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ISSUE 16 2014

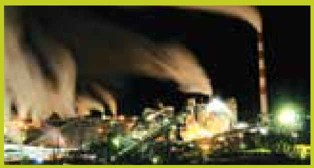
Remediation Australasia

DEALING WITH CLIMATIC UNCERTAINTY

Designing approaches for groundwater restoration PAGE 8

MUTAGENIC CARCINOGENS
How should Australia assess them?

FIBRE-OPTICS
How can we harness them for groundwater remediation?



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EDITOR'S NOTE

Welcome to Issue 16 of *Remediation Australasia*.

I hope you like the new appearance of the magazine, which is part of an overall update of our branding at CRC CARE, designed to give the organisation a fresh, vibrant feel.

This year is shaping up as an important one for the remediation industry in Australasia. Over recent years, there have been many calls for the industry to further improve its professional standards. As a result, CRC CARE is leading an initiative to do just that.

As you know, assessing and remediating contaminated sites is a complex and challenging task. Planning, executing and managing a remediation project requires specialised skills and advanced knowledge. Globally, there is a growing realisation that only appropriately qualified personnel should be allowed to perform these tasks. Accordingly, a number of countries are developing certification schemes to provide increased assurance for site owners, regulators and communities.

Thus, in the late 2000s, CRC CARE began discussions with the Australian Contaminated Land Consultants Association (ACLCA) on the need for a certification scheme for site contamination practitioners. Efforts to make this a reality are now well under way. The envisaged scheme aims to provide improved outcomes for all stakeholders and provide appropriate recognition for the profession, the expertise of practitioners working in a complex environment, and the profession's contribution to society.

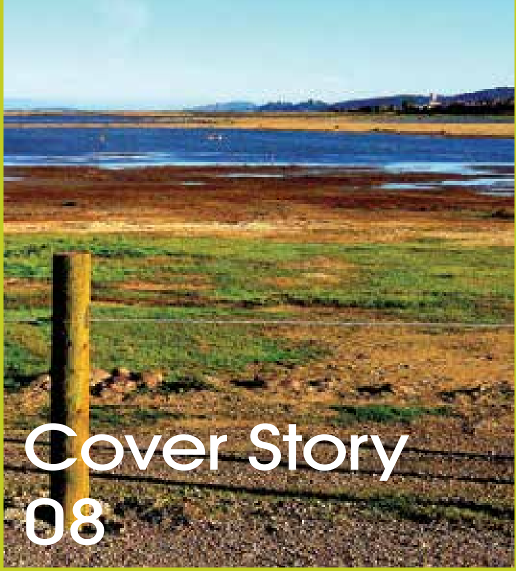
The details of the scheme are being developed through stakeholder consultation by representatives of the industry, ACLCA, regulators and CRC CARE, with the aim to launch in mid-2014. Keep an eye out for the next issue of *Remediation Australasia*, as well as www.crccare.com/products-and-services/certification-scheme, for more information.

In this issue we examine human exposure to carcinogens that can mutate DNA, and how the risks should be assessed – especially given that there is evidence showing that exposure is more dangerous for children than for adults. *Remediation Australasia* looks at the debate in Australia over whether 'age-dependent adjustment factors' should be incorporated into guides for assessing these cancer risks, as has occurred in the United States.

The magazine explores how human-driven climate change might influence the way we prevent, manage and clean up contamination. For a start, growing concern with climate change is driving the need for sustainable technologies with lower energy requirements. Issue 16 takes a look at one promising technology – zero valent nano-scale iron, generated from waste iron oxide, which can remediate of a broad range of recalcitrant metal working fluids. We also investigate the importance of strategies for preventing and remediating groundwater contamination that take into account the predicted impacts of climate change, such as sea level rise.

Other articles include a wrap-up of the background and current status of a low-energy, *in situ* method for treating contaminated groundwater using titanium dioxide and fibre-optic cables, and a look into the dirty world of illegal, clandestine drug laboratories – 'clanlabs' – and what must be done to minimise the dangers they pose to nearby residents.

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



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

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COVER PHOTO
Wetland restoration is helping to combat sea level rise and seawater intrusion into developed areas close to the shore.
Photo: Scott Warner

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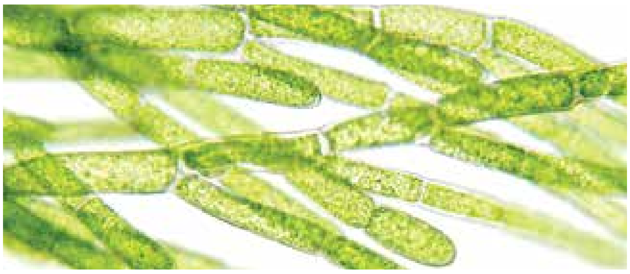
CONTENTS

Every Issue



Features

reMEDIAtion

Your guide to environmental contamination and remediation issues in the media

Algae for cleaning up Fukushima?

Three years after an earthquake devastated Japan, radioactive contamination from the Fukushima nuclear power plant remains an issue in seawaters around the site. A group of Japanese scientists are offering a unique solution in phytoremediation. After testing over 100 strains of algae, they have identified a strain that can eliminate 90% of radioactive caesium. Despite these promising results, the owner of the Fukushima site – the Tokyo Electric Power Company – has been slow to react to the research. State University of New York Professor Lee Newman suspects this may be due to a fear of technology they are not familiar with, as reported on The Voice of Russia website (bit.ly/1fVgLCz). Read the *Journal of Plant Research* article at bit.ly/1ek5xF6.

Meanwhile, a shortage of workers is slowing the remediation works that are being undertaken in the north of Japan. *Business Insider Australia* reported that scouts are now looking around large cities to recruit homeless people to undertake the manual work (http://ow.ly/w3WAS). The workers, who are paid less than minimum wage, are often left in debt after working as deductions for food, accommodation and laundry are taken from their pay.

Plastic consequences for seabirds

A recent study out of the University of Tasmania has shown that the impact of plastic pollution on marine birds goes deeper than a simple matter of ingestion. Marine birds are ingesting record amounts of plastic with the volume increasing over the period of a four-year study recently published in *Environmental Pollution* (bit.ly/1gLhM1Z). Beyond this, however, the study is the first to link the plastic to high levels of toxic metals in the birds.

National waste reporting 2013

National Waste Reporting 2013 – an online resource providing data on waste management and resource recovery in Australia – has been released by Department of the Environment. The resource builds on the baseline data presented in the *National Waste Report 2010*, and draws on a range of commissioned research, published sources and information provided by Australian, state and territory governments, business, industry and community organisations. It includes data sets and time series analysis which can be used to make informed and timely decisions about waste management and resource recovery. It can be accessed at bit.ly/1iCdSrF.

Photo by Jean-Etienne Minh-Duy Poirier, www.flickr.com/photos/jepoirrier/; creative commons https://creativecommons.org/licenses/by-sa/2.0/

Air pollution our largest risk

The World Health Organization (bit.ly/1jpGo4S) has just released 2012 figures linking 7 million deaths per year (one-eighth of all deaths) to air pollution. This more than doubles previous estimates and confirms air pollution as the world's largest single environmental health risk. The new data reveal a stronger link between both indoor and outdoor air pollution exposure and cardiovascular diseases, as well as between air pollution and cancer.

Asbestos signage for schools

A number of recent asbestos safety breaches in Victoria have resulted in legal action against the Education Department. WorkSafe reports identified that, despite the current asbestos management plan in place, one school had peeling lead paint and asbestos on site. Consequently, schools with asbestos present will now have to place explanatory signage on gates and buildings. The Education Department has promised ongoing support to schools while they implement the order, reports *The Age* (bit.ly/1dGBx6l).

Chinese pollution detectable from space

Despite the efforts of the Chinese government, many regions of the country still experience regular episodes in which pollutants greatly exceed the guidelines set by the World Health Organisation, reports the French National Centre for Scientific Research (CNRS) (http://ow.ly/w3QVB). The air quality monitoring network in China regularly reports on pollution levels, but the difficulty of covering all geographical locations means that gaps are present in the data collection. However, a recent breakthrough has shown that ground level contamination in China is detectable by infrared satellite. This discovery will enable more accurate and thorough monitoring of China's pollution episodes.

Arsenic behind the wall

A team at the University of California, Berkeley, has developed a way to filter arsenic from drinking water and lock it up in concrete used for construction, where it remains unavailable to people and the environment, according to *New Scientist* (http://ow.ly/w3YHH). Water is placed in a container fitted with steel plates. A small voltage is fed through the plates to encourage rusting. Arsenic binds to the rust, which can be easily collected and integrated into concrete. The technology is being tested in India.

E-waste scheme making inroads

The *EnviroInfo* website reports that the National Television and Computer Recycling Scheme (bit.ly/1izXTJn) recycled more than 40,000 tonnes of electronic waste (e-waste) – discarded items such as computers and televisions – in its first year of operation (http://ow.ly/w3Xg0). The scheme was established by the Federal Government to encourage industry to better deal with e-waste that would otherwise need to be stockpiled or dumped at landfill sites.

Groundwater restoration in a time of climatic uncertainty

Scott D. Warner, Principal, ENVIRON International Corporation

As we move further into the 21st century, it is crucial that strategies for preventing and remediating groundwater contamination must take into account the predicted impacts of climate change.

