

Issue #7 2011

Remediation Australasia



**HEALTH SCREENING
LEVELS**
for petroleum hydrocarbons



**REMOVING
VOCs**
through photocatalytic
oxidation



**REAL-TIME
TOOLS**
how they improve
conceptual site models



Cooperative Research Centre for Contamination
Assessment and Remediation of the Environment

CRC CARE is Australia's leading science-based partnership in assessing, preventing and remediating contamination of soil, water and air. With a unique mix of industry, university and government agency partners, CRC CARE's research program focuses on the challenges of best practice policy, better measurement, minimising uncertainty in risk assessment, and cleaning up.



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Hello, and welcome to the first printed edition of *Remediation Australasia*.

This issue of *Remediation Australasia* is an exciting step toward the future of the Australasian Remediation Industry Cluster (ARIC) – the umbrella under which Remediation Australasia is housed.

Remediation Australasia is a quarterly publication featuring the latest industry news, research updates, case studies, developments in contaminated site law and policy, and advances in technology and practices in contamination assessment and remediation.

For some years now, our magazine has been published online for ARIC members to access via our website, also entitled Remediation Australasia.

Our members come from all over the world, and share an interest in learning about developments in the remediation industry – a growing industry whose needs we strive to meet through our research outputs, including the *Remediation Australasia* magazine.

The step we have taken in moving to a printed publication represents the strength of our role and responsibilities in communicating current and relevant research to industry.

ARIC's parent organisation, CRC CARE, will continue to share research outcomes with industry until at least 2020, after winning its bid in December 2010 for a further 9 years of funding support from the Commonwealth's Department of Innovation, Industry, Science and Research (DIISR).

The second term of CRC CARE officially commenced in July 2011, and will continue to sponsor ARIC as the primary vehicle to disseminate its knowledge to the Australian and international remediation industry. This will be achieved through the delivery of this magazine, as well as training courses, workshops, and the biennial CleanUp Conference.

This year's CleanUp Conference is being held from September 7–15, combining the 6th International Workshop on Chemical Bioavailability in the Terrestrial Environment and the 4th International Contaminated Site Remediation Conference.

I encourage you to take the time to complete, or forward on, the free subscription form on page 29 to any colleagues or clients who you feel would be interested in, or benefit from, ARIC and its activities. Membership is free, and enables you to receive updates on ARIC activities and free editions of the magazine.

ARIC is a rapidly growing group which relies on the input of its members to achieve its goals. I welcome you to join ARIC so you or your organisation can participate in the process of improving the professionalism, effectiveness and efficiency of remediation services in Australasia. I also invite you to contribute to *Remediation Australasia* by sending relevant information on coming events, new technologies, case studies and relevant industry information to aric@crccare.com.

ARIC has received much support from its implementation committee and I would like to acknowledge their significant contributions to date. Given the rapid increase in its membership, ARIC is looking forward to enhancing its Advisory Committee ensuring that, in addition to end-user sector representatives, it also has the skill set required to further strengthen its ability to deliver on its objectives to address issues that impede the efficient and effective remediation of contamination, to facilitate communication across the industry and provide strategic direction for the sustainable growth of the remediation industry.

I hope you enjoy the articles and updates in our latest edition of the magazine, and look forward to your ongoing support.

Prof Ravi Naidu
Managing Director, CRC CARE
 Editor, *Remediation Australasia*

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Health screening levels

for petroleum hydrocarbons in soil, soil vapour and groundwater

by Prashant Srivastava, CRCCARE



Petroleum hydrocarbons are typical contaminants at most Australian contaminated sites, and can be harmful to human health if exposure occurs above certain concentrations. Human health and ecological risk assessments of contaminated sites are conducted to determine whether the concentration of a contaminant poses unacceptable risk(s) to human health and/or to ecological values. There is general guidance available on how the assessment of risk associated with contaminants should be carried out, but limited detailed information or agreement on the specifics associated with hydrocarbon contamination has been available.

In Australia, the approach for triggering further investigation during contaminated site investigations is to determine whether the concentration of contaminant of concern in soil and/or groundwater exceeds the adopted investigation level. A limited number of investigation levels exist for petroleum hydrocarbons, but

they do not extend to a variety of soil types and aquifer situations, nor to the assessment of volatile hydrocarbons. In the 2006 review of the *Assessment of Site Contamination National Environment Protection Measure* (NEPM), the National Environment Protection Council (NEPC) identified the need for national guidance on petroleum hydrocarbon levels for assessing site contamination.

In 2006, the Cooperative Research Centre for Contamination Assessment and Remediation of the Environment (CRC CARE) took the initiative in collaboration with NEPC, state jurisdictions and industry to develop a comprehensive set of health screening levels (HSLs) for petroleum hydrocarbons in soil, soil vapour and groundwater for a variety of soil types and depths in different land use scenarios. In order to harmonise the national approach to contaminated site assessment, CRC CARE invited Australian environment and health

regulators, industry representatives, environmental practitioners and scientific researchers to be part of a project advisory group (which oversaw the development of HSLs), and to provide guidance.

A series of studies were undertaken as part of the HSL project, and numerous workshops were held with the project advisory group to address the technical and policy issues. A review of current practices and methods for developing and applying HSLs and clean-up guidelines was carried out. Subsequently, a comprehensive review was conducted on 'total petroleum hydrocarbon' (TPH) fractions and how these are assessed locally and internationally. A 'collapsed' fraction approach was adopted after reviewing the physical, chemical and toxicological properties of the various hydrocarbon fractions, and following discussions with Australian analytical laboratories on the feasibility of analysis of these fractions.

The project focused primarily on the vapour exposure pathway from subsurface sources of specific petroleum hydrocarbons for various land uses and depths below the surface. The Johnson and Ettinger model has been widely used and studied, and was adopted as the primary method to determine vapour exposure. The model has been used assuming a finite source and without biodegradation. The adaptation of the model to Australian conditions has considered Australian human health exposure factor guidance and a range of soil and building variables including soil moisture, soil organic carbon content, building ceiling height, areal ratio of cracks in concrete slabs, air exchange rate and concrete slab thickness.

As part of the HSL derivation, CRC CARE commissioned research on under-slab biodegradation of petroleum hydrocarbon contamination. The research identified the site conditions that are conducive to biodegradation of petroleum hydrocarbon compounds in the under-slab subsurface, and the factors that may be applied to HSLs developed in the absence of biodegradation. In this way, the HSLs are applicable to a wide range of real world circumstances.

The assumptions and methodology used to derive the Tier 1 HSLs are the result of extensive consultation with the Australian regulatory, industry and consultant community. The methodology used may also form the basis for higher levels of assessment (Tier 2 and Tier 3 assessment), or for a risk assessment on substances other than petroleum hydrocarbons. An extension model, which can be used to derive screening levels for higher tier assessments or site-specific scenarios, has also been developed.

The suite of HSL documents comprises the following:

- Summary – provides a summary of the suite of HSL documents
- Part 1: Technical development document – details the HSLs themselves, and processes and assumptions in deriving the HSLs



- Part 2: Application document – details how and when the HSLs should be applied
- Part 3: Sensitivity assessment – details how different variables affect the HSLs, and
- Part 4: Extension model – the model can be used to derive HSLs for Tier 1 and higher levels.

These documents describe the technical development and assumptions used in the derivation of HSLs for petroleum hydrocarbons in soil and groundwater, and how the HSLs should be applied. It must be emphasised that the HSLs can only be directly applied to petroleum contamination sources and not to pure compounds, as solubility limits incorporated into the HSLs were derived based on typical compositions of petrol and diesel. The HSLs may be applied to other fuel types (e.g. kerosene, aviation fuel and fuel oil) subject to further information in the particular circumstances to confirm applicability. Detailed information on the model inputs and assumptions (e.g. soil properties, sub-slab attenuation, organic carbon content, chemical properties and building modelling parameters), and overall limitations are provided in the technical development document. It is essential that practitioners become familiar with the limitations of HSLs and how the derived values may be affected by site-specific conditions.

The summary document was prepared for incorporation into the revised NEPM; it has been supplied to the NEPC and remains under consideration.

It is worth emphasising that the HSLs represent the best collective view of the available science and application of Australian approaches on selection of health criteria and exposure parameters. The document underwent several international peer reviews by experts in the US, Canada and Australia. Given the innovative nature of the work, CRC CARE will monitor national and international developments, and publish updates as and when necessary.

CRC CARE encourages the use of the HSLs and the underlying methodology by jurisdictions and site assessors for health risk assessment purposes. It is recommended that these documents be referred to for technical details on the key assumptions for the derived HSLs and on their application, and for limitations on their use. Other considerations such as aesthetics, ecology and explosive/fire risk may need to be addressed separately.

The documents are available now on the CRC CARE website, www.crccare.com, as Technical Report no. 10, *Health screening levels for petroleum hydrocarbons in soil and groundwater*. ■



Using real-time tools to develop

Higher quality conceptual site models

by Camillo Coladonato, ERM



During the lifecycle of environmental contamination projects, several key decisions must be made to achieve the desired outcome (e.g. identification or mitigation of risk, regulatory closure). These decisions are based on an understanding of site conditions and are founded on a broad spectrum of scientific elements such as geology, hydrogeology, contaminant behaviour in the subsurface (i.e. fate and transport) and exposure pathways, as well as many societal considerations. All of these elements are components of a conceptual site model (CSM), which is a planning tool used to organise available information into a clear structure. An effective CSM enables stakeholders and decision makers to understand complex environmental issues, and facilitates identification of data gaps that may inhibit achievement of the desired outcome for a site.

CSMs are typically developed through several phases of assessment conducted using traditional field methodologies such as soil boring and monitoring

well installation, and quantifiable laboratory analytical data. Despite the significant amount of effort and money required to complete these assessments, CSMs developed using only traditional methodologies typically have a reasonable degree of uncertainty. This can often be a result of drawing interpretations from a spatially limited number of discrete data points, in what are commonly quite heterogeneous and complex hydrogeologic systems.

