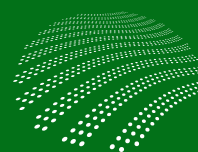


Cooperative Research Centre for **Contamination
Assessment and Remediation of the Environment**

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TECHNICAL REPORT NO.32

Development of guidance for contaminants of emerging concern

Cooperative Research Centre for Contamination Assessment and Remediation of the Environment, Technical Report series, no. 32
July 2014

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CRC for Contamination Assessment and Remediation of the Environment

Technical Report no. 32

**Development of guidance for
contaminants of emerging concern**

July 2014



Executive summary

Emerging contaminants are a concern for contaminated site assessment, management and remediation. The first-tier priority contaminants that were identified at a February 2012 forum were perfluorinated chemicals PFOS and PFOA, methyl tertiary-butyl ether (MTBE), benzo[a]pyrene (BaP), weathered hydrocarbons and polybrominated diphenyl ethers (PBDE).

This report, which is focused on the current status of guidance in Australia and overseas, aims to progress guidance development and is based on contaminant-specific issues which are of significance to stakeholders. Guidance development includes the development of screening criteria and remediation and management guidance. The purpose of this paper is to propose a way forward.

The National Environment Protection (Assessment of Contaminated Sites) Measure (NEPM) is primarily focused on the standards for assessment of contamination. A number of generic guidance under NEPM may be used in the context of first-tier priority contaminants. The NEPM and the National Health and Medical Research Council (NHMRC) also provide some screening criteria for first-tier priority contaminants, but additional Australian criteria for PFOS, PFOA and MTBE are yet to be established (NHMRC 2008; NHMRC & NHMMC 2011). The National Remediation Framework (NRF) currently being developed by CRC CARE includes guidance which could be relevant for remediation of emerging contaminants.

Screening, remediation and management guidance available for first-tier priority contaminants in overseas jurisdictions is based on substantial information about the impacts, sources, toxicity and exposure pathways for most of these contaminants (except weathered hydrocarbons). Some components of international research can be applied in the derivation of guidance, although it is essential to specifically review available information in the Australian context. There is a relationship between the effort required to develop new standards or thresholds, the availability of existing standards/thresholds, applicability of overseas standards/thresholds and generation of new scientifically-robust information.

CRC CARE proposes that a review of overseas guidance, together with best available scientific data in the Australian context, can provide a reasonable step towards the development of guidance for assessment and remediation of first-tier priority contaminants. The following table summarises suggested guidance development for these contaminants in the short to medium term:

Contaminant	Screening levels	Remediation and management guidance
PFOS and PFOA	To be developed	To be developed
MTBE	To be developed	To be developed
BaP	Soil HILs, GILs, ESLs available	To be developed
Weathered hydrocarbons	May be considered	To be developed
PBDE	Soil HILs available	To be confirmed

Acronyms

AFFF	Aqueous film forming foams
BaP	Benzo[a]pyrene
BCC	Biosolids contamination concentration
BTEX	Benzene, toluene, ethylbenzene and xylene
CSM	Conceptual site model
EDC	Endocrine disrupting chemical
EIL	Ecological investigation level
ERA	Ecological risk assessment
ESL	Ecological screening level
FTS	Fluorotelomer sulfonate
GIL	Groundwater investigation level
HIL	Health investigation level
HSL	Health screening level
MCL	Maximum contaminant level
MDH	Minnesota Department of Health
MTBE	Methyl tertiary-butyl ether
NEPM	National Environment Protection (Assessment of Contaminated Sites) Measure
NRF	National Remediation Framework
PBDE	Polybrominated diphenyl ether
PFOA	Perfluorooctanoic acid
PFOS	Perfluorooctanesulfonic acid
POP	Persistent organic pollutants
RfD	Oral reference dose
SQG	Soil quality guidelines
TRV	Toxicity reference value
US EPA	United States Environmental Protection Agency

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1. Background

1.1. Overview

First-tier priority contaminants were identified for CRC CARE at a forum held in February 2012. These contaminants are the perfluorinated chemicals PFOS and PFOA, methyl tertiary-butyl ether (MTBE), benzo[a]pyrene (BaP), weathered hydrocarbons and polybrominated diphenyl ethers (PBDE).

The US EPA defines contaminants of emerging concern as:

‘Chemicals... that previously had not been detected or are being detected at levels that may be significantly different than expected. ...the risk to human health and the environment associated with their presence, frequency of occurrence, or source may not be known (US EPA 2014a).’

A contaminant may be emerging because a new source or a new pathway to humans has been discovered or a new detection method or treatment technology has been developed. An emerging concern may refer to a new concern for known contaminants.

The National Environment Protection (Assessment of Contaminated Sites) Measure (NEPM) was updated in 2013. The substances for which health investigation levels (HILs) have been established were increased from 31 to 41, ‘to include priority contaminants under the Stockholm Convention on Priority Organic Pollutants’ (NEPC 2013). The NEPM and Australian water guidelines provide some screening criteria for first-tier priority contaminants, but additional criteria are yet to be developed (NHMRC 2008; NHMRC & NHMMC 2011).

In developing Australian guidance for contaminants it is important to take cognisance of their prevailing uses and ongoing sources in Australia. Persistent organic pollutants (POPs) including PFOS, PFOA and PBDE have mostly been phased out, but remain highly persistent and detectable in the Australian environment. Nonetheless, the scale of distribution and occurrence of first-tier priority contaminants in Australia is largely unknown (and may remain so).

In October 2013 and April 2014, the CRC CARE Policy Advisory Committee considered the guidance currently available in Australia and overseas for first-tier priority contaminants. The Policy Advisory Committee was concerned with health and environmental consequences of contaminants and recognised the varied availability of data on occurrence, fate and toxicity of these contaminants in the Australian context. For example, New South Wales indicated concerns about the potential impact of perfluorinated compounds on waterways at Botany Bay and water catchments from previous use of aqueous film forming foams (AFFF) in firefighting. Queensland supported testing of replacement non-perfluorinated fire-fighting foam products. These scenarios depict different contaminant issues which may need to be prioritised and also indicate a need for a timely approach to manage human and ecological risks. It is anticipated that guidance on emerging contaminants will be useful in managing contaminants which are detected in the environment.

1.2. Work to date

CRC CARE Technical Report no. 24 Analytical methods for priority and emerging contaminants reviews analytical methods for contaminants of emerging concern. Analytical methods need to demonstrate detection sensitivity and selectivity for managing contaminants. The report indicates no significant analytical methodology gaps for first-tier priority contaminants, although tools to assess laboratory performance such as readily accessible proficiency testing schemes are required (CRC CARE 2013).

CRC CARE Technical Report no. 29 Environmental impact of priority contaminants provides a comprehensive review of information and data which can contribute to the potential development of screening levels and analytical laboratory methods. Potential remediation technologies, regulatory guidance and data gaps are also indicated. It appears that there are sufficient data and information available to develop soil and groundwater screening guidance levels for some first-tier priority contaminants at this stage (CRC CARE 2014).

Data required to develop guidance for weathered hydrocarbons are limited. CRC CARE Technical Report no. 29 indicates that there are no routine methodologies for the quantification of polar transformed products in hydrocarbon mixtures. There are also gaps in data relating to toxicological assessments of polar transformed products and their synergistic/antagonistic effects in weathered hydrocarbon mixtures. Weathered hydrocarbons may comprise varying complex mixtures of naphthenic acids, naphthoic acids and phenols, including alkylphenols.

Research on phenol is at a slightly more developed stage than other weathered hydrocarbons, because it is widely commercially produced. However, toxicity for polar compounds should be assessed as part of complex mixtures (not individually) in order to assess synergistic and antagonistic effects. As a result, guidance will also need to consider complex mixtures.

1.3. Purpose

This report aims to progress guidance development, focused on the current status of guidance in Australia and overseas, and is based on contaminant-specific issues which are of significance to stakeholders. Consequently, the purpose of this report is to propose a way forward.

Emerging contaminants are a concern for contaminated site assessment, management and remediation. In section 2 of this report, some guidance relevant to emerging contaminants available in the NEPM is outlined. The NEPM addresses, to some extent, laboratory analysis, risk-based assessment methodology and investigation levels based on risk-based methodologies. In cases where contaminant-specific investigation levels have not been developed under the NEPM, other national and international sources and their guidance values are identified. This gives an appreciation of the varied developments in managing emerging contaminants nationally and abroad.

The National Remediation Framework (NRF) currently being developed by CRC CARE includes guidance which could be relevant for remediation of emerging contaminants. This is

highlighted in section 3, which also focuses on the findings of CRC CARE Technical Report no. 29 which describes potential remediation technologies for first-tier priority contaminants.

Potential areas for site-specific guidance issues not addressed in section 2 have been outlined in section 4 – providing insight on the diversity of issues that can arise when dealing with emerging contaminants. The wider context of national and international examples indicates that the development of guidance for emerging contaminants requires a comprehensive approach. Such an approach should comprise identification and contextualisation of priority site-specific issues in consultation with stakeholders to ensure targeted research, and systematic and coordinated guidance development. This is significant because of the need to progress guidance development in the Australian context.

Section 5 is significant in that it discusses a way forward by summarising findings.