Henry Darcy, the great French engineer who made many contributions to the field of hydraulics and to whom we thank for his pronouncement of the primary tenant for predicting fluid flow (i.e. Darcy's Law), wrote in 1856:

> *"The goal of a water distribution system is to bring to the various parts of a city the amount of water required to meet its needs."*
>
> **Darcy 1856 in Bobeck, 2004.**[1]

More than 100 years before Darcy's description of the public fountains of Dijon, France, the French botanist De Jussieu penned:

> *"There is nothing of more interest to magistrates than maintaining the healthfulness of the water that serves both men and animals and preventing accidents that can cause the water to become polluted, whether in springs, rivers, and streams where it flows or in places where diverted water is stored, or in the wells used as sources."*
>
> **De Jussieu 1733.**

Both of these French scientists, one a pragmatic water resources engineer, and the other a research bio-scientist recognised the public benefits of a reliable, clean and plentiful source of water for public and personal use. Considering their advanced thinking, it is possible that one, or perhaps both, of them could also have predicted today's collision between the anthropogenic and ecological worlds with regard to protecting and assuring adequate water supply in the face of our chronic climatic evolution.

Though climatic prediction has historically been a difficult endeavour to achieve at a satisfactory level of certainty, the widely acknowledged and accepted influence of the developed world on the earth's climatic system makes such predictions substantially more difficult. The evidence is strong that modern society is now dealing with a pronounced change in one of the planet's key parameters – global temperature – and this change coincides with an increase in our industrial productivity (for example, see the US Environmental Protection Agency for various lines of evidence www.epa.gov/climatechange/science/causes.html). Given this, both Darcy and De Jussieu may, posthumously, not be unkind to the introduction of a new geologic epoch within our informally coined 'Anthropocene'[2] that we can informally designate as the 'Climatopocene'.

Remedial efforts at industrial areas near shorelines will be prone to sea level change considerations.

Scott Warner

Evidence of the changing patterns have been expressed by many government agencies around the globe. For example:

- in Australia, the Commonwealth Scientific and Industrial Research Organisation (CSIRO) forecasts less rainfall and longer dry periods, though possibly more short-duration intense precipitation events;
- in California, USA, the Department of Water Resources emphasises that precipitation and runoff patterns are changing, and extreme climatic events will become more frequent (note that California is currently experiencing an unprecedented drought situation);
- for North America, the US National Oceanic and Atmospheric Administration expects a continuing trend of big heat events and big rain events (and note the unprecedented severe cold and snow conditions across the midwest to eastern United States during the 2013–14 winter season).

For the remediation professional, long-term climatic changes should be heeded because of the resultant effect on the perceived stability of the hydrologic system for which our remedial measures must be designed to incorporate. How we consider and adapt to the changing conditions will have a strong influence on the design of reliable and protective groundwater contamination mitigation measures.

From a historical perspective, Western countries such as Australia and the United States saw environmental protection – in the form of wide-reaching federal and local jurisdictional laws and statutes – commence in the late 1970s and then explode in the 1980s[3], with rapid expansion through the remainder of the twentieth century and into the 2000s. Both countries developed laws based on both ambient- and technology-driven regulatory strategies to incorporate the philosophies that environmental clean-up approaches should achieve 'background' conditions and/or be based on the best available technology at the time.

However, both countries have evolved differently over the years, with the United States enacting Federal pollution laws (such as the Federal Water Pollution Control Act and 'Superfund' laws in the 1970s and 1980s) earlier than Australia, which itself developed project-specific pollution abatement efforts such as the Captains Flat Agreement of 1975 (see: www.comlaw.gov.au/Details/C2004C00425).
For both countries, and others in the developed world, the expectation was that scientists and engineers could design and implement remedies that would efficiently return contaminated land back to pre-impact and thus background, or ambient, quality.

During the late 1980s and into the 1990s, it became apparent that removing spilled chemical constituents from groundwater systems, or completely eliminating the impacts of mine-site drainage on downgradient streams and water resources, was not an easy or inexpensive endeavour. Early attempts to remove organic chemicals, such as chlorinated solvents and pesticides, from aquifers using groundwater pumping seldom achieved complete removal of the contaminant. While hydraulic pumping systems could help to keep a contaminant plume stable, contaminant removal efficacies were low and maintaining the pumping system became more and more expensive.

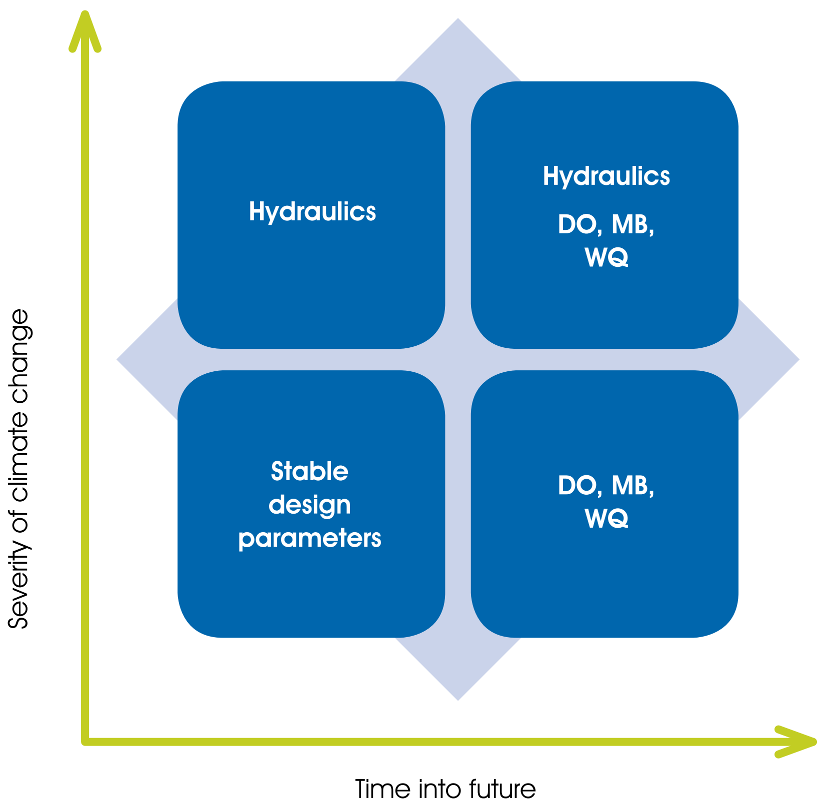
Through the 1990s and into the 2000s, innovative contaminant removal strategies using hydraulically 'passive' remedies, such as bioremediation and permeable reactive barriers, found a home alongside remedies that incorporated natural attenuation processes to reduce the potential for contaminants to pose major health and environmental hazards to sensitive receptors.

These hydraulically passive measures, referred to as *in situ* remediation approaches, were designed to work with the ambient groundwater flow and geochemical conditions in the area of impact, and were intended to operate in the relatively stable and consistent site-specific flow and hydrochemical conditions of the subsurface. A major tenet of these passive approaches was that they were not intended to quickly 'clean' a contaminant plume; rather, they were (and continue to be) used mostly as a 'line in the sand' to stop the migration of a plume before it reached a sensitive downgradient area. In other words, they were designed to isolate the source area from downgradient resources. Thus, these remedies were expected to last for many years or even decades until the source area was depleted or removed. It is likely that the designers seldom envisioned changes to ambient hydraulic or geochemical conditions over time.

Though these passive systems were designed to work under ambient conditions, care to understand short-term seasonal changes in groundwater flow directions, for example, were often considered. Small shifts (perhaps 10 to 15 degrees) in the direction of the lateral hydraulic gradient could be accounted for in the design, and monitoring would assess the performance of the remedy through these short-term changes. Little attention, however, was likely given to the potential influence of small seasonal changes or variability in geochemical conditions (e.g. dissolved oxygen, pH, specific electrical conductance and temperature) on the in situ remedy.

With the occurrence of long-term and chronic climatic change and variability, however, major perturbations to groundwater level and flow conditions will need to be assessed. Major changes to groundwater level and flow patterns are also likely to influence the background water quality. Dissolved oxygen and temperature conditions in a groundwater system will be influenced first, and these changes will alter the characteristics of the microbiological system and further affect inorganic conditions (see Figure 1).

