- Composting of RDS is a viable way to turn a waste material into a valuable resource and potentially reduce contaminants to a level where application to land would be possible without resource consent.

- The information available from this study does not allow for conclusions to be drawn about the metal leaching potential of the final composted product. This lack of information means that the regulatory requirements and the potential environmental effects for RDS compost reuse are not clearly defined; however, any risk from heavy metal leaching can be address via the addition of stabilising materials that effectively immobilise and/or chemically 'lock-up' these contaminants.

- To confirm whether resource consent would be required for use of composted RDS significant consultation and liaison with the regulatory authority is required.

- Opportunities to influence regulation to allow for composted RDS application to land should be investigated (for example a specific rule in a regional plan if required).

- The AMA produces vegetative material on this network that could be diverted to compost with RDS.

- Composting and reusing RDS will meet the NZ Waste Minimisation Act and Waste Strategy Objectives of reduction of the amount of waste that is disposed of and lessen the environmental harm of waste.

- Composting and reusing RDS will allow the AMA and NZTA to work towards the objectives of resource efficiency and GHG emissions reduction in line with their Environmental Management Plan Objectives.

- Composting and reusing RDS will meet the AMA objectives of finding opportunities for of Value for Money, Positive Legacy, Network Efficiency, Healthy Organisation and Customer Stakeholder Obligations.

Recommendations

The following outlines the recommendations to further understand the viability of composting and reusing RDS on the AMA network.

- To confirm existing regulatory requirements for reuse with the regulatory authority.

- For NZTA to proceed with a small-scale composting trial to allow for understanding of:
    - Environmental effects of the final product, including leaching potential of contaminants (i.e. heavy metals) and, importantly, the efficacy of stabilising-agents to reduce leaching to levels well below guideline levels
    - Practical operational requirements and costs for a composting facility
    - Optimisation of proportion of RDS to vegetative material for composting
    - Confirm that the final product will be fit for purpose
    - Confirm the accumulation risk of contaminants when applied to the AMA Network
    - Allow for final recommendation whether or not to proceed with composting of RDS

- Investigate partnership opportunities with:
    - Existing composting operations
    - The Auckland Council to determine disposal options for the RDS from Local roads
    - The Auckland Council to influence the regulatory processes that may need to be followed to enable safe and responsible reuse of RDS (perhaps by developing a specific rule)

Conclusion

The preliminary findings of this study are very encouraging for composted RDS to be turned from a waste material to a resource. The recommendation is for NZTA to proceed with a composting trial study which will enable key information gaps to be addressed, allowing an informed decision to be made regarding the feasibility of establishing a pilot plant to implement RDS composting and reuse on the AMA network. Further, there may be opportunities for NZTA to utilise the results of this study and any subsequent trial to address RDS disposal on a national scale.

1 Introduction

1.1 Background

On the Auckland Motorway network stormwater runoff is a major contributor of suspended sediment and associated contaminants to urban stormwater. To reduce the environmental impacts of road runoff the roads are swept and catch pits and stormwater treatment devices (SWTDs) are used to capture this material before it is transported into aquatic receiving environments. Interception of road-derived sediment (RDS) generates a 'contaminated' waste stream that requires landfill disposal.

Road network operators are aware of the need to reduce waste disposed to landfill and optimise resource efficiency.

One way of achieving this is by reusing or recycling RDS. The generally large soil content of these materials and typically moderate levels of contaminants, coupled with increasing landfill disposal costs, has encouraged the Auckland Motorway Alliance (AMA) to investigate the use of RDS for beneficial applications such as roadway fill, landfill daily cover, or as a component in engineered products (e.g., concrete/asphalt), and a component of compost and soil conditioners.

The cost of disposing RDS is becoming an important issue for road network operators (landfill disposal costs for RDS in Auckland currently charged between $90 and $180 per tonne). However, reducing costs is not the only driver for reusing RDS. There are potential benefits from better alignment with national strategies on sustainability and waste reduction, from generating a product of value (e.g. compost), reduced carbon emissions (from the reduction of methane generating waste being disposed of to landfill and reduced fuel use from minimisation of transportation of RDS).

The AMA, as part of its maintenance duties, also manages landscaping, weeding and planting of the berms alongside the motorway. This maintenance results in significant amounts of vegetative material being produced on the network. This vegetative material has the potential to be utilised as a feed stock for compost and may be mixed with RDS to produce a compost.

This document reports the results of a feasibility study investigating the potential to use RDS and vegetative material from the Auckland Motorway network as a feedstock for compost and producing a useful resource. The study also investigates the possible regulatory implications of this option and the feasibility of the AMA operating and managing the composting process from collection to use as compost.

1.2 The Auckland Motorway Alliance Network

1.2.1 Background of AMA

The Auckland Motorway Alliance (AMA) was established on 1 October 2008 to operate and maintain Auckland's motorway network. NZTA via the Auckland Motorway Alliance is dedicated to improving the motorway experience for all its stakeholders.

The AMA is responsible for the maintenance of the Auckland motorway network (Figure 1.1). Part of this maintenance includes the removal and disposal of RDS from roads, catch pits, and stormwater treatment devices (SWTD).

Figure 1-1 Map of Auckland Motorway Alliance Network

1.3 Definition of RDS from the AMA

The term Road Derived Sediments (RDS) is used in this report to describe all sediment 'waste' collected from the AMA-managed road network as part of regular maintenance operations, and includes the following:

- Roadside sweepings
- Catch pit sediments
- Filter material from stormwater treatment devices such as sand filters and stormfilters)
- Accumulated sediments from stormwater ponds and other stormwater assets (eg. soakage pits, drainage channels, swales, infiltration trenches etc).

1.4 NZTA Drivers for this Study

1.4.1 The New Zealand Waste Minimisation Act and Waste Strategy

The Waste Minimisation Act 2008 provides a legislative framework for solid waste management in New Zealand. The Act encourages a reduction in the amount of waste that is generated and disposed of in New Zealand and aims to lessen the environmental harm of waste.

The Act also aims to benefit the economy by encouraging better use of materials throughout the product life cycle, promoting domestic reprocessing of recovered materials and providing more employment.

The key provisions of the Act are outlined below:

- Put a levy on all waste disposed of in landfills to generate funding to help local government, communities and businesses reduce the amount of waste
- Help and, when necessary make, producers, brand owners, importers, retailers, consumers and other parties take responsibility for the environmental effects of their products through product stewardship schemes
- Allow for regulations to be made making it mandatory for certain groups (for example, landfill operators) to report on waste to improve information on waste minimisation

The Waste Minimisation Act introduced Landfill levies in 2008 for waste disposed of to landfill. The Purpose of this levy is to incentivise waste creators to find alternative reuse options for waste.

1.4.2 NZTA Environmental Management Plan

NZTA have an Environmental Management Plan or EMP (2008) that includes resource efficiency and climate change mitigation objectives. The activities of minimising waste disposal to landfill and maximising recycling and reuse opportunities are the methods by which NZTA propose to achieve these objectives.

1.4.2.1 Resource Efficiency

Specifically the following resource efficiency objectives in the EMP (2008) relate to RDS reuse:

- "RE1 Manage energy consumption and waste associated with Transit's business in a cost effective and sustainable manner.
- RE2 Make resource efficiency an integral part of all state highway activities."

1.4.2.2 Climate Change and Carbon Minimisation

Although specific objectives have not been developed in the EMP (2008), the following Climate Change mitigation activity relates to RDS reuse:

- Reduce, reuse, recycle and substitute resources to lessen the amount of waste requiring permanent disposal.

1.5 Auckland Motorway Alliance Drivers

1.5.1 Water Quality

The AMA has objectives to minimise water quality impacts from activities on the network. Removal of RDS from the network also removes contaminants from the network.

1.5.2 Carbon minimisation

The AMA has undertaken a carbon or greenhouse gas (GHG) inventory. One of the most significant sources of greenhouse gas emissions from the network is from disposal of waste to landfills and the subsequent production of methane from this waste.

RDS disposal to landfill contributes to the total GHG emissions produced by the AMA and any reduction will result in a decrease in GHG emissions.

1.5.2.1 Auckland Motorway Alliance Key Result Area

The AMA has Key Performance Indicators that they must work towards to achieve the objectives of NZTA. The reduction of RDS being disposed of to landfill and instead becoming a resource that can be utilised has positive implications for a number of AMA key indicators. The following briefly outlines each indicator and how RDS reuse may impact them.

Value for Money - Opportunities

The costs of disposal of RDS are high for the AMA and there is an opportunity to minimise costs for disposal while enabling resource efficiency for RDS.

Positive Legacy

Implementing a process that can reduce the disposal of waste to landfill and finding a way to produce a useful resource will ensure a positive legacy by the AMA. Further, the results of this study may have implications for other areas of the NZTA network.

Network Efficiency

Minimising the amount of travel related to RDS disposal to landfill will enable improvements in Network efficiency.

Customer Stakeholder Obligations

Customers and stakeholders now typically expect an organisation to find ways to minimise cost, reduce waste and environmental effects and efficiently use resources. Reuse of RDS may provide a way to enable all of these expectations to be improved.

Healthy Organisation

An organisation that is working towards innovative methods to improve efficiencies and reduce waste will likely be a healthier organisation.

1.6 Objectives of Study

The objectives of this study were:

- To investigate opportunities to reuse an existing waste stream that is produced on the Auckland Motorway Network – road derived sediments (RDS).
- To understand the international and national regulatory framework for reuse of RDS.
- To determine what risks that the reuse of RDS might pose to the environment and human health if applied to land.
- To investigate the potential of composting RDS for use as a soil conditioner on the network.
- To investigate how vegetative material from the AMA network may facilitate RDS reuse options.
- To investigate a potential composting site and system for composting RDS.
- To understand the costs and benefits, both financially and environmentally, that the proposed reuse of RDS might have for the NZTA.

This study has assessed the feasibility of reusing RDS and vegetative waste streams as a soil amendment on the AMA network.

1.7 Scope of Study

This study includes the following components:

- A national and international literature review to understand typical contaminants in RDS.
- A review of national regulations and guidelines for comparison (i.e. with typical concentrations) and to understand the regulatory framework for RDS reuse.
- Sampling and analysis of RDS from seven samples on the AMA network to understand the contaminant concentrations.
- A review of the sources and uses of vegetative material on the AMA network.
- A review of the benefits of composting RDS so it can be reused on the network.

2 Road Derived Sediment – National and International Context

2.1 Typical Contaminant Levels and International Guidelines

There are a number of issues that need to be considered to ascertain which of the various reuse options for RDS are potentially suitable for New Zealand conditions. RDS is known to contain moderate levels of contaminants including heavy metals and petroleum hydrocarbons.

The following literature review outlines the typical contaminants found in RDS. While most of the studies on RDS are from overseas there are a small number of New Zealand studies that have reported contaminant concentrations of street sweepings and catch pit sediments.

The literature review also outlines relevant international soil contaminant guidelines in relation to RDS reuse.

New Zealand guidelines and regulatory documents will be outlined separately in Section 3.

2.1.1 Organic contaminants (TPH and PAHs)

The main organic contaminants of interest in RDS are petroleum hydrocarbons. The total amount of petroleum hydrocarbons is referred to as TPH (total petroleum hydrocarbons), which includes all petroleum-derived compounds. An important class of organic contaminants are polycyclic aromatic hydrocarbons (PAHs). PAHs are listed by the US EPA as priority contaminants, because of their persistence in the environment and potential toxicity (including carcinogenicity). PAHs are present in petroleum-based products (oil, diesel, bitumen) and are formed through the incomplete combustion of petroleum and other fuel types (e.g. wood, coal).

2.1.2 TPH concentrations

The concentration of TPH in RDS typically ranges from a few hundred to a few thousand milligrams per kilogram, or mg/kg (refer to Table 2.2). Based on the limited number of studies, the median concentration of TPH in RDS is in the range of 1000–2000 mg/kg. The concentration of TPH appears to be dependent on both traffic volume and catchment usage – with high volumes of traffic and industrial catchments resulting in the highest concentrations. For example, Latimer et al. (1990) reported TPH concentrations of 353, 1680 and 3490 mg/kg for road dust from residential, highway and industrial sites, respectively. In recent NZ studies, the median of 11 Christchurch street sweepings was 680 mg/kg, and the median of 15 sweepings collected from Auckland, Christchurch and Hamilton was ca. 1200 mg/kg (Depree, 2008). In a study involving 36 catch pit sediments sampled from around Auckland City, Moore et al (2007) reported a median TPH concentration of ca. 2000 mg/kg.

2.1.3 TPH Guidelines

Most soil quality guidelines do not include a value for TPH, however, in the U.S, Snohomish County (Washington) specify a maximum TPH concentration of 2750 mg/kg for Class A street waste. Additionally, Collins and Moore (2000) specified that one of the conditions for the reuse of RDS to be classified as a low risk activity was that it should contain <1000 mg/kg TPH. Based on this latter condition, it is possible that RDS, in particular catch pit sediments, would benefit from either dilution or treatment (biotic/abiotic degradation) to address any potential risks posed by elevated TPH concentrations.

2.1.4 PAH concentrations

The median concentration of PAHs in RDS can vary, but typical concentrations appear to be between 5–8 mg/kg. The concentration of PAHs do not appear to be related to traffic volume, since RDS from Tokyo roads (100,000 vehicles per day) contained 4 mg/kg of PAHs (Takada et al. 1991) compared to RDS from residential areas in Worcester, Massachusetts (9000 vpd) that contained 325 mg/kg of PAH (Mathisen et al. 1999). Research both here (Depree and Olsen 2005) and in the U.S. (Mahler et al 2005) has highlighted the role that coal tar-based road binders have on generating elevated concentrations of PAHs in RDS. Mahler et al (2005) reported ca. 60-fold higher concentrations of PAHs in runoff particulates from parking lots seal coated with coal tar, compared to untreated asphalt parking lots. Coal tar binder use in NZ was phased-out during the late 70's with only very minor use occurring into the early 80's. While legacy coal tar contamination has been shown to be an ongoing source of elevated PAHs in RDS in older suburbs of Christchurch and Auckland, it is not envisaged to be an issue for RDS collected from the Auckland motorway network.

Table 2-1 Soil quality guidelines (Dutch and Canadian) for PAHs

PAH	Dutch SQG[a] (mg/kg)	Canadian SQGs (mg/kg)	
		Residential/ parkland	Commercial/ industrial
Phenanthrene	31	5	50
Benzo[a]anthracene[c]	2.5	1	10
Benzo[a]pyrene[c]	7.0	0.7	0.7

2.1.5 PAH Guidelines

Of the 16 US EPA 'priority' PAHs, the seven suspected carcinogenic PAHs (cPAH) are of greatest concern. Accordingly, most guidelines tend to specify maximum levels for individual cPAH compounds, which depending on the land use (residential vs industrial), are typically between 1 and 10 mg/kg (Table 2-1). U.S. guidelines for cPAH in reused RDS are very restrictive (compared to heavy metal limits), for example Oregon Department of Environmental Protection 'soil cleanup' guidelines (Collins and Moore, 2000) permit individual cPAH concentrations of between 0.1 (residential) and 1 mg/kg (industrial) while Snohomish County (Washington) specify a maximum total (sum of all 7 cPAH) of 1 mg/kg for 'Class A' street waste (CWC, 1997).

Table 2-2 Hydrocarbon (TPH and PAH) concentrations in RDS (i.e. road sweepings, street dust and catchpit sediment)

TPH (mg/kg)	PAH[1] (mg/kg)	Comment	Reference
Street dust/sweepings			
680	5.6	n=11 (Christchurch)	Depree & Rijkenberg 2010
1190	4.7	n=15 (Ham, Akld, ChCh)	Depree 2008
-	4.40	Dunedin (New Zealand)	Brown and Peake 2006
(112–505)	30	Mixed land use type	Mathisen et al. 1999
1054	7.7	Interstate/state highways	Hindin 1993
2030		Oregon, US	Ghezzi et al. 2001
	3.4	Road dust (>10,000 vpd)	Takada et al. 1991
	16.7	Expressway: inside tunnel	Takada et al. 1991
	3.4	Expressway: outside tunnel	Takada et al. 1991
353		Residential	Latimer et al. 1990
3490		Industrial	Latimer et al. 1990
1680		Highway	Latimer et al. 1990
	7.5	Street dust	Yang and Baumann 1995
Catchpit sediments			
1220	8.0	n=18 (Ham, Akld, ChCh)	Depree 2008
1950		n=36 (<1000 to >20,000 vpd)	Moores et al. 2007
	3.8	Residential (500 vpd)	Karlsson and Viklander 2008
	17	Arterial (25,500 vpd)	Karlsson and Viklander2008
1788	-	Interstate/state highways	Hindin 1993
-	6.53	Dunedin, NZ	Brown and Peake 2006
1620	7.1	Mixed land use type	Mathisen et al. 1999

1. median or mean PAH concentration

2.1.6 Heavy metals – lead, copper and zinc

Heavy metals are well described contaminants of both stormwater discharges and RDS. Lead, copper and zinc are the metals most commonly found in RDS from the emissions and debris associated with vehicle use (Table 2-3). Lead was a component of petrol for many years in New Zealand and was removed in 1996. Copper discharges are thought to come from the breakdown of brake pads on cars and zinc discharges from the breakdown of tyres during typical vehicle use.

