Issue 5 2011

Remediation Australasia

The impact of CLIMATE CHANGE on contaminated sites

IN-SITU THERMAL REMEDIATION

A closer look at the advantages

MOULDS AND ASTHMA

Is your home or office harming you?

MANAGING ELECTRONIC WASTE

one of the world's rapidly growing problems

CRC**CARE**™

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.

Collaborations between major industry participants, researchers and end users, nationally and internationally

Producing a generation of young Australian professionals highly skilled at solving and preventing contamination

Extensive industry training and workshop program

Fast-tracking science to the field through a national demonstration sites program

Promoting industry access to new technology and knowledge through the Australian Remediation Industry Cluster (ARIC)

www.crccare.com

editor's note

It has been a very hectic period since the last edition of the magazine, with most of my time focused on CRC CARE's rebid application. Having made it to the shortlist of successful applicants, a team of CRC staff, researchers and partner representatives took part in an extensive second round interview process in September.

It gives me great pleasure to announce to you, the readership of our magazine, that CRC CARE has been successful in our bid for a further 9 years of funding support from the Commonwealth's Department of Innovation, Industry, Science and Research (DIISR). This will take CRC CARE through to 2020.

Supporting our application has been the number of success stories to come out of CRC CARE I, instilling the confidence in DIISR to extend our funding – not only the achievements of CRC CARE as an organisation, but also those individual achievements of our staff, students and researchers. To this end, some of the CRC's success stories include:

- A unique partnership between industry and regulators
- 10 guidance documents adopted by regulators
- 7 patents; 4 technologies applied
- 287 journal papers published
- 56 PhD students supported
- 1,500 environmental managers trained
- 3 international conferences delivered, and
- The successful establishment of ARIC as an industry cluster and information network.

In moving forward, CRC CARE II will have an increased focus on helping to develop uniform national standards for assessing and remediating contamination. As part of the planning that went into our extension application, the CRC CARE II research agenda was developed through an extensive consultation process with end users, which identified four central research programs:

- best practice policy
- better measurement
- reducing uncertainty in risk assessment, and
- cleaning up.

CRC CARE II will officially commence in July 2011, and implement its research program that will also educate and train a further 70 PhD students and 2300 environmental managers. CRC CARE II will also continue to sponsor the Australian Remediation Industry Cluster (ARIC) as the primary organising vehicle to disseminate the knowledge to the Australian remediation industry. The free ARIC membership offer was intended to expire on 31 December 2010, but will be extended until 30 June 2011.

For the interest of the ARIC members and readers of the magazine, I have included some information on the research agenda of CRC CARE II on page 19.

On behalf of CRC CARE and ARIC, I hope that everyone has had a merry Christmas.

I look forward to catching up with you in the New Year.

Prof Ravi Naidu

Managing Director, CRC CARE

Editor, *Remediation Australasia*

Remediation Australasia is a quarterly industry magazine produced by the Australian Remediation Industry Cluster (ARIC) for the Australian remediation industry.

Circulation

The publication is currently distributed to more than 2,000 recipients throughout Australasia, free of charge.

Editorial and production

Editor: Ravi Naidu

Sub-editor: Andrew Beveridge

Sub-editor, production:
Sharmin Patard

Editorial enquiries

Andrew Beveridge, CRC CARE
T. 08 8302 3937 / M. 0429 779 226
E. Andrew.Beveridge@crccare.com

Front cover image: © supplied by Ross Sadler

contents

features

every issue

Green remediation: A way to enhance

The environmental, social and economic footprints of your cleanup project

John Collins,
VeruTEK Technologies

Green remediation is the application of technologies and approaches that enhance a cleanup project's environmental, social, and economic footprints. It is a holistic approach that incorporates sustainability concepts and life-cycle thinking over a broad scope and time horizon. The development of green technologies for remediation has two important benefits: first, the development of better, cheaper, safer and more sustainable solutions to remedy the ubiquitous contamination of the environment, which is a legacy of the industrial revolution. But, more than that, development of green technologies provides unique opportunities for green job creation, enhancement of the health and wellbeing of the nation, and for the constructive use of financial reserves of the some of the world's largest corporations. In addition, the development of green technologies for the environment has collateral benefits of contributing to advanced technology development for other industry sectors such as energy, water and defence.

Green technologies for environmental contamination are currently being developed by CRC CARE in alliance with a US company, VeruTEK Technologies. VeruTEK has developed several green technology platforms – microemulsion catalysis, zerovalent metal synthesis with plant oils, green catalysts, and surfactant-enhanced in-situ chemical oxidation (SISCO) that are being optimised and further developed by CRC CARE and VeruTEK scientists.

This green and high-tech collaboration between CRC CARE and VeruTEK is somewhat unique in the world of environmental remediation, but this type of collaboration is more common in other more advanced technology fields. While pharmaceutical companies spend more than $35 billion per year to develop cures for human sickness, minimal research and development is conducted to develop cures for environmental problems which can subsequently lead to human sickness. The further development of a green technology industry will provide jobs not only for scientists, engineers and researchers, but also for blue collar workers involved in field implementation. The cleanup of 2,500 contaminated sites would produce sustainable employment for 40,000 laboratory and office workers, and 75,000 construction-related workers.

VeruTEK is already working in Australia with private-sector partners. They are working for Lend Lease and AECOM on the large green development in the world at Sydney Harbor (the Barangaroo development). VeruTEK is commencing trials of a remediation to treat soil and groundwater contamination from a from a former coal works plant.

The innovative technology known as SISCO enables the remediation of certain contamination where it lies (in-situ), beneath the ground, rather than the traditional excavation method.

Lend Lease has been appointed by the Barangaroo Delivery Authority to undertake the remediation of historic contamination of the old Miller's Point Gasworks on the site. Barangaroo Delivery Authority chairman Mike Collins said that this application for green remediation marks the first step in the final resolution of this historic contamination problem which has adversely affected this part of Sydney for the best part of a century.

The health ecological impact of these contaminants is just beginning to be addressed in the Western world and the emerging BRIC (Brazil, Russia, India and China) countries. Australia has an estimated 100,000 potentially contaminated sites in cities and regional areas throughout the nation, and the cost of cleanup is estimated to exceed $5 billion. EPA has identified more than 294,000 contaminated sites across the US. These sites can be found anywhere – in towns and cities, near rivers, and beneath homes.

Recently, construction was stopped beneath a New York City school due to coal tar contamination with benzene and thousands of other contaminants found in the soil and groundwater. This contamination was left behind from a manufactured gas plant that operated in the 1900s. This type of story is not unusual and more toxic contaminated sites will certainly be found, especially in the fast-growing emerging BRIC economies.

Contaminated sites contain chemical by-products of our industrial society that have, until recently, been improperly disposed of and dumped. Benzene, naphthalene, dioxin, polychlorinated biphenyls and pesticides are the commonly known contaminants, but there are tens of thousands of other chemicals also present that are not measured in common soil and water analysis. Environmental contaminants have long been known as sources of cancer, especially in children, with incidence rates increasing every year. More recently, California Environmental Protection Agency has linked the incidence of autism to pesticide exposure in mothers during pregnancy.

Previously, with so many poor cleanup choices and the certainty of incomplete cleanup, companies have often preferred to legal delay to remedial action. As a result, most of the money in environmental cleanup has gone to expensive lawyers and not to the actual work of making the nation healthier. The lack of suitable technologies to cleanup the nation's toxic waste has had a detrimental effect on the nation's health and national businesses. Fortune 500 companies have reserved anywhere from $500 billion to $1 trillion to cleanup their contaminated sites. These financial reserves are based on the implementation of antiquated technologies.