Developing an accurate conceptual model of a contaminated land site, and conducting effective Tier 1 and Tier 2 studies, are crucial to best practice when characterising a site. The sheer volume of data to be collected and processed when investigating a contaminated site requires the use of up-to-date techniques in the most cost-efficient way. To achieve this objective, a variety of screening tools can be applied to collect large volumes of spatial data in a cost-effective manner to better enable definition of source area and plume architecture. Once this has been completed, a relatively small

number of soil, groundwater, and/or soil vapour samples can be collected from strategically selected locations for quantitative analysis using a certified laboratory.

As an alternative to traditional investigation tools and approaches, high resolution site characterisation (HRSC) – using direct push, real-time tools – can provide a more efficient process for developing rigorous CSMs through the application of proven scientific principles, investigation approaches and site characterisation tools. This approach can significantly reduce uncertainty, and enables development of more sustainable decision making and solutions to address subsurface contamination issues. Recent experience with HRSC programs at sites with more than a decade of investigation and remediation history found that source areas were overlooked in past investigations, potential risks to receptors were missed and remediation programs were unsuccessful. Implementation of a

HRSC approach brings significant reductions in business risk, stakeholder concerns and life-cycle costs. Some of these direct push, real-time tools used for HRSC are currently available in Australia, and have already been adopted by site owners and consultants to develop higher resolution CSMs.

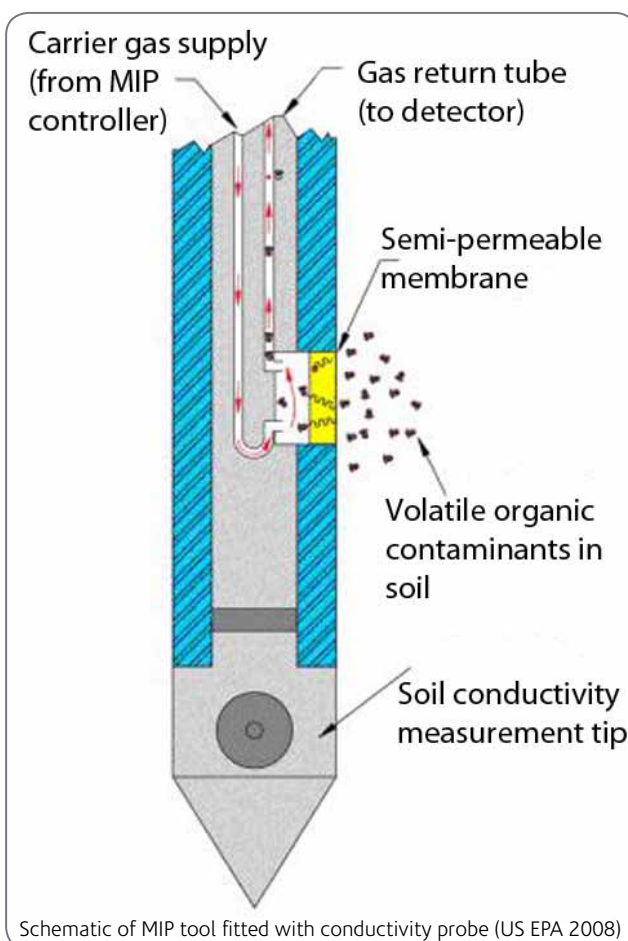
Membrane Interface Probe

The Membrane Interface Probe (MIP) is a direct push, real-time, direct sensing tool that provides continuous semi-quantitative data on the distribution of volatile organic compounds (VOCs) in the subsurface. The tool is affixed at the head of a Geoprobe® drill rod string. The probe on the MIP is equipped with a porous polytetrafluoroethylene membrane set into a steel plate that is heated electrically to volatilise organic compounds present in the soil and/or groundwater adjacent to the probe. Depending on the molecular size, some VOCs pass through the membrane by diffusion under a concentration gradient. Once a compound has passed through the membrane, it enters a sampling stream of inert gas which carries it to detectors at ground surface. A variety of detectors can be employed using the MIP, including a photoionisation detector (PID) to measure aromatic compounds, a dry electrolytic conductivity detector (DELCD) to measure chlorinated compounds, a flame ionisation detector (FID) to measure petroleum hydrocarbons, chlorinated solvents and methane, and an electrical conductivity (EC) dipole array to measure the electrical conductance of the soil and fluids in the soil. This variety of detectors makes the MIP applicable to investigating sites with a broad suite of potential contaminants. A real-time continuous profile of the results from these detectors versus depth is then developed.

MIP results have been used at numerous sites in the US and Europe to define the three-dimensional source area architecture or the location of plume cores within two-dimensional cross sections.

The diagram adjacent (below) depicts a complex three-dimensional source area architecture present in two discrete depths within a sandy aquifer defined in part by using an MIP. In this figure, chlorinated hydrocarbon contamination is depicted in shades of green, yellow and orange, with the orange representing the highest relative concentrations. The purple color in this figure represents the three-dimensional distribution of sodium permanganate (an oxidant injected to remediate the chlorinated hydrocarbon contamination), which was inferred from measurements taken by the EC probe.

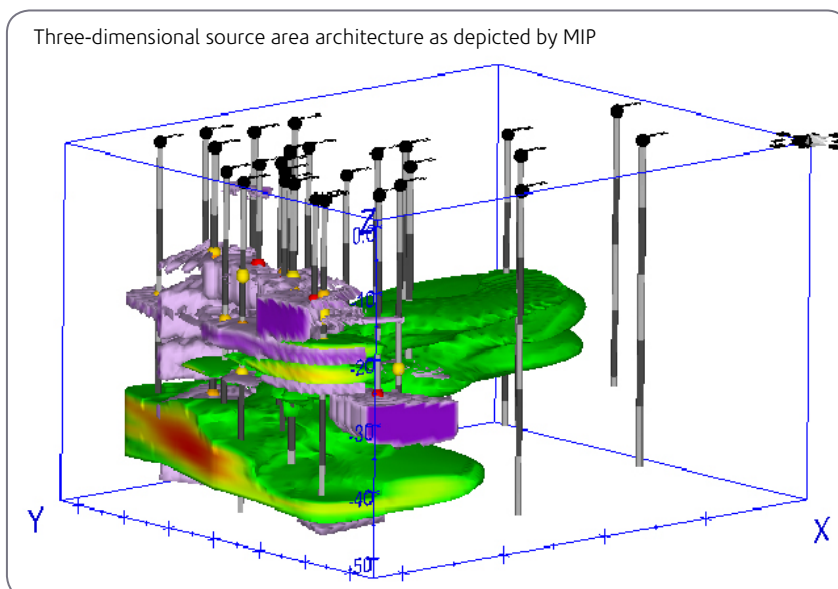
This MIP program was conducted after injecting approximately 25% of the total permanganate volume, and was used to evaluate the distribution of the permanganate relative to the contaminants. Based on the results of this dynamic HRSC program, it was determined that chlorinated hydrocarbons existed upgradient of the initial injection area (i.e. to the upper right of the figure).



As a result, the remedial injection program was modified to address this newly-discovered area of contamination, and expanded to further address the deeper contamination.

Laser Induced Fluorescence

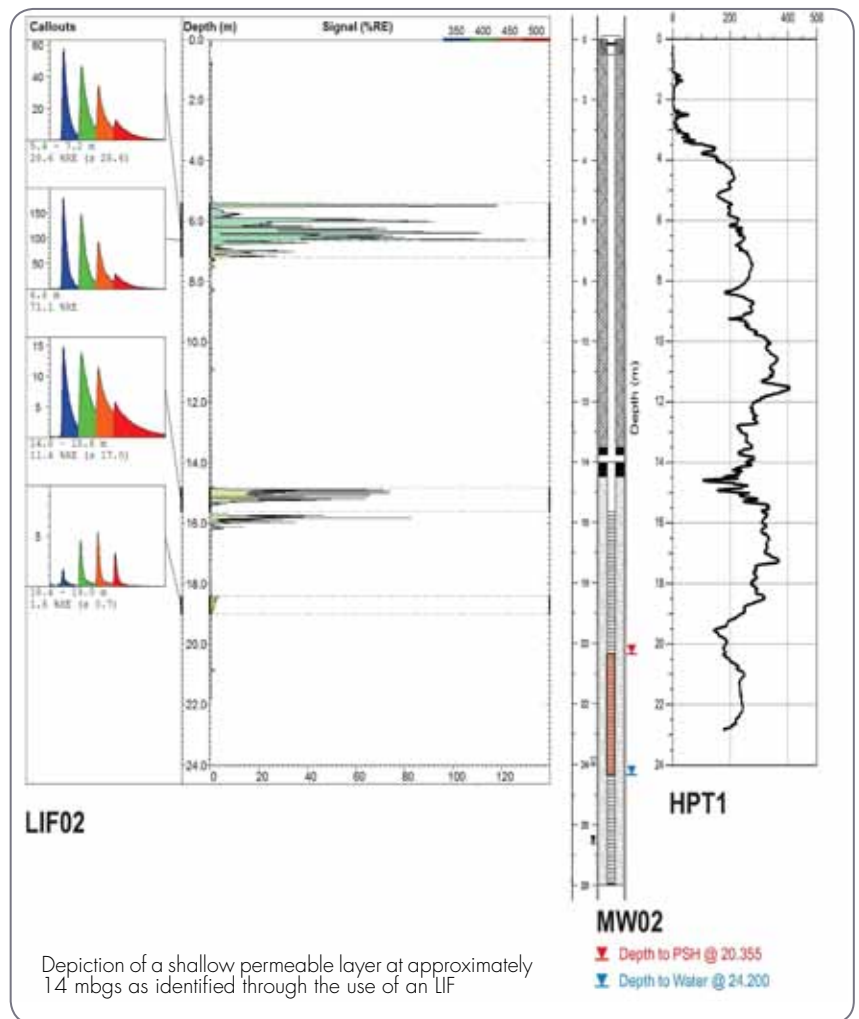
The Ultra-Violet Optical Screening Tool (UVOST®) Laser Induced Fluorescence (LIF) is a direct push, real-time, semi-quantitative and qualitative direct sensing tool that uses UV laser light to cause fluorescence in non-aqueous phase liquids (NAPLs), which can then be measured. The tool is affixed at the head of a Geoprobe® drill rod string. Laser light is sent through a fibre optic cable placed within the Geoprobe®



rods. It then exits a sapphire window and strikes the adjacent soil matrix as the probe is steadily pushed into the ground. The fluorescence emitted by soil is collected by a second sensor, and transmitted via fibre optic cable back up the drill rod string to the instrument for detection and analysis. This allows for a continuous profile of fluorescence versus depth to be developed.