Table 2-3 Lead, copper and zinc concentrations in RDS (includes road sweepings, street dust, catchpit sediments and retention pond/swale sediments)

Metal concentration[a] (mg/kg)			Comment	Reference
Lead	copper	Zinc		
Street dust/sweepings				
112	35	212	n=11, Christchurch	Depree & Rijkenberg 2010
117	55	336	n=15 (Ham,Akld,ChCh)	Depree 2008
18.3	8.9	49.0	n=199, Florida	Jang et al. 2009
83	63.4	294	Oregon, US	Ghezzi et al. 2001
1710	275	975	street dust	Harrison and Wilson 1985
1354	115	513	street dust, London	Thornton 1991
19.7	9.6	38.5	residential /commercial	Liebens 2001
289	129	528	Dunedin , NZ	Brown and Peake 2006
160	126	1170	residential/commercial	Li et al. 2001
249	124	962	25,000 vpd, NZ	Zanders 2005
1880	143	534	urban (13 samples)	Harrison 1979
6630	206	1600	car parks (8 samples)	Harrison 1979
123	14.9	47.8	residential	Latimer et al. 1990
1410	228	655	industrial	Latimer et al. 1990
840	90	336	highway	Latimer et al. 1990
106	167	434	13 kerbside samples	Sutherland et al. 2001
186	185	675	15 kerbside samples	Andrews and Sutherland 2004
Catchpit and SWTD sediments				
133	85	464	n=15 (Ham,Akld,ChCh)	Depree 2008
189	105	409	China, catch pits	Duzgoren-Aydin et al. 2006
262	179	424	Dunedin, NZ	Brown and Peake 2006
9.7	19.3	98.0	n=82, catch pit	Jang et al. 2010
7.6	13.3	47.5	n=73, pond sediment	Jang et al. 2010
142	27.4	254	commercial pond sed.	Liebens 2001
121	27.1	268	commercial swale sed.	Liebens 2001
112, 160	286, 426	888, 1337	values for 2 ponds	Hares and Ward 2004

[a] median or mean metal concentrations

It is unclear why the concentrations of heavy metals in RDS were so low in Florida studies (Jang et al. 2009, Jang et al. 2010). With respect to the NZ studies, the concentrations tend to be around 100-200 mg/kg for lead, 40-180 mg/kg copper and 210-450 mg/kg for zinc.

2.1.7 Heavy Metal Guidelines

The 2012 NZ biosolids guidelines (NZWWA, 2003) specify maximum values for lead, copper and zinc of 300 mg/kg, 100 mg/kg and 300 mg/kg, respectively, for 'grade a' solids. The guidelines recommend that biosolids meeting these criteria be applied to land as a permitted activity, and therefore have been used as a useful starting point for assessing the environmental feasibility of reusing RDS in NZ (Depree 2008, Depree & Rijkenberg 2010).

Based on the above assessment criteria, and RDS leachate toxicity testing (Depree 2008), zinc is presumed to be the most problematic heavy metal with respect to any potential environmental impacts of reusing RDS.

2.2 Alternatives to Landfill Disposal

The key to successfully implementing reuse strategies for RDS is that it needs to be viewed as something of value (i.e. a potential product) rather than as a waste material needing disposal (AASHTO 2004).

The following outlines the findings of the literature review with respect to many of the alternative disposal or reuse options for RDS utilised internationally.

2.2.1 General considerations

Alternatives to landfill disposal of RDS need to be both economically and environmentally feasible. Any cost savings from a potential reuse application (relative to landfilling) need to be balanced against the requirement to adequately address the potential risk posed by placing these materials back in the environment. As such, alternatives to landfilling RDS need to consider the potential risk of contaminants being mobilised, in either particulate or dissolved form, from the site and subsequently dispersed into the wider environment. To further mitigate risk, in addition to having maximum permitted contaminant concnetrations, the reuse of RDS is often limited to land that is a specified distant from any surface waters/wetlands and that are not routinely accessed or have contact with people (i.e. garden, parks etc).

To be economically feasible and practical the reuse option must be less expensive than the combined cost of disposal and the purchase of new materials (which has been circumvented through reuse of roadwaste). As such, both high landfill tipping charges and the production of high value RDS-based products contribute to the economic feasibility of reusing RDS. For example, there is clearly more scope to develop an RDS reuse programme in Christchurch where tipping charges are ca. $200 per tonne, compared to Hamilton where they are closer to $70 per tonne.

2.2.2 International context for reusing RDS

Much of the activity relating to reusing RDS has occurred in North America, in particular, the States of Florida (Liebens 2001, Jang et al 2010), Washington (CWC 1997), Massachusetts (Mathisen et al. 1999) and Oregon (Collins and Moore 2000; Ghezzi et al. 2001), but also at a Federal level via the American Association of State Highway and Transportation Officials (AASHTO) and Federal Highway Administration. Although more recently, in Europe, the focus on how to manage (via safely reusing) the large quantities of often contaminated dredged sediment has been extended to include RDS. For example, in France, Petavy et al (2010) has compared two methods for treating RDS to reduced TPH and PAH concentrations prior to use as 'treated sediments' in civil engineering applications.

In the US, AASHTO released a comprehensive manual entitled *Environmental stewardship practices, procedures, and policies for highway construction and maintenance* (AASHTO 2004). The AASHTO report included a chapter entitled 'Roadside management and maintenance: Beyond vegetation' (Chapter 10), which provides information on a number of different applications pertaining to the reuse, recycling and/or treatment of RDS. These include:

- Fill-type applications
- Daily cover at landfills
- Cement and concrete production
- Asphalt production
- Compost/soil conditioner production

Of the above RDS reuse applications, the first two do not adequately address environmental issues as they involve using untreated RDS as cheap fill material rather than as a resource. Concrete and asphalt reuse applications incorporate both dilution and physical immobilisation (i.e. contaminants locked into a solid matrix) of RDS contaminants, but do not really embrace the concept of resource efficiency and conversion of a waste material into something of value.

The production of a useable compost/mulch/soil conditioner from RDS (as a major feedstock material) was considered the most preferred option for implementing a feasible RDS reuse programme for the Auckland motorway network for the following reasons:

- The AMA produces vegetative material
- Composting RDS may transform it from a waste material to a resource
- The AMA network has the appropriate opportunities to use the compost produced

Accordingly, this reuse application is the sole focus of this scoping report.

2.3 RDS reuse for compost/soil conditioner production

2.3.1 Literature examples

The use of RDS for conditioning soil can reduce management costs substantially, and in doing so, reduce landfill costs and the purchase of new soil amendment materials. RDS generally has moderate to high permeability, moderate nutrients, adequate water retention and forms an effective growing medium (AASHTO 2004).

RDS can be directly composted or blended with pre-formed compost. Colorado Springs (Colorado) municipality has achieved a 100% reduction in the volume of catch pit sediments landfilled by dewatering, screening and blending the RDS with compost (Mathisen et al. 1999). The City of Long Beach, California, diverts 95% of the 16,000 tonnes of sweepings collected annually to a composting facility (Kidwell-Ross 2006). This process composts only the organic material (including paper); with the fine sand and dirt fraction being used as daily cover for landfills. The Washington Department of Transportation (DOT) mixes catch pit sediments with wood chips to produce an effective growing medium used in freeway infields and medians (Collins and Moore 2000).

As part of a large roadwaste management strategy for Oregon DOT, field trials involving the composting of RDS (limited to sweepings) were undertaken using various ratios of screened RDS, dry mulch and green mulch placed in 1.1 m^3 composting bins (Ghezzi et al. 2001). Feed stock ratios ranged from 4 parts organic/1 part RDS, through to 100% RDS (i.e. no added organic material). Unfortunately the study did not report on the ‘compostability’ of the various mixtures, but the authors did report reduced TPH concentrations and minimal contaminant mobilisation (i.e. leaching) in runoff water from the compost cells.

2.4 Addressing potential risks from contaminants in RDS

2.4.1 Previous toxicity data on RDS

2.4.1.1 Toxicity of RDS leachates

There is concern about reusing RDS because of the potential for contaminants, particularly heavy metals, to become mobilised in runoff water. For applications such as compost and/or soil conditioners, the contaminants in the RDS are exposed to rainfall and, as such, there is potential for particulate heavy metals to solubilise and transfer into the dissolved phase (i.e. leaching). Once in the dissolved phase, the heavy metals can be transferred to aquatic receiving environments via runoff, which presents a potential risk to biota.

The toxicity of RDS leachates is dependent on the concentration of metals, which, in-turn, is largely determined by two parameters:

1) leachate pH; and

2) leachate concentration of dissolved organic carbon (DOC).

For mobile metals, such as zinc, leachate concentrations are largely determined solely by solution pH, with solubility increasing rapidly with decreasing pH. The leaching of metals like copper, which interact strongly with organic matter, is more influenced by the presence of DOC, with increased DOC concentrations facilitating the solubilisation of copper.

The other arbitrary parameter determining leachate concentration is the liquid (water) to solid (RDS) ratio (i.e. L/S) used in the laboratory to generate the leachate solution. The US EPA synthetic precipitation leaching procedure (SPLP) uses an L/S ratio of 20. Obviously, a lower ratio (and hence more concentrated leachate) will be expected to yield greater concentrations of metals in the RDS leachate. Accordingly, any comparisons between different studies need to take into account the L/S ratio employed to prepare the leachate solutions.

2.4.1.2 Leaching of metals from NZ RDS: comparison with hazardous concentrations (HC_{50})

Table 2.4 hows the median and inter-quartile range of leachate concentrations of lead, copper and zinc from two NZ studies – one involving eight RDS samples from Auckland, Christchurch and Hamilton with an L/S ratio of 20 (Depree 2008), and the other consisting of 11 street sweepings from Christchurch with an L/S ratio of 5 (Depree and Rijkenberg 2010). To provide some 'toxicity context' for these results, concentrations (mg/m^3) that are hazardous to 50% of aquatic species (HC_{50} – derived from numerous toxicity data sets of different aquatic organisms, Verbruggen et al. 2001) have been included. A quick comparison of HC_{50} values with leachate concentrations indicates that, undiluted, the RDS leachates contain potentially toxic concentrations of copper and zinc. For both studies, the concentration of lead (ca. 12-13 mg/m^3) was about an order-of-magnitude lower than the HC_{50} aquatic value of 150 mg/m^3.

Table 2-4 Lead, copper and zinc leaching from NZ RDS

	Depree 2008	Depree & Rijkenberg 2010	HC_{50}, mg/m^3 (Verbruggen 2001)
No. of samples	8	11	-
L/S ratio	20	5	-
lead (mg/m^3)	12 (8-14)	13 (10-21)	**150**
copper (mg/m^3)	66 (28-104)	36 (34-51)	**18**
zinc (mg/m^3)	304 (225-673)	165 (117-198)	**89**

2.4.1.3 Toxicity of RDS leachates

Harrington-Hughes (2000) devised a 'potential for harm' classification system (Table 2-5) based on the 50% effects concentration (EC_{50}), which is defined as the concentration of a leachate (expressed as a percentage of the undiluted solution) required to cause an 'effect' in the assay organisms (at the 50% level), relative to control samples. In the case of commonly used algal toxicity tests, the 'effect' is growth inhibition – so the EC_{50} concentration is the percentage of undiluted leachate required to inhibit algal growth by 50%, relative to controls. Note: the EC_{50} values are dependent on the initial leachate concentration which is influenced by the L/S ratio; Harrington-Hughes used an L/S ratio of 4. The criteria shown in Table 2-5 were derived from a study to determine the environmental impact of various road construction and repair materials (including asphalt, cement, slag, scrap tyres, aggregate fly-ash etc).

Table 2-5 Classification scheme relating leachate EC_{50} with 'potential for harm' (Harrington-Hughes, 2000)

Potential for harm	EC_{50}%[a]
Extremely high	<10
High	10–20
Moderate	20–75
Low	>75

[a] EC_{50} derived from leachates prepared from extractions with L/S ratio of 4

The EC_{50} values from three different studies, including the two NZ studies from Table 2.4, are summarised in Table 2.6. The two NZ studies used the same freshwater alga *Psuedokirchneriella subcapitata* (formerly known as *Selenastrum capricornutum*), used by Harrington-Hughes (2000). The study by Hinden (1993) used a commercial bacterial bioluminescence assay (Microtox). The results show that there is considerable variation in the toxicity of RDS leachates, for example, Depree (2008) reported at least a 50-fold difference in EC_{50} values from eight RDS samples, ranging from 2.2% to greater than 100% (which means the undiluted leachate was not toxic enough to inhibit 50% of the control growth). Using the assessment criteria of Harrington-Hughes, on average the two NZ studies showed that the 'potential for harm' from reusing RDS was only moderate. It is also emphasised that RDS leachates would be significantly diluted in the receiving environment. Depree and Rijkenberg (2010) reported that for Christchurch street sweeping leachates, dilution factors of approximately 25 and 35 were required to meet the ANZECC zinc and copper water quality guideline values, respectively.

Table 2-6 EC_{50} Values for three RDS Studies

Comment	No. samples	L/S ratio	EC_{50} (%) range	Mean EC_{50} (%)
Depree (2008) – NZ Transport Agency Report, RDS from Akld, ChCh and Ham				
All samples	8	20	2.2 - >100	-
'toxic' RDS[a]	5	20	2.2 - 85.7	29
Depree and Rijkenberg (ChCh City Council) – street sweepings				
All samples	11	5	19 - >100	-
'toxic' RDS[a]	4	5	19 - 82	50
Hinden (1993) Wasington Dept of Transportation report – various RDS				
fresh road sweepings	14	4	1 - 41	13
weathered road sweepings	12	4	5 - 100	25
wet catch pit sediments	5	4	4 - 35	13
dry catch pit sediment	3	4	7 - 14	10

[a] refers to leachates that yielded an EC_{50} value (i.e. <100%)

2.4.2 Reducing the toxicity of contaminants in RDS: Dilution and Stabilisation

It is apparent that there is the potential for adverse effects from reusing untreated or undiluted RDS. This risk has lead to the development of an RDS reuse methodology that, via a combination of contaminant removal, stabilisation or dilution processes, enables the safe and responsible reuse of RDS.

Of the contaminants of concern in RDS, TPH are the only contaminant class where removal is possible via abiotic and biotic degradation pathways. For example, after 8-9 month intervals, land-farming (Petavy 2010) and composting (Ghezzi et al. 2001) have reportedly reduced TPH concentrations in RDS by 60% and 50%, respectively. In contrast, PAHs and most certainly heavy metals cannot be 'treated out'. For these reasons, treatment options to reduce the potential risks of RDS contaminants are limited to (Depree 2008):

1. **Physical entrapment** - locking up the metal contaminants by incorporating the RDS into a solid matrix such as concrete or asphalt.

2. **Dilution -** blending the RDS with clean material for the purpose of reducing particulate contaminant concentrations to a certain level (i.e., below a particular regulatory guideline value).

3. **Stabilisation -** adding chemicals/materials for the purpose of reducing the mobility of metals in RDS (e.g. pH control, chemical modification and/or sorption). In contrast to 'dilution,' this will reduce the concentration of leachate contaminants, even though the particulate concentrations may be comparable to unstabilised RDS.

Physical entrapment by locking the RDS (and associated contaminants) into a solid cementitious or asphaltic matrix is an effective method for immobilising contaminants; however, this was outside the scope of the report. Accordingly, subsequent discussion is limited to *dilution* and *stabilisation*.

2.4.3 Stabilisation - Phosphate amendment to reduce heavy metal solubility

Addition of phosphate to precipitate metal phosphates (in particular lead) has been extensively studied as an in situ remediation technique for metal-contaminated soils. Many studies have shown that phosphate amendment can be successfully used to stabilise heavy metals, such as lead and zinc, in soils (Cotter-Howells and Caporn, 1996; Kumpiene et al. 2008). For example, Wang et al. (2001) reported a 99% reduction in leached lead in a field situation. In addition, McGowen et al. (2001) reported a 19-fold reduction in zinc mobility for a smelter-contaminated soil amended with only 0.05% phosphorus (added as diammonium phosphate fertiliser). Copper, however, has not been reported to be stabilised by phosphate amendment.

Depree (2008) reported a 90% reduction in the concentration of leached zinc from a Christchurch catch pit sediment. The major limitation of phosphate addition is that due to anion exchange with organic matter on mineral surfaces, it generates increased concentrations of dissolved organic carbon (DOC) in leachate solutions. This is detrimental since DOC complexes with, and solubilises, heavy metals such as copper. Accordingly, the use of phosphorus to stabilise heavy metals is only recommended for RDS samples that yield very low concentrations of DOC.

2.4.4 Leachate pH

Leachate pH is one of the most important factors determining the solubility of heavy metal contaminants (Jordan et al. 1997; Sauve et al. 2000; Impellitteri et al. 2002; Linde et al. 2007). As shown in Figure 2-1, this is especially important for zinc where at pH values less than ca. 6 cause a dramatic increase in leachate concentrations. Depree & Rijkenberg (2010) reported a pronounced reduction in the concentration of zinc as the pH of the RDS leachate was increased. For example, there was a 5-fold reduction in leachate zinc when the pH increased from 6.5 to 7.5. Values higher than ca. 8 would further reduce leachate zinc concentrations; however, this is undesirable with respect to growing medium properties and the mobilisation of copper (via increased DOC).