The development of cost-effective, complete, and reliable green technologies will reduce the reserves needed for cleanup, and will contribute to the wellbeing of our nation's businesses. The funding of green technology development that cost-effectively clean up contaminated soils and groundwater will permit release of these reserves to create new green jobs and industry.

"While pharmaceutical companies spend more than $35 billion per year to develop cures for human sickness, minimal research and development is conducted to develop cures for environmental problems which can subsequently lead to human sickness."

These contaminants move with the existing groundwater beneath schools and residence sites, where contaminants vaporise into gas and are sucked into interior living spaces.

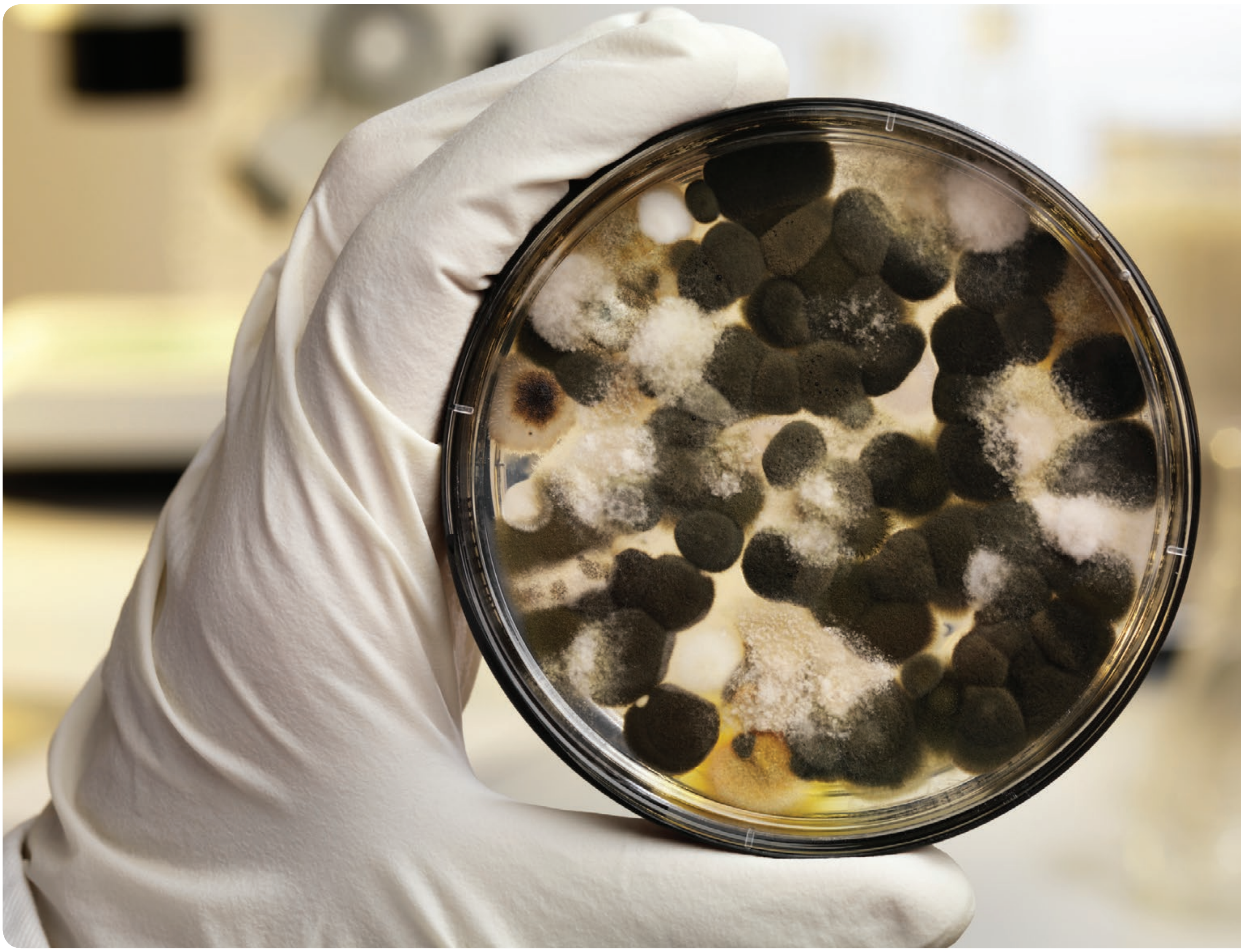
Recently, New York State found that 92% of homes had breathable benzene vapours present, exposing children to unacceptable amounts of contaminants. Remarkably, little cleanup to these toxic sites has been accomplished over the past 30 years. The primary methods of cleanup today – landfilling or placing walls around the contamination – were developed in pre-Roman times. Both technologies leave the environmental contamination legacy for future generations to deal with, either in leaking landfills or within leaking containment walls.

The development of green and sustainable technologies to clean up the toxic legacy is a necessary part of any industrial society. The advent of a new administration in Washington provides the opportunity to bring environmental cleanup technologies out of the 19th century and into the 21st. A clean environment would be the best gift and the truest legacy to pass on from this generation to the next. ■

Moulds: the major trigger of asthma?

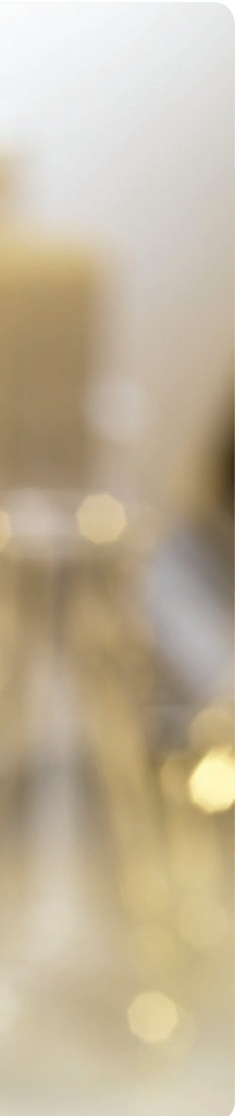
Ramakrishnan Balasubramanian, Megharaj Mallavarapu, Thangavadivel Kandasamy, Thavamani Palanisami and Ravi Naidu, CRC CARE and Centre for Environmental Risk Assessment and Remediation

Indoor environment determines health, comfort and performance of the occupants. Air quality within the building environments and outside is an important determinant of health and productivity. Illness or effects particularly associated with buildings such as sick building syndrome, building related illness, and multiple chemical sensitivity are partly due to the contributions from mould infestation.



Moulds are very important biodeteriogens and refer to the visible colonies of fungal growth on the surface of any substrate that provides water, oxygen and nutrients. Fungi or moulds are ubiquitous in the environment, and humans are always exposed to different components of them. But, several mould species have the potential to infect or cause allergy or toxicity in humans, resulting in various symptoms and disease states.

In 1873, it was suggested that inhalation of mould spores might produce respiratory allergy (Experimental research on the causes and nature of *Catarrhus nestivus* (hayfever or hay asthma)). Subsequently, the specific moulds were reported to be a cause of allergic asthma. As the prolific producers of potentially allergenic proteins, moulds elicit sensitising IgE (immunoglobulin E) antibodies and asthma is the only well-documented form of IgE-mediated disease in which airborne fungal allergens are involved. The mould-induced illness can be due to proteins causing Type I allergy, structural elements such as β-1,3-glucans and melanins, microbial volatile organic compounds (MVOCs), mycotoxins and other secondary metabolites released from spores and colony fragments.