2. Guidance related to assessment of site contamination NEPM

2.1. Overview

The National Environment Protection (Assessment of Contaminated Sites) Measure 1999 contains guidance relevant to emerging contaminants (Attachment A).

Schedule A, *Recommended general process for assessment of site contamination*, provides the recommended decision-making process for assessment of site contamination. Site investigation and laboratory analysis of site samples contribute to the development of a conceptual site model (CSM). The extent of contamination is compared with investigation and screening levels, and then a further series of decision-making steps is followed to determine if remediation action and/or management plans are required (Attachment B).

Generic guidance is provided which may be used in the context of first-tier priority contaminants. Schedule B3, *Guideline on laboratory analysis of potentially contaminated soil*, provides methods for laboratory analysis of potentially contaminated soils and is applicable to a range of contaminants including BaP, phenols and MTBE.

The NEPM also includes generic methods and principles for risk-based assessments:

- Guidance on site-specific health risk assessment (Schedule B4)
- Guideline on ecological risk assessment (ERA) (Schedule B5a)
- Guidance on the framework for risk-based assessment of groundwater contamination (Schedule B6)

Risk assessment methodologies need to incorporate contaminant-specific guidance values i.e. investigation and screening levels. Establishment of guidance values provides a critical step towards better assessment and characterisation of health and environmental risks from contaminants (as per the NEPM, Schedule A, *Recommended general process for assessment of site contamination*).

The NEPM includes methods and principles for investigating soil and groundwater contamination levels (Schedule B1), and ecological investigation levels (Schedule B5b). Guidance values are designed based on the best available scientific information. There are different types of investigation and screening levels applicable for first-tier priority contaminants under the NEPM, Schedule B1, as described below.

2.2. Health investigation and screening levels

Health investigation levels (HIL) are provided for a broad range of metals and organic substances and are applicable for assessing human health risk via all relevant exposure pathways. Schedule B7a provides guidance for health-based investigation levels based on Australian health policy (enHealth 2012a; enHealth 2012b).

NEPM Schedule B7b provides exposure scenarios and settings. Derivation of soil HILs considered different generic land uses (NEPM, Appendix C). The accompanying NEPM

Toolbox also provides Microsoft Excel spreadsheets for HIL calculations, with provisions for adding for site-specific values to improve HIL calculations. The exposure scenarios considered in the derivation of HILs for all these contaminants included ingestion of soil/dust, dermal absorption during contact with soil/dust and inhalation of dust (NEPM, Appendix B).

The NEPM also provides specific guidance in terms of soil HILs for benzo[a]pyrene, PBDEs and phenols (Tables 1 to 4). Phenols are one of the four groups of polar transformed products formed by hydrocarbon weathering. Phenols include phenol, cresols, xlenols and trimethylphenols. Based on low availability of toxicity information for weathered hydrocarbons in the medium term, guidance development may need to focus on risk-based remediation approaches.

Table 1. Soil HILs for BaP and toxicity equivalent PAHs. *Note: – (dash) means pathway not included in the derivation of HIL.*

HIL Scenario	HIL (mg/kg)	Contribution from exposure pathways			
		Ingestion of soil/dust	Ingestion of home-grown produce	Dermal absorption of soil/dust	Inhalation (dust)
Residential A	3	yes	–	Yes	minimum
Residential B	4	yes	–	Yes	minimum
Residential C	3	yes	–	Yes	minimum
Commercial D	40	yes	–	Yes	minimum

(NEPM, Schedule B7 – Appendix A2 The derivation of HILs for PAH and Phenols.)

Table 2. Soil HILs for PBDEs.

HIL Scenario	HIL (mg/kg)	Contribution from exposure pathways			
		Ingestion of soil/dust	Ingestion of home-grown produce	Dermal absorption of soil/dust	Inhalation (dust)
Residential A	1	yes	8	yes	minimum
Residential B	2	yes	–	yes	minimum
Residential C	2	yes	–	yes	minimum
Commercial D	10	yes	–	yes	minimum

(NEPM, Schedule B7 - Appendix A5 The investigation of HILs for PCBs and PBDEs)

Table 3. Soil HILs for phenol.

HIL Scenario	HIL (mg/kg)	Contribution from exposure pathways			
		Ingestion of soil/dust	Ingestion of home-grown produce	Dermal absorption of soil/dust	Inhalation (dust)
Residential A	3000	Yes	yes	yes	minimum
Residential B	45,000	Yes	–	yes	minimum
Residential C	40,000	Yes	–	yes	minimum
Commercial D	240,000	Yes	–	yes	minimum

(NEPM, Schedule B7 – Appendix A2 The derivation of HILs for PAH and Phenols.)

Table 4. Soil HIL for cresols.

HIL Scenario	HIL (mg/kg)	Contribution from exposure pathways			
		Ingestion of soil/dust	Ingestion of home-grown produce	Dermal absorption of soil/dust	Inhalation (dust)
Residential A	400	Yes	yes	yes	minimum
Residential B	4700	Yes	—	yes	minimum
Residential C	4000	Yes	—	yes	minimum
Commercial D	25,000	Yes	—	yes	minimum

(NEPM, Schedule B7 – Appendix A2 The derivation of HILs for PAH and Phenols.)

HILs are designed based on best available scientific information. For phenol (and cresols), there was a significant data insufficiency with regard to dermal absorption toxicity and bioavailability, and consequently default values were used. For example, bioavailability was assumed at 100 per cent, and dermal absorption values for semi-volatiles available from US EPA were adopted. Site-specific bioavailability values may be adopted, where available (NEPM Schedule B7, Appendix A2).

Health screening levels (HSL) are provided for selected hydrocarbons and fractions are applicable to assessing human health risk. Predominant exposure pathways for hydrocarbon contaminants include direct inhalation of vapours from contaminant sources and direct contact with affected soil and groundwater. HSLs in the NEPM were developed for selected hydrocarbons (including BTEX) by CRC CARE, and the principal reference for HSL methodology is CRC CARE Technical Report no. 10 *Health Screening Levels for Petroleum Hydrocarbons in Soil and Groundwater (parts 1-3)*. It is important to note that chemical properties and subsurface behaviour of MTBE are different from BTEX and other hydrocarbons, and so a re-evaluation of traditional site characterisation is warranted.

Soil HILs/HSLs for PFOA/PFOS and MTBE have not been developed for Australia.

Sources of exposure for PFOS/PFOA include inhalation of contaminated air or ingestion of contaminated water and food. These are non-volatile contaminants so there is not exposure expected via inhalation. PFOS/PFOA is emitted into the environment from domestic and commercial uses, leachates from landfill and run-off from various applications. As a consequence, it will be useful to develop soil HILs for PFOA/PFOS. Soil criteria will also be useful to determine occurrence in industrial and municipal biosolids (and water quality criteria for contaminant in leachates). (See discussion in section 4, as biosolids and leachates are beyond the scope of the NEPM).

The Australian standard for MTBE is a maximum of one per cent of petrol (Fuel Standard (Petrol) Determination 2001). The major sources for potential environmental harm from MTBE are fuel stations, leaks and spills. The major exposure pathway is inhalation at locations where MTBE is used or transported. Compared to BTEX, MTBE has a higher affinity for groundwater, with poor soil adsorption or soil vaporisation attributes. However, resistance to biodegradation makes it important to consider soil HSLs.

Soil HSLs may be useful for weathered hydrocarbons because they are a cause for concern in contaminated sites where hydrocarbons have been present. There are no overseas examples of soil guidance for these contaminants and Australia can establish a leading

position in the technical research and guidance development for weathered hydrocarbons. Given the significant deficiency in toxicity data (which may not become available for many years), a risk management approach for petroleum hydrocarbons is recommended (see section 3.1).

Some soil quality guidance values for MTBE and PFOA/PFOS can be identified from an analysis of soil guidance used in Australia and/or overseas:

- US EPA residential soil screening guidance value for PFOA is 16 mg/kg and for PFOS is 6 mg/kg for south east regions (US EPA 2014b)
 - US EPA's PFOA/PFOS guidance values are also applied in relation to dumping of biosolids in agricultural land
- US EPA does not provide soil screening criteria for MTBE. Guidance relevant to soil is focussed on prevention (e.g. leaks in underground storage tanks), remediation and clean-up levels (API 2000; California EPA 2000).

2.3. Groundwater investigation levels

Groundwater investigation levels (GILs) are concentrations of a contaminant in groundwater above which further investigation or a response is required (NEPM). GILs are applicable for assessing human health and ecological risks from direct contact with groundwater. Surface water and waste water (recycled water) are also significant in the context of first-tier priority contaminants and are outlined in section 4.

GILs are generally adopted from Australian water quality standards and refer to direct exposure pathways (such as consumption). They can ideally take into account a full range of water use if contamination occurs within close proximity, including:

- Drinking water (NHMRC NHMMC 2011)
- Agricultural use – stock watering and irrigation
- Fresh and marine aquatic systems i.e. water quality guidance, where available, also incorporates aquatic ecological health risks (ANZECC & ARMCANZ 2000), and
- Recreational use (NHMRC 2008).

A number of Australian water guidelines and standards provide guidance values for GILs and these are generally reflected in the NEPM Schedule B1, Table 1C (A list of water guidance within Australia and overseas is also tabulated in Table 6). Australian Water Quality Standards also determine sediment guidance values – for BaP, the trigger value is 430 µg/kg dry weight. Sediment guidance values have not been developed for other contaminants.

