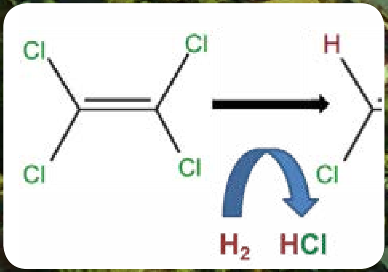
Issue 14 2013

Remediation Australasia

REGULATOR SPECIAL ISSUE

LARGE-SCALE RENEWAL & MORE

PEAKING OR PLENTY
Finding the balance of phosphorus



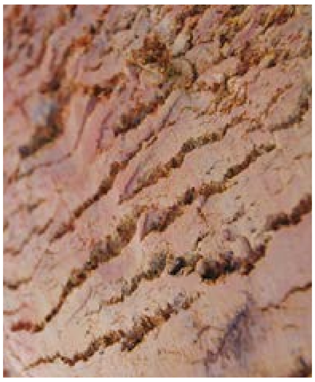
BIOREMEDIATION
A case study

FROM THE FRINGE
New opinion column takes aim at planning processes

CRC CARE

A safer, cleaner environmental future

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)

Cooperative Research Centre for Contamination Assessment and Remediation of the Environment

www.crccare.com

editor's note

Welcome to Issue 14 of *Remediation Australasia*.

This issue coincides with CleanUp 2013, the 5th International Contaminated Site Remediation Conference (www.cleanupconference.com), to be held in Melbourne, Australia, on 15-18 September. At the time of publication, CleanUp is barely two weeks away – still plenty of time to register! The program is more exciting than ever, kicking off with a series of workshops before the official launch on Sunday evening. The Monday-to-Wednesday presentation and poster sessions have something for everyone involved with contaminated sites, and the Tuesday night gala dinner will feature several awards along with world-class entertainment.

CleanUp 2013 is proud to welcome Dr Vivian Balakrishnan, Singapore Minister for the Environment and Water Resources, who will deliver the Commemorative Brian Robinson Lecture, which acknowledges the efforts of an environmental hero whose vision, ideas and leadership were a force for global sustainability. Among many other roles, Dr Robinson was the longest serving Chairman/CEO of EPA Victoria. He will forever be remembered here at CRC CARE for his exemplary work as chair of our bid for federal funding, until he resigned due to ill health in 2004. The success of this bid ensured the CRC became a reality in 2005. Sadly, Brian passed away on 1 May 2004.

It is no secret that contaminated sites provoke strong emotions from a range of people on diverse aspects – from issues of human and environmental health, to how to best remediate (or even whether remediation should be carried out at all). One of the goals of *Remediation Australasia* is to promote free and open discussion on these issues. In that light, I'm pleased to introduce the magazine's new opinion section, From the fringe (a play on a word that is commonly used in remediation circles, whether it be urban, capillary, or one of several other fringes), which invites authors to share their views on a topic of contention. Our inaugural column sets forth some strong thoughts on how development planning processes, as they relate to potential contamination, might be improved.

Issue 14 also features an Environment Protection Authority special section, with news and views from the South Australian and Victorian EPAs, as well as a European perspective from Italy's regulatory agency. We also take a look at the problem of peak phosphorus, and how this ties in with environmental pollution, feature a bioremediation case study, and serve up all of our regular sections.

I'll wrap up with a note on something to look out for in future issues of Remediation Australasia. It is widely acknowledged that one of the problems with Australasia's contaminated sites industry is the lack of any official form of accreditation for environmental consultancies and their remediation professionals. This has resulted in a varying displays of knowledge and competence – not all of it satisfactory – as well as an overly diverse range of views on how assessment and clean up should be approached. With that in mind, CRC CARE is working towards a national accreditation scheme for consultants. Once launched, this will establish a benchmark for consulting industry, ensuring that anybody charged with the important role of cleaning up contaminated sites will adhere to rigorous, nationally consistent standards of best practice to promote service excellence. These standards will: ensure a high level of consultant competency; assure end-users; and establish training resources to enhance consultants' professional development. This promises to be a major step forward for an industry that has for too long evolved faster than the standards that it should be compelled to meet.

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

Errata: *Remediation Australasia* wishes to let readers know that the following text was omitted in the article *Soil vapour intrusion into homes: a case study*, published in Issue 12 (pages 20–23):

Disclaimer: This article is a modified version of the public health report:
Evans *et al.* 2010, 'Vapour intrusion in suburban dwellings', *Public Health Bulletin SA* 7(1), pp. 48–52 (www.health.sa.gov.au/pehs/publications/PublicHealthBulletin1-pehs-sahealth-100407.pdf). More information can be found in the further reading list at the end of the article.

Low-resolution versions of some of the article's images were also mistakenly published. These errors have been corrected in the online version of Issue 12 (bit.ly/1eWqasf).

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every issue

Your guide to environmental contamination and remediation issues in the media

reMEDIAtion

New government documents on impact assessments and waste

Designed to provide guidance on administering assessments, the newly released *Environmental Impact Assessment Client Service Charter* is now available from the Department of Sustainability, Environment, Water, Population and Communities charter website (bit.ly/122Cd0P). DSEWPaC intends for the Charter to promote more transparency in environmental impact assessments, and help streamline the assessment process by allowing greater collaboration between the Department and relevant parties.

The newly released *Hazardous Waste Data Assessment* document – available from the DSEWPaC website (bit.ly/12jc1m2) – contains up-to-date data on the volumes of hazardous waste created in Australia. Comprising two sections, a data assessment and a summary report, the Assessment is designed to support the Australian Government in its collaboration with states and territories to reduce the amount of hazardous waste and improve waste-recovery procedures. ■

NPI 2011-12 dataset released

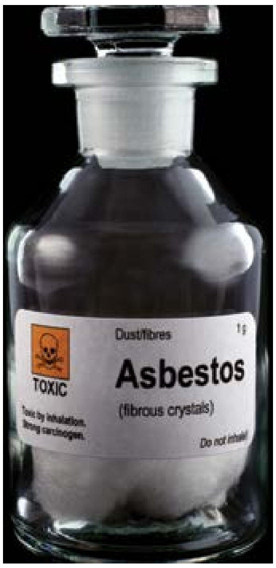
The annual pollutant data for 2011-12 has been released on the National Pollutant Inventory website – npi.gov.au. The site, which has a comprehensive search feature, contains fact sheets and information for students, teachers and the public. ■

Koala code for remediation success

In study published in the *Journal of Applied Ecology*, researchers have shown that the return of flora does not necessarily indicate the return of fauna in mine site rehabilitation projects. Using the Australian favourite, the koala, as a model, the study has shown that the return of flora to a level endorsed by government does not have any correlation to the levels of animal re-entry and habitation in the area. The study suggests that both flora and fauna should be used as criteria to better represent a true ecosystem restoration. Read the full article at bit.ly/14kjpxk. ■

A halt on underground gas

The Queensland underground coal gasification (UCG) industry has been told that it must have the ability to safely decommission UCG sites before such facilities can be opened. UCG is the process by which coal is converted to gases and liquids *in situ* via controlled partial combustion. Although the scientific review panel saw potential for UCG, Queensland Minister for Natural Resources and Mines Andrew Cripps has said, "like all emerging industries, the UCG industry must demonstrate it can be conducted in a manner that is environmentally safe, and that it can adequately co-exist with other resource activities." The scientific assessment and final report can be downloaded from bit.ly/1dgFuyV. ■



Asbestos woes slow NBN roll-out

Potential exposure to asbestos in up to 1.5 million Telstra pits has caused controversy in the recent stages of the National Broadband Network (NBN) roll-out, with Telstra facing a possible $50 million remediation bill, according to a June report in the *Daily Telegraph* (bit.ly/13iqFuP). With safety of NBN contractors in mind, work on some areas of the roll-out has been delayed. However, *The Australian* (bit.ly/18paWdx) reports that subcontractors in Western Australia and their branch of the Communication Workers Union are considering legal action against Telstra after going without pay for 12 weeks because of associated work stoppages. ■

Letter to *Remediation Australasia*

Hello Professor Bolan,

I read with interest your article in the CRC CARE Issue 9 of 2012 [Green cap for contaminated land: Transforming landfills and mine dumps into usable land], *describing your use of the giant reed plant for phytocapping applications.*

MEA (Measurement Engineering Australia) is an old established Adelaide-based measurement engineering company, and over the years we have done some interesting work on the phytocapping project at the Wollert Landfill in Melbourne, looking at water movement.

My own doctorate (Adelaide University – Civil and Environmental Engineering, 2009) was on the measurement of very slow flows in nature, including the percolation rate of rainfall through the landscape.

Our special strengths as a company are in soil moisture and climate measurements, with new work on plant-based sensors to monitor water stress and solar-powered radio networks to move data via the Internet.

All the best with your work,
Andrew Skinner
Engineering Director
MEA

P.S. Arundo donax *looks exactly like a 'bamboo' grown by myself and many old Italian gardeners for use as tomato stakes. Could it be?*

Professor Bolan responds:

Arundo donax could well be the 'bamboo' you mention. When attending a conference in Italy in 2011, I recall seeing *Arundo* growing along the railway track and in backyard gardens as a wind breaker. ■

Contaminated oysters lead to law review

The Mercury reports that gastroenteritis caused by eating contaminated Tasmanian oysters – linked to a leaking sewerage pipe – has led the state's Environment Protection Authority (EPA) to revisit waste laws for Tasmanian waters. It confirmed that although the laws are complex and hold exceptions, discharge of sewage is not allowed in state waters. EPA director Alex Schaap is confident that this rule, when monitored properly, is adequate to protect swimmers and marine flora and fauna. ■

Polluted waters on the nose for fish

Fish in polluted waters are losing their sense of smell, according to a news report in *Scientific American* (bit.ly/1478nh1). The disruption to their olfactory system may affect their ability to find food or a mate – ultimately putting species at risk. Researchers from the University of Lethbridge have shown however, that if the water in their habitats is remediated, their sense of smell returns. ■

Home buyers getting more than they bargained for

A loophole in NSW real estate legislation is allowing houses to be sold or rented without disclosing the previous use of the house as clandestine drug laboratories, according to a report in the *Herald Sun* (bit.ly/15Yo73w). This practice could be exposing hundreds of unwitting residents to chemicals more harmful to humans than asbestos. ■

Court throws out mining lead-poisoning case

The ABC reported in June the findings of a peer-reviewed study that asserted that Xstrata mining operations, not natural deposits, were to blame for elevated blood-lead levels in Mt Isa children (bit.ly/11XOQxh). The study's author, Macquarie University's Professor Mark Taylor, raised concerns about the yearly average emission model employed by the lead-in-air guidelines, stating that "it doesn't take into account short-term emissions across the town." However, in July the *Courier Mail* reported that the Supreme Court struck out the pleadings of lawyers acting on behalf of Sharlene Body, the mother of Sidney Body, who recorded high blood-lead levels (bit.ly/14Mbje7). Justice David Boddice found that the case failed to show a definite link between mining and the elevated lead levels. ■

Contaminated sites management in Italy: the state of the art and unresolved issues

Laura D'Aprile, Italian National Institute for Environmental Protection and Research (ISPRA), Rome, Italy

A *Remediation Australasia* special report investigates the state of contaminated site management in Italy, and how it fits in with the remainder of Europe.

Contaminated sites management is a major environmental problem in most European countries.

In 2011-12, the European Soil Data Centre of the European Commission (EC) conducted a project to collect data on contaminated sites from national institutions in Europe using the European Environment Information and Observation Network for soil (EIONET-SOIL).

According to these data,[1] Europe is estimated to have more than 2.5 million potentially contaminated sites and around 342,000 identified contaminated sites. Municipal and industrial wastes represent the largest contribution to soil contamination (38%), followed by the industrial/commercial sector (34%). Mineral oil and heavy metals are the main contaminants, representing around 60% of soil contamination. The management of contaminated sites in Europe is estimated to cost around 6 billion Euros (AUD$8.9 billion at time of printing) annually.

Soil contamination is one of the soil threats covered by the Soil Framework Directive proposal[2] that sets out common principles for soil protection across Europe. Contamination is one of the most controversial parts of the directive, and at the March 2010 Environment Council a minority of Member States blocked further progress due mainly to reasons related to respecting subsidiarity principle (decentralisation of decision-making), and the proposal remains on the Council's table.

The lack of a common European regulatory framework leads to the application of different criteria and procedures for the identification and management of contaminated sites across Europe. There are two key consequences of this lack of a common view on management of contaminated sites:

- different levels of human health and/or environment protection in different Member States
- different criteria for the identification of remediation priorities, leading in some cases to market distortions.

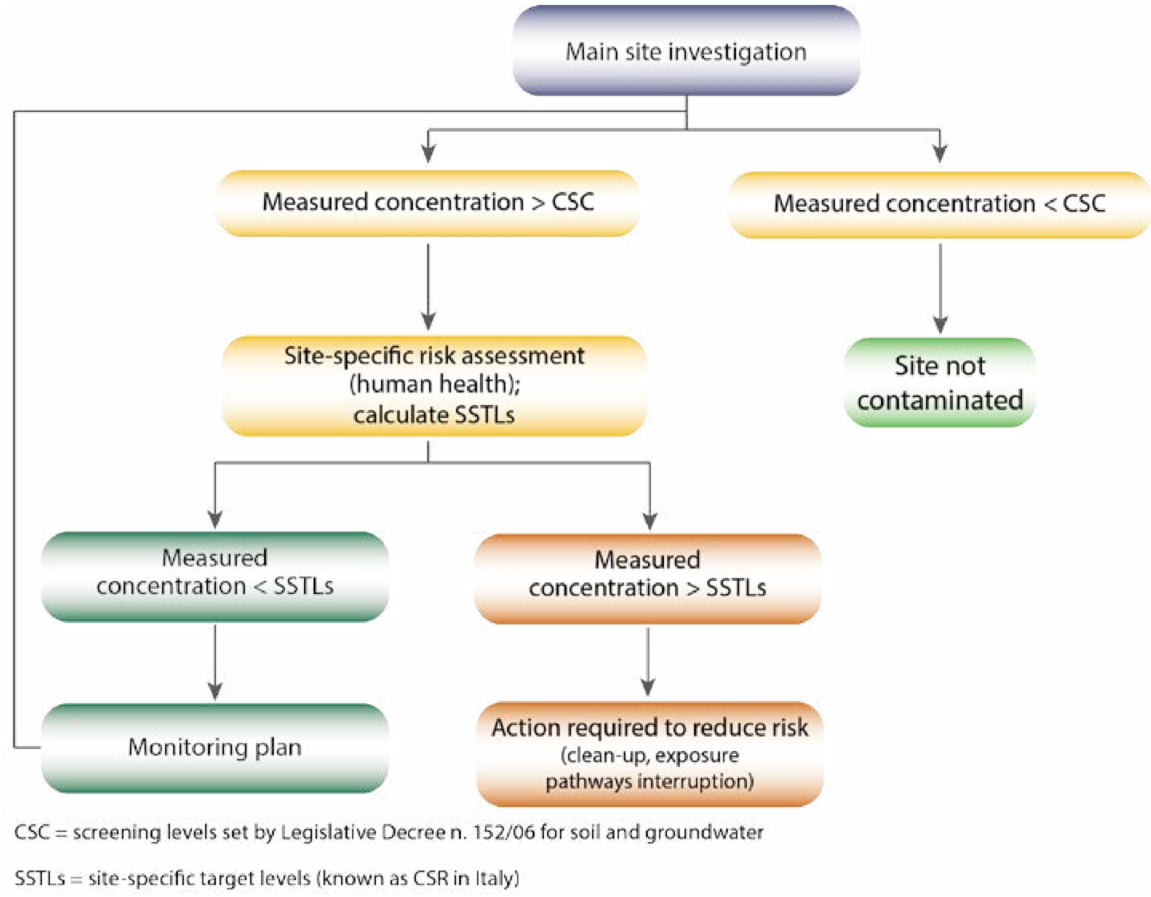


Figure 1: Procedure for the management of contaminated sites according to Legislative Decree n.152/06 and subsequent revisions.