Asthma, a chronic disease with symptomatic and variable obstruction to airflow within the lungs, is common during childhood and can persist or occur new during adulthood. The suspected causes are many indoor and outdoor air pollutants including moulds, and different environmental factors can affect morbidity and mortality from asthma.

Globally, asthma affects 300 million people, largely those in developing urban and industrialised areas. In Australia, over 2 million suffer from asthma and the total cost of asthma in terms of pharmacy costs, productivity and absenteeism is between $720 and $800 million annually. By 2020, about 29 million Americans will suffer from asthma, with the cost to society of US $18 billion a year.

Asthma has a multifactorial etiology, largely determined by genetic predisposition and exposures to environmental triggers. Moulds are one of the many well-known triggers of asthma exacerbation. The dose-response relationship between exposure to fungi and disease symptoms is difficult to establish because the allergenic and nonallergenic fungal (glucans, proteases, other enzymes and toxins) components are responsible for the health effects of moulds.

Moulds: diversity and pervasiveness

Fungi of 100,000 identified species are taxonomically grouped as zygomycetes, ascomycetes, and basdiomycetes.

The forms of fungi range from single-celled to microscopic filaments (hyphae) to large mats of mycelium (aggregated hyphae). Fungi reproduce through spores, produced by ordinary hyphae or on specialised fruiting bodies (spore-producing fruiting bodies). The asexual forms of ascomycetes and a few basidomycetes produce conidia. Spores or components of fungi are agents of human and animal illness. Moulds occur in indoor and outdoor environments, and their presence, numbers, species and biological properties vary with geographic locations, climate, season, and other factors. Individual fungal species may contain 40 or more distinct allergens which include spores, conidia, mycelia, and other fungal particles capable of inducing IgE antibodies. The common indoor moulds are species of *Alternaria, Penicillium, Cladosporum, Stachybotrys* and *Aspergillus*. Based on water activity (a_W), requirements on laboratory substrates and responses to changes in aw, moulds growing on building materials are grouped as primary colonisers (capable of growing at a_W < 0.8), secondary colonisers (requiring a minimal a^W between 0.8 and 0.9) and tertiary colonisers (requiring a_W > 0.9).

Tertiary colonisers are also known as the water-damage moulds, and include the toxic species such as *Stacybotrys chartarum, Chaetomium globosum, Trichoderma sp.* and *Memnoniella echinata*. In the asthmatics' homes, mould species of *Scopulariopsis brevicaulis* and *Trichoderma viride* can be significantly more. The most important factor, and micro-climates with very high a_W – even in an indoor environment with low relative humidity – can facilitate the mould growth on building materials. The classical microscopic examination or the culture-based assays are inadequate; detection and measurement of metabolites such as β-(1-3) glucans, ergosterol (24β-methylcholesta-5, 7, trans 22-trien 3β-ol), proteases and specific immunochemicals for allergens and molecular methods such as mould-specific quantitative polymerase chain reaction are required to identify and quantify mould species and their components.

Buildings: human-made ecosystems

Buildings such as homes, schools, and workplaces are human-made ecosystems, and an average person remains indoors up to 85 - 90% of his time.

Indoor environment determines health, comfort and performance of the occupants. Illness or effects particularly associated with buildings such as sick building syndrome, building related illness, and multiple chemical sensitivity are partly due to the contributions from the mould infestation. Fungal colonies growing on building materials release particles (0.3 μm), which are smaller than spores. The building

> “The relationships among the poor indoor environments, especially dampness and the ensuing mould growth, and asthma incidence have been well reported.”

materials are complex matrices with various combinations of wood, paint, dust, metal, wallpaper and others. A number of environmental factors such as humidity and air movement contribute to the mould growth in the buildings. The relationships among the poor indoor environments, especially dampness and the ensuing mould growth, and asthma incidence have been well reported.

The first line recommendation in the management of asthma is avoidance, both allergenic and nonallergenic fungal components. Presently, human exposure assessments are not regularly made due to lack of suitable techniques for quantifying particles, spores or components of moulds, and the absence of reference standards for many MVOCs and mycotoxins, the standardised operating procedures for sampling and the assessment methodologies for the buildings.

Environmental assessment: risks and remediation

Air quality within the building environments and outside is an important determinant of health and productivity. No guidance limit on the exposure levels for airborne concentrations of mould has been set in the USA. But, the EC guidelines state that if the indoor levels exceed 500 cfu (colony-forming units) m-3, then possible remediation is required.

The Australian guidelines are similar to that of WHO (1990). Short sampling times for air are frequently used to obtain quantitative information on the viable spores of culturable fungi. But, the air as well as the settled dust, surface and building materials require new assessment methods such as environmental relative mouldiness index and those for detecting fungal components, mycotoxins, and MVOCs. Quantification of fungal components, toxins and MVOCs can facilitate the detection of hidden moulds and provide the clinical relevance to asthma incidence.

Avoidance of illness or effects associated with buildings and remediation necessitate proper guidelines. Focus on prevention and initiatives on research about the environmental risks and assessment and public education are necessary now to reduce the prevalence and severity of asthma in homes, schools, and workplaces. ■

Call for Papers
NOW OPEN

CleanUp 2011

6th International Workshop on Chemical Bioavailability in the Terrestrial Environment (7–9 September 2011)

and the

4th International Contaminated Site Remediation Conference (11–15 September 2011)

Hilton Adelaide hotel

On behalf of CRC CARE and the Australian Remediation Industry Cluster (ARIC), I invite you to join us for the biennial CleanUp conference, to be held at the Hilton Adelaide hotel, in South Australia.

CleanUp 11 will combine the 6th International Workshop on Chemical Bioavailability in the Terrestrial Environment (7–9 September 2011) and the 4th International Contaminated Site Remediation Conference (11–15 September 2011).

The CleanUp Conference is the premier Australian-based conference related to the contaminated site and remediation industry.

It is expected that CleanUp 2011 will have an attendance comparable to the 2009 conference, which attracted over 500 scientists, engineers, regulators, and other environmental professionals from 25 countries. Delegates were able to promote technology transfer and exchange information, innovations and developments in fundamental and applied environmental research towards the assessment, management and remediation of environmental contamination.

The organising committee is pleased to again have secured the Hilton Adelaide hotel as the host venue for the events. This medium sized venue enables attendees to focus on the tightly paced program and exhibits, and to easily meet and share ideas and information.

Ample networking will be possible with a full complement of lunches, receptions, and other meals being served during the breaks in the program. After the sessions conclude each evening there will be poster sessions and networking drinks, with the conference dinners again expected to be a highlight of the social program. At the conclusion of each day's activities, conference participants will find ample sightseeing, shopping and dining options nearby. Located on central Victoria Square, the Hilton Adelaide hotel is in the heart of Adelaide city.

Your contribution to these events is welcome as a presenter, sponsor, exhibitor or delegate.

I look forward to seeing you at the conference in 2011.
I know you will value the experience.