Among first-tier priority contaminants, Australian drinking water standards already exist for BaP, 10 ng/L (Table 5). Fresh and marine water guidelines exist for BaP (in terms of a low reliability estimate) and phenol under the *Australian guidelines for freshwater and marine water quality*. Primary sources of water contamination are human settlements and industry.

Table 5. Water quality standards showing Australian values for BaP.¹

Drinking water health/aesthetic	Fresh	Marine	Recreation	Agriculture
0.01 µg/L	*0.2 µg/L	*0.2 µg/L	**(0.01 µg/L)	—

*As per NHMRC 2011, it was not possible to derive High or Moderate reliability trigger value due to data deficiency. The value shown is a low reliability trigger value (at 95%). The bioaccumulation potential of BaP has not been accounted for. Site specific bioaccumulation effects should be taken into account, or otherwise, a 99% confidence of 0.1 µg/L is recommended if data are unavailable.

** As per NHMRC 2008, if a substance occurs in recreational water at a concentration of ten times that stipulated in the drinking water guidelines, the substance may merit further consideration (Guidelines for Managing Risks in Recreational Water, s. 9.3).

A number of water quality criteria can be identified from an analysis of guidance values used interstate and/or overseas (Table 6). These indicate a need for further review to derive appropriate values in the Australian context.

MTBE concentrations ranging up to 7 mg/L have been reported in the scarcely available Australian groundwater reports. This is well below the health and aesthetic drinking water guideline values in USA and Canada (Table 6). Aesthetic thresholds for MTBE are higher than health thresholds, providing an acceptable guidance value for drinking water. However, MTBE groundwater (and soil) guidelines may be developed, such as for petrol distribution systems, storage and filling stations (also for spill incidents).

Australian drinking water guidelines have not been developed for MTBE, PFOS/PFOA, PBDE and weathered hydrocarbon mixtures, and therefore cannot be used to determine conservative guidance for other uses (e.g. groundwater). The US EPA also recommends that drinking water criteria be used in instances where other specific use criteria have not been determined (US EPA 2014a). Where site-specific values are unavailable, drinking water guidance provided a conservative guidance value in risk-based decision-making.

Drinking water guidance has now been developed overseas for MTBE, PBDEs, PFOS/PFOA and phenol. There are also some overseas fresh water, marine and agricultural use guidance for first-tier priority contaminants. Overseas guidance needs to be reviewed in the Australian context, as per Australian water quality standards. Additional research will be needed to understand Australian aquatic toxicity and biomagnification effects of contaminants.

Aquatic ecological effects of first-tier priority contaminants are a significant concern. Among first-tier priority contaminants, the Australian guidance is limited to low reliability water guidance value for BaP and phenols, and limited sediment criteria. Lack of aquatic toxicological and biomagnification studies in the Australian context is a key difficulty for the development of reliable aquatic ecological guidance values. For practical reasons, it may also be useful to consider contamination levels of surface water at catchments in regard to first-tier priority contaminants (see section 4).

The Australian water quality guidelines also consider that, if a substance occurs in recreational water at a concentration of ten times that stipulated in the drinking water guidelines, the substance may merit further consideration (NHMRC 2008, s. 9.3).

¹ The drinking water criterion of 0.01 µg/L translates into the groundwater investigation levels (GIL) as per NEPM, Schedule B1: Table 1C.

Table 6. Water quality standards showing Australian guidance values in bold, if available. In instances where Australian standards are not available, overseas standards are used.

Substance	Drinking Water health/aesthetic	Fresh	Marine	Recreation	Agriculture	Notes
Benzo[a]pyrene	0.01 µg/L	*0.2 µg/L	*0.2 µg/L	0.01 µg/L	-	
MTBE	0.02 mg/L for MTBE based on its odour threshold (Canada Health)	3.4 mg/L (BC, Canada)	0.44 mg/L (BC, Canada)	0.02 mg/L (BC, Canada)	11 mg/L for livestock watering (BC, Canada)	
	0.02–0.04 mg/L for organoleptic responses (US)	51 mg/L long term, 151 mg/L short term (US)	18 mg/L long-term, 53 mg/L short-term (US)	In absence of specific criteria, drinking water guidelines are used (US)	In absence of specific criteria, drinking water guidelines are used (US)	
PFOS	0.3 µg/L (US/Minnesota)	0.65 ng/L (US)	-	As above	As above	Important to base criteria on fish consumed (pathway)
		0.65 ng/L (Netherlands)	0.00053 µg/L (Netherlands)			0.53 µg/L for surface water intended for drinking (Netherlands)
PFOA	0.04 µg/L (USA/New Jersey)	-	-	As above	As above	
	0.02 µg/L (USA/Nth Carolina)					
	10 µg/L (UK)					
PBDE						
<i>triBDE</i>	0.0005 µg/L (EC)	46 ng/L (BC, Canada)		As above	As above	
<i>tetraBDE</i>	0.0005 µg/L (EC)	24 ng/L (BC, Canada)		As above	As above	
<i>pentaBDE</i>	0.0005 µg/L (EC)	0.2 ng/L (BC, Canada)		As above	As above	
<i>hexaBDE</i>	0.0005 µg/L (EC)	120 ng/L (BC, Canada)		As above	As above	
<i>octBDE</i>	0.0005 µg/L (EC)	17 ng/L (BC, Canada)		As above	As above	
<i>nonaBDE</i>	0.0005 µg/L (EC)	-		As above	As above	
<i>decDBE</i>	0.0005 µg/L (EC)	-		As above	As above	
Weathered hydrocarbons						
<i>Phenol</i>	6mg/L for up to 10 days (US) 5mg/L (Japan), 0.5mg/L (EC)	320	400	(Phenolics: 2)	As above	
<i>Others</i>	-	-	-	As above	As above	

*As per NHMRC, NHMMC (2011), it was not possible to derive High or Moderate reliability trigger value due to data deficiency. The value shown is a low reliability trigger value (at 95%). The bioaccumulation potential of BaP has not been accounted for. Site specific bioaccumulation effects should be taken into account, or otherwise, a 99% confidence of 0.1 µg/L is recommended if data is unavailable.

**US EPA has established oral reference doses (RfD) for PBDEs (See Table 7)

2.4. Ecological investigation and screening levels

For contaminated sites, ecological investigation levels (EILs) are developed for metals and organic substances and are applicable for assessing risk to terrestrial ecosystems. EILs address three groups of land uses:

- Areas of ecological significance
- Urban residential/public open space, and
- Commercial/industrial

EILs can be developed based on the NEPM, Schedule B5b *Methodology to derive ecological investigation levels in contaminated soils*. The methodology is 'flexible and can deal with a variety of different land uses, risk pathways and toxicity data'. It could also be used to derive other soil quality guidelines (SQGs) that have different purposes and/or different land use (section 3).

The NEPM currently includes EILs for arsenic, chromium, zinc, copper, lead, nickel, naphthalene and DDT. These are commonly found in urban environment from anthropogenic sources.

2.4.1. Ecological screening level (ESL)

Ecological screening levels (ESL) are developed for petroleum hydrocarbons and are applicable to assessing risk to terrestrial ecosystems. ESLs can be developed based on section 2.6 of NEPM, Schedule B1 *Guideline on investigation levels for soil and groundwater*. Among first-tier priority contaminants, ESL has only been developed for benzo[a]pyrene (Box 1).

Similarly, EILs/ESLs and/or SQGs may be developed for first-tier priority contaminants based on their different land uses (section 4).

Box 1:

Application of EIL/ESL for benzo[a]pyrene

The EIL for benzo[a]pyrene was reviewed in 2010 based on the limited toxicity data available – earthworm and two plants (Warne 2010). Data limitations did not allow the full use of EIL methodology. Applying the EIL Methodology as far as possible allowed low reliability values for benzo(a)pyrene to be derived. The low reliability value of benzo(a)pyrene using the EIA methodology was 88 mg/kg dry soil.

Given an absence of Australian biomagnification data, Warne (2010) recommended the adoption of the Environment Canada SQG values as equivalent ESLs – 0.7 mg/kg dry soil for urban residential and public open space land uses, and 1.4 mg/kg dry soil for commercial and industrial land uses.

The NEPM indicates the following ESLs for benzo(a)pyrene:

- Areas of ecological significance: 0.7 mg/kg dry soil
- Urban residential and public open space: 0.7 mg/kg dry soil
- Commercial /industrial: 1.4 mg/kg dry soil

2.4.2. Need for EILs/ESLs for emerging contaminants

ESLs and EILs relate only to terrestrial and aquatic ecological risks in contaminated site assessments.

Aquatic health and ecological risks are addressed by the *Australian guidelines for freshwater and marine water quality* (ANZECC and ARMCANZ 2000). The methodology for deriving aquatic ecological screening levels is also provided in the NEPM Schedule 5Bb, Appendix B.

In the NEPM, the aquatic criteria are reflected in GILs and include drinking, fresh and marine water.