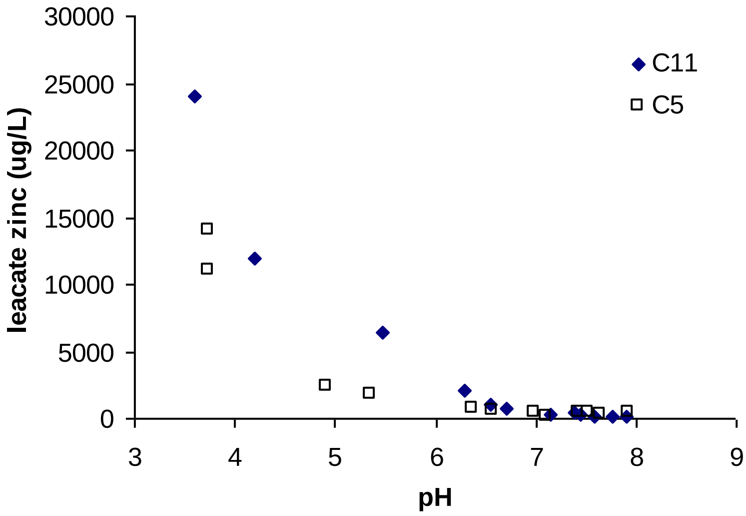


Figure 2-1 Effect of leachate pH on solubilisation of zinc (Depree and Rijkenberg 2010)

2.4.5 Alkaline Modifiers

Depree and Rijkenberg (2010) successfully employed coal fly ash (Huntly power station) to increase the pH of RDS/compost mixtures, which, in-turn, significantly reduced the leachate concentration of the problematic heavy metal, zinc. The optimum pH value for the leachate was between 7.5 and 8.

Even if the pH of composted RDS is in the range of 7 to 8, the addition of an alkaline modifier provides buffer capacity against any potential acidification caused by further humification/degradation or organic matter. In the absence of any alkaline modifier, there is the potential risk for very large increases in heavy metal mobilisation (especially zinc) if, over time, leachates from the RDS compost become progressively more acidic.

2.4.6 Benefits of composting: Introduction of organic matter (OM)

A benefit of composting RDS is that as well as producing a useable product, it requires the addition ofvegetative material to provide the required organic matter (i.e. 20-50%) content in the final product. Thisvegetative material not only dilutes the concentration of contaminants initially present in RDS, but the composting process has been shown to reduce TPH concentrations significantly (Ghezzi et al. 2001). Although composting does not significantly reduce the concentration of PAHs or heavy metals, the composting process generates humified (i.e. aged) organic matter that binds to, and hence reduces the availability of both metals and PAHs (ie contaminant *stabilisation*). The reduced availability means the contaminants, in particular mobile metals like zinc, are less prone to leaching, which mitigates the amount of contaminants escaping into the surrounding environment via runoff. Laboratory experiments show peat, compost and activated carbon, are efficient at removing organic and metal contaminants from stormwater and retaining these contaminants when flushed with clean water (Clark et al 2006). However, Trowsdale et al. (2006) and Laing (2006) showed organic materials can have a 'first flush' effect, shown in Figure 2-2, as dissolved organic material and very fine organic material are washed from the filter matrix.

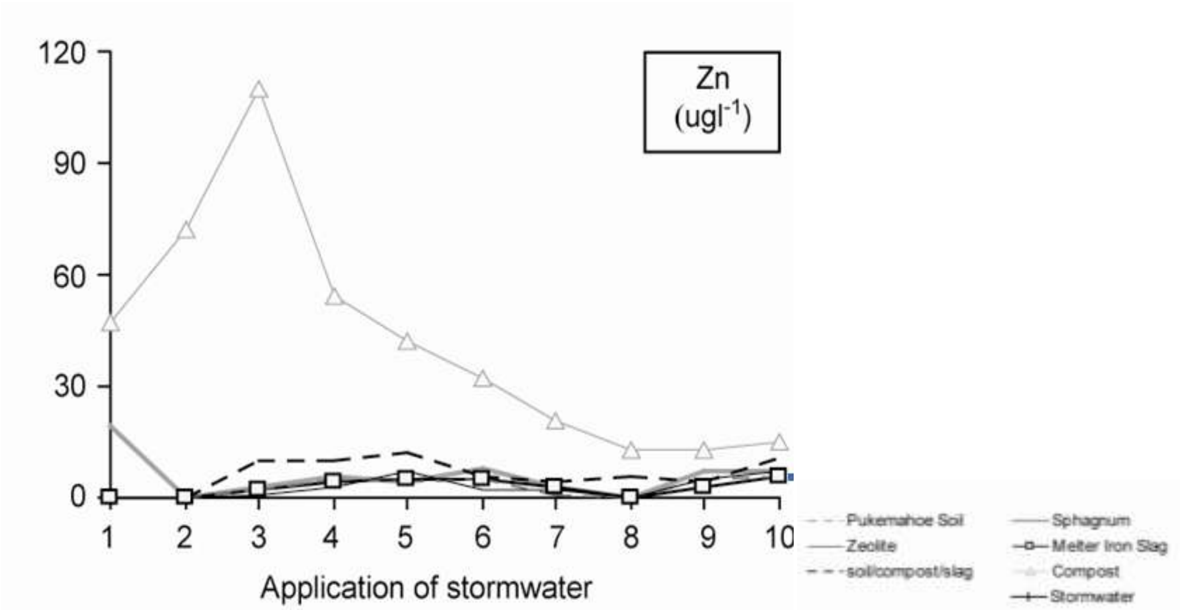


Figure 2-2 The % removal of Zinc from 10 sequential applications of road runoff by different filter media in a laboratory leaching experiment. Fresh compost is the upper grey line (Trowsdale et al. 2006)

This effect is also reflected in Depree and Rijkenberg (2010) results - simply blending RDS with preformed compost for 3 days prior to extraction did not reduce heavy metal leaching. An example of the ineffectiveness of fresh compost addition at reducing zinc leaching in the short term is illustrated in Figure 2-3.

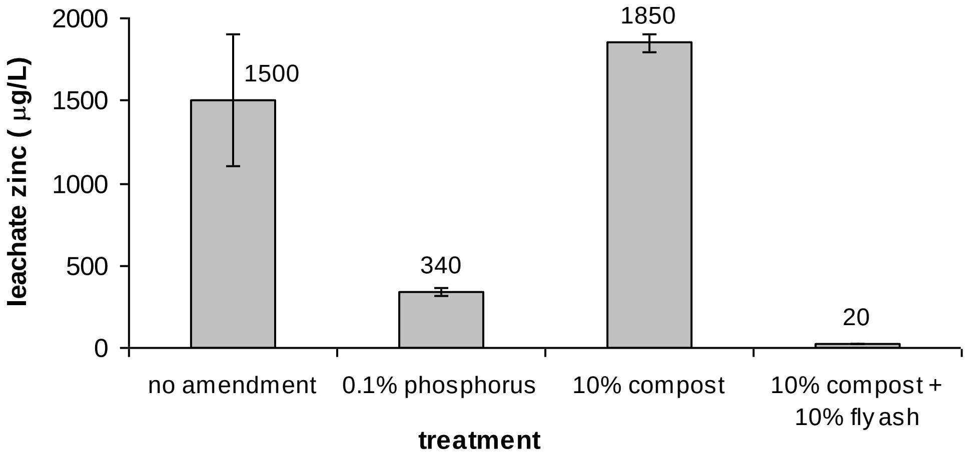


Figure 2-3 The effect of different stabilising amendments on the leaching of zinc from a Christchurch catch pit sediment

Organic mulch has been shown to be effective at trapping contaminants from road derived stormwater in Auckland's North Shore over several years. This is illustrated in Figure 2-4 by the zinc concentration in mulch increasing over time as the mulch removes this contaminant from road runoff. This is why stable organic matter (i.e. aged compost, peat or shredded wood) is a key component of biofiltration substrates used to reduce contaminants in stormwater (Clar et al 2007, Hunt and Lord 2006).

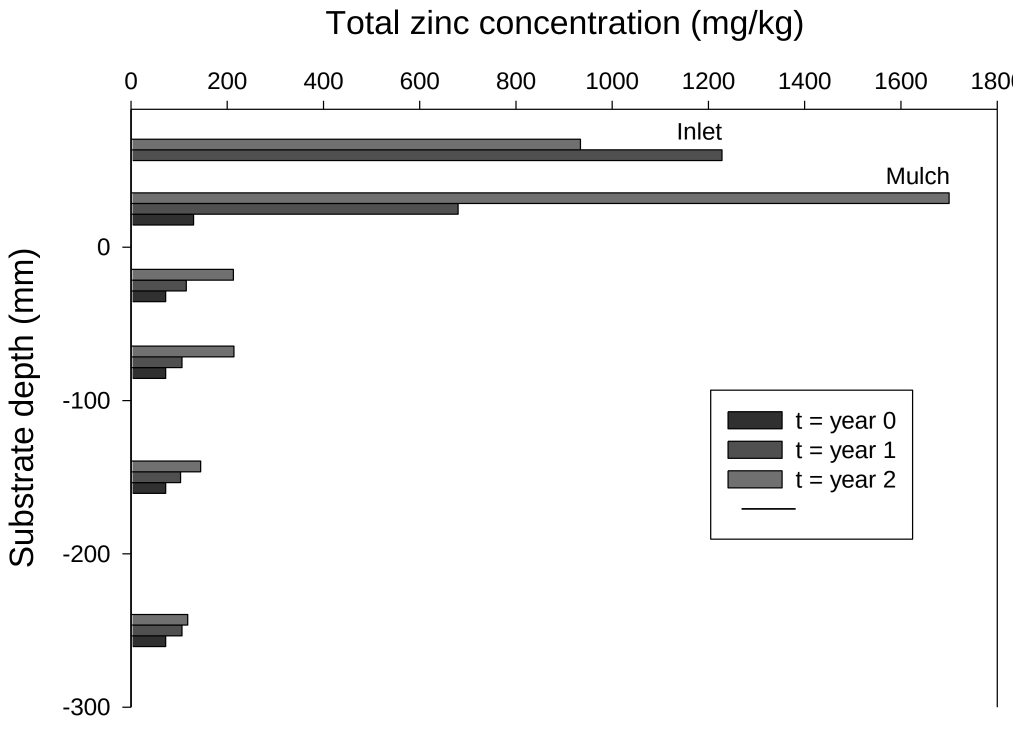


Figure 2-4 The build-up of zinc over two years in mulch and soil of a rain garden receiving runoff from a road conveying 16,000 vehicles/weekday (one third trucks) in North Shore City. The inlet samples were RDS that had accumulated each year adjacent to the three inlets.

The blending of RDS with low to moderate C:N ratio vegetative waste (e.g., arborist mulch) before commencing the composting process may, therefore, enhance favourable metal-to-organic matter binding interactions. This may have the added benefit of reducing labile fresh organic matter in RDS that generates dissolved organic carbon (DOC) in leachates. During the composting process DOC is generated by decomposition of organic matter, however, as the compost matures this component is reduced, and any leachate generated during the composting process is captured. The generation of significant amounts of DOC from the final composted product is undesirable as it enhances the mobilisation of heavy metals, especially zinc and copper (i.e. facilitates the transfer of particulate-bound metals into the dissolved phase).

3 New Zealand Soil Contaminant Guidelines and Regulations

There are a number of guideline documents used in New Zealand relating to soil contaminant levels in relation to their risk to the environment and human health. These documents can be either regulatory standards or guideline documents. The regulatory documents provide the framework within which RDS reuse would have to be considered. The guideline documents provide a comparison to acceptable soil contaminant limits.

The sections below outline the regulatory and guideline documents that are most relevant to RDS reuse including:

Guideline

- Guidelines for the Safe application of Biosolids to Land, MfE (NZWWA 2003)
- New Zealand Standard 4454:2005 Composts, Soil Conditioners and Mulches

Regulatory

- Proposed National Environmental Standard for Assessing and Managing Contaminants in Soil
- Resource Management Act (1991)
- Proposed Auckland Regional Plan: Air Land and Water
- TP 153, Background Concentrations of Inorganic Elements in Soils from the Auckland Region

3.1 Biosolids Guidelines

The "Guidelines for the Safe Application of Biosolids to Land" MfE (2003) (the Guidelines) is a document that provides guidance for reuse of the solid fraction of wastewater treatment process. When wastewater is treated solids are generally a by-product. These solids are known to contain potential contaminants including heavy metals, nutrients and pathogenic bacteria and viruses.

The guidelines specify a dual classification system based on the s*tabilisation* (Grade A or B) and *contaminant content* (Grade 'a' or 'b') of the biosolid material. *Stabilisation* in this case refers to the extent of treatment to eliminate and/or reduce pathogens, vector attraction and offensive odours. The highest quality grade biosolids (Aa) are classified as 'unrestricted use biosolids', and are recommended to be allowed to be used without resource consent being required. Grades Ab, Ba and Bb are classified as 'restricted use biosolids', and can only be applied to land with site specific controls imposed in accordance with resource consent.

Contaminant limits for Grade 'a' and 'b' biosolids are listed in Table 3-1.

Table 3-1 Maximum contaminant concentrations for Grade 'a' and Grade 'b' biosolid classification in New Zealand (adapted from NZWWA 2003)

Contaminant	**Grade 'a' µg/g dry weight)**		**Grade 'b' (µg/g dry weight)**	**Typical RDS Contaminant Ranges (mg/kg)(Literature Review)**
	Until 31/12/2012	After 31/12/2012		
Arsenic	20	20	30	-
Cadmium	3	1	10	-
Chromium	600	600	1500	-
Copper	300	100	1250	40-180
Lead	300	300	300	100-200
Mercury	2	1	7.5	-
Nickel	60	60	135	-
Zinc	600	300	1500	219-450

3.2 Composting Standards

The dual drivers of processing vegetative waste and processing RDS, and the fact that previous research has suggested that RDS requires at least mixing to minimise contaminant release, has resulted in the suggestion that composting RDS is a viable option for the AMA

The New Zealand Standard 4454: 2005 "Composts, Soils and Soil Conditioners" provides a voluntary standard for compost production to minimise the potential for "these products to present a risk to the environment or public health".

Although not a regulation, use of the standard as a comparison and for guidance in relation to compost production will enable NZTA to be confident that compost produced from RDS is of high quality. Table 3-2 summarises the composting standard contamination limits and compares them to typical RDS contaminant levels.

Table 3-2 New Zealand Standard 4454: 2005 "Composts, Soils and Soil Conditioners" Physical, Chemical and biological requirements

Substance (mg/kg)	Composted Product	Typical RDS Contaminant Ranges (mg/kg)(Literature Review)
Arsenic	20	-
Boron	200	-
Cadmium	3	-
Chromium (total)	600	-
Copper	300	40-180
Lead	250	100-200
Inorganic Mercury	2	-
Nickel	60	-
Zinc	600	219-450
DDT	0.5	-
Dieldrin	0.05	-
Total PCB's	0.5	-

3.3 Resource Management Act

The Resource Management Act (1991) is the legislation that sets out how New Zealand will manage its environment. For the reuse of RDS the RMA is the regulation that NZTA must comply with.

Section 15 of the RMA regulates discharges of contaminants to air land or water and states.

Discharge of contaminants into environment

"(1) No person may discharge any—

(a) contaminant or water into water; or

(b) contaminant onto or into land in circumstances which may result in that contaminant (or any other contaminant emanating as a result of natural processes from that contaminant) entering water; or

(c) contaminant from any industrial or trade premises into air; or

(d) contaminant from any industrial or trade premises onto or into land—

unless the discharge is expressly allowed by a national environmental standard or other regulations, a rule in a regional plan as well as a rule in a proposed regional plan for the same region (if there is one), or a resource consent."

Section 15 applies to the application of RDS-containing products onto land, and any discharges from it, and is regulated nationally by the National Environmental Standards – Assessing and Managing Contaminants in soil and in Auckland by the Proposed Auckland Regional Plan: Air Land and Water (PARP: ALW).

3.4 National Environmental Standards – Assessing and Managing Contaminants in Soil

The Ministry for the Environment (MfE) is proposing National Environmental Standards (NES) as regulations under the Resource Management Act for "Assessing and Managing Contaminants in Soil".

The purpose of the standard is to ensure soils are safe for use in relation to human health.

Although the proposed standards are related to existing contamination in soils and required "clean up" or management standards they provide a comparison for understanding the potential limitations of applying RDS-containing materials to land.

Table 3-3 below summarises the proposed soil guideline values under the NES for both organic and inorganic substances. The standard includes values for various exposure pathways and land uses. This table only includes the land use most comparable to that found on the AMA network.

Table 3-3 Proposed National Environmental Standards Soil guideline value for the protection of Human Health

Landuse/ Substance (mg/kg)	Commercial industrial/ outdoor worker maintenance	Typical RDS Contaminant Ranges (mg/kg)(Literature Review)
Arsenic	70	-
Boron	400,000	-
Cadmium	1600	-
Chromium iii	NL	-
Chromium IV	6300	-
Copper	290000	40-180
Inorganic Lead	7000	100-200
Inorganic Mercury	4200	-
BaP (eq)	300	5-8
DDT	1000	-

Dieldrin	160	-
PCP	360	-
Dioxin (TCDD)	1.4	-
Dioxin Like PCB's	1.2	-

3.5 Proposed Auckland Regional Plan: Air, Land and Water (2001)

The Auckland Regional Council is responsible for the management of discharges to the environment in the Auckland region. The regulatory document that is used to ensure that discharges are managed adequately is the Proposed Auckland Regional Plan: Air, Land and Water (2001) (PARP: ALW).