Professor Ravi Naidu
Managing Director
CRC CARE

CRC CARE™ ARIC Australian Remediation Industry Cluster CRC Australia

Decision-making support tools for

Managing electronic waste (e-waste)

Peeranart Kiddee, Ravi Naidu and MH Wong, CRC CARE and Centre for Environmental Risk Assessment and Remediation

Electronic waste is one of the world's rapidly growing problems. In most countries around the world, including Australia, it is projected that the volume of e-waste materials is growing at a rate of 3 - 5% per annum and will be three times that of other individual waste streams in the solid waste sector.

There are a number of definitions of the term 'electronic waste' (or e-waste), which is also known as 'waste electrical and electronic equipment'. For the purposes of this article, e-waste is defined as consisting of old, end-of-life electronic devices – such as televisions, refrigerators, washing machines, vacuum cleaners, computers, computer peripherals and mobile phones – which original users no longer want because they are obsolete or irreparable.

E-waste is one of the world's rapidly growing problems. In most countries around the world, including Australia, it is projected that the volume of e-waste materials is growing at a rate of 3 - 5% per annum and will be three times that of other individual waste streams in the solid waste sector. The advent of new design and technology at regular intervals in the electronic sector is causing the early obsolescence of many electronic items used around the world today. For example, the introduction of digital televisions in Australia and worldwide has posed significant challenge with the management of millions of analogue televisions that are currently being disposed in prescribed landfills, despite its potential adverse impact on the environment. Coupled with this, it is now widely recognised that the lifespan of many electronic goods has been substantially reduced due to advanced electronics, attractive design and compatibility. For example, the average lifespan of a new model computer has decreased from 4.5 years in 1992 to an estimated 2 years in 2005 and is further decreasing.

A UNEP report estimates that more than 130 million computers, monitors and televisions become obsolete each year, and that amount is growing each year in the United States. The UNEP report further reveals that around 500 million computers will become obsolete in the United States alone between 1997 and

E-waste categories

E-waste is classified into 10 different categories including

- large household appliances
- small household appliances
- IT and telecommunications equipment
- consumer equipment
- lighting equipment
- electrical and electronic tools (with the exception of large-scale stationary industrial tools)
- toys, leisure and sports equipment
- medical devices (with the exception of all implanted and infected products)
- monitoring and control instruments
- automatic dispensers.

Visit **http://bit.ly/e-wasteDirective** for more information on these categories.

2007, and that 610 million computers are to be discarded in Japan by the end of December 2010. It is estimated that in China 5 million new computers and 10 million new televisions have been purchased every year since 2003 and around 1.11 million tonnes e-waste is generated every year, coming mainly from electrical and electronic manufacturing and production processes, end-of-life of household appliances,information technology products and imports from other countries. In Canada it is estimated that 140,000 tonnes of waste electrical and electronic equipment is generated annually.

Compared to already-developed countries, the e-waste problem in developing and transitioning countries is not as great; financial constraints on local communities and the nation as a whole (in the latter countries) work to extend the number and half-life of electronic goods. However, a major e-waste problem exists when already-developed countries export their e-waste (currently, 80% of it) to developing countries, resulting in a flood of unusable electronic goods. Given the limited policies, safeguards, legislation and enforcement, imported e-wastes and electronic goods have led to serious human and environmental problems in these countries. Concern arises not just from the large volume of e-wastes imported in developing countries, but also with the large list of toxic chemicals associated with e-wastes. Numerous researchers have demonstrated that toxic metals and polyhalogenated organics including polychlorobiphenyls (PCBs) can be released from e-waste, posing extreme risk of harm to humans and the environment.

A review of a published report on e-waste problems in developing countries reveals that developing countries and countries in transition such as China, Cambodia, India,

Indonesia, Pakistan, and Thailand, including African countries like Nigeria, receive e-waste although the problems within these countries differ considerably. For instance, while African countries mainly reuse disposed electronics, Asian countries dismantle them – in mostly unsafe manners. With the recent recognition of social and human health problems experienced in some developing countries, it is worth noting that China, India, and other Asian countries have recently amended their laws to address e-waste imports. Moreover, some manufacturers of electronic goods have also attempted to safely dispose of e-waste with advanced technologies.

Impacts of e-waste

The rapid growth of e-waste and the effectiveness of its management will have profound impacts on the environment and human health. E-waste management via disposal in landfill, recycling or incineration can cause hazardous risk to the environment and human health. E-waste disposal in landfills is seen to be a serious problem, given the volume of material disposed and the toxicity of many substances released from such wastes. The pollutants have the potential to migrate through soils and groundwater within and around landfill sites. Organic and putrescible material in landfills decomposes, and is transported by water to percolate through soil as landfill leachate. Where such materials have been incinerated using tools that do not capture emissions, significant levels of toxic substances have been found in the emissions. Such toxic substances have been shown to pose risk to both environment and humans at the site, and also away from the site due to the movement of the toxic substances with wind.

Managing e-waste

Developed countries worldwide have focussed on the establishment of new policies for managing e-wastes. However, is a dearth of decision support tools that environmental managers, including regulators, could recommend for managing electronic tools. Using life cycle assessment and other critical parameters, CRC CARE researchers – in collaboration with Hong Kong Baptist University – are developing such a tool. ■

Advertise with *Remediation Australasia...*

Remediation Australasia gives advertisers access to an emerging market of clients and product users each time we publish a new issue.

Remediation Australasia is now distributed to more than 2,000 recipients, 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.

See our advertising packages at **www.remediationaustralasia.com.au** for more information.

Want more information about advertising in *Remediation Australasia?*

CONTACT ARIC

aric@crccare.com

www.remediationaustralasia.com.au

...Australia's only dedicated environmental remediation magazine.

The *Remediation Australasia* magazine is distributed quarterly to all ARIC members by post and email notification. The magazine features a range of material of relevance and interest to members, including:

- Case studies
- Regulator updates
- Reports from industry groups
- Technical articles
- News relating to new technologies and developments in the industry, and
- Training, international conferences or events in Australasia.

The editorial team welcome your suggestions for content, as well as article submissions.

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

Get in touch with the editorial team if you are interested in contributing any content - whether it be an article or simply a photo. You won't have to sweat over the editorial details; we can edit and format your article ready for publication.

Just flick an email to aric@crccare.com, and we'll take care of the rest.

Climate change and contaminated sites

Ross Sadler, Griffith University

Climate change will undoubtedly be one of the major challenges facing human and environmental health in the decades to come.

An enormous amount of research has been published on the science of climate change during the past 10 years, not to mention the resulting political initiatives and debates. Yet, there has been an almost total neglect of one very important topic associated with climate change – namely, how climate change will affect the behaviour and bioavailability of pollutants already in the environment. Although these comments could be applied to every environmental compartment, there has never been a satisfactory study of the effect that climate change will have on contaminated sites. This article will discuss a few relevant points, with a view to opening doors for further consideration by investigators, remediators and owners of contaminated sites.

Manifestations of climate change

Although increases in greenhouse gases are held responsible for much of the observed climate forcings, there is little evidence to suggest that these increased gas levels will have a direct effect on contaminated sites.

In general, the effects of climate change are generally thought of as being manifested through:

- changes in soil/water/air temperatures
- changes in rainfall patterns
- increased incidence of extreme weather events, and
- rises in sea levels.

Temperature and climate change

A great amount of emphasis has been placed on arguments regarding what the overall global warming that results from climate change will be. The best current estimates place this value at between 2 and 4.5°C, but in terms of pollutant behaviour, these temperature increases are less significant than those associated with the seasonal perturbations that arise from climate change. It is these latter, short-term temperature fluctuations that are more significant in affecting pollutant behaviour. There are plenty of recorded instances of winter minima in Australia rising by 4 - 5°C in abnormal seasons. It is a simple matter to insert data of this kind into computer models of pesticide attenuation.