Aquatic ecological criteria are especially important in monitoring ecological risks from perfluorinated chemicals from AFFF. Perfluorinated chemicals include legacy PFOS/PFOA and other emerging contaminants including fluorotelomers (such as 8:2 FTS and 6:2 FTS) either as parent compounds or degradation products (Seow 2012). Aquatic ecosystems are a major sink for these contaminants and groundwater contamination provides a significant pathway. Groundwater contamination and water catchment contamination can occur as a result of the use of biosolids from wastewater treatment plants as agricultural fertiliser or soil. Over time, perfluorinated chemicals (and degradation products) can become concentrated in the sediments that constitute biosolids at wastewater treatment plants.

2.4.3. Challenges

The National Environment Protection Council's (NEPC) public consultation during the development of EIL/ESL methodology noted several public concerns regarding the methodology. Concerns were addressed by inclusion of examples in the form of case studies (e.g. benzo[a]pyrene), and a spreadsheet was developed for the NEPM toolbox. This will be useful for future determination of ecological quality guidance values for emerging contaminants.

It should be noted that the development of ESLs/EILs requires input from an array of (eco)toxicity and biomagnification information and data that have yet to be developed for some emerging contaminants e.g. weathered hydrocarbons.

The need for greater investigation based on EILs/ESLs may not be warranted for some contaminants which have been phased out except in specific situations e.g. PBDE is an issue in built environments and, to a lesser extent, in landfills (section 4).

CRC CARE Technical Report no. 29 *Environmental impact of priority contaminants: A literature review* identifies some toxicity and biomagnification literature which can be used to derive EILs/ESLs for first-tier priority contaminants.

Guidance limits for ecological quality for additional first-tier priority contaminants can be identified from an analysis of guidance values used overseas, although these are best developed in the Australian context:

- Ecological risk limits (aquatic) in Netherlands for PFOS (Moermond et al 2010):
 - Maximum acceptable concentration for ecosystems: 36 µg/L (fresh), 7.2 µg/L (marine)

- Serious risk concentration for water ecosystems: 930 µg/L (fresh & marine)
- Derivation of site-specific ecological risk criteria used by Minnesota Pollution Control Agency – Methods for determination of criteria for toxic pollutants, for which numeric standards not promulgated (MPCA 2008). This approach provides a consistent approach to assessing overall health and environmental risk for emerging contaminants using site-specific bioaccumulation and other factors based on best available science. Health guidance values used in derivations are already available in the form of toxicity reference values.

2.5. Toxicity reference values

Toxicity reference values (TRV) are human health-based guidance values such as oral reference doses and slope factors. TRVs form a key component in deriving Australian soil HILs. TRVs are available for all first-tier priority contaminants except weathered hydrocarbons (Table 7).

Screening levels for PFOS/PFOA can be derived in the Australian context based on TRVs or benchmark dose.

Table 7. Example of TRVs: Oral reference doses (RfD) / slope factor developed for assessing environment quality guidance values.

Contaminant	RfD / slope factor
PFOS	0.000075 mg/kg (MDH 2007b)
PFOA	0.00014 mg/kg (MDH 2007a)
PBDE	
<i>tetraBDE</i>	1 x .0001 mg/kg (US EPA 2014a)
<i>pentaBDE</i>	2 x 0.001 mg/kg/day (US EPA 2014a)
<i>hexaBDE</i>	2 x 0.0001 mg/kg/day (US EPA 2014a)
<i>octBDE</i>	3 x 0.001 mg/kg/day (US EPA 2014a)
<i>decBDE</i>	7 x 0.001 mg/kg/day (US EPA 2014a)
MTBE	For carcinogens, slope factor developed: 7.3 mg/kg/day (US EPA 2014a)
BaP	For carcinogens, slope factor developed: 0.0018 mg/kg/day (US EPA 2014a)

Key Australian tools for the derivation of health-based criteria include:

- enHealth 2012 Australian Exposure Factor Guide, Department of Health, Canberra.
enHealth 2012 Environmental Health Risk Assessment: Guidelines for Assessing Human Health Risks from Environmental Hazards, Department of Health, Canberra.

2.6. Summary

There are a number of reasons for the differences in guidance values among countries including derivation methods, and the variability in local geographical, cultural and political conditions (Syikili 2012). For example, in Australia soil the commercial HIL for benzo(a)pyrene is 40 mg/kg (NEPM 2013). Commercial soil screening level for benzo(a)pyrene in UK is 76 mg/kg (DEFRA 2014).

It is important at this stage to gauge how to proceed with development of guidance values in the Australian context. Risk-based assessment of site contamination requires HIL, GIL and ESL/EIL inputs. Management limits for petroleum hydrocarbons will also need to be appropriately considered, as per NEPM, schedule B1 s2.9.

There is potential to develop soil HILs/HSLs for PFOS/PFOA and MTBE at this stage but not for weathered hydrocarbon products. TRVs are available for all first-tier priority contaminants.

Overseas agencies such as Minnesota Department of Health (MDH) also provide important clearing house for TRVs on emerging contaminants (e.g. RfD and slope factors). This information is adopted by the Minnesota Pollution Control Agency to derive guidance. TRVs, such as RfD and slope factors generated by MDH, are adopted in the derivation of Australian site contamination criteria when applying health and ecological risk-based methodologies as per NEPM.

There is a need for greater focus on toxicity and biomagnification effects of weathered hydrocarbons due to lack of national and international studies. CRC CARE is in a leading position to generate research on these contaminants in the Australian context. CRC CARE Technical report no. 29 *Environmental impact of priority contaminants: A literature review* provides the best available scientific data on toxicity and biomagnification. There is also a need to focus research on terrestrial ecological pathways for all first-tier priority contaminants among Australian plant and animal groups.

Review of overseas guidance values for contaminated site assessment, together with the best available scientific information in the local context, can be used to develop Australian EILs/ESLs for PBDE, PFOS/PFOA (and MTBE). This approach was used in the derivation of ESLs for benzo(a)pyrene.

Alternative management approaches may be adopted due to the narrow range of occurrence of some of the contaminants which are no longer manufactured or imported, and have limited scientific information – PBDE, PFOS/PFOA and MTBE.

Table 8 illustrates the Australian guidance already developed for first-tier priority contaminants. There is very limited guidance available for the vast majority of first-tier priority contaminants.

Table 8. Summary of Australian guidance available.

Contaminant	Soil HIL	GIL	ESL/EIL
PBDE	NEPM Schedule B7 App A5 – Guidance on the derivation of health-based investigation levels for PCBs and PBDEs	–	–
Benzo[a]pyrene	NEPM Schedule B7 App A2 – The derivation of HILs for PAHs and phenols	Australian Drinking Water Guidelines; Australian Guidelines for Freshwater and Marine Water Quality; Guidelines for Managing Risks in Recreational Water.	Warne 2010, ASC NEPM Toolbox NEPM Schedule B1, Table 1B(6)
PFOS/PFOA	–	–	–
MTBE	–	–	–
Weathered hydrocarbons	Guidance needs to consider complex mixtures		
<i>Phenol & cresol</i>	NEPM Schedule B7 App A2 – The derivation of HILs for PAHs and Phenols	Australian Guidelines for Freshwater and Marine Water Quality; Guidelines for Managing Risks in Recreational Water (for phenol)	–
<i>Other phenols</i>	–	–	–
<i>Naphthenic acids</i>	–	–	–
<i>Naphthoic acids</i>	–	–	–
<i>Alkylphenols</i>	–	–	–

3. Guidance for remediation

Development of assessment guidance values remains an important step in ensuring adequate implementation of the NEPM Schedule A, *Recommended general process for assessment of site contamination*. In cases where remediation is the next step following assessment of contaminated sites, or for any other reason, guidance may be developed to assist remediation.

The National Remediation Framework (NRF) will provide guidance on remediation of contaminated sites. Contaminant-specific remediation guidance that may be developed for first-tier priority contaminants based on the NRF is outlined.

3.1. Guidance on remediation methods and techniques

CRC CARE Technical Report no. 29 *Environmental impact of priority contaminants: A literature review* provides some analysis of potential remediation technologies. Given the extent of information available on remediation methodologies for first-tier priority contaminants (especially benzo[a]pyrene, MTBE and PFOS/PFOA), remediation guidance based on methodology could readily be developed to address potential remediation technologies identified in CRC CARE Technical Report no. 29 (Table 9).

Guidance on remediation methodologies is important to ensure that method selection and development for remediation is optimised to suit environmental conditions and minimises transformation into other potentially harmful contaminants.

The significant deficiency in toxicity data (which may not become available for many years) for weathered hydrocarbons and the need to consider these as complex mixtures, indicates the need for a risk-based approach for remediation (Brassington et al 2007; CSWRB 2012; Tiwary et al 2013; Mohler et al 2013; Zemo et al 2013). Consequently, this paper recommends a long term risk assessment approach for remediation of hydrocarbons using techniques such as bioremediation to reduce risk rather than (only) reduce in total petroleum hydrocarbon loads. Verification for bioremediation, for example, could be driven by the objective of optimising environmental conditions to reduce risk. This is because bioremediation is known to work well for remediating soils contaminated with petroleum hydrocarbons.

Table 9. Potential remediation techniques based on CRC CARE Technical Report no. 29, and potential for guidance.

