Issue 11 2012

Remediation Australasia

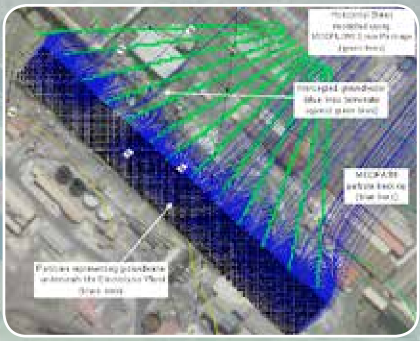
SPECIAL EDITION: LANDFILLS BUMPER ISSUE

Landfills and energy production

Cleaning up to produce energy

Sampling and analysis plans

A crucial first step



Groundwater remediation

Hobart zinc smelter case study

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

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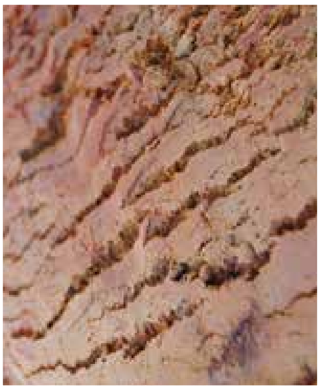

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editor's note

Welcome, reader, to Issue 11 of *Remediation Australasia*.

I would like to extend a warm welcome to those of you who have recently joined ARIC. If you are a newcomer, you may not be familiar with our scope or purpose. ARIC was launched in July 2007 to promote the Australian remediation industry. Our goal was to make the industry more competitive by introducing advanced new site assessment and remediation technologies, build capacity and develop skills in these areas, and share information about technology, policy and market opportunities in Australia and beyond.

How effective has ARIC been in fostering networking among industries, universities and policy makers, and, as a consequence, expanding the remediation industry? Since its launch in 2007, ARIC has attracted around 2,500 members worldwide, and is now the technology diffusion arm of CRC CARE. ARIC has actively:

- built capacity in the remediation industry sector by hosting training workshops for new and imminent graduates
- extended new technologies by enhancing networking among companies, consultants, researchers and policy makers
- collaborated with local Environment Protection Authorities to diffuse new policy as well as the outcomes of the National Environmental Protection Measure, and
- conducted workshops for industry and government to identify knowledge gaps in environmental and remediation industry policy.

When the seeds of CRC CARE were sown in 1999, the remediation industry was worth $300 million per year. Following the establishment of CRC CARE and ARIC, this figure has grown to more than $3 billion. International companies focusing on remediation have also increased in number, from a small handful to more than 20. In this environment of rapid growth, ARIC's challenge – to drive growth further and deliver even more value in the remediation industry – is significant indeed.

ARIC relies on researchers and personnel involved with contaminated site assessment and remediation to contribute to workshops and conferences. These training events are crucial in educating policy makers and the community about contaminants that harm the environment and human health, as well as about potential liability issues.

The insights, case studies, reports, explorations and innovations from our magazine contributors and industry members – along with our readers' support – are an integral to ARIC's ability to achieve its mission. In this light, we are seeking to expand and disseminate our knowledge even further.

The current issue of ***Remediation Australasia*** includes a particular focus on landfills. The large volume of waste that we generate, much of which finds its way into landfills, is an intergenerational issue – will we leave this for our children and grandchildren to manage? To me, the concept of 'zero waste', although admirable, is a pipe dream – we are never likely to see a manufacturing sector or individual households that can exist without generating waste. Tell us what you think – I welcome your thoughts on waste management, landfills old and new, and where you believe the remediation industry will be 20 years from now.

As always, please contact us via **aric@crccare.com** if you have any feedback or would like to contribute. We would love to hear from you.

Prof Ravi Naidu

Managing Director, CRC CARE

Editor, *Remediation Australasia*

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

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Front cover image: A Thiess Services remediation project in Western Australia saw the relocation of contaminated landfill after the deployment of an innovative remediation technique. **Turn to page 20 to read the full story.**

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contents

features

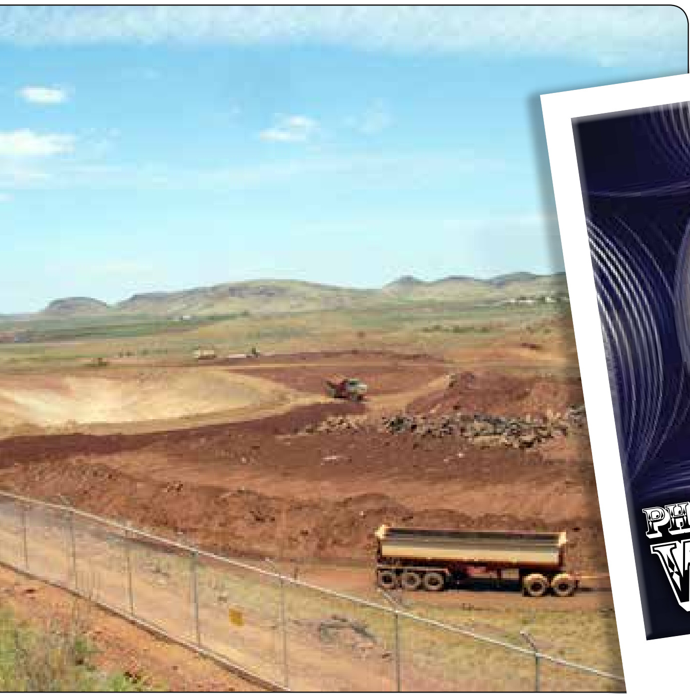



PHOTO COMPETITION
WINNER!
22


Intercepted groundwater
(blue lines terminate
against green lines)
Particles representing groundwater
underneath the Electrolysis Plant
(black dots)
24

every issue

ReMEDIAtion

Your guide to environmental contamination and remediation issues in the media

Recycling trumps landfills

A new report confirms the Australian recycling sector is a bigger employer and generates more revenue than the landfill sector, but significant barriers remain to its growth and development.

The report draws on recent figures that 26 m t of material was recycled in Australia in 2008/09. The study noted the value of recycling in Australia was around $6.145 billion. Most of this revenue (50% or so) is attributed to the sale of recovered materials, but the report cautions markets are highly variable. More than half ($3.8 billion) of the revenue from recycling was generated in NSW and Victoria.

The contribution of the recycling sector to Australian employment is estimated at a little less than 1% - meaning approximately 22,000 people (full time equivalents) are employed in recycling in Australia.This equates to 9.2 full time employees for every 10,000 t of waste processed.

While recycling remains a relatively small employer in Australia, the report makes clear the environmental benefits of recycling are considerable. In total, the report estimates recycling generate approximately 241,000,000 GJ-equivalent of energy savings. This is enough energy to power around 5 million homes.

A summary of the barriers impeding greater recycling put a lack of investment in recycling and limited infrastructure as the primary challenges facing the sector. A lack of business recycling uptake, the distance of materials to markets and consumer behaviour are also key barriers.

More information: http://bit.ly/RecycleReport ■

Tas EPA approves first hazardous landfill

Tasmania is set to get its first Category C landfill licenced to take hazardous waste, with the hope of getting rid of materials previously stockpiled or sent interstate.

Southern Waste Services – a conglomerate run by Kingborough, Sorell, Clarence City and Tasman councils – will build the proposed $10 million new landfill project. The group hope to build the facility at the Copping landfill site, which has been operating as a Class B landfill since 2002. The Copping landfill is located about 50km east of Hobart near Marion Bay.

With a proposed void capacity of 300,000 cubic metres, the site recently received approval from the Tasmanian EPA. The site would cover about 2.5ha on the 707ha site, which is currently a former quarry.Major hazardous wastes waiting for a home in Tasmania include 200,000 tonnes of Jarosite from Nyrstar's zinc smelter in Hobart, but the site will also receive a range of hazardous wastes including acids, alkalis, inorganic and organic chemicals, paints, solvents, pesticides, oil, clinical wastes and industrial sludges. See ***Using groundwater interception systems*** on pages 24-28 for a case study on remediating groundwater contaminated by heavy metals emanating from the smelter.

More information: http://bit.ly/TASEPAhazwaste ■

'Plastic Oceans' - a Catalyst report

A plastic bag outlives its usefulness after around 15 minutes. A plastic bottle might last a little longer, party balloons a whole occasion. But the ocean likes to hang onto these discarded treasures for decades, even centuries – giving many other consumers a taste for plastic. Of concern is the prevalence of plastic being found in birds, in some cases representing up to 8% (the equivalent of a person carrying 3 - 5 kg of plastic in their stomach). It's estimated that 3.5 m pieces of new plastic enter the world's oceans daily. Carried on global currents, they accumulate in huge circulating gyres causing countless injuries to marine life along the way.

A nationwide study to tackle these questions, and is the first time marine debris has been assessed on such a huge scale. To fill in information gaps CSIRO is joining forces with Earth Watch and training up volunteers.

Mercury is just one of the many toxic contaminants found in and on plastic debris. Aside from death, mercury can cause a wide array of effects from

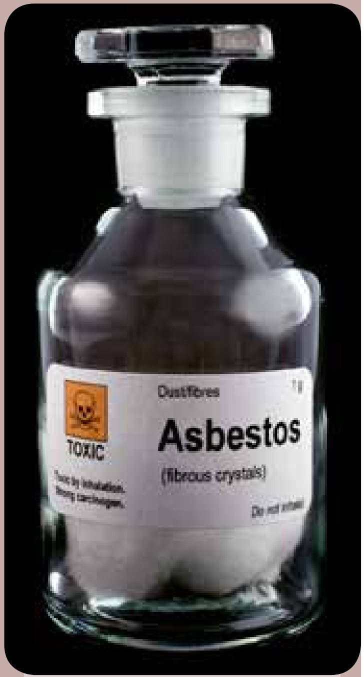
INSET A plastic bag can spend centuries in the ocean.

neurological damage to infertility. It is estimated that fish in the North Pacific now consume up to 24,000 t of plastic a year. As one predator eats another contaminates biomagnify. This means the most vulnerable animal to the effects of toxic plastic contamination is the one at the very top of the food chain: us. With each one of us contributing around 67 kg of plastic waste a year, avoiding single use plastics can make an enormous difference to the environment and ultimately are own wellbeing.

More information: http://bit.ly/CatalystPlastic ■

Asbestos takes its toll

Children who spent their childhoods exposed to asbestos in the north-west of Western Australia are now developing a range of cancers or dying at a rate well above the average population, according to a new study by researchers from The University of Western Australia.



A new asbestos study is looking at the long-term health of children exposed to asbestos in WA.

Mining of the potentially deadly blue asbestos at Wittenoom, 1106km north of Perth, ceased in 1966 and the town was later closed after airborne fibres in dust from mining operations were found to cause malignant mesothelioma, lung cancer, asbestosis and other serious diseases.

While data collection has previously looked at asbestos-related diseases caused by occupational asbestos exposure among men (either working in asbestos mining towns or using asbestos products), this study is the first to look at the long-term health of children exposed to asbestos at Wittenoom.

The study, published in the ***American Journal of Industrial Medicine***, shows that girls who lived in Wittenoom up to the age of 15 have been more likely to develop mesothelioma, ovarian and brain cancers and have had increased death rates. Boys who spent their childhood and early teenage years in Wittenoom during the years that asbestos was mined (1943-1966) now have elevated rates of mesothelioma, leukaemia, prostate, brain and colorectal cancer, diseases of the circulatory and nervous system, and excessive death rates.

These 'Wittenoom kids' are now reaching the age where chronic adult diseases are becoming more prevalent and many have died.

More information: http://bit.ly/Wittenoom ■

Action needed to reduce hazards from chemicals

Coordinated action by governments and industry is urgently needed to reduce the risks to human health and the environment posed by the unsustainable management of chemicals worldwide, according to a new report by the United Nations Environment Programme (UNEP).