There is not a specific provision in the PARP: ALW for reusing RDS. Rather a number of policies and rules can be considered to apply to this reuse application, either for comparison or as the means by which RDS reuse would be regulated. These rules and policies are contained in Chapter 5 of the PARP: ALW "Discharges to Land and Water" and include:

- Sewage Solids
- Contaminated Land
- Landfills
- Other discharges to land and water

3.5.1 Sewage Solids

The regulations for sewage solids (often called biosolids) are the most similar to RDS reuse due to the similarities in contaminants of concern (heavy metals) and the similar potential reuse options. The main difference between sewage solids (or biosolids) and RDS is that sewage solids have higher risks for reuse due to the potential presence of microbiological and viral pathogens and its nitrogenous content.

Issues – Sewage Solids

The PARP: ALW acknowledges the potential for beneficial reuse of sewage solids both for resource efficiency initiatives (as a fertiliser) and for cost minimisation reasons. However, it cautions that care is required to protect surface and ground water quality as well as public health due to the presence of nutrients, pathogens, heavy metals and synthetic organic contaminants.

Policy – Sewage Solids

The PARP: ALW section for sewage solids reuse has the following policies:

- "To encourage the treatment and reuse of ***sewage***, ***sewage solids***, ***washwater*** and wastes from production land activities in a sustainable manner, while avoiding, remedying or mitigating adverse effects on the environment and public health."
- " Promote the reuse of treated sewage and sewage solids where it can be demonstrated that:

(a) The extent and nature of the wastewater and solids will not pose a threat to the environment or to human health;

(b) The current and proposed future use of the land will not be adversely affected; and

(c) Ground and surface water resources are not at risk from contamination."

- " The reuse of sewage solids is appropriate where it can be demonstrated that:

(a) The sewage solids contain concentrations of nutrients, heavy metals, pathogens and synthetic organic chemicals which are acceptable and sustainable within the environment in which they will be applied and into which they may migrate; and

(b) The reuse of sewage solids will not create a risk to public health."

Rules – Sewage Solids

The rules for sewage solid disposal to land do not include a permitted activity rule. If a permitted activity rule were included in the plan then there would be some circumstances when application to land would not require ARC approval (consent).

So any discharges of sewage solids to land require a resource consent application. The activity is either "controlled" which means a number of stringent performance criteria must be met for the discharge consent to be assessed as controlled or if those criteria cannot be met it is discretionary.

A "controlled" activity means that the application for consent cannot be declined by the council, will not usually require notification and the matters of control are limited to those specified in the rule and relating to the discharge.

If the performance measures for a controlled activity cannot be met then the application will become "discretionary". A discretionary activity can be declined and the matters for control are not limited to those relating the discharge. In addition, applications that are discretionary are more likely to be publicly notified.

3.5.2 Contaminated Land

The contaminated land rules in the PARP: ALW are intended to provide a regulatory framework for management or *remediation of contaminated land* to a standard appropriate for the protection of human health and the environment.

These guideline values associated with the contaminated land rules are for "clean-up" purposes and not specifically applicable to RDS reuse. However, they do provide a comparison for understanding when soils are considered contaminated (and so a risk to the environment or human health) with the types of contaminants typically found in RDS.

Schedule 10 of the PARP: ALW provides the guidelines used for many typical soil contaminants to determine if soils are considered contaminated. These are shown in the table below (Table 3-4).

Table 3-4 PARP: ALW Schedule 10 Contaminated Land Permitted Activity Criteria

Contaminant	Permitted Activity Soil Criteria (mg/kg)		Typical RDS Contaminant Ranges (mg/kg)(Literature Review)
	Discharge	Human Health	
Arsenic	100	30.0	-
Benzo (a) pyrene (equivalent)	2.15	0.27	5-8
Cadmium	7.5	1.0	-
Chromium (total)	400		-
Copper	325		40-180
Total DDT	12 or 0.7	8.4	-
Lead	250		100-200
Mercury	0.75		-
Nickel	105		-
Zinc	400		219-450

3.5.3 Discharge Other

The “discharge other” rules of the PARP:ALW allow for capture of any activity that may result in the discharge of contaminants to land in a manner that may result in those discharges entering water. Under these rules there is provision for permitted activity status to be applied for if the material can be shown to be very low risk.

This process, however, is not well defined and may require further information being obtained through analysis of RDS and/or the RDS-containing compost product.

The discharge other rule that applies to RDS:

“Any discharge, which is not otherwise provided for in any other rule in this chapter is a Discretionary Activity.”

RDS and Discharge Other Rules

To determine if the RDS-containing compost product is considered a “discharge to land” it must first be compared to Auckland Background Soil limits for all potential contaminants (Table 3-5). If the material is above these limits they must go through the permitted activity process or will require resource consent for discharges to land.

Table 3-5 TP 153, Background Concentrations of Inorganic Elements in Soils from the Auckland Region compared to Typical RDS Levels

RDS Source	Typical RDS Contaminant Ranges (mg/kg)(Literature Review)	Auckland Background Soil levels (TP153) (non-volcanics) (mg/kg)
Copper	40 – 180[1]	1-45
Lead	100-200[1]	5.6-25
Zinc	219 – 450[1]	9.2-179
PAHs (BAPeq)	5 – 8	-
TPH	1000 -2000	N/A

3.6 RDS Contaminant Levels Compared to Guideline values

The following table (Table 3-6) compares the guideline values outlined above to the median RDS values derived from the literature review.

Only the contaminants of concern for RDS (copper, lead, zinc, TPH and PAH's) have been compared here.

Given that contaminant levels in typical NZ RDS are comparable, and in some cases, lower than the 'grade a' NZ biosolids guideline values, and considerably lower than the NZ composting guideline (see Table 3.6) values there is considerable scope for the AMA/NZTA to develop and implement an RDS reuse initiative that is environmentally responsible.

However, Table 3.5 shows that typical RDS contaminant levels would exceed Auckland background non-volcanic soil limits and as such would need to be managed as a contaminated material. Furthermore, RDS contaminant levels also would exceed contaminated land criteria in comparison to Schedule 10 of the PARP:ALW. This indicates that RDS application to land would not be able to occur without some form of treatment.

Table 3-6 RDS Contaminant Levels Compared to Guideline values - Summary

RDS Source	**Typical RDS Contaminant Ranges (mg/kg)(Literature Review)**	**Auckland Background Soil levels (TP153) (non-volcanics) (mg/kg)**	**PARP:ALW Schedule 10 (mg/kg)**	**NES Guideline Levels (Health)(mg/kg)**	**Biosolids Grade 'a' levels (mg/kg) [post 2012]**	**Compost Standard**
Copper	40 – 180[1]	1-45	325	29000	300 [100]	300
Lead	100-200[1]	5.6-25	250	7000	300 [300]	250
Zinc	219 – 450[1]	9.2-179	400	-	600 [300]	600
PAHs (BAPeq)	5 – 8	-	2.15	300	-	-
TPH	1000 -2000	N/A	-	-	-	-

1 For copper, lead and zinc median ranges from New Zealand Studies

4 Composition of RDS from the AMA

4.1 Amounts, Sources and Disposal Costs of RDS

The sources and quantities of RDS from the AMA network are varied and include:

- catch pits
- stormwater ponds
- sandfilters
- street sweepings

RDS is removed via sucker trucks, street sweeping trucks and excavators by contractors. Estimated quantities of the various RDS types removed from the AMA network are summarised in Table 4-1.

Street sweepings make up around 20% of the total and these are drier material than most of the rest of the RDS collected. They are fairly consistent in volumes over the year as street sweeping is undertaken regularly. Material removed from catch pits is usually much wetter than street sweepings and contains more debris and leaf fall. This RDS is also in consistent volumes as catch pit clean outs are regularly undertaken throughout the year. Similarly, RDS removed from stormwater treatment devices (i.e. ponds/streams/drains, soak holes, filters and pipes) is wet (similar to catch pit material), however it is more sporadic as stormwater maintenance on such devices occurs on a six monthly or yearly (or more) basis.

Table 4-1 AMA RDS Volumes, Variability, and Disposal Cost

RDS Source	Tonnes/annum	Year to year variability	Average Cost per tonne (2010)	Average disposal cost per year
Street sweepings	700	Low	$93	$65100
Catch Pits/slot drains	280	Low	$170	$47600
Stormwater Ponds	1000	High	$170	$170000
Sand filters	430	Low	$170	$73100
Soak Holes	40	Low	$170	$6800
Sedimentation Pipes	200	High	$170	$34000
Stream/Drain Sediments	400	High	$170	$68000
Total	3200	-	-	$464600

4.2 Current Alternative Disposal Options of RDS

There are a number of disposal facilities in the Auckland region where organisations can dispose of material that is surplus to requirements including:

- Clean fills
- Managed Fills
- Composting Operations

4.2.1 Cleanfills

A cleanfill site can be either a site that accepts and reuses cleanfill or a construction site that requires fill. Usually they do not have resource consents (unless very large). However, for a material to be considered "cleanfill" there are specific criteria that needs to be met.

For the material to be defined as cleanfill the Ministry for the Environment Cleanfill Guidelines (A Guide to the Management of Cleanfills – January 2007) requires:

"Cleanfill material includes virgin natural materials such as clay, soil and rock, and other inert materials such as concrete or brick that are free of:

- *combustible, putrescible, degradable or leachable components*
- *hazardous substances*
- *products or materials derived from hazardous waste treatment, hazardous waste stabilisation or hazardous waste disposal practices*
- *materials that may present a risk to human or animal health such as medical and veterinary waste, asbestos or radioactive substances*
- *liquid waste. "*

Using this definition RDS cannot be disposed of as cleanfill even if the contaminant levels are significantly low as it is likely to contain both leachable and putrescible material.

4.2.2 Managed Fills

Managed fills are fill sites that need filling (often old quarry sites for example) and have some allowance to take fill that is not strictly cleanfill. These sites have resource consents and requirements at each site are variable.

The acceptable material that may be included in managed fill are:

- *Cement (dry) and cement wastes*
- *Dredging spoil*
- *Glass fibres (including Pink Bats)*
- *Mine tailings/spoil*
- *Plasterboard (gib/drywall)*
- *Plastic and polystyrene*
- *Low-level contaminated soils, rock, gravel, sand, clay, etc.*
- *Timber (natural)*

- *Tyres*

The table below give two examples of limits for managed cleanfill sites in Auckland.

Table 4-2 Managed Clean Fill Acceptance criteria mg/kg

	Puketutu	Ridge Road	AMA RDS Range
Arsenic	12	20	-
Cadmium	0.65	1	-
Chromium	125	64	-
Copper	90	130	22-85
Lead	65	60	16-49
Nickel	320	70	-
Zinc	1160	200	80-380

Although RDS contaminant levels are below the managed fill guideline levels disposal to these fills is understood to be limited by the consistency of the RDS (as it contains significant amounts of water). However manged cleanfill requirements could not be confirmed.

4.3 Future Volumes and Costs of RDS Disposal

There is an expectation that both the volumes and costs of disposal of RDS will increase in the future for the following reasons:

- Increased cost per tonne disposed due to regulatory costs for landfills.
- Increasing volumes generated due to more stormwater treatment devices and a number of capital projects coming into the network.
- Increasing pressure from regulations to minimise discharges to landfills.

5 RDS Sampling and Analysis

To determine what contaminant levels may be present in RDS from the AMA network a sampling and analysis programme was devised. The full sampling and analysis methodology can be found in Appendix A with a summary provided in the sections below.

5.1 Sampling Methodology

In total, seven RDS samples were collected in May/June 2010, consisting of three road sweepings, one catch pit and three stormwater pond sediments (Table 5-1). Sampling sites for pond sediments and catch pit sample are shown in Figures 5.2 – 5.4.

Table 5-1 Sampling details of the seven Auckland Motorway RDS samples

RDS sample #	RDS type	short name	Location
AMA-1	Forebay pond sediment	Pond-CMJ	Newton Pond, SH16 CMJ Core
AMA-2	Forebay pond sediment	Pond-causeway	Causeway Lagoon Pond,SH18 Upper Harbour Bridge and Causeway (westbound)
AMA-3	road sweeping	Sweeping-CMJ	CMJ-Port links
AMA-4	road sweeping	Sweeping-Oteha	SH1 (North) Oteha-Harbour bridge
AMA-5	road sweeping	Sweeping-SH22	SH22 (Butcher Rd)
AMA-6	catchpit	Catch pit-SH18	SH18 Upper Harbour Corridor (westbound) at Unsworth Drive
AMA-7	Forebay pond sediment	Pond-Titoki	Titoki Pond, SH18 Upper harbour Corridor (eastbound)

Figure 5-1 Newton Pond, SH16 CMJ Core (AMA-1)

Figure 5-2 Causeway Lagoon Pond, SH18 (westbound) Upper Harbour Bridge and Causeway (AMA-2)

Figure 5-3 Catch pit sediment, SH18 Upper Harbour Corridor (westbound) at Unsworth Drive

Figure 5-4 Titoki Pond, SH18 Upper harbour Corridor (eastbound)

5.2 Processing

Samples were dewatered and separated into <9mm and >9mm fractions. They were then dried in an oven at 50 °C.

For each RDS sample, two 50 g subsamples (based on dry weight) were prepared – one for PAH/TPH analysis and the other for heavy metals analysis. All chemical analyses were carried out by Hill Laboratories in Hamilton.

The following summarises the analytical techniques used for analytes. Further detail can be found in Appendix A.

- The total concentration of metals in the <9mm composite RDS sample was determined via large-scale (50 g) acid extraction. A suite of six heavy metals were analysed, including cadmium, chromium, copper, lead, nickel and zinc, although discussion is limited to copper, lead and zinc.
- The PAHs analysed were the 16 priority PAHs listed by the US EPA.
- Particulate TPH analyses were carried out by Hill Laboratories (Hamilton) using standard methods US EPA 8015B/NZ OIEWG.
- The method quantified the TPH in 3 carbon bands, C7-C9 (gasoline), C10-C14 (diesel) and C15-C36 (heavy).
- Organic matter was determined by the 'loss on ignition' method (Organic Laboratory, NIWA Hamilton).
- pH measurements were done on 1:1 suspensions of RDS to aqueous solution.

6 Results of RDS Analysis from the Auckland Motorway Network

6.1 Heavy metals, PAHs and TPH

The medians and ranges of TPH, PAH and heavy metal concentrations in the seven AMA RDS samples are summarised in Table 6-1. The reported concentrations are for the <9mm fraction of the RDS, which represented between 75 and 94% (median 84%) of the total mass collected. The concentration of contaminants within the <9mm fraction will of course be concentrated in the finer fractions, however, for the purposes of this scoping study, it was important to determine concentrations that represented the majority of the mass of the RDS that is being considered for reuse.

Table 6-1 Summary of contaminant concentrations (mg/kg) in the <9mm fraction of AMA RDS samples

contaminant	median	mean	range	Typical Values (Literature Review)
TPH	670	465	<70-1000	1000 -2000
PAH[1]	0.95	0.82	0.10-1.13	5-8
cPAH[2]	0.37	0.33	0.05-0.47	-
BaP equivalents[3]	0.11	0.09	0.01-0.12	-
copper	59	58	22-85	40-180
lead	29	31	16-49	100-200
zinc	250	222	80-380	219-450

[1] sum of 16 EPA PAHs listed as priority contaminants. [2] sum of the seven PAHs considered carcinogenic. [3] Calculated using the toxicity equivalency factors (TEFs) (Nisbet and LaGoy, 1992).

Compared to literature values (Table 6-1), the concentrations of contaminants in AMA RDS are relatively low. With the exception of PAHs and lead, the concentrations were comparable to the median concentrations reported in the <9mm fraction for RDS (sweepings) collected from city streets in Christchurch (Depree and Rijkenberg, 2010). The median concentrations of TPH, PAH, copper, lead and zinc for the Christchurch samples were 680, 5.6, 35, 112 and 212 mg/kg, respectively. The benefit of the AMA RDS is that in addition to relative low concentrations of metals, the levels of PAHs were also very low at ca. 1 mg/kg. This was 5-times lower than what was reported for Christchurch RDS, and probably reflects the absence of any historic coal tar use on the motorway network. Being that some guidelines can be very restrictive when it comes to carcinogenic PAHs, the low concentrations in AMA RDS is very encouraging with respect to environmental feasibility and compliance of a compost-based reuse application. Figure 6-1 summarises the PAH concentrations relative to some potentially relevant guideline values.