Over time, climatic conditions will necessitate our continued monitoring of hydraulic and geochemical parameters, as well as our use of well-developed



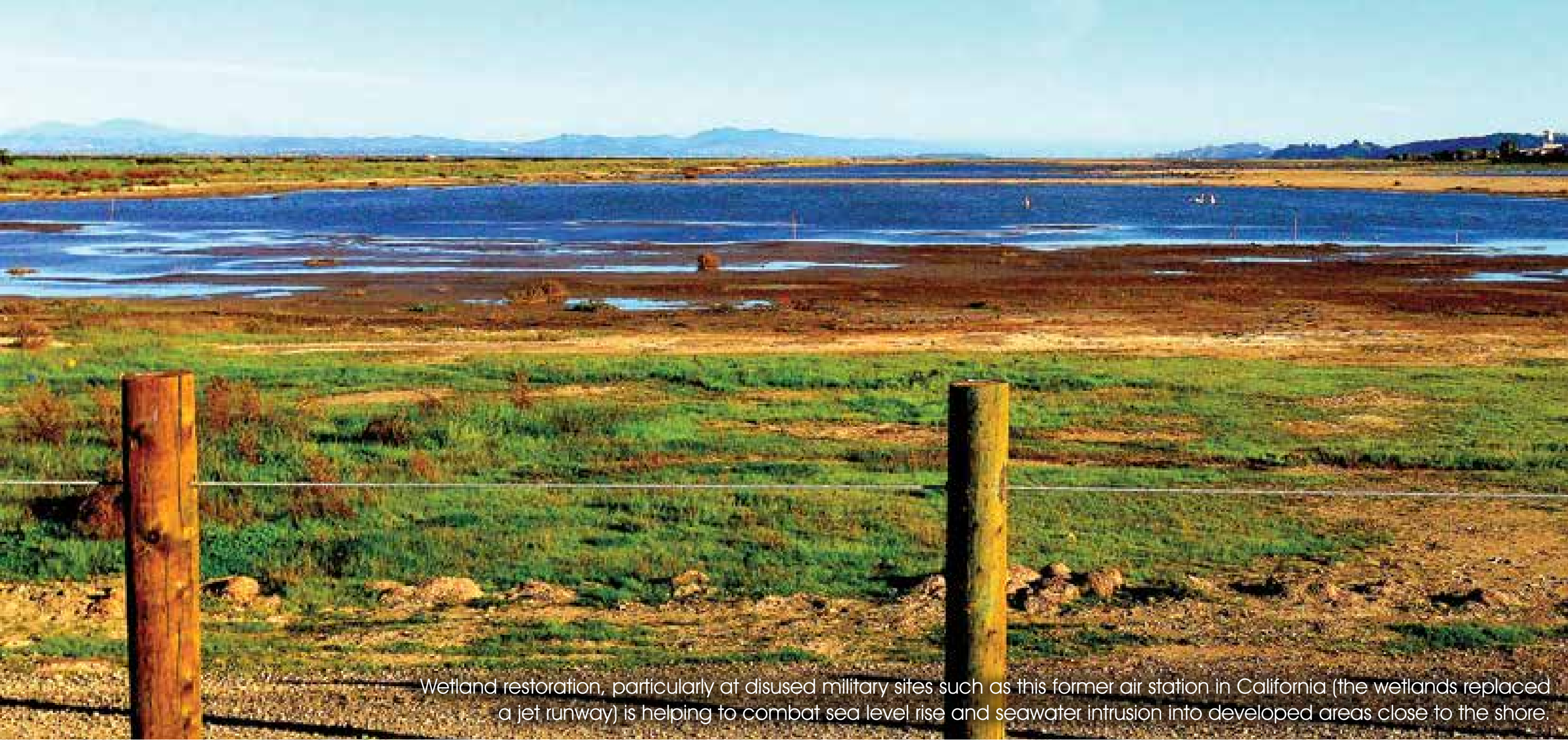
DO = Dissolved oxygen

MB = Microbiology

WQ = Water quality parameters (pH, specific conductance, temperature)

Hydraulics = hydraulic gradient (magnitude and direction), water velocity, water levels

Figure 1: Necessity of assessing remedy design parameters as severity of climate change influence increases.



Wetland restoration, particularly at disused military sites such as this former air station in California (the wetlands replaced a jet runway) is helping to combat sea level rise and seawater intrusion into developed areas close to the shore.

Scott Warner

predictive scenarios to assess long-term changes. If climate change is rapid, our designs will likely incorporate those changes today; if climate change asserts a slow and chronic influence, we will have to monitor and adjust as time moves forward.

In situ remedies, whether designed as a bioremediation approach or as an abiotic system, are sensitive to ambient oxygen and temperature conditions in the aqueous system. Inorganic conditions (the prevalence of major inorganic species including bicarbonate, sulphate, calcium and sodium), on the other hand, directly influence the potential for mineralisation and thus pore-space loss within several types of in situ remedy. Additionally, groundwater remediation measures will need to account for changes in recharge (from precipitation variability) and systems near a shoreline may need to account for long-term changes in sea or lake levels.

Under the premise of climate change and its impact on hydraulic systems, the convention of assessing and designing 30-year groundwater remedies may no longer be relevant from a performance perspective, even though the this approach was primarily developed for financial assessment reasons. The reality is that our remedial strategies could benefit from adaptive approaches to both passive and active restoration concepts. This will require a better understanding of how our remedial systems age, either acutely or chronically, with changing hydraulic conditions, and how we can engineer and monitor remedial systems using reliability-based methods under different hydraulic scenarios.

We also may need to consider occasional physical adjustments to implemented remedies. These may include increasing the geographic footprint of an installation, adding a different bio-enhancement solution to a bio-remedy, or adding small-scale active hydraulic enhancements (forced gradient methods, including pumping) to otherwise hydraulic passive remedies.

Keeping both Darcy's and De Jussieu's observations current will not be our challenge moving forward. Rather, our challenge will be to remain flexible with our designs, promote adaptive strategies, and continue to educate the regulatory community and the public on the advances in groundwater protection that we develop as our journey through the Climatopocene continues.

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Assessment of mutagenic carcinogens in Australia

Belinda Goldsworthy and Rosalind A. Schoof, ENVIRON

Experimental evidence suggests that exposure to mutagenic carcinogens – cancer-causing agents that act at the level of DNA – is more dangerous for children compared with adults. In the USA, age-dependent adjustment factors (ADAFs) have been incorporated into guides for assessing cancer risks associated with exposure to such chemicals. Workshops held in Australia during 2012 and 2013 discussed the merits for and against adoption of ADAFs in Australian risk assessments, with no clear agreement reached. This article presents a summary of the current situation in the US and Australia.

Setting the scene

In Australia, cancer risks from childhood exposures to chemicals are generally analysed using methods based on exposure to adults, which assumes that chemicals are equally potent in both early and later life. However, literature from animal studies shows that perinatal exposure (during pregnancy and immediately after birth) to mutagenic carcinogens in conjunction with adult exposure usually increases the incidence of tumours or reduces the latent period before tumours are observed. These observations were made from chemical exposures that act via a mutagenic mode of action. Therefore, it can be considered that children are more susceptible to mutagenic carcinogens than adults largely due to differences in biological processes, such as immaturity in the immune system and more frequent cell division during development.

The US national approach

In their document *Supplemental Guidance for Assessing Susceptibility for Early-Life Exposure to Carcinogens*, in 2005 the US Environmental Protection Agency (EPA) released guidelines for assessing risks to children associated with early-life exposure to mutagenic carcinogens. The document states that:

> *"….there can be greater susceptibility for the development of tumours as a result of exposures to chemicals acting through mutagenic mode of action, when the exposures occur in early lifestages compared with later lifestages."*
>
> **p29, http://ow.ly/w3Xtq.**

The guidance suggests that ADAFs should be applied for mutagenic carcinogens, for the age groups '0 to 2 years' and '2 to <16 years' (see Table 1). The ADAF of 10 was derived from a large-scale desk-top quantitative study described in detail in the US EPA 2005 guidance, and the ADAF of 3 represents a decline in potency expected to occur as children mature.

Table 1. US EPA (2005) Age-dependent adjustment factors

Age group	ADAF
0 – <2 years	10
>2 years – <16 years	3
> 16 years	No adjustment

Currently, the US EPA identifies 19 compounds that are thought to be mutagenic carcinogens, and for which the ADAFs should be applied during risk assessments involving infants, children and adolescents. To avoid any confusion regarding which compounds are

considered to be mutagenic, the US EPA has published a list on their website (http://ow.ly/w3XDv).

Selected US state approaches

The California EPA went one step further than the Federal EPA in 2009, and proposed applying an early life adjustment scheme in the assessment of all carcinogens, not just mutagenic carcinogens. With respect to the ADAF values, the California EPA's Technical support document for cancer potency factors states that:

> *"We intend to apply this weighting factor to all carcinogens, regardless of purported mechanism of action, unless chemical-specific data exists to the contrary. In cases where there are adequate data for a specific carcinogen of potency by age, we would use the data to make any adjustments to risk."*
>
> **pp 3–4, http://ow.ly/w3XyB.**

The Minnesota Department of Health (MDH) also recommends application of the ADAFs for all carcinogens on the basis that the 2005 Federal US EPA guidance did not address a key EPA Science Advisory Board recommendation. MDH's 2010 document *Risk assessment advice for incorporating early-life sensitivity into cancer risk assessments for linear carcinogens* states:

> *"Certain groups of non-mutagenic carcinogens with known modes of action serve as important examples in support of applying a default factor to non-mutagenic carcinogens when the mode of action is unknown. The Review Panel suggests that the Agency reconsider limiting the application of adjustment factors only to mutagenic agents and instead apply a default approach to both mutagenic and to non-mutagenic chemicals for which mode of action remains unknown or insufficiently characterized (US EPA, 2004)."*
>
> **p1, http://ow.ly/w3XQw.[1]**

The MDH also provides guidance for when the ADAFs are not required, including when:

- data are sufficient to calculate a chemical specific early-life cancer slope factor (e.g. vinyl chloride)
- the carcinogen dose-response is considered to be non-linear in the appropriate exposure range (e.g. chloroform), and
- the cancer slope factor is developed from studies that incorporate exposures during early life.