Managing contaminated sites in Italy: regulatory and technical tools

In Italy, the first regulatory act dealing with contaminated sites management was issued in 1986 (Law n. 349 regarding high environmental risk areas). Following this law, many other regulatory acts dealt with the identification and funding of site remediation priorities, but the first *ad hoc* technical regulation on contaminated sites can be identified in the decree of the Ministry of the Environment n. 471 issued in 1999.

The key points of this technical regulation include:

- definition of contaminated site as a site in which fixed-limit values for soil and groundwater are exceeded
- development of limit values for soil (residential and commercial/industrial use) and groundwater (drinkable use)
- definition of technical procedures and criteria for investigation and remediation of contaminated soil and groundwater
- definition of regional inventories of contaminated sites
- definition of the National Priority List sites.

After some years of application of the 1999 decree, in 2006 the regulatory framework for the management of contaminated sites was radically changed. The approach moved from a 'limit value criterion' to a risk-based approach.

The Framework Environmental Legislation issued in 2006 (Legislative Decree n. 152/06) provides in its Title V, subsequently revised and integrated through many regulatory acts, the indications for the management of contaminated sites in Italy. The procedure applied is summarised in Figure 1.

Human-health site-specific risk assessment is required following the main investigation of the site if the screening levels for soil, subsoil (according to the use of the site) and groundwater set by Legislative Decree n. 152/06 are exceeded. The site-specific risk-assessment is applied to derive site-specific target levels (SSTLs), called CSR (*concentrazioni soglia di rischio*, or risk threshold concentrations). If the CSR are exceeded, the site is considered contaminated and further action is needed to clean up the site and/or to interrupt exposure pathways.

It is worth mentioning that this approach is in accordance with the procedure proposed by the EC in the Soil Framework Directive (COM (2006), 232, EC) that is now under discussion at European Union (EU)

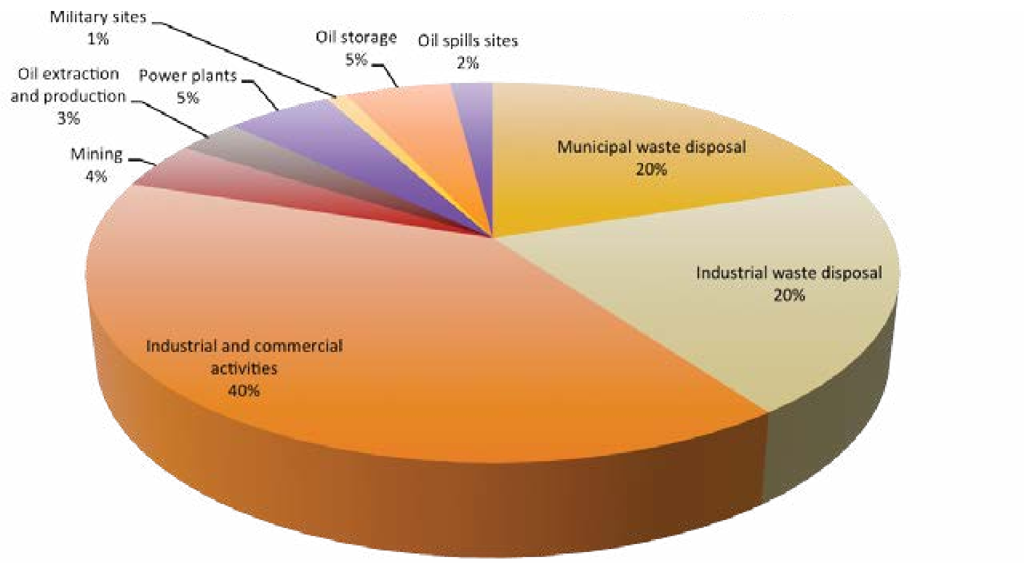


Figure 2: Contribution of different human activities to soil contamination (%).[4]

level. Article 10.1 of the text proposed by the EC states:

> *Member States shall (…), identify the sites in their national territory where there is a confirmed presence, caused by man, of dangerous substances of such a level that Member States consider they pose a significant risk to human health or the environment, hereinafter 'contaminated sites'. That risk shall be evaluated taking into account current and approved future use of the land.*

The Italian Ministry of the Environment is responsible for managing the remediation activities of National Priority List Sites, and to do this it receives technical support from the National Institute for Environmental Protection and Research (ISPRA). In cooperation with the National Health Institute, the National Institute for Prevention and Safety at Work, and the Regional Environmental Protection Agencies (ARPA/APPA), in 2005 ISPRA developed the national guidelines for the application of human-health risk assessment at contaminated sites. The guidelines, *Criteri metodologici per l'applicazione dell'analisi assoluta di rischio ai siti contaminate* (Criteria and methodology for the application of risk assessment at contaminated sites), were updated in 2006 (revision 1) by adding the procedure for the development of SSTLs. The latest revision of the guidelines was published on March 2008 (revision 2).[3] All the documents are available in Italian on the ISPRA website (www.isprambiente.it).

The developed procedure follows the tiered ASTM risk-based corrective action approach and sets the following human health target values according to the indications of the National Health Institute:

- acceptable value for the individual (one contaminant, one or more exposure pathways) carcinogenic risk: 10^{-6} (i.e. we can accept that one in a million of the exposed population can be affected by cancer due to environmental contamination)
- acceptable value for the cumulative (many contaminants, one or more exposure pathways) carcinogenic risk: 10^{-5}
- acceptable value for individual and cumulative risk for non-carcinogenic substances: 1.

Groundwater risk is calculated by comparing the concentrations at the point of compliance (the location where an enforcement limit should be measured and must not be exceeded) calculated by ASTM-RBCA Fate and Transport equations with fixed groundwater values developed for drinkable use.

There are a number of additional technical tools for the risk-based management of contaminated sites:

- RiskNet, dedicated software implementing ISPRA guidelines, available since 2012 (developed by the University of Rome and tested by Reconnet network, see www.reconnet.net for further details)
- a database of chemical, physical and toxicological parameters developed by the National Health Institute and National Institute for Worker Safety in 2005 and now under revision
- technical protocols for the selection and validation of site-specific parameters to be used as input values in risk assessment
- specific guidelines for soil-gas measurement and use of soil-gas values in risk assessment (ongoing work).

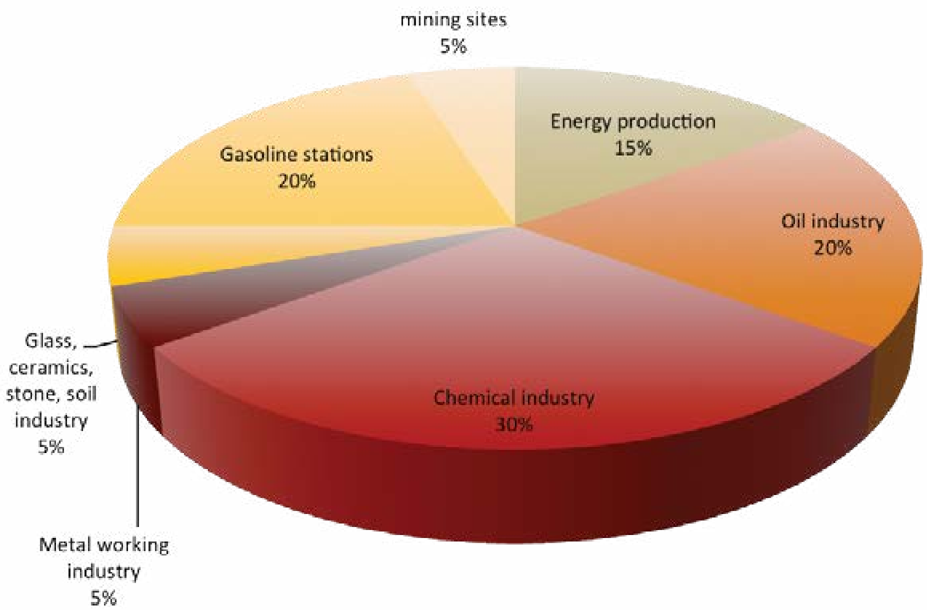


Figure 3: Contribution of different industrial sectors to soil contamination (%).[4]

The size of the problem and the work done: data collected by ISPRA

According to the data collected from the regional focal points by ISPRA and published in the 2012 Environmental Yearbook,[4] Italy is estimated to have 15,131 potentially contaminated sites, 6027 sites at which screening levels (CSC, see Figure 1) were exceeded, and 4837 sites defined as contaminated according to the regulatory definition (i.e. risk-based clean-up levels exceeded). The yearbook listed 3088 remediated sites (1300 located in Lombardia region, with very few remediated sites in the southern regions).

Regarding the origin and type of contamination, some interesting data and information were collected by ISPRA for the EIONET-SOIL project on contaminated sites management progress in the EU. The results of this exercise are shown in Figures 2, 3 and 4.[4]

The contribution to local soil contamination is due mainly to industrial and commercial activities and industrial/municipal waste disposal. Industrial activities are the main source of soil contamination in the northern part of Italy, while legal and illegal waste management is the main concern in the southern regions.

The industrial sectors that make the largest contribution to soil contamination are the chemical and oil industries and petrol stations.

The main contaminants in both solid and liquid matrix are heavy metals and hydrocarbons (aromatic, chlorinated, polycyclic aromatic). The presence of high concentrations of heavy metals in soil and groundwater is, in many cases, due to the geochemical background. High concentrations of arsenic, beryllium, manganese and iron were found at many sites owing to specific geological conditions (e.g. volcanic soils).

Where to from here?

In recent years Europe has seen major advances made in the management of contaminated sites. In Italy, both regulatory and technical tools have been developed to provide regional authorities with homogeneous criteria and assure the same level of protection of human health and the environment.

Despite this, several issues remain unresolved:

- As mentioned in the previous paragraphs, current Italian regulation on contaminated sites management requires risk assessment to evaluate human health risk. However, poor communication of these risks to the general public often generates confusion and sometimes panic.
- The ASTM-RBCA Tier II approach can be empowered by improving the significance of the data. The use of bioavailability and speciation data for heavy metals contamination can significantly reduce the uncertainty of the model application, but standard procedures must be developed. In this sense, it is very important for different countries to share scientific and practical knowledge.
- Vapour intrusion is a major problem at contaminated sites and is frequently overestimated by using the ASTM-RBCA equations. We can 'adjust' the model by using biodegradation and/or the results of direct measurements of soil-gas and indoor/outdoor air. However, since direct measurements can

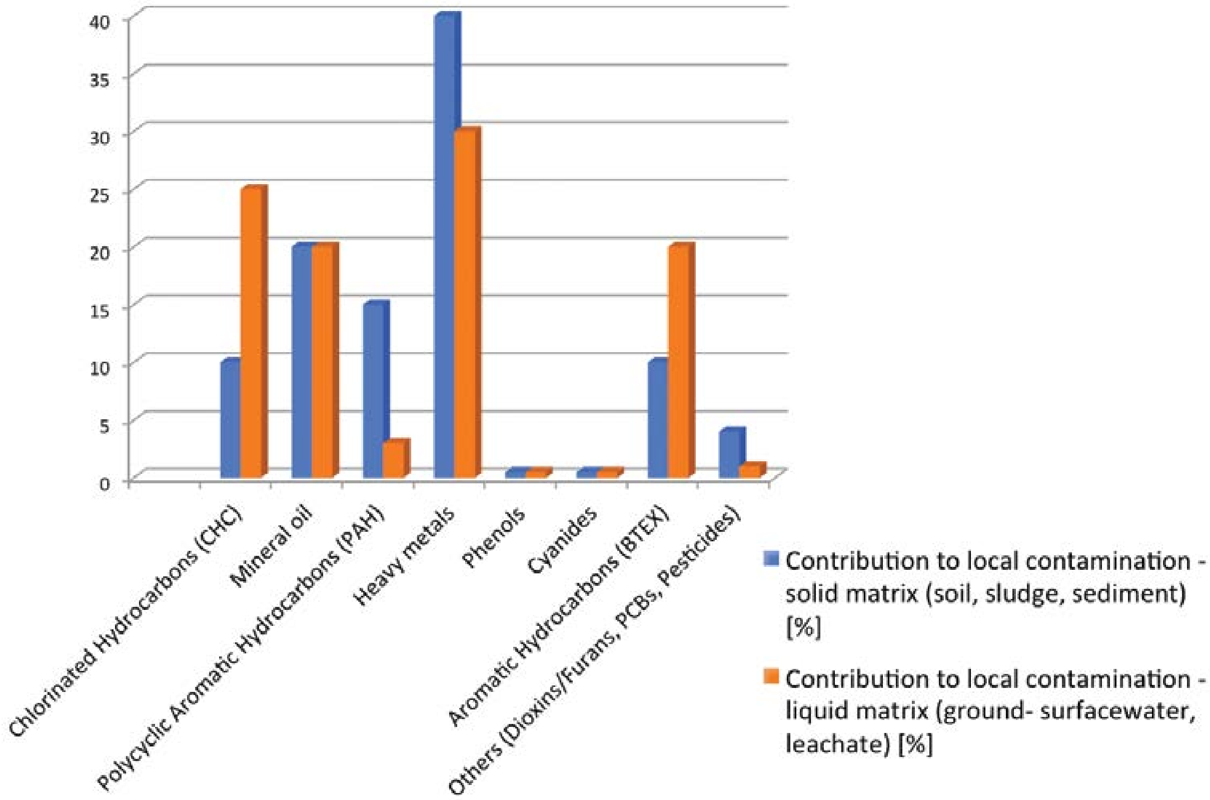


Figure 4: Main contaminants for soil and groundwater.[4]

be confusing and it can be difficult to identify the source, we must analyse multiple lines of evidence.

