

# **Assessing the Environmental Effects of New and Recycled Materials in Road Construction**

## Proposed Guidelines

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## Executive summary

The introduction of new or alternative (recycled wastes) materials in road construction may have benefits in terms of cost reductions, improved surfacing or pavement performance. However, it is essential to ensure that such innovations do not result in long-term negative impacts on the environment e.g. through the leaching of toxic chemicals into waterways.

The aim of this research, conducted in 2005–2006, was to develop guidelines to provide assistance to New Zealand roading authorities, roading contractors and suppliers when deciding whether to approve, or seek approval for, new or recycled materials for road construction. The guidelines do not consider environmental impacts, such as sediment runoff, which are associated specifically with construction activities. Guidelines for minimising environmental impacts during construction have been published previously and will also apply to construction activities using new or recycled materials.

A three-stage process for material evaluation is recommended. The process is outlined below:

### **Stage 1: initial assessment**

The initial stage involves using all existing information and data in order to determine (a) if the material is hazardous and (b) whether or not it needs to undergo approval by the Environmental Risk Management Authority (ERMA) prior to use in road construction in New Zealand. Where insufficient information is available on the chemical composition or ecotoxicity of the material, Stage 2 testing is recommended.

### **Stage 2: material screening tests**

This stage involves a screening test of the material to determine if it contains leachable contaminants that may cause an environmental impact if released. The leaching procedures suggested (based on the US EPA Toxicity Characteristic Leaching Procedure (TCLP) Test Methods for Evaluating Solid Wastes Physical/Chemical Methods, Method 1311) aim to provide a conservative estimate of whether the material contains hazardous contaminants in a leachable form. Leachates are assessed by chemical analysis and tested for aquatic ecotoxicity. The test results are assessed by comparison to New Zealand landfill waste acceptance criteria (WAC) for Class B landfills and ecotoxicity criteria.

### **Stage 3: comprehensive environment impact assessment**

The third stage is a comprehensive assessment that may be required if Stage 2 assessment indicates that the material contains contaminants that could leach out and cause harm to the environment. This stage involves a more comprehensive environmental impact assessment using data from less conservative (more realistic) leaching tests which include site parameters (e.g. geometry and hydrology) to model the release, transport and fate of the contaminants over time from the source to the potential receiving environments/receptors. The report suggests how such an assessment could be made, but development of a detailed process is beyond the scope of the present document.

## **Abstract**

Guidelines were developed to assist New Zealand roading authorities, roading contractors and suppliers when deciding whether to approve, or seek approval for, new or recycled materials for road construction. A three-stage process for material evaluation was recommended:

### **Stage 1: initial assessment**

Existing information should be examined to determine (a) if the material is hazardous and (b) whether or not it needs to undergo approval by the New Zealand Environmental Risk Management Authority. Where sufficient information is not available, Stage 2 testing is recommended.

### **Stage 2: material screening tests**

This stage involves a conservative screening test of the material to determine if it contains environmentally harmful leachable contaminants. Leaching procedures based on the US EPA Method 1311 (TCLP) are suggested. Leachates are assessed by comparison to New Zealand landfill waste acceptance criteria for Class B landfills and ecotoxicity criteria.

### **Stage 3: comprehensive environment impact assessment**

Third stage assessment may be required if stage 2 indicates that the material contains environmentally harmful contaminants which are leachable in significant concentrations. A comprehensive environmental impact assessment is undertaken using data from more realistic leaching tests which include site parameters to model the release, transport and fate of the contaminants over time.



## **1 Introduction**

The introduction of new or alternative (recycled waste) materials in road construction may have benefits in terms of cost reductions, improved surfacing or pavement performance. However, it is essential to ensure that such innovations do not result in long-term negative impacts on the environment e.g. through the leaching of toxic chemicals into waterways. These environmental considerations arise from the government strategies, policies and statutory obligations of organisations such as the Environmental Risk Management Authority (ERMA), which is responsible for approving the use of hazardous substances under the Hazardous Substances and New Organisms (HSNO) Act (1996), Land Transport New Zealand (meeting national targets of environmental sustainability of roading systems under the New Zealand Transport Strategy (2002)) and Regional Authorities (responsible for environmental protection under the Resource Management Act (RMA) (1991)).

The aim of this research, undertaken in 2005–2006, was to develop guidelines for appropriate test methods and assessment criteria by which Transit New Zealand (TNZ), local authorities and contractors can evaluate possible adverse environmental effects of new, recycled or alternative materials, and techniques used in road construction.

The first chapter of this report provides background information related to road construction materials and overseas practice related to their environmental assessment and test methodologies. The guidelines developed in the present work were written as a 'stand-alone' document and are presented in Appendix A.

## 2 Background

### 2.1 Road construction materials and application

Materials used in road construction (Table 2.1) can be subdivided into four main categories based on their employment in the different parts of the road structure:

- subgrade reinforcement and embankment materials,
- sub-base materials,
- basecourse and surfacing materials (TNZ 2005).

Materials used to construct peripherals (e.g. curb and gutter, medians), or road furniture (e.g. signs and edge markers) are not considered in the following discussion.

**Table 2.1 Conventional materials used in road construction.**

Application	Material used
Subgrade reinforcement and embankments	soil lime cement/concrete aggregate
Sub-base	aggregate lime cement
Basecourse	aggregate lime cement bitumen
Surface	bitumen kerosene/diesel concrete aggregate adhesion agents/emulsifiers polymer modifiers

### 2.2 Subgrade reinforcement and embankment construction

The subgrade layer is made up of *in situ* material (i.e. soil or rock) that is compacted to provide a surface over which the sub-base course is placed. An embankment refers to a volume of fill material (soil or rock) that can be placed and compacted for the purpose of raising the grade of a roadway above the level of the existing surrounding ground surface.

### 2.3 Sub-base

The sub-base generally consists of lower quality, coarse-graded (up to 65 mm) aggregates laid on the subgrade to make up additional pavement thickness, prevent intrusion of the subgrade into the basecourse, or to provide a working platform (TNZ 2005). The sub-base aggregates can be stabilised with lime, cement or, occasionally, bitumen which has been foamed or emulsified to increase strength. Various proprietary stabilising agents are also available.

## **2.4 Basecourse**

The basecourse is the aggregate layer immediately below the driving surface layer(s). The basecourse layer acts as the main load-bearing and strengthening component of the pavement structure and serves to reduce the stress applied to the subgrade layer and provide drainage for the pavement structure. The basecourse is usually constructed from crushed aggregates (up to 40 mm) and can, if necessary, be strengthened by stabilisation in the same manner as the sub-base layer.

## **2.5 Surface**

The surfacing layer (also called the wearing course) is the uppermost layer of the pavement structure. Surfacing is intended to prevent the entrance of excessive quantities of surface water into the underlying pavement layers and to protect the basecourse from abrasion damage from traffic. Surfacing must also provide sufficient friction (skid resistance) for safe driving. Surfacing materials can be subdivided into three major categories:

- bitumen intimately mixed with graded aggregate and compacted on the road (asphalt mixture),
- single-sized aggregate spread onto a sprayed bitumen film (chipseal), and
- concrete.

New Zealand roads are constructed almost exclusively using different types of asphalt mix and chipseal.

### 3 Recycled materials used in road construction

In New Zealand, alternative uses for waste materials are being sought in an effort to reduce the amount of wastes going into landfills. This is integral to the national waste strategy (Ministry for the Environment (MfE) 2002). Thus, waste producers are being encouraged to reduce the production of wastes and to identify mechanisms through which their waste materials may be recycled or reused. The re-use of materials such as building and demolition wastes, slags, fly ashes and others in the construction of roads can provide an attractive alternative means of disposal, provided, of course, that engineering performance is not compromised.

Internationally, recycled materials used in road construction generally fall into one or more of the following categories (Chesner 1997, Ormsby & Fohs 1990, OECD 1997, van Tassel et al. 1999a & 1999b, Baldwin 1997):

- mineral filler,
- aggregates for chipsealing, asphalt mixtures for pavement construction, basecourse stabilisers, and
- bitumen additives and modifiers.

Presently in New Zealand, the only materials recycled into the road structure on a regular basis are waste rock, asphalt millings, waste concrete and waste oil, although it is likely that a wider variety of materials will be considered in the future (Boyle & Khati 1998, Bailey et al. 2001). Based on overseas practice, a number of potentially recyclable materials are discussed in the remainder of this chapter.

#### 3.1 Waste rock

Most material in this category is basecourse aggregate from failed pavements that is recycled *in situ* by adding stabilisers. Some waste rock from mineral processing may be used in the same way as conventional aggregates are in the base, sub-base and subgrade layers. However, waste rock from mining operations needs careful screening to ensure that the geochemistry and physical characteristics are favourable. For example, trace metal leachability and acid-generating potential would limit the use of pyrite-rich rock from coal mining.

#### 3.2 Reclaimed Concrete

Reclaimed concrete material (or crushed concrete) consists of high-quality, well-graded aggregates (usually mineral aggregates) bonded by a hardened cementitious paste (Turner-Fairbank Highway Research Foundation (TFHRF) 2006). The aggregates comprise approximately 60–75 % of the total volume of concrete. Crushed concrete can be used as aggregate material in basecourse and sub-base layers. To be used as an aggregate, foreign debris and reinforcing steel must be removed. Possible contaminants in reclaimed concrete that could affect the environment include calcium hydroxide that can leach from unweathered broken surfaces and cause an increase in alkalinity.

### 3.3 Reclaimed asphalt

These materials are generated when asphalt surfacings are removed for reconstruction or resurfacing, or to obtain access to buried utilities. When properly crushed and screened, this material consists of high-quality, well-graded aggregates coated by bitumen that can be used as an aggregate in base, sub-base and subgrade layers. Reclaimed asphalt is made up of 93–97 % of mineral aggregates. Only a minor percentage (3–7 %) consists of hardened bitumen (TFHRF 2006). Harmful contaminants in reclaimed asphalt will principally arise from vehicle emissions (including tyre and brake pad wear) deposited on the surface. During recycling, contaminants are redistributed from the surface to the underlying layers but a net increase in concentration does not occur. Leaching of pollutants from recycled asphalt has been found to be insignificant (Brantley & Townsend 1999, Legret et al. 2005). However, when reclaimed asphalt is incorporated into new asphalt surfacings, potentially harmful aromatic process oils can sometimes be added to 'rejuvenate' the old oxidised bitumen.

### 3.4 Reclaimed chipseal

A relatively recent innovation involves breaking up old chipseal surfacings into <50 mm fragments and reincorporating them *in situ* into the basecourse as aggregate (Gray & Hart 2003). The process does not involve the addition of any new material to the basecourse (other than possible fresh basecourse aggregate), so chipseal should not present any environmental contamination risk.

### 3.5 Crushed bricks

Crushed bricks can be used as alternatives to aggregates in the sub-surface layers. The issue of contaminants being released should not arise, provided the bricks originate from an uncontaminated clay source and are not made from recycled waste material such as fly ash.

### 3.6 Coal fly ash

Fly ash is produced by burning of pulverized coal in a coal-fired boiler. It is a fine-grained, powdery particulate material. Fly ash has been used for several decades as an embankment or structural fill material, particularly in Europe, and its use in this application is becoming more widely accepted in the USA. When used as a fill material (as a substitute for soil), fly ash must be conditioned to ensure that the material is not too dry and dusty, or too wet and unmanageable. When fly ash is at or near its optimum moisture content, it can be compacted to its maximum density and will perform in an equivalent manner to well-compacted soil (TFHRF 2006). Because fly ash may exhibit pozzolanic properties, self-cementing properties or both, it can (and has been) successfully used as part of the binder in stabilised base or sub-base construction applications.

Because coals from different sources vary, as well as because of differences in the design of coal-fired boilers, not all fly ash is the same. Although there may be differences in the fly ash from one plant to another, day-to-day variations in the fly ash from a given power plant are usually quite predictable, provided plant operation and coal source remain constant. However, fly ash can vary substantially if it is obtained by burning coal with other fuels (such as natural gas or wood) or with other combustible materials. The principal components of coal fly ash are silica, alumina, iron oxide and calcium, with

varying amounts of carbon. Low levels of metals such as iron or aluminium may also be present and may present a leaching hazard.

### **3.7 Melter slags**

Melter slag is the waste material that forms on the surface of molten metal during steel and iron production. The steel industry produces two kinds of slag: one from the production of iron and one from the steel-making process. The slag occurs as a molten liquid melt and is a complex solution of silicates and oxides with low levels of aluminium, iron and other metals that solidifies upon cooling. The slag is then crushed and screened to produce an aggregate. Synthetic aggregates produced as co-products in the iron and steel industry have been successfully used in both basecourse and sub-base layers for many years internationally (TNZ, 2006a).

### **3.8 Spent foundry sands**

Spent foundry sand is clean, uniformly sized high-quality sand that is bonded to form moulds for making metal castings. Bonding is usually achieved with bentonite clay, but proprietary systems based on polymers such as phenol formaldehyde resins are sometimes used. Foundry sand is re-used repeatedly in the foundry processes until, eventually, the particles become too fine to use. At this point, they become 'spent' foundry sands and are considered waste materials. Foundry sand, prior to use, is a uniformly graded material. The spent material, however, often contains metal from the casting, and oversized mould and core material containing partially degraded binder. Spent foundry sand may also contain some leachable contaminants, including heavy metals and phenols that are absorbed by the sand during the molding process and casting operations (Javed & Lovell 1995, Ham et al. 1989). Phenols are formed through high-temperature thermal decomposition and rearrangement of organic binders during the metal-pouring process. The presence of heavy metals is of greater concern in nonferrous foundry sands generated from nonferrous foundries (TFHRF 2006).