Australia's approach

Although the US EPA (2005) guidance for early-life exposure is not formally adopted in Australia, it is acknowledged in the 2012 Department of Health – Environmental Health Standing Committee (enHealth) risk assessment guidelines. This document states that:

> *"While Australian environmental health authorities have not enunciated specific policies relating to applying these US early-life risk assessment strategies, additional precaution tends to be applied on a case-by-case basis when justified by relevant data."*
>
> **p19, http://ow.ly/w3Y0R.**

In addition, ADAFs were incorporated into the recently released National Environment Protection (Assessment of Site Contamination) Measure (NEPM), with one aspect of the NEPM describing the US EPA ADAF approach, and recommending to Australian risk assessors that:

> *"This process should be considered for individual contaminants where there is clear evidence of a mutagenic mode of action."*
>
> **p50, Schedule B4, http://ow.ly/w3Y5t.**

The large impact that ADAFs can have when making evidence-based risk assessments is illustrated by considering benzo(a)pyrene, a coal tar hydrocarbon. Residential soil health investigation levels (HILs) for benzo(a)pyrene both with and without application of ADAFs are shown in Table 2 (adapted from Schedule B7, Appendix A2, www.scew.gov.au/nepms/assessment-site-contamination). Both sets of health investigation levels are included in the NEPM guidance to illustrate the influence of different toxicological values, and the application of ADAFs, on the resulting HIL value. The recommended benzo(a)pyrene health investigation levels for residential and recreational open space are those values which incorporate the ADAFs.

Table 2. Residential soil health investigation levels (HIL-A) for benzo(a)pyrene (mg/kg)

	Oral TRV2	Oral TRV3
Without ADAF	20	8
With ADAF	6	3 (adopted value)

Table notes: TRV = toxicity reference value

The adoption of the ADAF significantly influences the resulting health investigation levels for benzo(a) pyrene in soil for residential and recreational land use, which further illustrates the effect that ADAFs can have on the overall risk assessment outcome and resulting management options. Certainly, in some situations, the decision about whether to apply the ADAF can significantly influence risk assessment results and consequently influence whether costly remediation is required or not. This decision to adopt ADAFs is often made by health risk assessors without formal toxicological training, and who often rely on best-practice and national guidance to make this decision.

Looking ahead

The merits for and against adoption of ADAFs in Australian risk assessments were discussed during recent workshops in Australia, including the Toxicological Excellence for Risk Assessment (TERA) Dose-Response Assessment Workshop in July 2012 and the Life Stage-Specific Human Health Risk Assessment Workshop in March 2013. No obvious agreement amongst peers was reached. With such differing industry opinions, there is a need for clear guidance in situations where the ADAF may or may not be applied to ensure a consistent and robust approach in this country.

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A fibre-optic photocatalysis hybrid system for groundwater treatment

Ho Kyong Shon, Aaron Katz, Andrew McDonagh (University of Technology Sydney)
and Ravi Naidu (CRC CARE)

This article presents the background and current status of a low-energy, *in situ* method for treating contaminated groundwater using titanium dioxide and fibre-optic cables. The approach builds on previous work using optical fibres to break down organic compounds.

Groundwater contamination by micropollutants

Groundwater systems are a common endpoint for many sources of pollution derived from human activity, including industry, agriculture, and municipal wastewater. Despite advances in water treatment methods, groundwater contamination can be difficult to remediate and is a social and political issue. Of particular concern are compounds that are discharged more or less unaltered into the environment, and which resist the common treatment methods. Although many of these contaminants are found only at low concentrations and are therefore termed 'micropollutants', they may have pharmaceutical, antibiotic or insecticidal activity, or can be highly bioactive compounds that affect the environment. At present, pump-and-treat systems as well as reactive permeable membranes may be used as treatment options for micropollutants, but these are relatively costly methods that require significant infrastructure.

Titanium dioxide can break down micropollutants

Titanium dioxide (TiO_2) is a bright white semiconducting material that has been used for many years as a pigment. As it is non-toxic, it is commonly used in paints and in many food and personal care items, including sunscreens. In the 1970s it was discovered that TiO_2 acts as a photocatalyst when exposed to ultraviolet (UV) light. When TiO_2 absorbs sufficiently energetic light, an electron becomes excited to the extent that it can react with other compounds.

A fibre-optic photocatalysis hybrid system for groundwater treatment

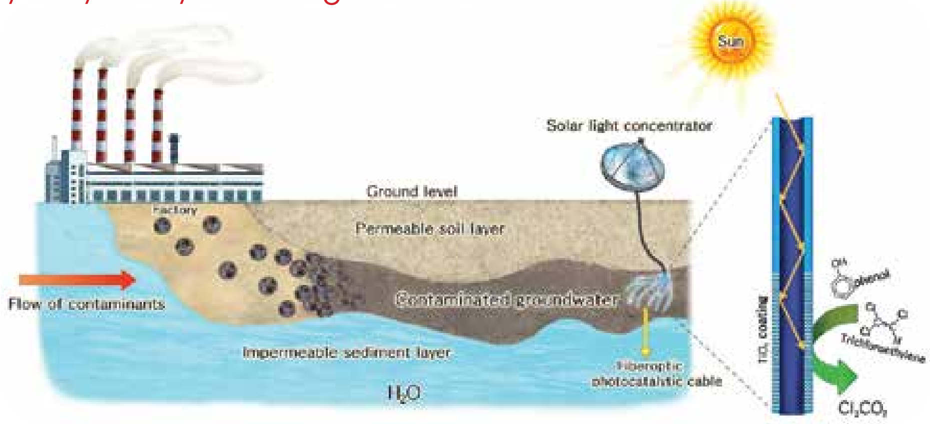


Figure 1.
In situ groundwater treatment by the hybrid fibre-optic photocatalytic system.

Although this excited electron can directly cause the breakdown of some contaminants, of greater relevance to the question of pollutant remediation is that it preferentially generates highly reactive secondary molecules, such as hydroxide radicals. These radicals can react with organic compounds, resulting in their destruction by oxidation. The process is relatively simple: for TiO_2 to produce active free radicals, only UV light and water are required. The presence of other compounds such as oxygen or hydrogen peroxide can accelerate these reactions.

Acting in this way, TiO_2 has the ability to break down most organic compounds, including large range of micropollutants. Among these are:

- bisphenol-A, associated with breakdown of plastics
- chlorinated aromatics, derived from combustion and other sources
- prescription and over the counter drugs such as carbamazepine or ibuprofen, and
- insecticides such as terbufos.

Under ideal conditions, after oxidisation by free radicals these contaminants can be completely mineralised into small compounds such as carbon dioxide, phosphates, nitrates, and others that can then be utilised by plant life.

Barriers to on-site application of TiO_2

While the use of TiO_2 nanoparticles as photocatalysts has been studied extensively, a number of barriers exist relating to their application on a large-scale. The simplest way to use TiO_2 as a decontaminant is in a slurry suspension illuminated by submerged lamps or solar light. While this is a simple and effective approach, it requires that the nanoparticles be separated from the treated solution. As an alternative, films of TiO_2 applied to solid supports have also been explored. The most common method of achieving this coating outcome is to expose the supporting material to a slurry of TiO_2 nanoparticles, followed by a simple drying step.

A wide array of materials can be used as TiO_2 supports, including glass, steel, pebbles, and various polymers. However for the treatment of groundwater, these design options would also require a pump-and-treat system: the water would be extracted, treated, and then discharged back the watershed. For simplicity and reduced costs, a system in which supports with TiO_2-coated catalytic films can be placed into the body of water for in situ activation and treatment is ideal. Fibre-optic technology offers an approach to this desired outcome.

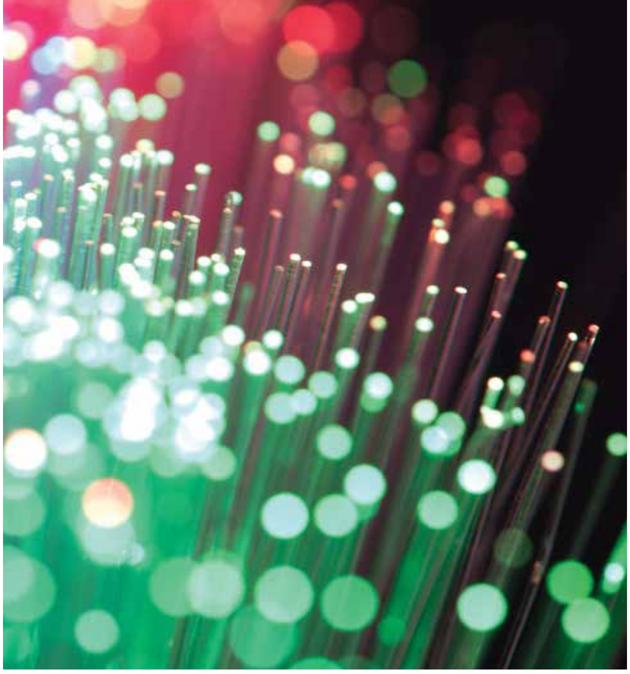
Optical fibres plus TiO_2 for in situ water treatment

An optical fibre is a specially constructed fibre made of two concentric layers: a core and a cladding. The layers are commonly made from quartz, glass and various polymers. The optical properties of these layers create conditions where light entering one end is transmitted through the fibre and emerges at the opposite end. The light is constrained in the fibre as it undergoes total internal reflection at the interface of the two layers; the fibre acts like a pipe for light.

Most of the materials currently used as layers in optical fibres are suitable as supports for TiO_2 films. Removing the outer, cladding layer on a section of the fibre and replacing it with TiO_2 prevents total internal reflection from occurring, allowing some of the light to escape. This 'leaked' light is absorbed by the TiO_2 film, and thus photocatalysis can occur.