These risks are compounded by the steady shift in the production, use and disposal of chemical products from developed countries to emerging and developing economies, where safeguards and regulations are often weaker, says the report.

UNEP's recently released Global Chemicals Outlook highlights the major economic burden caused by chemical hazards, particularly in developing countries. Sound chemicals management can reduce these financial and health burdens, improve livelihoods, support ecosystems and reduce pollution.

The release of the report - the first comprehensive assessment of its kind - follows renewed commitments by countries at the Rio+20 summit in June to prevent the illegal dumping of toxic wastes, develop safer alternatives to hazardous chemicals in products, and increase the recycling of waste, among other measures.

The Global Chemicals Outlook lays out other specific recommendations for countries, corporations and civil society to accelerate progress towards the 2020 goal, and ensure the sound management of chemicals. More information: http://bit.ly/UNEPchemreport ■

US funds Agent Orange clean-up in Vietnam

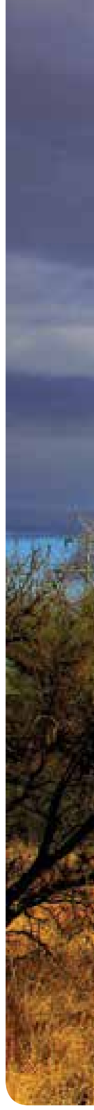
During the Vietnam War, what's now known as Da Nang International Airport was a major storage depot for Agent Orange. This was the name used for one of the powerful herbicides and defoliants used by the U.S. military in herbicidal warfare against opposing forces. Da Nang is just one of 28 former US Military bases that were contaminated with toxic chemicals that continue to pose a health risk.

America's International Development agency,USAID, has committed more than $40 million to help clean up the remains of Agent Orange at Da Nang Airport.

Charles Bailey (director, Aspen Institute's Agent Orange in Vietnam Program): It's now 37 years after the end of the war, but the harmful affects of dioxin contamination left by the spraying of Agent Orange is still being felt by millions in Vietnam, including children. But recent progress has created a window of opportunity for the US symbolised by this groundbreaking next week for the US to intensify its effort and ensure its commitment to reduce the public health impact in Vietnam.

Agent Orange was one of a class of herbicides that the US military used during the 1960s in Vietnam. It destroyed, it was a defoliant, it destroyed the vegetation over large areas, but along with it came this contaminant dioxin and this is the source of today's concern. Dioxin is highly poisonous.

Listen to this report at ABC Radio Australia: http://bit.ly/ABCAgentOrange ■



Landfilling the energy gap

Nanthi Bolan, Balaji Seshadri and Ramya Thangarajan

While landfilling provides an economic means of waste disposal, if not managed properly, it can degrade the environment through the release of contaminants. The major environmental challenges associated with the sustainable management of landfills are surface water and groundwater contamination, and greenhouse gas (GHG) and odour emissions.

Landfills as a biorefinery

Safe waste disposal is one of the major environmental issues facing society today, and landfills – sites developed for the disposal of waste material, which is usually buried and covered with soil – provide the most economical and simple means of disposing waste globally. For example, in Australia, the majority of municipalities have been managing landfill sites for waste disposal, with more than 2,000 landfill sites estimated nationwide. Despite a significant increase in the reduction, reuse and recycling of solid waste, disposal to landfill will inevitably remain the most widely used waste-management method.

In recent times many local governments have introduced engineered landfills with gas recovery systems, which aim to capture methane (CH_4) as a fuel source. Increasingly, revegetation (i.e. 'phytocapping') is practiced in traditionally managed landfill sites to mitigate the environmental impacts resulting from leachate generation and GHG emissions. Revegetation also provides a major source of biomass for energy production, making such landfill sites potential locations for biorefineries – facilities that process and convert biomass into products such as fuels, power, heat and useful chemicals. This article provides an overview on the role of landfills as potential biorefinery sites for biomass production and harnessing CH_4 as a fuel source.

Revegetation technology to manage landfill sites and to produce biomass

The primary objective of landfill design and management is to contain waste materials and limit off-site transport of dust and leachate. Traditionally, landfill covers have been designed to minimise water entry through the use of low permeability layers (e.g. compacted clay caps and geosynthetic liners). However, often this is not achieved because, as landfills age, cracks form due to drying and wetting cycles. Therefore, constructed caps are vegetated to prevent exposure and degradation of the clay barrier. Even though the primary management goal is to develop vegetation cover to increase evapotranspiration and prevent cap exposure, high-yielding plant species may be established, as long as adequate rooting substrate is maintained.

Increasingly, phytocaps are being considered for use at a range of waste-disposal sites in many countries, including Australia. This alternative technology enhances the aesthetic qualities of landfills, many of which are adjacent to urban communities. It also introduces economic benefits such as biomass generation for energy, timber and fodder. Biomass feedstocks can be grouped into four general categories (see far right).

The production of biofuel feedstock needs to address long-term ecological sustainability, reduction in production costs, and production on a large scale using non-agricultural crops and sites that are not used for agricultural production. However, some agricultural crops can be grown on landfill sites if they target bioenergy production and thereby negate any threat to food security or pressure on agricultural lands.

The type of biomass required for industrial energy production is principally determined by the energy conversion process and the form in which the energy is

FIGURE 1 Irvington Generating Station. Operated by Tucson Electric Power, the station produces electricity by fossil fuel combustion. The fuels used consist of coal, natural gas, liquid fuel and landfill gas. SOURCE Bill Morrow http://bit.ly/FlickrBillMorrow

"Revegetation provides a major source of biomass for energy production, making landfill sites potential locations for biorefineries – facilities that process and convert biomass into products such as fuels, power, heat and useful chemicals."

required. Numerous plant species have been tested for commercial energy farming internationally. Perennial grasses/herbaceous plants in particular may be suitable for biomass production on closed landfill. The C_4 plants, such as *Miscanthus*, switchgrass and Napier grass have been proposed as the main perennial grass species for energy production because of their high photosynthesis rates (plants exhibit two main photosynthetic pathways, known as C_3 and C_4, with the latter being more efficient and characteristic of higher-biomass plants). In addition to grasses, woody plants could also be used for biomass production on closed landfill sites with purpose-built phytocaps. An ideal energy crop for a landfill site should have high yield and low nutrient demand, and require low input for maintenance and harvesting.

Technologies for biomass conversion to energy

Biomass can be converted into fuels and carbon-based products by biochemical and thermochemical methods (see Figure 1). Thermochemical routes of biomass

THE FOUR BIOMASS FEEDSTOCKS CATEGORIES

ENERGY CROPS
herbaceous and woody crops, industrial crops, agricultural crops and aquatic crops

AGRICULTURAL RESIDUES AND WASTE
crop waste and animal waste

FORESTRY WASTE AND RESIDUES
mill wood waste, logging residues, tree and shrub residues

INDUSTRIAL AND MUNICIPAL WASTES
municipal solid waste, sewage sludge and industry waste

Some of these may be produced on landfill sites and can be used in generation of heat or electrical energy, or as transport fuels in the form of solid (e.g. wood), liquid (oil seeds) or gas.

FOUR BENEFITS OF LANDFILL GAS CAPTURE-AND-COMBUSTION PROJECTS

Improved groundwater quality resulting from effective leachate collection and disposal

Improvement of air quality through burning less coal for electricity generation and reduction of LFG released into the air

Reduced risks of dangerous CH_4 gas concentrations

Reduced exposure of residential areas to unattractive odours

conversion are more attractive and have certain advantages, including higher productivity, complete utilisation of feedstocks leading to multiple products, applicability to a wide range of feedstocks, and better control over the process relative to biochemical processes. Thermochemical conversion routes include pyrolysis, liquefaction and gasification.

Pyrolysis is the thermal decomposition of biomass to liquid (bio-oil), solid (char) and gaseous products in the absence of oxygen at 350-700°C. Based on the operating temperature and residence time, the process is known as slow pyrolysis, intermediate pyrolysis, or fast/flash pyrolysis. In slow pyrolysis, heating of biomass takes place at slow heating rates (5 - 80°C/min) and long residence times (600-6000 s) and results in higher char yield compared with high heating rate (1000°C/min) with extremely short residence times (0.5-5 s) in fast pyrolysis. The liquid yield in slow pyrolysis is low (30%) compared with fast pyrolysis (75%). Hence, commercial pyrolysis units adopt fast/flash pyrolysis to maximise bio-oil yield and produce biochar. Since biochar has an estimated longevity of 100 to 1000 years in soil, it can be considered as a significant means for sequestration of CO_2 from the atmosphere to the soil.

Thermochemical liquefaction (TCL) is the conversion of biomass in sub/supercritical water reactions. TCL resembles the pyrolysis process in some ways, where biomass is heated in an oxygen-free atmosphere in the presence or absence of a catalyst that enhances the hydrolysis, depolymerisation and condensation reactions to produce bio-oil (also called bio-crude) as the major product along with gases, water solubles and char as co-products. However, unlike pyrolysis where the biomass conversion takes place at near or slightly above atmospheric pressure, in TCL, biomass is converted at significantly higher pressures (5 to 40 atm) and lower temperatures (280-370ºC). A key difference is that TCL can process wet biomass without drying and is therefore energetically more efficient than pyrolysis.

Bio-oil produced from TCL is usually a dark brown, viscous liquid that has a distinctive odour similar to pyrolysis bio-oils and is a complex mixture of oxygenated hydrocarbons and water from the original biomass. The major constituent in TCL gaseous products is CO_2 (>70%) with traces of CO, H_2, CH_4, C_2-C_4 gases, NH_3 and H_2O. Char can be used as high-value products such as soil conditioner.

Gasification is the conversion of biomass into a combustible gaseous fuel by partial oxidation of biomass at high temperature in the range of 800-900ºC. The process can take place in air, oxygen or steam as the reaction medium. The resulting gas, known as producer gas (or syngas), is a mixture of CO, CO_2, H_2, CH_4 and N_2 gases. The gas is more versatile than the original solid biomass, and can be burnt to produce heat and steam, or used in internal combustion engines or gas turbines to produce electricity. Gas quality and composition can vary depending on the gasifying agent, the method of operation, operating conditions and biomass composition and properties.

Methane capture as a fuel source

Landfill gas (LFG) recovery, although an expensive technology, is being implemented and adopted in many developed countries, including Australia. Feasibility of LFG system greatly depends on which gases, and how much CH_4, are emitted by the landfill. In recent years in Australia, LFG projects have increased in number and production, from only 15 projects in 1998 to 42 in 2005, with a total electricity output of 103 MWh. Similarly, in the US, there has been a dramatic increase in the number of projects aiming to convert LFG to energy. In 1999 there were 300 operational facilities, which

FURTHER READING

Bolan, NS, Thangarajan, R, Seshadri, B, Jena, U, Das, KC, Wang, H & Naidu, R 2012, 'Landfills as a biorefinery to produce biomass and capture biogas', *Bioresource Technology* (accepted manuscript) doi: 10.1016/j.biortech.2012.08.135

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increased to 555 facilities in 2010 producing approximately 14 TWh electricity.

Global CH_4 emissions from landfill are estimated to be in the range of 9-70 m t/yr. Introduction of CH_4-capture cap designs, where LFG is collected and combusted either as a source of electricity or disposal, is likely to reduce CH_4 emissions by approximately 5 m t/yr. Capturing LFG helps to reduce odours and other hazards associated with LFG emissions, and reduces the contribution of CH_4 to global climate change. Furthermore, combustion of LFG for the production of energy contributes to GHG emission reduction in two ways. LFG capture prevents the release of CH_4 into the atmosphere (as a GHG, CH_4 is 25 times as powerful as CO_2) and the electricity subsequently produced by LFG combustion produces less CO_2 than conventional fossil fuel combustion.