For pesticides currently in use (whose half-lives are of the order of several months), one can show that two warmer-than-normal winters can reduce the residual amount of contaminant by an order of magnitude. In terms of sites contaminated by these pesticides, the consequence will be a more rapid loss of pollutant and hence a faster return to near-pristine conditions – provided there is no further input. However, the downside of this fact is that these pesticides will be seen by users to lose their effectiveness more rapidly. As pesticide application is normally an ongoing process, the inevitable response from industry will be increased application and hence increased contamination rates.

Extreme weather events

Seasonal perturbations are closely linked to extreme weather events. A commonly-noted manifestation of these phenomena will be the increased frequency (and hence duration) of droughts.

In terms of contaminated sites, these droughts will obviously lead to a more facile distribution of particle-bound contaminants and an increased evolution of dust particles (and associated contaminants) into the atmosphere. This consequence will be of particular significance for improperly sealed tailings dams, and sites where contaminants have prevented the growth of vegetation, or where the vegetation has become denuded as a result of climate change.

Included in the category of increased weather events will be the increased intensity and distribution of cyclones, heavy rainfall events, etc. A clear example is provided by a 2006 study which showed no overall change in annual rainfall in Central India, when 1951 data were compared with those of 2006. There was, however, a significant change in the pattern of delivery, with the rainfall now appearing as several heavy events rather than more regular gentle precipitation. Sudden heavy rainfall events which immediately follow extended periods of drought will provide another mechanism of colloid-bound export from contaminated sites. Data already exist in respect of this type of transport from

"…A more rapid loss of pollutant… [means] that these pesticides will be seen by users to lose their effectiveness more rapidly [and] the inevitable response from industry will be increased application and, hence, increased contamination rates."

agricultural areas of North Queensland, and these could well provide a model for pollutant export of this kind from other areas.

In addition to pollutant export, the sheer destructive effect of extreme weather events can never be overestimated. Predictions of climate change almost invariably indicate a future wider distribution of such events. For example, although typhoons are currently only experienced in the northern part of Vietnam, it is predicted that later this century they will also be experienced regularly in Ho Chi Minh City (Saigon). Of special significance to contaminated sites will be considerations such as whether tailings dams have sufficient freeboard, whether drums of waste, unexploded ordnances, etc. can be mobilised, and how stable landfills can be expected to be under these conditions.

Clearly, the problem will be at its most acute when the influence of such events is extended to areas where they traditionally did not occur and hence, waste dumps were not designed to cope with events of this kind. A lesser-researched potential effect of climate change on contaminated sites is the ability of temperature-precipitation ratio to change the properties of soil organic matter. There is no doubt that if climate change is reflected in perturbations of this kind, there could be significant changes in mobilisation of soil-bound organics and inorganics. Temperature-precipitation regimes are known to interact with soil type in terms of pollutant mobility in soils.

Rising sea levels

There is a close parallel between the predicted effects of rainfall from extreme weather events on contaminated sites. Inundation by climate-change mediated sea level rises clearly has consequences in all low lying coastal areas. In the case of coastal cities and towns, this can include port facilities and rail yards, etc., which are known centres of contamination.

Associated with sea level rises is the ability for storm surges to affect much wider areas than is currently the case.

For example, predictions for the city of Cairns show that a large portion of the central business district will be subject to storm surges associated with extreme weather events by 2050.

It is also noteworthy that sea level rises will result in increased salinisation of estuaries, with attendant consequence for retention of pollutants by ecosystems. Modelling of climate change-mediated effects on physicochemical parameters shows mangrove communities, which are currently a significant sink for pollutants, to be particularly sensitive in this regard. A significant redistribution of semivolatile pollutants into the general environment can therefore be expected from the salinisation of such estuaries as a result of sea level rise.

It is hoped that his short discussion provides a springboard for future consideration of the effects of climate change on contaminated sites. There is no doubt that the predicted effects have major consequences in regards to both the behaviour of pollutants at contaminated sites and, indeed, the formation of contaminated sites in the future. The result will provide major challenges for regulators, remediators and researchers.

Note: A detailed review of climate change and contaminant behaviour will be published in the upcoming edition of *Toxicological and Environmental Chemistry*: Sadler, R, Gabric, A, Shaw, G, Shaw, E & Connell, D 2011, 'An opinion on the distribution and behaviour of chemicals in response to climate change, with particular reference to the Asia-Pacific region', *Toxicological and Environmental Chemistry*, vol 93, pp. 3–31. ■

CRC CARE II Research Program

Ravi Naidu, CRC CARE

CRC CARE has been successful in a bid for a further 9 years of funding support from the Commonwealth's Department of Innovation, Industry, Science and Research (DIISR). This will take CRC CARE through to 2020.

The CRC CARE II research agenda was developed through an extensive consultation process with end users, which identified four central research programs: best practice policy, better measurement, reducing uncertainty in risk assessment, and cleaning up.

Some information on the research agenda of CRC CARE II is as follows:

Program 1: Best practice policy

There is no national policy guidance for remediation in Australia, and remediation is specifically excluded from being part of a National Environment Protection Measure (NEPM). There exists some guidance at the state level, but this is fragmented, inconsistent, and does not provide the balanced approach that is necessary. A key limitation of the existing guidance is that generally, it does not address the issues of uncertainty, the requirements for adequate long term management, or economic and social factors. CRC CARE II will provide the necessary forum and the body of knowledge to support the development of a national framework for the remediation of contaminated sites.

Program 2: Better measurement

Identifying and measuring contamination with sufficient certainty for decision-making purposes within a budget is a major challenge for remediators. Current measurement methodologies and technologies have many limitations which can lead to considerable uncertainty, time delays and increased costs in the site assessment process. The most critical of these limitations are:

- The lack of methods and technologies to accurately measure and characterise complex and ill-defined mixtures of compounds, such as naturally degraded materials (e.g. weathered hydrocarbons) and emergent contaminants (e.g. product additives).
- The inability to measure and characterise contamination that extends across different mediums (i.e. soil, air, water, food and biological).
- The inability of many methods and technologies to accurately detect and measure at the concentrations that are determined to be important by risk assessment methods.
- The inability to conduct rapid analysis in the field.

This program will target the development of next generation analytical methods, and the development of new innovative field-based technologies to provide faster & more efficient assessment of site contamination.

Program 3: Minimising uncertainty in risk assessment

Although risk assessment is a central component of Australia's regulatory system, it suffers from major limitations, such as:

- significant gaps in information on the effects and fate of chemical compounds in the environment
- a lack of comprehensive information on contaminant bioavailability
- insufficiently developed and agreed methods of risk assessment, and
- existing models that rely on assumptions or data borrowed from other countries.

The uncertainty created by the lack of appropriate data and knowledge means that the risk parameters on which remediation solutions are based, can be over-conservative or erroneous. This results in remediation efforts that may be overly elaborate (representing wasted cost and effort), or fail in their goal of protecting public health and environment. Program 3 will seek to reduce this uncertainty through the development of new technology, methods and knowledge that will more reliably identify, quantify and estimate:

- the changes in the manner in which contaminants interact with their environments over time (exposure pathways) and across major soil types, and
- the toxicity and bioavailability of heavy metals, weathered hydrocarbons and other emerging contaminants on human health and ecosystems.