Therefore optical fibres are an ideal tool for in situ groundwater treatment due to their ability to support films of TiO_2 and their capacity to transfer light underground.

A scheme illustrating how such a system would work in the field is illustrated in Figure 1. A bundle of fibres featuring bound TiO_2 films is placed underground in a contaminated area, with the top illuminated by solar light. Once in place the system would operate continuously with sufficient sunlight. This type of system is suitable for remote areas as it would require only a small above ground area for a solar light collector and does not require a power, water or other consumable supply.



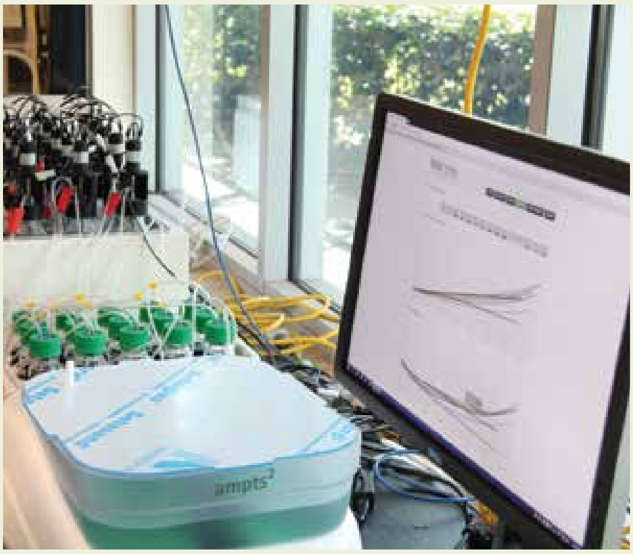
Refining the TiO_2-coated optical fibres water treatment system

While the combination of TiO_2 coatings with optical fibres is very promising as a water treatment technology, there are a number of development hurdles still to be overcome before widespread use is possible. A top priority is to create a stable, highly active coating with a long lifetime in real world conditions; this has not yet been demonstrated. Current coatings tend to undergo either chemical or physical failure, or a combination of both. This manifests as deactivation and/or detachment of the TiO_2 after a short period of use, and a fibre bundle with an impractically short lifetime.

Despite these hurdles, the use of TiO_2 coated optical fibres shows great promise for the efficient remediation of ground water contaminated by a wide array of pollutants. Once we have refined the development of highly efficient TiO_2 coated fibres, we plan to move forward by examining the capacity of the fibres to degrade real-world micropollutants in distilled water and in synthetic groundwater.

Waste to energy: cutting costs and increasing revenue

In recent years, using anaerobic digestion technology to treat organic waste – and at the same time generate energy – has become more popular. Current disposal methods, such as disposing solid waste to landfill, are usually cost intensive and do not provide any revenue to the disposer. Rising electricity and natural gas prices are also important factors driving this shift in thinking as many industries seek alternative sources of energy.



Anaerobic digestion is a well-established technology, with thousands of plants worldwide treating industrial, agricultural, livestock and food waste, as well as other organic waste.

The first step in considering an anaerobic digestion plant is to assess the biomethane potential (BMP) of the organic waste. CRC CARE now provides such a testing service for organisations seeking to cut their waste disposal costs and generate revenue through bioenergy production. Our new Swedish-made *Automated Methane Potential Testing System-II (AMPTS-II)* is used for testing biomethane potential from any organic waste material. The resultant data is then used to design of a full-scale system.

What is biogas?

Biogas comprises methane that is derived by biological activity of anaerobic bacteria on the organic matter present in waste.

CRC CARE's BMP testing

Our equipment can test biogas generation potential from any organic waste material at controlled conditions over a period of 20 to 40 days. By analysing the biogas for methane and carbon dioxide content, we determine the potential energy value of the biogas. BMP can be tested at mesophilic (around 37°C) as well as thermophilic (around 50°C) temperatures.

Why should you test BMP?

Although it is possible to estimate BMP based on available literature, the most accurate assessments are obtained when BMP is analysed from fresh samples of waste. This is because a number of factors (e.g. type of feed used for livestock, use of antibiotics, water quality) determine the quality and quantity of waste, and thus its potential for methane generation.

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BMP testing with the *AMPTS-II* provides valuable information that not only helps determine the optimal technical design of the full-scale anaerobic digester, but also its economic feasibility.

How can CRC CARE help?

CRC CARE's *AMPTS-II* can analyse the biogas potential of any organic substrate. *AMPTS-II* represents the state of the art in analytical equipment for measuring biogas at a laboratory scale. *AMPTS-II* replicates the operations of a full-scale anaerobic digester, complete with built-in mixing system, gas scrubbing and online volume measurement.

With *AMPTS-II*, CRC CARE can test the BMP of any organic waste sample, either as single substrate, or co-substrate for co-digestion. Co-digestion can often improve the quality of digestate as well as the biogas yield.

The data generated from a CRC CARE analysis forms part of an overall feasibility study, which provides the information required to for the optimal technical specifications of the full-scale anaerobic digester design.

Advantages of the *AMPTS-II* system

The major advantages of *AMPTS-II* include:

- User-friendly interface for experimental set up
- Real-time data analysis and overview
- Automatic real-time pressure and temperature compensation for volume measurement
- Fully automatic biogas measurement and data logging
- Real-time gas flow and volume normalisation
- Replica of full-scale system with temperature maintenance, mixing system, gas scrubbing and volume measurement
- Stand-alone equipment with embedded data acquisition and web server for remote access
- Able to test four samples simultaneously in triplicate
- Possible to analyse biogas production at mesophilic as well as thermophilic temperatures
- Provides valuable information for design and economic feasibility of full-scale anaerobic digestion system

Typical applications for the *AMPTS-II* system

Because any organic waste is suitable for the *AMPTS II* system, CRC CARE is able to provide BMP analysis for a comprehensive range of waste applications, including but not limited to:

- Piggeries
- Poultry farms
- Dairy farms
- Municipal solid waste
- Fruit and vegetable waste
- Wineries
- Bakeries
- Feedlot industry
- Abattoirs
- Beverages

The *AMPTS-II* system is an invaluable tool for planning the production of renewable energy – in the form of biogas – from any organic waste material.

If you are interested in cutting your waste management costs and generating revenue from renewable energy production, contact CRC CARE:

Dr Jayant Keskar,
CRC CARE Waste Program Coordinator
Ph +61 8 8302 5036 M +61 429 134 764
Email: jayant.keskar@crccare.com

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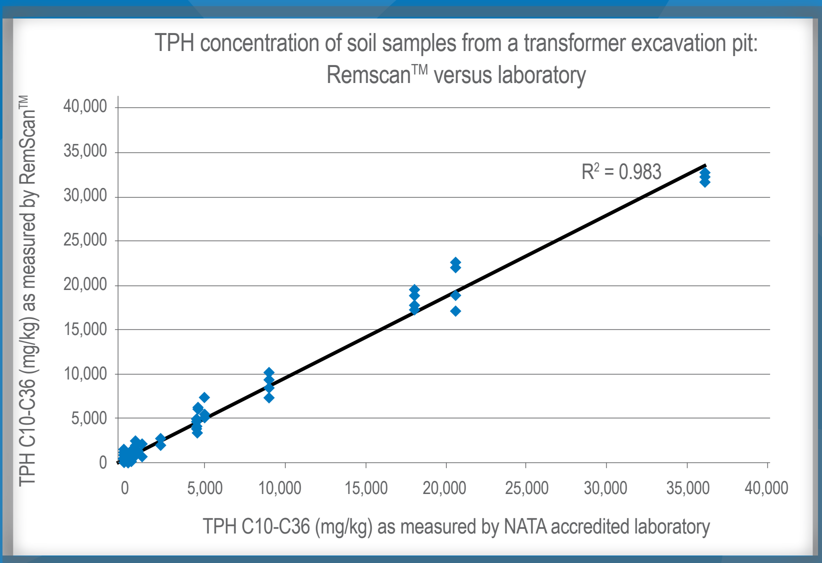

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Harmonising nanotechnology with biological processes for low-energy remediation

Ian Thompson, University of Oxford, and Sheeja Jagadevan, University of Michigan

Growing concern with climate change is driving the need for sustainable technologies with lower energy requirements that can deal with contaminants in an environmentally acceptable way. Preliminary results employing zero valent nano-scale iron generated from waste iron oxide sourced from an acid mining source are encouraging. This new approach is particularly promising for its ability to remediate of a broad range of recalcitrant metal working fluids.

By applying sufficient energy, most instances of contamination in the environment and end-of-pipe industrial effluent can be treated. In the worst-case scenarios, soils are dug up and buried, whilst highly contaminated waters from industry can be treated by employing such techniques as reverse osmosis, electrocoagulation, ultrafiltration or other techniques. However, none of these technologies are sustainable, either demanding enormous amounts of energy or leaving a legacy of contamination that has to be dealt with by the next generation. A growing concern with climate change is also driving the need for technologies with lower energy requirements that can deal with contaminants in an environmentally acceptable way.

Exploiting biological systems is an increasingly desirable option for environmental clean-up and contamination prevention, since it is sustainable, cost effective in terms of capital investment and maintenance, and flexible in respect to scale-up.