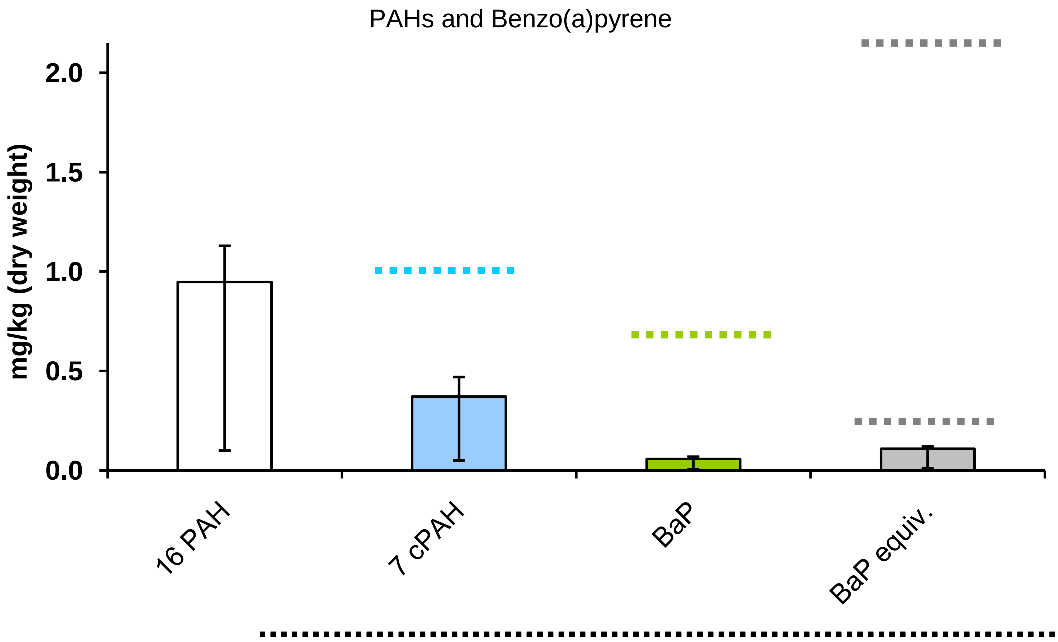


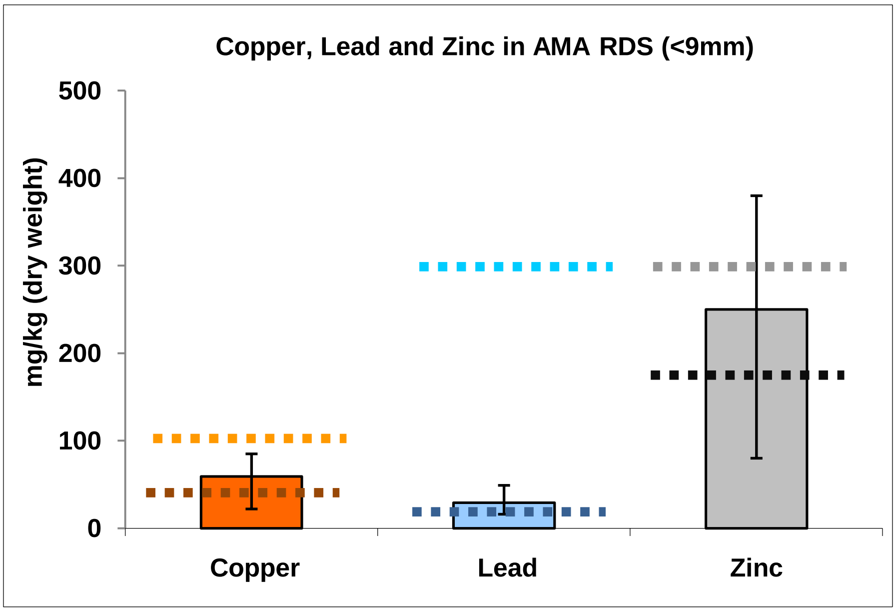
Figure 6-1 Concentrations of PAHs in AMA RDS (n=7) and some indicative guideline values..

Blue dashed line is 'Class A' street waste limit (Snohomish County, Washington) of 1.0 mg/kg (CWC, 1997).

BaP (benzo[a]pyrene), green dashed lined is Canadian soil quality guideline value of 0.7 mg/kg (CCME, 2007).

Grey dashed lines are Proposed Auckland Regional Plan: Air, Land and Water (Schedule 10) BAP eq limit of 2.15 mg/kg for discharges and 0.27 mg/kg for the protection of human health.

As mentioned previously, the NZ biosolids guidelines ('grade a' post 2012 values, NZWWA 2003) have been used as 'proxy' limits for assessing RDS suitability (Depree 2008, Depree and Rijkenberg, 2010). These specify maximum concentrations for copper, lead and zinc of 100, 300 and 300 mg/kg, respectively. Of the seven sites, the only exceedence was 380 mg/kg of zinc measured at Titoki Pond (Figure 6-2). Based on the results of the seven AMA RDS samples, the most problematic contaminants (with respect to environmental compliance) are zinc and copper. It is, however, important to emphasise that these guideline comparisons relate to undiluted RDS, whereas the final product (compost/soil modifier/top soil etc) would require at least a 1:1 dilution with vegetative material to increase organic matter content to sui levels (i.e. >20%).



Light dashed lines represent 'grade a' (post 2012) contaminant maxima specified in the NZ biosolids guidelines (NZWWA, 2003) – 100, 300 and 300 mg/kg for copper, lead and zinc.

Dark dashed lines show Auckland Regional Council TP 153 non-volcanic background soil limit maximums for copper, lead and

Figure 6-2 Median concentrations of copper, lead and zinc in AMA RDS (n=7). Error bars represent range of concentrations.

The median TPH concentration of 670 mg/kg was consistent with the median of 680 mg/kg reported for 11 Christchurch road sweepings (Depree and Rijkenberg, 2010). Interestingly, TPH concentrations for three of the RDS samples, including AMA-1 (pond-CMJ), were below the detection limit of 70 mg/kg. Most soil quality guidelines do not include a value for TPH, however, in the U.S, Snohomish County (Washington) specify a maximum TPH concentration of 2750 mg/kg for Class A street waste. Additionally, Collins and Moore (2000) recommended that for reuse of RDS to be classified as a low risk activity that it should contain <1000 mg/kg TPH. Based on these maxima, the concentration of TPH, even in undiluted RDS, does not appear to be an issue with respect to environmental risk.

6.2 Contaminant variation across the individual RDS samples

The concentrations of copper, lead, zinc and PAHs for the individual RDS samples are given in Figure 6-3a-d. Because of the small sample size (n=7), it is difficult to draw any conclusions as to whether some types of RDS material are generally more contaminated, and therefore less preferable for reuse applications. Accordingly, from a contaminant perspective, all types of RDS from the network should be considered for reuse, unless additional information identifies particular types of materials from the network as 'hot spots'.

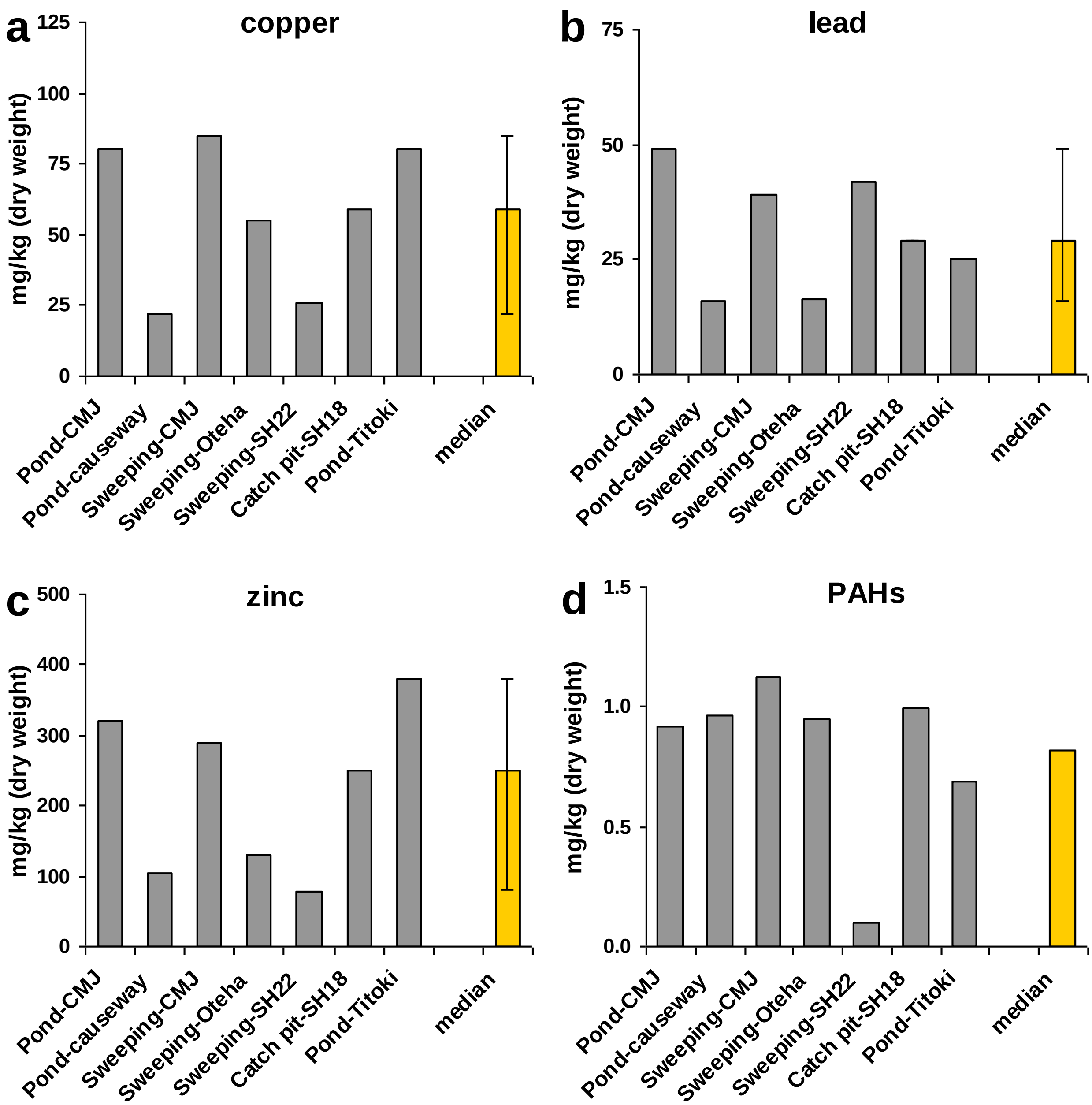


Figure 6-3 Concentrations (mg/kg dry weight) of copper (a), lead (b), zinc (c) and PAHs (d) in individual AMA RDS samples (<9mm)

With the exception of Sweeping-SH22, the concentration of PAHs was very consistent across the RDS samples ranging from 0.7 to 1.1 mg/kg (Figure 6.3d). The detection of only 0.1 mg/kg of PAHs in Sweeping-SH22 RDS indicates this sample contained relatively few anthropogenic inputs of contaminants. This was also reflected in the copper (Figure 6-3a) and zinc (Figure 6-3c) concentration of 79 mg/kg and 26 mg/kg, respectively, although the lead concentration of 42 mg/kg was relatively high (Figure 6-3b). The combination of low contaminant concentrations and physical appearance of the RDS (refer to Figure 6-9), and the SH22 RDS sample is probably not representative of typical network road sweepings.

In general, the metal concentrations were highest at Pond-CMJ, Sweeping-CMJ, Catchpit-SH18 and Pond-Titoki – at these sites the average concentration of copper, lead and zinc was 76, 36 and 310 mg/kg. In contrast, the three RDS samples, Pond-causeway, Sweeping-Oteha, and Sweeping-SH22, had mean copper, lead and zinc concentrations of 34, 25 and 105 mg/kg. With the exception of lead, which is on the outer limit of the 5.6-25 mg/kg background range for Auckland soils, the copper and zinc concentrations are well within the respective soil background levels of 1-45 mg/kg and 9-179 mg/kg.

6.3 Physical characterisation

The proportion of RDS that passed through a 9 mm sieve ranged from 68-94%, with a median value of 84% (Figure 6-4). This was very similar to the value of 83% (inter-quartile range of 81-85%) reported by Depree and Rijkenberg (2010) for 11 Christchurch road sweeping samples. The screening size typically used for pre-treatment of RDS is 20-25mm. The screening size of 9 mm was selected because of the need to limit the particle size for contaminant analysis (i.e. subsample heterogeneity).

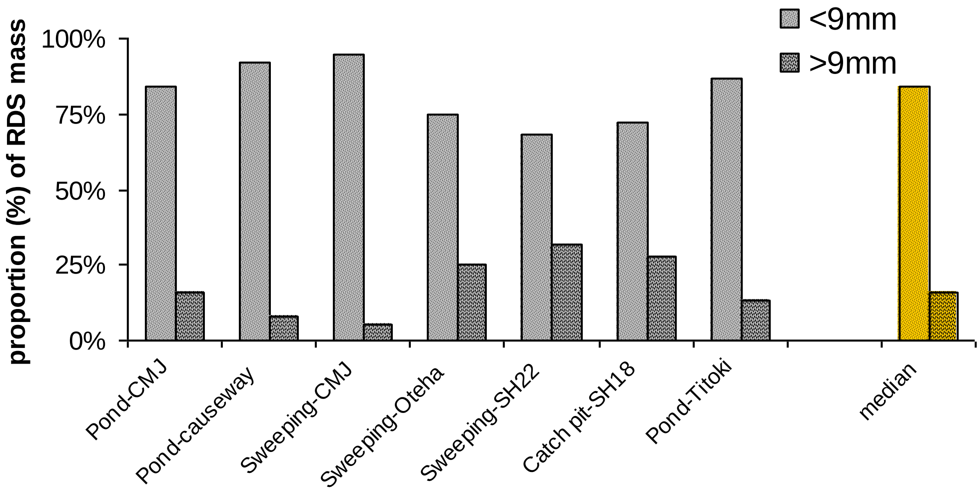


Figure 6-4 Proportion (%) of RDS mass (dry weight) passing through 9mm sieve

6.3.1 Smaller particle size fraction of RDS (<9mm)

Organic matter content in the <9mm fraction of RDS ranged from 2.0% in 'Pond-causeway' through to 12.3% in 'Pond-Titoki' (Figure 6-5), with a median content of 7.1%. This was comparable to the median of 8.6% reported for OM content of Christchurch RDS (Depree & Rijkenberg, 2010). With pond sediments spanning the range of organic matter content, it is difficult to make generalisations about the characteristics of RDS based purely on type (i.e. sweeping vs pond sediment).

At the time of sampling, it was observed that the forebay sediment at 'Pond-CMJ' and 'Pond-causeway' were very coarse, relative to the 'mud-like' sample taken from the outlet at 'Pond-Titoki'. In contrast to the pond sediments, the organic matter content of road sweeping was less varied, ranging between 6 and 9%. Despite the 6-fold range in organic matter content of the RDS samples, it is not envisaged that this will be a problem with respect to producing a viable compost/soil amendment product. The NZ composting standards specify a minimum organic matter content of 25%, and so assuming a 1:1 (RDS tovegetative material) blend is used to dilute contaminants (initial amount ofvegetative material added will be determined by average mass loss on composting), thevegetative material component alone is sufficient to meet the required standard for organic matter content. The appearance of the <9 mm fraction of the seven RDS samples is shown in Figures 6-6-6-9.

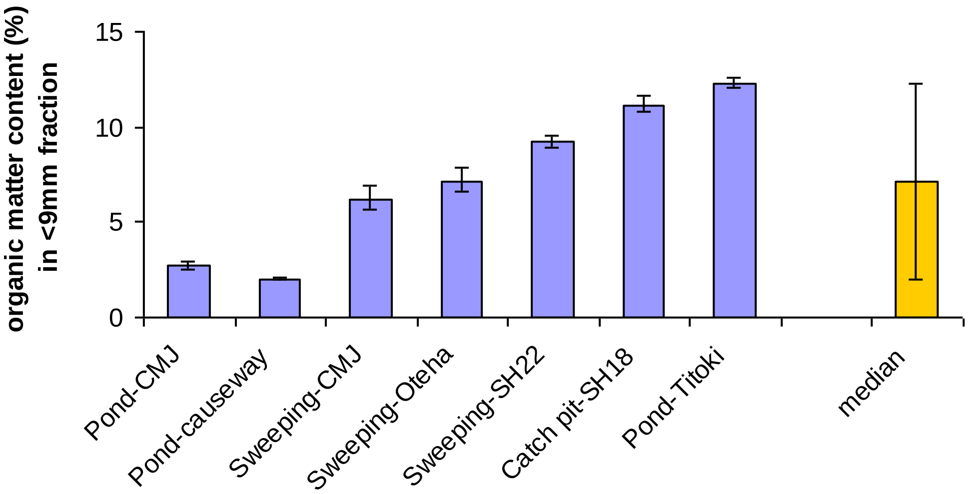


Figure 6-5 Organic matter content (%) in the <9mm fraction of RDS. Error bars on blue bar represent range of triplicate values; error bars on median represent range of median values for the seven RDS sites

Figure 6-6 <9mm fraction of RDS from 'Pond-CMJ' AMA-1 (left) and 'Pond-causeway' AMA-2 (right)

Figure 6-7<9mm fraction of RDS from 'Sweeping-CMJ' AMA-3 (left) and 'Sweeping-Oteha' AMA-4 (right)

Figure 6-8 <9mm fraction of RDS from 'Sweeping-SH22' AMA-5 (left) and 'Catch pit-SH18' AMA-6 (right)

Figure 6-9 <9mm fraction of RDS from 'Pond-Titoki' AMA-7

The approximate uncompacted dry density (note: this was not determined via a 'standard method') of the RDS samples ranged from 780 kg/m^3 (Pond-Titoki) to 1500 kg/m^3 (Pond-causeway) with a mean of 1100 kg/m^3 (Figure 6-10). Not surprisingly, the trend in RDS density corresponded to organic matter content (Figure 6-5). To provide a comparison, the uncompacted density of a sandy loam and clay loam are 1510 kg/m^3 and 1260 kg/m^3, respectively (Rivenshield and Bassuk, 2007). Increasing the organic content obviously decreases the density. In the case of the aforementioned 'clay loam' (1260 kg/m^3) the addition of 10 and 33% peat reduced the uncompacted density to 1150 kg/m^3 and 960 kg/m^3, respectively.