### **3.9 Scrap tyres**

Rubber from scrap tyres has been used in pavement and surfacing construction in various ways since the 1930s but only occasionally in New Zealand (Patrick & Logan 1993). Tyre rubber itself can be considered inert under ambient road conditions, although additives used in the manufacture of tyres are potentially harmful to the environment (e.g. aromatic process oils).

### **3.10 Glass**

In the last ten years or so, the amount of glass recycled in New Zealand has increased significantly from 30 000 tonnes in 1994 to 90 000 tonnes in 2004 (Thomas 2005). This has resulted in an oversupply of reclaimed glass in most areas of New Zealand. International research has shown that crushed recycled glass can be successfully used in a variety of aggregate applications (Thomas 2005), although in some circumstances, bitumen is stripped off the glass by water, which can be a problem when glass is used in asphalt mixtures (Griffiths & Krstulovich 2002, Wheeler 1996). When waste glass is crushed to particle sizes similar to those of natural sand, it exhibits properties of an aggregate material. Incorporating a small proportion of reclaimed glass (cullet) into basecourse aggregates offers an alternative for local

authorities to sending the excess stockpile to landfill. Five percent cullet is a conservative allowable proportion for roading applications, according to TNZ (2006a & 2006b), although higher proportions (e.g. 15–30%, depending on application) have been used overseas. In terms of potential environmental impact, reclaimed glass in roading materials should not be expected to release any harmful chemicals into adjacent land or water, provided that the cullet used undergoes quality assurance for its source and contamination level. The risk of contamination would be greater from glass used to contain hazardous materials, or from light bulbs, cathode ray tubes, fluorescent tubes and vehicle windscreens.

### **3.11 Waste motor oil**

Waste motor oil is still used as a dust suppressant on unsealed roads (MfE 1997), though its use for that purpose has diminished in recent years. Waste motor oil contains high concentrations of engine wear metals and polyaromatic hydrocarbons (PAHs). These contaminants can be leached or dispersed on particulates, as the dust suppression activity is only temporary.

### **3.12 Waste plastic**

Waste plastic from industrial sources or domestic recycling schemes can be chopped or shredded and added to asphalt mixture as part of the aggregate fraction (Zoorob & Suparma 2000, Punith & Veeraragavan 2003). Other processes exist whereby plastics are incorporated into the bitumen fraction of the mixture (Daly et al. 2002, Yousefi et al. 2000). The use of plastics in the sub-base and basecourse layers is also feasible. Although most common high volume plastics including polyethylene, polyethylene terephthalate (PET), polyvinyl chloride (PVC) and polystyrene are inert under ambient road conditions, the leaching of additives is a possibility that should be considered.

## 4 Road construction materials as a potential source of environmental contamination

Incorporating new or recycled waste material into the road structure creates the potential for unknown environmental impacts. These impacts can be divided broadly into:

- immediate affects associated with road construction or maintenance, and
- more gradual affects arising from the materials when in situ and occurring over the life of the road.

Guidelines for minimising mechanical losses from dust emissions and sediment runoff during construction with conventional materials have already been developed (Montgomery Watson Ltd 1999a, 1999b, 1999c) and will also apply to construction activities using new or recycled materials. The present study deals with the development of guidelines to evaluate the longer term effects caused by gradual leaching or volatilisation of contaminants to the environment.

After construction, the principal mechanism for the release of contaminants from the roadway (and of any physically dispersed material from dust or surface abrasion) is through leaching to soil, surface water and groundwaters. Contaminants leached from roading materials enter waterways and soil during and immediately after rain, with contaminant levels generally being greatest in the initial runoff and following dry periods without rainfall (Sriyaraj and Shutes 2001). The other potential route is through direct evaporation of volatiles (e.g. bitumen cutters), although for the majority of road materials, this route is likely to be negligible.

Increased concentrations of contaminants may have a toxic effect on both aquatic and terrestrial organisms, and ultimately on humans. The degree of impact that can occur depends on:

- the concentration and toxicity of the contaminant,
- the physical and chemical properties of the receiving environment (which affects the bioavailability of the contaminant), and
- the type and sensitivity of the receptor (exposed) organisms.



## **5 Material assessment methodologies**

### **5.1 General findings from the literature**

A literature search found that most studies to assess the environmental impact of construction and recycled materials were based on the assessment of the potential impacts on surface and groundwater. The majority of all potential adverse short and long-term effects relate to water and soil contamination. Tested materials are normally screened for potential aquatic impact using leaching tests. A high-level framework for evaluating recycled materials in road construction has been developed by Eighmy & Chesner (2001). Both engineering and environmental performance factors to be considered are discussed, but specific assessment criteria are not provided.

Recent studies on the environmental impacts of construction materials have been undertaken in Europe by Hjelmars (2003), van der Sloot & Dijkstra (2004) and Kosson et al. (2002). In the United States, the Transportation Research Board has developed an assessment framework to estimate the environmental effects of conventional, recycled or waste construction and repair materials on surface and groundwaters near highways (Harrington-Hughes 2000, Nelson et al. 2001a).

### **5.2 European impact assessment methodology**

Standardisation of environmental testing methods for construction products (including road materials) is currently being undertaken by the European Standardisation Organisation (CEN) as part of the development of the Construction Products Directive. It is recognised that environmental performance should be based on contaminant release (leaching) rather than simple content.

Hjelmars (2003, 2001) has discussed the current European approach to the use of alternative construction materials and outlined a series of steps for approaching impact assessment. This procedure follows the methodology of the European prestandard ENV<sup>1</sup> 12920 (ENV 1997) for determining the leaching behaviour of wastes under specific conditions and applies the methodology to alternative road construction materials. The methodology focuses on characterising the release mechanisms through which contaminants from roading materials are leached, and then modelling their subsequent transport through (and attenuation in) environmental media to a receptor or 'point of compliance'. A diagram of the ENV 12920 approach is shown in Figure 5.1.

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<sup>1</sup> ENV is code used by CEN to indicate a prestandard.

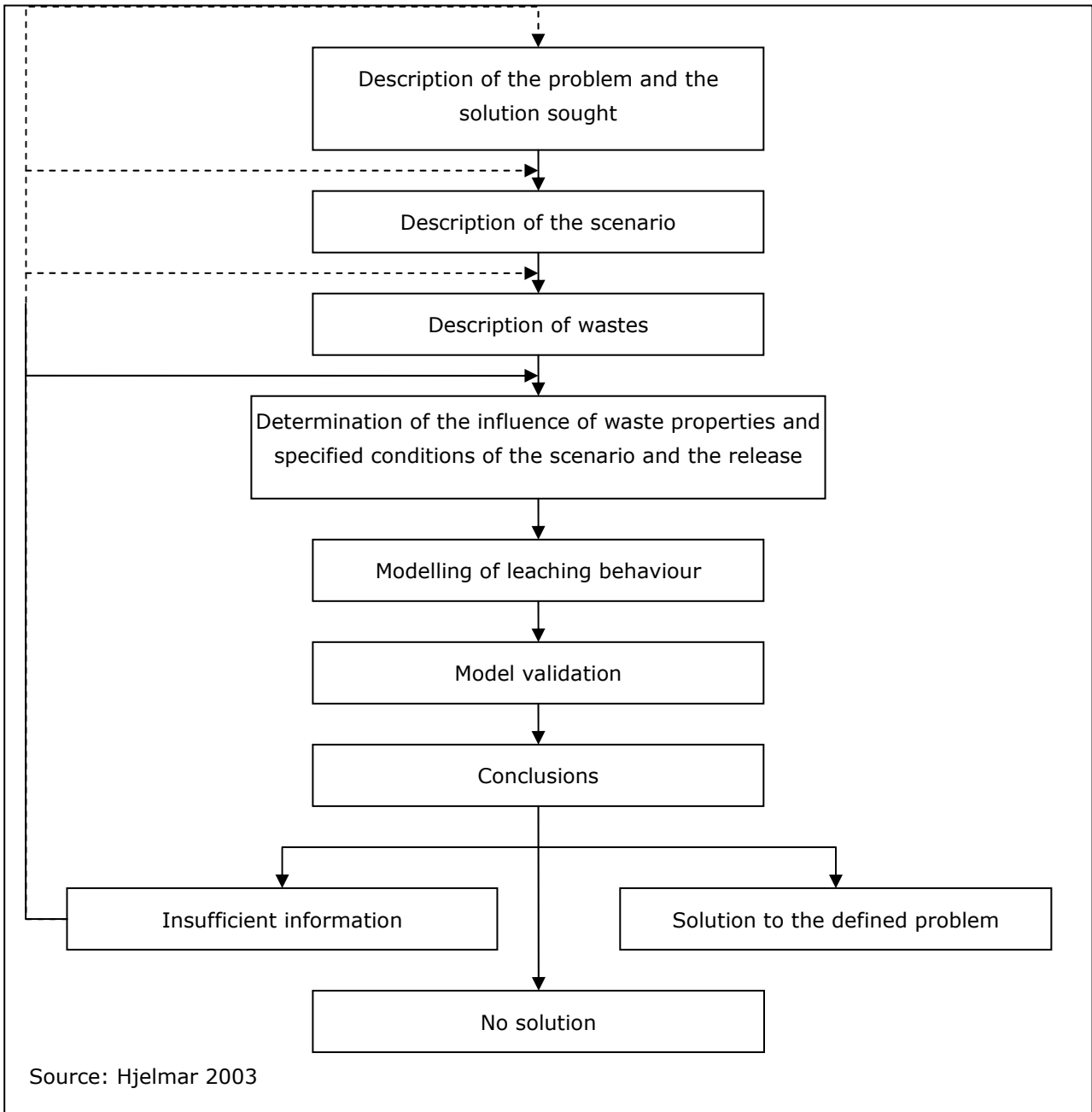


Figure 5.1 Impact assessment procedure for waste and leachates described in ENV 12290.

The suggested approach is site specific; it requires:

- data on the material types used,
- the shape and size of the construction, and
- geotechnical, hydrological and climate data for the specific landscape where construction will take place.

The procedure requires both the modelling of water flow and the release of contaminants as well as the attenuation of contaminants through the environmental medium to be considered. The model calculates contaminant concentrations at specified 'points of compliance', and results are assessed on the basis of

groundwater quality standards. Inputs to the model are provided by appropriate laboratory leaching tests. Although specific testing procedures are not given in ENV 12920, Hjelmar (2003) emphasises that it is essential that the leaching tests used should reflect the likely leaching mechanism in the field (percolation or diffusion controlled – see Chapter 7). Van de Sloot & Dijkstra (2004) note that only inorganic contaminants from largely inorganic materials are considered in the procedure. This is justified by the need to have an operational and relatively simple system for the development of general criteria. However, the need for an impact assessment methodology that goes into more detail for organic constituents has been acknowledged (van der Sloot & Dijkstra 2004).

As in ENV 12920, the detailed methodology presented by Kosson et al. (2002) for the environmental assessment of waste and secondary materials also involves scenario modelling. An initial conservative batch leaching (availability) test at a high liquid/solid (L/S) ratio (100) provides information on the maximum potential for contaminant release without considering the time frame involved. Further analysis involves scenario modelling based on site information such as water infiltration rate, and more realistic leaching tests that determine the effect of pH and L/S ratio.

The Alternative Materials (ALT-MAT) project was a collaborative study undertaken by seven European countries to define methods by which the suitability of alternative materials in road construction can be evaluated (Reid et al. 2001). The work considered engineering evaluation in addition to environmental effects. The ALT-MAT project presented a simple site scenario-based model, similar in principle to those discussed above for environmental assessment. The model aims to predict the leaching of inorganic contaminants into groundwater from granular materials, but is conservative in that it does not account for the attenuation of contaminants during transport through the soil matrix.

### **5.3 The U.S. Transportation Research Board methodology**

A comprehensive study of the environmental impact of construction and repair materials was undertaken by the Transportation Research Board under the National Co-operative Highway Research Program [sic] (NCHRP). An overview of the programme is given by Harrington-Hughes (2000) and Nelson et al. (2001a); see also Huber et al. (2001), Nelson et al. (2001b) and Thayumanavan et al (2001) for summaries of the work. Details of the experimental work are given by Eldin et al. (2000), Nelson et al. (2000) and Nelson et al. (2000b). All reports associated with the study and the computer model developed are available on CD (NCHRP 2001). The study considered the effects of both organic and inorganic contaminants. A methodology for assessing road construction materials was developed (Figure 5.2).