LFG is often extracted from landfills using a series of wells and a blower/vacuum system. This system directs the collected gas to a central point where it can be processed and treated according to its ultimate use. From this point, the gas can be flared, used to generate electricity, replace fossil fuels in industrial and manufacturing operations, upgraded for direct use, or processed into an alternative vehicle fuel.

Due to economic and infrastructure constraints, only a small fraction of landfill CH_4 is harvested and used for electricity production. Although LFG capture and use has been widely practiced in developed countries, its application in developing countries could be limited by a number of factors, including lack of legislation enforcing LFG extraction with or without utilisation, unfavourable financial performance to attract investment funding, and lack of technology know-how and infrastructure.

Filling the energy gap

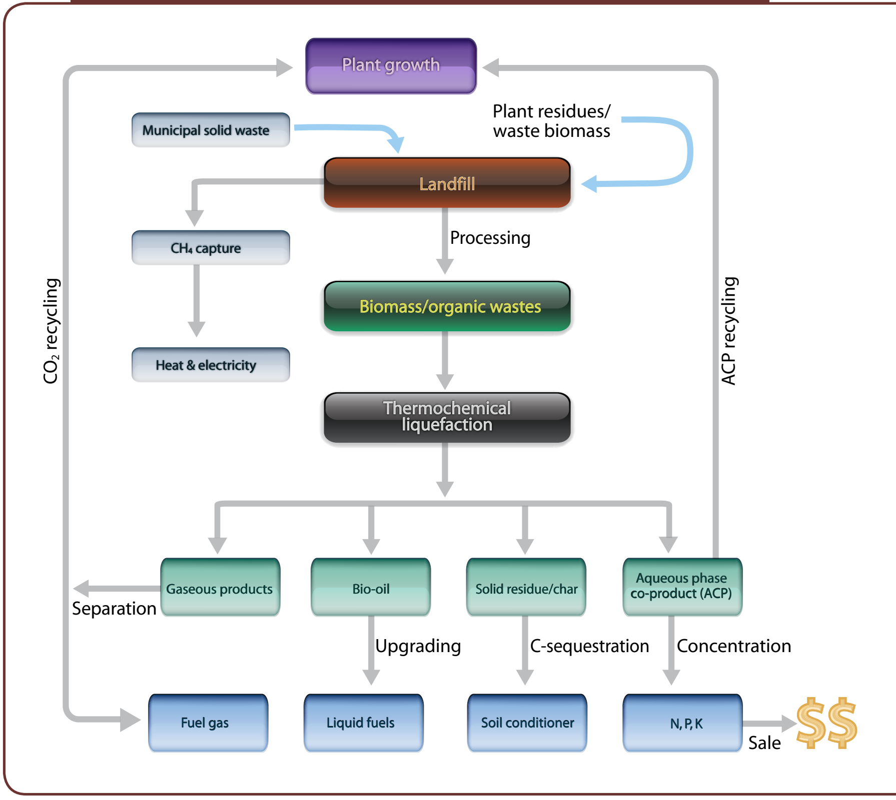
While the primary objective of phytocapping landfill sites is to mitigate leachate generation, this technique can be used to revegetate the area with endemic plants species for the creation of a natural ecosystem and to produce biomass for energy production.

Although the potential landfill area available for biomass production is relatively small compared with other marginal and degraded lands such as mine sites, landfill sites are readily accessible, thereby providing an attractive option for biomass production. Biomass from landfill sites can be converted to energy through various processes including pyrolysis, gasification and co-generation.

Landfills with gas-recovery systems can be used to capture CH_4 as a fuel source. LFG capture is likely to contribute to a number of environmental and social benefits including improved groundwater and air quality, reduced risks of CH_4 gas emissions, reduced exposure of residential areas to odour, and improved local employment opportunities and community programs. ■

This article is a condensed version of the resource paper: Bolan et al. 2012, 'Landfills as a biorefinery to produce biomass and capture biogas', Bioresource Technology (doi: http://dx.doi.org/10.1016/j.biortech.2012.08.135); further details can be found in the reference list at the bottom of the page.

FIGURE 1 Conceptual biorefinery for production of fuels and value-added co-products from landfill waste via TCL, along with carbon sequestration.



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Trash and treasure:

Mining landfills for energy and more

Paul Clapham, SKM Consulting

With its origin in the domestic midden, landfill represents the oldest method of dealing with the waste from human societies. However, landfill is increasingly being seen as the least desirable option for managing our waste. The waste hierarchy (Figure 1) favours higher-order management options as such waste prevention, reuse of waste materials, recycling, and energy recovery in preference to landfilling. In response to this, many nations have adopted (or are in the process of adopting) legislation that requires the pre-treatment of waste before its disposal to landfill. For example, the European Union's Landfill Directive requires the pre-treatment of waste sent to landfill within its member states (e.g. the United Kingdom, the Republic of Ireland, Germany, France, etc.). Some countries (e.g. Sweden), as well as some municipalities in North America, have banned the landfilling of organic waste and/or recyclable materials such as metals, plastics, paper and glass. Nevertheless, it can be argued that there is a place for landfill as part of an integrated waste management solution. In some circumstances, such as remote communities, landfill can represent the best practicable environmental option for the management of waste. The rationale for this is that the carbon impact of landfilling of recyclable materials produced by remote communities is significantly less than that of transporting the materials to distant reprocessing plants.

A range of alternative waste treatment technologies (AWTs) enable the recovery of recyclable materials and organic waste from mixed waste streams. For example, mechanical biological treatment (MBT) is a generic term for various combinations of sorting and separation technologies that extract recyclable materials (including metals, cardboard, plastics, glass and other inert materials) from the organic fraction of municipal solid waste (MSW) and commercial and industrial (C&I) waste streams. The separated organic fraction is either composted to produce a 'compost like output' (CLO), or alternatively it can be processed via anaerobic digestion (AD) which produces biogas – a methane rich fuel that can be burnt in an internal combustion engine or furnace to produce electricity. The CLO and digestate (the semi-solid material left over in the AD reactor once the process has completed) can be used to restore brownfield sites.

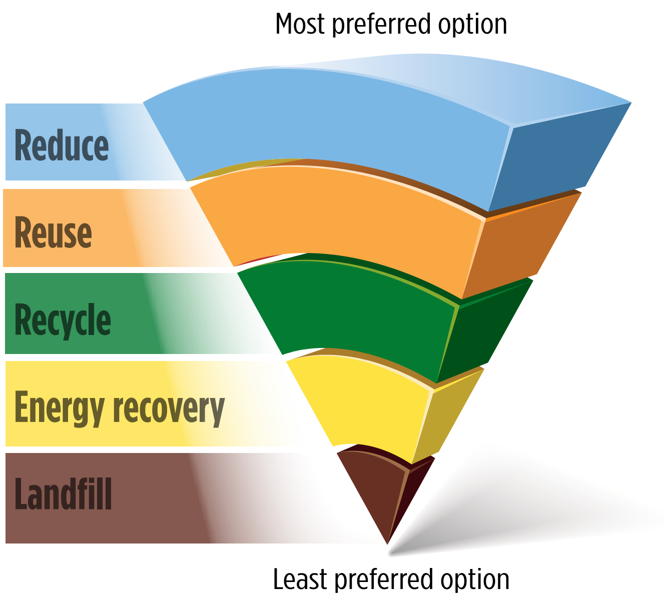
Other forms of AWTs include the advanced thermal technologies pyrolysis and gasification. The pyrolysis process thermally degrades organic waste and plastics in the absence of air or oxygen to produce synthesis gas ('syngas') which is rich in hydrogen and methane. Gasification uses higher temperatures and sub-stoichiometric quantities of air, oxygen or steam to produce syngas from organic materials. Plasma gasification is a technology that is starting to be used to recover energy from mixed waste streams through syngas production, whilst facilitating the recovery of metals and an inert slag from the inorganic fraction of the waste.

The use of AWTs means that only residual materials are sent to landfill, thereby helping to reduce society's impact upon the environment in terms of mineral extraction whilst maximising the remaining void space in existing landfills. However, over a century of landfilling industrial and municipal waste has left us with a legacy of scattered sites, which in many cases represent environmental hazards, but at the same time can be considered treasure troves of previously used resources.

This article is the first of a series of three that considers landfill and landfill mining (i.e. the recovery of energy and resources from landfills) in the context of sustainable materials management.

The Organisation for Economic Co-operation and Development (OECD) Working Group on Waste Prevention and Recycling has defined sustainable materials management (SMM) as an approach to promote sustainable materials use, integrating actions targeted at reducing negative environmental impacts and preserving natural capital throughout the life cycle of materials, taking into account economic efficiency and social equity. The first policy principle of SMM is to preserve natural capital; the second is to design and manage materials, products and processes for safety and sustainability from a life-cycle perspective. At face value, SMM appears to have little in common with the landfilling of waste. However, if one considers landfills as potential repositories of resources, then their exploitation through landfill mining can help satisfy the first policy principle of SMM; the better management of recovered resources through the

FIGURE 1 The waste hierarchy



production and consumption life-cycle (Figure 2) can help satisfy policy principle 2.

Before considering landfill mining in detail, it is important to understand the history of landfilling, and how the age and composition of a landfill influence its value in terms of the resources that it may contain. Up until the mid-1970s, landfills (even within developed nations in Europe and North America) were unsophisticated affairs that bore closer resemblance to dumpsites than designated waste management facilities. In traditional societies, the contents of dumpsites were largely of organic origin and the material decayed over time releasing the greenhouse gases carbon dioxide (during the aerobic phase) and methane (during the anaerobic phase). Other environmental issues included odour problems from the decaying matter, and the production of a liquid leachate with a high biochemical oxygen demand (BOD) that was capable of adversely affecting water quality in the local area.

By contrast, a modern sanitary landfill is typically a well-engineered facility that is lined either with clay or a geosynthetic membrane to prevent the contamination of groundwater; and is equipped with extensive collection and treatment systems for leachate and landfill gas. Many large landfills in Europe and North America are now substantial generators of renewable energy from the combustion of landfill gas (which is rich in methane), produced by the decomposition of the organic matter in the waste (also see 'Landfilling the energy gap' on p. 8). The collected landfill gas is burnt in dedicated gas engines on site to produce electricity which is exported to the grid.

Over time, the range of wastes that have been landfilled has varied, reflecting our changing culture. The industrialisation of society has led to the production and disposal of industrial wastes (many of which are toxic), as well as changes in the composition of the municipal waste stream (i.e. waste that is collected from households and similar properties by councils). In the past it was common practice to dispose of both municipal wastes and industrial wastes (including liquid wastes) in the same landfill – a process known as co-disposal. Much of this disposal of waste was unregulated and led to significant local environmental and health impacts.

Reforms in landfill practices have been gradually introduced in North America, Europe, and other parts of the world over the course of the last 30 years, which has meant that liquid wastes are now either treated or solidified before being sent to landfill and MSW and C&I waste are either sent to different categories of landfill, or are deposited into separate cells within the same landfill. Thus, older landfills typically contain a wide variety of waste materials that have been deposited in an unstructured way; whereas more modern landfills generally contain wastes that are more consistent in character – though the composition of different municipal waste streams can vary considerably between different councils within the same country.

In its simplest form, landfill mining can take the form of scavenging – a practice that is all too common in developing countries. Health and safety risks alone make the scavenging of landfills an unacceptable practice, but it can be difficult to outlaw such activities where local employment opportunities are limited, and there is insufficient resource available to enforce local laws and regulations forbidding such activities.

"In its simplest form, landfill mining can take the form of scavenging – a practice that is all too common in developing countries. …At the other end of the spectrum, industrial technologies can be applied to the mining of landfills."

At the other end of the spectrum, industrial technologies can be applied to the mining of landfills. In its most developed form, landfill mining recovers more than just energy from the decaying waste. The true purpose of landfill mining is to maximise resource recovery from both closed and operational landfills. The re-opening of a closed landfill can be problematic. In older landfills, the distribution of different waste types within the landfill mass can hamper the efficient recovery of valuable materials from the waste mass; the disturbance of the waste material can cause health, safety, and environmental issues. Where there is no documentary evidence about the waste that was deposited in a landfill, it is good practice to investigate the waste mass using bore holes or sample pits, to build up a picture of the waste present in the landfill before mining commences.