Contaminant	Information	Notes
BaP	<ul style="list-style-type: none"> Physical-chemical: solvent extraction/soil washing, supercritical fluid extraction, subcritical fluid extraction Biological: bioremediation, phytoremediation Chemical: chemical oxidation, photocatalysis, electrokinetics Thermal: incineration, thermal desorption, vitrification 	<ul style="list-style-type: none"> Substantial information May be possible to proceed with guidance
MTBE	<ul style="list-style-type: none"> MTBE remediation of contaminated groundwater may be achieved using a variety of technologies Pump and treat, air sparging, in situ bioremediation, in situ chemical oxidation, phytoremediation, natural attenuation 	<ul style="list-style-type: none"> Substantial information May be possible to proceed with guidance Technology selection is highly dependent on site specific conditions, remediation timeframes and budget. Available: <i>Guidelines for Investigation and Cleanup of MTBE and Other Ether-based Oxygenates</i> (California EPA, 2000)
PFOA/PFOS	<ul style="list-style-type: none"> Thermal technologies (preferred) including incineration and sonochemistry Low concentrations of PFOS/PFOA can be removed from wastewater through reverse osmosis, nano-filtration and activated carbon Advanced oxidative processes (AOP) to treat contaminated water 	<ul style="list-style-type: none"> Substantial information Range of some selected techniques is more effective in preventing harmful by-products May be possible to proceed with guidance
PBDE	<ul style="list-style-type: none"> Removal of PBDE-containing material Minimisation of PBDE-containing dust Debromination of PBDEs through application of (nanoscale) zero valent iron Photo-degradation Treating PBDE containing material using thermal techniques 	<ul style="list-style-type: none"> Limited information available. Guidance development may proceed with regard to some remediation techniques that are available.
Weathered hydrocarbons	<ul style="list-style-type: none"> Not provided because of limited information Remediation techniques for phenol 	<ul style="list-style-type: none"> Insufficient information (except phenol) Literature search on remediation of phenol is required together with guidance.

3.2. Remediation endpoints

In practice, remediation occurs in the absence of Australian value-based criteria for many first-tier priority contaminants. International guidance values, although not ideal, currently provide a basis for remediation and management of some of the first-tier priority contaminants e.g. PFOS/PFOA.

Note that for benzo[a]pyrene, assessment guidance developed on the basis of soil HILs, GILs and ESLs under the NEPM provide an indication of ecological and health risk levels. These do not directly translate into remediation endpoints or clean-up levels (for examples of clean-up levels from the US, see Table 10).

The determination of remediation endpoints remains a challenge for most other contaminants and would comprise significant stakeholder consultation. For emerging contaminants, groundwater and soil endpoints may need to be developed with regard to remediation objectives (under NRF). Contaminant-specific remediation guidelines may thus incorporate such endpoints.

Table 10. Clean-up levels in US based on composite US EPA and state values.

Contaminant	Resident soil (mg/kg)	Industrial soil (mg/kg)	Tap water (ug/L)	Max. contaminant level (MCL) (ug/L)	Protection of groundwater screening levels	
					Risk-based (mg/kg)	MCL-based (mg/kg)
MTBE	0.43	0.022	0.12		0.0028	
BaP	0.015	0.21	0.0029	0.2	0.0035	0.24
PBDE	0.016	0.057	0.0022			

Data extracted from US EPA 2014d.

4. Other guidance

4.1. Overview

At the CRC CARE risk assessment workshop in February 2012, stakeholders agreed that the focus should be on the impact of contaminants rather than on the source. Impacts of contaminants are widespread and a range of potential sites/issues is briefly outlined in this section. Investigation and screening levels discussed in section 2 relate to risk assessment of contaminated sites, and contribute to decision-making using the NEPM.

Remediation of first-tier contaminants sometimes requires disposal of highly contaminated products. For this, or any other reasons, additional related guidelines may also be developed or improved. Particularly for POPs, guidance may be enhanced to use health and ecological criteria in (and not limited to):

- Quality grading of biosolids
- Quality grading for waste water, especially for recycling
- Designing landfills to prevent first-tier priority contaminants leaching into the vicinity
- Occupational standards, and
- Assessing health risks in surface water e.g. catchment areas and bays.

Consequently, some key areas for guidance development or improvement based on contaminant-specific issues are discussed in this section:

- Biosolids
- Landfill
- Workplace
- Built environment
- Surface water, and
- National management strategy for contaminants (see guidance on POP).

Contaminant management relates to the wider management actions required to assess and mitigate health and environmental risks from contaminants, and is based on an inventory of contaminants and a risk assessment process to determine an action strategy to mitigate risks.

The NEPM also refers to the widespread impacts of contaminants. The NEPM Schedule B5b *Methodology to derive ecological investigation levels in contaminated soils* states that the methodology can be extended to other soil quality guidelines, SQGs (in addition to EILs):

‘Examples of other SQGs include negligible risk target values, clean-up guidelines (goals that a site remediation must meet), intervention values (guidelines that, if exceeded, require immediate action in the form of

remediation), and agricultural guidelines (guidelines to protect the long-term sustainability of agricultural land). The same basic methodology could also be used to derive guidelines for contaminants in products that are added to soil such as soil amendments, biosolids, fertilisers and re-use of wastes or by-products. In fact, guidelines for cadmium, copper and zinc for Australian biosolids applied to agricultural land have been developed using a very similar method.' (NEPM Schedule B5b s 2.1)

4.2. Biosolids

Biosolids are a solid product from municipal and septic wastewater treatment processes which have been treated to make them safe for further use. Issues with regard to emerging contaminants may be occurrence of PFOS/PFOA and other contaminants in:

- industrially contaminated biosolids and
- municipal biosolids in agricultural land.

A study conducted in Australia's metropolitan cities shows that PBDE is highest in estuarine sediments in urban and industrial locations, particularly downstream from sewage treatment plants (Toms et al 2006). This is indicative of the occurrence of emerging contaminants in sewage and the need for monitoring.

New Zealand has developed additional guidelines for the application of biosolids to land. The objective of these guidelines is to maximise sustainable biosolids use to ensure a high level of protection for both the environment and public health.

In Australia, biosolids are usually regulated using guidelines that apply to a state or territory, or adopting national guidelines or those adopted by other states. The national guidance provides a broad framework, while states and territories generally provide a more detailed code. Concentration guidance values for first-tier priority contaminants especially PFOS/PFOAs and PBDEs is not provided (and contaminant occurrence is also unknown). National and some state guidelines are outlined below.

4.2.1. Australian national guidelines

The *Australian guidelines for sewerage systems: Biosolids management* (2004) indicates that guideline values for contaminants provide safeguards for public health, commodity markets and the environment (NRMMC & NWQMS 2004). Guidance values are adopted from:

- Australian and European scientific data and practice, and the health and environmental risk assessment methodology
- United States Environmental Protection Agency (US EPA)
- National Environment Protection (Assessment of Site Contamination) Measure, and
- Consideration of regional requirements and practices

Adverse health outcomes from chemical contamination of biosolids could result from repeat exposure over long periods of time. If biosolids are tainted by contaminants from domestic or industrial sources its use for agricultural purposes may result in the accumulation of chemicals in agricultural commodities. National food standards provide a reference point when determining guidance values for contaminants.

Use of biosolids varies accordingly and may be quality-graded for:

- Land application uses, including residential
- Agriculture
- Institutional landscaping – recreational: e.g. parks and racecourses, subject to specific site management
- Institutional landscaping – non recreational: urban land applications such as freeway road and landscaping where public access is limited
- Forestry, land rehabilitation – e.g. mine sites or similar land application such as landfill final surface rehabilitation, subject to specific site management and environmental protection practices.
- Municipal landfill-biosolids (sewage sludge) not suitable for beneficial use, may be disposed to municipal landfill, on-site disposal at a wastewater treatment plant or on land specifically dedicated for biosolids disposal, and
- Controlled landfill or thermal processing – biosolids (sewage sludge) untested or containing high levels of contaminants which fail TCLP testing and require disposal to a controlled landfill, or by thermal processing.

4.2.2. State guidelines: examples

Example 1: The *South Australian biosolids guidelines for the safe handling and reuse of biosolids* uses biosolids contamination concentration (BCC) to grade quality of biosolids (EPA SA 2009). Contaminants that are endocrine disrupting chemicals (EDC) are of particular interest. However, there is limited availability of Australia ecological criteria for EDCs like PBDEs and PFOS/PFOA.

Example 2: The *New South Wales EPA environmental guidelines: use and disposal of biosolids* (1996) includes:

‘review and adoption of risk assessment of contaminant acceptance concentrations via appropriate exposure pathways using methodology generally followed in establishing the ‘US EPA 40-CFR 503 sludge regulations and the results of research presently being undertaken by NSW Agriculture, State Forests and CSIRO’ (EPA NSW 1996).

Example 3: The *Victoria EPA Guidelines for environmental management: Biosolids land application* provides specific criteria for grading biosolids for land application (EPA Victoria 2004). In terms of contaminants, soil HILs and EILs from NEPM and food standards (maximum limit, maximum residue limit) are used as criteria for categorising biosolids as unrestricted quality. Unrestricted quality biosolids are deemed to have sufficiently low contaminant levels that specific management controls are not needed.