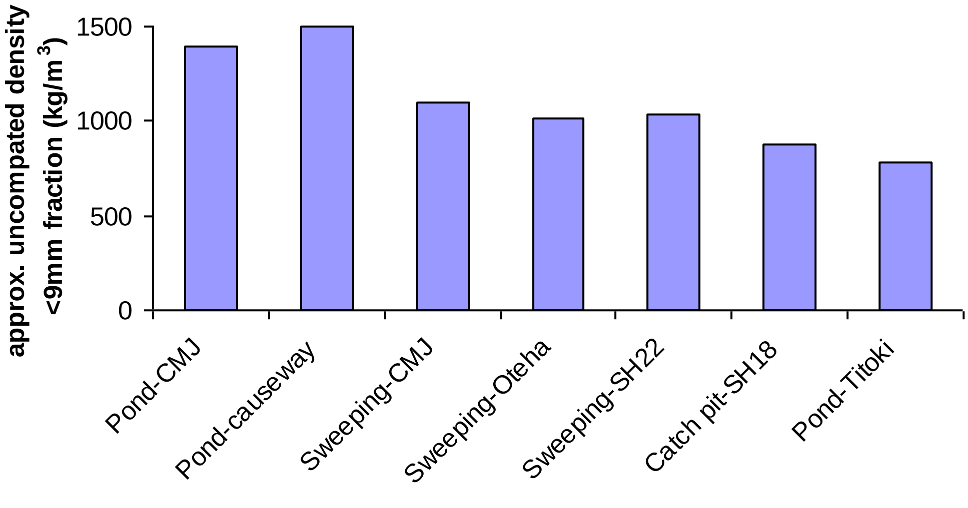


Figure 6-10 Approximate uncompacted dry densities of the <9mm fraction of RDS samples

6.3.2 Larger particle size fraction of RDS (>9mm)

Typically the reuse of RDS involves pre-screening at 20-25mm to remove trash and other undesirable debris. When considering a composting application for RDS the aim is to maximise the capture of compostable material; a concern is that pre-screening may remove a lot of vegetation/organic matter (including compostable litter such as paper) from the feedstock material. The heterogeneity of the >9mm RDS fraction circumvented organic matter content determinations, however, from the approximate dry density (Figure 6-11), using gravel (1500 kg/m^3) and straw (ca. 125 kg/m^3) as model 'organic' and 'inorganic' reference materials, the 'organic' content was estimated.

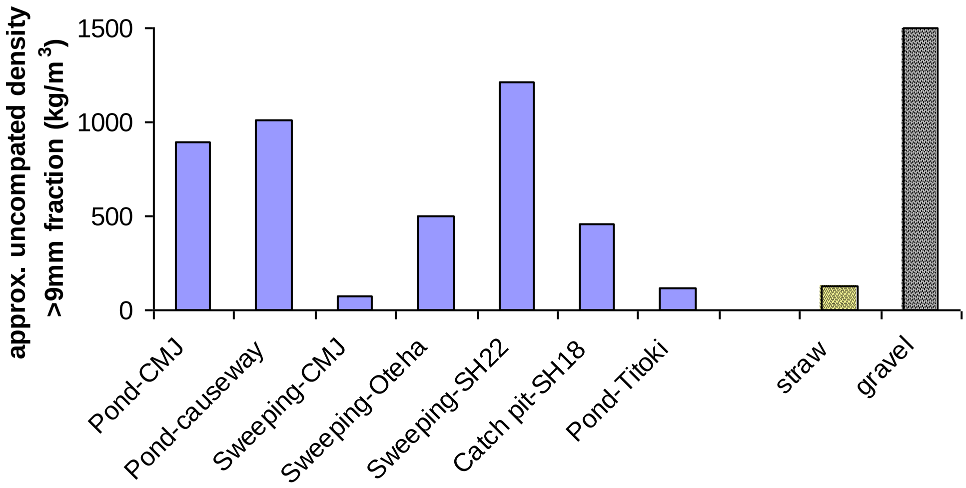


Figure 6-11 Approximate uncompacted dry density (kg/m^3) of the >9mm fraction of AMA RDS samples. The respective densities of 125 and 1500 kg/m^3 for straw and gravel are literature values.

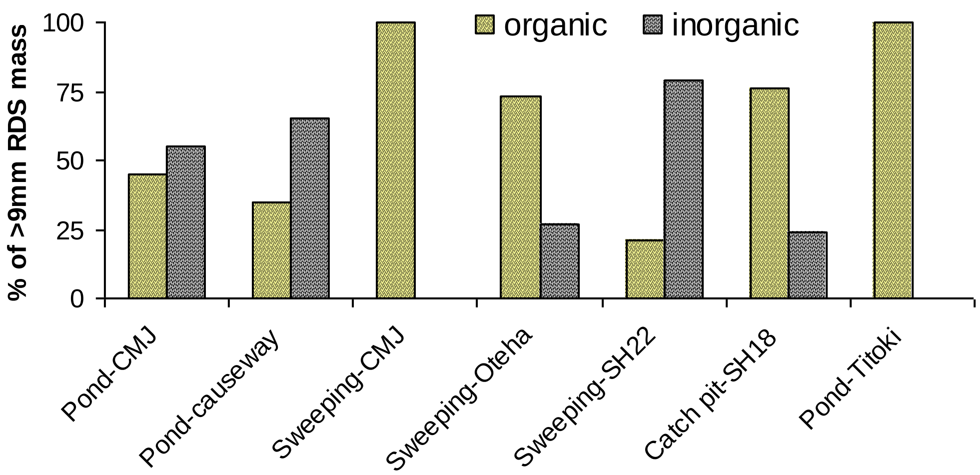


Figure 6-12 Estimated organic and inorganic content (%) of >9mm fraction of AMA RDS samples

Estimates of organic (i.e. compostable material) and inorganic (i.e. stones/gravel) content are given in Figure 6-12. The proportion of organic material in the >9mm fraction varied considerably; from ca. 100% compostable matter in 'Sweeping-CMJ' (AMA-3) and 'Pond-Titoki' (AMA-7) to at least 70-80% stone/gravel content in 'Pond-causeway' (AMA-2) and 'Sweeping-SH22' (AMA-5) (note: visual inspection of these two samples suggest the proportion of gravel/stone is closer to 100%). The range of inorganic-to-organic materials in the >9mm RDS fractions is illustrated in Figures 6-13-6-16.

Figure 6-13 >9mm fraction of RDS from 'Pond-CMJ' AMA-1 (left) and 'Pond-causeway' AMA-2 (right)

Figure 6-14 >9mm fraction of RDS from 'Sweeping-CMJ' AMA-3 (left) and 'Sweeping-Oteha' AMA-4 (right)

Figure 6-15 >9mm fraction of RDS from 'Sweeping-SH22' AMA-5 (left) and 'Catch pit-SH18' AMA-6 (right)

Figure 6-16 >9mm fraction of RDS from 'Pond-Titoki' AMA-7

The NZ composting standard specifies limits on the amount of 'contaminants' in the >5mm fraction, which includes rigid plastic, plastic film, glass, metal and stones. Although no analyses were carried out on the >5mm fraction, the amount of trash (excluding stones/gravel) was determined in the >9mm fraction to at least give some indication of the amount of 'contaminants' in RDS from the Auckland motorway network. The percentage of litter in RDS mass >9mm fraction ranged from 1-18% (Figure 6-17), with the highest values corresponding to the road sweeping samples 'Sweeping-CMJ' (AMA-3) and 'Sweeping-Oteha' (AMA-4). Litter content is expected to be higher in sweepings, since it contains large/heavy material that may not be transfer to pond/catch pit RDS, and also low density rubbish (i.e. paper, cigarette butts) that is not expected to accumulate in other types of RDS. In contrast 'Sweeping-SH22' (AMA-5) only contained 1% litter; however, this sample was from a rural area and, as mentioned, was probably not representative of AMA network sweepings. The litter isolated from the >9mm fraction of the AMA RDS samples is shown in Figures 6-18-6-21.

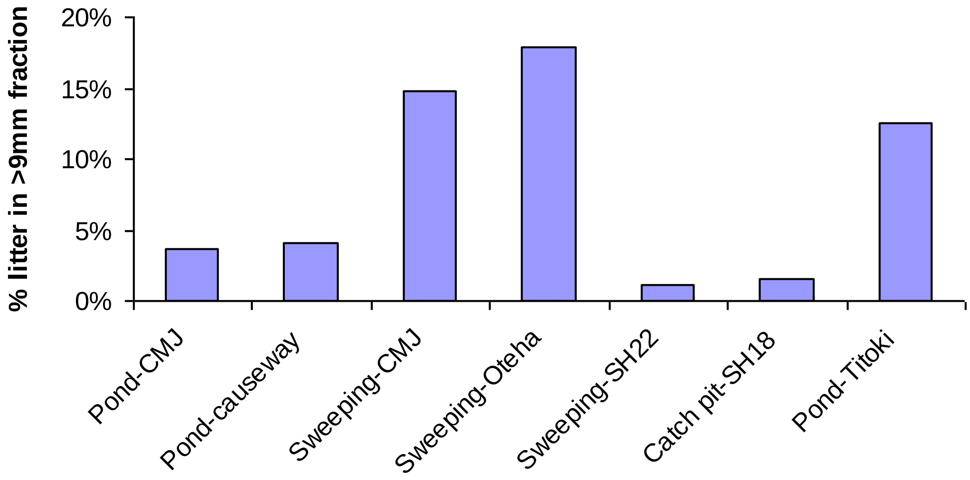


Figure 6-17 Proportion (%) of litter in >9mm fraction of AMA RDS samples


Figure 6-18 Litter in >9mm RDS fraction from 'Pond-CMJ' AMA-1 (left) and 'Pond-causeway' AMA-2 (right)

Figure 6-19 Litter in >9mm RDS fraction from 'Sweeping-CMJ' AMA-3 (left) and 'Sweeping-Oteha' AMA-4 (right)

Figure 6-20 Litter in >9mm RDS fraction from 'Sweeping-SH22' AMA-5 (left) and 'Catch pit-SH18' AMA-6 (right)

Figure 6-21 Litter in >9mm RDS fraction from 'Pond-Titoki' AMA-7

7 Current Practice - Vegetation and RDS Reuse and Disposal

One component of this feasibility study was the understanding that there was vegetative material available from the AMA network to compost with the RDS. The following sections describe the:

- vegetation that is available, and where it is sourced from
- positive aspects of the vegetative material for use as a compost feedstock
- costs of present uses
- possible costs if used as a compost feedstock.

7.1 Sources, types and amounts of Vegetative Material

There are three main sources of vegetative material from the AMA network:

- arborists mulch,
- non-mulchable prunings (flaxes, vines); and
- logs.

Potential additional sources are grass clippings, which are currently mulched and returned during the mowing process, and street sweepings. Street sweepings contain 6 to 9 % organic matter on average, however, at specific locations and times of the year the proportion of coarse organic matter can be a primary component, for example in areas with deciduous trees in autumn and in recently mulched areas. Currently there is no separation of RDS.

The dominant vegetation material removed from the motorway network, by volume, is arborist mulch (Table 7.1). This product is generated from mulching, grinding or chipping woody vegetation during removal or pruning of trees and shrubs on the network and during clearance operations associated with special or capital projects. Vegetation is removed from the road corridor to:

- maintain required sightlines and clearance along roads (known as TOC work)
- remove ‘dangerous’ trees and parts of trees that may fall onto roads (TOC)
- create or maintain access to stormwater ponds , light poles, etc to allow maintenance work and for Special Projects such as replacing fencing and creating sound walls

The mulching machinery currently used to chip vegetation can process logs up to about 500 mm diameter. The few logs that cannot be mulched are either left on site or carted to stockpiles at an AMA storage site in Pahurehure. Four key properties make arborist mulch a particularly valuable material for use in composting.

- It is delivered to site in a relatively consistent particle size range and density because it has been mulched or ground. This means it is unlikely to need further processing before composting. Arborist mulch can be composted without amendments.
- It has almost no contamination from sediment, litter, metal, plastics or other materials/contaminants typically found in vegetative material delivered to landfills and which require a high level of manual scrutiny and sorting prior to composting.
- It does not contain lawn clippings or fruit/rose tree prunings (which can be associated with elevated copper levels), and has low potential to generate large amounts of DOC content because it

has a high wood component. Furthermore, it does not contain food or other organic materials that make handling difficult and potentially odorous.

- Arborist mulch from Target Outrun Cost (TOC) is supplied in relatively consistent weekly volumes throughout the year. This reduces the need to stockpile material.

Figure 7-1 Arborist mulch being produced woody weeds (cotoneaster, privet and spanish heath) at Ramarama. This mulch must be composted to kill weed seeds before reuse.

A small volume of logs >500 mm diameter are unable to be mulched. These are either left on site or carted to the storage site at Pahurehure. Very little non-woody vegetation is removed from the network as all grass mowing is done without catchers. Non-woody vegetation includes material that cannot be mulched such as flax and weedy vines (moth plants were targeted in summer 2010). Other waste that can have a high vegetation component is removed from the network during drain and stormwater grate clearance. Vegetation or mulch (bark or wood chip) that is washed over stormwater grates and impedes water flow is removed, however, these events are unusual, highly localised (as only freshly spread mulch is generally vulnerable) and generate small volumes of material. Old weed matting can have a high vegetation component; weed mat seen at Pahurehure can have 5 to 10 cm of adhered roots and leaf litter. This could form a useful compost or soil amendment once the plastic breaks down. In the future vegetative material may also be generated during renovation of swales.

Sources, volumes and tonnages of vegetative material are estimated, by type in Figure 7-2. The TOC arborist mulch estimate is based on 100 m^3/month of which 30 m^3 is immediately blown back onto the harvesting site and 70 m^3 is mulched into a truck. Of the 70 m^3 trucked, about 50 m^3 is leafy/twiggy material and 20 m^3 is whole trees. These products are differentiated as whole-tree mulch is lighter, slower to break down, and potentially higher value as it can be used as a medium-term weed suppressant with high aesthetic value. About 3600 m^3 of fresh arborist mulch is produced through TOC work each year, with relatively consistent volumes produced each month and can be considered the 'base load' available for composting. Examples of TOC work include poplar removal at the Takinini Interchange (all mulch was retained on site for landscaping) and the 'vegetative envelope clearance pruning vegetation through the central motorway junction (mulch is generally removed to Pahurehure stockpiles).

Table 7-1 Sources, estimated volumes and tonnages of vegetative material from the AMA

Vegetative Material Source	**M^3 p.a. 'trucked'**	**Tonnes p.a. 'trucked'**	**Year to year variability**
TOC Arborist Mulch – ex prunings & small trees	2600 (50 m^3/week)	740 (260-310 kg/m^3)	Low
TOC Arborist Mulch – whole trees	1000 (20 m^3/week)	450 (420-440 kg/m^3)	Low
Arborist Mulch from Capital Works Projects	variable	1000 to tens of 1000's	High
Logs (>200 mm diameter)	low volumes	n.a.	Low
Organic RDS (mulch, leaves)	currently included in RDS (6 to 9%)		High
Special project: e.g. Pest Plant Project		9000 – 14500	High

The volume of 'base load' arborist mulch produced by TOC work is dwarfed by the highly variable volumes of vegetation produced by special projects and capital works projects. These projects have a lead time of months to years and are generally 6 to 24 month producers (and consumers) of mulch. A special project that is not confirmed but that would generate very large volumes of arborist mulch suitable for composting is the "Pest Plant Initiative" which proposes removal of woody and non-woody weeds from the AMA network. The Pest Plant Initiative has been costed on the basis of 340 days of a 'small tree' crew producing 20 to 40 m^3/day (6,800-13,500m^3 arborist mulch) and a large tree crew producing 60 to 90 m^3/day over 350 days (21,000-31,000 m^3 of arborist mulch).

Confirmed special projects in 2010/2011 include the Visual Quality and Noise Wall projects. Most mulch generated from Visual Quality projects is used immediately on site as non-composted arborist mulch to assist weed control and nutrition of the subsequent plantings, and to supplement off-site mulch. Mulch from weed species containing seeds or fruit is not used immediately, but either transported to Tuakau where it is composted by Franklin Tree Services (and subsequently purchased as a compost or mulch, depending on particle size) or stockpiled at Pahurehure.

Figure 7-2 Types of arborist mulch. From left to right: fresh tree mulch from acacias (a weed tree); prunings from native shrubs; and, partly composted arborist mulch from Takanini Interchange

7.2 Current Use and Disposal: Vegetative Material

Only vegetative material removed as part of street sweeping, catchpit or stormwater device maintenance has a direct disposal cost. As all street sweepings are currently treated similarly, with no separation of those with a high proportion of coarse organic matter, the cost of disposal of is the same as 'standard' RDS

Until 12 months ago, vegetative material was mulched and carted to Tuakau for disposal. Now vegetative material mulched onto the area from which it is taken incurs no disposal cost, although if the mulch contains viable weeds, costs for later weed control may be incurred. About 70% of arborist mulch from TOC work is transported. Transport of vegetative material from the source site is effectively 'free' for the last load each day by Franklin Tree Services, as the truck returns to base where composting occurs in open piles. Vegetative material removed during the TOC 'Sunday tree run' therefore has no disposal charge. Vegetative material in excess of a truckload incurs disposal costs based on the time and/or distance to the disposal site and also through loss of productivity, but the cost of transporting arborist mulch is included in the cost of vegetation trimming or removal. Arborist mulch containing weed species has been taken to the contractor's (Franklin Tree Services) depot at Tuakau where it is composted to kill weeds and sold as compost or mulch, depending on particle size and age. Over the last 12 months an increasing proportion of TOC arborist mulch has been stockpiled at Pahurehure, particularly mulch from whole trees as this has the highest value and least weed risk.