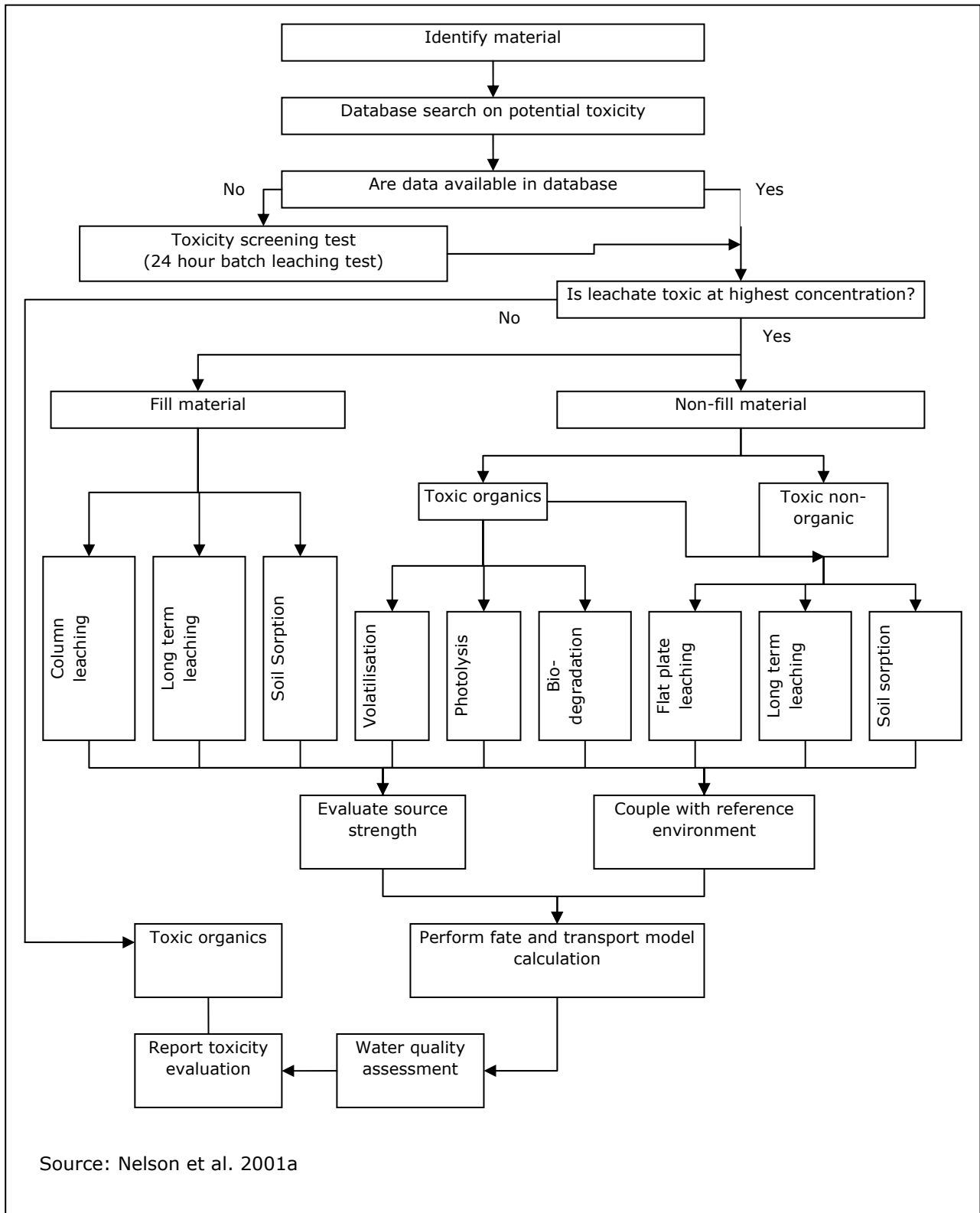


Figure 5.2 A method for assessing the toxicity of potential materials to be used for road construction.

An assessment starts with a search through a database to see if the material has already been evaluated for toxicity. If sufficient data are available, additional laboratory testing is not needed. Materials that have been used with the greatest success have generally undergone significant laboratory and field demonstration testing to ensure that performance criteria defined for the material and application would be met. In some cases (e.g. blast furnace slag, recycled asphalt pavement and coal fly ash), special test methods and specifications have been developed and criteria for use established.

If adequate data do not already exist, a stringent screening (batch leaching) test is applied to the pure material (i.e. not necessarily in the form to be used in practice) and aquatic ecotoxicity tests carried out. The material is crushed to a particle size  $\leq 0.25$  inch and agitated with deionised water at a 4:1 L/S ratio at 20°C for 24 hours (Nelson et al. 2000b). If the screening indicates no toxicity, no further testing is required. Otherwise, a set of more realistic leaching tests (relevant to the actual application of the material in question) are carried out, including column percolation and a flat plate leaching test to simulate the transport of chemicals from an in-place, flat, compacted material surface as a function of time. The method also incorporates steps to model remediation of contaminants which are likely to occur through the natural processes of soil sorption, biodegradation and photo-degradation. Chemical and ecotoxicity tests are carried out on the leachates and the data used in a computer model to calculate contaminant concentrations at points up to several metres from the road. Site conditions (e.g. geometry or water inflow rates) to be used in the model are selected from a set of 'reference environments' which represent typical road environments.

## 6 Use of leaching tests for environmental impact assessments

Leaching is the primary mode through which contaminants from road construction materials enter the environment. Leaching tests can be used to evaluate possible environmental harm through chemical analysis or ecotoxicity testing of the leachates (either through direct interpretation of the results or as input to dispersal models as discussed in Chapter 8). However, laboratory leaching tests may not model field conditions very accurately; the test conditions tend to be more severe than leaching in the field. Interpretation of the results is usually based either on chemical analysis or ecotoxicity testing.

Chemical analyses of leachates can be undertaken and the measured concentration of contaminants compared with some criteria or standard, if available. A drawback of this method is that chemical analysis is limited to those contaminants that are both known and measurable, i.e. if the material contains harmful contaminants that are unknown, they will not be quantified by the analysis.

Ecotoxicity tests assess structural or functional changes that may occur in plants or other organisms in contaminated soils or waterways. Ecotoxicity tests are usually carried out in laboratories, using standard test species. Ecotoxicity testing is a more direct way to measure the environmental hazards of specific materials. Ideally, results of tests should be related to the actual leachate concentrations in the receiving environment at the time of testing (Harrington-Hughes 2000, Nelson et al. 2001a).

Attenuation of leached contaminants are usually not considered in the testing methodologies. These contaminants can occur in the field through processes of removal, reduction and retardation (RRR processes), including soil sorption, photo-degradation and biodegradation (Harrington-Hughes 2000, Nelson et al. 2001).

For evaluating road construction materials, the available test methodologies are usually poor approximations to field conditions. In the USA, a comprehensive study of leaching test methodologies undertaken by the Washington State Department of Ecology revealed that only a few studies compared laboratory leaching test results to actual field data, and most of the studies to date focused on leaching of inorganic rather than organic constituents (DoE 2003).

A wide variety of parameters will affect leaching rates and leachate concentrations achieved in laboratory tests (Table 6.1). Many of these factors are site-specific and cannot be reproduced easily under laboratory conditions. They can be adequately assessed only using full-scale field studies.

**Table 6.1 Main factors influencing leaching processes (from Van der Sloot & Dijkstra 2004)**

<b>Chemical processes</b>	<b>Physical factors</b>	<b>External factors</b>
dissolution pH chemical form total composition/availability redox acid-base buffering composition of water phase/ionic strength temperature time	percolation diffusion surface wash off granular/monolithic (particle size or monolithic) porosity permeability tortuosity erosion	amount of water contact time pH of environment temperature redox of environment dissolved organic matter (DOC)/ adsorption

## 7 Leaching test design

### 7.1 Types of test

Leaching tests can be grouped into two broad classes: equilibrium tests (batch leaching under controlled pH) and non-equilibrium tests (column leaching under various water flow rates, and monolithic surface leaching). Batch leaching tests simulate equilibrium leaching behaviour (i.e. the concentration of a constituent that will leach under a defined pH, temperature and water/solid ratio), whereas column percolation tests provide cumulative release data that describe leaching rates (concentration versus time) under conditions of constant surface renewal. Column tests model field conditions more closely than batch tests (which are primarily a measure of leaching 'potential') but are more difficult to undertake. Monolithic tests (sometimes called Tank tests) determine the leaching rates from a defined surface area where mass transfer across the solid/liquid boundary controls the leaching or flux rate. Such tests are suitable for formed materials such as impermeable concrete slabs.

More detailed descriptions of the generic leaching test methodologies are given in the rest of this chapter. In most of the procedures, the pH of the water used is usually specified and lies in the range 4-8. If toxicity testing is to be carried out on the leachate, the initial pH of the leaching water should be neutral at the start of the procedure. The tests are usually carried out at a temperature of 20–25°C. A large number of leaching tests in current use are discussed in a recent report from the Washington Department of Ecology (DoE 2003).

### 7.2 Batch leaching tests

Granular material is placed in a container which is filled with a specific amount of water. The solid and liquid fractions stand or are mixed over specified period of time (from several hours to days) without renewing the leaching solution with the object of reaching equilibrium. The time taken to reach equilibrium will vary for different constituents and also depends heavily on the particle size of the material. In cases where specific constituents are of interest, their concentration can be monitored and the test extended until equilibrium is reached. In most cases, an exact chemical composition is unknown and equilibrium is assumed. Brannon et al. (1994) report that 24 hours is sufficient for PAHs and inorganics to achieve equilibrium in the leachate of dredge sediments. For materials with larger particle sizes, much longer times may be required; for a material with a maximum particle size of 2 mm, a period of 48 hours is suggested from theoretical considerations (Kosson et al. 2002). The leachate is removed from the container at the end of the test, filtered and then analysed. The amount of water in contact with the tested material is referred to as the liquid/solid ratio (L/S) and is expressed in L/kg. Tests are sometimes performed in multiple steps with different L/S ratios. The extracts are filtered, combined and analysed for the components of interest. Results are normally expressed as mg/kg of tested material as a function of L/S ratio. A simplified batch extraction test is shown in Figure 7.1.

Commonly used batch leaching tests for waste and recycled materials are shown in Table 7.1.



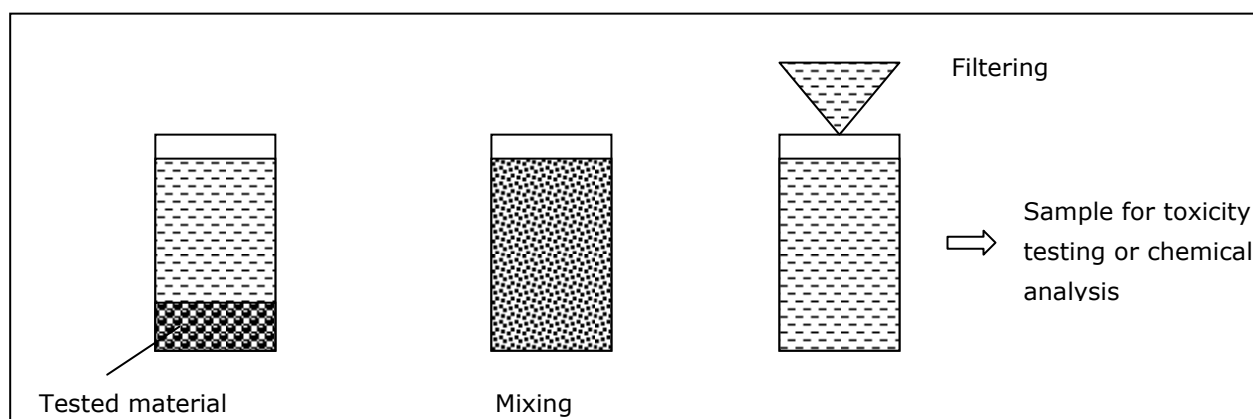


Figure 7.1 Simplified batch leaching test procedure for obtaining samples for analysis.

Table 7.1 Characteristics of commonly used batch leaching tests for waste and recycled materials.

Test method	Particle size (mm)	L/S ratio	Leachant water	Time	Temperature (°C)	Designed for	Source
EPA <sup>a</sup> SW-846 Method 1311 Toxicity Characteristic Leaching Procedure	<10	20:1	pH 4.93 (with acetic acid)	18 hours	23°C	Organic and inorganics, volatile and non-volatile. Intended to assess leaching from wastes in landfills where organic acids are produced through microbial action.	US EPA 1992b
EPA SW-846 Method 1312 Synthetic Precipitation Leaching Procedure	<10	20:1	pH 4.92 or pH 5 (with nitric and sulphuric acid)	18 hours	23°C	Organic and inorganics, volatile and non-volatile. Intended for wastes in monofill dumps which are subject to acid rainfall typical of that experienced in the US.	US EPA 1992b
ASTM <sup>b</sup> D 3987 Standard Test Method for Shake Extraction of Solid Waste with Water	As found	20:1	Natural pH	18 hours	18–27°C	Non-volatile inorganics.	ASTM 2004
NEN <sup>c</sup> 7371 Maximum Availability Test <sup>d</sup>	<0.125	50:1	Sequential extractions at pH 7 then pH 4 (leachates combined for analysis)	3 hours for each extraction	20°C	Non-volatile inorganics	NEN 2004
EN 12457 (parts 1–4) Characterisation of waste – Leaching Compliance Test for Leaching of Granular Waste Materials and Sludges ,parts 1 4	<4 or (part 4) <10	2:1 8:1 or 10:1	natural pH	24 hours	20°C	Non-volatile inorganics	CEN <sup>e</sup> 2002
DD CEN/TS 14429 Characterisation of Waste – Leaching Behaviour Tests – Influence of pH on Leaching with Initial Acid/Base Addition	<1	10:1	pH 2 to 12 (8 separate extractions)	48 hours for each extraction	20°C	Non-volatile inorganics	CEN 2005

Notes to Table 7.1:

- a Environmental Protection Agency
- b American Society for Testing and Materials
- c NEN: Nederlands Normalisatie-Instituut (code used by CEN to indicate a standard developed in the Netherlands)
- d This test is a development of the earlier NEN 7341.
- e Comité Européen de Normalisation (European Committee for Standardisation)

### 7.3 Column/percolation leaching tests

The column (upflow percolation) test is performed using a column filled with granular test material and leached with slowly flowing water (so that the sample material is not mechanically agitated). In this way, the test material is constantly exposed to fresh water. Water flow is usually in an upward direction to reduce the possibility of blockage through the migration of fine particles. Concentrations of leached constituents are measured periodically in the eluate and are expressed as mg/L versus percolated water volume (L/S ratio) or as a cumulatively leached concentration (mg/kg). A simplified column leaching procedure is shown in Figure 7.2.