Restricted grade material requires land application management controls to ensure protection of environment, public health and agriculture. Restricted quality biosolids takes into consideration additional criteria such as regulatory controls on contaminant limits for fertilisers and effective sewer input controls that can result in readily achievable biosolids quality. Grading currently considers contaminants such as DDT, PCBs, heavy metals and organochlorine pesticides (as currently reflected in NEPMs).

There is scope to review the state and territory biosolids (landfill, waste water) management in the context of Australian guidance for contaminants already developed, and/or to be developed. In the case of emerging contaminants, guidance remains to be developed and adopted, as appropriate. Further research generated on toxicity and biomagnification of emerging contaminants for the development of EILs and HIL has potential to provide an Australian context to biosolids management guidance values.

In Australia, contamination guidance values for selected contaminants are used in grading biosolids, and do not specifically test for first-tier priority contaminants. The occurrence of first-tier priority contaminants, especially PFOS/PFOA, in biosolids in Australia is generally not known. In some cases, NEPM criteria may be used (e.g. Victoria) to grade biosolids in the Australian context. The US EPA Region 4 (south east) has determined ecological soil screening guidance for PFOA/PFOS which is applied in the biosolids context.

While this section focuses on biosolids, it is also important to note that wastewater that is recycled is also a concern for environmental health reasons. Recycled water quality standards may incorporate guidance values for first-tier priority contaminants, especially PFOS/PFOA and PBDE.

4.3. Landfill

Queensland stipulates maximum total contaminant levels in different types of soil used as cover material in landfill operations (DEHP 2013):

- PFOA 16 mg/kg PFOS 6 mg/kg
- Phenols in clay-lined landfills 100 mg/kg, double lined landfills 250 mg/kg, and
- m-cresol/o-cresol/p-cresol in clay-lined landfills 250 mg/kg, double lined landfills 500 mg/kg.

Queensland also stipulates allowable leachate contaminant levels from landfills (DEHP 2013):

- BaP at clay lined landfills 0.002 mg/L and for double lined landfills 0.02 mg/L
- Phenols in clay-lined landfills 1 mg/L, double lined landfills 10 mg/L, and
- For m-cresol/ o-cresol/ p-cresol in clay-lined landfills 2 mg/L, double lined landfills 20 mg/L.

Leachates are also a source of small amounts of PBDE, also emissions from waste incineration.

4.4. Workplace

Examples:

- Perfluorinated chemicals from AFFF
- PBDEs – manufacturing stopped in 2007. Current issues arise with regard to dust from PBDE containing materials in the built environment.

The American Conference of Governmental Industrial Hygienists (ACGIH) has developed a workplace environmental exposure level of 5 milligrams per cubic metre (mg/m^3) for decaBDE, with ongoing air monitoring required if dust levels of penta and octaBDE exceed $5 \text{ mg}/\text{m}^3$ (US EPA 2014c).

4.5. Built environment (indoors)

Although importation and manufacture of octaBDE and pentaBDE were banned in 2007, PBDEs remain an ongoing concern. PBDEs are increasingly recognised as an issue in homes and buildings. PBDE was found to be commonly present in dust and material in homes in a study in Western Australia in 2013 (Stasinska et al 2013). The study indicated that electrical appliances, fixtures and fittings in the home were common sources of PBDEs. Other sources of PBDEs include landfill leachates and emissions during waste incineration.

4.6. Surface water

In some cases drinking water guidance values have not been developed. Surface water from catchments used for drinking may be assessed for contaminants in the absence of drinking water guidance. This applies to sites where current or past first-tier priority contaminants use in the vicinity may be a health concern (drinking water and/or fish consumption).

For example, Minnesota Pollution Control Agency's *Methods for protection of surface waters from toxic pollutants for which numerical standards not promulgated* is based on toxicity value provided in terms of oral reference doses (RfD), drinking water, and fish consumption guidance values (STS Consultants Ltd 2007a; STS Consultants Ltd 2007b). In this example, development of surface water quality guidance values for PFOS/PFOA entails a site-specific literature review aimed at the development of key aquatic species-based bioaccumulation and biomagnification data. The Minnesota Pollution Control Agency's guidance for surface waters has been applied to PFOS and PFOA for the Mississippi River and Lake Calhoun.

Site-specific guidance values such as developed for Mississippi River and Lake Calhoun cannot be applied broadly; however, the methodologies applied are of interest. Only the health-based guidance values such as RfD and slope factor developed by Minnesota Department of Health can be directly applied in Australian context (Table 11).

Specific data on aquatic species and toxicity may be similarly assessed for water catchments (or fishing lakes) in Australia.

Table 11. Oral reference doses developed for assessing environment quality guidance values for PFOS/PFOA by MDH (data extracted from STS Consultants Ltd 2007a, STS Consultants Ltd 2007b).

Contaminant	RfD	Heath-based guidance value	Fish consumption criteria	Water and fish consumption criteria
PFOS	0.000075 mg/kg	0.3 µg/L for groundwater	(developed for Mississippi River and Lake Calhoun)	(developed for Mississippi River and Lake Calhoun)
PFOA	0.00014 mg/kg	0.5 µg/L for groundwater		

4.7. National management strategy

Many types of generic guidance exist for POPs at the international level, some of which have also been applied in the national context. Examples:

- Guidance for the inventory of PBDEs listed under the Stockholm Convention on POPs (UNEP 2012)
- Guidance on best available techniques and provisional guidance on best environmental practices relevant to Article 5 and Annex C of Stockholm Convention on POPs

5. Next steps

The development of further guidance for first-tier priority contaminants is expected to consider existing frameworks such as:

- Contaminated site assessment and management, as per NEPM
- Contaminated site remediation (as per the National Remediation Framework), and
- Additional management guidelines for biosolids, landfills etc. outlined in section 4.

The NEPM provides some generic guidance that may be used in the context of first-tier priority contaminants e.g. laboratory analysis and risk assessment. The development of guidance through the establishment of investigation and screening levels however, provides a critical step towards better assessment and characterisation of health and environmental risks from contaminants.

Table 8 summarises those first-tier priority contaminants for which Australian guidance is available (and the type of guidance), as well as those gaps for which guidance is not available. The guidance identified comprises threshold values, including (but not limited to) HILs/HSLs/GILs/EILs. A lack of specific types of guidance for particular contaminants may result from no perceived need for such guidance (e.g. EIL for asbestos), or from a lack of suitable information required for the development of guidance. In some cases, guidance may comprise a management approach, particularly where it is either not feasible to establish specific threshold values (e.g. asbestos) or where the contaminant is a complex and/or variable mixture (e.g. weathered hydrocarbons). In some cases an interim management approach may be appropriate prior to the development of threshold values.

A preventative management approach involves banning the import, sale and/or use of a substance, or products containing the substance – examples would include many POPs listed in the Stockholm Convention. The difficulty may then relate to the assessment, management and remediation for contaminants still used to limited extents and/or in isolated locations (as with PFOS/PFOA in AFFF), or legacy contamination from past use. Another matter that may also be related is the impact with regard to treatment plants, landfills, workplace and surface water etc.

Site-specific criteria may be developed for PBDE, PFOS/PFOA, phenol and MTBE at high priority sites, if required. Where site-specific bioavailability and/or ecotoxicity/biomagnification research is not available, overseas guidance may provide insight for a conservative approach.

5.1. Proposed way forward

In October 2013, the Policy Advisory Committee considered that CRC CARE could take the lead in developing guidance for prioritised emerging contaminants, particularly those for which Australia has a leading research position. For example, there is potential to develop EILs for PFOS/PFOA and MTBE at this stage but not for weathered hydrocarbon products. There is a need for greater focus on understanding

the chemical properties, toxicity and biomagnification effects of weathered hydrocarbons due to lack of national and international studies.

CRC CARE is in a leading position to generate further research on first-tier priority contaminants in the Australian context – for example CERAR based PhD project on ecotoxicity of PFOA/PFOS (Mayilswami 2014 – *in press*). CRC CARE Technical Report no. 29 also provides some scientific data on toxicity and biomagnification. Research on terrestrial ecological pathways for all first-tier priority contaminants in relation to Australian soil, plants and animals is requisite for developing ecological investigation and screening criteria.

There are several priority contaminants for which information from overseas provides an avenue for CRC CARE to develop guidance. Overseas agencies such as Minnesota Department of Health also provide an important clearing house for toxicity reference values on emerging contaminants (e.g. RfD and slope factors). TRVs are available for all first-tier priority contaminants (except weather hydrocarbons). This information can be adopted to derive Australian guidance values in an efficient and timely manner. TRVs have also previously been adopted in the derivation of Australian site contamination guidance values for other contaminants when applying health and ecological risk-based methodologies as per the NEPM.

Table 12 provides information on the guidance that may be developed, and for which sufficient information is available (whether from Australia or overseas) for first-tier priority contaminants. Additional generic types of guidance are addressed in the NEPM (attachment A and C). Petroleum HSL methodology and guidance values were developed through CRC CARE Technical Report no. 10 *Health screening levels for petroleum hydrocarbons in soil and groundwater*. The National Remediation Framework is also expected to provide additional remediation guidance. Apart from these, Australian-based guidance values may also be incorporated into other guidance e.g. biosolids and landfill.

Table 13 summarises different types of Australian guidance values that may be required in terms of first-tier priority contaminants. It also identifies those circumstances in which guidance may not be needed.