Both MIP and LIF results can be combined with other data streams (e.g. soil type, permeability, laboratory analytical data) to develop cross-sections or combined logs to better depict the distribution of contaminants in the subsurface relative to hydrogeologic conditions. In the case of the LIF, the waveforms observed can be used to distinguish different petroleum NAPL signatures (which result from distinct fluorescent response by different products being present, or differing degrees of weathering).

This tool has been proven to be particularly useful in developing a more refined understanding of LNAPL source zones and migration pathways, which can often be misrepresented when relying solely on soil bore screening via PID or observed NAPL thicknesses in monitoring wells. For example, the LIF has been used to confirm the existence of man-made preferential pathways associated with improperly screened or constructed monitoring wells at service stations where multiple phases of site assessments and remediation activities have been conducted. As depicted in the diagram on this page, during the initial assessment conducted using traditional methodologies, monitoring wells were installed within the main water bearing zone thought to be below a homogeneous clay deposits. However, measurements taken by the EC probe revealed the presence of a shallow permeable layer at approximately 14 mbgs. The profile of fluorescence from the LIF also indicated that the monitoring well introduced, what appeared to be, a vertical connection between the shallow perched (14 mbgs) and the deeper primary regional aquifer (20–22 mbgs) through the annular space of the boring.



Geoprobe® Hydraulic Profiling Tool

The Geoprobe® Hydraulic Profiling Tool (HPT) is a direct push, real-time, semi-quantitative tool available in Australia since early 2010 that is used to evaluate hydraulic properties of unconsolidated soils. The tool is affixed at the head of a Geoprobe® drill rod string. The HPT probe is equipped with a small stainless steel screen that is used to inject water at a constant low flow rate into the formation as the probe is advanced into the subsurface. Injection pressure, which is monitored and plotted with depth, is an indication of the relative hydraulic properties (i.e. the permeability) of the soil. The HPT probe is also equipped with an EC probe to measure electrical conductance of the soil and fluids in the soil. The combination of relative permeability and EC data can be used to develop a continuous profile of stratigraphic and hydrostratigraphic changes in real time. Data sets can then be calibrated by a small number

of confirmatory soil borings to allow interpolation of the findings to wider areas across the sites. The use of these calibrated representations of site geology and hydrogeology have proven to be effective (especially when combined with other data sets such as LIF or MIP) to develop more robust CSMs, depict plume architecture and identify perched water bearing zones using 3D geological modelling software packages.

In summary, HRSC is a strategic, effective, fast and sustainable method for conducting site investigations that can significantly reduce the uncertainty embedded in assessments conducted using traditional field methodologies. Implementation of a HRSC approach can also bring significant reductions in business risk, stakeholder concerns and life-cycle costs and, as a result, the HRSC approach improves the overall sustainability of an environmental project for the benefit of all parties involved. ■

Establishing a national remediation framework

While there are more than 160,000 potentially contaminated sites in Australia, there is no national guidance framework for remediation, and it is specifically excluded from being part of a National Environment Protection Measure.

Although some remediation regulation exists at the state level, it is fragmented, over-conservative and inconsistent between state jurisdictions. In addition, the guidelines for assessment of site contamination provided by the National Environment Protection Measure (NEPM) remain constrained by significant knowledge, technology and data gaps, and are ill-equipped to provide clear direction on dealing with complex and emerging contaminants and problems. These shortcomings are exacerbated by public misconceptions about contamination, and by the absence of a strategy for industry and governments to effectively engage the community on these issues.

CRC CARE seeks to address these gaps by providing a collaborative research platform to support the development of a national guidance framework for remediation. To this end, in May 2011 CRC CARE took the initiative to 'champion' the first step towards the development of a harmonised national remediation framework for Australia. A workshop was coordinated, and attended by representatives of Australian contaminated land regulatory agencies and major industry bodies, to consider the elements that could comprise a national remediation framework for Australia.



Based on the outcomes of this workshop, CRC CARE (in conjunction with stakeholders) is now forging ahead with the development of an Australia-specific framework for the remediation and management of contaminated sites.

It is expected that the national remediation framework will comprise guidance on the practical aspects of site remediation and management, and will build on guidance already promulgated by states and territories.

CRC CARE has established a Framework Steering Group to be chaired by Stuart McConnell,

Director: Future Focus with EPA Victoria, which will provide overarching guidance for the development of the national remediation framework and will oversee the planning and delivery of the framework. Feedback from the first meeting of the Framework Steering Group will be presented at the 4th International Contaminated Site Remediation Conference, being held in Adelaide from 11 – 15 September 2011 as part of the CleanUp 2011 Conference, with future updates and information published in the *Remediation Australasia* magazine. ■



Removing VOCs through photocatalytic oxidation

by Ruh Ullah and Shaobin Wang, Curtin University of Technology

Since the dawn of the era of industrialisation, toxic compounds such as sulfur dioxide, nitrogen oxide, carbon monoxide and various volatile organic compounds (VOCs) have contributed to pollution of the global environment.



The presence of VOCs in air has been identified as extremely perilous, and a potential cause of incurable diseases including carcinoma. The World Health Organisation (WHO) has estimated that 2.8 million people die each year as a result of polluted indoor air. In developed countries like the US, Europe and Australia, people spend more than 90% of their time in closed environments such as homes, rooms, offices and cars. EPA studies have shown that the indoor concentration of VOC pollutants is 20% higher than the outdoor environment – therefore, risks associated with exposure to VOCs are becoming more severe.

Long-term exposure to VOCs is detrimental to human health, and has been linked with sick building syndrome (SBS). Numerous air purification techniques such as air filtration, high efficiency particulates air (HEPA) filters, electronic air filters, dust filters, ionic purifiers, adsorption filters, thermo-catalytic combustors and photocatalytic filtrations have been developed to mitigate indoor pollutants and reduce the possible risks they pose to human health. A technical comparison of various VOC removal techniques has suggested that photocatalytic oxidation of VOCs can be a better alternative, based on the efficiency and cost of the process.

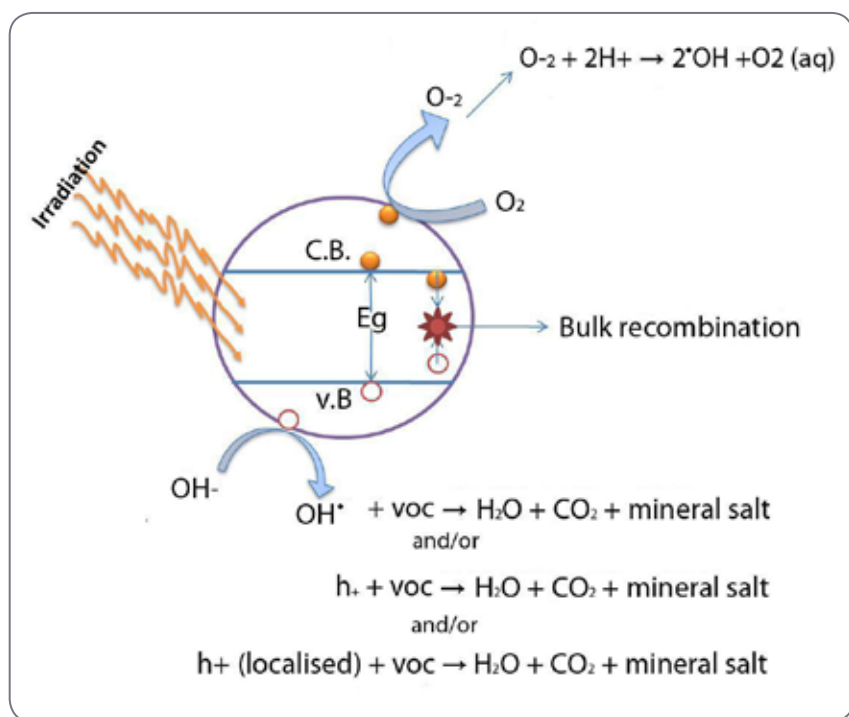


Sources of VOCs

Daily, we encounter thousands of VOCs. It has been established that a single type of VOC can be produced by various sources, making it complicated to assign emission of particular VOCs to a particular source.

Newly-constructed buildings consisting of paints, varnishes, adhesives, vinyl wallpaper and plywood have a considerable amount of benzene, toluene, methylbenzene, xylene, styrene and formaldehyde, while building renovations produce high levels of methyleisobutyle ketone, tetrahydrofuran and alkanes. Floor carpets, wall plasters and nail polishes are also sources of toluene, xylene and acetone emissions respectively. All-purpose cleaners, disinfecting cleaners and spot removers are potential sources of carbonyls, hydrocarbons, glycol ethers, 4-nonylphenol and nonylphenoethoxylates.

Garages attached to residential units can emit various VOCs with comparatively high concentrations of benzene. Home kitchens which use LPG and town gases as fuel have been reported as potential sources of more than 50 different types of VOCs, where formaldehyde, acetaldehyde and benzene were found in abundance.



Photocatalysis techniques which can also be used for hydrogen production via water splitting along with VOC disintegration, both in water and air

In summary, the most common VOCs detected in different environments, and produced by various sources, are benzene, formaldehyde, aldehydes, toluene, xylene, 1, 3-butadiene and acetaldehyde.

Health issues associated with VOCs

Human exposure to VOCs is a realistic concern that requires urgent attention, both from the scientific community and the public, to eradicate and/or mitigate their toxicity and severe health effects.

Exposure to these toxic compounds via ingestion, dermal contact and inhalation can cause various types of dangerous diseases. VOC inhalation has been identified as a main process through which humans can be adversely affected. Various acute and chronic health effects including respiratory effects, neurological toxicity, lung malignancy, throat and eye irritations, neurological symptoms, headaches, dizziness, depression, and even cardiovascular diseases can be attributed to VOCs. Benzene, one of the more abundant VOCs generally emitted, is known to be carcinogenic and a cause of leukaemia.