However, there are significant differences between treatment of domestic wastewaters (which are readily biodegradable) and industrial effluent which, in many cases, is intrinsically too toxic for treatment by biological systems. Consequently there have been few successful attempts by biologists to treat such problematic waters on a large scale. This has resulted, until comparatively recently at least, in the problem holders having no disposal option other than landfill with all its associated environmental hazards. There is the added problem of transportation to licensed sites, resulting in increased carbon footprint and exposure risks.

The problem with metal working fluids

Metal working fluids (MWF) double as lubricants and cooling agents in the mechanical engineering industry for cutting, drilling and grinding metal pieces. They are chemically defined and complex consisting of oil, emulsifiers, surfactants (petroleum, sulphonated, ethoxylate products), corrosion inhibitors (amines, fatty acid salts, borates), extreme pressure agents (long chain chloroalkanes, sulphur, chlorine, phosphorus) and friction reduction agents (fatty esters and amides), as well as alkaline reserve compounds (sodium hydroxide, ethanolamines).

To prevent biodeterioration of MWFs, formaldehyde-, phenolic- and chlorine-based , and other biocides are added specifically by manufacturers to extend their working life. This combination of biocides together with other chemical constituents make MWF especially toxic. Indeed they have been associated with health concerns for engineering machine workers including skin hypersensitivity, asthma and lung disease, even in extreme cases to cancer. Added to this is the volume of waste MWF produced annually: globally at least 2 billion litres of concentrate are produced which is normally diluted ten-fold for use, so adding to the volume of wastewater which has to be safely disposed of.[1]

There is increasing realisation amongst MWF manufactures that producers will have to take longer-term stewardship of their products, and that this will necessitate greater involvement in end-of-life disposal, increase the drive for more effective treatment methods, and require the design of more sustainable products.

Stricter regulation such as those imposed by the European Directive (2000/76/EC) has stimulated exploration into alternative routes for disposing of toxic recalcitrant wastes including physico-chemical methods, such as vacuum evaporation, chemical de-emulsification and ultra-filtration. However, as well as being very energy demanding, the equipment requires high capital costs and typically merely concentrates the toxic residue. Added to this, many of the physical treatment methods employed are not effective for the increasingly popular synthetic forms of MWF, which typically have components with smaller molecule size and so are not reliably treated by ultrafiltration.

A biological treatment alternative

An alternative MWF waste-management strategy is that of biological treatment. Several studies have demonstrated that aerobic microbiological treatment processes can successfully degrade most of the organic load of the waste, in many cases reducing the chemical oxygen demand (COD) from an initial concentration of 150,000 mg/L down to 2000–5000 mg/L.[2,3,4] At these final levels the discharge is classified by most local authorities and countries to be sufficiently treated for discharge to municipal water treatment or, increasingly, for the water to be re-used on site.

Typically the simpler smaller chemical constituents are rapidly metabolised by inoculated bacteria in the bioreactor-based treatments. However, larger, less bioavailable synthetic and even toxic constituents can persist and require further treatment before safe disposal. What is required are technologies and

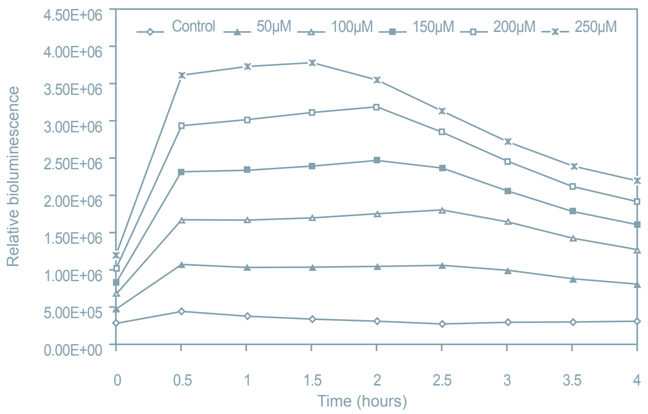

Figure 1: Quantitative response of the ADP1_recA_lux to different concentrations of H_2O_2. Mean standard deviations of triplicates are shown.

approaches which can work in harmony with microbial processes and ensure complete degradation of even the most recalcitrant MWF constituents by providing more extreme oxidative and reductive conditions which complement biological processes.

Approaches that have previously been successfully employed to achieve more vigorous treatment are advanced oxidation processes including Fenton oxidation, which centres on the generation of hydroxyl radicals from hydrogen peroxide, catalysed by ferrous ions, ultrasonic irradiation and photocatalysis. However, all have their limitations - for instance, in the case of the last-mentioned the light-quenching properties of MWF prevents activation of the catalysts.

Combining advanced oxidation methods, such as the Fenton reaction, with biodegradation has previously been successfully employed for treating recalcitrant contaminants.[5] However, until our studies little was known of how a hybrid sequential approach might be effective for sustainable treatment of MWF effluent. A key concern and focus of our studies was optimising the dose of the hydrogen peroxide required for the Fenton reaction, whilst paradoxically being incompatible with biological steps because of its toxicity.

Specifically, the peroxide oxidises cellular components including liberating all four bases from the DNA to form single strand breaks. In order to reduce this toxic effect a program of H_2O_2 concentrations optimisation was undertaken by employing the bioreporter, *Acinetobacter baylyi* ADP1_recA_lux.[6] This chromosomally based biosensor expresses bioluminescence when exposed to DNA-damaging toxicants and so acts as a proxy to the response of other microbial cells exposed to the treatment system. With this approach cells undergoing DNA damage respond by luminescing, thus providing an immediate report of genetic damage. Using this approach we investigated the impact of DNA damage on increasing the concentration of H_2O_2 from 50 to 250 mM. Not surprisingly this revealed that as the concentration of H_2O_2 increased so did *Acinetobacter baylyi*-ADP1 luminescence, which was indicative of DNA damage and reflecting the toxic nature of the reagent (Figure 1). All H_2O_2 additions investigated were found to be toxic to some extent.

Interestingly, parallel studies to determine the optimal concentrate of Fe^{+} and H_2O_2 for MWF effluent degradation revealed that in fact the most effective concentration was not the highest investigated, but was determined to be 14.92 mM of H_2O_2 and 5.62 mM of Fe^{2+}. At this optimal concentration H_2O_2 was completely utilised, as reflected by biosensor assessments. These studies demonstrated that Fenton pre-treatment of the MWF effluent greatly increased the biodegradability index of the effluent, which can be seen in Figure 4. The biodegradability index, expressed here as the ratio of the COD: Biological Oxygen Demand (BOD) after five days of incubation (BOD_5). What this means is that the Fenton's reagents had the indirect effect of altering the chemistry of the recalcitrant MWF by increasing the proportion that was biodegradable. This together with additional simultaneous lowering of the toxicity of the wastewater worked to favour a greater degree of biodegradation of constituents that were previously impervious to biological processing.

Thus an ideal treatment would be one that incorporated the benefits of the vigorous nature of the Fenton reaction for attacking and degrading recalcitrant components, whilst avoiding toxicity issues associated with the hydrogen peroxide. A potential way forward in this regard is that of Fenton oxidation with the modification of employing zero valent nano-scale iron (NSZVI).

A key feature of nano-scale reactions – which is highly relevant to our objective of reducing the toxicity of H_2O_2 – is the ability of the NSZVI to intrinsically generate reactive oxygen species and hydroxyl groups. This enables the classical Fenton reaction but obviates the requirement to add extraneous hydrogen peroxide. It also has the obvious advantages of lower cost and reducing exposure to a potentially toxic reagent.

The COD is the measure most environmental regulators use to determine treatment limits and consent for discharge to the environment. Temporal measures of the COD were made and the data (Figure 2) represents the ratio of wastewater COD to initial COD_0 (COD/COD_0). The rapid 60% v/v decrease in the COD was attributed to the in situ production of hydrogen peroxide and other oxygen species generated from the ambient air, which are collectively referred to as free reactive oxygen species (28). These are potent oxidizing agents indiscriminately degrading the majority of organics present in the MWF. The significance of the role of air in contributing oxygen is clearly illustrated when the same reaction was repeated in a nitrogen atmosphere which resulted in less than a 5% w/v decrease in terms of COD reduction.

These results stimulated further study to determine more precisely the key features of the nano-scale Fe that made it so effective at degrading MWF effluent. The role of free radicals was confirmed by testing with tert-butanol, a known hydroxyl scavenger. Subsequent observations also revealed that NSZVI was most effective at reducing the COD in more acidic conditions.

The promising nature of our work to optimise the NSZVI treatment of MWF led to scaled-up laboratory studies employing four-litre bioreactors. We tested MWF effluent encompassing a COD range from 2000 to 160,000 mg/L. Since biodegradation is the most sustainable approach, this was employed as the first stage of a sequential treatment. Previous studies had demonstrated that biodegradation-based treatment was a very effective initial step typically removing 85% to 100% of COD within the laboratory bioreactors.[7] This reflected the fact that the inoculated bacterial community is typically highly effective at mineralising the readily degradable components of the MWF, which represents the bulk of the waste. In many instances this leads to COD decreasing to legal consent levels so that they can be discharged to sewer or considered to be sufficiently decontaminated to be recycled on site.