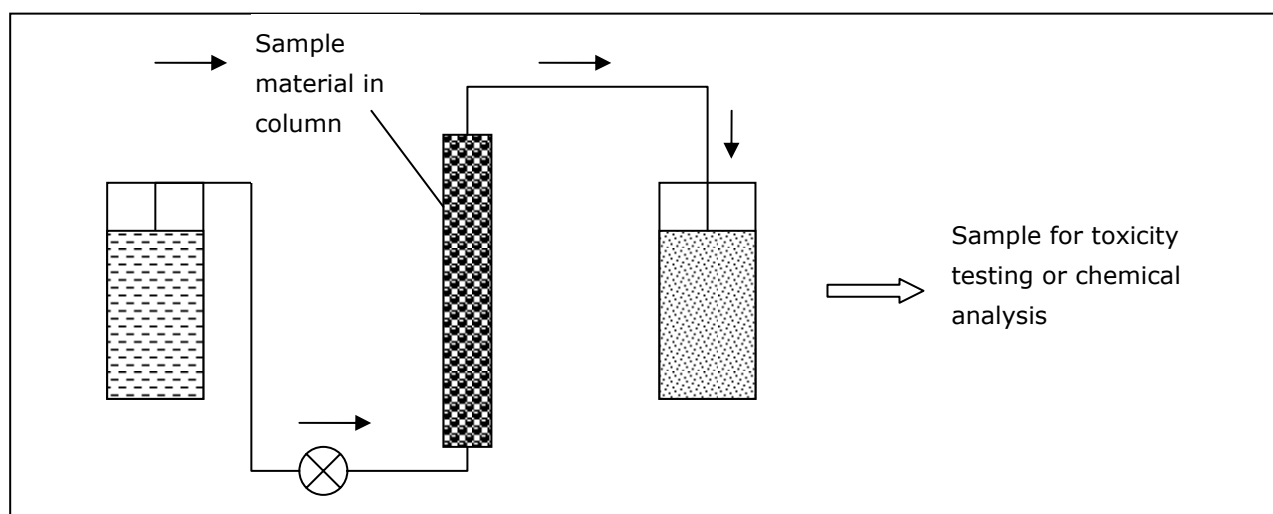


Figure 7.2 Column (percolation) leaching test procedure.

Commonly used column/percolation leaching tests for waste and recycled materials are shown in Table 7.2.

Table 7.2 Commonly column/percolation tests for waste and recycled materials.

Test method	Particle size (mm)	Leachant water	Flow rate	Temperature (°C)	Designed for	Source
ASTM D 4874 Standard Test Method for Leaching Solid Waste in a Column Apparatus	<10	natural pH.	Adjust to achieve column void volume exchange time of 24 hours	Ambient	Non-volatile organics and inorganics	ASTM 2006
DD CEN/TS 14405 Characterisation of waste – Leaching Behaviour Tests – Upflow Percolation test (under specified conditions).	<10	natural pH	12 or 48 ml/hr depending on column size (5 or 10 cm diameter respectively)	20°C.	Non-volatile organics and inorganics	CEN 2004

## 7.4 Monolithic leaching tests

These are batch leaching tests appropriate for monolithic materials. Monolithic materials are usually defined (van der Sloot & Dijkstra 2004) as those where the release of constituents to the surrounding water is diffusion controlled (in contrast to loose granular materials where the release is percolation rate controlled).

Examples of monolithic materials include formed products and materials which usually have small surface area/weight ratios compared to granular materials such as bricks, plastic drainpipes, concrete slabs and bitumen films. The test material is placed in a tank and water is added. Over a specified period of time, concentrations in the water are measured. The results of the chemical analysis of the leachate are expressed as the cumulative mass of leached chemical per surface area of the sample ( $\text{mg/m}^2$ ), as a function of time.

The most commonly used monolithic leaching test is NEN 7375, which is a development of the earlier NEN 7311. The characteristics of this test are shown in Table 7.3.

**Table 7.3 Characteristics of the monolithic leaching test NEN 7375.**

Test method	Sample surface area	L/S ratio	Leachant water	Time	Temperature (°C)	Designed for	Source
NEN 7375 Leaching Characteristics – Determination of the Leaching of Inorganic Components from Moulded or Monolithic Materials with the Diffusion Test – Solid Earthy and Stony Materials.	>75 cm <sup>2</sup>	2 to 5 times sample volume	Natural pH	64 days	20°C	Non-volatile inorganics	NEN 2004b

## 7.5 Simulation of field conditions

One approach is to use a climate chamber that can simulate the effects of real environmental conditions on materials by accelerating the freeze-thaw and wetting-drying cycles that would occur naturally. More commonly, actual field measurements are made with a lysimeter; typically, for granular or fill materials, this consists of a contained volume of material constructed *in situ* and exposed to the elements as it would be in practice. Leachate from the lysimeter is collected from a drain. Comparing the results of leaching tests with field lysimeter and climate chamber tests indicates that in the laboratory, column percolation tests are likely to provide a more realistic simulation of the actual leaching behaviour of granular materials in the field than batch tests (Reid et al. 2001).

## 8 Leachate analysis

### 8.1 Chemical analysis

Chemical analysis can include determination of specific elements including metals, specific ions, organic carbon and different organic compounds. Chemical methods for these types of analyses are well developed and can be performed according to the US EPA or European Union standards, among others. For analysing organics, the usual approach is solvent extraction and concentration of the aqueous leachate, which is then followed by gas chromatography, gas chromatography–mass spectroscopy or high pressure liquid chromatography. Inorganics can be determined by ion chromatography or, more commonly, atomic absorption spectrometry or inductively coupled plasma atomic emission spectrometry.

The leachates from roading construction materials are typically chemically complex and are likely to contain a combination of organic and metallic compounds, and ions in solution. It can be difficult or impossible to analyse for all possible toxicants. Sometimes it is not clear which component of the leachate will have the greatest impact, or the toxicology of a measured component is unknown. A prohibitively costly, extensive analysis of leachate constituents can be avoided by assessing the potential environmental impact using the leachate directly in toxicity tests.

### 8.2 Direct ecotoxicity assessments

Ecotoxicology is the study of the harmful effect of chemicals on environmental resources. Direct data (i.e. data generated by ecotoxicity tests) and indirect data (comparison of concentrations with protective environmental criteria) are used to predict the ecotoxicological hazard of a material. Much of our understanding of chemical impacts on the environment is based on the results of well-established standardised ecotoxicity tests. The primary advantage of toxicity tests over the exclusive use of chemical analysis is the ability to assess the effect of chemically undetected or unidentified constituents, and also to allow consideration of the toxicity of a complex mixture of chemicals. Measuring toxicity allows a quantitative measurement of the direct effects of leached roading materials (Eldin et al. 2000).

Under the methodology that was developed in the US to evaluate highway construction and repair materials, the environmental impact was measured in terms of aquatic toxicity and chemical concentrations of toxic substances (Eldin et al. 2000). Leachate ecotoxicity tests were conducted using organisms such as the freshwater macroinvertebrate *Daphnia magna* (water flea) and the freshwater green alga *Selenastrum capricornutum*. Both a plant (algae) and an animal (*Daphnia*) species were selected for testing of the roading materials because plants and animals have biological differences which would cause them to react differently to different chemicals. A microbial test (Microtox – a kit test that used a luminescent marine bacterium) was also evaluated but concerns over the Microtox test sensitivity and its applicability limit its use in assessing roading materials. Laboratory protocols for toxicity evaluation using freshwater green alga *S. capricornutum* and water flea *D. magna* were developed from existing methods used by the US EPA for evaluating industrial effluents and other kinds of hazardous chemical assessments.

Two specific measures of toxicity are used in the US method: lethal concentration (LC<sub>50</sub>) for *D. magna* and growth inhibition (EC<sub>50</sub>) for *S. capricornutum*. The LC<sub>50</sub> is the median lethal concentration, being a statistically derived concentration of a substance that can be expected to cause death in 50% of organisms exposed for a specified time and the EC<sub>50</sub> is the median effect concentration, which is a statistically derived concentration of a substance that can be expected to cause a 50% reduction in growth or in the growth rate of organisms (ERMA 2001).

The European impact assessment framework proposed by Hjelmar (2003) for assessing alternative raw materials for construction purposes does not use direct ecotoxicity assessments. Rather, it focuses on characterising the release mechanisms through which contaminants from roading materials are leached and their subsequent transport through (and attenuation in) environmental media. It also compares modelled environmental concentrations with groundwater criteria.

However, a broad search of the literature from Europe indicates that, under the European Directive on hazardous waste (91/689/EEC and the European Council Decision 94/904/EC), regulatory bodies are grappling with how best to describe waste in terms of the hazardous criterion H14: 'Ecotoxicity'. Many publications from Europe either support or are conducting research to investigate how direct ecotoxicity testing can be incorporated into their assessment approach e.g. Deventer & Zipperle 2004 (Germany), Vaajasaari 2005 (Finland), Environment Agency 2005 (United Kingdom), Lapa et al 2002 and UNEP 2001 (EC), and MoE/MoH 2001 (Czech Republic). Many of these reports have been published in recent times and reflect both the lack of development in this area as well as current trends in this area.

In the UK, the Environment Agency guidance material on the testing of hazardous wastes recommends testing the water accommodated fraction (WAF) of a waste using the same types of ecotoxicity tests recommended in the Eldin et al. (2000) report from the USA, i.e. 48 h *D. magna* acute lethality and the 72 h algal growth inhibition test. The recommendation is that the WAF be limit-tested at 100%. If 100% WAF causes ≥50% ecotoxic effect in either of the tests then the waste is considered ecotoxic (Environment Agency 2005). It is believed that assessing ecotoxic hazards of waste materials based solely on aquatic toxicity data would result in the same classification as an assessment that included terrestrial data. Terrestrial tests are recommended only if there is reason to believe that a waste contains substances that have effects only on the terrestrial environment. In such a case, the 100% leachate could be used in a terrestrial plant germination and growth test and/or a soil organism test such as the collembola (springtail) reproduction test or the earthworm acute test.

ERMA recommends similar standardised test methods for assessing substances with potential ecotoxic properties (ERMA 2001). These international tests include those using *D. magna* and *S. capricornutum*.

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## **Appendix A: Guidelines for evaluating the environmental effects of road construction materials in New Zealand.**

This appendix is designed as a stand-alone document for the use of interested parties.

## **A1 Introduction**

### **A1.1 Aims**

These guidelines aim to provide a simple screening process for evaluating possible adverse environmental effects on water, groundwater and soil from the leaching of contaminants from new or recycled materials used in road construction. Effects on human health are not explicitly considered. The guidelines are intended to provide assistance to New Zealand roading authorities, roading contractors and suppliers when deciding whether to approve or seek approval for new or recycled materials for road construction. The guidelines do not consider environmental impacts associated specifically with construction activities such as sediment runoff. Guidelines for minimising environmental impacts during construction have been published previously (Montgomery Watson Ltd 1999a, 1999b, 1999c) and will also apply to construction activities using new or recycled materials.

### **A1.2 Disclaimer**

It is important to note that the legal framework governing the use of potentially environmentally harmful materials in New Zealand is set out principally in two pieces of legislation (see Chapter 2), the Hazardous Substances and New Organisms (HSNO) Act 1996 and the Resource Management Act (RMA)1991. Approval by Transit New Zealand or other roading authorities for the use of a material in road construction, on the basis of the present guidelines, in no way affects the legal obligations of the users of the materials under these or other relevant Acts.

### **A1.3 Process overview**

A three-stage process for material evaluation is recommended. The process is outlined below and shown schematically in Figure A1.1.

#### **Stage 1: initial assessment**

The initial stage involves taking advantage of all existing information and data in order to determine:

- if the material is hazardous, and
- whether or not it needs to undergo approval by the Environmental Risk Management Authority New Zealand (ERMA) prior to use in road construction in New Zealand.

Where there is insufficient information available on the chemical composition or ecotoxicity of the material, Stage 2 testing is recommended.

#### **Stage 2: material screening tests**

This stage involves a screening test of the material to determine if it contains leachable contaminants that may cause an environmental impact if released. The leaching procedures suggested aim to provide a conservative estimate of whether the material contains hazardous contaminants in a leachable form. Leachates are assessed by chemical analysis and tested for aquatic ecotoxicity. The test results are assessed by comparison to New Zealand landfill waste acceptance criteria (WAC) for Class B landfills and the ERMA regulations.



**Stage 3: comprehensive environment impact assessment**

The third stage is a comprehensive assessment that may be required if Stage 2 assessment indicates that the material contains contaminants that could leach and cause harm to the environment. This stage involves a more comprehensive environmental impact assessment using data from less conservative (more realistic) leaching tests which include site parameters (e.g. geometry and hydrology) to model the release, transport and fate of the contaminants over time from the source to the potential receiving environments/receptors. Suggestions are made as to how such an assessment could be made but development of a detailed process is beyond the scope of this document.