Aromatic VOCs (benzene, toluene,

xylene) detected in closed buildings have been found to cause ophthalmic symptoms, tiredness and headaches in office workers. Various other SBS symptoms such as eye dryness, runny nose, dry throat, nasopharyngeal symptoms and lethargy were also observed in office building occupants. The average concentration of formaldehyde in homes and offices is about 0.05 mg/m³; the odour of formaldehyde can be perceived at 0.1 mg/m³. Eye irritation can occur at 0.36 mg/m³, and lungs may be affected at a concentration of 1.0 mg/m³.

There is evidence that increased instances of asthma in children are due to the presence of VOCs in cleaning products, solvents and indoor air. Prevalence of asthma and other chronic respiratory disorders in children located near industrial regions with copious VOCs were much higher compared to those in non-industrial areas. The most serious effect of VOCs on human health has been demonstrated in the connection between exhaled VOCs and the instance of lung cancers. Breath samples collected from cancer patients showed 22 different types of VOCs including benzene, derivatives of benzene and alkane derivatives, indicating that these toxic

compounds have a strong relationship to carcinoma.

VOC removal techniques

Removal of VOCs from both indoor and outdoor environments is not only highly recommended, but a top priority for various health organisations. A range of techniques have been introduced to reduce the potential adverse health effects, either by preventing exposure to VOCs or by partial reduction of these compounds. Ventilation can be used to control the concentration of total VOCs in indoor environment by extracting polluted air from indoors and allowing fresh, purified air to enter from the outside environment.

An advanced version of ventilation (high efficient particulate air filter, or HEPA) and its modified forms have been proven effective for reduction of other air pollutants like particulate matter, NO, SO_x and greenhouse gases, etc. However, this technique has not been useful in reducing the concentration of total VOCs to the lower magnitudes recommended by international health organisations.

Plasma pollutant control technology requires high pressure and power to produce powerful radicals, which react with the pollutant gases and reduce their concentration. Although this technology is useful in minimising the concentration of hazardous air pollutants produced in industries, it remains non-applicable to public places and residential areas due to the high power requirements and other associated limitations.

Thermal oxidation or combustion of VOCs is an oxidation technique which can disintegrate various VOCs into non-hazardous compounds. However, the pitfalls of this method include the requirement of an elevated temperature (900–1500°C), and production of NO as a by-product.

Condensation, absorption and adsorption techniques possess the ability to remove VOCs, but have limitations in relation to temperature, concentration, VOC boiling points and solubility, and surface area. Physical adsorption, chemisorption,



adsorption by activated carbon and adsorption by zeolite are more recent applications which are still being tested for their ability to effectively remove VOCs. Adsorption by activated carbon (the most often used technique) is not particularly beneficial, as the competitive adsorption of different VOCs reduces the effectiveness of the process. The most challenging and crucial limitations of the adsorption process are the lack of material re-useability, very low efficiency for specific VOCs, and impracticality at high temperature.

Photocatalytic oxidation of VOCs

Technical attributes like feasibility, compatibility to work at ambient temperature and pressure, suitability for lower concentration of VOCs (at ppb levels), extremely low energy requirements, better removal efficiency, re-useability and longer lifetime of the photocatalysts make photocatalytic oxidation a unique process for VOC decomposition.

Photocatalytic oxidation techniques can be operated at very low power, and sunlight is sufficient in completely decomposing hazardous VOCs to mineral salt, CO₂ and water. The image on the previous page briefly illustrates photocatalysis techniques which can also be used for hydrogen production via water splitting along with VOC disintegration, both in water and air.

Since 1972, heterogeneous photocatalysis has been investigated as a technique for VOC removal and hydrogen production via UV light irradiation using TiO₂ as a photocatalyst.

Highly oxidative species (i.e. hydroxyl radicals ($\cdot\text{OH}$) and super oxide ($\cdot\text{O}_2$)) are produced when metal oxide and/or sulfide (such as TiO₂, ZnO, CdS etc.) is exposed to UV light in the presence of water and oxygen. These two species have high oxidative power, and are capable of decomposing most of the VOCs residing on the surface of materials (or in the near vicinity of the materials).

Some successful results on the photocatalytic degradation of VOCs in gaseous forms with non-doped, cation-doped and anion-doped TiO₂ irradiated with black light ($\lambda < 380$ nm) have shown that this technique is viable and can be used on a large scale. However, the system does have some technical issues including humidity effects, low adsorption of VOCs, lower efficiency at low ppm of VOCs, competitive adsorption of water and VOC molecules, and photocatalyst lifetime.

To overcome these issues, extensive efforts have been made to modify and/or substitute the most credible material (i.e. TiO₂) and make the system capable of working with only visible light ($\lambda > 400$ nm) irradiation. Various techniques such as doping, co-doping, coupling of the photocatalysts (TiO₂/ZnO, TiO₂/SnO₂ and ZnO/SnO₂) and surface modification have been applied to achieve the required results. Until now, nitrogen-doped TiO₂ has shown excellent performance for photocatalytic decomposition of VOCs, owing to the synergetic effect of high porosity, acidic surface, and band gap miniaturisation by anion ions like nitrogen and sulfur. However, humidity and competitive adsorption of water and intermediates have a negative effect on the photocatalytic oxidation of VOCs.

VOC degradation rates depend on the concentration of OH radicals produced by the light irradiation, and concentration of VOCs present in the vicinity. Higher intensity of suitable light radiation generates a large number of reactive species, which in turn decompose VOC molecules that are in contact with the photocatalytic material.

In a typical office, the intensity of artificial visible light is approximately 0.1–0.2 mW/cm²; photocatalytic reactors developed to date require 10–100 times more intense light (1.0–10.0 mW/cm²) in the range of UVA to UVB. Light intensity of 0.25 mW/cm² has been recommended for degradation of 2 ppm of formaldehyde at normal temperature and pressure. Investigations have shown that formaldehyde levels

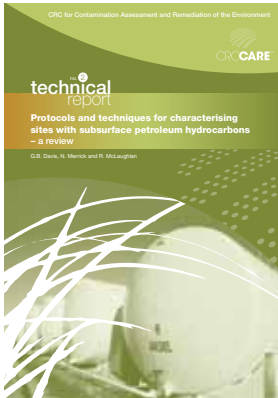
are 4.2 ppm in homes (about half of that in offices) and 34 ppm in newly-manufactured homes. The Australian National Health and Medical Research Council has suggested a permissible level of various pollutants in air (including formaldehyde) in the range of 0.1 ppm, similar to the WHO guidelines for formaldehyde exposure.

To reduce the concentration of VOCs in general, and formaldehyde in particular, to the WHO recommended level of 0.1 ppm through currently available commercialised photocatalysts, a large amount of UV light irradiation is required. Consequently, the applicability of the process using currently available technologies becomes difficult due to the UV light requirements. Further investigation is required to develop photocatalysts which can operate efficiently at the available artificial light and/or sun light in the intensity range of 0.1–0.2 mW/cm².

Summary

Numerous indoor and outdoor sources and activities emit a large number of extremely toxic VOCs. Among these, formaldehyde, acetaldehyde and benzene have been detected both in indoor and outdoor environments with very high concentration ratios, which can cause fatal diseases. Although various physical and chemical techniques have been suggested to mitigate the concentration of these toxic compounds and their prevailing effects, these techniques are not efficient enough to completely remove or disintegrate VOCs. Photocatalytic decomposition via sunlight irradiation and suitable photocatalyst materials has been proven as a viable technology to completely mineralise VOCs compounds at lower levels. This technology is capable of working with very low power and ambient temperature, and completely decomposes VOCs into mineral salt, water and CO₂. However, this method of VOC decomposition is in very preliminary stages, and still needs much attention to be completely developed. ■

technical reports



Technical Report no. 2

Protocols and techniques for characterising sites with subsurface petroleum hydrocarbons - a review

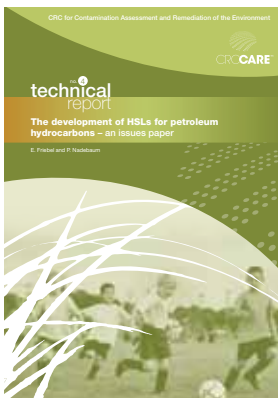
A review of current practices and protocols regarding characterisation of petroleum releases into soil and groundwater environments, and the identification of research opportunities for further investigation. This review forms part of the CRC CARE project to develop a unified national approach to characterising petroleum-impacted sites.



Technical Report no. 3

Natural attenuation: a scoping review

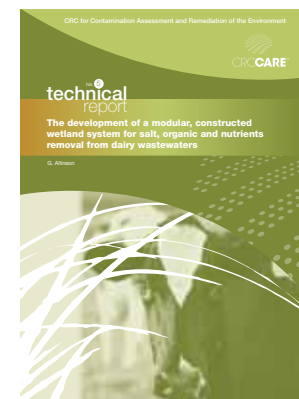
A review of national, international and industry information about the natural attenuation of petroleum hydrocarbons, with a focus on Australian studies. This report identifies scientific knowledge gaps which are relevant to the application of monitored natural attenuation in Australia.



Technical Report no. 4

The development of HSLs for petroleum hydrocarbons - an issues paper

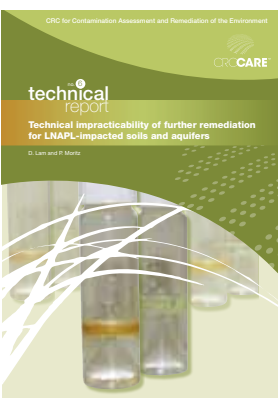
This report identifies issues and provides a commentary on relevant literature and practices regarding petroleum hydrocarbon contamination, which has assisted in preparing a detailed scope and basis for the development of health screening levels and clean-up criteria for petroleum hydrocarbons.



Technical Report no. 5

The development of a modular, constructed wetland system for salt, organic and nutrients removal from dairy wastewaters

A desk-top study designed to provide 'proof-of-concept' for the use of the giant reed *Arundo donax* in constructed wetland systems designed to remove contaminants from dairy processing factory wastewater streams.