The extraction of the waste material from the landfill can be achieved through the use of mechanical diggers which feed a combination of sorting and separation equipment to recover metals, and separate out the dense inorganic material such as builder's rubble, stones and glass. The quality of the plastics that are recovered from landfill is usually poor, making them unsuitable for recycling. This material is usually added to the recovered organic fraction (which may include partially decomposed paper, cardboard, wood and woody vegetation) to produce a waste-derived fuel that is fed into an energy recovery plant.

There is a variety of energy from waste processes that can be used to process material recovered from a landfill. Combustion plants using reciprocating grates are the mainstay of the energy from waste industry. Modern energy-from-waste plants are complex facilities that control the combustion of the waste to minimise the production of furan and dioxins. while acid gases and heavy metals are removed from the flue gases using a variety of clean-up equipment including lime injection, bag filters and electrostatic precipitators. The residues from the combustion process are

- incinerator bottom ash (the burnt material that is left on the grate after it has passed through the combustion chamber)
- fly ash (the fine-grained material that is carried through by the combustion gases), and
- air pollution control residues, that are usually highly caustic due to the use of an excess of lime to neutralise the acid gases.

More recently, plasma technology has been applied to landfill mining. This process treats the recovered waste at temperatures in excess of 2,000°C which vaporises the organic material in the waste (both the plastics and the vegetable matter) to produce a hydrogen-rich syngas which is combusted to produce electricity. The metals present in the waste melt to form a pool of molten metal that can be tapped off. The various metals can then be separated out using metallurgical processes. Any inorganic matter present in the waste fed to the plasma gasifier becomes a vitrified slag that has a low leaching potential and can be used as a construction material, engineering fill or road base.

The increasing scarcity of certain resources (such as semi-precious metals that are used in computer circuit boards and other electronic equipment) as well as rising energy costs will help to stimulate further interest in landfill mining. In addition, landfill mining has the potential to help restore degraded land for productive use, as well as cleaning up environmental problems due to poor waste management practices in the past.

The next article in this three-part series will take a more detailed look at the technologies that are used to mine landfills, whilst the final article will consider the concept of enhanced waste management – an approach that considers the use of landfills as temporary stores of materials until economic conditions or technological advances make their recovery viable. ■

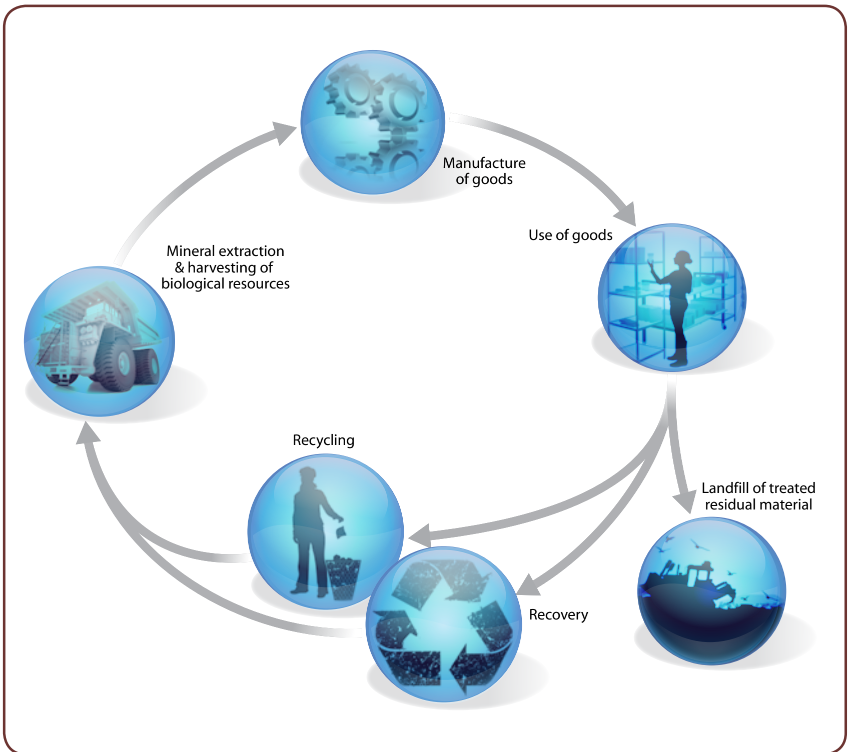


FIGURE 2 The production and consumption life cycle

Using your conceptual site model:

What to consider when developing your sampling and analysis plan

Ruth Keogh and James Corbett, Parsons Brinckerhoff

The development of a sampling and analysis plan (SAP) is the first step in the implementation of an intrusive investigation program to assess whether contamination is present at a site on which potentially contaminating activities have occurred. Every SAP must include clear objectives and should detail information such as sampling patterns, locations and depths, appropriate field methodologies, laboratory analytical programs and procedures, and quality assurance/quality control (QA/QC) requirements.

To ensure that a SAP provides the best possible chance of encountering any contamination present at the site, it is essential to base this plan on the foundation of knowledge obtained during the site characterisation and historical investigation program[1], and refined via the development of the preliminary conceptual site model (CSM).[2] A CSM is a written or a pictorial representation of an environmental system and the biological, physical and chemical processes that determine the transport of contaminants from sources through environmental media to environmental receptors in the system[3] (ASTM International E1689-95 (2008) Standard Guide for Developing Conceptual Site Models for Contaminated Sites).

As with the development of a CSM, intrusive site investigation may prove to be an iterative process if contamination is present, and a SAP should therefore be developed for each stage of work, taking account of the results obtained during any preceding stages.

To develop an appropriate SAP, it is important to consider the following issues on a site-specific basis. It is also prudent to allow some flexibility once field personnel are deployed, field conditions are better understood and professional experience and judgement can be brought into play.

What are your objectives?

Establishing clear objectives is a fundamental first step and should take account of factors such as client requirements, current and future land uses and the phase of work underway. For example, the requirements of an initial site investigation program may vary substantially to those of a validation program undertaken subsequent to remediation whereas in the latter stages of site investigation (when remediation is likely to be required) it is also important to collect additional site data (e.g. geophysical properties) relevant to remediation design.

To this end, the data quality objective (DQO) process (as defined by US EPA (2000)[4] and discussed in Standards Australia (2005)[4]) can provide valuable assistance in structuring an investigation program such that relevant questions are posed at the start, an appropriate SAP is developed and optimal data are obtained. A DQO also helps organise a complex problem into a series of more manageable problems.

FURTHER READING

[1] Keogh, R & Corbett, J 2012, 'Developing a comprehensive conceptual site model: What should you be looking for and where?', *Remediation Australasia*, Issue 8

[2] Keogh, R & Corbett, J 2012, 'Developing a comprehensive conceptual site model: Using your site history information effectively?', *Remediation Australasia*, Issue 10

[3] ASTM International 2008, *Standard Guide for Developing Conceptual Site Models for Contaminated Sites*, E1689-95..

[4] US EPA 2000, Guidance for the *Data Quality Objectives Process QA/G-4*, EPA/600/R-96/055, Office of Environmental Information, Washington DC.

[5] Standards Australia 2005, *Guide to the Sampling and Investigation of Potentially Contaminated Soil Part 1: Non-Volatile and Semi-Volatile Compounds*, Australian Standard AS4482.1-2005, Sydney, New South Wales.

Which samples should you submit for laboratory analysis, and what should you analyse for?

The nomination of samples for laboratory analysis, and the choice of appropriate analytes, can be based initially on the results of the site history investigations and preliminary CSM, with consideration given to the following:

- likely sources of impact (surface vs. subsurface chemical application/release)
- possible preferential migration pathways (media and depth(s) most likely affected)
- likely contaminants of potential concern/behaviour (e.g. persistence, mobility) and possible breakdown products of individual chemicals, and/or
- data requirements for remediation design (including geophysical requirements).

Field conditions will also play a pivotal role in refining the analytical program. Factors such as the presence of imported fill material(s), inclusions of foreign bodies capable of causing contamination (e.g. asbestos or ash/cinders/slag), abnormal field parameter (e.g. photoionisation detector or water quality) results, and visual or olfactory evidence of contamination (e.g. odour, staining) should prompt sample selection for relevant analyses and may result in the modification of the original SAP.

What should you look for and where should you look?

There are a number of strategies that have been developed to maximise the efficiency and robustness of sampling programs, including accelerated site characterisation techniques which advocate the collection of large volumes of low-resolution data to provide good spatial coverage of a site, rather than just high-resolution data at limited sampling points. Whichever sampling strategy is employed will be highly dependent on site characteristics and project objectives. Factors such as relevant media, appropriate sampling patterns (e.g. random, targeted/judgemental, stratified and/or systematic), locations and depths should be identified based on the results of the previous site characterisation and historical investigations, as well as the preliminary CSM, taking into account the following:

- site area
- confirmed and/or likely contaminant source locations, as identified from:
  - locations and types of current and former site infrastructure and other relevant features
  - current and former site activities
- likely soil profile, depth to groundwater and the nature of the aquifer(s) underlying the site
- possible preferential contaminant migration pathways, and
- potential receptors, exposure pathways and routes.

Consideration should also be given to obtaining background data in order that regional conditions can be defined and naturally occurring substances identified.

For subsequent site assessment programs, the project objectives (e.g. delineation of previously identified contamination, validation of excavated areas and/or collection of data for remediation design) as well as available field and laboratory data will play a strong role in determining the scope of the sampling program.

How should you ensure that appropriate field methodologies and QA/QC procedures are adopted?

Guidance on relevant field methodologies and QA/QC procedures is available in a number of publications relevant to Australian conditions, including (but not necessarily limited to):

- *Australian/New Zealand Standard (1998) Water Quality Sampling, Part 1: Guidance on the Design of Sampling Programs, Sampling Techniques and the Preservation and Handling of Samples*. AS/NZS 5667.1:1998
- Department of Environment (1998) *Draft Guidelines for the Assessment & Management of Contaminated Land in Queensland*
- Department of Environmental Protection (2001) *Development of Sampling and Analysis Programs. Contaminated Sites Management Series*
- EPA Victoria (2000) *Groundwater Sampling Guidelines*
- National Environment Protection Measure (1999) *National Environment Protection (Assessment of Site Contamination) Measure: Schedule B(2) Guideline on Data Collection, Sample Design and Reporting*
- South Australian Environment Protection Authority (2007) *Regulatory Monitoring and Testing Groundwater Sampling*
- Standards Australia (2005) *Guide to the Sampling and Investigation of Potentially Contaminated Soil Part 1: Non-Volatile and Semi-Volatile Compounds. AS4482.1-2005*

The choice of appropriate field techniques should be primarily aimed at collecting representative and reproducible data. To this end, the selection of field sampling techniques will be largely dictated by a combination of the project objectives, field conditions, nature of contaminants, likely extent of impacts, required data and professional judgement. QA procedures should include the following (as a minimum):

- employment of trained and experienced personnel in the field
- recording of detailed field notes, including soil logs, well construction information and water purging/sampling records
- use of dedicated sampling equipment or decontamination of sampling equipment prior to, and between, the collection of individual samples
- calibration of field instruments and recording of calibration data
- correct location of proposed sampling points, in accordance with SAP plans, adjusted as required on the basis of field conditions and observations
- recording of individual sampling locations (e.g. GPS co-ordinates, surveying)
- unique identification of individual sampling locations and samples
- use of laboratory-supplied sample containers with appropriate preservatives (where required)
- collection of QC samples in accordance with rates stipulated in relevant standards or guidelines, including blind coded field duplicate and triplicate (spilt) samples and blanks (equipment rinsate, trip, field and container)
- appropriate sample preservation following collection and during transport
- transportation to analytical laboratories within specified analyte holding times and using chain-of-custody documentation
- selection of analytical laboratories that are accredited by the National Association of Testing Authorities for the selected analytes, and
- stipulation of required analytical parameters, including laboratory detection limits (i.e. taking account of relevant screening criteria and/or remediation goals) and analytical procedures.