- Some parts of the risk assessment procedure should be harmonised. The same procedure applied in different EU countries could lead to different results because different physical, chemical and toxicological parameters are used.
- In Italy, risk assessment application to groundwater at contaminated sites must be integrated with EU Water Framework Directive objectives in order to avoid costly and unsuccessful remediation actions.
- Contaminated site issues are strictly related to industrial development and economics: a common EU regulatory framework would be welcome.
- The international scientific knowledge of risk assessment is solid but some aspects (not involving 'political' issues) should be harmonised at least at EU level (e.g. much work must be done on sharing chemical, physical and toxicological parameters).
- Available studies and research activities on bioavailability, metal speciation and vapour intrusion should be readily shared in order to establish a common framework. A national position is more solid if supported by others ('the more we, the stronger we are').

In conclusion, strong and scientifically sound communication planning is the only way to convince the general population (and politicians!) that remedial action is effective in protecting human health and the environment.

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1. Panagos, P, Van Liedekerke, M, Yigini, Y & Montanarella, L 2013, 'Contaminated Sites in Europe: Review of the Current Situation Based on Data Collected through a European Network', *Journal of Environmental and Public Health*, vol. 2013, Article ID 158764, 11 pages, http://dx.doi.org/10.1155/2013/158764
2. COM 232 2006, EC Proposal for a Directive of the European Parliament and of the Council establishing a framework for the protection of soil and amending Directive 2004/35/EC.
3. ISPRA 2008, *Criteri metodologici per l'applicazione dell'analisi assoluta di rischio ai siti contaminati*, www.isprambiente.it.
4. ISPRA 2012, *2013 Environmental Year Databook*, www.isprambiente.it.

ASC NEPM amendment implementation

Recent changes to the Assessment of site contamination national environmental protection measure (ASC NEPM) – by way of an amending instrument – took effect on 16 May 2013. As part of the amended process all original ASC NEPM schedules have been repealed and substituted with the relevant new schedules.

The ASC NEPM is available for download at www.scew.gov.au/nepms/assessment-of-site-contamination.html.

Responsibility for the implementation of the amended ASC NEPM lies with each individual jurisdiction.

Transition arrangements

- Arrangements for the implementation and transition of the amended ASC NEPM vary from state to state.
- Details of the transition arrangements are available at www.scew.gov.au/node/939.
- A 12-month transition period has been agreed to in principle for all states and territories.
- During this 12-month period, work considered to be substantially progressed may be submitted as per the original 1999 ASC NEPM.
- By the end of this 12-month period – on 16 May 2014 – all ASC reports must be consistent with the amended NEPM.

Resources to assist the transition

It is important that you seek information and clarification for any factors regarding the implementation of the amended ASC NEPM during this 12-month period. The following resources are recommended:

- your local EPA
- NEPM workshop presentations, available from CRC CARE (www.crccare.com/education/training/nepm/nepm_training.html)
- NEPM workshop DVD, available from CRC CARE
- where appropriate, your own legal advice.

REGULATOR SPECIAL

EPA SA's vision for the future

Dr Campbell Gemmell, Chief Executive, Environment Protection Authority South Australia

Dr Campbell Gemmell
Photo: EPA SA

When Dr Campbell Gemmell arrived in South Australia 18 months ago to take up his appointment as the Chief Executive of the Environment Protection Authority (EPA), the environmental regulator was under heightened media and community scrutiny of its management of site contamination notifications and investigations.

In fact, within the first 100 days in his new position, the former Scottish EPA Chief Executive appeared before a parliamentary inquiry into the EPA and site contamination, to provide the EPA SA's closing statement and update the inquiry panel on improvements to the Authority's processes and communications.

Community concerns about soil and groundwater contamination have been considerably allayed over the past two years, with much greater transparency and public access to site contamination information via the EPA website and more active media engagement.

Some progress has also been made on assessing the hundreds of historical government records relating to potential site contamination prior to the establishment of the EPA in1995. Site owners now take a much more public role in investigating and managing contamination cases.

But Dr Gemmell has a vision for further reforms and improvements to the management of site contamination in South Australia: a holistic approach that provides consistency and cohesiveness, and delivers better environmental, social and economic benefits.

On my arrival in South Australia I was not at all surprised to find that, like all industrialised regions throughout the world, the state faces significant legacy issues with regard to site contamination associated with past activities such as gasworks, service stations, drycleaners, former EPA licensed sites and closed landfills.

Fortunately, the foundation for the management of site contamination in South Australia is solid, with world class legislation in place. But there are also numerous opportunities for reforms and improvements in planning, information management, remediation, waste management and community engagement that can make good systems better and place South Australia at the forefront as a long-term leader in the field of site contamination management.

Planning

There are strong links between contaminated land, contaminated groundwater, waste and resource management, health, planning and economic development. The EPA is very keen to play a positive and solutions-focussed role in progressing these linkages and objectives in the common interests of South Australia. The time is ripe to begin strategically to tackle our legacy and make real progress.

A recent internal review of the EPA's scope and role in the state's planning and development system has identified site contamination and how it fits within the planning system as an issue requiring improvement.

Planning authorities have an important role in managing the objects of the Development Act 1993 but there is confusion about their role in the assessment of site contamination and the appropriate processes. Currently, the only guidance for planning authorities regarding site contamination is Planning Advisory Notice 20 provided by the Department of Planning, Transport and Infrastructure (DPTI). This advisory guideline is out of date, confusing and often not used.

The EPA needs to be much more involved in the planning process and getting in early to make sure that contamination issues are appropriately considered by those who are dealing with developments.

It is also important to recognise that site contamination is a significant health and environmental problem which requires the use of site contamination auditors and consultants with the appropriate technical expertise. The assessment and remediation of contamination can be lengthy and costly depending on the issues at a site and the nature of the proposed development.

The EPA is working with DPTI to integrate site contamination into the planning system in a way that is consistent and clear to all planning authorities. Ideally, this will include:

- Timely, appropriate and consistent consideration of site contamination, particularly through the rezoning and development application stages
- Recognising the National Environment Protection Measure (NEPM) process for the assessment of site contamination
- Integrating the audit system – which is designed to assist planning authorities and government in managing their liability, and to ensure the community can rely on redeveloped land being suitable for residential use – and the South Australian planning system.
- Clarification of site contamination criteria for use by planning authorities and site contamination consultants
- Changes to the Development Regulations to support the framework developed
- Building capacity of development proponents, planning authorities and site contamination consultants
- The sharing of site contamination and historical licence data to allow the Development Assessment Commission to view the information held by the EPA and inform its decision making.

This way we can ensure that South Australian land is fit for its intended purpose – providing confidence to effectively deliver the state's urban development agenda.

Assessment and information management

It is estimated that there are approximately 4000 contaminated sites in South Australia,[1] the vast majority located in the greater Adelaide area. The EPA database holds records for approximately 1450 sites, some of which have been appropriately remediated. In comparison, EPA Victoria has 8000 sites on record and estimates there are 10,000 contaminated sites in Victoria.[1]

Since the requirement for site contamination of groundwater to be reported to the EPA came into effect in July 2009, there have been approximately 402 notifications. In addition, there are approximately 950 historic files from the former SA Health Commission and Waste Management Commission that require assessment.

This information, in the form of consultancy reports and notifications, must be methodically assessed to determine the validity, risk and urgency. This is essential to establish if land and groundwater is fit for its intended or current purpose, particularly for new residential and other sensitiveuse development. Furthermore, proactive assessment of these known potentially contaminated sites needs to be available to the development sector, the community and the government, allowing remediation costs to be better managed or avoided in the future.

The EPA's ability to focus on managing, assessing and sharing this large volume of historical information already in its possession will mitigate risk and liability to developers and reduce the regulatory liability to the EPA.

Remediation

Remediation is a costly exercise but, when undertaken proactively and appropriately, allows previously contaminated land to be confidently used for public and social benefit. The new Royal Adelaide Hospital site (featured in *Remediation Australasia* Issue 13) is a good example.

The remediation of contaminated land overseen by the EPA provides confidence that potential impacts of contamination on residents and workers are appropriately considered and minimised. It also allows precious land close to the CBD, such as the Bowden Urban Village development, to be made available for more people to live closer to the city.

South Australia would also benefit from the establishment of an assessment and remediation fund to deal with sites that pose a high risk and are (or are likely to become) the responsibility of the government. We can look to experiences in the United States (the US EPA Superfund) the United Kingdom (land remediation tax relief)and the European Union (remediation funds and integrated use of landfill tax, enterprise zones and collaborative development mechanisms) to see how differing models operate effectively.

Waste management

Best practice management of site contamination also critically connects to how we manage, recycle or reuse, and ultimately dispose of waste materials, including contaminated soils. This requires a strong remediation and soil resource recovery industry that adopts leading-edge technologies and methods.

South Australia's waste management, recycling and resource recovery agenda – led by Zero Waste SA – is progressing and, importantly, identifies soil, waste and water remediation technologies as key waste-industry capabilities to be developed and supported. This is essential, particularly for better management of soil storage and remediation systems, and ensures that only the materials that qualify for higher-costing special handling or remediation receive this treatment and, wherever possible, materials are re-used. The *EPA Standard for the Production and Use of Waste Derived Fill* (under the auspices of the *South Australian Waste to Resources Environment Protection Policy 2010*) provides the rules for everyone to follow.

Public-sector developers and project managers are in a position to lead the way with a commitment to sustainable procurement practices that seek to optimise reuse of materials that are fit for purpose and do not compromise the environment or human health.

Updated national guidelines

Progress in achieving a nationally harmonised system to assess, manage and remediate site contamination has been significant, with the recently amended *National Environment Protection (Assessment of Site Contamination) Measure 1999* (NEPM). The NEPM now provides an updated nationally consistent approach for the assessment of site contamination to ensure sound environmental management practices are adopted by the community, including regulators, site assessors, site contamination consultants, auditors, landowners, developers and industry parties.

A state strategy for the nationally agreed 12-month implementation of the amended NEPM has been developed by the EPA. The strategy includes the review of existing guidance and a process to have the amended NEPM made into an environment protection policy under the Environment Protection Act 1993 (available at bit.ly/17uPLo0) at the end of the 12-month national transition period.

We have already commenced a process of reviewing existing guidance to ensure appropriate integration and consistency with the amended NEPM and we will consult with stakeholders to provide comments on revised or new guidelines as they are developed.

Community and stakeholder engagement

The community's right to know about site contamination that has the potential to compromise public health and safety is fundamental. The EPA's recent reforms in proactive community and stakeholder communications have taken great steps forward.

The EPA's Public Register is a statutory obligation to make prescribed environmental information and documents available to the public. What became very apparent to the EPA was that this predominantly paper-based information needed to be made more transparent and accessible to the public. And so began a long-term project to make this information more accessible via the EPA website.

Excavation of contaminated soil as part of the Brompton Redevelopment project (2006). *Photo: EPA SA*

Groundwater contamination notifications (Section 83A of the *Environment Protection Act 1993*) were the first set of documents to be indexed and searchable online. These were followed by environmental authorisations (licences), enforcement actions, environment protection orders and site contamination audit notifications, terminations and reports. Copies of these documents can be obtained, free of charge, upon request to the EPA.

Our aim now is to take this further by enhancing the search capabilities of the website to make it even easier for property owners and residents to locate information about site contamination in their neighbourhood with features such as clickable maps to complement suburb and postcode searches.

Informing the public of significant site contamination investigations has also been improved with the implementation of public communication protocols that clearly set out how and with whom we will communicate, to ensure that all stakeholders are appropriately informed according to the level of risk and impact. Site owners are also now playing a more active role in stakeholder communications and engagement, taking greater ownership of the issue and recognising the importance of being responsible corporate citizens.

Future improvements to communications and engagement include further use of digital communications and social media to reach audiences who have turned away from traditional mainstream media (newspapers, television and radio).

The EPA is also engaging with key stakeholders including site contamination auditors and our interstate counterparts. We are conducting a series of sessions with auditors to look at the audit system and identify opportunities for improvement. Our partnership with CRC CARE at the policy, operational and technical levels is highly valued and presents a great opportunity for us given our shared interests. We also value ongoing discussions with EPA Victoria and New South Wales EPA aimed at sharing experiences and knowledge in dealing with legacy and environmental challenges.

Getting there

Like all jurisdictions in the industrialised world, we are grappling with the challenges of site contamination and the limited nature of financial resources. *The EPA's Strategic Plan 2012-15* identifies the challenges of legacy issues, increasing urban infrastructure development and renewal, and inappropriate or illegal management of wastes and resource recovery. We will get there by pursuing our strategic priorities of robust regulation, sound science, partnerships and engagement and being an adaptive organisation.

We have embarked on an organisational change program to ensure that our people and systems are geared to be an effective, modern environmental regulator. This will see us:

- implementing the updated national guidelines for collaborative, national harmonisation
- influencing planning and government strategy at an early stage to ensure appropriate management of contaminated sites
- supporting the site contamination auditing system with the necessary guidance and training
- regulating and supporting best practice waste management to make the most of resource recovery and reuse
- progressively improving access to site contamination information
- engaging and partnering with industry and professional sectors and other stakeholders at all stages of planning, managing, remediating and developing contaminated sites.

The EPA is keen to play a positive, solutions-focused role in a holistic approach to the management of site contamination in South Australia. Working together with government, industry, environment practitioners and the community we will achieve smarter, better and more timely outcomes for everyone and the environment. This matters – for our economy, our communities and our environment.

REFERENCE

1. Natusch 1997 in *Accounting for Contaminated Sites: How Transparent are Australian Companies?* (from Ji & Deegan 2011, *Australian Accounting Review 57* vol. 21 Issue 2)

Precinct-scale urban renewal – challenges and opportunities

Mitzi Bolton, Janine Dridan, Laura-lee Innes, Anne Northway, Sean Shiels and Barry Warwick (EPA Victoria), and Ravi Naidu, Bruce Kennedy and Prashant Srivastava (CRC CARE)

Large-scale urban renewal projects are inherently complex, and involve accordingly complex contamination issues. Overcoming the attendant challenges will require new frameworks for managing contaminated environments.

Melbourne, seen here from the air, is experiencing large-scale, inner-city urban renewal, such as that occurring at Fisherman's Bend. *Photo: iStockphoto/David Iliff*

In Victoria the demand for affordable housing supply is driving the redevelopment of underutilised urban land for residential, commercial and recreational purposes. This has led the Victorian Government to rezone 240 hectares of underutilised land close to Melbourne's CBD as the start of the Fishermans Bend Urban Renewal Area (FBURA) Project. This is the largest inner-city rezoning in Australian history.

The FBURA urban renewal project, and others like it, offer multiple advantages from a social, economic and environmental perspective, including: rejuvenation and use of unproductive land; increasing the density of urban environments; reducing transportation impacts; reducing pressure to develop land on city fringes; and enhancing lifestyle and job opportunities. Unfortunately, a long history of industrial activity at many of these sites means that land and groundwater are often contaminated and have the potential to harm human health and the environment. Thus while the redevelopment or reuse of such sites (often defined as 'brownfields' sites) may be challenging and complicated by the presence of hazardous substances and contaminants, their clean-up improves and protects the environment and may result in many benefits for the local community.