Technical Report no. 6

Technical impracticability of further remediation of LNAPL-impacted soils and aquifers

A literature review representing the initial phase of work in a larger program seeking to develop a consistent approach to determining end points for LNAPL remediation. The scope includes a review of literature relevant to LNAPL remediation end points and national and international practices.



Technical Report no. 7

Development of policies for the handling, disposal and/or beneficial reuse of used foundry sands - a literature review

A literature review of the current and existing policies for the handling, disposal and potential beneficial reuse options for used foundry sands. This review examines the current industry and regulatory practice concerning the disposal and the potential options for beneficial reuse of used foundry sands, and identifies data gaps where future research could be focused.



Technical Report no. 8

Review of the current international approaches to total petroleum hydrocarbon assessment

A detailed review of the background to international approaches on total petroleum hydrocarbons, to ascertain the basis of decisions on differences in the use of TPHCWG fractions and associated toxicological, fate and transport data and the specified scope of works.



Technical Report no. 9

Petroleum vapour model comparison

A comparison of internationally recognised and widely used models of vapour behaviour, for their use in modelling petroleum vapours in soil profiles and their movement from the subsurface into built structures. The report recommends one of these models for use in the development of health screening levels, and considers the need for inclusion of biodegradation and finite lifetime sources in modelling approaches during the development of HSLs.

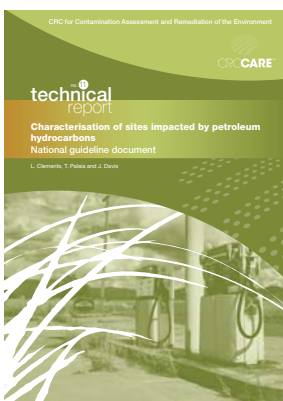


Technical Report no. 10

Health screening levels for petroleum hydrocarbons in soil and groundwater

A four-part report establishing a set of health screening levels for petroleum hydrocarbons in soil and groundwater. This report consists of:

- Part 1: Technical development document
- Part 2: Application document
- Part 3: Sensitivity assessment
- Part 4: Extension model



Technical Report no. 11

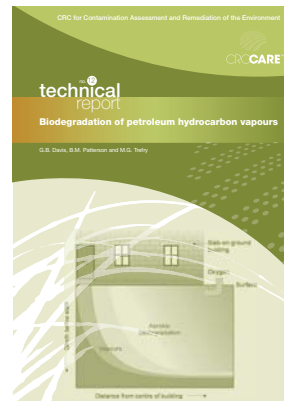
Characterisation of sites impacted by petroleum hydrocarbons: National guideline document

A guidance document providing industry, consultants and regulators a national approach to the characterisation of petroleum hydrocarbon-impacted sites. This document unifies current guidance and provides support for innovative technologies and approaches.

Technical Report no. 12

Biodegradation of petroleum hydrocarbon vapours

This report outlines the role of biodegradation in reducing petroleum hydrocarbon vapour intrusion into slab-on-ground buildings for the application of Tier 1 or human health screening levels.



Technical Report no. 13

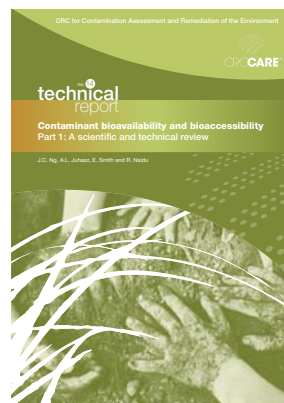
Field assessment of vapours

A report updating the international knowledge available related to guidance and methods of vapour assessment. This report discusses the processes underlying vapour behaviour and the design issues for field assessment of vapours, and reviews available guidance and compares investigation and sampling techniques. A framework for vapour assessment and screening is suggested.

Technical Report no. 14

Contaminant bioavailability and bioaccessibility

A review of the current bioavailability and bioaccessibility approaches, methods and limitations to help in determining their use and application in site assessment. This review evaluates the bioavailability and bioaccessibility of contaminants via the incidental soil ingestion pathway, focusing on inorganic contaminants such as arsenic and lead.



Technical Report no. 15

A technical guide for demonstrating monitored natural attenuation of petroleum hydrocarbons in groundwater

A practical guide on how to understand natural attenuation processes and their monitoring requirements, in order to establish whether MNA is an acceptable and reliable remediation and/or management strategy for sites impacted by petroleum hydrocarbons.

Technical Report no. 16

Safe on-site retention of contaminants. Part 1: Regulatory approaches and issues - a legal perspective

Part 1 of this report examines a range of legal and policy issues that arise when in-situ retention is proposed as a remediation strategy. It surveys the current state of relevant law and policy across a number of jurisdictions within Australia, and explores how the same issues have been addressed in various jurisdictions in North America and Europe.





Technical Report no. 17

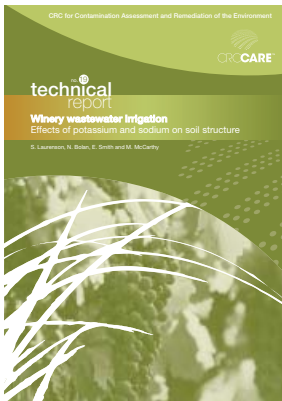
The Australian experience: A comparative analysis of the effects of contamination and its remediation on individuals and communities at two Australian sites

A study exploring community feelings, perceptions and attitudes to land contamination and its remediation. Data was gathered through community surveys, interviews, focus groups and other methods to examine the attitudes at two contaminated land sites in New South Wales.

Technical Report no. 18

Selecting and assessing strategies for remediating LNAPL in soils and aquifers

A report providing information and a framework to address some of the challenges in remediating light non-aqueous phase liquid (LNAPL) contamination. Provides guidance in selecting and matching the performance of remediation technologies to a range of subsurface settings, risk reduction targets, and concerns. The report also identifies gaps in the current understanding of remediation process and performance in the various subsurface settings.



Technical Report no. 19

Winery wastewater irrigation: Effects of sodium and potassium on soil structure

A report studying the effects sodium and potassium have on soil structure when added to soil through the application of winery wastewater to land.

other publications

Engaging the community: a handbook for professionals managing contaminated land

A framework for community consultation in the context of contaminated site projects. This handbook also describes the communication principles that can be used in community consultation. (hardcopy available only, enquire with CRC CARE)



fact sheets

- | | | | |
|------------------------------------|---------------------------------------|---------------------------------------|---|
| Fact sheet no. 1 – Contamination | Fact sheet no. 4 – Bioremediation | Fact sheet no. 7 – Toxic metals | Fact sheet no. 10 – Pesticide residues |
| Fact sheet no. 2 – Risk assessment | Fact sheet no. 5 – Zero waste | Fact sheet no. 8 – VOCs and POPs | Fact sheet no. 11 – Water quality |
| Fact sheet no. 3 – Remediation | Fact sheet no. 6 – Acid sulfate soils | Fact sheet no. 9 – Indoor air quality | Fact sheet no. 12 – Perfluorochemicals (PFCs) |

available at www.crccare.com

Development and harmonisation of Site contamination law

by Elizabeth Brandon, University of South Australia

Despite the growth of international environmental law in the past few decades, there is no global treaty that specifically and comprehensively addresses site contamination, whether in its own right or as a sub-issue. There is a wealth of international, regional and bilateral laws, and while some of these instruments will provide indirect relevance to site contamination, they offer little in terms of detailed guidance. As a result, there is currently a genuine and urgent need for guidance on a comprehensive regulatory approach to the management of site contamination.

This need exists not only in developed countries seeking to improve fragmented and inadequate laws, but increasingly also in developing countries and economies in transition that are encountering site contamination problems for the first time. The latter face two choices: either to try to forge their own approach to site contamination, at the risk of repeating mistakes already made by others; or to look for external guidance. In the absence of any international agreements or influential guidelines, countries are likely to emulate approaches taken in other countries.

Most developing countries and economies in transition do not have specific legislation for contaminated sites. Some developed countries have specific legislation, but there is minimal harmonisation between their approaches. Many other countries rely on more general environmental protection laws which may be inadequate to manage the complex problem. Given the lack of any site contamination



law in most countries, and the inadequacies of laws relating to contaminated sites in the remaining countries, there is a prima facie case for harmonisation on the issue.

Harmonisation of site contamination law and policy could improve standards of management, resulting in fewer health issues, less environmental harm, a lesser burden on future generations and greater legal certainty for land users.

Harmonisation of site contamination law may be achieved in different ways, such as through international law (e.g. treaties), institutions (such as the World Bank) and actors (e.g. industry groups). There are several existing global and regional instruments that could be benchmarked which promote harmonisation on an environmental issue of some (indirect) relevance to site contamination, such as the Stockholm Convention on POPs, 2004, which covers only one class of contaminants (organics) but provides a useful model for a larger, more comprehensive treaty on

contaminants.

Achieving an international instrument on site contamination is likely to be a challenging, long-term goal. Alternative vehicles for harmonisation, such as international, regional and bilateral lending institutions and international organisations, should therefore be explored. These may play an important role, directly or indirectly, in developing law and policy on site contamination. Another avenue is the promotion of a 'model law' on site contamination.

This development of any 'model law' on site contamination needs to be sufficiently flexible to adapt to diverse socio-economic, political, legal and geographical conditions.

Likely features would include a universal definition of 'site contamination'; provisions on the allocation of responsibility; and elements of contaminated site prevention, identification, assessment and remediation. Optional elements may include



provisions for transparent decision-making on site contamination, such as requirements for clear underlying scientific values and public participation in decision-making procedures.

Within Australia, it is important to recognise that there is some, albeit limited, guidance for remediation already in existence, at both the national (through the Australian and New Zealand Environment Conservation Council (ANZECC) guidelines) and state levels (EPAs). However, there exist significant gaps in the guidance provided for the remediation planning and implementation process and disparities in guidance and terminology between states.