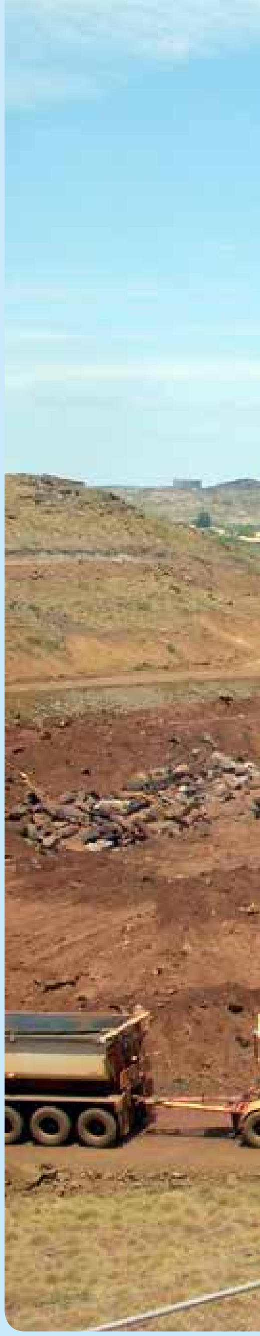
In addition to the above, consideration should also be given to obtaining any necessary permits or clearances, as well as developing an appropriate health, environment and safety plan prior to attending the site.

The Standards Australia document for Australian Standard AS4482.1-2005[4] states that 'no sampling plan, however exhaustive, can completely eliminate the possibility that contaminants are present on a site – a satisfactory sampling plan is one which has an acceptable probability of detecting the presence of contaminants'. However, basing your SAP on a firm foundation of knowledge regarding the site (as defined in the CSM), rigorous planning, and adapting your approach in response to field conditions will provide the best chance of encountering any site contamination present. ■

Reducing contamination levels:

An innovative approach to relocating landfill

Michelle Cousins and Ian Brookman, Thiess Services



A remediation project in Western Australia has used a new method to chemically treat contaminated soils on-site, thereby reducing the chemical classification to a lower class. This process enabled the reclassified material to be relocated to a landfill cell. These works were the first of their kind in the Pilbara region; only a handful of similar projects have been undertaken in Perth.

A joint remediation venture between Thiess' construction and services arms, and Hicks Civil & Mining, has successfully completed a $30 million contract at the Rio Tinto Cape Lambert Port Facility. Named 'Garlanja', the venture is unique in its approach to fostering the employment and training of an Aboriginal workforce in Western Australia, and also in its approach to remediation.

Cape Lambert is one of the sea ports used to export iron ore from Rio Tinto's mining operations in the Pilbara. Rio Tinto is developing the port to more than double its annual capacity, and so Garlanja was contracted to move the existing 40-year-old Cape Lambert landfill to enable construction of the port facility's stockyards.

The landfill, constructed in the 1970s as part of the original Cape Lambert Port, needed to be relocated about 5 km from its current location. This relocation took the Garlanja team nearly 11 months to complete, during which a total of 250,000 m^3 of waste were recovered from the old landfill. The remediation and relocation works included

- the excavation of 180,000 m^3 of contaminated waste and 70,000 m^3 of non-contaminated material
- sorting and classifying of existing landfill cell contents
- bulk earthworks
- road and drainage works, and
- works to construct a new best-practice landfill cell.

The landfill contained significant amounts of asbestos, hydrocarbon and heavy metal-contaminated soils, batteries, oil drums, conveyor belt, concrete, general waste and scrap steel.

Once the waste was sorted, tested and classified, road trains hauled it to the new landfill site. The newly classified Class 1 landfill was constructed using a series of bunds and included a high-density polyethylene (HDPE)-lined Class II cell. When finished, the landfill was closed with more than 48,000 m^3 of clean material including a 1 m-thick cap. The works also included security fencing, access road construction and future cell preparation.

"This (project) avoided the transport of more than 20,000 tonnes of contaminated waste over 1,600 km to Perth for disposal at specified landfills. The technology... has set the precedent for contaminated waste management methods in the Pilbara in years to come."

During works, high-efficiency particulate air filters were fitted to all machines to filter potentially asbestos-contaminated soil. Work practices were reviewed and modified where required to provide a safe workplace. To ensure any contaminated materials were handled without risk, ongoing monitoring and sampling of groundwater, dust, fibrous building materials, hydrocarbons, gases and heavy metal particulates was undertaken throughout the excavation process.

A treatment first

Garlanja, in consultation with the client, project managers Sinclair Knight Merz, and the Western Australia Department of Environment and Conservation, proposed a method to chemically treat the class IV contaminated soils on-site. This reduced the classification of the contaminated soil containing hydrocarbons and heavy metals to a lower class and enabled the reclassified material to be relocated to the new cell. The method involved adding a proprietary blend of cementitious material and activated carbon to the contaminated soil to immobilise and stabilise the hydrocarbons and heavy metals. This avoided the transport of more than 20,000 t of contaminated waste over 1,600 km to Perth for disposal at specified landfills. The technology, along with significant savings to the client and the environment, has set the precedent for contaminated waste management methods in the Pilbara for years to come.

The project was successful on a number of fronts, including no lost time injuries on site over 67,000 work hours, and a 25% cost reduction through the use of the treatment process. Rio Tinto's head office in London commissioned an audit of the Cape Lambert Project which included all aspects of health, safety and environment. A special commendation was given by the auditors for the immobilisation works at the landfill. The works were recognised as being innovative and exceeding the scope, rather than just being compliant with the works specified. ■

Announcing the W
Remediation Austr

Back in July, we asked you for your photos of all things environmental. The photos we received from across Australia showed us how many different industries our readers come from! The winning entry was from Mark Hunter (right), with his image of a dust monitoring consultant.

As it was such a difficult competition to judge, with a spectacular array of images from stunning locations, gorgeous environmental scenes, curious images of laboratory work and a unique insight into on-site investigations, we've also included two notable entries that caught also our eye. Visit **www.facebook.com/CRCCARE** to browse even more entries.

Taken a photo lately that you'd like to share with us for publication? Flick it to **aric@crccare.com** and we can come up with a story to match for future issues.

Submitted by Prue Pettett, CDM Smith. Underground m practices will help ensure the habitat of ***Limnodynaste ornatus*** (ornate burrowing frog) will remain intact – taken during field assessments in the Emerald region fo a proposed underground mining project, which is set demonstrate how farming and mining can work togeth

Submitted by Ben McCarthy, LandCorp. An impact compactor traverses a site in the Australian Marine Complex (Henderson, WA) following geotechnical improvement works. Instead of removing acid sulfate soil, high-impact energy dynamic compaction methods minimised waste, environmental management requirements and cost. The site is now home to significant marine, oil and gas-based companies, and is critical to servicing the oil and gas fields off Australia's north-western shelf.

INNERS of the
alasia photo competition!

Submitted by Mark Hunter, JBS Environmental. This photo, taken through some piling ducts, depicts a colleague dust tracking on a job in Sydney's west.

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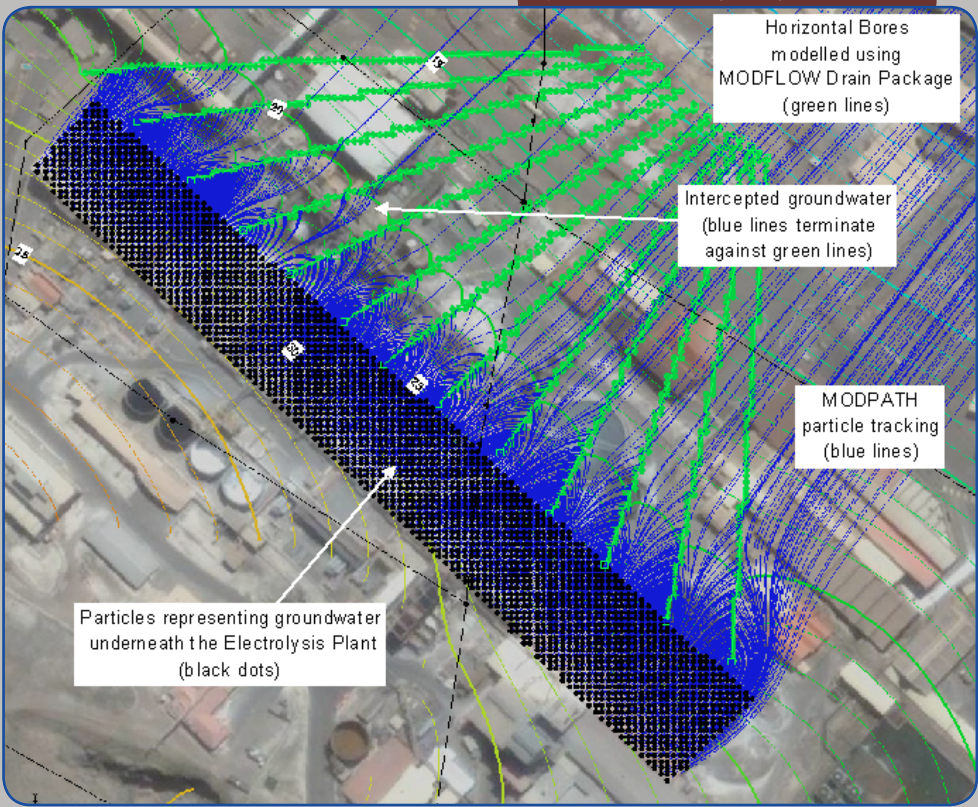
Nyrstar's Hobart zinc smelter:
Using groundwater interception systems

Barry Mann, GHD Pty Ltd

FIGURE 1 Final design layout of Nyrstar's groundwater interception system (GIS)



The Derwent estuary is a place of extraordinary natural beauty and great biodiversity. Situated at the heart of the Hobart metropolitan area, it is the largest estuary in south-eastern Tasmania, covering almost 200 km^2.

Despite the estuary's iconic status, sediments in the lower Derwent show extremely high levels of heavy metal contamination, in part as a result of the activity of the nearby zinc smelter, formerly operated by Pasminco and now owned by mining and metals company Nyrstar.

The state government-funded Derwent Estuary Program (DEP) has found that levels of mercury, lead, zinc and cadmium in sediments and aquatic (benthic) organisms exceed national guidelines, to the point that it cautioned against consuming fish from the Derwent in general, and advised against consuming shellfish altogether. While this situation has improved, Nyrstar recognised that groundwater contamination remained a major pollution and compliance issue.

Between 1996 and 2002, the majority of heavy metals entering the Derwent from the smelter were considered to be associated with diffuse, rather than point sources, and groundwater appeared to contribute the largest proportion of heavy metals. Existing pilot systems intercepted some of the heavy-metal loading in groundwater discharged to the Derwent River, but Nyrstar's groundwater interception system (GIS; Figure 1) aims to provide significant further reductions.

Responding to the need to remediate the existing contamination, in 2005-06 Nyrstar retained GHD to conduct a review of existing pilot groundwater remediation schemes, followed by detailed hydrogeological investigations in 2006-07. The latter included additional nested monitoring bores, pumping test and analysis, and hydrochemical analysis, to provide a better understanding of site groundwater conditions relevant to remediation design. Using the results, GHD produced preliminary designs for a full-scale groundwater remediation system, with key objectives of maximising metals recovery underneath the main source (the electrolysis plant) while minimising operation and maintenance requirements.