Program 4: Cleaning up

CRC CARE I has achieved one of its primary objectives in gaining the acceptance of a 'risk-based' approach to management of contaminated sites. This was a significant achievement, given that the preferred approach to remediation has been excavation and transport of contaminated material to prescribed landfills. This achievement (as well as the increased cost of landfill) has led to another paradigm shift in the remediation of contaminated sites, with the focus now on in situ management with triple bottom line principles in mind.

However, Australia lacks the knowhow for the application of remedial technologies to realise alternative strategies that achieve significant risk reduction and cost savings.

This program will develop, evaluate and demonstrate innovative clean-up technologies that provide effective management options for in situ remediation and management of priority contaminants, such as heavy metal(loid)s, hydrocarbon (weathered and new), acid sulfate and mixed contaminants.

In-situ thermal methods in environmental remediation

Dr Bruce McGee,
McMilllan McGee Corporation

Thermal (heat-based) technologies essentially consist of applying heat to the subsurface to remove volatile and semi-volatile contaminants from soil and groundwater. In-situ thermal techniques for removing contaminants from soils include electrical resistance heating, electromagnetic heating, hot air injection, steam injection, vitrification and electro-thermal dynamic stripping process (ET-DSPTM). A significant advantage of using thermal technologies is that contaminant mass-transfer limitations of traditional remediation technologies are not encountered, given the ease with which vapourised chemicals can be removed from the soil as opposed to liquid phase extraction.

Thermal methods can be designed to deal with both dense non-aqueous phase liquid (DNAPL) and light non-aqeuous phase liquid (LNAPL) -distributed contaminants. LNAPLs are less dense than water, and are typically petroleum-related fuels and distillates. Due to their buoyancy, the distribution of LNAPLs in the subsurface is generally limited to the vadose zone and the water table. Synthetic chlorinated solvents, coal tars, and heavy

The corner of the apartment building where the underlying soil is contaminated with benzene and other hydrocarbon compounds. The rig is drilling a well less than 1 m the side of the building where an electrode was located.

fractions of petroleum distillation are generally classified as DNAPLs because they are denser than water. Sites with DNAPL contamination are categorically more difficult to investigate and remediate than LNAPL sites. Laboratory-scale research indicates that heating the subsurface to steam-temperature may allow nearly complete removal of DNAPL.

It is particularly important to characterise the location of the chemicals in the soil prior to designing the thermal treatment system. This is frequently achieved through modelling, a critical step in maximising a project's outcome and minimising costs and duration. Prior to startup, conceptual models are typically run to predict the in-situ power density distribution (created by the flow of current under the force of an applied voltage) and, therefore, the heat flow and contaminant removal. Typically, the flow of current (and thus the power density distribution) selectively follows migration pathways and contaminant distribution, creating highly efficient contaminant removal mechanisms.

The Shell North Hill project, performed in 2002 by McMillan-McGee Corporation in Calgary, Alberta, Canada, demonstrates the benefits of in-situ thermal remediation in a populated area. This site, located adjacent to a former fueling station, was highly contaminated with hydrocarbon and benzene impacted soils. Excavation was not a viable option as the contaminated zone was partially covered by an occupied apartment building.

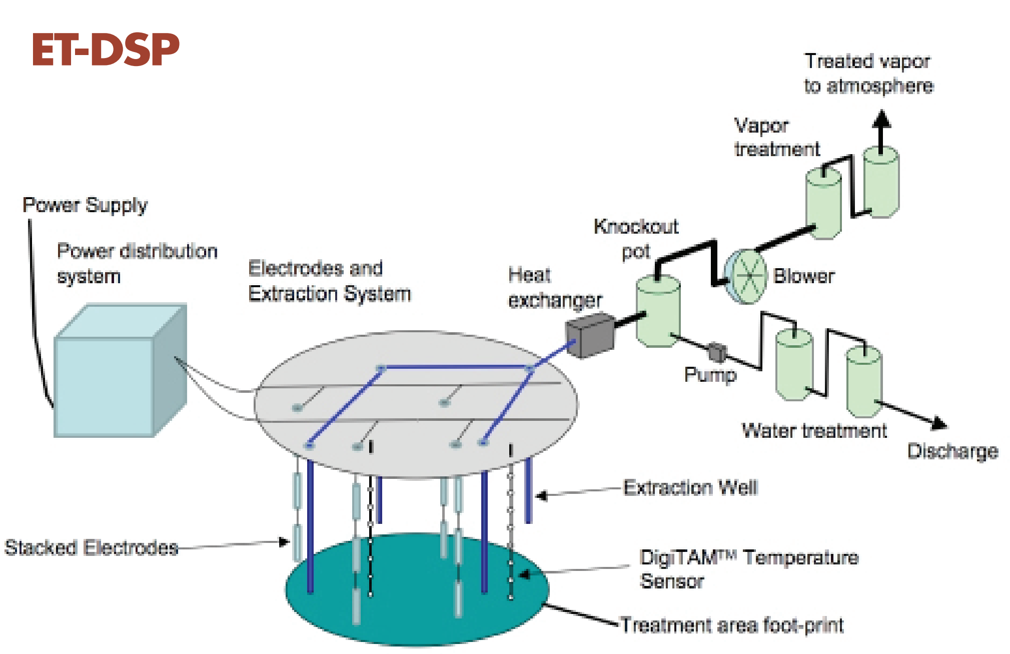
The Shell North Hill project used ET-DSPTM to remediate benzene, toluene, ethylbenzene and xylene (BTEX) compounds from under the occupied apartment building and to mitigate potential vapour intrusion pathways into the building. Operating within several engineering, environmental, and safety constraints, a design was developed in order to conduct an electrical heating and in-situ extraction operation that was unobtrusive to the day-to-day activities of the residents. The extraction facilities and ET-DSPTM system were also designed to reduce noise levels to well below acceptable levels and virtually eliminate induced surface voltage.

ET-DSPTM is an electrical resistive heating, in-situ thermal remediation technology using three-phase power augmented with the ability to inject into the electrodes to affect convective heat transfer. Three-phase electrical energy is delivered to contaminated soils by way of a power delivery system (PDS). The PDS is then connected to a pattern of symmetrical electrode wells (possibly with multiple electrodes stacked in a well) strategically placed around the perimeter and adjacent to the volume of contaminated soil. A water circulation system provides water to the electrode wells to prevent overheating, to affect convective heat transfer, and to reduce the electrical resistivity of the subsurface materials.

The pattern of electrodes is designed so that conventional three-phase power can be used to heat the soil. The distance between electrodes and their location is determined from the heat transfer mechanisms associated with vapour extraction, electrical heating and fluid movement in the contaminated zone. A multi-phase, multi-component, 3-D thermal model is used to simulate this process.

The temperature increase achieved using ET-DSPTM results in an increase in vapour pressure of the compound, decreases viscosity of compounds with low vapour pressure, and can also create an increase in microbiological activity (*note*: vapour pressure is a measure of how a compound distributes itself between its pure form (solid or liquid) and the airspace above it. The higher the vapour pressure, the more a compound prefers to be in the vapour phase and the more volatile the compound). Raising the vapour pressure of volatile

FIGURE 2 ET-DSPTM technical diagram



and semi-volatile contaminants increases their ability to volatilise and to be easily extracted.