Large-scale urban renewal projects inevitably raise complex contamination issues. Accordingly, such projects challenge the abilities of existing frameworks for managing contaminated environments to deal with this complexity. Recent reviews of the Victorian framework for managing contaminated environments have highlighted gaps and inefficiencies in the current approach, resulting in increased delays and costs to development projects. In response to these and other issues, Environment Protection Authority (EPA) Victoria is implementing its Contaminated Environments Strategy to improve the way it operates and interacts within the current framework. In addition, EPA Victoria is working closely with the Department of Environment and Primary Industries and the Department of Transport, Planning and Local Infrastructure to establish the strategic policy framework for managing contaminated environments, including precinct-scale remediation projects such as Fishermans Bend (for which the Cooperative Research Centre for Contamination Assessment and Remediation of the Environment – CRC CARE – is providing assistance).

EPA Victoria has identified three aspects of a strategic framework for managing precinct-scale remediation projects that need further exploration:

1. setting remediation end points or goals
2. providing the framework to make complex remediation decisions
3. engaging multiple stakeholders with sometimes opposing ideas on remediation goals.

These challenges are not new or unique to the remediation sector, and EPA Victoria does not claim to have the perfect solution. In reality they cannot be addressed by any single organisation operating in isolation. The primary goal of this article is to bring attention to the challenges and opportunities with the hope that it will stimulate further discussion and collaboration within the contaminated environment remediation sector and help identify practical solutions.

Setting remediation goals and planning

At the highest level it is important to be clear about the goals of remediation. This may seem like a simple issue to address but it is inherently complex and often

Construction on the Yarra River in Melbourne.

informed by values which are not necessarily based on science or economics. People's values are defined by what they care about, which is invariably subjective. Nevertheless, it is imperative when embarking on precinct-scale remediation projects that the principles and end points of remediation are clear and well understood by all stakeholders. A lack of clarity at this stage of a project can be amplified at later stages and result in uncertainty and inconsistency in decision making, with the accompanying delays and costs. At worst, contamination problems may remain unresolved even after investing significant time and resources.

Thus, establishing remediation goals also helps the project team to determine the decisions that need to be made throughout the project – these are fundamental to the selection of appropriate technologies for site assessment, risk characterisation and clean up. Failing to establish remediation goals may also substantially increase time and cost, given that the absence of clear goals necessitates that conservative assumptions should be applied at every stage of the project.

It is critical, for example, to understand whether the goal of remediation is to restore the environment for a defined beneficial use or to reduce unacceptable risks – in other words, is the goal to remove risk or to manage it? The implication of adopting one over the other is significant and has repercussions in what is expected of remediators. Both end goals have advantages and disadvantages. Setting a beneficial use as the end goal provides certainty and clarity on the remediation target but inherently places less weight on cost and off-site impacts such as energy use. On the other hand, a risk-based approach takes account of cost and off-site impacts but can be perceived as a compromise that provides less certainty in the long term.

This touches on perhaps one of the most debated aspects within the remediation sector: how much remediation is needed? Many argue that the level of remediation is site dependent, and sits within a narrow boundary, as too much or too little clean-up are both suboptimal. Given this variability, the final outcome would seem to be the result of a sound decision-making procedure that takes account of local conditions as opposed to a pre-defined specified target to be met. So how then do we design a process that allows us to determine the level of remediation required? This ultimately leads to the consideration of the design and application of decision frameworks.

Understanding regulations and establishing decision frameworks

The investigation and clean-up of former industrial sites for redevelopment may be subject to a variety of state legislation and policies, and local government requirements. It is therefore important to be familiar with this information at the outset, and to work closely with the regulatory authorities throughout the site assessment and clean-up process.

Decision frameworks are used to address the difficulties that decision makers have in handling large amounts of complex information in a consistent way. Precinct-scale remediation projects present numerous challenges and opportunities for decision makers since they often consider larger areas (usually with numerous pollution types and sources), a greater number and combination of remediation technologies, and the number and breadth of stakeholders interested in the decision.

Upscaling traditional approaches to the management of contaminated environments for precinct-scale projects has not proven to be effective, partly owing to the need for the existing framework to be reformed in some areas, but also due to the added complexity that comes with precinct-scale remediation. Indeed, recent research commissioned by EPA Victoria has failed to identify comparable multi-site-owner remediation projects in other Australian jurisdictions, although limited case examples are available overseas.

The principles of modern regulation suggest that remediation should be risk-based, outcome-focused and cost-effective. To achieve this we need decision frameworks to structure decision making, yet provide sufficient flexibility, transparency and robustness for stakeholders to respect decision outcomes. These challenges are greater at the precinct scale of remediation, but this scale also provides opportunities to drive innovation and creativity in the techniques and technologies used for remediation, and thus may ultimately achieve better environmental outcomes.

Such frameworks should have an adequate scope, ensuring the consideration of a wide range of competing objectives. They should allow the application and integration of a range of decision support tools – such as risk assessment, economic appraisals, and a wide range of environmental assessment tools – and must explicitly manage uncertainty. There would also be great merit in reviewing existing decision frameworks to identify characteristics that would be important in precinct-scale remediation decision making.

Engaging stakeholders

The challenges faced in designing and applying industry, academia, government and community stakeholder engagement programs for land remediation are exacerbated when operating at a precinct level of development. Simply put, this is because more of the government, industry and community are affected by precinct-level development, with redevelopment of multiple sites (often with multiple owners), and contamination of land or groundwater cutting across multiple site boundaries. Nevertheless, successful stakeholder involvement is a key component of effective decision making and the level of engagement should, at the very least, be proportionate to the risk posed by the contaminated site. The National Environment Protection Measure (1999 amended 2013) provides some guidance on engaging community stakeholders.

A key challenge, given the scale of precinct remediation, is that redevelopment of land across a precinct may occur over very different time scales, as the timing of investments in remediation will often be very different across a precinct even if the remediation required is the same. These timing differences may result in situations where new residents co-exist with clean-up or industrial activities in other parts of the precinct for lengthy periods of time. Residents need information on possible health risks and necessary precautions for living with contaminants over the life of the project. Persistence and a range of strategies are required to ensure that the messages reach as many people as possible. This can be difficult in large developments and over long time frames during which residents move in and out of the precinct.

Given that some residents may not have English as a first language, information must be translated and interpreted. Where one-on-one communication is not practical, demographic data may be used to present information in the likely languages. There are other sectors of the community that will also require efforts tailored to enable them to be informed and to participate in decision making. Another key challenge, not unique to but definitely complicated by precinct-level development, centres around who should bear the costs of remediation, and how these costs are fairly and transparently determined and allocated among those stakeholders.

Thus, decisions need to be made on how stakeholder involvement is governed and managed. This should: identify and engage stakeholders; define those phases of decision making in which an increased involvement of stakeholders might be useful; and clarify the extent to which stakeholders can influence decisions on alternatives and the identification of preferred solutions. Intergenerational equity is difficult because future generations cannot participate in decisions made by the current generation. Novel approaches will need to be developed to address this.

Conclusion

The challenges involved in precinct–wide remediation are significant and cannot be addressed in isolation; they require sector-wide involvement and collaboration among all stakeholders.

The National Remediation Framework being developed through CRC CARE also offers significant opportunities to consider these matters.

The 5th International Contaminated Site Remediation Conference (CleanUp 2013), to be held in Melbourne in September 2013, includes a session dedicated to urban renewal. This session offers an opportunity for the remediation community to come together and focus on these and other challenges that we share. EPA Victoria is keen to identify examples of practical solutions to these challenges from within Australia and internationally.

Navigating a low-level contaminated site through the planning approval process

Mark Gardiner, Business Development Director, Qattro, and executive member, Urban Development Institute of Australia (South Australia).

This column – the first in *Remediation Australasia's* new opinion section, From the fringe – takes a slightly tongue-in-cheek look at the processes to gain development planning consent, and the impact of these on the property developer or investor.

To start with: the title of this piece could easily have seen 'low' replaced with 'no', as we shall see as the story unfolds. Second: to protect the innocent, and even the not-so-innocent, the names of people, places and organisations have been changed to keep the main players anonymous – not so they can continue on this path but so we all might learn a better way ahead. Thus, what may seem like a pessimistic story will end on a note of hope for better outcomes in the near future.

It was a steamy hot day in the inner western suburbs of Adelaide as a developer began to negotiate through the vendor's agent for the purchase of a now closed commercial site (let's call it a former pot centre). The developer took advice from a fairly well-established urban infill company, which advised that a contract be drawn up with a reasonable due diligence period to enable enquiries to be made as to previous use.

The council advised that a site history report should be sought and thus a contract was drawn up after lengthy negotiation with a vendor who assumed that this process to gain planning approval could not take more than a few months. A contract was drawn up and a six-week due diligence period commenced during which a site history report was completed (cost $2500). The information on previous use prompted council to ask for soil testing. The contract was signed subject to the dwelling approval, but with a backstop date, to be fair to both the vendor and the purchaser, and as suggested by the urban infill developer.

Another six weeks passed and another invoice for $11,500 was produced. This report showed that a small amount of ash existed in two areas that would be taken care of when setting the site level and confirmed the already known fact that the development plan contains a map of known subsurface water-table contamination by trichloroethene (TCE). From here it really does start to get irritating for all concerned. This area of potential groundwater contamination is so well known that it already has its own map in the development plan – you might think that a couple of steps could have been leapfrogged, instead of starting from scratch.

We move along to groundwater testing – another six weeks and $18,000. The cost is high because the developer is required to determine the depth at which contamination begins and must use equipment that can bore down to 30 metres. Despite this, the TCE was found at 6 metres, though this wasn' thought to be a problem, given there was no intention to draw bore water and the vast majority of the site will have a 1-metre concrete slab and parking for a three-storey apartment building between the ground and the occupants. Naïve thoughts indeed.

Now we must ask why the council planner would not take the word of a comprehensive written report that cost an arm and a leg. At this time, we also note that all backstop dates for planning conditions with the vendor have expired and the purchaser must back his development instinct and go unconditional after only a slight price adjustment to claw back some of the impending costs. The planner wants an Environment Protection Authority (EPA)-licensed auditor to check the work of the well-qualified, highly regarded environmental consultant who wrote the report that states that the land is fit for residential use. And we should remember that this consultant has liability insurance.

Now, Liability. This is the word that leaps to the top of the pile from this point on. We now have an environmental consultant who is willing to put his reputation on the line and even proffer to council a legal document stating that there is no legislation in the development plan that compels an audit. Despite this, and despite the EPA having qualified planning staff willing and able to give an opinion, council decides that only way to satisfy themselves legally is via an audit request. (Refreshingly, a level-headed auditor told me recently that he would be happy to meet with the EPA once a month to sign off such low-level sites.)

It is quite possible that planning consent would never have been obtained if it wasn't for the tenacity of the developers, who insisted that the contamination could be reserved as a matter to be dealt with prior to development approval. Consent was provided as long as the developer had an 'interim advice' letter from an EPA-licensed auditor. In the best part of the process so far, this was obtained – for only $550 – and consent was granted.

At this stage the developer still hoped council would allow the consultant to provide his own reference report and liability. It was a courageous, but ultimately futile attempt; council made planning consent conditional either on an audit. Alternatively, the consultant could issue a legal letter to which council would respond at the cost of thousands of dollars of taxpayers' money.


Artist's impression of the final product (when permission is finally granted to build). *Photo: Qattro*

The obvious idea would be to appoint the level-headed EPA-licensed auditor to get on with it, as by now everybody is punch-drunk from the whole process. But…it turns out that the auditor, having written the interim advice letter, had precluded himself from being recognised independent – despite being familiar with the report and thus the most economic choice.

Now, I don't want to cast too many aspersions but, at the risk of treading on a toe or two, I will take the hit for the development industry and state that some auditors have given the game a bad name. Fact. Not pretty to read, but fact. This can be seen in what transpired next.

Three EPA-licensed auditors offered three vastly different quotes, none of which were fixed. Fee generation is open to a lot of conjecture and for now I will leave it at that. The cheapest quote was $22,000 to read the consultant's report – a report for which the consultant charged $14,000 to write.

As the audit nears its end and all parties limp towards the – rather obvious – conclusion of 'don't go near the groundwater' and 'fit for residential use', the tally comes to 27 weeks of reports plus about 8 weeks of wrangling, all the negotiating in between, and some $54,500 in costs (plus time), on top of holding costs of around $6750 per month for the developer. This last figure reminds me of a certain MP who asked the question, "but isn't this all just the cost of doing business", to which the answer is, "only if you make it so".

In other words the red tape has simply increased the cost of affordable housing. It has put this developer off venturing his private capital into this industry again. It has made it ever more difficult to provide affordable housing, because, like every other cost, it will be passed on to the end user.

So what have we learned? Well, for one, education of urban planners is paramount. It is not their fault. How can we ask them to take responsibility? We must find better ways to resolve these issues, with public safety paramount. Planners need direction, not guidance, from the EPA, and I believe that EPA South Australia, at least, is moving in that direction.

I can hear some of you issuing forth with some cynicism, but if Adelaide is to become a vibrant city, less reliant on high-carbon-footprint commutes, then we must approach with foresight the issues of low-level potentially contaminated sites. If we fail to do this, huge swathes of suburban mixed-use zones will remain fallow, unable to contribute to quality affordable housing in the way that they should.

Postscript: the auditor has requested a further test to check direction of the flow of the water at 6 metres below… the developer continues to spend, argue and resign themselves to further delays in development approval.

Opinions expressed in *From the fringe* are not necessarily those of *Remediation Australasia.*

Case Study

Enhanced anaerobic bioremediation using a non-emulsified vegetable oil blend

Pamela J Dugan and Sean Davenport, Carus Corporation;
David Barker and John Hesemann, Burns & McDonnell

Enhanced anaerobic reductive dechlorination with non-emulsified and emulsified vegetable oils has been implemented at thousands of commercial and military field sites globally. The wide variety of compounds that can be anaerobically biodegraded using vegetable oils includes chlorinated ethenes, chlorinated ethanes, halomethanes, perchlorate, nitrate, certain metals, and explosives.[1]

In practice, the organic substrate amendments are initially fermented to yield molecular hydrogen (H_2) and low-molecular-weight fatty acids such as acetate, lactate, propionate, and butyrate. The short-chain low-molecular-weight fatty acids then provide carbon and energy to the microorganisms, which in turn facilitate reductive dechlorination. During reductive dechlorination, the parent chlorinated ethene – for example perchloroethene (PCE) – is sequentially dechlorinated whereby a chlorine atom is removed and replaced with a hydrogen atom to form the less-chlorinated daughter products trichloroethene (TCE), 1,2-*cis*-dichloroethene (cDCE) and vinyl chloride (VC). When this process goes to completion, ethene is ultimately formed as the non-toxic end product (Figure 1).