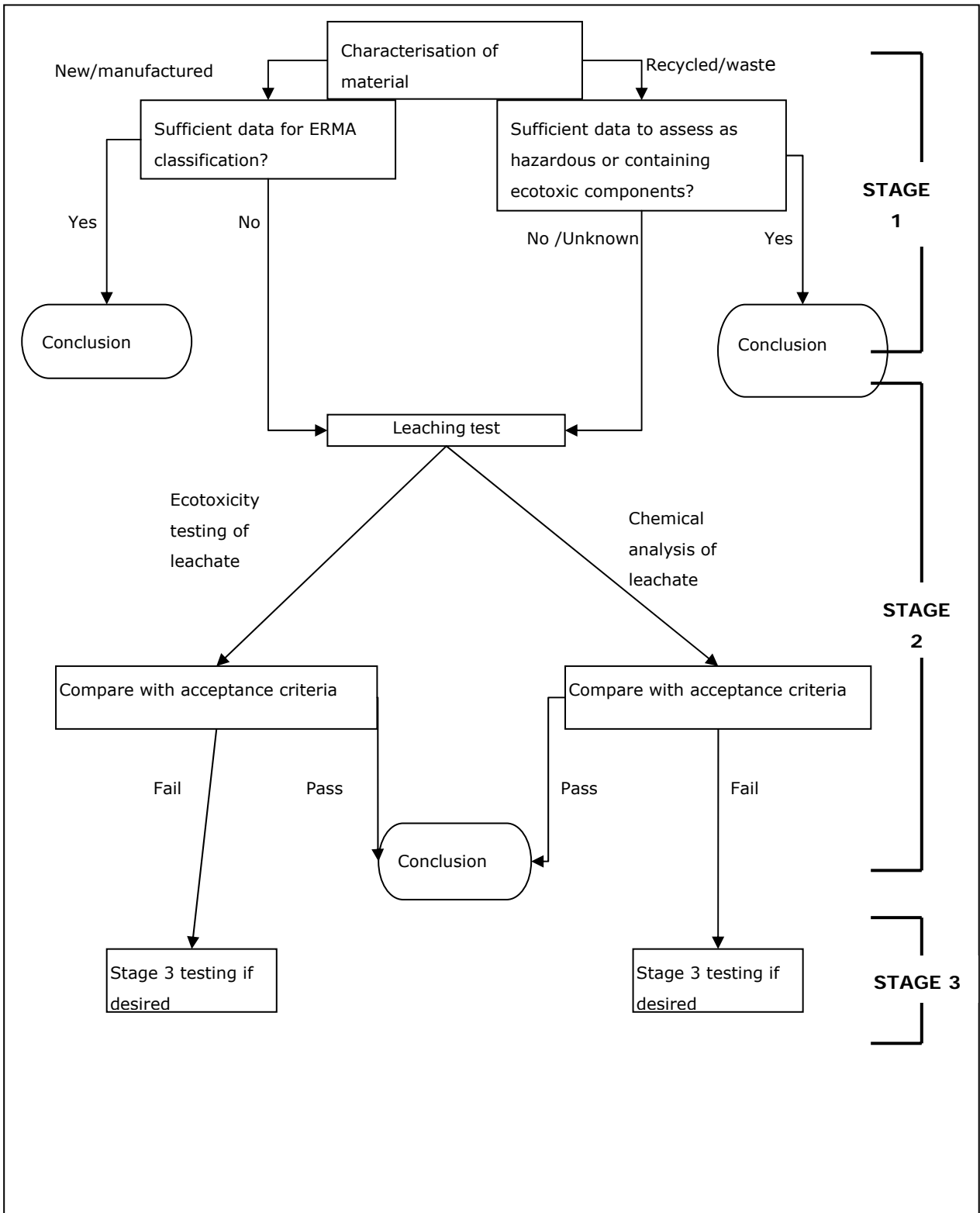


Figure A1.1 Environmental evaluation of road construction materials – process diagram.

## **A2 Stage 1: initial assessment**

### **A2.1 Purpose**

Stage 1 of the process is to gather information in order to determine (based on what is already known about the material) whether the new material or recycled waste is considered hazardous to the environment. The following guide suggests likely sources of this information.

### **A2.2 Legislation, regulations and guidelines**

This part of the chapter provides general guidance pertaining to environmental legislation and regulations that an applicant may face when proposing to use new or recycled materials in roading construction. These guidelines are not a substitute for qualified legal advice regarding the Acts or their application by regulatory authorities.

From the perspective of environmental management, the RMA and the HSNO Act 1996 broadly deal with the management of hazardous materials, and act in a complementary way to protect the environment from the adverse impacts of such materials. The HSNO Act regulates the use of hazardous chemicals in New Zealand. The RMA (1991) sets out the regulatory framework for managing the effects of land and water use activities, and discharges to the environment.

#### ***A2.2.1 The HSNO Act 1996***

The HSNO Act 1996 was introduced to protect the environment, people and communities from the adverse effects of hazardous substances and new organisms. Under the HSNO Act, a hazardous substance is any substance that exceeds the level defined in regulations of any of the following properties:

- an explosive nature (including substances, articles and pyrotechnics such as fireworks),
- flammability,
- ability to oxidize (that is, to accelerate a fire),
- corrosiveness,
- acute or chronic toxicity (adverse human health effects),
- ecotoxicity, with or without bioaccumulation (i.e. it can kill living things either directly or by building up in the environment), or
- the ability to generate a hazardous substance on contact with air or water.

The Act came into force as of July 2001. It requires that approval is sought (from ERMA) for all hazardous substances that are deliberately manufactured, formulated in or imported to New Zealand (including naturally occurring substances) for the first time (i.e. if not legally present in New Zealand before 2 July 2001). Existing hazardous substances (i.e. those legally present before 2 July 2001) have been or are being transferred from the older legislation (such as the Dangerous Goods Act 1974 and the Toxic Substances Act 1979). Most dangerous goods and scheduled toxic substances were transferred to the HSNO on 1 April 2004, with most remaining hazardous substances transferred by 1 July 2006.

If the reader is uncertain about whether or not a roading material has been or is approved for use in New Zealand under the HSNO Act, he/she can search the ERMA website for further information (ERMA 2006c). Alternatively, a Status of Substance determination can be requested from ERMA.

The Act does not normally require approval to be sought for hazardous waste materials unless they are imported. 'Waste materials' in this sense are materials that have no value or present a disposal cost to the generator at the time of initial generation. However, wastes that are subsequently processed or modified (i.e. manufactured) may be considered a 'new' material and, if hazardous, require ERMA approval. Clarification as to whether a given material can be considered a waste or not, and whether it may be exempt from the Act, should be sought from ERMA. Non-hazardous new substances or wastes do not need approval. Manufactured articles are normally not covered by the HSNO Act. However, if manufactured in New Zealand, their component substances may be covered by the Act.

ERMA considers manufactured articles to be those for which the intended use is primarily to do with physical form or shape, rather than chemical composition. In road construction, drainpipes and geofabrics, for example, would be considered manufactured articles, but asphalt mixture would not. Controls imposed by the Act extend for the lifetime of the substance. Hence, use of materials derived by processing post-consumer wastes may still be governed by the original controls on the component substances.

#### ***A2.2.2 Resource Management Act 1991***

The RMA focuses on managing the adverse environmental effects of activities such as road construction (though not the activities themselves). In this present context, it specifically restricts the discharge of contaminants to the environment and requires local authorities to control the use of land for the storage, use and disposal of hazardous substances. The RMA has a broader definition of 'hazardous substance' than the HSNO Act which includes hazardous wastes. Chapter 15 of the RMA specifically refers to the discharge of contaminants into the environment.

All discharges of contaminants to air or water – and to land, if the contaminant may contaminate water or is on industrial or trade premises – require a discharge permit unless the discharge is specifically allowed by a rule in a regional plan or regulations. Conditions will be included in the regional rule or discharge permit to control any adverse effects of the discharge. Where HSNO controls exist for a regulated substance that is present in waste, these will form the basic requirements (i.e. consent conditions) under the RMA. However, the RMA also deals with site-specific issues and this includes cumulative effects of discharges from a range of sources.

#### ***A2.2.3 The New Zealand Hazardous Waste List***

The New Zealand Waste List, called the 'L-Code' (MfE 2006) is neither an Act nor a regulation, but is a database maintained by the Ministry for the Environment (MfE) that provides guidance on wastes generated by various industry sectors and municipal wastes. The L-Code contains a wide range of wastes, including those that are regarded as hazardous. The L-Code can be consulted to evaluate whether a recycled material for use in road construction is likely to contain hazardous substances that may have an adverse impact on the environment. The most recent version of the L-Code can be accessed online.

Many recycled materials that may be/are used in road construction fall under category #17: 'Construction and demolition wastes'. Construction and demolition wastes are generally regarded as high volume, low risk wastes; soil, concrete and rubble are often disposed of in clean fills which have restrictive acceptance criteria and which do not accept hazardous waste.

#### ***A2.2.4 New Zealand regulatory requirements for new or recycled materials in road construction***

As discussed above, different regulatory requirements apply according to the nature of the material in question. The various scenarios that may arise are outlined below.

- 1. If a material has historically been used in road construction in New Zealand and is not known to have hazardous properties** or to release contaminants into the environment, then its use is not likely to be controlled under the HSNO Act or the RMA. Quarried aggregates are an example of this type of material.
- 2. If a material has historically been used in roading construction in New Zealand and is known to have hazardous properties**, it will be transferred under the HSNO Act (1996). Hazardous properties include ecotoxicity characteristics. If a material that exhibits hazardous properties is approved under the HSNO Act (1996), ERMA will set controls to ensure that its use does not result in any adverse impacts on the environment. An example of this type of material is kerosene. If the material is not considered to be hazardous then its use will not be controlled.
- 3. If a new material (imported or manufactured) is proposed for use in road construction in New Zealand**, it will require risk assessment by ERMA under the HSNO act prior to receiving approval for use in New Zealand (if the material is deemed by ERMA to be similar to an existing substance, then a full assessment will not be required). The applicant must provide ERMA with enough information to allow them to decide whether or not the material has hazardous characteristics and therefore whether it falls under the HSNO regulations or not. If the material does have hazardous properties, further information regarding the environmental fate and toxicity of the material will be required. If a material that exhibits hazardous properties is approved under the HSNO Act (1996), ERMA will set controls to ensure that its use does not result in any adverse impacts on human health or on the environment. An example of this type of material would be a new type of adhesion agent. If the new material is not considered to be hazardous then its use will not be controlled.
- 4. If a material is proposed for use in road construction in New Zealand (irrespective of whether it is deemed 'hazardous' or not under the HSNO Act)**, the potential environmental impacts of its application in road construction will still need to be assessed under the RMA. Any information collected as part of a HSNO assessment will be able to contribute to an environmental impact of the proposed activity (e.g. construction of a road using a recycled waste material) as required under the RMA in the Assessment of Environmental Effects (AEE). This information will assist local authorities in their decision to give consent to the activity and for setting the appropriate consent conditions for the activity.
- 5. If the material proposed for use in road construction is a waste product generated in New Zealand**, it is unlikely to be covered by the HSNO Act ('waste' in this sense would not necessarily include processed post-consumer waste). However, under the RMA, the applicant will be

required to provide information regarding the likely environmental impact of the waste when used for building roads. This will include information about the chemical contaminants present in the waste, and their fate and toxicity. An applicant can refer to the L-Code (MfE 2006) to assess whether the waste is likely to have hazardous properties. An example is waste plastic from an industrial process.

- 6. If the material proposed for use in road construction is a waste product generated outside of New Zealand** and it is classed as a hazardous waste under the Basel Convention, then approval must be sought under the HSNO Act and a permit will be required to import it. Under the RMA, the applicant must provide information regarding its likely environmental impact when used for making roads. This will include information about the chemical contaminants present in the waste, and their fate and toxicity.

## **A2.3 The process for assessing materials**

### ***A2.3.1 Initial steps***

The following procedure is a step-wise process that potential importers, manufacturers or users of a new road construction material can use to assess whether or not their material might be considered hazardous under the HSNO Act 1996.

The first step is to decide whether the material in question was deliberately manufactured or formulated (and hence may be considered a 'substance' under the HSNO Act) or is a waste or by-product. Materials that fall under the HSNO Act will either have been approved or will require approval by ERMA and may have controls placed on their use. If an applicant has any doubt as to the classification of a material, he/she should consult ERMA (2006a).

To decide whether a substance requires Stage 2 testing, follow the process diagram in Figure A2.1.