In the Shell North Hill project, heating the soil close to the boiling point of water changed the phase of the contaminant from liquid to gas. Once the contaminant is in the gas phase, it is readily removed from the soil through vapour extraction wells located around the perimeter of the electrode wells. Approximately three to four pore volumes of vapour can be extracted daily from the soil, as compared to the same volume of liquid extraction over a period of three months, hence the immediate and obvious benefit of vaporising the liquid chemicals.

Figure 3 shows the vapour pressure for several volatile and semi-volatile chemicals that are of particular interest in in-situ thermal remediation and are common chemicals of concern at contaminated sites. At atmospheric pressure and 10°C, the chemicals are in the liquid phase as shown by the blue bars (vapour pressure at 10°C) being below atmospheric pressure. By isothermally decreasing the pressure to the vapour pressure of the chemical, the chemical goes from a liquid to a vapour phase. For example, this occurs at 49995.75 pascals for pentane. Rather than decrease the pressure as the temperature is increased (for example, to 90°C), the vapour pressure increases so that the chemical exists as a vapour at atmospheric pressure. This is indicated by the purple bars extending above the atmospheric pressure datum at 90°C.

At the Shell North Hill site, the major components of the remediation system were located next to the site. Facilities were also located inside one leased apartment unit, which was constructed into an operational site. Electrodes can be placed vertically from an exterior wall, horizontally beneath the structure or, in this case, vertically through the floor slab. Vapour extraction piping was installed

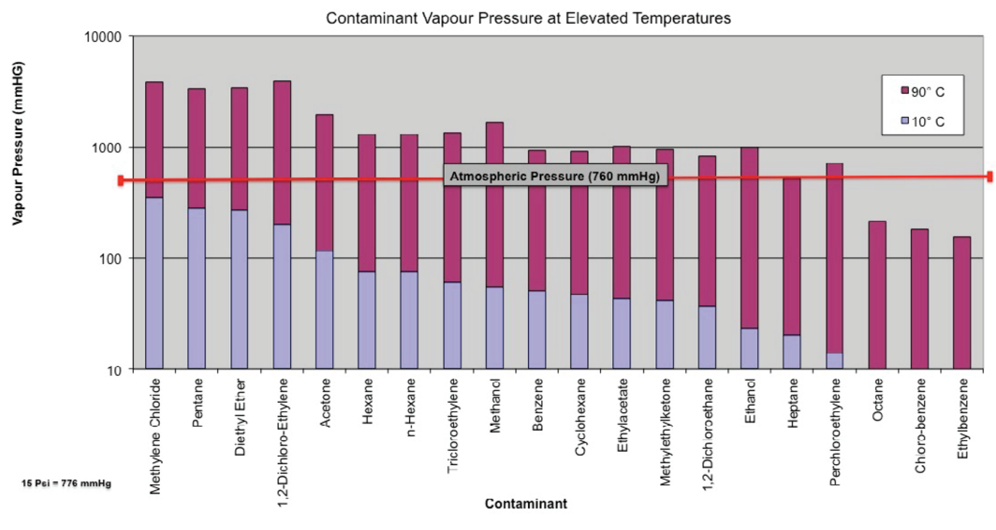


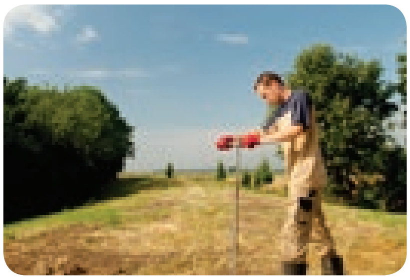
FIGURE 3 Vapour pressures of common contaminants of concern

between the zone of heating and the substructure for the building in order to collect vapours generated by the heating, to prevent the collection of vapour beneath the substructure of the building, and to reduce the risk of vapour entering the onsite structure.

At Shell North Hill, substantial temperature increases were measured within the electrode array groups during the electrical heating period. The average initial in-situ temperature increased from 10°C to 80°C after 31 days. During the remediation process, several confirmatory samples were extracted from the target soil. The results consistently showed a significant reduction in the concentration of the hydrocarbons with non-detect levels being achieved in all of the samples tested. Benzene concentrations initially in excess of 7.5 mg/kg at 1.5 to 5.5 metres below ground surface, tested below laboratory detection limits (0.02 mg/kg) at the conclusion of the project.

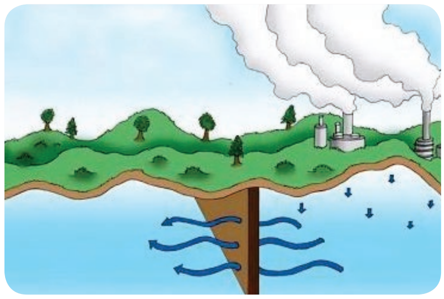
In conclusion, in-situ thermal remediation has evolved to a commercial treatment technology in the environmental industry. A multitude of volatile and semi-volatile chemicals have been successfully remediated to non-detection levels using thermal methods. While this article focused on the application of one such method, in-situ thermal technologies can also be used in conjunction with other chemical or biological technologies to enhance reaction, destruction and removal rates. The future of thermal remediation is focused on reducing costs, time, and ease of execution. ■

Research RoundUp



Research RoundUp, an ARIC initiative and recent addition to *Remediation Australasia*, features current research on environmental contamination assessment and remediation in Australia. Research Roundup aims to keep you up-to-date with current research on environmental contamination assessment and remediation in Australia. By keeping content succinct and focusing on particular projects, *Remediation Australasia* makes it easier for you to find the time to read about areas which are relevant to you. ■

Groundwater remediation using a subterranean reactive barrier



Experience from Europe and North America suggests that groundwater pollution in Australia will become a more serious issue in the future. The current technique for groundwater treatment is based on the 'pump and treat' method, which is unlikely to be economic or sustainable in the long term. A method of remediating polluted groundwater that is gaining increasing attention is the placement of a permeable reactive barrier (PRB) downgradient of the contaminant plume. The barrier allows the groundwater to pass, but remediates the pollutants in the process. There are several aspects to be investigated for a successful implementation of a PRB technology. A good understanding is required of the groundwater flow dynamics, and the engineering aspects of a successful PRB installation must be clear and feasible. A suitable reactive material for use in the PRB also needs to be adopted, or even developed.

A CRC CARE project, completed and reported in 2009-10, focused on the development of a reactive material. Catalyst properties such as morphology, chemical composition, its stability and its regeneration were reviewed, and catalyst activity was investigated in a batch reactor system developed in the lab. The catalyst effectiveness was measured by analysing its capacity to reduce the concentration of the parent molecule, as well as total organic carbon. The technology developed in the project allows simultaneous adsorption and oxidative removal of contaminants. In particular, the pollutants are brought into contact with a $Co_2+/KHSO_5$ reagent to generate a highly active sulfate radical, which readily attacks and oxidises the organic pollutants in wastewater. ■

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

It has often been observed that contaminants present in groundwater decrease over time in both quantity and concentration as a result of physical, chemical and biological processes which occur naturally within the soil and groundwater. This is commonly referred to as 'natural attenuation' or NA. The benefits of using NA as a remediation and management approach can be significant compared with active remediation. However, this strategy also has risks that need to be managed.

When the decision is taken to employ NA, monitoring its effect is essential to assess performance and to confirm that the objectives of remediation and contaminant management are met. This process is commonly referred to as 'monitored natural attenuation' or MNA.

In acknowledging that environmental clean-up regulations vary between Australian state and territory jurisdictions in relation to MNA, CRC CARE initiated a project with the aim of producing a nationally harmonised, and practical, guide for demonstrating MNA of petroleum hydrocarbons in groundwater that would be acceptable to Australian regulators.