Hydrogeology

The site is located on a rocky headland, and the steep hydraulic gradient present between the electrolysis plant and the Derwent River (in the order of 0.1 to 0.2 m per metre) reflects the steep topographic gradient (Figure 3).

The estimated range of groundwater flow velocities at the site is between 70 and 150 m/year. These are relatively fast groundwater flow rates, with important implications for a groundwater remediation system, which would need to cope with transient, high-rate, low-volume groundwater conditions.

The site geology (Figure 2) is characterised by two main bedrock types: Jurassic-aged dolerite (brown coloured zone) and sandstone (green coloured zone). The two bedrock types are separated by a large fault zone which runs directly beneath the electrolysis plant. Detailed hydrogeological investigations identified horizontal layering in the dolerite. Two saturated zones were identified generally between 5-15 m, and 20-25 m depth respectively, which are separated by a massive, unsaturated layer ranging from 5 to 15 m thick. Pumping test analysis indicated shallow aquifer permeability in the order of 0.3 to 0.5 m/day. Deep aquifer permeability was approximately one third of the shallow aquifer. Importantly, testing did not indicate that the faulted zone was acting as a preferential pathway for groundwater contamination.

The dissolved zinc plume is situated directly down hydraulic gradient of the electrolysis plant (Figure 4), and extends to the Derwent River approximately 400 m away. The high levels of zinc – and to a lesser extent, cadmium and copper, which remain dissolved due to the low pH (2 to 3) groundwater – were attributed to historic and current releases from zinc sulfate as well as acid feedstock storages and pipes in the vicinity of the electrolysis plant. Dissolved zinc concentrations range from 82 to 13,700 mg/L, averaging around 7000 mg/L downgradient of the plant.

FIGURE 2 Geology of Nyrstar's zinc smelter site

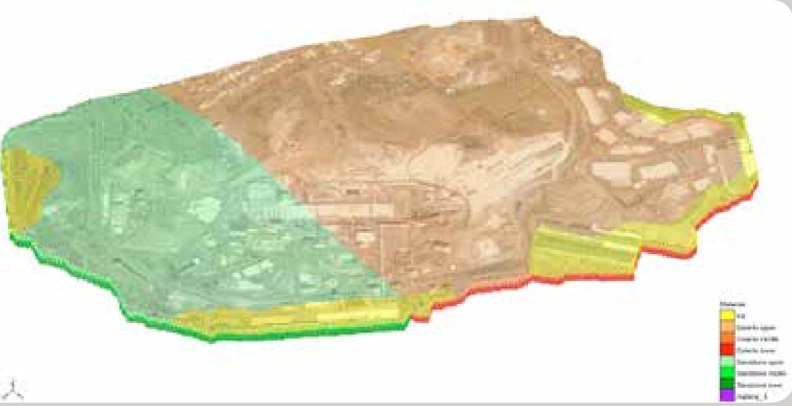


FIGURE 3 Groundwater elevation contours across the site.

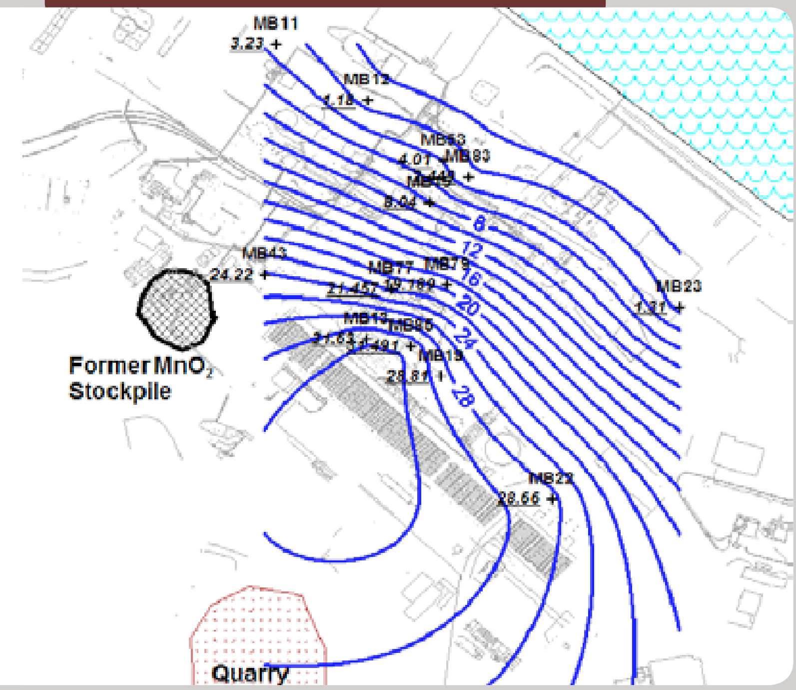
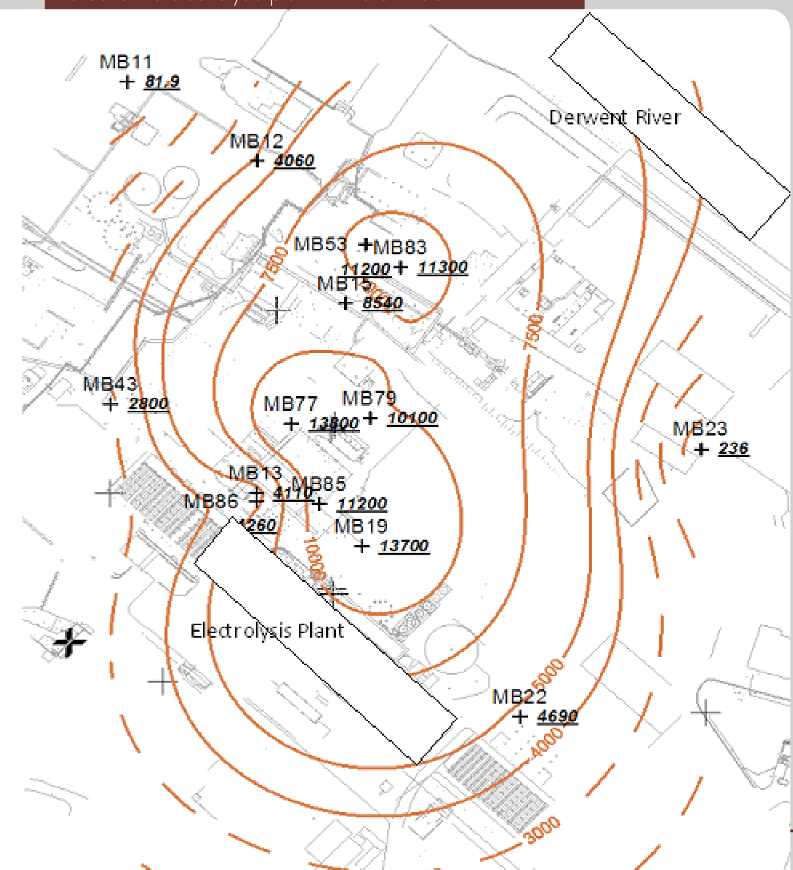


FIGURE 4 The extent of zinc groundwater contamination around the electrolysis plant in March 2007



Dissolved zinc flux to river

Based on the advective flow rates and mapped zinc concentrations, the estimated flux of dissolved zinc to the Derwent River ranged up to 130 tonnes per year. The current groundwater recovery schemes remove an approximate total range of between 40 and 70 t/yr.

Conceptual site model - conceptual system design

The conceptual system design was based on a The conceptual system design was based on a series of horizontal bores, spudded in at a location topographically lower than the electrolysis plant and terminated at a specified depth below the plant. The bores would then free-drain any groundwater intercepted beneath the plant and the bore entry point. While the concept of free-draining horizontal bores (commonly used to dewater mine pits) is not new, the key unknown construction variables which significantly influence costs are:

- how many bores are required
- how long the bores need to be, and
- how deep the bores need to be to provide effective capture of contaminated groundwater between the plant and the river.

System design modelling

To answer the above questions, a three-layer numerical groundwater model (Visual MODFLOW) combined with a particle tracking model (MODPATH) was built to assess the degree of capture provided by different bore layout designs. The bore numbers, lengths, angles and termination depths were all subject to design modelling. A total of 14 different designs, both free-draining and pumping, were evaluated.

Flow data from the existing horizontal pilot bore (referred to as EB02) were used to assist in calibration (Figure 5). The green line in the top left corner, and near and parallel to the river, is EB02. Note that the model predicts particles to bypass EB02 and discharge to the river (purple cells).

The Nyrstar GIS design was based on a series of 13 free-draining, 150 mm diameter horizontal bores ranging in length from 160 to 220 m each, with a total length of just under 2,000 m. The horizontal bores are arranged in a fan-like pattern, grade upwards at 1:125, and terminate at between 20 to 22 m below the electrolysis plant. The green lines represent the horizontal bores, while the blue lines indicate the path of a particle in groundwater. This design provided the greatest degree of capture (approximately 90%) in the area of highest zinc concentrations, located between the electrolysis plant and the process control building, and was free-draining. The latter was an important objective for Nyrstar, who wanted to keep operation and maintenance requirements to a minimum.

The model design was used as a basis for technical specifications for drilling contractor tenders.

The successful tenderer was selected primarily on their ability to track the borehole position and grade with high accuracy. This was an important consideration, given that the number, angle, termination depth and grade of the boreholes were critical to capture efficiency and, just as importantly, the boreholes were to be drilled underneath critical plant infrastructure. The bores were manifolded together and flow is directed to a wastewater storage pond. The system was commissioned in August 2008 and first operated in September 2009. The horizontal bores were spudded into a large retaining wall, taking advantage of a cleared area due to recent decommissioning of an old plant area (Figure 6).

Performance monitoring results

The system performance was measured by four key indicators:

- predicted vs. measured drain inflows
- drawdown of the shallow aquifer water table in the vicinity of the borefield
- the concentrations of heavy metals in intercepted groundwater, and
- the mass recovery rate of heavy metals in intercepted groundwater.

Drain inflows

Predictions of the inflows to the drainage borefield indicated a steady state inflow to the borefield of approximately 30 m^3/day. Inflows for the period were measured (including an assumed average inflow of 15.5 m^3/day for March–September 2010, when measurements were not taken), taking account of daily rainfall and 30-day moving average rainfall at Lutana station. Inflows ranged between 13 to 34 m^3/day, averaging around 16 m^3/day (i.e. approximately half of the predicted inflow).

FIGURE 5 The calibrated flow and particle tracking model.

This is probably due to the highly variable rainfall conditions during the monitoring period, to which the borefield is very responsive. The ability to respond to increased rainfall, groundwater recharge and generation of contaminant plumes was a key objective of the free-draining system.

Watertable depression between electrolysis plant and river

Drawdowns measured in monitoring bores located downgradient of the electrolysis plant screened in the shallow aquifer were plotted, indicating a drop in water level, varying from a 3-4m decrease in MB77 and MB79 (shallow aquifer), to an approximately 0.8 m drop in MB84 (deep aquifer). The smaller degree of decrease in MB84 is attributable to the deeper water level in this bore (around 12 m) and therefore the smaller head over the drainage bores, relative to the other bores (between 1 and 4 m). In general, the data showed that the water table underneath and downgradient of the electrolysis plant is being depressed, indicating successful capture of contaminated groundwater in the key source area. The recovery of water table levels after December 2009 was due to shutting in of the system.

FIGURE 6 The finished bore manifold at the base of the retaining wall.

Metals concentrations in intercepted groundwater

Figure 7 is a combined plan and plot which shows the zinc concentrations in intercepted groundwater.

Zinc concentrations were measured in individual bores, as of December 2008, approximately 2 months after commissioning. The highest zinc concentrations occurred in the upriver bores, located under the western end of the electrolysis plant. These bores are installed into dolerite rock, whereas downriver bores are installed in sandstone. Heavy metal concentrations were recovered by the GIS for the period September 2009 to March 2010, showing an average zinc concentration of around 7,000 mg/L, with other metals at concentrations an order of magnitude lower. It is unclear whether the different hydrogeology is responsible for the variation in zinc concentrations, or whether this is due to differences in plant operation and spill locations. In terms of volume and mass, 1 m^3 (1,000 L) of groundwater contains on average 7 kg of zinc.