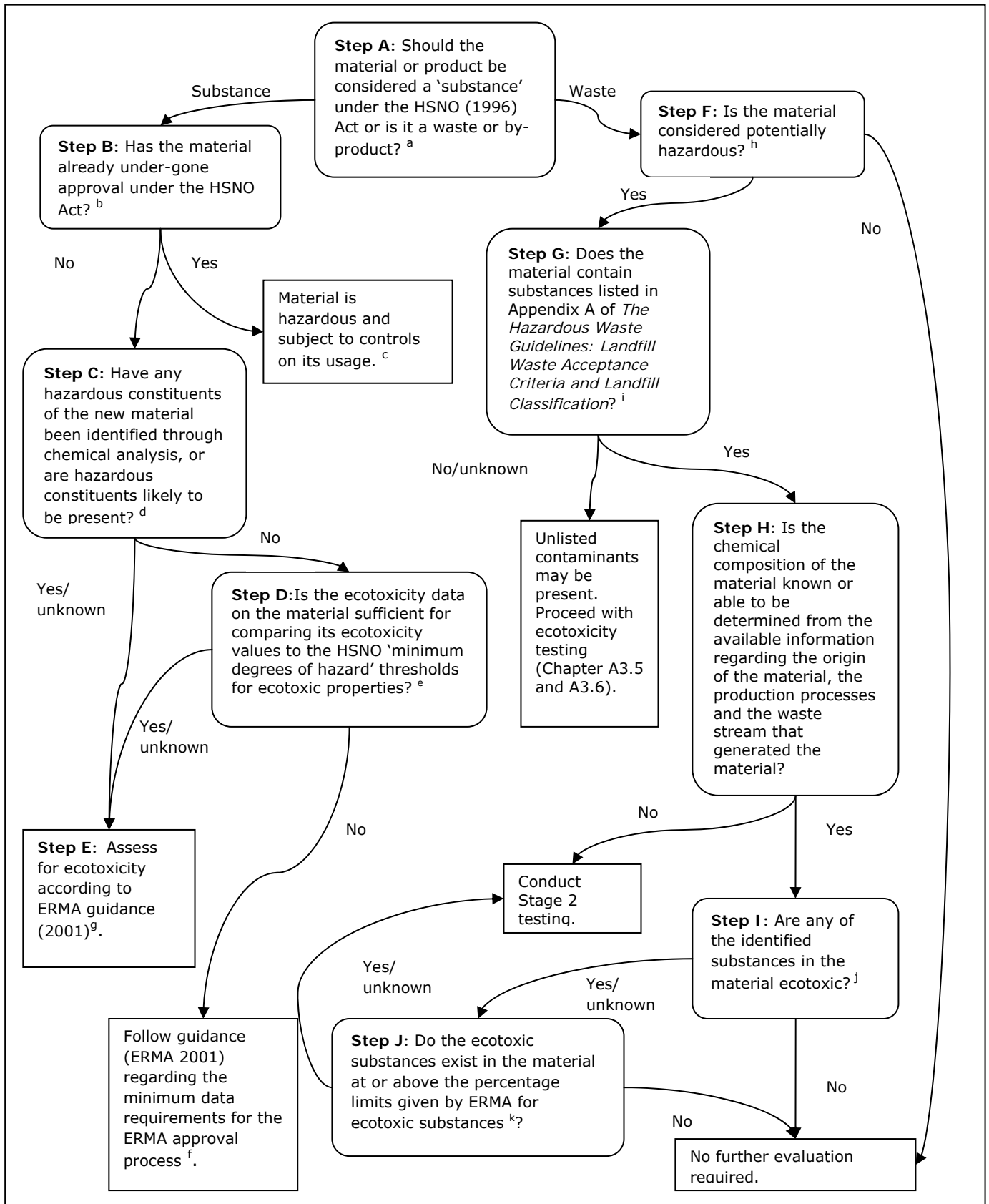


Figure A2.1 Process diagram for deciding whether a substance needs Stage 2 testing.

**Notes to Figure A2.1:**

- a Under the Act a substance is defined as:
  - i. any element, defined mixture of elements, compounds or defined mixture of compounds, either naturally occurring or produced synthetically, or any mixtures thereof;
  - ii. any isotope, allotrope, isomer, congener, radical, or ion of an element or compound which has been declared by the Authority (i.e. ERMA), by notice in the Gazette, to be a different substance from that element or compound;
  - iii. any mixtures or combinations of the above; or
  - iv. any manufactured article containing, incorporating or including any hazardous substance with explosive characteristics.
- b Check on <http://www.ermanz.govt.nz/search/registers.html> or request a Status of Substance determination. The importer, manufacturer or user of the new material will need to assess whether or not the material has 'hazardous characteristics' under the HSNO Act 1996. The manufacture, importation or use of a hazardous substance in New Zealand without an approval from ERMA is an offence under section 25(1) of the HSNO Act. The initial responsibility for determining if the new material is hazardous rests with the importer, manufacturer or user of the substance. ERMA provides some guidance material to assist with this (ERMA 2001); however, it is strongly advised that the potential applicant contact ERMA for guidance before making an application (ERMA 2006a). Informal advice on whether or not a substance is hazardous and/or covered by an existing approval can be sought from ERMA for a small fee.
- c An assessment of its ecotoxicity will have been included in the approval process and may provide useful information for determining environmental risk if used in road construction. Controls such as Environmental Exposure Limits (EELs) may have been set that will need to be taken into consideration for its final use. Stage 2 or 3 testing may be useful to assess whether the material will pose an unacceptable risk to the environment and human health.
- d Based on knowledge of the raw materials or processing conditions used.
- e See Table A2.1. ERMA provides links to internet sources of information that may be useful (ERMA 2006b).
- f Obtaining ERMA approval will, in most cases, require data on the ecotoxicity of the material at different concentrations in water. However, most materials used in road construction will be poorly soluble in water so obtaining aquatic ecotoxicity data is problematic. The approach usually taken in such cases is the generation of a WAF from a leaching test as described in Chapter A3.6.1. In all cases, before an applicant undertakes an extensive testing programme, he/she should discuss details of the proposed work with ERMA to ensure that the testing methodology is appropriate.
- g If the material is deemed not hazardous in this initial assessment then ERMA approval under the HSNO Act is not required. Validation of the assessment by ERMA is not required but the assessment should be thoroughly documented.
- h In the New Zealand Waste List, hazardous wastes in each category are identified with an asterisk. For a full list showing the details of each hazardous waste category, refer to the MfE website (MfE 2006). A greater detail of each waste category is contained in Appendix B of the UK Technical Guidance document WM2 on Hazardous Waste: Interpretation of the definition and classification of hazardous waste. This can be accessed online (SEPA 2006).
- i MfE 2004
- j In other words, would they trigger the ERMA 'minimum degrees of hazard' for Class 9 substances (specifically, 9.1 aquatic toxicity, and/or 9.2 soil toxicity)?
- k For acute aquatic ecotoxicity, the cut-off percentage is <1%ww unless the substance has an acute LC<sub>50</sub> or EC<sub>50</sub> of <0.1 mg/L. For soil ecotoxicity, the cut-off percentage is also < 1%ww and the DT<sub>50</sub> (half life in soil) is <30 days unless the substance soil ecotoxicity value is <0.1 mg/kg.



**Table A2.1 Limits and definitions of ecotoxicity, according to the Hazardous Substances Act (1996) (minimum degrees of hazard) regulations.**

<b>Schedule 6, 2. Minimum degrees of hazard for substances with ecotoxic properties</b>	
<b>1 A substance with ecotoxic properties is not hazardous for the purposes of the HSNO Act (1996) unless:</b>	
a	The substance is ecotoxic to aquatic organisms because: (i) data for the substance indicates that the fish (96 hour) LC <sub>50</sub> <sup>a</sup> is ≤100 mg/L or, (ii) data for the substance indicates that the crustacean (48 hour) EC <sub>50</sub> <sup>b</sup> is ≤100 mg/L or, (iii) data for the substance indicates that the algal or aquatic plant (72-96 hour) EC <sub>50</sub> is ≤100 mg/L or, (iv) data for the substance indicates that the chronic fish, crustacean, algal or aquatic plant NOEC <sup>c</sup> is ≤1 mg/L or (v) in the absence of NOEC data, data for the substance indicates that it is not rapidly degradable and is bioaccumulative; OR
b	The substance is ecotoxic to soil organisms because: (i) data for the substance indicates that the plant or soil invertebrate (14 day) EC <sub>50</sub> is ≤100 mg/kg, or (ii) data for the substance indicates that the a 25% reduction of micro-organism respiration, or nitrification (28 day) occurs at ≤100 mg/kg dry weight of soil; OR
c	The substance is ecotoxic to terrestrial vertebrates because: (i) data for that substance indicates an acute avian or mammalian oral or dermal LD <sub>50</sub> <sup>d</sup> is ≤ 2000 mg/kg, or (ii) data for that substance indicates an acute avian or mammalian LC <sub>50</sub> is ≤5000 ppm diet, or (iii) data for that substance indicates a chronic avian or mammalian MATC <sup>e</sup> ≤100 ppm diet; OR
d	The substance is ecotoxic to beneficial terrestrial invertebrates because the data for that substance indicates an acute contact or oral LD <sub>50</sub> of ≤25 µg/bee; OR
e	The substance is designed for biocidal action.
<b>2 A substance referred to in subclause (1) (e) is not hazardous for the purposes of this schedule if :</b>	
a	The substance is designed for biocidal action against a virus, protozoan, bacterium or an internal organism in humans or other vertebrates; AND
b	The substance does not meet any of the minimum degrees of hazard specified in subclause 1(a) to (d).

Notes to Table 2.1:

- a LC<sub>50</sub>: the median lethal concentration, being a statistically derived concentration of a substance that can be expected to cause death in 50% of organisms exposed for a specified time.
- b EC<sub>50</sub>: the median effect concentration, being a statistically derived concentration of a substance that can be expected to cause an adverse effect in 50% of organisms; or a 50% reduction in growth or in the growth rate of organisms
- c NOEC: (no-observed effect concentration) the highest concentration of a substance that does not produce a significant ecotoxic effect in an organism or in an organism population.
- d LD<sub>50</sub>: the median lethal dose, being a statistically derived single dose of a substance that can be expected to cause death in 50% of organisms.
- e MATC: Maximum Acceptable Tolerance Concentration. This is the geometric mean of the NOEC and LOEC where the NOEC and LOEC are derived from the same study.

## **A3 Stage 2: material screening tests**

### **A3.1 Purpose of Stage 2**

Where there is not enough information available on either the chemical composition of a new or recycled waste material, or on the potential ecotoxicity of that material, Stage 2 testing should be conducted. Stage 2 involves laboratory testing to see if toxic contaminants are likely to be released (leached) from the roading material at a level that is likely to cause an adverse impact in the environment. New materials and recycled waste materials are subject to the same testing regime.

Stage 2 assessments consist of a simple batch leaching test to:

- determine if leachable concentrations of potential contaminants are below the specified acceptance criteria, and
- determine if the leachate is toxic to aquatic and/or soil organisms using direct ecotoxicity testing of the leachate (at 100%).

Ecotoxicity tests are necessary, as the bioavailability of substances in environmental media may not be accurately reflected simply in measured (total) concentrations. Additionally, chemical analysis is interpreted in terms of the toxicity of the pure chemical species and cannot take any 'mixture' interactions fully into account, as the presence of some species may be unknown. Such interactions can negate, add to or increase the toxicity experienced with exposure to a single chemical.

Stage 2 assessments do not cover ecotoxicity that results from environmental contamination caused by release of fine particles from roading materials. These impacts (such as those resulting from sediment runoff) are associated specifically with construction activities. Guidelines for minimising environmental impacts during construction have been published previously (Montgomery Watson Ltd 1999a, 1999b, 1999c) and will also apply to construction activities using new or recycled materials.

Before an extensive testing programme is undertaken, details of the proposed work should be discussed with ERMA and TNZ or the appropriate local authorities to ensure that the results of the testing work will meet all relevant concerns.

### **A3.2 Material classification**

For the purposes of assessments made using these guidelines, construction materials are divided into two classes:

1. materials exposed to the action of traffic and hence subject to wear and abrasion (examples include sealing aggregates, bituminous surfacings and road marking paints), and
2. materials not exposed to the action of traffic (examples include aggregates used in sub-surface pavement layers and basecourse stabilising agents).

### **A3.3 Sampling**

A representative sample of the material must be used in the evaluation. Applicants should consider batch-to-batch variation and the possible effects of weathering on stockpiles of material. Combined samples from a number of batches or samples collected over a period of time may be required. Evidence that the consistency of the material composition has been properly considered should form an integral part of the material evaluation.

### **A3.4 Form in which the material is tested**

The following principles should be applied:

1. Materials that will be used as mixtures or blends with other materials in practice should be tested in that form at the highest concentration used. For example, aggregate stabilising additives which are expected to be used at up to 3%ww should be tested at that concentration in a suitable aggregate matrix.
2. Materials that will remain essentially as discrete elements of the road structure should be tested in their 'pure' form. For example, road marking paints or a waste material to be used as fill (without significant mixing with other aggregate material) should be tested without dilution.
3. Materials that are likely or designed to react or cure rapidly after construction (e.g. basecourse stabilisers) should be tested in the form they are in when first introduced to the road structure and again in a form approximately equivalent to that likely after 30 days *in situ* (other time intervals can be used if warranted by particular features of the material).
4. Materials intended as modifiers or additives to bitumen (e.g. adhesion agents or polymeric additives) should be tested at the appropriate concentration in bitumen as part of an asphalt mixture with 5% bitumen content. The TNZ mix 10 (TNZ 2005) aggregate grading or similar is suitable. For the purposes of a leachate screening test, this approach provides a much larger surface area of bitumen than could be conveniently obtained in a monolithic test (e.g. flat plate).

### **A3.5 Batch leaching test for chemical analysis**

#### ***A3.5.1 Leaching test procedure to obtain leachate for chemical analysis***

The leaching method recommended is the US Environmental Protection Agency (EPA) Toxicity Characteristic Leaching Procedure (TCLP) Test Methods for Evaluating Solid Wastes Physical/Chemical Methods, Method 1311 (US EPA 1992a)). For materials used in the surfacing layer (class 1 section 3.1), the standard TCLP procedure (clause 7.1.3) is modified so that the material must pass or be crushed or cut to pass through a 300 µm sieve.