The project has been supported by GHD Pty Ltd, and had drawn on a review of international, national and industry information on MNA presented in a CRC CARE Technical Report prepared by McLaughlan et al. (2006). It is expected that the final guidance document, expected to be published in March 2011, will focus on the scientific understanding of the process of MNA of petroleum hydrocarbons and whether it is likely to meet technical requirements imposed by regulators. While the guidance focused on petroleum hydrocarbons, the same principles may be applied to other organic contaminants which are subject to similar processes of natural degradation. *For further information, browse Technical Report 15 at* ***www.crccare.com***. ■

Investigating and optimising metal immobilisation in biosolids

In many countries, landfill is still a major method for biosolids disposal. However, increases in landfill costs and demand for fertilisers are likely to increase the recycling value of biosolids in agriculture. A project being undertaken by UniSA aims to develop optimised biosolids with decreased risks in terms of contaminant bioavailability, and to assist with the disposal of water treatment residuals. The research, making use of synchrotron analysis, will:

- compare sludges produced through different wastewater treatment systems, and investigate the nature of oxides present and their role as sorbents
- Investigate options for more controlled reaction of oxides in sludge to produce optimised metal and P retention and fixation
- assess the reversibility of fixation in currently produced biosolids and in optimised biosolids
- assess the nutrient availability over time as a result of metal fixation optimisation.

Sewage sludge samples have now been collected from over 40 Australian wastewater treatment plants in all states and territories, urban and rural, as well as from the US and the UK. Isotopic and synchrotron-based techniques have been employed to understand the speciation and distribution processes controlling metal bioavailability in biosolids. The main aim of this research, which is due for completion in June 2012, is to open the door to safer agricultural use of nutrients derived from biosolids. The research will also identify new avenues for the safe reuse of industrial wastes such as water treatment residuals. ■

Deciding when to cease clean-up of LNAPLs

Light non-aqueous phase liquids (LNAPLs) are oily contaminants that float on the surface of groundwater and can be particularly difficult to remediate. In many aquifers, regardless of the level of LNAPL remediation effort, it will rarely be possible to achieve total removal of LNAPLs. A CRC CARE research project, being undertaken by CSIRO, has reviewed international practice in deciding the amount of resources to expend on LNAPL clean-up measures – in particular, identifying the point where cost-effectiveness is so low that no further action can be justified. As part of a ten-point remediation process for a typical site, the study recommended that the following measurable factors be taken into account: LNAPL transmissivity, LNAPL saturation remaining, LNAPL plume stability, dissolved stability of contaminant of concern, and asymptotic cumulative recovery from remediation efforts (indicating a lack of mobility and recoverability).

In some cases, even though LNAPL is detectable in wells, further recovery of LNAPL may be impracticable. Even if the plume is stable, remediation efforts may not provide any benefit in terms of reducing the risk to human health or the environment. The work undertaken so far in this project has been published as the CRC's Technical Report no. 6, and is available at **www.crccare.com**. Work is continuing with further guidance on LNAPL remediation technologies, end-points for LNAPL remediation, and LNAPL remediation in fractured-rock expected to be published by CRC CARE in 2011. ■

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 project being undertaken via the University of Technology, Sydney, is canvassing how public and private parties (including regulators, government agencies, civil society, NGOs and industry) currently interact in deciding on site clean-ups. The case study approach – which involves one case study in south-east Asia, one in the Pacific, and three in Australia – 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**). ■

ACLCA Update

Alex Simopoulos, URS Australia

2010 has drawn to a close, and reflecting back on the activities for the year, it is most satisfying to see that ACLCA has been operating successfully and viably across the five states. We thank the respective state presidents and their teams for this success. The focus on ACLCA core activities in providing training opportunities and professional development, interaction with related associations, and interfacing with regulators have been maintained and are progressing well for 2011.

On the national front, this year has seen a re-invigorated push to try to establish co-ordinated national collaboration between states. This was an initiative established in 2005 and is gradually being worked to fruition. One of the key contributions to success on this front has been the willingness of each of the states to develop an awareness of the consulting industry that transcends the state borders. To this, we owe a great vote of thanks to each of the state teams for their selflessness and vision.

There are a number of key initiatives being pursued by ACLCA on a national front at present, including common web presence; professional accreditation; standardisation of policies and rules sharing of workshop presentations; and interaction with fellow organisations such as ARIC and ALGA.

A particular success in 2010 was the coordinated response to the draft variation to the ASC NEPM. This saw each of the states assemble a team to review a fairly daunting volume of documentation in an equally daunting timeframe. The national team was able to agree on a format of response – a response which reflected the unity and collaborative spirit, while enabling state based differences to be raised. The dedication of the individuals involved lead to the preparation of a comprehensive, coordinated response, which was a testimony to the spirit of collaboration that exists among each of the states.

We are also delighted to have achieved participant status in CRC CARE II, which has recently been approved for funding. It is appropriate to thank Professor Ravi Naidu and the board of CRC CARE for accepting ACLCA's proposal for becoming a participant, and of course for their tireless effort and great skill in delivering a winning submission. ACLCA looks forward to the opportunities and rewards available for participants in CRC CARE II. ACLCA sees its participation as facilitating greater interaction between researchers and the consulting industry. Such interactions, as is evident in the existing track record of CRC CARE, leads to the provision of better service and technical standards in industry, and provides an opportunity to retain and develop key research capability in the country.

It is appropriate at this point to thank each of the state ACLCA presidents:

- New South Wales – Michael Dunbavan, (IPP – Andrew Kohlrusch)
- Queensland – Ian Swain
- South Australia – Steve Kirsanovs
- Victoria – Glenn Thiele
- Western Australia – Ivan Kwan

In closing, I note that ACLCA has achieved some progress on our national initiatives, however there are many more miles ahead on this road. The keys to achieving our national goals are largely the on-going collaborative support from each of the states, together with the successful interaction with our fellow associations ARIC and ALGA. ■

Publications Update

This section contains publications that have been published in the last three months since the last edition of *Remediation Australasia*. The publications may originate from research institutions, regulators or industry groups. Please let us know if you have any appropriate publications (no promotional material) to be included by sending details to **aric@crccare.com**.

South Australian EPA

The South Australian EPA has recently updated some guidance relevant to contaminated land as per below:

Transfer of liability
This information sheet is for vendors and purchasers intending to transfer or accept liability for site contamination with the sale or purchase of a property.

Information about site contamination audit reports and audit statements
This information sheet provides general information to those using and relying on site contamination audit reports and site contamination audit statements.

Implementing conditions of a site contamination report
This information sheet provides general information to those who need to implement conditions of a site contamination audit report.

Overview of the site contamination audit system
This information sheet provides an overview of the audit system, the components of the audit system and a summary of the audit process.

EPA Victoria

EPA Victoria has published a revised Landfill BPEM *(Siting, design, operation and rehabilitation standards of landfills)*. Standards for buffer distances, landfill design, construction, gas management, rehabilitation and community engagement have been updated. The EPA is currently developing guidance on landfill gas monitoring for release in 2011, and continues to work with wider Victorian government on buffer issues.

CRC CARE Publications

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

CRC CARE Annual Report 2009-10
For anyone interested in learning about CRC CARE's contribution to the remediation industry, the Annual Report is a very comprehensive overview of work carried out.

CRC CARE Fact Sheet 11: Water quality ■


No entry