Given the current political climate and a critical lack of public awareness of site contamination, an international treaty on site contamination can, at best, be regarded as a long-term option. While a soft law international instrument (such as a high-level declaration on site contamination) may be more feasible in the medium term, its prospects will also be determined by greater public awareness. It is concluded that a comprehensive 'model law' on site contamination would be the best means of promoting domestic site contamination law globally in the short term. Careful preparation and extension promotion by a prominent international 'champion' would be key to the widespread uptake of any 'model law'. ■

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Managing theory and practice:

The sustainability of sustainable remediation

by Gull Conroy, Flinders University

For many global industries, transition into the 21st century has coincided with a reconciliation of industry practices to incorporate the principles of sustainability. Popularised in the 1980s through *Our Common Future* and *Agenda 21*, sustainability emerged as a philosophy which reconceived the relationship between human progress and the environment. The so-called 'triple bottom line' was seen as a guiding principle for actuating sustainability by expanding the scope of decision-making to include social, economic and environmental agendas. Like others, the environmental remediation industry has sought to reconcile its practices and achieve sustainability through the triple bottom line.

In recent years, the adaptation of triple bottom line principles with current industry practices through stakeholder debate has compelled the shift toward 'sustainable remediation'.

Sustainable remediation can be defined as the practise of demonstrating, in terms of environmental, economic and social indicators, that an acceptable balance exists between the effects of undertaking the remediation activities and the benefits the same activities will deliver.

In 2010, a survey of the South Australian remediation industry was undertaken to gauge the response of stakeholders to the sustainable remediation paradigm. The purpose of the task was to characterise stakeholder response according to industry demographics and the transition itself.

Stakeholder responses were investigated in terms of their agreement with, and use of, core aspects of sustainable remediation and their experiences integrating the sustainability into their work practices.



The results

The major finding of the survey related to the application and use of sustainable remediation principles. The majority of respondents (84%) reported that they had been aware of sustainable remediation for 40 months or less, with an average response of 27 months.

Significantly, 77% of respondents indicated that their understanding of sustainable remediation concepts was adequate for use during the course of their work. Despite the level of comprehension reported, only 54% of respondents claimed to regularly use the principles of sustainable remediation during the course of their work.

Notwithstanding differences that each profession might have in applying

these principles, the marked difference between comprehension and application may suggest an underlying difficulty in operationalising the concepts of sustainable remediation during day-to-day activities.

Given this, it poses the question: what measures are necessary in the management and application of sustainable remediation to further support its adoption and implementation?

The survey finding that 68% of respondents had not received any formal training on how to apply sustainable remediation raises several important questions about the future of sustainable remediation, both in South Australia and the Australasian region, and the next steps in supporting its further adoption. ■



Government audits, reviews, inquiries and litigation

What is wrong with contaminated land management in Victoria?

by Mark Beaufoy, DLA Piper Australia



Melbourne, like other major cities in Australia, is experiencing rapid population growth, limits to outward expansion into greenfield sites and demand for in-fill or brownfield development. These developments are reflected in city planning policies such as *Melbourne 2030 – Planning for sustainable growth* and *Melbourne @ 5M*.

The new Ballieu Government's focus on urban renewal opportunities – such as the redevelopment of 200 hectares of industrial land at Fisherman's Bend and its renewed focus on the Docklands precinct – also reflects the attention being given to these issues. The government has recently enacted legislation (the Victorian Urban Development Authority Amendment (Urban

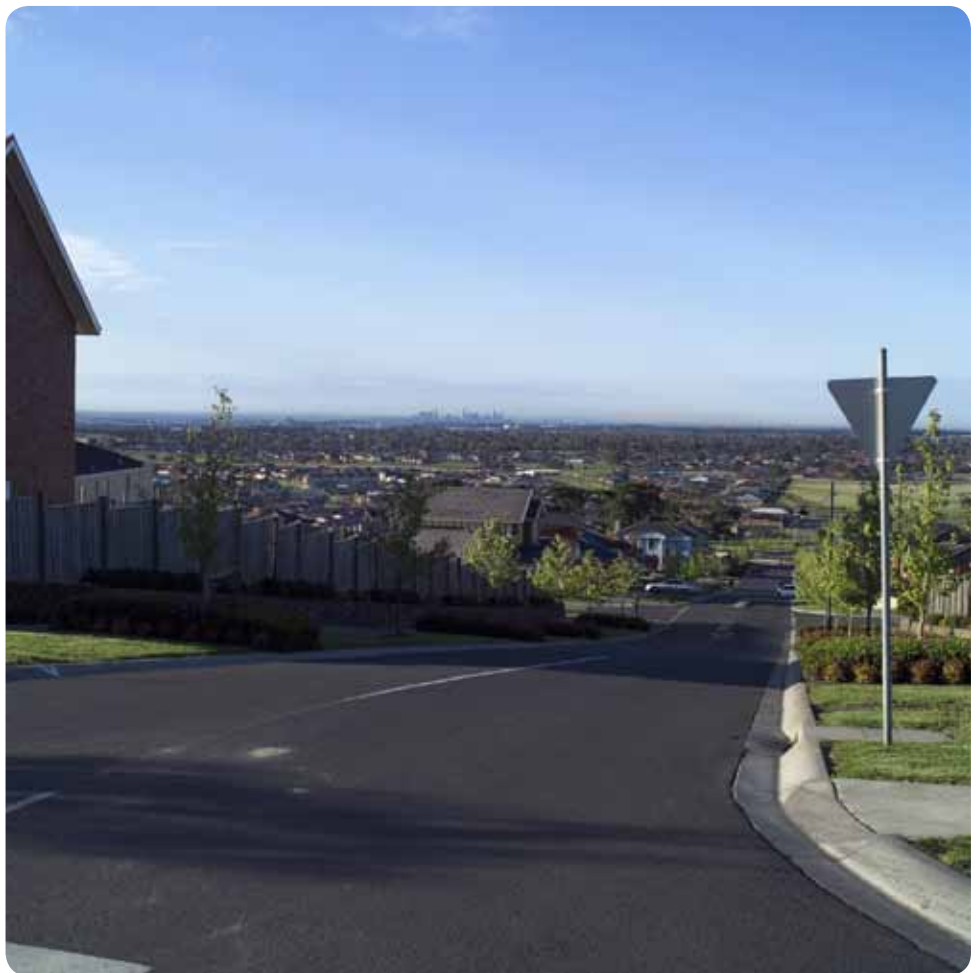
Renewal Authority Victoria) Act 2011) to establish a new Urban Renewal Authority Victoria to replace VicUrban and to coordinate the government's urban renewal focus.

Melbourne's brownfield sites represent both a problem and an opportunity. As greater attention is paid to in-fill development, the city's industrial past presents increasing challenges to the successful delivery of urban renewal planning policies. While most cities can highlight some iconic brownfield redevelopment sites (like Melbourne's Beacon Cove and Docklands developments or Sydney's Homebush Olympic site), these projects required the public to take on significant risk to make these projects a success.

The planning and environmental regulatory framework requiring investigation and clean-up of former industrial sites for more sensitive uses can impose significant cost, risk and delay. While Victoria was a pioneer in establishing the environmental audit system, a number of other states have recently updated their legislation that controls contaminated land management. For example:

- in New South Wales, the Contaminated Land Management Act 1997 (NSW) (2008 amendments commenced 1 July 2009)
- in Western Australia, the Contaminated Sites Act 2003 (WA) (commenced 1 December 2006)
- in South Australia, the Environment Protection Act 1993 (SA) – as amended by the Environment Protection (Site Contamination) Amendment Act 2007 (SA) (the 2007 Amendment Act assented 1 November 2007 but some amendments commenced 10 December 2007, others 20 November 2008 and yet others 1 July 2009), and
- in Tasmania, the Environmental Management and Pollution Control Act 1994 (Tas) – as amended by the Environmental Management and Pollution Control (Contaminated Sites) Act 2007 (Tas) which commenced in November 2007.

While Victoria's Environment Protection Act 1970 has undergone many significant amendments, it is now the oldest state environment protection legislation not to have been comprehensively reviewed and re-enacted, despite being amended more than 80 times in its 40-year history (Stan Krpan 2011, *Compliance and Enforcement Review – A Review of EPA's Approach*, EPA Victoria, p. 311). Victoria's environment protection legislation and planning framework for contaminated land management has received less attention than these other states, until recently.



Melbourne city viewed from suburbs. A long way to travel to work.

The recent review and reconsideration of the adequacy of Victoria's regulatory response was triggered by a number of 'crises' in the system, which resulted in:

- a series of significant pieces of litigation – for example, Premier Building and Consulting Pty Ltd v Spotless Group Limited (2007) VSC 377 and the Brookland Greens landfill gas incident and associated litigation *Wheelahan v City of Casey and Ors* (2011) VSC 215
- ombudsman inquiries and performance audits by the Victorian Auditor-General's office – for example, the investigation by the Victorian Ombudsman and report, *Brookland Greens Estate – Investigation into methane leaks* (October 2009), and *Hazardous Waste Management – Victorian Auditor-General's Report* (June 2010), which both included significant criticism of

the EPA's approach to compliance and enforcement. The Victorian Ombudsman is also currently conducting an investigation into the adequacy of environmental audits conducted in the Cairnlea Estate in Brimbank.

These 'crises' have also prompted some significant organisational changes at EPA Victoria, including a detailed review of the EPA's approach to compliance and enforcement (the EPA Victoria Compliance and Enforcement Review, which made significant criticisms of the EPA and recommendations for reform in the area of compliance and enforcement, including recommendations for greater activity by the EPA in this area. The EPA has also recently prepared a new compliance and enforcement policy). These changes will result in EPA taking a more proactive approach to compliance and enforcement of contamination clean-up and management,





including more frequent prosecution and the issuing of more notices. This is already starting to happen.

This renewed focus on compliance and enforcement is well overdue, especially when the comparative statistics on prosecutions and notices against pollution complaints and measures of environmental quality are taken into consideration (Krupan, pp. 41–46, 134–135, 173). However, there is also a serious risk of EPA Victoria becoming overly bureaucratic, inflexible and legalistic. As part of this more focused approach to compliance and enforcement, there has also been a general increase in the focus on the management of contaminated sites in Victoria. The EPA has clearly indicated this as a priority by making the management of legacy contaminated land a key priority of its new strategic plan. This will require more EPA engagement, assistance and guidance to industry and local government on the regulation and management of more difficult brownfield sites. However, if at the same time the EPA is less willing to engage and introduce some more commerciality and flexibility into its decision-making on brownfield redevelopment sites, there is the potential for more frustration, cost and delay.