During reductive dechlorination of chlorinated volatile organic compounds (CVOCs), the CVOCs serve as the electron acceptor and the H_2 from vegetable oil fermentation serves as the electron donor. Dechlorinating bacteria in the subsurface catalyse the sequential reactions, deriving energy in a process called dehalorespiration. For reductive dechlorination of CVOCs to proceed, sufficient hydrogen must be generated to meet the stoichiometric demand of target compounds (PCE, TCE and daughter products) and non-target species (e.g. other electron acceptors) in the subsurface. The amount of substrate required to support contaminant biodegradation and meet the stoichiometric demand of the target compounds can be affected by elevated levels of competing electron acceptors (e.g. oxygen, nitrate, manganese, iron) and needs to be accounted for to ensure effective dechlorination.

At many sites, abundant electron acceptors can limit the availability of hydrogen to support contaminant biodegradation. Therefore, substrates

<table>
<tr><th>Bioremediation product</th><th>Chemical formula</th><th>Monitoring well</th><th colspan="3">Percent composition (% by weight)[1]</th><th>H_2 (mol) per substrate (mol)[2]</th><th>H_2 (g) per substrate (mol)</th><th>H_2 (g) per substrate (g)</th><th colspan="2">H_2 (g) per product (g)[3]</th><th>H_2 (g) per product (kg)[3]</th><th>H_2 (g) per product (lb)[3]</th></tr>
<tr><td></td><td>-</td><td>grams/mol</td><td>Substrate</td><td>Emulsifier</td><td>Water</td><td>-</td><td>-</td><td>-</td><td colspan="2">-</td><td></td><td></td></tr>
<tr><td>Ethyl lactate</td><td>$C_5H_{10}O_3$</td><td>118.2</td><td>98</td><td>-</td><td>2</td><td>12</td><td>24.24</td><td>0.21</td><td colspan="2">0.20</td><td>201.06</td><td>91.22</td></tr>
<tr><td>Sodium lactate</td><td>$NaC_3H_5O_3$</td><td>112.1</td><td>60</td><td>-</td><td>40</td><td>6</td><td>12.12</td><td>0.11</td><td colspan="2">0.06</td><td>64.89</td><td>29.44</td></tr>
<tr><td>Ethanol</td><td>C_2H_6O</td><td>46.1</td><td>80</td><td>-</td><td>20</td><td>6</td><td>12.12</td><td>0.26</td><td colspan="2">0.21</td><td>210.42</td><td>95.47</td></tr>
<tr><td>Molasses</td><td>$C_{12}H_{22}O_{11}$</td><td>42.3</td><td>60</td><td>-</td><td>40</td><td>24</td><td>48.48</td><td>0.14</td><td colspan="2">0.08</td><td>84.97</td><td>38.55</td></tr>
<tr><td>Glycerol</td><td>$C_3H_8O_3$</td><td>92.1</td><td>75</td><td>-</td><td>-</td><td>7</td><td>14.14</td><td>0.15</td><td colspan="2">0.12</td><td>115.13</td><td>52.24</td></tr>
<tr><td>CAP 18® Anaerobic Bioremediation Product</td><td>Proprietary blend</td><td>~280</td><td>100</td><td>-</td><td>0</td><td>50</td><td>101</td><td>0.36</td><td colspan="2">0.36</td><td>360.07</td><td>163.37</td></tr>
<tr><td>Emulsified vegetable oil (60%)</td><td>$C_{18}H_{32}O_2$</td><td>280.5</td><td>60</td><td>10</td><td>30</td><td>50</td><td>101</td><td>0.36</td><td colspan="2">0.22</td><td>216.04</td><td>98.02</td></tr>
<tr><td>Emulsified vegetable oil (40%)</td><td>$C_{18}H_{32}O_2$</td><td>280.5</td><td>40</td><td>10</td><td>50</td><td>50</td><td>101</td><td>0.36</td><td colspan="2">0.14</td><td>144.03</td><td>65.35</td></tr>
<tr><td>Emulsified vegetable oil (35%) +</td><td>$C_{18}H_{32}O_2$</td><td>280.5</td><td>35</td><td rowspan="2">10</td><td rowspan="2">20</td><td>50</td><td>101</td><td>0.36</td><td>0.13</td><td rowspan="2">0.20</td><td rowspan="2">197.83</td><td rowspan="2">89.76</td></tr>
<tr><td>ethyl lactate (35%)</td><td>$C_5H_{10}O_3$</td><td>118.2</td><td>35</td><td>12</td><td>24.24</td><td>0.21</td><td>0.07</td></tr>
</table>

1 General formulations for competitor bioremediation products
2 Calculated from the reaction of substrate and water to bicarbonate, hydrogen ion and hydrogen gas
3 Calculated from % composition (by weight)

Ethyl lactate

$C_5H_{10}O_3+12H_2O \rightarrow 12H_2+5HCO_3^-+5H^+$

Sodium lactate

$NaC_3H_5O_3+6H_2O \rightarrow 6H_2+3HCO_3^-+Na^++2H^+$

Ethanol

$C_2H_6O+5H_2O \rightarrow 6H_2+2HCO_3^-+2H^+$

Molasses

$C_{12}H_{22}O_{11}+25H_2O \rightarrow 24H_2+12HCO_3^-+12H^+$

Glycerol

$C_3H_8O_3+6H_2O \rightarrow 7H_2+3HCO_3^-+3H^+$

Soybean oil (linoleic acid):

$C_{18}H_{32}O_2+52H_2O \rightarrow 50H_2+18HCO_3^-+18H^+$

Table 1: Hydrogen yield of bioremediation substrates.

that release higher hydrogen yields over extended periods of time are more favourable. As a way to compare the different products, fermentation reactions can be written as if the substrate is metabolised to bicarbonate, hydrogen cation and dihydrogen gas. Table 1 shows the theoretical hydrogen yield for a variety of bioremediation amendments on a molar and mass basis.

Case study using a non-emulsified vegetable oil blend: CAP 18® Anaerobic Bioremediation Product

Burns & McDonnell was selected by the Kansas Department of Health and Environment (KDHE) to perform environmental services for the former Cinderella Cleaners and Stickel Cleaners facilities located in Manhattan, Kansas, and listed under the State of Kansas Dry Cleaning Facility Release Trust Fund program. Historical chlorinated solvent releases associated with dry cleaning activities from these two facilities have been identified and characterised at the site and the primary contaminants of concern are PCE, TCE, cDCE and VC. Baseline groundwater sampling conducted prior to groundwater remediation in July 2009 showed maximum contaminant concentrations in groundwater as follows: PCE 11,000 µg/L, TCE 1770 µg/L, cDCE 700 µg/L, and VC 957 µg/L. The comingled contaminant plume extends approximately 1200 m east-northeast of the site towards the City of Manhattan public water supply wells #12 and #13. Seepage velocity was used in electron donor (CAP 18) dosage calculations with the estimated velocity ranges for the individual aquifer depth intervals as follows:

- 6-7.6 m bgs (below ground surface): 5.2 m/year
- 10.7-13.7 m bgs: 29.6 m/year
- 13.7-18.3 m bgs: 69.2 m/year

At the request of KDHE, Burns & McDonnell designed an innovative approach to remediate the groundwater contamination near the source area and reduce migration of the contaminant plume down-gradient of the site. In 2009, a Corrective Action Plan was prepared and an enhanced anaerobic biodegradation (EAB) groundwater treatment was successfully implemented. CAP 18, a non-emulsified vegeta ble oil blend, was selected as the electron donor substrate due to its compatibility with high groundwater seepage velocities, low cost, and extended longevity and reactivity in the subsurface. EAB treatment at the site consisted of the injection of a non-emulsified vegetable oil substrate, which creates an anaerobic environment in the aquifer. The

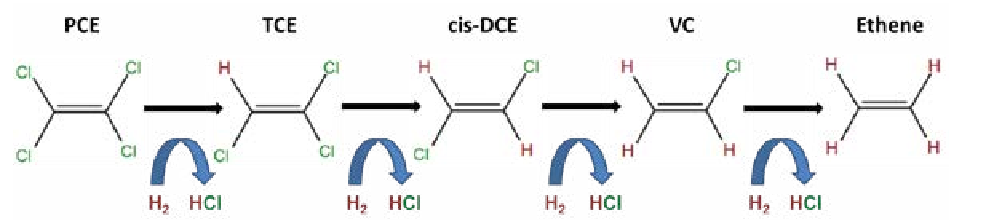

Figure 1: Biological reductive dechlorination of PCE.

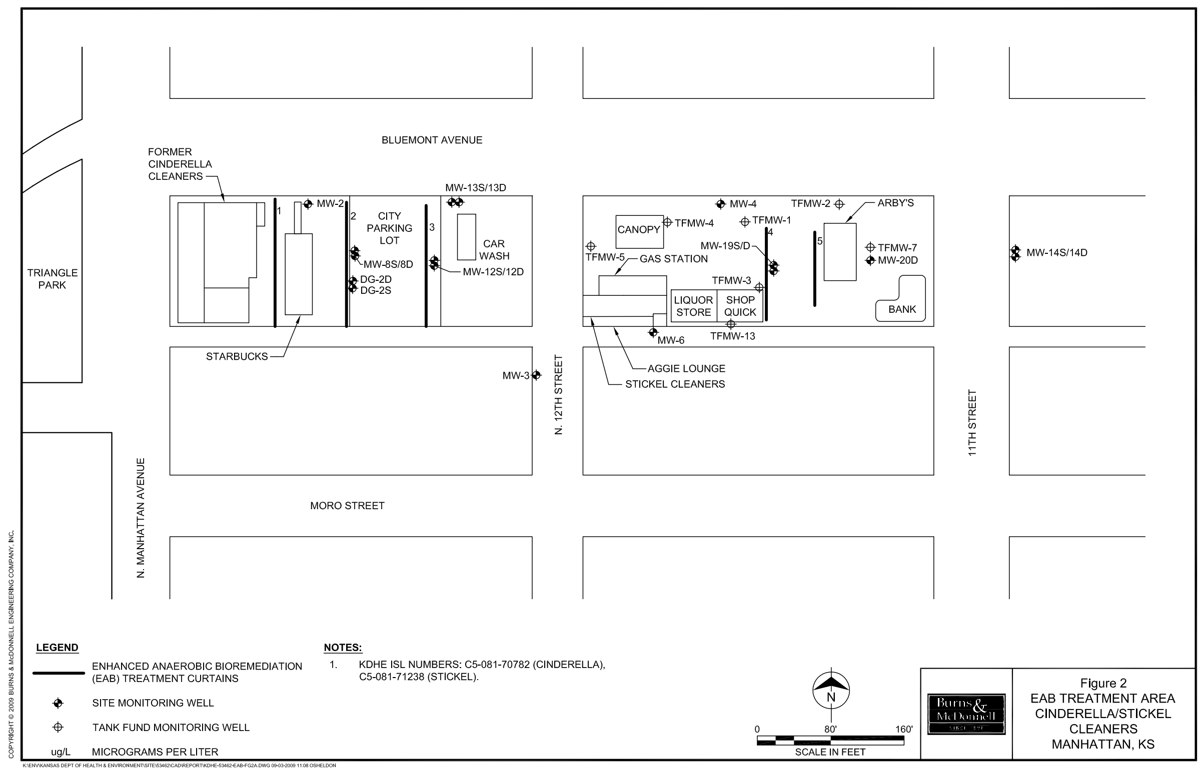

Figure 2: Cinderella–Stickel cleaners EAB target treatment area.

product consists of triacylglycerols, which are made up of fatty acids and glycerol. Once injected into the subsurface, the triacylglycerols slowly hydrolise, releasing free fatty acids and glycerol. The fatty acids, which consist of large hydrogen-rich molecules, are digested by microorganisms via beta oxidation (or other processes).

Non-emulsified vegetable oils offer many advantages over other bioremediation products because:

- They possess a viscosity similar to vegetable oil, they can be injected via monitoring wells or temporary points using standard grout pumps or diaphragm pumps.
- The product is not diluted with water, so 100% of the product contributes hydrogen to support bioremediation. Normalised to the cost of hydrogen produced, the product is less expensive than other soluble or insoluble substrates.
- The product degrades slowly and provides a long-term hydrogen source that lasts for years. Unlike more soluble or less viscous amendments, frequent re-injection or recirculation systems are not necessary.
- Non-emulsified vegetable oils are a concentrated hydrogen source, providing fuel to establish optimal groundwater conditions and overcome competitive demand.
- The product contains natural compounds that inhibit microbial reduction of acetate to methane and, compared with other substrates, yields efficient hydrogen utilisation for contaminant destruction rather than for methane production.

Specific advantages of CAP 18 (a proprietary blend) include:

- Composed of C18 fatty acids, it is a metabolically diverse substrate that produces a wide range of compounds for microbial hydrogen production and is therefore suitable for diverse aquifer conditions.
- It is an easy-to-inject amendment that will not travel vertically. The specific gravity of CAP 18 is very close to that of water (0.93), and the combination of viscosity and interfacial tension prevents upward migration of the product in saturated soils.

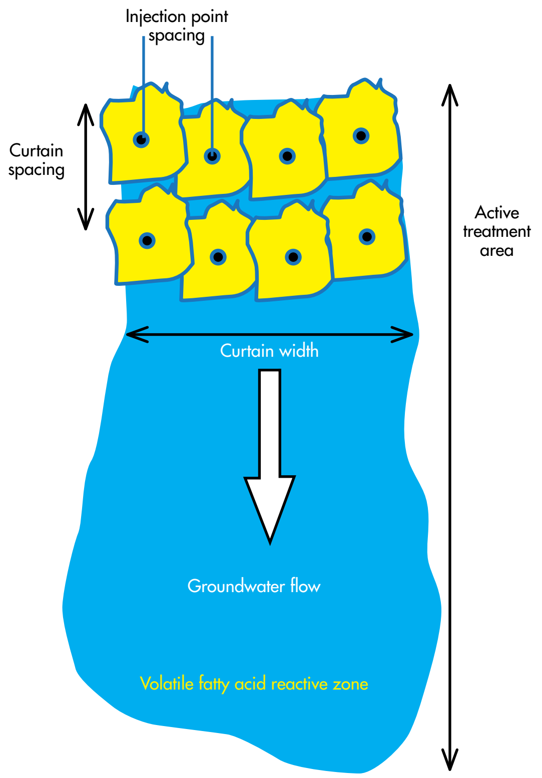

Figure 3: Overview of a CAP 18 curtain design.

EAB corrective action design and implementation

At the Cinderella–Stickel site, CAP 18 was distributed throughout the vertical treatment interval in the form of five substrate distribution curtains, oriented perpendicular to the direction of groundwater flow at the site. The vertical target treatment interval extended from the static groundwater surface (approximately 6 m bgs) to the top of bedrock (approximately 18 m bgs). Approximately 636 litres of CAP 18 was injected at a total of 59 injection points completed within the five injection curtains. A total of approximately 37,500 litres of CAP 18 was injected into the subsurface throughout the field implementation (see Figures 2 and 3).