For each contaminant, Table 14 identifies general areas where further information is required for guidance development. Careful consideration is needed with regard to the extent to which information gaps affect guidance development.

Table 12. Summary of available and potential guidance for emerging contaminants.²

1. Contaminant	2. Australian guidance available	3. Overseas guidance available	4. Guidance that may be developed or improved (see also, Table 13)	5. Priority guidance of particular interest to CRC CARE (tentative list)	5A. Importance of guidance	5B. Achievable with current information as per Table 14?	5C. Priority ranking for guidance development	5D. Approx timeline to commence guidance development
PFOS/PFOA	–	<ul style="list-style-type: none"> • Soil screening levels (e.g. US) • Drinking water criteria (e.g. US) 	<ul style="list-style-type: none"> • Soil, ecological and groundwater guidance • Remediation methods • Groundwater/soil endpoints • Possible other guidance e.g. biosolids, landfill • Site-specific guidance 	<ul style="list-style-type: none"> • Health and ecological criteria • Remediation and management • Possible other guidance – biosolids, landfill 	<p>High</p> <p>High</p> <p>High</p>	<p>Yes</p> <p>Yes</p> <p>–</p>	<p>High</p> <p>High</p> <p>–</p>	<p>Short term</p> <p>Short term</p> <p>–</p>
BaP	Soil HIL GIL ESL	<ul style="list-style-type: none"> • Soil, water quality • Clean-up levels for residential soil, industrial soil, tap water, and groundwater (e.g. US) 	<ul style="list-style-type: none"> • Remediation methods • Groundwater/soil endpoints • Possible other guidance/criteria e.g. landfill 	<ul style="list-style-type: none"> • Remediation and management • Possible other guidance-landfill 	<p>High</p> <p>High</p>	<p>Yes</p> <p>–</p>	<p>High</p> <p>–</p>	<p>Short term</p> <p>–</p>
Weathered hydrocarbons	<i>Soil HILs only for phenol and cresols</i>	<ul style="list-style-type: none"> • Risk-based remediation (e.g. UK) 	<ul style="list-style-type: none"> • Soil HIL, GIL and EIL • Remediation methods • Groundwater/soil endpoints (for mixtures) 	<p>Risk-based remediation (See Table 14)</p>	<p>High</p>	<p>Yes</p>	<p>High</p>	<p>Short term</p>

² Additional generic guidance is provided in NEPM. NRF is also expected to provide the overarching guidance framework.

1. Contaminant	2. Australian Guidance Available	3. Overseas Guidance Available	4. Guidance that may be developed or improved (see also, Table 12)	5. Priority guidance of particular interest to CRC CARE (tentative list)	5A. Importance of guidance	5B. Achievable with current information as per Table 13?	5C. Priority ranking for guidance development	5D. Approximate timeline to commence guidance development
PBDE	Soil HIL	<ul style="list-style-type: none"> • Soil, water quality • Clean-up levels for residential soil, industrial soil and tap water (e.g. USA) 	<ul style="list-style-type: none"> • GIL, EIL for most toxic/common PBDE congeners • Remediation methods • Groundwater/soil endpoints • Possible other guidance e.g. homes and offices, occupational, landfill 	<ul style="list-style-type: none"> • Remediation method(s) • Possible other guidance - landfill, occupational, built environment 	<p>High</p> <p>High</p>	<p>Yes</p> <p>–</p>	<p>High</p> <p>–</p>	<p>Short term</p> <p>–</p>
MTBE	–	<ul style="list-style-type: none"> • Water quality • Clean-up levels for residential soil, industrial soil, tap water and groundwater 	<ul style="list-style-type: none"> • Soil HIL, GIL and EIL • Remediation methods • Consider site-specific guidance (petrol distribution, storage and filling stations) • Groundwater/soil endpoints • Consider other guidance e.g. occupational, surface water 	<ul style="list-style-type: none"> • Screening criteria (health, aesthetic, ecological) • Remediation method(s) and/or risk-based remediation 	<p>High</p> <p>High</p>	<p>Yes</p> <p>Yes</p>	<p>High</p> <p>High</p>	<p>Short term</p> <p>Short term</p>

Table 13. Australian guidance values related to first-tier priority contaminants that are available (A), and those that may be developed (D) or improved (I).

	BaP	PBDE	PFOS/ PFOA	MTBE	Weathered hydrocarbons
Soil HIL	A	A	D	D	D
Drinking water	A	–	D	D	D
Groundwater	A, I	D	D	D	D
Ecological (terrestrial)	A, I	D	D	D	–
Biosolids*	D	D	D	D	Data deficient
Landfill environment**	D	D	D	D	
Built environment	–	D	–	–	
Workplace	–	D	D	–	
Surface water*** (human-health based)	D	D	D	D	
Waste water (recycled water)	–	–	D	–	

* Biosolids criteria for contaminant concentrations for grading may incorporate soil HIL and groundwater quality guidance values depending on intended use of biosolids (also Food Standards).

** Landfill soil covering criteria may adopt soil guidance values (e.g. Queensland), if appropriate. Leachates may incorporate groundwater and/or drink water guidance value, as needed.

*** May incorporate drinking water and/or aquatic ecology guidance, as appropriate, and needs to take into account health guidance values with regard to fish consumption.

Table 14. Further information that may be required for guidance development in the near future.

Contaminant	Further information that may be required for guidance development
PFOS/PFOA	<ul style="list-style-type: none"> Review overseas screening guidance in Australian context and incorporate Australian exposure pathway, ecotoxicity, biomagnification data etc., as needed. Review fresh, marine, and agriculture water quality guidance values in Australian context. Soil-groundwater endpoints, following review of available guidance and Australian scientific data.
BaP	<ul style="list-style-type: none"> Soil-groundwater endpoints, following review of available guidance and Australian scientific data. Improve reliability of fresh, marine, and agriculture water quality
Weathered hydrocarbons	<p><i>Short-term</i></p> <ul style="list-style-type: none"> Survey of oil companies for current approaches. Risk-based approaches for remediation of complex mixtures, i.e. method development. <i>Note that a risk-based management approach can be implemented to improve remediation methods for TPH so that risks are reduced overall.</i> Review of analytical methods and techniques <p><i>Longer term</i></p> <ul style="list-style-type: none"> Scientific research on human and ecological health-based risks, including identification of pathways, toxicity and bioaccumulation data for the development of health and ecological guidance values. Since a risk-based approach to method development is recommended, scientific research on ecotoxicity and bioaccumulation data may serve to improve any additional risks, if/when additional risks are identified. Soil-groundwater endpoints, following scientific research on human and ecological health-based criteria.
PBDE	<ul style="list-style-type: none"> Review overseas screening guidance in Australian context and incorporate Australian exposure pathway, ecotoxicity, biomagnification data etc., as needed. Review fresh, marine, and agriculture water quality guidance values in Australian context. Soil-groundwater endpoints, following review of available guidance and Australian scientific data.
MTBE	<ul style="list-style-type: none"> Review overseas screening guidance in Australian context and incorporate Australian exposure pathway, ecotoxicity, biomagnification data etc., as needed. Review fresh, marine, and agriculture water quality guidance values in Australian context. Soil-groundwater endpoints, following review of available guidance and Australian scientific data. Consideration of risk-based remediation approach

CRC CARE can lead a review of overseas guidance, together with best available scientific data in the Australian context, to provide a reasonable step forward to:

- Develop remediation methods guidance based on remediation technologies that are available
- Develop screening guidance for PFOS/PFOA
- Develop screening guidance for MTBE (see CRC CARE Technical Report no 10)
- Investigate other site-specific guidance, or guidance review, as may be required for first-tier priority contaminants, i.e. biosolids, landfill, wastewater, built environment, occupational and surface water
- Continue to develop scientific research to generate and/or improve Australian scientific data including soil, water and ecological toxicity and biomagnification
- Investigate groundwater/soil endpoints with regard to remediation objectives.

CRC CARE can similarly also contribute to:

- Developing health and ecological screening criteria for PFOS/PFOA, and
- Developing fresh and marine water guidance for PBDE, PFOS/PFOA and MTBE, if required.

Research proposals are being produced by CRC CARE to generate relevant information for guidance development, commencing in the next few months.

5.2. Final remarks

The wider context of national and international examples indicates that the development of guidance for emerging contaminants requires a comprehensive approach. Such an approach should comprise identification and contextualisation of priority site-specific issues in consultation with stakeholders to ensure targeted research, and systematic and coordinated guidance development. This is significant because of the need to progress guidance development in the Australian context.

A variety of communications tools is needed to inform and consult stakeholders (and the public) regarding guidance and research on first-tier priority contaminants. In the medium term, guidance for second-tier priority contaminants, and those for which a watching brief has been identified by stakeholders, may also be characterised.

Recognising that the process of guidance development and risk assessment for contaminants will be ongoing, given the large number of existing and emerging contaminants of concern, and the likelihood that sufficient resources will not be available in Australia to develop guidance for them all, it has been suggested that CRC CARE could consider scoping and establishing a scheme to identify and/or disseminate relevant information on emergent contaminants, based on the model employed by the Minnesota Health Department in the United States. Indeed one approach may be for CRC CARE to be a clearing house for dissemination of information generated by the Minnesota Health Department. CRC CARE has engaged a postdoctoral researcher (Dr Joytishna Jit) to progress this proposal.