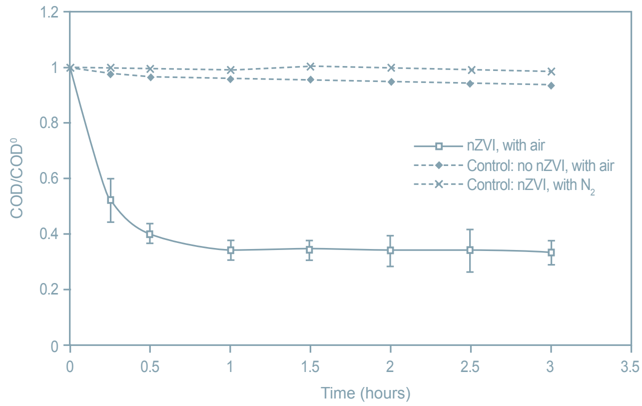

Figure 2: Reduction of COD by ZVI oxidation =(ZVI concentration-5g/L, pH=7.5) of MWF wastewaters in the presence and absence of air. Mean standard deviations of triplicates are shown.

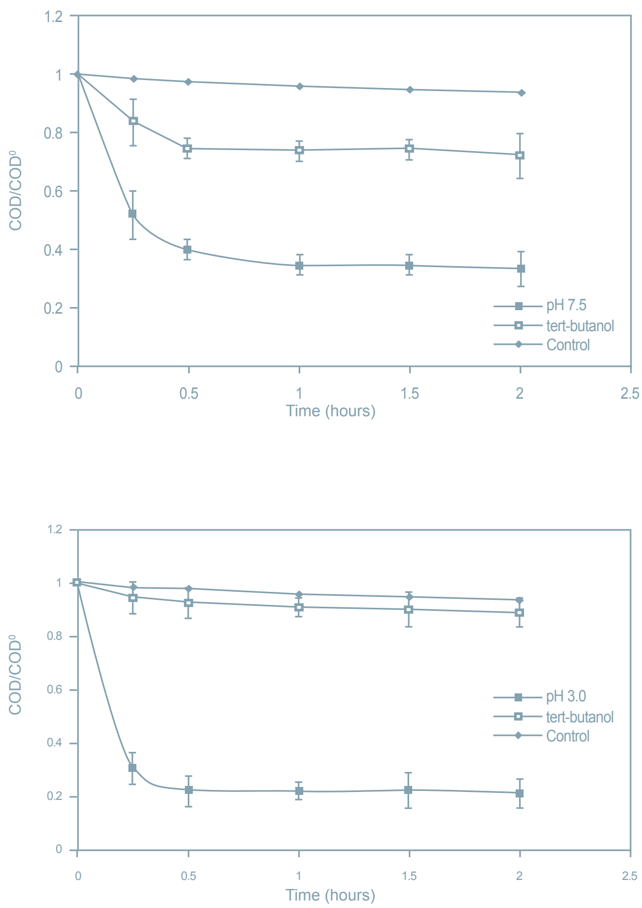

Figure 3: COD abatement by nZVI oxidation (nZVI concentration 5 g/L) in the presence and absence of tert-butanol at a. pH 7.5 and b. pH 3 respectively. Mean standard deviations of triplicates are shown.

Thus in initial trials a semi-synthetic waste was selected which had been pre-treated in established laboratory bioreactors inoculated with a suite of bacteria, selected specifically and demonstrated in previous studies to be highly effective at biodegrading waste MWF.[7] Starting at an initial effluent of 55,000 mg/L, biotreatment effectively reduced the COD load to 12,650 mg/L, a 77% decrease, with the remainder being composed of a mixture of constituents that were recalcitrant and resistant to bacterial degradation. Subsequent addition of ZVI led to a further 78% decrease (down to 2780 mg/L) and proved to be biodegradable by the same bacterial inoculum, leading to final reduction of nearly 95.5% (570 mg/L) of the total initial COD of the original, which was below normal consent limits (28).

This and other subsequent studies confirmed that a three-stage sequential treatment approach was highly effective at reducing the bulk of the MWF effluent COD load and importantly scored well in terms of sustainability.

As mentioned above, the NSZVI was most effective at reducing the COD of the MWF effluent in acidic waters (around pH 3) (Figure 3). However the treatment process neutralised the water making it more compatible with biological systems and a more appealing resource in terms of reuse.

Furthermore, the intrinsic generation of H_2O_2 avoided the risk of generating an effluent with high toxicity, resulting from persistent peroxide residues. Indeed the toxicity of NSZV-treated effluent based on the bacterial biosensor declined by 85%, again highlighting the advantage in terms of lowering risk and enhancing harmonisation with biological treatment methods.

The prospect of reprocessing spent NSZVI was investigated by collecting residual iron oxide/hydroxide precipitate after the MWF oxidation experiments, which was dried and reduced in hydrogen to enable regeneration. This was used again to treat successive batches of MWF in the same way as previously

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employed, up to three cycles. These studies revealed that the regenerated NSZVI was found to exert very similar COD reduction characteristics when compared to the performance of freshly prepared material.

Clearly the ability to recycle NSZVI as described would assist the overall economic potential of industrial-scale plants. The ability to recycle would eliminate waste and optimise material use, while only a small amount of the iron would be required. The potential of the same material to immobilise heavy metals is now being investigated.

Acknowledgement: we thank the Schlumberger Foundation for providing a Faculty for the Future Fellowship to Dr Jagadevan, and Bioresource Technology and Water Research for allowing the figures to be reproduced.

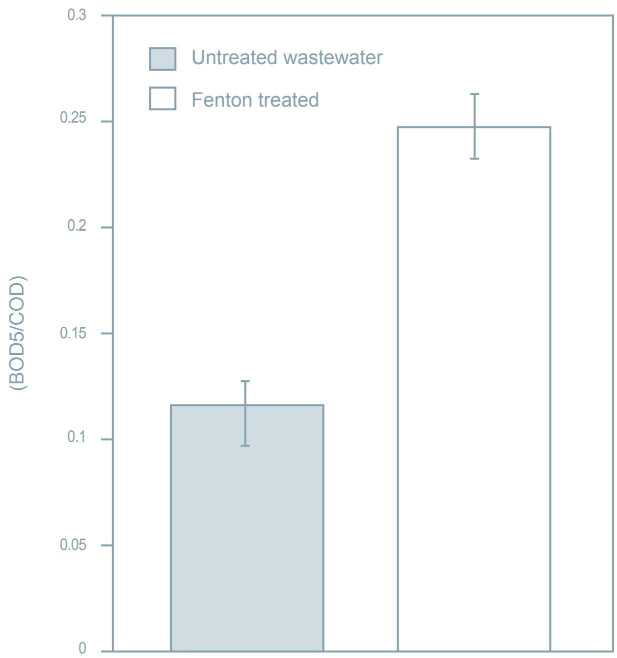

Figure 4: Biodegradability index (BOD_5/COD) of the untreated and Fenton treated MWF effluent. (Mean standard deviations of triplicates are shown).

Chemicals used in illegal drug manufacturing are often highly toxic, flammable and, in this case, explosive.

ChemCentre

Keep calm and clean up: peace of mind for communities through clan lab remediation

Yvette Leong, ChemCentre

Clandestine drug laboratories, also known as 'clan labs', are illegal operations where drugs are manufactured. Many of the chemicals involved in the manufacturing process are toxic, dangerous, highly flammable or explosive.

Clan labs themselves, and their remediation (clean up and decontamination to meet regulatory requirements), are growing issues in Australia. The number of clan labs discovered in the 2011–12 financial year across Australia was a record 809, with 70% of these found in residential areas.[1]

While locations for illegal drug manufacturing activities can be as varied as houses, motels, industrial buildings, secluded bushland and vehicles, the most common sites are rental properties.

Clan labs are now being treated as contaminated sites that pose potential health, financial and legal risks to inhabitants, property owners and managers.

Health risks of clan lab contamination

There is a growing body of evidence to show that long-term exposure to contamination from clan labs has adverse effects on human health.[2] These include throat irritation, respiratory and skin ailments, headaches and mental health problems. Children are particularly at risk.[3]

Even after drug manufacturing chemicals and equipment have been removed from a property, toxic chemicals may remain on surfaces and furnishings. Such residues include:

- illicit drugs, such as methamphetamine
- chemicals used in the manufacturing process, such as ammonia
- waste and by-products from drug manufacture.

Clan lab residues inside a dwelling may result in the property being deemed unfit for human habitation. In Western Australia, under the *Health Act 1911*, the owner of a property is obliged to ensure that any hazards are removed (including decontamination) before people can again use or live at the property.

To assess risks accurately, it is essential to determine the presence and quantity of chemical residues associated with the manufacture of illicit drugs, and to verify that clean-up operations have been successful.

Giving peace of mind to communities

Police officers and neighbours are exposed to critical safety hazards associated with clan labs. To minimise the risks, it is crucial that those involved in clean-up have strong knowledge of the relevant chemicals and their residues, as well as the often inappropriate equipment and storage vessels involved in illicit drug manufacturing.

In most Australian states, chemists – such as those working for the Western Australian government chemistry and forensic science laboratory ChemCentre – partner with police and law enforcement officials on site to detect, respond to, assess and dismantle clan labs.

Once a clan lab has been classified as a contaminated site, these chemists can work with home owners, government and regulatory agencies, and other occupational health and safety organisations to conduct follow-up analyses of the site. Such analyses ensure that the remediation has been successful and the area is safe.

It is important to assure affected communities that clan labs can be cleaned up to a level that ensures a safe area in which to live, work and play. Provided that well-trained personnel have the right tools, even very low levels of contamination can be assessed and cleaned up in a safe way.