The TCLP involves a 20:1 L/S ratio (100 g sample) and uses leachant water with a pH of 4.93. The sample is agitated for 18± 2 hours at 23 ± 2°C. The method is discussed in detail elsewhere (DoE 2003). A weak acid leaching test was chosen in order to provide a conservative estimate of contaminant leachability.

In some cases, modification to the TCLP (or adoption of an alternative method) may be necessary to account for particular features of the material or contaminant chemistry (e.g. reactivity with oxygen) or the material application. For further information, see OECD 2000.

### A3.5.2 Methods for leachate and material analysis

Analysis of the leachate for inorganic species can be readily undertaken by various methods including:

- atomic absorption spectrometry,
- inductively coupled plasma (ICP) – atomic emission spectrometry (AES),
- ICP-mass spectrometry (MS), or
- ion chromatography.

The same methods can be used for analysis of the material itself after digestion in strong acid; however, solid-state methods such as X-ray fluorescence are usually less expensive. Analysing the leachate for organic species will usually require extraction and concentration into an organic solvent and possibly derivatisation before analysis by gas chromatography/mass spectrometry (GCMS). The material itself can be extracted directly with solvent before organics analysis by GCMS (Loeper 1995).

A large number of standardised test methods are available, for example those provided by the US EPA (Table A3.1). A compendium of EPA methods of particular relevance is *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, 3<sup>rd</sup> Edition, EPA Publication SW-846* (US EPA 1992b)

Selection of a given method will depend on the nature of the material and the analytes in question as well as the cost and availability in New Zealand. Advice on the analyses required should be sought from an appropriate laboratory before any leaching tests are undertaken. Ideally, the laboratory undertaking the analysis should be accredited by International Accreditation New Zealand (IANZ) (or equivalent) for that method.

**Table A3.1 Representative US EPA methods for the chemical analysis of leachates and materials.**

Analysis	Method
Digestion	3051: Microwave Assisted Acid Digestion of Sediments, Sludges, Soils and Oils
	3050B: Acid Digestion of Sediments, Sludges and Soils
Inorganics	6010B: Inductively Coupled Plasma-Atomic Emission Spectrometry
	6020: Inductively Coupled Plasma-Mass Spectrometry
	7000A: Atomic Absorption Methods
Organics	8015B: Non-halogenated Organics Using GC/FID <sup>a</sup>
	8100: Polynuclear Aromatic Hydrocarbons
	8260B: Volatile Organic Compounds by Gas Chromatography/Mass Spectrometry (GCMS)
	8270C: Semivolatile Organic Compounds by Gas Chromatography/Mass Spectrometry (GCMS)
	8275A: Semivolatile Organic Compounds (PAHs and PCBs) in Soils/Sludges and Solid Wastes Using Thermal Extraction/Gas Chromatography/Mass Spectrometry (TE/GCMS)
	8310: Polynuclear Aromatic Hydrocarbons

a GC/FID: Gas chromatography with flame ionisation detection

### **A3.5.3 Screening criteria**

The recommended screening criteria are the absolute concentration and leachate concentration limits from the New Zealand waste acceptance criteria (WAC) for Class B landfills published by the New Zealand Ministry for the Environment are given in Tables A3.2 to A3.14 (MfE 2004). The WAC for Class B landfills are stringent criteria, as they aim to protect the environment from landfills that have limited or no systems engineered for collecting leachate or landfill gas, and which may be located in a sensitive environmental area. The Class B landfill characteristics are typical of most road construction sites; the WAC should be equally protective of the immediate environment of the road. Where the absolute concentration of contaminants in the waste material is known, the contaminants can be compared to these 'screening' concentrations. The use of total concentration limits in this way reduces the need for leachate testing. If the contaminant concentration is below the screening criteria then no leachate test is required (see Chapter 3.4.1). For contaminants with low water solubility, total concentration criteria provide the only WAC (Table A3.14).

Other acceptance criteria that were considered for use in these guidelines include the New Zealand drinking water standards (Ministry of Health 2005) for protecting human health, and the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC/ARMCANZ 2000) for protecting ecological receptors. However, these criteria only consider the final environmental concentration of chemicals (i.e. after mixing with the water from the receiving environment). Alternatively, the New Zealand WAC consider the concentration of chemicals in a leachate which is a more appropriate criterion for the leaching test suggested. Furthermore, drinking water standards and aquatic ecosystem criteria (whichever was the more conservative) were also used to derive values in the New Zealand WAC. The WAC have been based primarily on the US EPA TCLP limits, which in turn were derived directly from the US EPA drinking water standards. For those contaminants where there was no value given, the WAC were derived from an older version of the New Zealand Drinking Water Standards (Ministry of Health 2000) as well as the aquatic criteria given in the ANZECC/ARMCANZ 2000 guideline and older editions thereof (URS 2003).

The New Zealand WAC which are recommended for screening purposes in these guidelines were originally developed for Class B landfills. Class B landfills are existing landfills that have limited or no engineered systems for collecting leachate or landfill gas, and which may be located in a sensitive environmental area. These characteristics are typical of most road construction sites; the WAC should be equally protective of the immediate environment of the road.

**Table A3.2 New Zealand WAC for Class B landfills for inorganic substances.**

Substance	Screening criteria (mg/kg)	Concentration in leachate (mg/L)
Aluminium	80	4
Antimony	1.2	0.06
Arsenic	10	0.5
Barium	200	10
Beryllium	20	1
Boron	40	2
Cadmium	2	0.1
Chromium (VI)	10	0.5
Copper	10	0.5
Fluoride	400	20
Lead	10	0.5
Lithium	40	2
Mercury	0.4	0.02
Molybdenum	20	1
Nickel	20	1
Selenium	20	0.11
Silver	20	0.5
Tin	2,000	100
Vanadium	4	0.2
Zinc	20	1

**Table A3.3 New Zealand WAC for Class B landfills for aromatic hydrocarbons.**

Substance	Screening criteria (mg/kg)	Concentration in leachate (mg/L)
Aniline	0.4	0.02
Styrene	12	0.6

**Table A3.4 New Zealand WAC for Class B landfills for polynuclear aromatic hydrocarbons.**

Substance	Screening criteria (mg/kg)	Concentration in leachate (mg/L)
Naphthalene	20	1

**Table A3.5 New Zealand WAC for Class B landfills for other halogenated aromatic hydrocarbons.**

Substance	Screening criteria (mg/kg)	Concentration in leachate (mg/L)
1,2 Dichlorobenzene	0.4	0.02
1,3 Dichlorobenzene	100	5
1,2,3 Trichlorobenzene	100	5
1,2,4 Trichlorobenzene	80	4

**Table A3.6 New Zealand WAC for Class B landfills for the BTEX group.**

Substance	Screening criteria (mg/kg)	Concentration in leachate (mg/L)
Benzene	1	0.05
Toluene	200	10
Ethyl benzene	100	5
Xylene ( <i>m, o, p</i> )*	200	10

\* m, o and p stand for *meta*, *ortho* and *para* isomers respectively

**Table A3.7 New Zealand WAC for Class B landfills for chlorinated aliphatic hydrocarbons.**

Substance	Screening criteria (mg/kg)	Concentration in leachate (mg/L)
Vinyl chloride	0.4	0.02
1,2 Dichloroethene	20	1
1,3 Dichloropropene	4	0.2
Dichloromethane	4	0.2
1,1,1, Trichloroethane	400	20
1,1,2 Trichloroethane	1,000	50
1,1,2,2 Tetrachloroethane	100	5
1,2 Dibromo-3-chloropropane	0.4	0.02
1,2 Dichloropropane	2	0.1

**Table A3.8 New Zealand WAC for Class B landfills for other halogenated aliphatic hydrocarbons.**

Substance	Screening criteria (mg/kg)	Concentration in leachate (mg/L)
Bromodichloromethane	0.2	0.01
Bromoform	20	1
Dibromochloromethane	20	1



**Table A3.9 New Zealand WAC for Class B landfills for phenols.**

Substance	Screening criteria (mg/kg)	Concentration in leachate (mg/L)
2,4,6 Trichlorophenol	0.2	0.01
2 Chlorophenol	0.01	0.005
2,4 Dichlorophenol	0.01	0.005
Phenol	80	4

**Table A3.10 New Zealand WAC for Class B landfills for pesticides.**

Substance	Screening criteria (mg/kg)	Concentration in leachate (mg/L)
2,4 Dichlorophenoxyacetic acid (2,4 D)	20	1
Aldrin	0.000016	0.000008
Dieldrin	0.8	0.04
Endosulfan	0.6	0.03

**Table A3.11 New Zealand WAC for Class B landfills for phthalates.**

Substance	Screening criteria (mg/kg)	Concentration in leachate (mg/L)
Diethylphthalate	200	10
Dimethylphthalate	800	40
Di-n-butylphthlate	600	30

**Table A3.12 New Zealand WAC for Class B landfills for other organic substances.**

Substance	Screening criteria (mg/kg)	Concentration in leachate (mg/L)
Carbon disulphide	6	0.3

**Table A3.13 New Zealand WAC for Class B landfills for organometallic substances.**

Substance	Screening criteria (mg/kg)	Concentration in leachate (mg/L)
Tributyltin oxide (TBTO)	6	0.3

**Table A3.14 Total concentration limits for acceptance at Class B landfills.**

Substance	Total concentration (mg/kg)
Benzo(a)pyrene (BaP)	30
Carcinogenic PAHs as Benzo(a)pyrene equivalents <sup>a</sup>	30
Heptachlor epoxide	150
DDE <sup>b</sup>	50
DDT <sup>c</sup>	50

Notes to Table A3.14:

- a This parameter expresses all carcinogenic polyaromatic hydrocarbons (PAHs) in a mixture in terms of how potent they are compared to BaP. The 'BaP equivalent' concentration of a sample is the sum of the weighted potency factor of each compound in the mixture multiplied by the concentration of the compound in the mixture. The result is numerically equivalent to summing up risks attributable to individual PAHs in the mixture.
- b DDE: 1, 1-*bis*-(4-chlorophenyl)-2, 2-dichloroethene
- c DDT: 1, 1-*bis*-(4 chlorophenyl)-2, 2, 2-trichloroethane.

In all cases, analysis of the material and leachate should be carried out for the inorganics listed in Table A3.2. The decision to measure other species listed in Tables A3.3 to A3.13 must be made on a case-by-case basis using knowledge of the origin of the material, the production processes or the waste stream that generated the material.

Some highly ecotoxic compounds are not included in the New Zealand WAC list. Polychlorinated biphenyls (PCB) are not included, as they are prohibited substances and are not accepted at landfills. Naphthalene is the only PAH included as it is the most mobile and therefore considered a good 'indicator' compound for PAHs. Dioxins are not included, as their analysis is prohibitively expensive. Obviously, if unlisted but potentially harmful species are believed to be present in the roading construction material under consideration then they must be fully accounted for in the assessment.

### **A3.6 Batch leaching test for ecotoxicity testing.**

#### ***A3.6.1 Leaching test to obtain leachate for ecotoxicity testing***

The leaching method recommended is the US EPA TCLP (US EPA 1992a), with the following modifications:

1. For materials used in the surfacing layer (class 1 section 3.1), the procedure (TCLP clause 7.1.3) is modified so that the material must pass or be crushed or cut to pass through a 300 µm sieve.
2. The reagent (leachant) water (TCLP clause 5.2) is used as the extraction fluid (TCLP clause 5.7) without addition of acetic acid.
3. The leachate must not be acidified (TCLP clause 6.6 & 7.2.14).

In some cases, further modification to the TCLP (or adoption of an alternative method) may be necessary to account for particular features of the material or contaminant chemistry (e.g. reactivity with oxygen) or the material application. For further information, see the *Guidance Document on Aquatic Toxicity Testing of Difficult Substances and Mixtures* (OECD 2000).

The ecotoxicity of the leachate is assessed according to the screening criteria given in Chapter 3.5.3.

New manufactured materials for which information must be submitted to ERMA for classification under the HSNO regulations will require ecotoxicity data corresponding to different material concentrations (mg/L) in water (and possibly data on terrestrial ecotoxicity – see Chapter 3.5.2). Materials used in road construction, however, are unlikely to be readily water soluble in their applied form.

For sparingly soluble materials (e.g. mineral aggregates), toxicity tests are generally carried out using the WAF approach (King et al. 2001, OECD 2000). The principle is that the test material is brought in contact with water until those components that are soluble in water have reached an equilibrium concentration in the water phase. The water is separated from the insoluble material and test organisms are introduced. The concentration of the test substance is expressed as the 'bulk loading rate' (mg of substance per litre of water) rather than in terms of the aqueous concentration of the individual soluble components, which are unknown and impracticable to measure in most cases. For the same reason, it is often not practical to determine quantitatively if equilibrium of the contaminants with the water phase has been achieved. However, if one or more species of particular interest or environmental concern are known to be present and are readily amenable to analysis, then multiple tests using differing time intervals should be performed to confirm equilibrium. The leachate generated using the procedure above and modified further to include tests at various sample loading rates may be suitable as a WAF for ecotoxicity testing.

It is essential that the suitability of ecotoxicity data generated using the WAF method should be discussed with ERMA first before testing is undertaken.