In Auckland, arborist mulch, particularly weed-free arborist mulch, is changing from a waste product people pay to have removed, to a resource in increasing demand. North Shore, Manukau and Auckland City Parks Departments and Auckland Regional Council Botanic Gardens use all arborist mulch generated through their respective street tree or park maintenance contracts (e.g., with Treescape and Asplundh). There appears to be no excess arborist mulch available from these sources, as the volume of mulch produced does not meet their internal demand. Smaller tree pruning contractors may pay to dispose of vegetative material and arborist mulch, particularly for jobs remote from their depots.

Non-mulchable prunings are generated in very low volumes and disposal costs are also low. Flax can be disposed of in scattered places among existing plantings away from mown areas. Some weeds may need to be disposed to landfill in sealed bags (e.g. moth plant seed pods, *Agapanthus* and weeds that spread as fragments of stalk such as *Tradescantia*), but volumes are very low.

The logs >500 mm diameter that are not able to be mulched are currently either left on site or carted to Pahurehure, however logs have been used on National Highways for the following:

- Cultural purposes, eg, trees were removed from forests on the Northern Gateway alignment, lancewood were harvested for taiha (spears)
- Temporary retaining materials to prevent fill spilling over roots of adjacent trees (Northern Gateway), to mark boundaries of disturbance and define edges for spraying contractors
- Protect soils and mulches from erosion, where placed roughly perpendicular to the slope
- Create more favourable conditions for plants, insects and lizards by providing
  a) stable sites protected from wind and surface water erosion,
  b) elevated humidity and soil moisture,
  c) shelter from predators (underneath and within logs, under bark), and
  d) a food source for invertebrates of decaying wood (e.g. moths & beetles) and invertebrates that feed on fungi growing on decaying wood (e.g. Grafton Gully lizards).
  Logs can be used to enhance habitat in lakes, wetlands, riparian areas and water courses.
- Perching, foraging and nesting areas for birds (bringing seed into the site)
- Sites for seedlings to germinate above competition, for epiphytes and as substrates for fungi (hence insects)
- Firewood
- Barriers to exclude vehicles (including bicycles) from sensitive areas

The cost of 'disposing' of logs using these methods of reuse depends on the volume of logs moved (economies of scale), the need for specialist equipment, and the time taken to prepare the logs. Most logs are used where they are felled, avoiding transport costs. It would be unusual for logs to be purchased for any of the above purposes if they were not already available from the network; therefore they are of little monetary value.

7.3 Current Reuse - Vegetative Material

Mulches and composts generated from vegetative material are currently used on the network in amenity planting. Three organic mulches are used: fresh arborist mulch, composted arborist mulch and wood chip or wood pallet mulch. Decorative bark has also been used in the establishment of 'high amenity areas' (e.g., Hobsonville and areas around sculptures) but has not been used in TOC maintenance to date. The uses and key characteristics of these materials are given in Table 7-2.

The cost of each product depends largely on the volume ordered and method of delivery. 'Blowing' mulch is more expensive than spreading mulch with an excavator and rakes, but site conditions (slope and access) control the method used to apply mulch. Fresh arborist mulch is 'free' until it requires transportation. The saving that applies to using arborist mulch sourced from the motorway network and stockpiled at Pahurehure may only apply to tractor spread mulch as it may need reprocessing or grinding into a finer size to become suitable to blow onto sites where it is used.

Table 7-2 Types of organic products used on the Network and their cost

Material	Purpose	2010 Cost ($) Supply Only	2010 Cost ($) Spread
Fresh arborist mulch	Amenity, medium term weed suppression, water retention and supply plant nutrients. Not purchased	$0-15m^3$	$20-25 Blown $10 – 20 Excavator
Composted arborist mulch	Amenity, 1 to 3 year weed suppression, water retention and supply plant nutrients	$20-25/m^3$ purchased $0/m^3$ AMA on site $10/m^3$ AMA stockpile	
Wood chip / wood pallet mulch 'Reharvest'	Amenity, 3 to 4 year weed suppression, but can cause short term nitrogen stress Purchased, some arborist mulch from large trees has similar properties as wood chip	$23-$25/m^3$	
Decorative bark	Amenity and two to five year weed suppression, can cause nitrogen stress, does not condition soils	$50-60/m^3$	
Compost	A growing medium and soil conditioner for hostile sites (little topsoil, clay subsoils) where plants will otherwise fail. Must be covered with a mulch	$40 - 50/m^3$	

TOC projects to date have used very low volumes of any mulches and no compost. Landscaping in areas where trees have been removed has used arborist mulch sourced from the felled trees supplemented with imported mulch.

Capital projects are the largest producers and users of vegetative mulch on the network, followed by 'special funding projects' involving planting of perennial vegetation. Capital projects currently use enormous volumes of wood mulch and composted arborist mulch. Mulch is typically applied at 100 mm (but up to 150 mm) settled depth minimum for erosion control and weed control post planting (1000 m^3/ha). Examples of such applications include the Manukau Crossing and Manukau City Interchanges. Additional applications of mulch and soil conditioners are illustrated in Figure 7-3. The chemical properties of selected mulch and compost products are summarised in Figure 7-6.

Figure 7-3 The two main uses of organic material are as short to medium-term weed-suppressing mulches (left photo, Onewa Road) and as an amendment to poor-quality soils to ensure plant growth (right photo, the grey soil has failed to support plant growth)

Large capital projects typically import mulch rather than recycle vegetation that is removed and chipped from the site for the following reasons:

- Space available to store the chipped mulch may be limited and onsite expertise to manage the composting/storage of the mulch to ensure its quality needs to be contracted in.
- Planning and scheduling to avoid contamination (e.g. by mulching when privet does not hold fruit) and separate mulches is regarded as not cost-effective. Contamination means the mulch must be effectively composted before use to kill the weed seeds/branches.
- Very woody, coarse mulch gives a longer period of weed control for a similar application depth, and plants can be given fertiliser tablets at the time of planting to ensure adequate short-term nutrition.

In contrast, special projects through AMA generally reuse arborist mulch on site where possible. High access costs due to sites being located on active parts of the motorway encourage minimising truck movements (hence disposal and reuse of arborist mulch on site), and smaller sites allow more detailed planning(pers comms).

Table 7-3 Chemical properties of organic mulches and composts

Type of mulch or compost	**Chemical analysis**			
	pH	**C:N (%C:%N)**	**Cu mg/kg**	**Zn mg/kg**
Composted VCU mulch	6.4	31 (43:1.4)	50	130
Part-composted wood chip mulch	6.1	30 (21:0.7)	70	130
Bark chip mulch	5.5	128 (41:0.3)	80	50
Sawdust	5.8	420 (51:0.12)	3	13
Commercial Compost 1	7.9	12 (19:1.6)	190	260
Commercial Compost 2	7.1	32 (37:1.1)	120	190

**Wet mass can increase rapidly if stockpiles are uncovered and become wet.

7.4 Value Cost and Benefits of Current Disposal/Reuse

7.4.1 Value of Composted RDS/Vegetative Material for AMA

The value of composted RDS/vegetative material is influenced by the cost of opportunities foregone by using vegetative material for composting and the benefit of using the composted product on the AMA network. This is because, at least initially, the product would not be sold or used outside the road corridor network.

Arborist mulch currently trucked from the network and stockpiled is used to mulch special project amenity landscaping, saving \$10-25/m^3. For one site, the Takanini interchange, the mulched poplars generated 150 m^3 (\$3750 saving) of the total 325m^3 of arborist mulch used for the landscaping. The 3600 m^3 of arborists mulch generated from TOC maintenance work is therefore worth about \$18,000 to \$36,000 to AMA, and represents about half the 7500 m^3 of mulch anticipated to be used in the 2010/11 year. However, these savings must be put in the greater context of waste management for the network – annual disposal costs for RDS collected from the AMA network is an estimated \$450,000. Composted RDS/vegetative material by itself is unlikely to be effective mulch for weed control as the fines in RDS form a substrate in which seeds can germinate. However, the extent RDS/vegetative material can substitute for mulch depends on the proportion of RDS and its particle size, and the composting process. A surfacing of 100 to 150 mm of wood chip is likely to ensure weed suppression as well as providing enhanced growth of amenity vegetation. An equivalent to wood chip could be generated by sieving the final composted product, and using the >20 mm fraction to suppress weeds.

The composted RDS/vegetative material is likely to be a valuable soil amendment, providing nutrients and improving physical structure and water storage in degraded soils. It could also be a topsoil substitute. Use of soil amendments to enhance plant growth in some visual quality special projects has demonstrated the value of this approach; however, no soil amendments are currently used on TOC work. This means, unless composted RDS/vegetative material is used in special projects or capital works, or starts to be used in TOC maintenance, the cost of transport and spreading the new resource on the network is a new cost. The cost in 2010 would be \$10 to \$18/m^3 for spreading by tractor or blowing into existing plantings respectively – if the composted RDS/vegetative material has a bulk density of 600 kg/m^3 the disposal cost is \$17 to \$30/tonne. Current disposal costs for RDS are \$90-180/tonne.

Benefits from applying composted RDS as a soil amendment are reduced risk of plant failure, both at establishment and during unusual stresses such as drought (e.g. as seen this past summer through CMJ) and therefore greater amenity value. Faster growth rates during establishment may allow either a decrease in planting density or reduced weed maintenance costs (through a reduced time to canopy closure).

7.5 Projection of future volumes and quality of vegetation waste

The quality and volume of arborist mulch generated in the next 10 to 15 years from the AMA network are expected to change gradually. The vegetation will become less weedy in the long term and in the short term if the pest plant initiative is adopted. This means the requirement to reach high composting temperatures to kill weed seeds may not be necessary.

There is no data or estimate of mulch volumes that will be generated by confirmed capital projects that are either underway or pending. However, nearly all capital projects are likely to generate mulch that could be utilised on the network (or by a RDS composting plant) as the mulch is typically removed off site. Reuse by AMA would need to be negotiated on a case by case basis. A recent precedent is the use of arborist mulch generated from the Kingsland Cycleway on the AMA network.

Recently completed capital projects (i.e. Hobsonville and Northern Gateway) will need trimming beginning in 3 to 5 years depending on plant proximity to the road and plant species. This is likely to increase the volume of arborist mulch generated monthly until woody plants closest to the road are removed. For example, the Hobsonville segment has manuka immediately adjacent to road on parts of northern side (grass swales on the southern side). Some new motorway segments have edge vegetation that is unable to be mulched or used in a composting plant, for example the extensive flax plantings around Mt Roskill.

In the longer term, capital projects should create road edges that need minimal trimming. For example, Onewa Road and parts of Manukau motorway use herbaceous, non-creeping species (oioi and carex) to create a band of vegetation that does not need trimming in front of taller woody vegetation that is set well back from sight-lines. This strategy is also used where existing areas of the network are replanted. For example, pest plants (privet, acacia, cotoneaster) on the road edge are being replaced with *Muehlenbeckias, Coprosma acerosa* and small flaxes (*Phormium cookianum*). Larger trees will still need trimming, however, so in the medium-to-long term, overall monthly volumes of TOC arborist mulch are likely to be similar, but of higher quality (being whole trees or limbs of non-weedy species) as the area and length of road with perennial woody vegetation is increasing and area of mown grass verge decreasing.

7.6 Available Alternative Reuse Options

Options for reuse of vegetative waste produced as arborist mulch and logs on the AMA network are covered in Section 5. In the past, arborist mulch, especially if infested with weeds, was removed to Franklin Tree Services yards at Tuakau and composted. Given current demand for clean arborist mulch in Auckland, it is highly likely alternative 'markets' are available for AMA mulch generated from TOC work, particularly in city and regional council parks. Auckland Botanic Gardens has a shortfall of mulch and is readily accessible from northern motorway. Composting companies such as 'Mulchman' may also be interested in receiving arborist mulch.

There are limited options for disposal of RDS if it is classified as a contaminated material.

8 Discussion - Composting RDS

8.1 Composting

The results of this study thus far show:

- RDS from the AMA network on average has concentrations of PAH and heavy metals that are above concentrations found in background non-volcanic soils. It also contains some plant nutrients.
- RDS from the AMA network would therefore need treatment via dilution or stabilisation (or both) targeting leachable zinc and copper concentrations, before it could be used on the network (disposed to land)
- All catch pit and road sweepings are currently disposed to landfill at a cost of $90-180/tonne, and this cost is increasing faster than the rate of inflation.
- The organic content of <10% in RDS from the network, means coarse organic material(i.e. vegetative material) must be added to facilitate stabilisation (by composting) and to achieve the minimum amount of organic content for compost products of 20% - although in reality organic contents of closer to 40% are envisaged.
- The volume and quality of mulched vegetation generated from the network favours some level of composting of RDS with the resultant product being a potentially valuable resource: soil ameliorant, compost and/or mulch.
- Soil ameliorants, compost and mulch are currently used in on the AMA network in substantial volumes on new landscaping. The majority of these materials are imported (purchased).

To further understand the feasibility of composting RDS, the practical requirements of the composting process, site (including regulatory) and operational requirements were investigated.

8.2 Composting Process

Composting generally consists of a mix of carbon (woody material), nitrogen (green material), water and oxygen mixed together in the right ratios to allow for the breakdown of materials. Usually a pile of organic matter is formed and biological processes from in situ microorgasims rot the material to a stable form.

An estimate of inputs of feedstock materials (i.e. RDS and vegetative material) into a composting process resulted in an estimate of approximately 20 tonnes of material on average per day. This is from approximately 8 tonnes of RDS and 12 tonnes of vegetative material. The AMA network produces a fairly consistent volume of dewatered catch pit waste, road sweepings and TOC arborist mulch on a weekly basis. This provides an efficient base load for operation of a plant. The relatively consistent particle size, moisture content and C:N ratio of the TOC arborist mulch make it an ideal compost feedstock. In most composting operations vegetation is checked for contaminants before mulching or grinding – these steps are redundant for TOC arborist mulch. RDS contains metal, plastic, glass and organic contaminants such as paper. These may be reduced by screening the final composted product, allowing the organic materials to be naturally broken down (feasibility of these operations would need to be assessed via composting trials). In some recycling centres and compost manufacturers, plastic is removed by ‘blowing’, however, this is unlikely to be cost effective for a small-scale plant.

The process of composting RDS requires mixing arborist mulch and RDS in proportions that create a material with moisture content (note, it is envisaged that wastewater from the network may be used for adjusting moisture content), permeability (aeration) and carbon to nitrogen ratio that promotes an aerated composting process (Saebo and Ferrini 2006) that reaches and sustains the temperatures required to kill weed seeds during part of the process. The composting process is usually optimised to produce a stable material in as short a time as possible. Once initial composting is completed, the material (probably reduced in volume by about 25% for a 1:1 mix) is further matured for several months until it becomes relatively stable – this is indicated by a constant low temperature on disturbance and absence of an unpleasant smell when bagged for 24 hours (Saebo and Ferrini 2006).

Some composting processes, particularly in-vessel, appear to require less maturation time however at this stage a 3 month composting process can be considered typical.

8.2.1 Composting and Heavy Metals

There is general consensus in the scientific literature that aerobic composting processes increase the complexation of heavy metals in organic wastes, and that metals are strongly bound to the compost matrix and organic matter. This limits their solubility and potential bioavailability in soil (Smith 2009). Hence organic materials such as composts, peat and bark are generally effective for remediation of metal-contaminated soils, through both sorption and increasing pH (Olayinka et al 2008). The reactive surfaces onto which metals bind can be provided by humic acids in organic matter (Clemente and Bernal 2006; Alvarenga et al. 2008). Lead is the most strongly bound element; zinc has intermediate sorption characteristics. Copper mobility is correlated with dissolved organic carbon (DOC) (Beesley and Dickinson 2010). When compost is applied to soils as an amendment, the availability of most metals depends primarily on soil pH (particularly for zinc), metal concentration (competition for binding sites), and soil mineralogy & texture (sorption and buffering capacity).

8.3 Composting Operation Options

The composting process and its operations can range from the very simple to very high tech. Each type of composting system has benefits and drawbacks. Table 8-1 outlines the various type and comments on what the positive and negative aspects of these operations are.

Table 8-1 Summary of different composting process

Composting Operation Type	Description	Environmental and Regulatory	Set up Cost (relative to each type)	Other Comments
Turned Pile	Basic pile of compost turned on a regular basis (similar to home	Effects are difficult to manage and may have issues with odour and leachate.	Low	Site selection is important to mitigate effects.