Each curtain spanned the width of the groundwater plume and was completed using direct-push injection techniques. A generalised overview of a curtain injection strategy is provided in Figure 3.

The EAB injection strategy at the Cinderella-Stickel site consisted of five injection curtains at the two site areas: three curtains downgradient of the former Cinderella cleaners and two curtains downgradient of the former Stickel cleaners. Injection wells were spaced 4.5 m apart, and each curtain was spaced 15-24 m apart, with a total linear footage of 174 m for the five injection curtains. Each point was injected at 1.5-m intervals, with a varying injection volume of CAP 18 at each interval depending on the seepage velocity for each interval's lithology. The dosage amounts for each injection interval were:

- injection depths of 6-11 m bgs: approximately 4 litres per 1-1.5m interval
- injection depths of 11-14 m bgs: approximately 30 litres per 1-1.5m interval
- injection depths of 14-18 m bgs: approximately 132 litres per 1-1.5m interval.

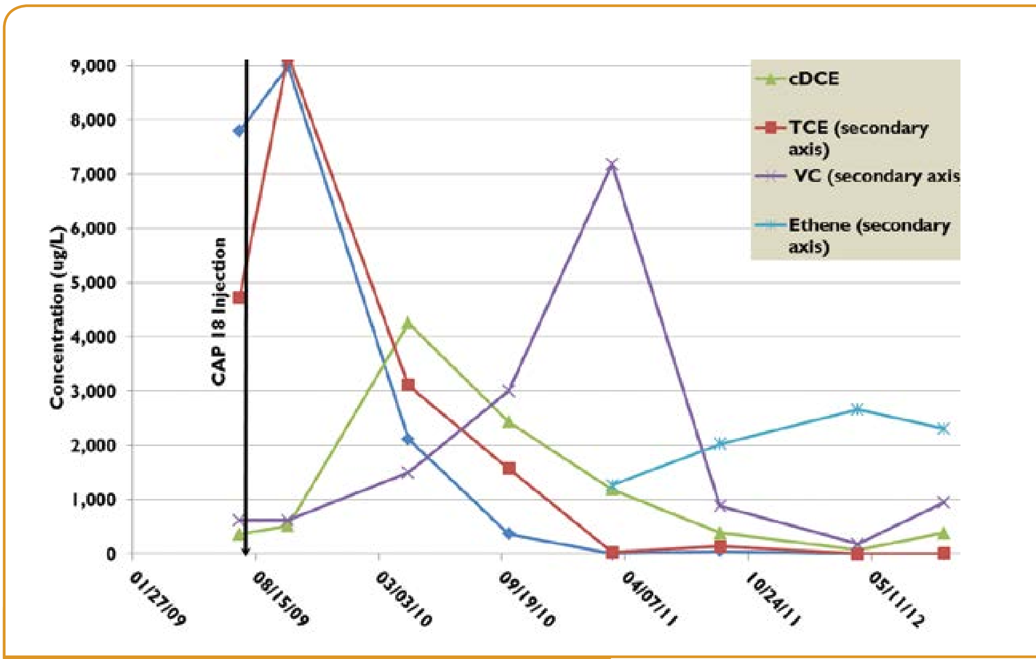

Figure 4: Monitoring well 8D (MW-8D) CVOC degradation.

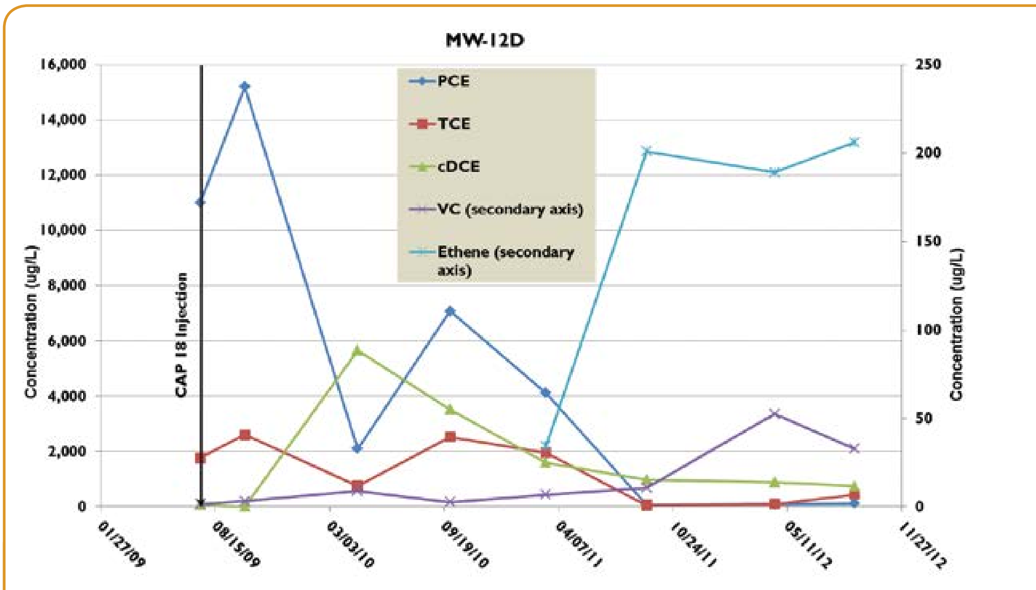

Figure 5: MW-12D CVOC degradation.

18 m bgs represents top of bedrock in this area. Approximately 1580 kg (approximately 636 litres) of CAP 18 were injected at each injection point.

Performance monitoring results

Since the conclusion of EAB injection activities at the site, groundwater sampling has been conducted at eight monitoring wells to provide data used in assessing performance of the EAB corrective action. A post-injection groundwater monitoring program has been conducted on a semi-annual basis from 2009 through 2012 using low-flow sampling techniques to evaluate the success of the EAB application at this site. Wells are sampled and analysed for EAB performance indicator parameters as well as known contaminants of concern (CVOCs). Concentrations of the presumptive parent compound for CVOC groundwater impacts at the site (PCE) have significantly decreased in all EAB performance-monitoring

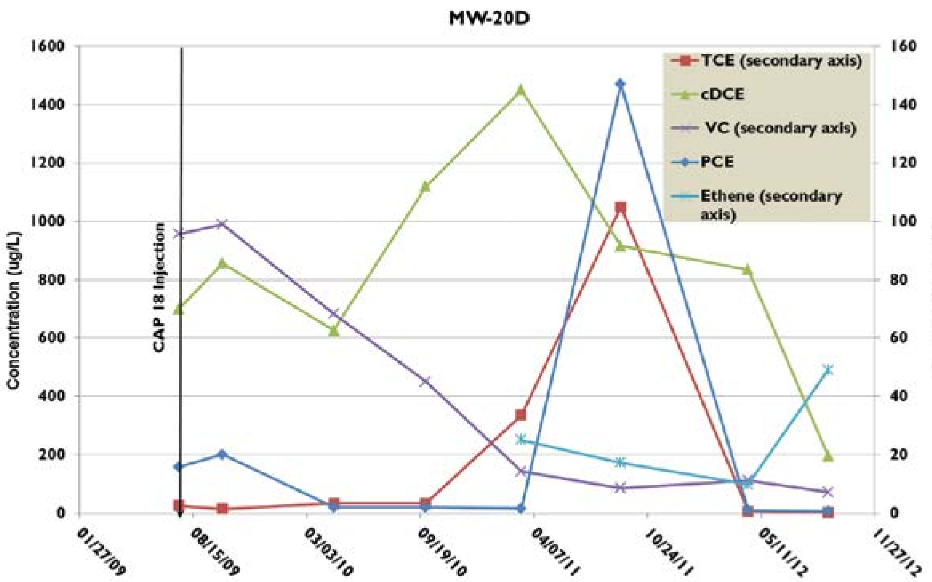

Figure 6: MW-12D CVOC degradation.

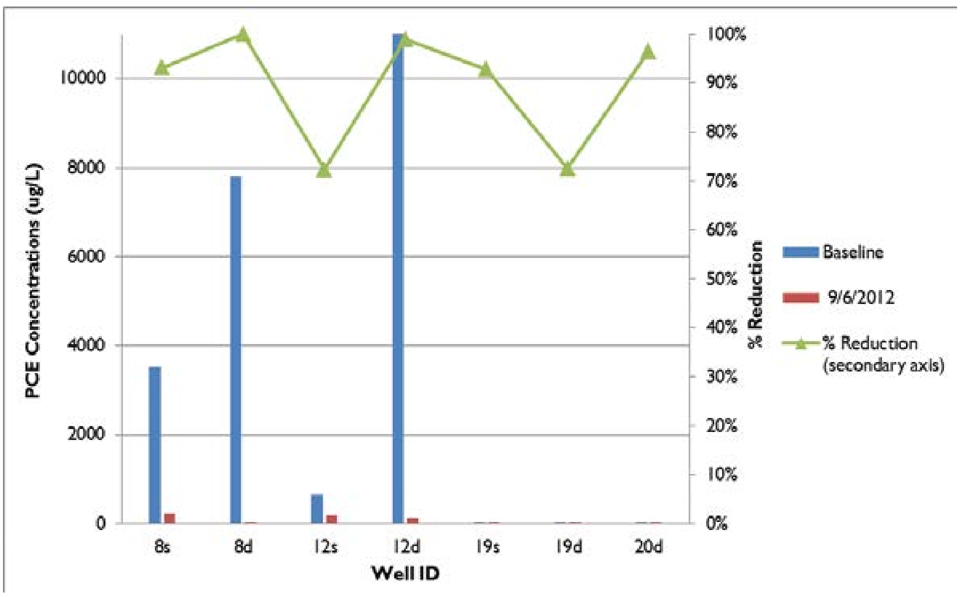

Figure 7: PCE performance assessment results and removal efficiencies.

wells since the completion of CAP 18 injection activities.

As of September 2012, PCE concentration reductions in the monitoring wells range from 72% to 100%, with six of the eight wells reporting reductions of 93% or greater. TCE concentrations have also decreased in seven of the eight monitoring wells since substrate injection while *cis*-1,2-DCE and vinyl chloride concentrations have increased in some wells as a normal function of the dechlorination process.

While concentrations of degradation products (*cis*-1,2-DCE and vinyl chloride) have increased at some wells, the formation of ethene, a terminal end product of reductive dechlorination, confirms that the treatment process is completely converting CVOCs into inert compounds. Ethene has been detected at six of the eight monitoring wells and at every monitoring well exhibiting an increase in *cis*-1,2-DCE or vinyl chloride concentrations. Consequently, the remaining *cis*-1,2-DCE or vinyl chloride impacts are expected to attenuate over time as the dechlorination process continues. The CVOC concentration trends for select monitoring wells are illustrated in Figures 4-6 and discussed below and right.

As shown in Figure 4, PCE and TCE concentrations increased to 9000 µg/L following the EAB injection, which would be an indicator of reductive dechlorination, and decreased rapidly to a low of < 2.0 µg/L at the latest sampling event in September 2012. This was followed by subsequent increases in both *cis*-1,2-DCE and VC as expected, due to PCE and TCE dechlorination, and subsequently decreased to concentrations below baseline levels. Ethene analysis for groundwater samples began in March 2011. Monitoring well 8D (MW-8D) ethene concentrations increased from March 2011 through April 2012, confirming complete dechlorination of targeted CVOCs.

Figure 5 shows that following the July 2009 EAB injection event, the observed TCE and PCE concentrations underwent a sharp decline and continue to remain consistently low following the September 2012 monitoring event. TCE concentrations followed a similar trend while *cis*-1,2-DCE concentrations spiked before the PCE and TCE decreasing trends began. Following the initial spike, *cis*-1,2-DCE decreased to levels slightly above baseline. Following the spikes and subsequent declines in PCE, TCE and *cis*-1,2-DCE concentrations, vinyl chloride levels increased but show a decreasing trend during the September 2012 sampling event.

As previously mentioned, this increase in vinyl chloride is expected during the dechlorination process and is considered temporary with ethene detections in MW-12D confirming that complete dechlorination of targeted CVOCs is occurring.

Figure 6 illustrates that PCE and TCE concentrations decreased following the July 2009 EAB injection event followed by a spike during the October 2011 sampling event before declining to consistently low levels after the September 2012 monitoring event. While *cis*-1,2-DCE concentrations increased from 600 to > 1400 µg/L, which is evidence of sequential dechlorination, this was followed by a continued and gradual decline. As with the other monitoring wells discussed above, ethene detections in MW-20D continue to confirm that complete dechlorination of the targeted CVOCs is ongoing.

EAB Performance Assessment

Figure 7 illustrates the PCE reductions and performance assessment results for the Cinderella-Stickel EAB site with removal efficiencies ranging from 72% to100%.

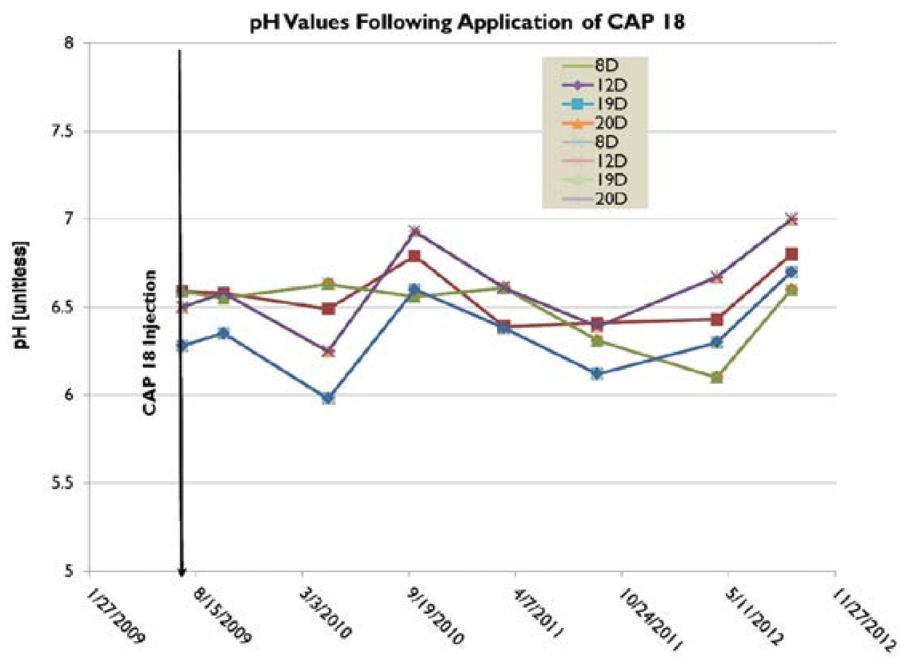

Figure 8: pH values following EAB at the Cinderella-Stickel Site, Manhattan, Kansas, USA.