### **A3.6.2 Recommended ecotoxicity test methods**

Aquatic ecotoxicity of the leachate should be measured using the freshwater macroinvertebrate *Daphnia spp* (48-hour acute lethality) and the freshwater green alga *Selenastrum capricornutum* (72-hour growth inhibition). These tests are recommended because of their widespread acceptance for testing the ecotoxicity of industrial and other waste effluents. Numerous international bodies have designed and approved methodologies for these tests, and a great deal of literature is available on these tests, including internationally standardised test methodologies (some of which are given in Table A3.15). The National Institute of Water and Atmospheric Research of New Zealand (NIWA) has developed several standardised aquatic testing protocols which are specific for New Zealand conditions. These tests use more appropriate native species as well as *S. capricornutum* and *Daphnia spp* (e.g. *Ceriodaphnia dubia* in place of *D. magna*) (Hall & Golding 1998).

In most cases, the assessment of ecotoxic hazards of waste materials based solely on aquatic toxicity data would result in the same classification as an assessment that included terrestrial data (Environment Agency 2005). In the Environment Agency methodology for ecotoxicity testing, terrestrial tests are recommended only if there is reason to believe that a material contains substances that have specific effects on the terrestrial environment. If deemed necessary, the tests recommended for assessing soil ecotoxicity are, firstly, a terrestrial plant germination and early growth test, and the collembola reproduction test. These two tests represent both a plant species and a soil invertebrate, and use common test species for determining soil ecotoxicity. The earthworm 14-day acute test is arguably one of the more common soil invertebrate methods used. However, this is not a very sensitive test; the longer, more intensive earthworm reproduction test is more appropriate. Landcare Research New Zealand has the in-house capability to run the terrestrial toxicity tests according to standardised protocols (O'Halloran et al. 1999).

Suitable test methods are given in Table A3.15. However, most of these methods are designed to allow the determination of a median effect level. This involves testing of a number of concentrations (or dilutions). The recommended screening criteria for the ecotoxicity tests, known as 'limit tests', follow the approach of the European Community, whereby the leachate can be tested without dilution (i.e. 100% WAF) and compared to the control (dilution water). This is a simpler and more economical version of a typical toxicity test. In general, 5 replicates of 10 organisms per treatment should be tested. For the algal test, each replicate should contain algae at a concentration of  $10^4$  organisms/mL. Treatments should include a control, 100% WAF and a reference toxicant wherever possible. In terrestrial limit tests, the 100% WAF could be used to provide the required moisture content of the test soil.

When the 100% leachate causes a higher level of toxicity (i.e. above the threshold given in Chapter 3.5.3), then further leaching tests at lower loading rates may be appropriate to determine the median effect levels. Determining median effects from a dilution series of the 100% WAF obtained at a single loading rate is generally not recommended. Dilution of the 100% WAF will produce test media with the same relative component concentrations, but in complex mixtures, saturation concentrations of poorly soluble components may actually be reached at low loading rates. Relative concentrations in the WAF may vary depending on the loading rate at which it was obtained. A multiple loading rate test programme may be included in the Comprehensive Environmental Impact Assessment (Chapter A4). Refer to the standard methodologies given in Table A3.15 for further guidance.

In future, the development of a guidance document containing a standard battery of ecotoxicity tests and outlining the methodology for limit tests and for determining median effect levels may be warranted.

**Table A3.15 Suitable test methods for assessing ecotoxicity levels.**

Test Protocol	OECD tests	US EPA tests	International Organisation for standardisation tests	European Community tests	New Zealand tests
<b>Crustacean</b>					
<i>Daphnia magna</i> immobilisation	202 (part I) (OECD 2004a)	850.1010 US EPA (1996a)	-	C2 (EC 1992)	-
<i>Ceriodaphnia dubia</i> immobilisation	-	-	-	-	Hall & Golding 1998 (appendix 5)
<b>Algal</b>					
<i>Selenastrum capricornutum</i> toxicity: growth inhibition	201 (OECD 1984)	850.5400 US EPA (1996b)	-	C3 (EC 1992)	Hall & Golding 1998 (appendix 4)
<b>Earthworm</b>					
<i>Eisenia fetida/andrei</i> reproduction test	222 (OECD 2004b)	-	11268-2 (ISO 1998)	-	-
<b>Collembola</b>					
<i>Folsomia candida</i> reproduction test	-	-	11267 (ISO 1999)	-	-
<b>Terrestrial plant tests</b>					
	208 (OECD 2003)	850 4200 850 4230 US EPA (1996c, 1996d)	-	-	-

### A3.6.3 Screening criteria

The recommended screening criteria are based on those of the UK Environment Agency (Environment Agency 2005). A material is considered ecotoxic if, during the test of the undiluted WAF, one of the following is observed (relative to the appropriate control):

1. ≥50% in the 48 h *Daphnia* test (i.e. 50% or more of the *Daphnia* are immobilised);
2. ≥50% in the 72 h algal test (i.e. 50% or greater reduction in algal growth);
3. ≥50% ecotoxic effect in
  - the terrestrial plant germination and early growth test, or
  - the collembola reproduction test.

Screening criteria with greater complexity would require a higher level of testing using various percent dilutions of the leachate (or WAF obtained at various loading rates) to define the median effect concentration. For example, the US ecotoxicity testing methodologies outlined in a recent study by the National Co-operative Highway Research Program (NCHRP) (Eldin et al. 2000) categorise impact into five

classes according to the percentage of pure leachate causing a 50% ecotoxic effect (i.e. the LC<sub>50</sub> or EC<sub>50</sub>. See Table A3.16).

**Table A3.16 Categories of ecotoxic impact proposed by Eldin et al. (2000).**

Impact category	Ecotoxicity level
Extremely high impact	LC <sub>50</sub> or EC <sub>50</sub> occurs at ≤10%
High impact	10% < LC <sub>50</sub> or EC <sub>50</sub> ≤20%
Moderate impact	20% < LC <sub>50</sub> or EC <sub>50</sub> ≤75%
Low impact	LC <sub>50</sub> or EC <sub>50</sub> >75%
No impact	No toxic effect is observed.

Lapa et al. (2000) propose similar ecotoxicity limits (Table A3.17).

**Table A3.17 Categories of ecotoxic impact proposed by Lapa et al. (2000).**

Impact category	Ecotoxicity level
Very high ecotoxicity	LC <sub>50</sub> or IC <sub>50</sub> occurs at ≤1%
High acute toxicity	1% < LC <sub>50</sub> or IC <sub>50</sub> ≤10%
Significant ecotoxicity	10% < LC <sub>50</sub> or IC <sub>50</sub> ≤50%
No significant ecotoxicity	LC <sub>50</sub> or IC <sub>50</sub> > 50%

The New Zealand HSNO minimum degrees of hazard regulations also use screening or ‘threshold’ criteria to identify and characterise the degree of ecotoxicity (Table A2.1). These criteria assume water soluble materials whose ecotoxicity can be expressed in terms of a concentration i.e. mg substance/L water. As discussed in Chapter 3.5.1, the leachate from poorly soluble materials may (after consultation with ERMA), be deemed suitable for determining ecotoxicity according to ERMA’s criteria. However, the methodologies for deriving median effect levels (i.e. LC<sub>50</sub> and EC<sub>50</sub>) require multiple loading rates of the material to be tested, which increases the complexity and cost of the test.

For simplicity, the limit test using the 100% (undiluted) WAF described by the UK Environment Agency (2005) are recommended as more economical. The criteria are just as likely to capture ecotoxic materials as the other criteria discussed above.

## **A4 Comprehensive environmental impact assessment**

If Stage 1 or Stage 2 testing indicates that the material may contain hazardous contaminants that may leach into the environment at unacceptable levels, a comprehensive environmental impact assessment using more realistic leaching tests and site modelling should be conducted in order to better delineate the potential adverse effects. The results may indicate that, under realistic conditions, hazardous contaminants will not be released in to the environment at harmful levels. Conversely, Stage 3 testing may indicate that specific controls or limitations on use of the material are required. Before an applicant undertakes an extensive testing programme, details of the proposed work should be discussed with

Transit New Zealand or the local authorities in question to ensure that the results of the testing work will meet all relevant concerns.

Stage 3 testing would involve the following, which have been derived from Kosson et al. 2002 and NCHRP 2001:

1. **Definition of field site parameters**, including water infiltration rate, construction geometry, and the soil type where the material is to be used. These parameters can be site-specific and involve on-site measurements or typical values based on generic construction scenarios. The data is used to define the principal contaminant release mechanism operating, usually either equilibrium controlled (for slow percolation through granular media) or mass transfer controlled (for monolithic materials or granular materials where percolation is very rapid).
2. **Measurement of intrinsic leaching behaviour and ecotoxicity** for specific constituents using various methods over a range of leaching conditions, including:
  - leaching of specific components as a function of pH,
  - leaching of specific components as a function of L/S ratio,
  - mass transfer rates,
  - acid and base neutralisation capacities, and
  - the effect of matrix sorption, and photo and biodegradation on specific constituents.
3. **The use of release models** incorporating measured leaching and site parameters to estimate release fluxes and long-term cumulative release data for specific constituents.
4. **Comparison of release estimates** to water quality acceptance criteria and assessment of ecotoxicity against suitable criteria.

Details of the type of testing and modelling required will vary on a case-by-case basis – a full discussion is beyond the scope of this document. A detailed process specifically designed for road construction materials, including test methods and modelling tools (in the form of a computer spreadsheet), has been published by the US Transportation Research Board (NCHRP 2001). This process is recommended (with adaptations if required) for Stage 3 testing. The modelling in this methodology makes use of a number of generic road construction scenarios rather than requiring site-specific design information.

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## Appendix B Glossary and abbreviations

<b>AEE:</b>	Assessment of Environmental Effects
<b>AES:</b>	Atomic Emission Spectrometry
<b>ALT-MAT:</b>	ALTernative MATerials in road construction
<b>ASTM:</b>	American Society for Testing and Materials
<b>BaP:</b>	Benzo(a)pyrene
<b>BTEX:</b>	benzene, toluene, ethyl benzene, xylenes.
<b>CEN:</b>	Comité Européen de Normalisation (European Committee for Standardisation)
<b>DDE:</b>	1, 1- <i>bis</i> -(4-chlorophenyl)-2, 2-dichloroethene
<b>DDT:</b>	1, 1- <i>bis</i> -(4-chlorophenyl)-2, 2, 2-trichloroethane
<b>DOC:</b>	Dissolved organic matter
<b>DT50:</b>	The time taken for the concentration of a compound to decrease to half its initial value.
<b>EC<sub>50</sub>:</b>	The median effect concentration, being a statistically derived concentration of a substance that can be expected to cause an adverse effect in 50% of organisms; or a 50% reduction in growth or in the growth rate of organisms
<b>EEL:</b>	Environmental Exposure Limit
<b>ERMA:</b>	Environmental Risk Management Authority, New Zealand
<b>EPA:</b>	Environmental Protection Agency, United States of America
<b>ENV:</b>	European prestandard put out by CEN (q.v.)
<b>FWHA:</b>	Federal Highways Administration (of the USA)
<b>GC/FID:</b>	Gas Chromatography with Flame Ionisation Detection
<b>GCMS:</b>	Gas Chromatography/Mass Spectrometry
<b>HSNO:</b>	Hazardous Substances and New Organisms
<b>IANZ:</b>	International Accreditation New Zealand
<b>ICP:</b>	Inductively Coupled Plasma
<b>ISO:</b>	International Organisation for Standardisation
<b>LC<sub>50</sub>:</b>	The median lethal concentration, being a statistically derived concentration of a substance that can be expected to cause death in 50% of organisms exposed for a specified time.
<b>LD<sub>50</sub>:</b>	The median lethal dose, being a statistically derived single dose of a substance that can be expected to cause death in 50% of organisms.
<b>LOEC:</b>	Lowest Observed Effect Concentration. The lowest concentration of a substance in an ecotoxicity test in which a statistically significant adverse effect on the exposed population of test organisms was observed compared with controls.
<b>L/S ratio:</b>	Liquid to Solid ratio.
<b>MATC:</b>	Maximum Acceptable Tolerance Concentration. This is the geometric mean of the NOEC (q.v.) and LOEC (q.v.) where the NOEC and LOEC are derived from the same study
<b>MfE:</b>	Ministry for the Environment, New Zealand
<b>MS:</b>	Mass Spectrometry
<b>NCHRP:</b>	National Co-operative Highway Research Program
<b>NEN:</b>	Code used by CEN (q.v.) to indicate standard developed in the Netherlands
<b>NIWA:</b>	National Institute of Water and Atmospheric Research, New Zealand

<b>NOEC:</b>	No Observed Effect Concentration. The highest concentration of a substance that does not produce a significant ecotoxic effect in an organism or in an organism population.
<b>OECD:</b>	Organisation for Economic Co-operation and Development
<b>PAH:</b>	Polyaromatic hydrocarbon
<b>PCB:</b>	Polychlorinated biphenyls
<b>PET:</b>	Polyethylene terephthalate
<b>PVC:</b>	Polyvinyl chloride
<b>RMA:</b>	Resource Management Act
<b>SEPA:</b>	Scottish Environmental Protection Agency
<b>TBTO:</b>	Tributyltin oxide
<b>TCLP:</b>	Toxicity Characteristic Leaching Procedure
<b>TFHRF:</b>	Turner-Fairbank Highway Research Foundation
<b>TNZ:</b>	Transit New Zealand
<b>WAC:</b>	Waste Acceptance Criteria
<b>WAF:</b>	Water Accommodated Fraction

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