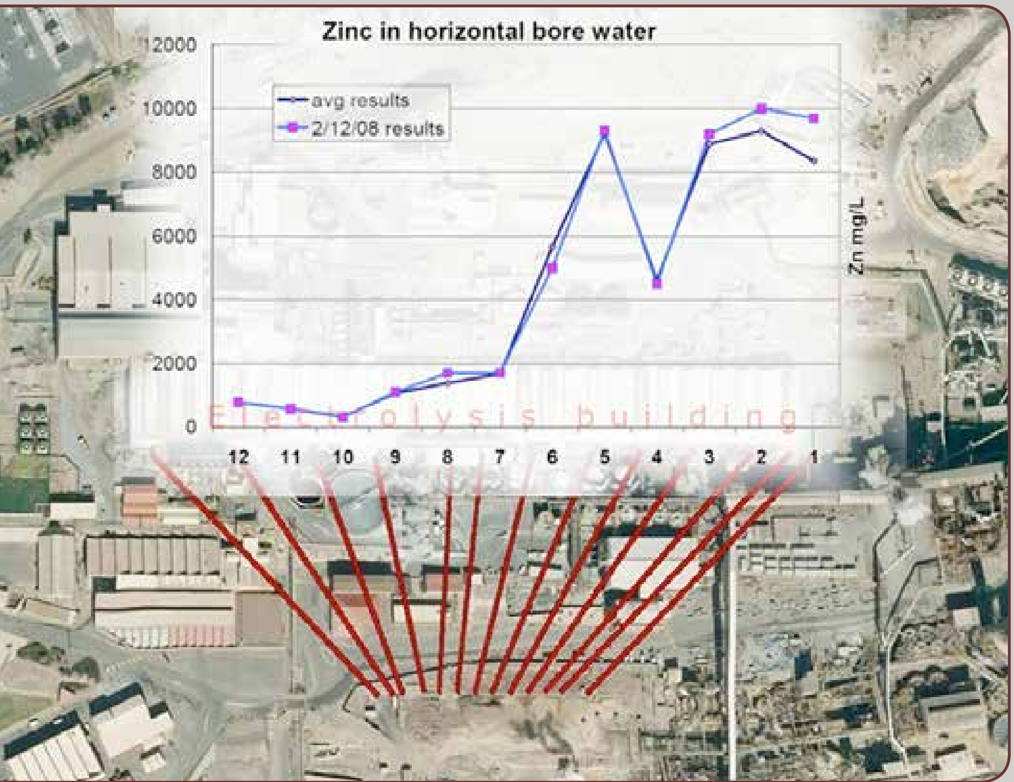


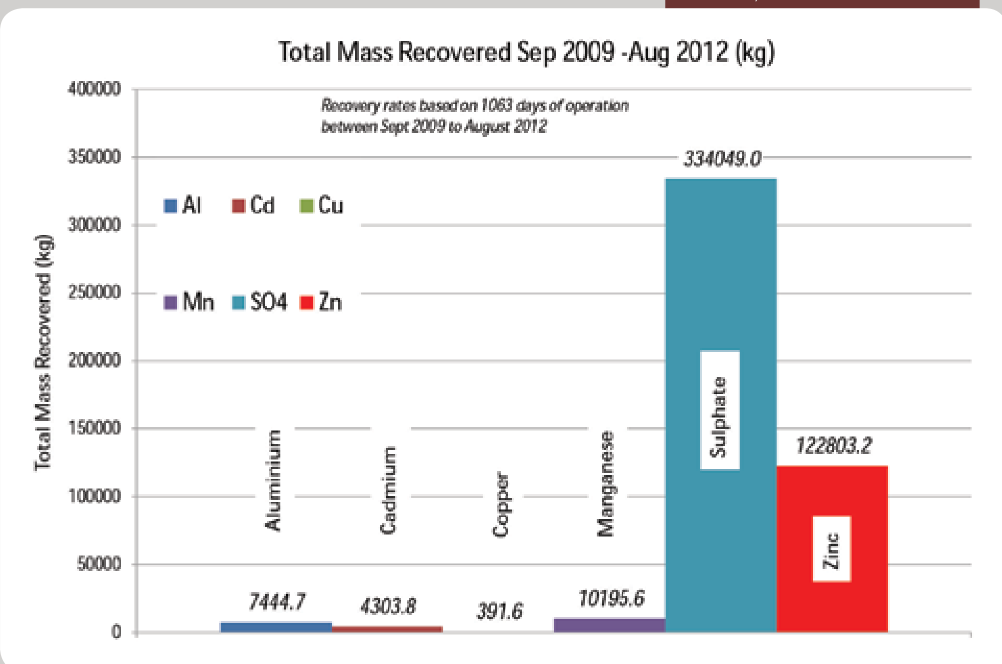
FIGURE 7 Zinc Concentrations in Nyrstar GIS as of December 2008

Mass recovery rates

Figure 8 shows the total mass of heavy metals and inorganics captured by the GIS for the period September 2009 to August 2012. The mass recoveries have been estimated based on average daily recovery rates. The figure does not include the estimated 3,500 m^3 of groundwater generated during system commissioning, when all bores were full of backed-up groundwater. At an average concentration of 7,000 mg/L zinc, the commissioning water is estimated to have contained approximately 25 tof zinc.

The mass recovery rates represent the removal of environmentally significant amounts of heavy metals from the Derwent River ecosystem. The Nyrstar GIS will provide an ongoing, low-maintenance means by which to significantly reduce heavy-metal loading to the Derwent River, and represents a marked improvement to the sustainable management of this critical ecosystem. ■

FIGURE 8 Mass recovery rates of heavy metals and sulfate



Living with waste: Australia's landfill future

Jade Herriman, Dustin Moore, Anna Gero, Damien Giurco, Stuart White, Leah Mason and Dana Cordell, UTS Institute for Sustainable Futures

Waste management in Australia is a complex and dynamic landscape, featuring a large and varied group of stakeholders including operators, regulators, entrepreneurs and community members, with varying levels of interest and awareness of waste issues. These groups are required to navigate a range of policies, regulations and legislative instruments from the national to the local level.

Currently, landfills play a significant role in the management of waste within Australia, where historically they have been the preferred means of disposing of waste. Landfills have long been the preferred means of disposing of waste worldwide. This continues to be the case globally and in Australia, where landfills play a major role in the management of waste. There are difficulties in managing increased waste generation using existing landfill systems. The historical, and in some cases, contemporary view that 'there is no lack of land to fill' is increasingly challenged by more recent developments in the social and physical landscape. These developments include:

- increasing population coupled with increasing consumption per head of population leads to rapidly filling landfills, and
- increasing proximity of settlements to landfills coupled with an increasing understanding of the social, economic and environmental impacts of landfill as a waste management technology is leading to difficulties in creating new landfills near large population centres.

Both factors point to increased costs of landfills as a waste disposal option through increased transport costs for all waste going to landfills which are sited ever further away from the sources of wastes.

Individual state and territory jurisdictions are the primary administrators of waste and resource recovery. It is their role to establish and manage policies and legislation, while local government has the primary responsibility for delivering services to the residential community and, in some cases, commercial enterprises as well.[1] Both local government organisations and private companies own and run waste infrastructure and provide waste collection and transport services.

There is an extensive body of literature on the direct (or 'tangible') costs and particular technological challenges of minimising local landfill impacts on the environment, specifically through containment of contamination and then remediation. The Commonwealth Government's current National Waste Policy[2] follows the waste hierarchy [see '*Trash and treasure: mining landfills for energy and more*' on p. 13], and aims to:

- avoid the generation of waste
- reduce the amount of waste (including hazardous waste) for disposal
- manage waste as a resource
- ensure that waste treatment, disposal, recovery and re-use are undertaken in a safe, scientific and environmentally sound manner, and
- contribute to the reduction in greenhouse gas emissions, energy conservation and production, water efficiency and the productivity of the land.

There is no high-level integrated framework or tool to support decision-making on sustainable waste mitigation strategies. The Institute for Sustainable Futures is undertaking the Landfill Futures project, which has reviewed current sustainability challenges as well as:

- emerging trends in sustainability frameworks for waste management
- technologies and systems for resource recovery and disposal
- waste policies at state and federal levels
- stakeholder views on the future of waste, and
- sustainable initiatives for managing waste as a resource.

FAST FACTS

Australia currently disposes of an estimated 20 million tonnes of waste to around 655 landfills.

During 2006-07, around 48% of Australia's waste was disposed to landfill.

Between 2001 and 2007, the volume of waste deposited to landfill increased by 12%.

FURTHER READING

Environment Protection and Heritage Council 2010, *National Waste Report 2010*, prepared for the Department of the Environment, Water, Heritage and the Arts

Department of Climate Change 2009, *National Inventory Report 2007 Volume 2*

Waste Management Association of Australia 2008, *Bioreactor landfill technology* – Discussion paper for information and comment

Some positive recent changes

Leaders in this field have identified a range of recent 'high points' – from the introduction of waste levies in Queensland, to changes in how organics and food waste are being treated nationally. Many of these recent changes affect local government as waste service providers.

Waste avoidance and its role in policy

Almost all state and territory waste strategies are framed within the waste hierarchy with avoidance at the top, mirroring the National Waste Policy and aligning to COAG's 1992 National Strategy for Ecologically Sustainable Development.

The Australian Capital Territory limits its aspirations to 'reducing' waste.[3] Despite this, there is very little commentary on the role of reduced consumption in achieving this policy objective.

Local government has a major responsibility for waste management.[4] The implications of a steadily increasing waste stream for local government are significant, as councils continue to try to manage the increasing burden of recovering or disposing of materials discarded by households and businesses.

Costs of waste disposal and waste recovery

Waste disposal and waste recovery methods have financial, environmental and social costs. Victoria's Zero Waste Strategy was backed by a benefit-cost analysis[5]; however, other states do not appear to be attempting to gain a robust understanding of the full costs associated with waste management and mitigation. The relatively low cost of landfill is another impediment to the development of alternative waste management and mitigation options. While the cost of landfill may continue to be adjusted to encourage the development of alternatives, levies do not always achieve the desired results. This may be in part due to the failure to factor intangible costs (such as consuming virgin resources) into pricing.

Waste industry and government stakeholders are interested in costing and pricing, as well as funding waste options. People aspire to a future for waste and waste management that has strong national leadership and adequate funding. There are a range of views about the extent to which waste levies (tied to waste disposal at landfills) should be used for waste avoidance/reduction activities versus general spending.

Can integrated resources planning be applied effectively to waste?

Integrated resources planning (IRP), also known as least-cost planning, is an approach to planning for resources that considers both supply-side (e.g. providing more of the resource) and demand-side (e.g. efficiency) interventions to make sure there is enough to meet future demands. IRP as an established and successful record of use, originally in the US energy sector in the 1970s, and more recently in the Australian water and energy sectors. Its strength is in evaluating new supply options and demand-management options on a consistent basis. IRP follows a cycle of planning, analysing, developing and selecting

FURTHER READING

[1] WME 2011, Waste Industry Report 2011/2012. Chapter 4 Commonwealth Waste Management Frameworks. www.wme.com.au/insidewaste/downloads/ch.4_IndustryReport_Preview.pdf

[2] Environment Protection and Heritage Council (EHPC) 2009, *National Waste Policy: Less waste, more resources*, Department of the Environment, Water, Heritage and the Arts.

[3] Department of the Environment, Climate Change, Energy and Water (DECCEW) 2010, *ACT Sustainable Waste Strategy 2010-2015*, Australian Capital Territory, Canberra.