Composting Operation Type	Description	Environmental and Regulatory	Set up Cost (relative to each type)	Other Comments
	composting)			
Aerated Static Pile	Material placed on perforated pipe and aerated using pressure.	May have limited control over leachate and odour (may be covered).	Moderate	Moderate processing time.
Windrow	Long rows of organic material – turned periodically. Usually uncovered.	Medium to high risk of odour and leachate discharges. Less concern about structures.	Moderate	Low operational requirements Long processing time
Enclosed	Fully enclosed usually with negative air pressure and odours sent through biofilter.	Effects management straight forward as odours and leachates can be controlled.	High	Can require services set up including electricity etc and operational staff.
In - vessel	Fully enclosed reactors – often metal tanks or concrete bunkers in which air flow and temperature can be controlled	Effects management straight forward as odours and leachates can be controlled.	High	Requires minimal operational staff time. May require maintenance and have corrosion issues.

8.4 Composting Site

For this study composting operations that are fully enclosed have been recommended. This is to minimise the likelihood of consenting requirements relating to discharges to air and discharges to land or water.

Considerations for any composting site include:

- waste intake
- material handling
- storage
- truck movements
- odour and discharge control.

Two composting companies were approached to understand what available options there are for setting up, and operating, a composting facility.

- HotRot NZ Ltd – manufactures in vessel composting systems.
- Arlo Group – an Irish company that has built and operates a wind row-based composting sites.

8.4.1 HotRot

www.hotrot.co.nz

HotRot NZ Ltd gave a summary of the requirements and costs for a composting plant that could process 20 tonnes of material per day. These are outlined below:

- fully enclosed composting unit with a tine bearing central shaft (Figure 8-2)
- feed hopper (Figure 8-3)
- exhaust air being transferred to a biofilter.
- processing is a continuous process and takes **10 -12 days with no further maturation required**.
- HotRot units would require **an operator for 1-2 hours/day**.
- estimated cost = **NZD$3.5 million dollars**.

Figure 8-2 Example of an in vessel composting system

Figure 8-3 The rotating tines at the feed hopper end of the system (Hot Rot)

8.4.2 Arlo Group – Tipperary Ireland

www.acornrecycling.com

Hydro-Tech Drainage Ltd – a company contracted to the AMA for street sweeping – contacted the Arlo Group (on behalf of the AMA) for more information on composting processes and plants. Arlo operate (and built) a composting plant in Tipperary Ireland that accepts street sweepings and catchpit sediments for processing.

The site they suggested would meet the AMA requirements was one that uses wind row composting process inside a large building. The wind rows are constantly monitored for temperature and the building is maintained at a negative air pressure. Air is filtered through a biofilter before discharge. The plant requirements and costs include:

- front marshalling Yard
- intake and Screening Building (Figure 8-4)
- concrete composting tunnels
- biofiltration System.
- estimated cost = €2 million or **NZD$3.6 million**

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Figure 8-4 Inside of Composting Building – Tipperary

8.5 Composting Site - Regulation

Any composting site will require specific regulatory and planning assessments and an assessment of effects. To better understand what the issues may be, a possible composting site was investigated.

The AMA has a site in the Pahurehure area (see Figure 8-5) that is used for general motorway uses. This site was investigated as a possible composting plant site for the purposes of outlining the considerations required when setting up a composting plant.

Figure 8-5 Pahurehure NZTA storage site

8.5.1 Territorial Authority

The site is located within the NZTA designation.

If the composting plant meets the description under the designation an Outline Plan would need to be prepared. If the composting plant does not meet the description then land use consents for the site would be required and assessments of effects to deal with noise, traffic etc would need to be prepared.

The proposed composting site is located on a small strip of land directly abutting State Highway One (SH1), see Figure 8-5 and falls within Papakura District Council. The relevant operative plan is the Papakura District Plan (the Plan).

It should be noted that the proposed site for the composting is listed in the Rural Schedule of the Plan as a site of national significance – item P6 – Takanini Pumicite.

8.5.2 Proposed Auckland Regional Plan

Depending on the size and set up of the composting plant it will need to consider the requirement for resource consent for the following:

- discharges to air (odour)
- discharges to land where it may enter water – Industrial and Trade Process Rules.
- discharges to the Coastal Marine Area (CMA) – stormwater

Resource consents for discharges to air are usually notified and will require a hearing process. This is dependent on the mitigation options implemented. However it is important to be aware that odour issues are often the riskiest part of a compost plant.

8.6 Costs of landfill disposal compared to composting

Some very basic calculations have been undertaken in Table 8-6 below to illustrate the potential cost savings from reusing RDS. These calculations may require refining and so any decisions made should not be based on solely on this information.

	Cost of Composting Plant (million NZ$)	Life Span of Plant (years-estimate)	Tonnes of RDS per year	Operational Costs (Staff time Only)	Maintenance Costs	Regulatory Costs	Approximate Cost per tonne of RDS	Cost of applying to the Network as arborists compost.	Indicative Cost of Composted RDS applied to Network/Disposal (per tonne)
Hot Rot	3.5	20	5000	(Staff 2 hours/day) $20000	Unknown	Unknown	$35	$25	$60
Arlo	3.6	35	5000	(Staff 2 FTE) $100,000	Unknown	Unknown	$21	$25	$46
No Composting	0	-	-	-	-	-	$150	-	$150

Table 8-2 Cost of RDS per Tonne after processing

9 Summary of Findings

Road derived sediments are a significant component of waste from the NZTA Auckland Motorway network.

International literature shows that RDS reuse is occurring in other parts of the world, particularly the USA. The New Zealand regulatory framework does not specifically allow for the reuse of RDS, however, there may be opportunities to enable this to occur in the future.

The contaminant levels found in RDS from the AMA (Table 9.1) are above the background soil limits in Auckland but are generally below all other guideline values. This means that the material must be considered contaminated, which limits the ability for it to be reused and applied to land without presenting some risk to the environment unless it undergoes some sort of treatment or stabilisation. However, the contaminant levels are sufficiently low for composting the RDS with vegetative material (also from the AMA network) to be a potential opportunity to turn this waste material into a resource.

Further investigation is required to determine the extent of leaching of heavy metals (namely zinc and copper) will occur from the final composted product, and how effective added stabilisers are at further immobilising residual heavy metal leaching.

Table 9-1 – Comparison of AMA RDS Contaminant Levels to Guideline values

RDS Source	AMA RDS Contaminant Ranges (mg/kg)	Auckland Background Soil levels (TP153) (non-volcanics) (mg/kg)	PARP:ALW Schedule 10 (mg/kg)	NES Guideline Levels (Health)(mg/kg)	Biosolids Grade 'a' levels (mg/kg) [post 2012]	Compost Standard
Copper	22-85	1-45	325	29000	300 [100]	300
Lead	16-49	5.6-25	250	7000	300 [300]	250
Zinc	80-380	9.2-179	400	-	600 [300]	600
PAHs (BAPeq)	0.10-1.13	-	2.15	300	-	-
TPH	<70-1000	N/A	-	-	-	-

The AMA produces sufficient vegetative material from its maintenance operations to provide a viable feedstock for composting of RDS. Although diversion of vegetative material used for mulch may result in some increased costs (purchasing mulch), this is more than offset by the potential to make significant savings on the ca. $450,000 spent disposing of the estimated 3000 tonnes of RDS generated each year from the AMA network.

To set up a composting facility AMA/NZTA would have to consider resource consenting issues relating to Land use, discharges to air and discharges to water. However, the requirements to obtain these would depend on the type and size of any operation and requires further investigation.

The key findings of this study are as follows:

- Composting of RDS is a viable way to turn a waste product into a resource.
- RDS on the AMA network has levels of contaminants (particularly copper, lead, zinc, TPH and PAH's) that are above Auckland background soil levels. As such it is likely that application of the untreated RDS to land without resource consent and potential risks to the environment would be not possible.
- Composting of RDS is a viable way to turn a waste material into a valuable resource and potentially reduce particulate contaminants and/or contaminant mobility to levels where application to land would be possible without resource consent (i.e. permitted activity).
- The information available from this study does not allow for conclusions to be drawn about the metal leaching potential of the final composted product. This lack of information means that the regulatory requirements and the potential environmental effects for RDS compost reuse are not clearly defined. However, previous research regarding the leaching potential of heavy metals from RDS, and the efficacy of stabilising additives to immobilise these contaminants, indicate there is considerable scope to reduce leaching well below any regulatotry requirements. This will be a key component of the recommended composting trial study.
- To confirm whether resource consent would be required for use of composted RDS significant consultation and liaison with the regulatory authority is required.
- Opportunities to influence regulation to allow for composted RDS application to land should be investigated (for example a specific rule in a regional plan if required).
- Maintenance of the Auckland motorway network produces sufficient vegetative material that could be diverted to compost with RDS.

- Composting and reusing RDS will meet the NZ Waste Minimisation Act and Waste Strategy Objectives of reduction of the amount of waste that is disposed of and lessen the environmental harm of waste.

- Composting and reusing RDS will allow the AMA and NZTA to work towards the objectives of resource efficiency and GHG emissions reduction in line with their Environmental Management Plan Objectives.

- Composting and reusing RDS will meet the AMA objectives of finding opportunities for of Value for Money, Positive Legacy, Network Efficiency, Healthy Organisation and Customer Stakeholder Obligations.

The following section outlines specific recommendations for a composting trial study to ensure the aforementioned information gaps are filled before making any final recommendations are made regarding a pilot RDS composting plant.

10 Recommendations

The following outlines the recommendations to further understand the viability of composting and reusing RDS on the AMA network.

- Confirm existing regulatory requirements for reuse with the regulatory authority.

- For NZTA to proceed with a small scale composting trial to allow for understanding of:
  - Environmental effects of the final product, including leaching potential of contaminants
  - Practical operational requirements and costs for a composting facility
  - Optimisation of proportion of RDS to vegetative material for composting
  - Confirm that the final product will be fit for purpose
  - Confirm the accumulation risk of contaminants when applied to the AMA Network
  - Allow for final recommendation whether or not to proceed with composting of RDS

- Investigate partnership opportunities with:
  - Existing composting operations
  - The Auckland Council to determine disposal options for the RDS from Local roads
  - The Auckland Council to influence the regulatory processes that may need to be followed to enable safe and responsible reuse of RDS (perhaps by developing a specific rule)

10.1 Time Frame for Recommendations

The time frame for the pilot trial and associated activities has been estimated based on the assumption that traditional composting (static pile) would be used. A period of 9 months would be required to complete the trial and all analyses.

10.2 Costs of Recommendations

To undertake the recommendations outlined in this report an approximation of costs has been determined at between $100,000 and $150,000.

These costs are provisional and should be considered indicative only.

11 Conclusion

The preliminary findings of this study are very encouraging for composted RDS to be turned from a waste material to a resource. The recommendation is for NZTA to proceed with a composting trial study which will enable key information gaps to be addressed, allowing an informed decision to be made regarding the feasibility of establishing a pilot plant to implement RDS composting and reuse on the AMA network. Partnership opportunities should also be investigated to support alternative composting options and regulatory requirements. Further, there may be opportunities for NZTA to utilise the results of this study and any subsequent trial to address RDS disposal on a national scale.

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Guideline and Regulatory Documents

Proposed Auckland Regional Plan: Air, Land and Water (2001)

Resource Management Act (1991)

Guidelines for the Safe application of Biosolids to Land, MfE (NZWWA 2003)

New Zealand Standard 4454:2005 Composts, Soil Conditioners and Mulches

Auckland Regional Technical Publication 153, Background Concentrations of Inorganic Elements in Soils from the Auckland Region

APPENDIX A

RDS Sampling and Analysis Methodology

Auckland Motorway Alliance

Road Derived Sediments - Sampling Methodology

June 2010

RDS collection and processing

Collection

Pond sediments and catch samples were sampled using shovel with at least 5 separate 'grab' samples used to collect approximately 5-10 kg of wet sediment. Road sweeping samples were collected by vacuum sweeping trucks with approximately 3-10 kg of wet material subsampled when the trucks contents were emptied at the yard. In total, 7 RDS samples were collected in May/June 2010, consisting of 3 road sweepings, 1 catch pit and 3 stormwater pond sediments (Table 1). Sampling sites for pond sediments and catch pit sample are shown in Figure 1a-d.

Table 0- Sampling details of the seven Auckland Motorway RDS samples

RDS sample #	RDS type	short name	location
AMA-1	Forebay pond sediment	Pond-CMJ	Newton Pond, SH16 CMJ Core
AMA-2	Forebay pond sediment	Pond-causeway	Causeway Lagoon Pond,SH18 Upper Harbour Bridge and Causeway (westbound)
AMA-3	road sweeping	Sweeping-CMJ	CMJ-Port links
AMA-4	road sweeping	Sweeping-Oteha	SH1 (North) Oteha-Harbour bridge
AMA-5	road sweeping	Sweeping-SH22	SH22 (Butcher Rd)
AMA-6	catchpit	Catch pit-SH18	SH18 Upper Harbour Corridor (westbound) at Unsworth Drive
AMA-7	Forebay pond sediment	Pond-Titoki	Titoki Pond, SH18 Upper harbour Corridor (eastbound)

Figure 0-1 Newton Pond, SH16 CMJ Core (AMA-1)

Figure 0-2– Causeway Lagoon Pond, SH18 (westbound) Upper Harbour Bridge and Causeway (AMA-2)

Figure 0-3– catch pit sediment, SH18 Upper Harbour Corridor (westbound) at Unsworth Drive

Figure 0-4 - Titoki Pond, SH18 Upper harbour Corridor (eastbound)

Processing

Road sweepings were processed as supplied, whereas catch pit and pond sediment were dewatered by playing samples in large plastic trays (ca. 1200 x 600 mm) and place on slight incline to enable water to drain away from the material (Figure XX1). This was adequate for AMA-1 and AMA-2, and along with the road sweepings (AMA-3, AMA-4 and AMA-5) were size fractionated using a 9mm sieve. Samples AMA-6 and AMA-7 were to cohesive to sieve and required added water to facilitate separation in <9 and >9mm particle size fractions. Sediment <9mm was then left to settle in large (5L) glass jars (to remove majority of the water) and then were 'de-watered' using the aforementioned process. For all 7 samples, the larger than 9mm fraction was washed with water to remove excess fine sediment before being transferred to oven and dried at 60°C for 3 days. The <9mm fractions were weighed and then stored in plastic bags. Duplicate subsamples of the wet <9mm fractions were dried in oven overnight at 80°C to determine the water content. The total mass of the <9mm fractions were corrected for water content to give dry mass. Subsamples of the seven RDS samples (<9mm fraction) were weighed out to give a dry-weight mass of ca. 50g. For each RDS sample, two 50g subsamples (based on dry weight) were prepared – one for PAH/TPH analysis and the other for heavy metals analysis. All chemical analyses were carried out by Hill Laboratories in Hamilton.

Figure 0-5 - Dewatering RDS sediment (AMA-2, 'Pond-causeway')

RDS particulate analyses

Heavy metals

Particulate heavy metal concentrations of the three smallest size fractions (<1, 1-5.6 and 5.6-9mm) were measured by ICP-MS after a nitric/hydrochloric acid digestion in accordance with standard method US EPA 200.2 (Hill Laboratories). A sample size of ca. 2g was used for the more homogeneous <1mm fraction, whereas a 40-50g sample was extracted for the two larger size fractions. The total concentration of metals in the <9mm composite RDS sample was calculated from the relative mass contribution of the individual size fractions. A suite of six heavy metals were analysed, including cadmium, chromium, copper, lead, nickel and zinc, although discussion is limited to copper, lead and zinc.

PAHs and TPH

Particulate PAHs analyses were carried out by Hill Laboratories (Hamilton) in accordance with standard methods US EPA 3540 and 3630. Briefly, large samples (ca. 50g) RDS composite samples (<9mm) were extracted with dichloromethane solvent using ultrasonication. The filtrates were cleaned up by silica gel chromatography and the PAHs quantified by gas chromatography mass spectrometry (GC/MS) operated in selected-ion monitoring (SIM) acquisition mode. The PAHs analysed were the 16 priority PAHs listed by the US EPA, which include the following: naphthalene; acenaphthene; acenaphthylene; fluorene; phenanthrene; fluoranthene; pyrene; benz[a]anthracene; chrysene; benzo[b]fluoranthene; benzo[k]fluoranthene; benzo[a]pyrene; indeno[1,2,3-c,d]pyrene; dibenz[a,h]anthracene; benzo[g,h,i]-perylene. The seven underlined PAHs are classified as carcinogenic PAHs (cPAH).

Particulate TPH analyses were carried out by Hill Laboratories (Hamilton) using standard methods US EPA 8015B/NZ OIEWG. Briefly, RDS were extracted with dichloromethane solvent using ultrasonication (same extract from PAH analysis used for TPH). The filtrates were analysed by gas chromatography equipped with a flame ionisation detector (GC-FID). The method quantified the TPH in 3 carbon bands, C7-C9 (gasoline), C10-C14 (diesel) and C15-C36 (heavy).

Organic matter (OM)

Organic matter was determined by the 'loss on ignition' method (Organic Laboratory, NIWA Hamilton). For <5.6mm size fractions, large samples (20–50g) were weighed in pre-weighed metal trays. The samples were heated to 100°C (to remove any water) and then reweighed. The dried RDS samples were then combusted at 400°C and reweighed – the difference between the dry (100°C) and combusted weight (400°C) being the amount of organic material present.

Leachate pH

pH measurements were done on 1:1 suspensions of RDS to aqueous solution. Because of the uncertainty sometimes introduced in pH measurement when low ionic strength solutions are used (ie water), as recommended by Miller and Kissel (2010), a 0.01M $CaCl_2$ solution was used.