Two other audits and inquiries highlight the importance of this current issue in Victoria. Firstly, the Victorian Auditor-General is currently conducting an audit of contaminated land management in the state, focusing on the role of EPA, the audit system and the role of local government. This audit is expected to be completed by November 2011. Secondly, the Planning Minister has recently appointed an Advisory Committee under the Planning and Environment Act 1987 to review the current system for making planning decisions about potentially contaminated land in planning scheme amendments and planning permit applications. This review is expected to be completed by September 2011, with an issues and options paper to be released in August. It is likely that these reviews will include recommendations for changes to legislation.

Clearly, the results of these current audits and inquiries will provide detailed consideration of the issues and options for reform in the current system. To some extent, the conclusions and recommendations will be limited by their terms of reference and the jurisdiction of the Victorian Auditor-General's office and the Planning Minister's Advisory

Committee – and thus will only really result in tinkering around the edges of the current system. Many of the more fundamental issues that may be identified through these reviews will not be implemented without a more detailed review of the primary environment protection and planning legislation (the 40-year-old Victorian Environment Protection Act 1970 and the Planning and Environment Act 1987) or the preparation of new legislation that relates specifically to contaminated land management and brownfield redevelopment.

Without reform, the contamination legacies of the past put at risk the realisation of urban renewal planning policies, and the ongoing consolidation and development of our cities for current and future generations. It is an issue of intergenerational equity experienced locally, as poor environmental practices of the past must be paid for today and in the future – from industrial pollution to inadequate landfill management and closure.

This issue is not going to be solved only by getting the legislation right; it also requires a complete package of financial risk-sharing, tax, property, planning and environmental regulatory and policy innovation, and incentives to attract the development and lending sectors to brownfield sites. There are many examples of this complex and comprehensive approach to brownfield redevelopment in the UK, US and Europe. For example, the World Bank recently published a guidance note on the management of brownfield redevelopment (World Bank, European and Central Asian Region, Sustainable Development Department, *The Management of Brownfield Redevelopment: A Guidance Note* (8 March 2010)), which examines many of the existing approaches and how they can be applied in developing and emerging economies. It is time for Australia to look more seriously at these approaches. ■

Training and events calendar

September

7–9 **gINT - Fundamentals of gINT** (day 1); **Developing your gINT environment** (day 2); **Supercharging gINT** (day 3)

Datgel / Melbourne

www.datgel.com/gINTTrainingMelbourneSept11.aspx

13–16 **Waste & Recycle 2011 Conference and Exhibition**

Perth / www.wasteandrecycle.com.au

21–23 **CSARM Short Course Series Module E: Risk-Based Site Assessment**

Contaminated Site Assessment, Remediation and Management (CSARM) / Sydney

www.science.uts.edu.au/pdf/csarm/module-E-2011.pdf

26–28 **Introduction to Australian Groundwater**

Sustainable Resource Industry Training (SRIT) / Perth

www.srit.com.au/course_details.php?id=29

26–29 **14th International River Symposium**

Brisbane

26–30 **Advanced Master Class in Australian Groundwater**

Sustainable Resource Industry Training (SRIT) / Perth

www.srit.com.au/course_details.php?id=9

28 **Vapour intrusion** (in conjunction with the Clean Air Society)

Henry Davis York / Sydney

October

4–7 **Groundwater Flow and Transport Modelling with GMS**

Sustainable Resource Industry Training (SRIT) / Adelaide

www.srit.com.au/course_details.php?id=23

5 **NEPM Advances: Developments that could catch you out**

Henry Davis York / Sydney

10–12 **GIS-based Modelling Using ArchHydro Groundwater**

Sustainable Resource Industry Training (SRIT) / Adelaide

www.srit.com.au/course_details.php?id=26

12–14 **1D/2D Hydraulic Modelling with SMS & TUFLOW**

Sustainable Resource Industry Training (SRIT) / Adelaide

www.srit.com.au/course_details.php?id=27

17–19 **Hydrologic Modelling using GIS and WMS**

Sustainable Resources Industry Training (SRIT) / Adelaide

www.srit.com.au/course_details.php?id=28

24 **Introduction to Monitored Natural Attenuation for Contaminated Site Remediation and Management**

ACLCA / Karstens, Melbourne

www.aclca.org.au/cms-events/index.phps

25–27 **Monitored Natural Attenuation for Groundwater Remediation and Management**

ACLCA / Karstens, Melbourne

www.aclca.org.au/cms-events/index.phps

28 **Bioremediation for Groundwater Contamination**

ACLCA / Karstens, Melbourne, Victoria, Australia

www.aclca.org.au/cms-events/index.phps

4–5 **International Committee on Contaminated Land Meeting**

USA EPA/ Washington DC, USA

www.iccl.ch/download/ICCL_2011_Meeting_Announcement.pdf

November

1 **Asbestos in Soil: Developments in Legislation, Policy and Practice**

CL:AIRE, in association with BOHS and the Environmental Industries Commission (EIC) / Manchester, Lancashire, UK

www.claire.co.uk

2–4 **CSARM Short Course Series Module F: Remediation Principles & Closure**

Contaminated Site Assessment, Remediation and Management (CSARM) / Sydney

www.science.uts.edu.au/pdf/csarm/module-F-2011.pdf

2 **Developers - Pitfalls for brownfields developments**

Henry Davis York / Sydney

7–11 **Advanced Master Class in Australian Groundwater**

Sustainable Resource Industry Training (SRIT) / Melbourne

www.srit.com.au/course_details.php?id=6

14–16 **Introduction to Australian Groundwater**

SRIT / Brisbane

www.srit.com.au/course_details.php?id=30

16 **Outcome of Cranbourne landfill experience**

DIA Phillips Fox / Melbourne

30 **Disclosure of contamination information in land transactions**

Minter Ellison Lawyers / Adelaide

Publications

In future editions of *Remediation Australasia*, new publications from CRC CARE will be featured. See pages 15–18 in this edition for a comprehensive list of CRC CARE Technical Reports and assorted publications. ■



The institutional dimensions of remediation decisions



Currently in Australia, the key drivers for remediation of contaminated land are (1) the need to safeguard public health, and (2) commercial development. Current regulatory approaches to remediation do not necessarily encourage regulators and industry to analyse the broader societal and environmental concerns that remediation projects can generate, or fully recognise the values that such concerns represent.

Elsewhere in the Asia-Pacific region, many countries have no specific policy or regulatory frameworks to drive remediation decisions or practices. There are opportunities in these countries for site remediation to be guided by broader development processes and institutions.

A CRC CARE project, undertaken at the University of Technology Sydney, will canvas how public and private parties including regulators, government agencies, civil society, NGOs and industry currently interact in deciding on site clean-ups. The project will investigate one case study in south-east Asia, one in the Pacific, and three in Australia. The case study approach will provide examples of current or recent decision making on site remediation, and should cast some useful light on policy and practice in this regard within our region.

The work will complement two CRC CARE legislative reviews in Australian and Asia-Pacific jurisdictions (see www.cslawpolicy.com). ■

Analytical tools and biosensors

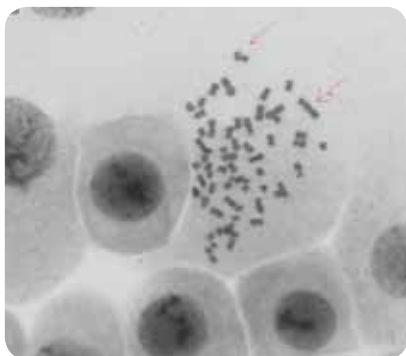
There is a growing need and market for improved microsensor tools (both chemically and biologically based) for real-time monitoring of chemical contamination in soil and water at highly contaminated sites.

Researchers at the University of South Australia aim to integrate conventional analytical techniques, contaminant sensitive probes and analysis with artificial neural networks to create new and specialised sensors. Components include, for example, a genetically modified bacterium with an ability to produce luminescence proportional to the amount of biologically available arsenic. Another is planned that responds to the presence of chromium. Cloning from *Bacillus megaterium* into an expression vector is in progress.



Success in chemically modifying an electrode to improve sensitivity, selectivity and stability for target metals was recognised in 2009 with the project leader receiving the inaugural Agilent Technologies Environmental Award. The project has also now achieved its goal of generating new IP, and commercial interest is being sought. ■

Using live cells for real-time measurement of toxicity



In terms of biological testings, so-called '3D cell models' sit between monolayer cells (2D) in a test tube and a live animal. In recent years, 3D cells have gained popularity for drug development and discovery research, and for routine diagnostic tests. It is expected that the 3D cell approach will also be taken up in toxicology research, given its potential to represent a whole organ system. In particular, the more realistic exposure to life-forms provided by 3D systems – in comparison to the current 2D monolayer cell technique – is expected to lead to real improvements in the accuracy of risk assessment.

In preliminary work, researchers funded by CRC CARE at the National Research Centre for Environmental Toxicology, University of Queensland, have applied the new technique to live cells exposed to BTEX compounds, the toxic volatile organics benzene, toluene, ethylbenzene and xylenes. This has enabled visualisation of

DNA damage in the nucleus of lung epithelial cells, and detection of the presence of H2AX, a stable protein which is specialised in the repair of double-strand DNA breaks. The response is very sensitive, making it easy to detect the potency of genotoxic compounds. This assay is a useful adjunct to the common comet and chromosome aberration assays.

This research aims to develop a battery of cell-based systems incorporated into compact portable equipment that can be taken to a contaminated site for in-situ real-time measurement of toxicological responses. Screening of suitable biological effect markers continued in 2009–10, and work on a prototype of the portable field equipment has been conducted in phase two of the project in 2010–11. ■

Speciation, bioavailability and toxicity of petroleum hydrocarbons



In Australia, at least 50% of contaminated sites being managed or regulated are related to petroleum hydrocarbons. However, the practice of grouping all types of hydrocarbons together for the purpose of assessing soil contamination, known as 'total petroleum hydrocarbon' or TPH, has limitations.