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APPENDIX A.

Types of guidance in the National Environment Protection (Assessment of Site Contamination) Measure

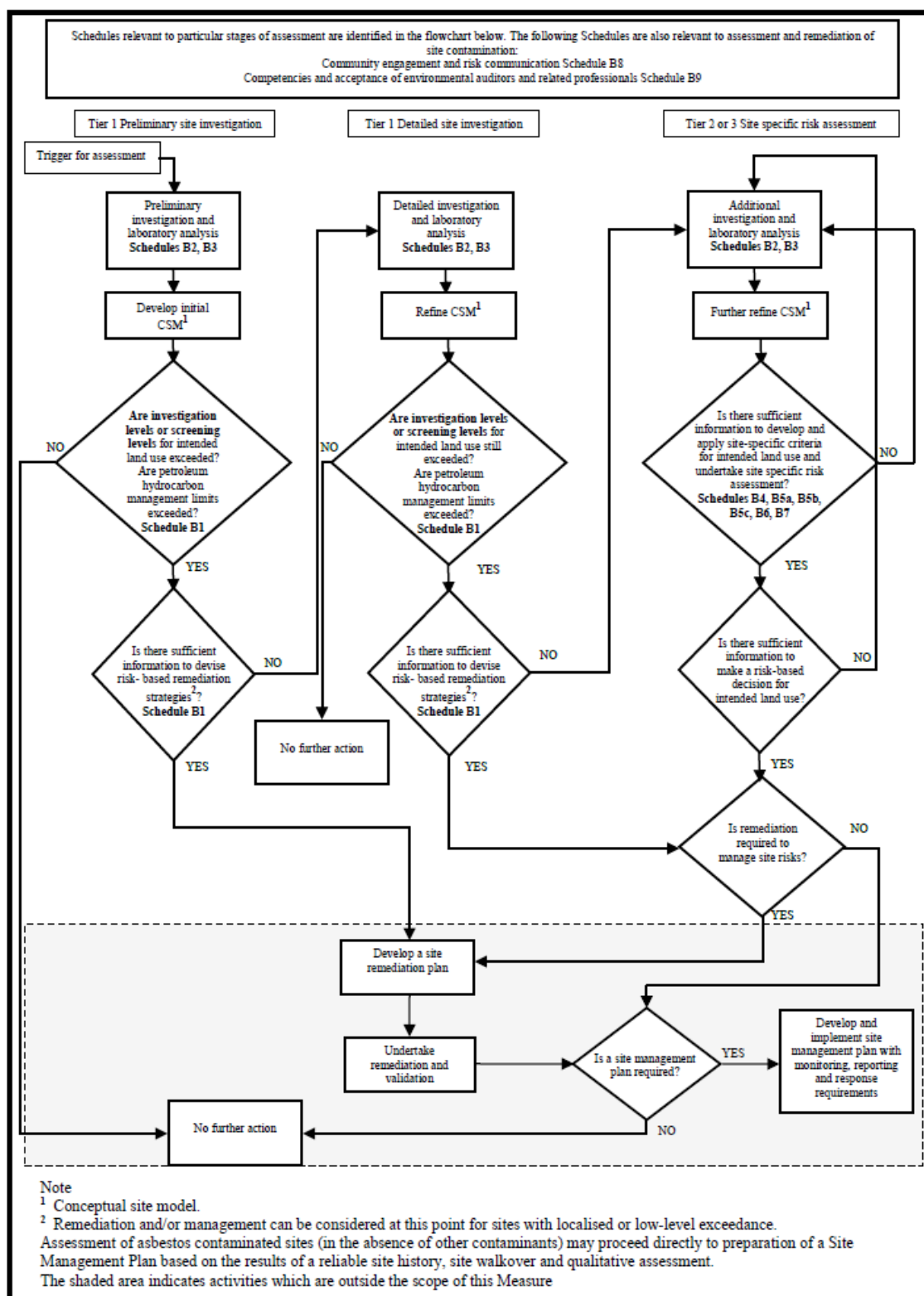
Type	Example from NEPM	Reference	Outline	Notes
Investigation levels	Guidance on investigation levels for soil and groundwater	Schedule B1	<ul style="list-style-type: none"> • Intro • Derivation of investigation and screening levels • Application of investigation and screening levels • Asbestos in soil • Case studies • Tabulated investigation and screening levels • Biblio 	
	EILs for arsenic, chromium, zinc, naphthalene, DDT, copper, lead and nickel	Schedule. B5c	<ul style="list-style-type: none"> • Compound • Exposure pathway • Toxicity assessment • Normalisation relationships • Sensitivity of organisms to Zn • Calculation for fresh & aged zinc contamination, etc. • Reliability of zinc quality guidelines • Comparison with other guidelines 	
Derivation of HILs	Guidance on the derivation of health-based investigation levels for PCBs and PBDEs	Schedule. B7, App. A5	<ul style="list-style-type: none"> • General, • Previous HIL, • Significance of exposure pathways, • Identification of toxicity reference values, • Calculated HILs, • References 	Appendix B for equations for calculating soil HILs Appendix C for calculations
	The derivation of HILs for PAHs and phenols	Schedule. B7, App. A2	<ul style="list-style-type: none"> • As above 	As above
Laboratory Analyses	Guidance on laboratory analyses of potential contaminated soils	Schedule B3	<ul style="list-style-type: none"> • Intro • Lab analysis • Quality • Sample • Analytical Methods • Physiochemical analyses • Metals, halides, non-metals, organics, leachable contaminants • Biblio 	Appendix – Determination of total recoverable HCs in soil

Methodology	Guidance on methodology to derive ecological investigation levels in contaminated soils	Schedule B5b	<ul style="list-style-type: none"> • Intro • EIL derivation methodology • Determining most important exposure pathways • Derivation of EIL values • Technical notes on methods used in EIL derivation methodology • Biblio 	<p>Appendix A – review & comparison of frameworks in other countries</p> <p>Appendix B – Method for deriving EILs that protect aquatic ecosystems</p> <p>Appendix C – Methods for determining bioavailability of contaminants & ERA</p>
Risk-based assessment	Guidance on the framework for risk-based assessment of groundwater contamination	Schedule. B6	<ul style="list-style-type: none"> • Intro • Site assessment process and terminology • Framework for applying water quality guidelines in the risk-based assessment of groundwater contamination • Biblio 	
	Guideline on site-specific health risk assessment	Schedule. B4	<ul style="list-style-type: none"> • Intro, • Australian Risk-assessment framework, • Data collection & evaluation, • Exposure assessment, • Toxicity assessment, • Risk characterisation, • Risk communication, • Biblio 	Appendix: Structure of Risk Assessment Report
	Guideline on Ecological Risk Assessment (ERA)	Schedule B5a	<ul style="list-style-type: none"> • Background & Intro • ERA framework • Preliminary ERA • Definitive ERA • Uncertainty • Reporting • Biblio 	<p>Appendix – Summary of EILs for fresh and aged contamination in soil with various land uses³</p> <p>Appendix B – Mixture of chemicals</p>

³ EILs available for zinc, arsenic, naphthalene, DDT, chromium, copper, lead and nickel. Land uses = area of ecological significance, urban residential/open public, commercial/industrial.

APPENDIX B.

Recommended general process for assessment of site contamination (NEPM, Schedule A)



APPENDIX C.

Summary of guidance, responsible agencies and development bodies

The types of guidance that may be developed for CECs (or other contaminants) may relate to:

- benchmarks for investigation/assessment
- methodologies to develop such benchmarks
- technologies (e.g. for analytical methods, remediation methodologies)
- methodologies to develop (site-specific) remediation objectives (refer NRF).

In addition, industry-specific or product-specific guidance may incorporate guidance for CECs.

The table below expands on these categories of guidance.

Guidance types	Responsible agency	Development body	Purpose / exposure
Investigation			
HILs	NEPC	NHMRC	Ingestion of soil, home-grown produce, dermal, inhalation of dust
HSLs	NEPC	CRC CARE	Soil, vapour, groundwater
GILs	NEPC	NWQMS	Drink, recreation, aquatic wildlife, sediments
EILs	NEPC	CSIRO	Terrestrial wildlife, bioaccumulation
ESLs	NEPC	CRC CARE	Terrestrial wildlife, bioaccumulation
Methodologies			
Analytical methods (soil)		CRC CARE	
Methodology to derive soil HILs	NEPC	NHMRC	
Methodology to derive EILs	NEPC	CSIRO	
Methodology to derive HSLs		CRC CARE	
Risk-based methods for contaminated site assessment	enHealth NEPC	enHealth NEPC	
Remediation			
Remediation framework		CRC CARE	[cf National Remediation Framework]
Selection of remediation methods (contaminant-specific)		CRC CARE	[cf National Remediation Framework]
End points (contaminant-specific)		CRC CARE	[cf National Remediation Framework]
Other guidance			
Occupational	NICNAS	NICNAS	Manufacturing (PBDE), filling stations (MTBE)
Surface water	NWQMS	NWQMS	Used in drinking water
Landfills	EPAs	EPAs	Landfill cap
Biosolids	EPAs	EPAs	Land application e.g. Victoria and NZ
Wastewater	NWQMS	NWQMS	Recycled water



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