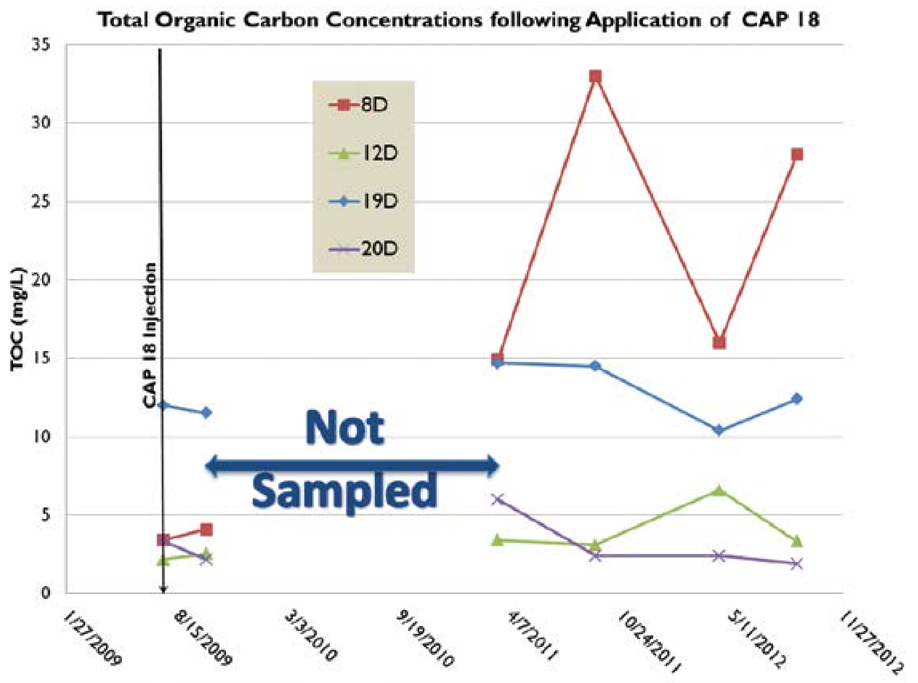

Figure 9: Total organic carbon values following EAB at the Cinderella-Stickel Site, Manhattan, Kansas, USA.

Geochemical assessment

EAB performance is often tracked by measuring a variety of geochemical parameters including: nitrate, sulfate, methane, pH, dissolved oxygen (DO), oxidation-reduction potential (ORP), total organic carbon (TOC), iron and ferrous iron. Post-EAB performance highlights of a few of these parameters are discussed below.

Complete dehalogenation to ethene at many field sites can be hindered by a number of factors including development of a low groundwater pH. To overcome this, some EAB substrates are amended with buffers in order to reach near neutral conditions. The slow release characteristics of CAP 18 limit the amount of acidity generated, which assists in maintaining favourable pH for dechlorinating microorganisms. The pH values measured before and following EAB curtain installation are provided (Figure 8).

Following initial pH decreases at the site, the latest sampling event recorded near neutral values (ranging from 6.6 to 7), which promote sustained microbial activity. In addition, TOC data can provide information on the transport of organic carbon in groundwater occurring downgradient from the CAP 18 curtains (Figure 9).

Figure 9 illustrates that elevated TOC levels (above baseline values) were measured in all wells; however, TOC levels would be expected to decline over time (as noted in MW-12 and MW-20D) as microbial growth and activity increases and the substrate is consumed.

Conclusions

This case study presents the results of a large-scale EAB field implementation of CAP 18 for clean-up of a chlorinated solvent plume in Manhattan, Kansas, USA. Field activities began with the baseline sampling in July 2009, with continued monitoring of CVOC degradation planned through 2013. The following provides a summary of the major conclusions drawn from the three years of data presented above:

- The Cinderella-Stickel site in Manhattan, Kansas, continues to show significant reductions in CVOC over three years with ongoing ethene generation
- The TOC concentration data suggest that substrate is still being released three years after a single application, and that bioremediation activity is ongoing
- As a result of the increased substrate utilisation efficiency, very high TOC concentrations are not required to support reductive dechlorination
- A large pH shift was not observed during the barrier lifetime, despite degrading >12,000 μg/L of PCE
- The slow-release characteristics of CAP 18 minimised large pH fluctuations that are commonly observed from soluble amendment injections, thus eliminating the need to co-inject costly buffers
- Complete anaerobic reductive dechlorination of PCE to ethene was stimulated through the application of CAP 18
- Anaerobic reductive dechlorination was observed to distances of almost 18 m from the CAP 18 curtains
- The injection of non-emulsified vegetable oil into the target treatment areas at depths up to 18 m was easily accomplished with direct-push tooling.

The costs associated with the EAB site treatment were around US$250,000. As a cost comparison, a traditional pump-and-treat system operating for 30 years with annual operation and management costs of approximately US$300,000 would cost US$9 million.[2]

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Phosphorus – peaking or plenty?

Nanthi Bolan, Rajasekar Karunanithi and Ravi Naidu, CRC CARE and Centre for Environmental Risk Assessment and Remediation, University of South Australia

Phosphorus is essential for life, and without it our crops would fail. Yet it is too often wasted, leaching into groundwater or running off into surface water, where it becomes a pollutant – stifling life, rather than feeding it. At the same time, the world's supplies are finite and we are rapidly approaching peak phosphorus. How do we find the right balance?

The top three

Nitrogen (N), phosphorus (P) and potassium (K) are the three major nutrients used in agriculture. These nutrients, which are required in large amounts compared with most other secondary and trace nutrients, are added to the soil in the form of fertilisers and manures. While N is derived from the atmosphere through biological and chemical N fixation, P and K are derived primarily from mineral sources. Thus we have an unlimited source of atmospheric N, and chemical fixation of this source to manufacture N fertilisers is limited only by energy supply. Biological fixation of atmospheric N by legume species also provides a major source of N input to soils. P and K, however, are sourced from finite sources of phosphate rocks and K minerals, respectively.

Peak phosphorus

All modern agricultural systems are dependent on continual inputs of phosphate fertilisers derived mainly from phosphate rock. Unlike N, P relies on a finite resource, and current reserves could be depleted this century. More concerning is that, before that point is reached, we will see a global peak in phosphate rock reserves, similar to the impending oil peak. While the exact timing of peak P may be disputed, it is clear already that the quality of remaining phosphate rock reserves is decreasing and cheap P fertilisers will be a thing of the past.

Peak P is linked to peak oil. For example, the oil price shock of recent years and growing concern about climate change have stimulated a dramatic increase in bioenergy crop production globally, which in turn has increased the demand for P fertilisers, and hence has hastened the arrival of peak P. A key difference between peak oil and peak P, however, is that although oil can be replaced with other forms of energy, there is no substitute for P in food production. P cannot be produced or synthesised and without this nutrient source we cannot produce food. A second key difference, this time on the plus side, is that, while oil is unavailable once it is used, P can be captured and recycled for use within economic, technical and environmental limits.

Although there is not enough reliable data to predict the peak period for P, it is clear that alternative P sources, along with technologies to enhance the efficiency with which plants use P, are required to ensure that the world's farmers have sufficient access to P in the long term to achieve food security. While the recent price spike in phosphate rock is likely to trigger further innovations in P recovery and efficiency measures, the market alone does not have enough adaptive capacity for the sustainable management of P in the long-term.

The current system – mining phosphate rock followed by the manufacture, transport, storage and application of fertiliser, and culminating in food processing and consumption – is inefficient. Fortunately, this means that there are many opportunities for both increasing efficiency and for capturing used P in human and animal excreta, and food and crop residues.

This paper presents an overview of various strategies used in managing P in organic amendments including the disposal of P-rich waste by applying it to farmland (i.e. land application), with particular emphasis on the potential for surface and groundwater contamination. Since poultry manure is produced in large quantities and used extensively in agricultural production, we will focus on this organic amendment.

Unlocking the soil phosphorus bank

Many agricultural soils in Australia and New Zealand contain a huge reserve of P. For example, some of the intensive dairy farming volcanic ash soils in New Zealand contain as much as 2400 kg P per hectare (kg/ha) in the root zone. In these intensive dairy farms, the average annual uptake of P by pasture is 40–60 kg/ha, most of which is returned to soils as unused herbage, dung and urine. The net annual loss of P from the soil is about 8 kg/ha. Many intensively farmed Australian soils have a significant reserve of P in the rooting zone.

A common question in the farming sector is, "Is it possible to unlock this reserve soil P so that it becomes plant available?" To answer this intriguing question, we need to understand the reactions of P fertilisers in soils and various processes involved in unlocking the reserve pool of soil P for food production.

The easiest way to unlock soil P is to improve root interception and root turnover, mining pockets of soil that are rich and undepleted. To better unlock this reserve, we also need: soil tests that reflect the capacity of

Farm workers in China scatter fertiliser over rice fields. *Photo: IRRI* soil to supply nutrients including P; improved nutrient budgeting techniques; and soil sampling techniques that account for both the horizontal and vertical stratification of nutrients that have arisen with modern cultivation and agronomic practices.

Recovering and recycling phosphorus

The use in agriculture of organic amendments such as biosolids, poultry and animal manures, and farmyard compost holds dual benefits for the waste-producing industry and primary producers. For waste-producing industries, land application provides a primary avenue for safe and beneficial recycling of these resource materials. For agricultural producers, these organic amendments are an alternative source of nutrients and thus negate the traditional routes of disposal for these valuable resources, such as landfilling, incineration and ocean dumping. These organic amendments can also be used help rehabilitate fragile disturbed lands such as mine sites.

Optimum use of these byproducts requires knowledge of their composition in relation to beneficial uses and environmental implications. Most of the environmental problems associated with land application of organic amendments have centred on potential contamination of groundwater and/or surface water with N, P and heavy metals. The application of organic amendments as a nutrient source is generally based on N input, which is likely to provide more of other nutrients (especially P) than is required by crops.

Cost-effective and innovative solutions are needed to expand the range of acceptable options for managing nutrients, especially P in organic amendments. This will involve refining feed rations to animals, using feed additives to increase P absorption in animals, managing and recovering P in organic amendments, moving organic amendments from surplus to deficit areas, finding alternative uses for organic amendments, and targeting conservation practices to critical areas of P export during land application.

Phosphorus input in poultry feed

P is an essential minerals for all animals. It plays critical roles in cellular metabolism, as a part of the energy reservoir of the cell, in cellular regulatory mechanisms, and in bone development and mineralisation. Through its involvement in these metabolic and structural processes, P is essential for animals to attain their optimum genetic potential in growth and feed efficiency as well as skeletal development.

Of all poultry operations, the laying hen industry typically feeds birds much more P than they require, largely because of concerns about inadequate mineralisation of egg shells and skeletal abnormalities resulting in poor egg production and increased morbidity and mortality. Better management of P in feed can reduce problematically high levels of P in poultry manure (see *Feed management*).

One-third of the P taken up by poultry is present in the forage as inorganic P, which is easily digestible. The other two-thirds are present as organic P, especially in the form of phytic acid and phytate. The P stored in this way is not bioavailable for poultry or pigs. The most P-rich components in the feed include mono-calcium phosphate, dicalcium phosphate and monosodium phosphate. Typically, poultry utilises less than one-third of feed P, with the remainder excreted in manure, which can then be applied to land for crop use. Phytic acid P is not readily bioavailable to poultry, and to meet the P needs of the bird, inorganic P must be added to the diet. If added to feed, the enzyme phytase can liberate much of this P, thereby enhancing the utilisation of P by poultry.

Phosphorus management in poultry litter

Among the various nutrients in poultry litter, N and P cause some environmental concerns. P in poultry litter is present mainly in solid phase as organic and inorganic P. The amount of total P in poultry litter varies with the diet and bedding material, and ranges from 0.3% to 2.4 % of dry matter. Fractionation studies have shown that a large proportion of P in poultry litter is in acid soluble fraction, indicating low bioavailability. Mineral species, such as struvite ($MgNH_4PO_4.2H_2O$), octocalcium phosphate ($Ca_4H(PO_4)_3.3H_2O$) and dicalcium phosphate ($CaHPO_4.2H_2O$) have been identified in the solid fraction of poultry manure. P in poultry manure can be managed sustainably through improvements in feed, manure, soil and nutrient management practices (Figure 1).

Feed management

P in manure can be reduced by feeding the birds less P or treating feed to improve P-utilisation efficiency. Various feed and management strategies that reduce P in poultry litter have been investigated. The first of these strategies formulates feeds closer to the birds' actual P requirements. A second feeding strategy being tested is to use phytase, an enzyme that enhances the efficiency of P recovery from phytin in grains fed to poultry. Phytase breaks down the P-phytate bonds making the P bioavailable for absorption by the bird. Another approach is to increase the bioavailability of P in poultry feeds by reducing the amount of phytate in the feed. Using low-phytate corn in poultry feed, for example, can increase the availability of P and other minerals and proteins

Table 1: Nutrient contents of organic amendments (g/kg).

Nutrient	Poultry manure	Biosolids	Pig manure	Mushroom compost
Nitrogen	32.8	21.7	18.2	17.5
Phosphorus	17.8	8.5	7.5	5.3
Potassium	15.2	2.5	8.2	9.2
Calcium	18.5	2.3	4.2	21.5
Magnesium	6.2	1.4	3.7	5.2
Sulphur	8.5	5.7	3.4	3.5

that are typically phytate bound. A combination of these strategies should result in a reduction in excreta P.

Manure management

Poultry manure is rich in plant nutrients including N, P, K, sulphur (S), calcium (Ca) and magnesium (Mg) (Table 1). Manure management practices include the recovery and immobilisation of P in the litter. Commercially available manure amendments, such as alum, can reduce ammonia (NH_3) volatilisation, leading to improved animal health and weight gains; they can also reduce the solubility of P in poultry litter.[1] For example, the dissolved P concentration (11 mg/L) of surface runoff from fescue (a common pasture species) treated with alum-amended litter was much lower than from fescue (83 mg/L) treated with unamended litter.[2]

Undoubtedly, the most direct way to resolve P surpluses at a regional or watershed level is to simply transport poultry litter to areas where P is needed for crop production.[3] However, increasing haulage costs remain a major limitation for economic and environmentally safe P reutilisation.

For manure P relocation to be sustainable requires forms of processing that decrease the manure volume, increase P concentration, and produce a more valuable product with alternative use options. Such poultry litter management technologies can be grouped into five types of process: screening, densification, biological, thermochemical and chemical. Thermochemical and chemical processing – approaches that are likely to yield a value-added product – are described below.

Thermochemical processing

Thermochemical processes use high temperatures to break the bonds of organic matter and reform intermediate compounds into synthesis gas, hydrocarbons fuels, and/or a charcoal residue. Solid residues from these processes are P-dense materials that can be reused as fertiliser. Thermochemical processing can be performed at large centralised facilities where poultry litter is combusted to produce heat and electricity. The byproduct of combusted poultry litter is ash with high P content, which can be used as fertiliser or P supplement in poultry feed. However, such facilities have sparkled major environmental concerns because poultry litter combustion emits nitrogen oxides, carbon monoxide and sulfur dioxide, which require effective gas clean-up.