TPH is defined as carbon range from C_6 to C_{35} and includes a wide variety of complex compounds. As such, it is not a direct indicator of risk to humans or to the environment. In particular, without separation and identification of the hydrocarbon types present at a site, the associated risks cannot be accurately established.

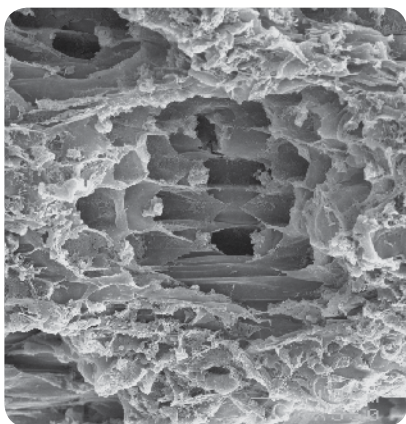
The complexity of diesel fuel, commonly found as a contaminant, is a useful example. Typically, diesel fuel contains 75% saturated hydrocarbons (primarily paraffins including n, iso, and cycloparaffins), and 25% aromatic hydrocarbons (including naphthalenes and alkylbenzenes), with the average chemical formula for common diesel fuel $C_{12}H_{23}$, ranging from $C_{10}H_{20}$ to $C_{15}H_{28}$. Carbon chain lengths are C_8 to C_{26} , with the majority in the C_{10} to C_{20} range. Different grades of diesel fuel oils are used by cars, commercial trucks, buses, marine engines and trains. Lubricating oils are also highly variable in composition.

A CRC CARE project at the University of South Australia aims to help in understanding the speciation, bioavailability and toxicity of individual petroleum hydrocarbons, especially the commercial products such as diesel and lubricating oil in soil.

The research completed so far in this project has shown that the used oils from motor vehicles are more toxic than the respective fresh oils to ecosystem functioning.

Further research from this project will aim to help in the determination of ecological safe limits for individual hydrocarbon fractions and therefore enable more efficient development of feasible and effective bioremediation technology for the treatment of soils impacted by petroleum hydrocarbons. ■

Findings show changes needed in metal phytoavailability assessment



The accurate estimation of the phytoavailability (availability to plants) of trace metals in soils and solid wastes is important in assessing their risk to the environment.

The adjacent image from a scanning electron microscope demonstrates how aluminium toxicity causes the cells in plant roots to tear apart.

In this CRC CARE project, undertaken by researchers at the University of Queensland, a large dataset consisting of 5,700 individual data points was taken from the literature, and the effectiveness of various chemical extractants to predict the phytoavailability of Cd, Zn, Ni, Cu and Pb was examined across a range of soil types and contamination levels.

The data suggest that generally, the total soil trace metal content, and trace metal concentrations determined by complexing agents (such as the widely-used DTPA and EDTA extractants) or acid extractants (such as 0.1 M HCl and the Mehlich extractants) are only poorly correlated to plant phytoavailability. Further, even though it would appear that neutral salt extractants (such as 0.01 M $CaCl_2$, 0.1 M $NaNO_3$ and 1.0 M CH_3COONH_4) provide a better indication of metal phytoavailability across the range of metals of interest, trace metal concentrations determined by these neutral salt extractants were also only poorly correlated to plant phytoavailability in most instances.

The data analysed in this project indicate that none of the commonly used chemical extractants can be used to consistently predict availability of trace metals to plants.

Findings from the research indicate that it is not currently possible to predict plant growth and metal uptake based upon the results of commonly used soil tests. Research findings suggested that, where soil tests indicate that a soil has an elevated metal content, simple plant growth studies should be conducted using the material of interest to provide a direct indication of potential metal uptake and toxicity rather than using soil analyses alone to attempt predict plant performance and metal uptake. This finding has important implications for mining and other organisations seeking to revegetate land contaminated by waste dumping, spills, or other industrial or extractive activity. ■



ARIC forums move to LinkedIn

ARIC has now established itself on the professional network of LinkedIn.

LinkedIn is the world's largest professional network, with over 100 million members and growing rapidly. LinkedIn connects you to your trusted contacts and helps you exchange knowledge, ideas and opportunities

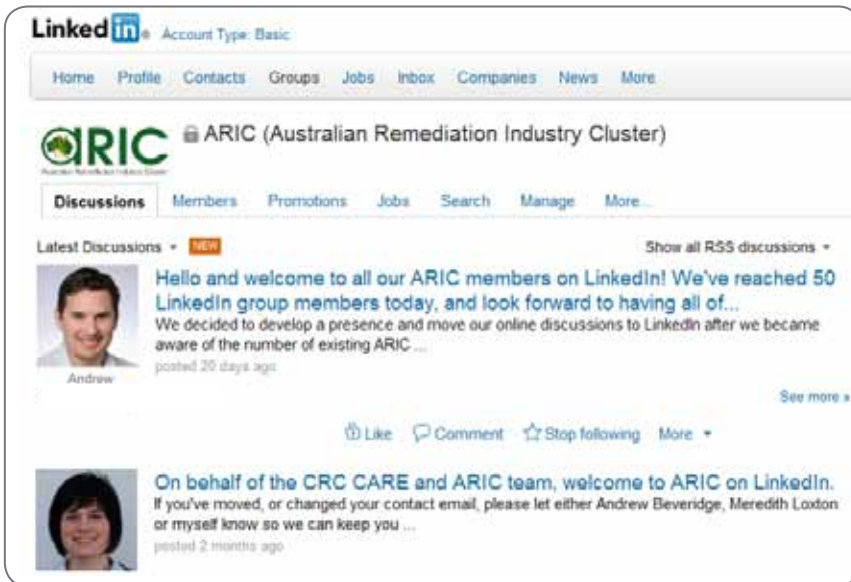
with a broader network of professionals.

Professional member groups on ARIC (and any other online site) are only as good and useful as the members make them. Members receive value and benefit from participating in the group in a number of ways:

- they can connect directly with each other and tap into the information that is shared and distributed daily on LinkedIn
- they can ask questions of the group
- they can use the forum to discuss industry topics, post articles and ask questions, and
- it provides a LinkedIn identity and point of reference for a community of interest.

The ARIC management team anticipate that this group will help individuals create new connections, and help build a new narrative on contamination site remediation issues within the region.

To join ARIC, visit <http://linkd.in/oi03ZM> or complete the membership form on the ARIC website (or see page 29). ■



CRC CARE is a multi-partner Australian research organisation developing innovative technologies to assess, prevent and remediate the contamination of soil, water and air.

World-class researchers at CRC CARE work with industry on global contamination issues, engaging with major end-users such as the mining and petroleum industries, environmental regulators, government organisations, small-to-medium sized enterprises, and consultants.

A structured research program is complemented by a focus on educating and training post-graduates and industry professionals to support the growth of highly qualified and suitably trained researchers and decision-makers in the area of environmental risk assessment and remediation.

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Contribute to the *Remediation Australasia* magazine

Our quarterly magazine *Remediation Australasia* is sent to all members of ARIC, either by post or by email.

The magazine features a range of material of interest to members, including:

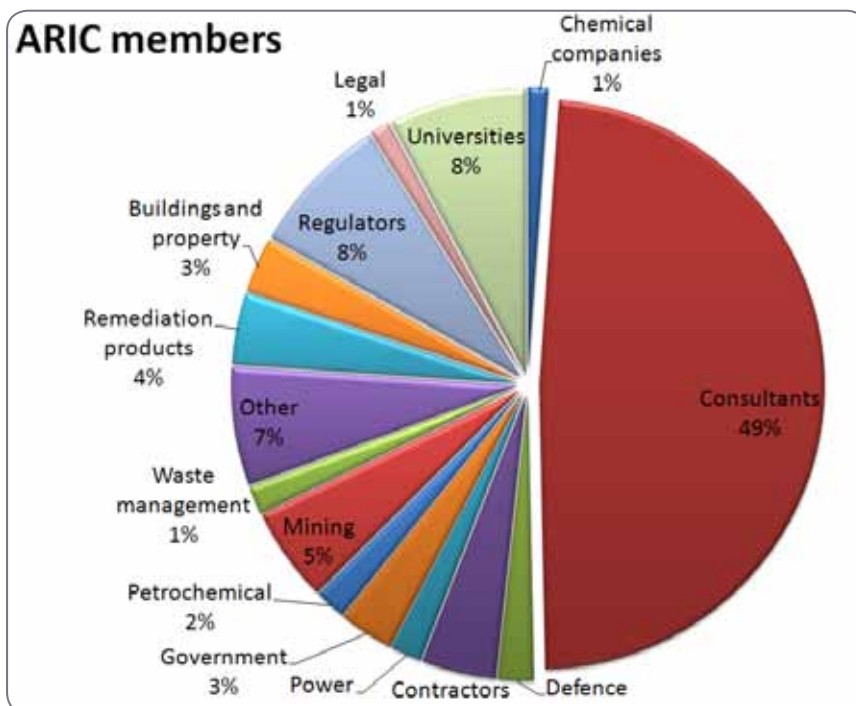
- Case studies
- Regulator updates
- Reports from industry groups
- Advertisements
- Full technical articles (typically 1–3 pages, including illustrative material)
- News relating to new technologies and developments in the industry, and
- Training, international conferences or events in Australasia.

The magazine welcomes your articles and suggestions for content.

Submitted articles must clearly explain the topic (technology or research, for example), implications for industry, and how this information can be used to facilitate change or greater understanding of important issues.

Advertorial content will not be accepted when submitted as an article (contact advertising team with any advertorial enquiries).

Please write or e-mail us if you are interested in volunteering a little of your time, an article, or a photo. You won't have to sweat over the editorial details; we can proofread, edit, and format your article ready for the magazine. Please visit the website for further information on production deadlines: www.remediationaustralasia.com.au/ ■



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Membership subscription to ARIC and the publication is free, and membership is constantly growing – ARIC now has more than 400 members, not only exclusive to the Australasian region (Australia, New Zealand, Papua New Guinea, western Pacific Islands), but also from the United States, Canada, India, Germany and Russia. Visits to the publication online come from more than 80 countries, resulting in an even wider readership of the magazine.

Please write or e-mail us if you are interested in advertising opportunities, or visit the website for further information on advertising rates and production deadlines: www.remediationaustralasia.com.au/ ■

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