Clan labs are being discovered in every Australian state, but the problem is a global one, affecting any place in the world where drugs are manufactured illegally.

To combat the hazards of clan labs, increased public awareness and understanding of the importance of thorough clean up must go hand in hand with greater remediation expertise and the wider availability of remediation services. Such an approach will give new occupants, as well as the community at large, peace of mind whenever a clan lab is discovered.

Hannah Crisp, chemist at ChemCentre, gets suited up for a clan lab investigation with Western Australian Police and the Department of Fire and Emergency Services.

WA Police

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RESEARCH ROUNDUP

Research roundup keeps you up to date with current research on environmental contamination assessment and remediation in Australia.

LNAPL remediation guidance

In recent years, CRC CARE has produced a series of technical reports related to the assessment, management and remediation of light non-aqueous phase liquid (LNAPL) petroleum hydrocarbons in the subsurface. These technical reports provide strategies to assess, quantify and remediate LNAPLs and the associated adsorbed, dissolved and vapour phases. Following the success of *Technical Report 18: Selecting and assessing strategies for remediating LNAPL in soils and aquifers* – which describes technologies available in the marketplace – CRC CARE is preparing a new report to provide a practical outline of how to use to these technologies in the field. Aimed at industry project managers, environmental consultants, remediation practitioners, site owners, site operators, and regulators of contaminated sites in Australia, the new report is intended to serve as a functional guide to LNAPL remediation. The guide will also form a platform for a consistent, trans-jurisdictional approach to the management of LNAPL impacts across Australia, and will overlap with the management of subsurface petroleum hydrocarbons.

Risk-based management of petroleum hydrocarbon contaminated soils

Although regulatory guidelines, such as National Environment Protection (Assessment of Site Contamination) Measure, set achievable total petroleum hydrocarbon (TPH) levels, local licensing conditions often set unrealistic goals for TPH. An example of this came with an Australian site containing a stockpile of several tonnes of petroleum-hydrocarbon-contaminated soils. The soil had been land-farmed for over 10 years, removing light hydrocarbon fractions. However, the soil had a significant amount of heavy hydrocarbon fractions (>C15). The local site licensing condition stated that the soil could not be reused unless the TPH concentration in the soil was at the background level (i.e. zero). This licensing condition is almost impossible to achieve, due to presence of recalcitrant heavy hydrocarbon fractions.

This situation provided a unique opportunity for CRC CARE to demonstrate to the relevant regulatory agency that a risk-based approach should be considered. A CRC CARE team conducted studies of leachability, bioavailability and ecotoxicity of the soil as per Organisation for Economic Co-operation and Development guidelines. The research indicated that sensitive ecotoxicity indicators, such as *Daphnia* (an algae), earthworms, grasses and microbes thrived in the soil. The research demonstrated that the soil in question do not pose a risk to ecological receptors and is therefore safe to be reused.

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Asbestos case study
CARE AWARD 2013
Innovative toxic seal-off
Issue 14 2013
Remediation Australasia
REGULATOR SPECIAL ISSUE
LARGE-SCALE RENEWAL & MORE
BIOREMEDIATION
A case study
FROM THE FRINGE
New opinion column takes aim at planning processes
Issue 13 2013
Remediation Australasia
HOW TO CLEAN UP FOR A HOSPITAL
MERCURY
How do we manage this dangerous contaminant?
NULL AND (A)VOID
Statistics in contaminated land data assessment

TRAINING & EVENTS CALENDAR 2014

May

6–8
Waste 2014

Coffs Harbour City Council/Coffs Harbour NSW
www.waste2014.impactenviro.com.au

19–22
Ninth International Conference on Remediation of Chlorinated and Recalcitrant Compounds

Battelle/Monterey, California, USA
http://battelle.org/media/battelle-conferences/

20–21
Innovating with Asia 2014

CRC Association/Perth WA
http://crca.asn.au/events/annualconference/

June

22–27
5th Congress of the International Society for Applied Phycology 2014

ISAP/Sydney
www.isap2014.com

25–27
AWA Biosolids and Source Management National Conference

Australian Water Association/Melbourne
www.awa.asn.au/bsmconference

Sepetmber

17–19
ENVIRO'14

Australian Water Association & Waste Management Association of Australia/Adelaide
www.enviroconvention.com.au

October

29–31
EcoForum 2014

ALGA/Brisbane
www.ecoforum.net.au

November

10–14
7th International Congress on Environmental Geotechnics (7ICEG)

WALDRON SMITH Management/Melbourne
www.7iceg2014.com

December

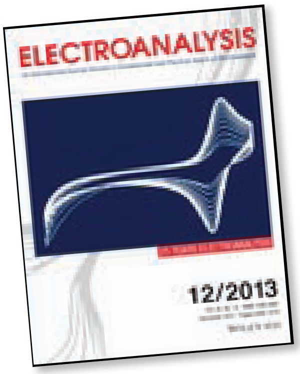
7–12
Royal Australian Chemical Institute national Congress

RACI/Adelaide
www.racicongress.com

PUBLICATIONS UPDATE

This section contains publications that have been published since the last edition of *Remediation Australasia*. The publications may originate from research institutions, regulators or industry groups. Let us know if you have any appropriate publications (no promotional material) for inclusion by emailing **victoria.leitch@crccare.com**

Du, J, Chadalavada, S, Chen, Z & Naidu, R 2014, 'Environmental remediation techniques of tributyltin contamination in soil and water: A review', *Chemical Engineering Journal*, vol. 235, pp. 141–150.

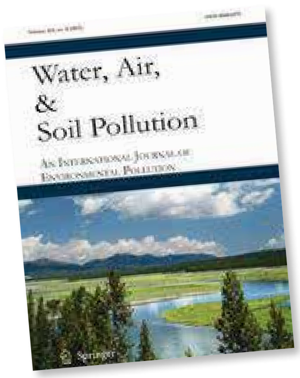


Yang, D, Wang, L, Chen, Z, Megharaj, M & Naidu, R 2013, 'Investigation of Copper(II) interface on the anodic stripping voltammetry of Lead(II) and Cadmium(II) at bismuth film electrode', *Electroanalysis,* vol. 25, iss. 12, pp. 2637–2644.

Huang, L, Weng, X, Chen, Z, Megharaj, M & Naidu, R 2014, 'Synthesis of iron-based nanoparticles using oolong tea extract for the degradation of malachite green', *Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy,* vol. 117, pp. 801–804.

Weng, X, Chen, Z, Chen, Z, Megharaj, M & Naidu, R 2014, 'Clay supported bimetallic Fe/Ni nanoparticles used for reductive degradation of amoxicillin in aqueous solution: Characterization and kinetics', *Colloids and Surfaces A: Physicochemical and Engineering Aspects,* vol. 443, pp. 404–409.

Sarkar, B, Naidu, R, Krishnamutri, GSR & Megharaj, M 2013, 'Manganese(II)-catalyzed and clay-minerals-mediated reduction of chromium(VI) by citrate', *Environmental Science and Technology,* vol. 47, iss. 23, pp. 13629–13636.



Duan, L & Naidu, R 2013, 'Effect of ionic strength and index cation on the sorption of Phenanthrene', *Water, Air, & Soil Pollution*, vol. 224, pp. 1700–1717.

Seshadri, B, Bolan, NS, Kunhikrishnan, A, Choppala, G & Naidu, R 2013, 'Effect of coal combustion products in reducing soluble phosphorus in soil II: Leaching study, *Water Air and Soil Pollution*, vol. 225, pp. 1777–1787.

Royal Australian Chemical Institute National Congress

Call for Abstracts is closing soon!

ABSTRACT SUBMISSION DEADLINE 9 MAY 2014

The RACI2014 Scientific Program Committee invites authors to submit abstracts for presentation within any of the RACI2014 symposia. Submissions are sought for oral and poster presentations at the RACI National Congress to be held from 7-12 December 2014 in Adelaide.

A stimulating scientific program is being planned with plenary lectures, abstracts and thematic poster sessions.

Please read the abstract guidelines on the website for full details including themes.
www.racicongress.com/abstracts

Confirmed Plenary Speakers

Associate Professor Alán Aspuru-Guzik, Harvard University

Professor Phil Baran, The Scripps Research Institute

Dr Stacie Canan, Global Health Division, Celgene Corporation

Professor Makoto Fujita, The University of Tokyo, Japan

Professor Hubert Girault, Ecole Polytechnique Fédérale de Lausanne

Professor Katharina Landfester, Max Planck Institute

Professor David Leigh, University of Manchester

Professor Daniel Nocera, Harvard University

Professor Greg Scholes, University of Toronto

For the full biographies of confirmed speakers to the RACI 2014 National Congress please visit the Congress website at **www.racicongress.com**

Key Dates

Call for Abstracts Opens 2 December 2013

Registration Opens 2 December 2013

Abstract Submission Deadline 9 May 2014

Notification of Acceptance of Abstract June 2014

Early Bird Registration Closes 1 August 2014

Accommodation Booking Deadline 30 September 2014

Congress Dates 7-12 December 2014

Scientific Program Themes

- Synthetic Chemistry
- Fundamental Interactions in Chemistry
- Advanced Materials
- Chemical Health and Safety
- Chemistry in Health
- Chemical Analysis and Sensing
- Community Engagement

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