Chemical processing

A chemical treatment process, named 'quick wash', was recently developed for extraction and recovery of P from poultry litter and animal manure solids.[4] The quick wash process consists of three consecutive steps: 1) P extraction, 2) P recovery, and 3) P recovery enhancement. In step 1, organically bound P is converted to soluble-P by rapid hydrolysis reactions using selected minerals or organic acids. This step also releases P from insoluble inorganic phosphate complexes. The washed litter residue is subsequently separated from the liquid extract and dewatered. In step 2, P is precipitated by addition of lime to the liquid extract to form a calcium-containing P product. In step 3, an organic poly-electrolyte is added to enhance the P grade of the product. The remaining solid residue (washed litter) has a more balanced N:P ratio that is more environmentally safe for land application and use by crops.

Soil management

Soil remediation involves chemically fixing P so it becomes less mobile in soil. Materials that have been shown to effectively reduce P solubility and P transport to surface water and groundwater include byproducts of:

- drinking-water treatment residuals (WTRs) treated with alum – i.e. aluminium-based byproducts
- red mud from aluminium processing industries – i.e. iron-based byproducts
- coal combustion products – i.e. Ca-based byproducts.

Several types of best management practices have been proposed to utilise these byproducts in efforts to reduce off-site P transport. Examples include application to the soil surface in vegetative filter strips to reduce

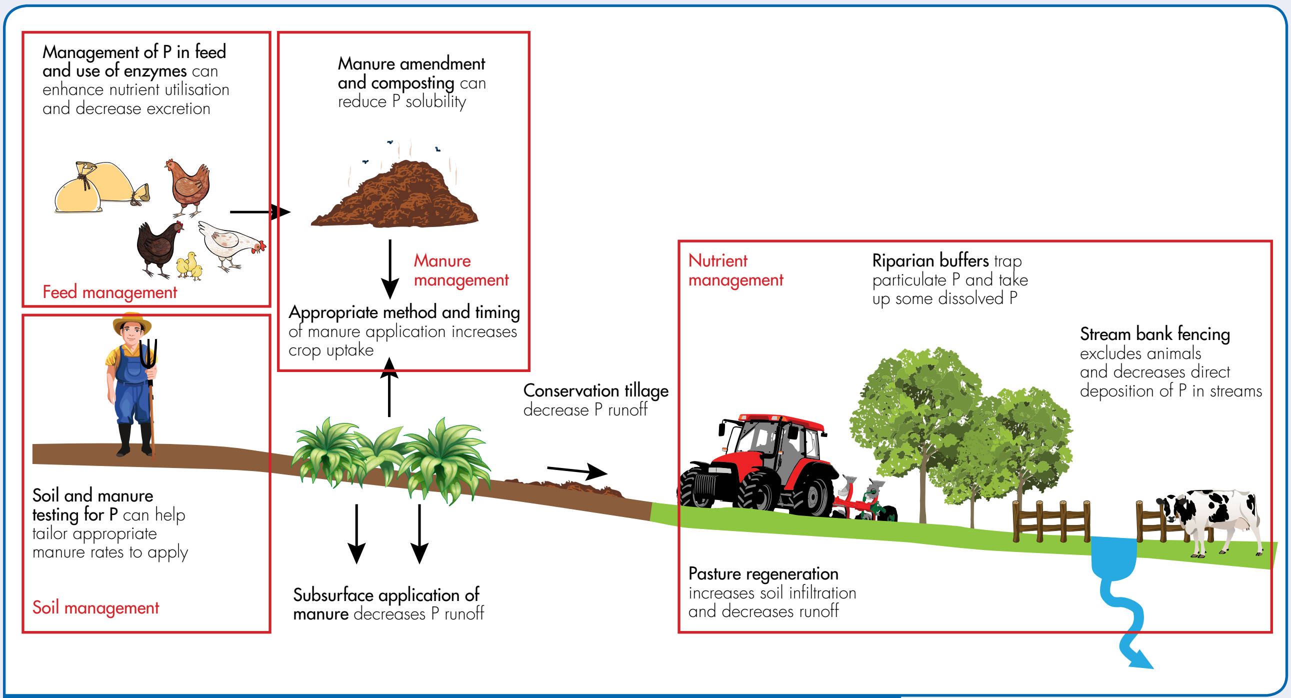

Figure 1: Best management practices for minimising phosphorus loss in poultry farming systems. Figure adapted from Sharpley et al. (2007).[6]

runoff P losses and incorporating the byproducts into high-P soils to reduce extractable P concentrations. In one study, WTRs incorporated into soil with high P concentrations reduced runoff P losses by between 19% and 67% compared with controls.[5] A reduction in extractable P of between 10% and 91% occurred after WTRs were blended with the high-P soil and poultry litter.

Nutrient management

The application of poultry manure based on crop N requirements is likely to provide more of other nutrients (especially P) than is required by crops. For example, applying 9 tons/ha of broiler litter, a rate commonly used to meet the N requirements of agronomic crops, will provide approximately 270 kg/ha of N, 100 kg/ha of P, 165 kg/ha of K and Ca, 45 kg/ha of S and Mg, and 2–5 kg/ha of Mn, Cu and Zn. Depending on the crop species grown, this may result in the some of these nutrients, especially P, accumulating in soils, leading to contamination of surface water and groundwater sources.

Several best management practices have the potential to reduce nutrients in runoff water and loading to surface waters.[6] These can be grouped into two broad categories: (1) technologies to reduce excessive nutrient levels in the soil, and (2) technologies to reduce discharges of nutrients via runoff or sediment loss from over-application of manure. For example, growing high-biomass-yielding plants can remove large quantities of nutrients and may be a promising remedial strategy for exporting and reducing excess soil nutrients. Bermuda grass and certain warm-season annual grasses produce large dry matter yields, and thus, take up large quantities of applied nutrients.

The way forward

While the exact timing of peak P may be disputed, it is clear already that cheap P fertilisers will be a thing of the past. By applying smart, sustainable management practices, we can reduce P wastage – much of which contaminates the environment – and contribute to food security by using P more efficiently in agriculture.

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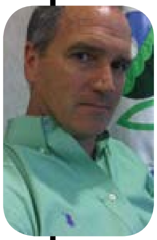
The commemorative Brian Robinson Lecture

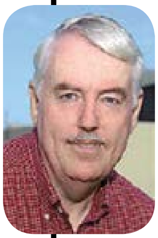
CRC CARE is pleased to announce that the lecture will be delivered by Dr Vivian Balakrishnan, Singapore Minister for the Environment and Water Resources. We welcome him to CleanUp 2013 and look forward to hearing him speak.

Here is a taste of the invited speakers for the 5th International Contaminated Site Remediation Conference – visit the conference website for information on all of the eminent researchers and practitioners who have been invited to present.



Carlos Pachon
Office of Superfund Remediation and Technology Innovation, US EPA
Innovative remediation strategies and green remediation: achieving environmental protection with a smaller environmental footprint

Julie Wroble
US EPA, Region 10
Recent trends and developments in asbestos in soil (ASBINS) – US EPA perspective



Ian Duncan
Bureau of Economic Geology, University of Texas
A critical review of reported and documented groundwater contamination incidents associated with unconventional gas

Renato Baciocchi
University of Rome
Perspectives for changing assumptions and improving models in risk assessment

Kyle Alexander
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Research RoundUp

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Long term stability of remediated acid sulfate soils

Acid sulfate soils are typically rich in stable iron minerals that form after the oxidation of pyrite. Re-establishing tidal inundation in an iron-rich acid sulfate soil landscape generates considerable potential for reductive dissolution of mineral phases.

The CRC CARE national demonstration site for innovative acid sulfate soil management at East Trinity, near Cairns in Queensland, continues to provide a foundation for the development of remediation technology for high-value coastal lowland acid sulfate soils. Previous research has shown that the lime-assisted tidal exchange (LATE) approach is very effective in triggering geochemical processes that improve acute soil acidity. This approach is capable of remediating acid sulfate soils of below pH 3 to near-neutral in around one year.

The onset of reductive dissolution of iron oxides in combination with tidal hydraulics has effectively mobilised a large store of secondary iron minerals at East Trinity. The specific effects of tidal dynamics, salinity and organic carbon on biogeochemical cycling of iron are key factors in the LATE remediation of acid sulfate soils. The consequences of accelerated iron mineral transformations to reduced phases, as well as mobilisation and repartitioning of contaminants, are central short-term features of the remediation process that have unresolved long-term implications for site management and transferability of LATE. Further research is needed to assess the technology's transferability and ability to contribute to long-term stability of the remediated soils. ■

Health risk guidelines for Port Hedland

Port Hedland, Western Australia, is a major and expanding export port for iron ore and other mineral ores. The WA Government along with industry have developed a *Port Hedland Air Quality and Noise Management Plan* to reduce the impact of dust and noise from these export activities on residents in the town. Key components of the plan include a health risk assessment and setting appropriate ambient air dust limits. The Port Hedland Industries Council, established to implement the plan, has committed funds to the WA Department of Health to conduct the Health Risk Assessment.

This project will investigate the nature and source (mineral or combustion) of dust particles in the Port Hedland area. The data will provide supporting information for a health risk assessment specific to Port Hedland, as required by the plan, and help the Department of Health and the Department of Environment and Conservation determine the suitability of the current interim standard for Port Hedland. The data from this study will also inform a review of the National Environment Protection (Ambient Air Quality) Measure, particularly whether different limits for particulates in ambient air based on the predominant source are appropriate. ■

Community consultation in selection of remediation technologies

The continual growth of Australia's remediation efforts depends not only on mechanical or technical sophistication and efficiency, but also on acceptance and understanding by the wider community. This project is addressing how communities can best be involved in the selection of remediation technology, and will provide a robust evidence base to support effective community consultation practices. The project aims to:

- foster the understanding of how communities engage with, contribute to, and enhance development through remediation
- allow Australian communities, governments and other key stakeholders involved in remediation to better understand the strengths of both unique and shared aspects of their processes, thus providing opportunities for learning and development
- develop and facilitate knowledge exchange to provide a comprehensive and shared information base of effective processes
- contribute to the strength of institutional arrangements that guide remediation processes. ■

Assessment of flux-based criteria for management of groundwater contamination

Concentration-based criteria are commonly used in Australia and internationally to regulate the management of contaminated groundwater environments, measure success of remediation, and assess risk to receptors. However, in many circumstances contaminant flux (mass flow rate of a contaminant across a surface boundary) is an important consideration, particularly for measuring the success of remediation or predicting duration and extent of impact. Currently there is no consensus or guidance on the criteria that should be used for interpretation and performance of flux measurements.

A recently completed CRC CARE project canvassed the advantages of flux-based assessment of groundwater contamination. The project:

(i) reviewed relevant national and international policy, regulation and practice regarding the flux-based assessment of groundwater contamination and how this complies with Australian regulatory guidance

(ii) reviewed the technical options and techniques, including geophysical methods, for measuring groundwater fluxes

National Park Service/ Alice Wondrak Biel

(iii) identified and recommended technology options that are suitable for adoption in Australia

(iv) conceptualised how a flux-based approach might be applied and adopted in Australia.

CRC CARE plans to publish the project's findings. ■

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9-13 Global Minerals Industry Risk Management
JKTech/Brisbane
www.g-mirm.com

11-13 Risk based site assessment
University of Technology Sydney/Sydney
www.science.uts.edu.au/courses/csarm.html

15-18 CleanUp Conference
CRC CARE & ALGA/Melbourne
www.cleanupconference.com

November

3-6 American Society of Agronomy, Crop Science Society of America and Soil Science Society of America Annual Meetings
ASA, CSSA and SSSA/Tampa, Florida USA
https://www.acsmeetings.org/

6-8 Remediation principles and closure
UTS/Sydney
www.science.uts.edu.au/courses/csarm.html

19-20 Australasian Waste & Recycling Expo
Diversified Exhibitions Australia/Melbourne
www.awre.com.au

2014

28 April – 2 May
8th Australian Workshop on Acid and Metalliferous Drainage
JKTech/Adelaide

10-14 November
7th International Congress on Environmental Geotechnics (7ICEG)
Waldron Smith Management/Melbourne
www.7iceg2014.com

7-12 December
Royal Australian Chemical Institute national Congress
RACI/Adelaide
www.racicongress.com

October

2-3 Global Minerals Industry Risk Management (for executives)
JKTech/Perth
www.g-mirm.com

14-16 Coal Seam Gas Water Management
Resourceful Events /Brisbane
csg-water.com

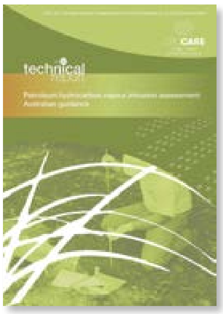
21-23 Practical Monitoring for Improved Environmental Performance
JKTech/Fremantle
jktech.com.au/practical-monitoring-improved-environmental-performance-resources-sector-wa

21-25 Global Minerals Industry Risk Management (for managers)
JKTech/Bunbury
www.g-mirm.com

24-25 Current development trends of solid waste treatment technology
VUREIA/Hanoi, Vietnam

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**.



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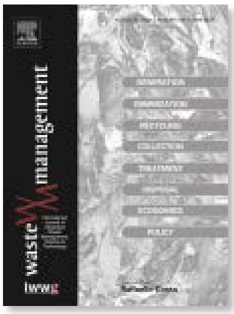

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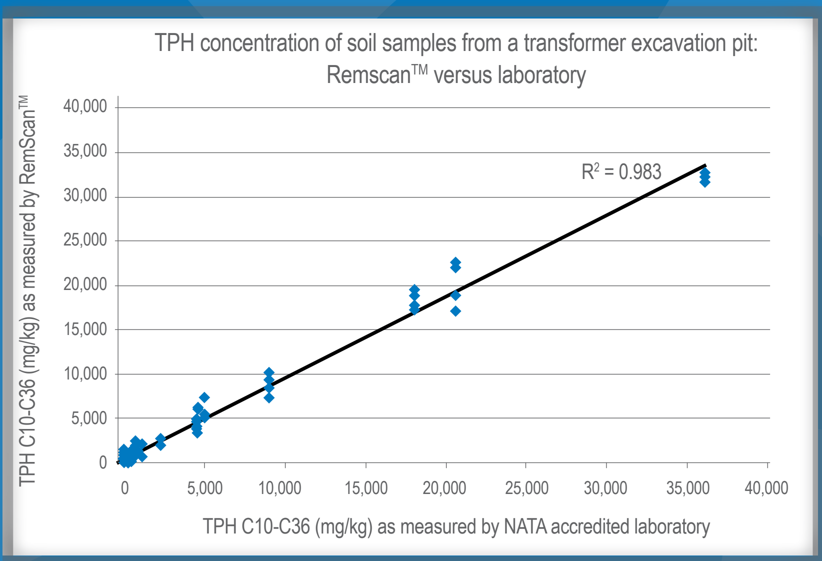

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