[4] Australian Local Government Association 2008, *Inquiry into the Management of Australia's waste streams*, Canberra, Australia.

options based on least-cost and sustainability criteria.

The next step involves implementing a portfolio of waste minimisation (demand reduction) and management (e.g. increasing landfill supply) options to achieve supply-demand balance, followed by monitoring and evaluation as part of an adaptive management philosophy. IRP can also be linked to deliberative processes for agreeing on goals and generating and selecting options, to assist with reconciling trade-offs and planning under uncertainty. Although IRP has been successfully applied in the Australian water sector and internationally in the energy sector, it has not yet been applied in systems with the variety of materials currently involved in the waste system.

Possible information gaps

At federal and state government levels, existing waste policy poses a strong challenge for addressing fragmentation in the waste system. This is evident when observing inconsistencies in waste-management knowledge and expertise, and differing levels of infrastructure constraints to innovation in waste management, across states and territories.

Discussions about the relative merits of landfill, waste-to-energy technologies and composting technologies for alternative waste management are taking place in a rapidly changing technical environment, often with limited independent guidance. This is particularly clear with respect to local government, which must continue managing a steadily growing waste burden while responding to community expectations about public health standards and key environmental issues.

There are inconsistencies in waste data, standards and definitions across Australia's jurisdictions.

"At federal and state government levels, existing waste policy poses a strong challenge for addressing fragmentation in the waste system."

Data availability is a key concern for Australia, as data at all levels of government are either poor, not publicly available or not being used for decision making. Some levels of government may have reservations about using comparative data to rank performance across jurisdictions (either across all local governments within a jurisdiction or across states and territories in Australia).

Conclusions

Australian cities and towns face considerable challenges to mitigate and manage growing waste production from an increasing, ever-consuming populace. To tackle these challenges, the waste industry – together with stakeholders across the production consumption chain – must adopt new supply-and-demand strategies to reduce waste generation, improve waste management and protect our environment, all in a transparent and cost-effective manner.

This research challenges the effectiveness of the objectives and targets set by state and territory governments, without detailed implementation plans informed by consideration of the real costs in involved in the day-to-day management of waste. It observes that the economic and financial constraints on local government are not always well represented in the objectives and target setting of state government policy.

There is a need for decision-making frameworks that can adequately assess different waste mitigation and management options against agreed objectives, in specific contexts. As the costs and impacts for all forms of waste disposal and mitigation become better understood, the costs and objectives of waste policy will need to be better integrated. The industry also needs to better understand community expectations regarding levels of service, manage the risks entailed in more sophisticated waste management/mitigation systems, minimise greenhouse gas emissions, and develop the expertise required to achieve sustainability across the waste, energy and land-use planning nexus.

High-quality, robust and relevant information is needed to help the sector make decisions concerning these emerging challenges. Effective waste management and mitigation planning in Australia require the collation and analysis of strategic data and a long-term view to inform an adaptive decision making process, as well as acknowledge the constraints of the past. Importantly, waste reduction and waste management infrastructure must be considered together, as sister strategies to meeting the goal of managing material flows in sustainable settlements. ■

This paper is based on findings of the CRC CARE-funded Landfill Futures project undertaken by the Institute for Sustainable Futures, which were presented under the title Waste Futures: project overview and preliminary findings to the Australian Centre of Excellence for Local Government researcher's forum at University of Technology, Sydney on 15 December 2011.

FURTHER READING

[5] Allen Consulting Group, 2003. *Benefit–Cost Analysis of Victoria's Towards Zero Waste Strategy,* Report to Eco-Recycle Victoria.

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Perception of brownfield sites: Myth or reality?

Connie Susilawati and Kelsey Thomas, Queensland University of Technology

The scarcity of large parcels of land in well-serviced areas is one motivator for redeveloping industrial or commercial property that is abandoned or underused and often environmentally contaminated – so-called brownfield land. Poor industrial waste disposal practices caused by industrial activities including gas works, factories, railway land and waste tips have contributed to many instances of contaminated land identified as brownfield sites. It is estimated there are between 10,000 and 160,000 brownfield sites in Australia, with Queensland accounting for around 4000 of these.[1]

Despite the range of definitions available for the concept of brownfield sites, there is a stigma attached to that term – meaning that the public perceives the site as risky. Further, the redevelopment of a brownfield site is perceived as costlier and riskier than working with a greenfield site (piece of usually semi-rural property that is undeveloped except for agricultural use).[2]

Brownfield site redevelopment is often put in the too-hard basket by private developers who would prefer to develop greenfield sites, which are perceived to incur lower costs and risk levels. This stigma has been experienced at some brownfield sites where contamination issues are perceived by the public but don't actually exist.

In this article we examine public opinion and perceptions of brownfield sites, including findings from a public survey. We also look at the problems, and the positive and negative impacts, of remediating brownfield sites.

The redevelopment of brownfield sites offers such economic, social and environmental benefits as the renewal of suburbs and centres, creation of new jobs, the introduction of new investment into the area in the form of new development, increased new and additional housing options, reduced commuting times, a reduction in public health issues, and improvement in the quality of life through additional services and infrastructure due to new development and renewal.

However, the historical connotations can mean that the public perceives brownfield sites as contaminated, which can be a major barrier for redevelopment – even when this is not necessarily the case. Perhaps this recognition of negative public perception of brownfields sites has had some impact on the composition of the current *South-East Queensland Regional Plan 2009-2031*, in which the words 'sustainable development', 'urban renewal', 'infill development', 'contaminated land' and 'greenfields' appear to have been used instead of the word 'brownfields'. The most common definition of sustainable development, as used by the Queensland Department of Infrastructure and Planning in the current version of that regional plan, is 'development that meets the needs of the present without compromising the ability of future generations to meet their own needs'.

It is important to note that 'brownfield' does not necessarily mean 'contaminated', and that contamination for some brownfield sites are issues of perception, not reality. As well as dampening the enthusiasm for redevelopment, this leads to the same negative

FIGURE 1 Risks

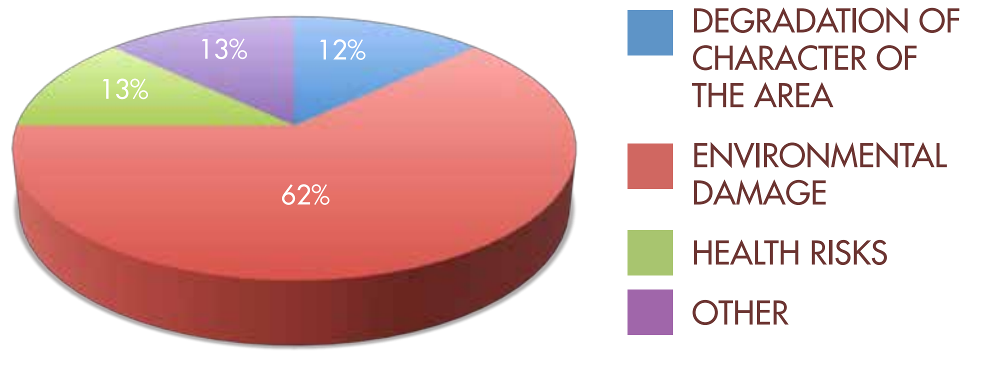


TABLE 1 Level of concern demonstrated by people living in redeveloped brownfield areas. 0 = no concern; 10 = grave concern.	Respondents UNAWARE of nearby brownfields	Respondents AWARE of nearby brownfields
Redeveloped brownfield site	4.33	3.65
Redeveloped contaminated site	6.33	3.75

connotations associated with a site that is actually contaminated. Additionally, the communication about the existence of contaminated land sites and proposed remediation solutions are very complex, and has to be balanced between procedure and outcomes.

Brownfield redevelopment

Queensland first legislatively addressed the issue of brownfield and contaminated land in 1991 with the *Contaminated Land Act*, which led to the *Queensland Environmental Protection Act 1994* with the aim to 'protect Queensland's environment while allowing for development that improves the total quality of life, both now and in the future, in a way that maintains the ecological processes on which life depends (ecologically sustainable development).' The *Queensland Environmental Protection Act 1994* places great emphasis on managing the environment and, in chapter 7 of the act, outlines the management of known contaminated sites and potentially contaminating activities in Queensland to prevent environmental and health risks. Management is led by the Department of Environment and Heritage Protection (DEHP). DEHP provides advice on legislation and technical requirements, reviews contaminated site investigations and approves site management plans.

To reduce the level of risk for land buyers, potentially contaminated sites are registered with the Environmental Management Register (EMR) and Contaminated Land Register (CLR) by the Queensland government; DEHP maintains this register. Registration on the EMR is required for land that is (or has been) used for notifiable activities (activities that are likely to cause contamination) or has been contaminated by a hazardous contaminant. DEHP states that the 'registered sites pose a low risk to human health and the environment under the current land use', and that 'entry on the EMR does not mean the land must be cleaned up or that the current land use must stop'. DEHP states that registration on the CLR is for 'proven contaminated land which is causing or may cause serious environmental harm… when scientific investigation shows it is contaminated and action needs to be taken to remediate or manage the land'. Scientific investigations and site management plans are carried out by industry professionals, and reviewed by DEHP.

When a site is located in a built-up urban area, constraints are placed on the type of development due to the site shape, access to the site, the greater town planning restrictions, and any restrictions due to existing infrastructure maximum allowances. Redevelopment can also place increased strain on existing infrastructure and public services, erode green space in the case of vacant sites and infill development, and negatively impact neighbours through noise and air pollution. The redevelopment of a brownfield site can negatively and positively change the amenity, and values of the suburb.

One such example is the Brisbane Urban Renewal Project, which was initiated in 1991 to renew urban areas in Brisbane. A combined area of approximately 730 hectares covering the suburbs of Fortitude Valley, New Farm, Teneriffe, Newstead and Bowen Hills was earmarked by the Brisbane City Council for renewal.

The areas have transformed from declining, outdated and unattractive precincts to vibrant, diverse inner urban areas of increasingly high amenity. The majority of works are complete, but not all areas are finished.

FURTHER READING

[1] Brebbia, CA 2008, *Brownfields IV: Prevention, Assessment, Rehabilitation, Restoration and Development of Brownfield Sites*, Portugal, WIT Press.

[2] Johnston, N 2010, 'Unlocking the productive potential of brownfield sites', *Remediation Australasia*, Issue 3.

TABLE 2 Purchase and rent decisions based on EMR/CLR checks

	Respondents UNAWARE of nearby brownfields		Respondents AWARE of nearby brownfields	
	Performed a check	Did not perform a check	Performed a check	Did not perform a check
For purchasing	26	4	16	0
For renting	5	25	7	9

Brownfields
areas of land previously used for industrial or other purposes available to be redeveloped for alternative purposes *(Queensland Government)*

Contaminated land
land so damaged by industrial or other development that it is incapable of beneficial use without treatment

Infill development
new development that occurs within established urban areas where the site or area is either vacant or has previously been used for another urban purpose. *(Queensland Government)*

Urban renewal
regeneration of disused industrial or government land which may be suitable for residential development

Greenfield sites
areas of undeveloped or 'raw' land free from contamination… that are suitable for urban development.

Queensland Department of Infrastructure and Planning

Negative impacts of brownfield sites

Vacant, unused brownfield sites (whether contaminated or only perceived as contaminated) contribute to a loss in property value, loss of jobs, loss of tax revenue, a threat to public health and the environment, and potential liability for the contamination.[2] During development, blow-outs in expected cost and time can be anticipated, due to the remediation of the contamination, and the potential for lawsuits and liability relating to the remediation of the site.[2] A site located in a built-up urban area can constrain the type of development possible, due to the site shape, access to the site, greater town planning restrictions, and existing infrastructure maximum allowances. Brownfield redevelopment can also place increased strain on existing infrastructure and public services, can erode green space in the case of vacant sites and infill development, and negatively affect neighbours through noise and air pollution. The lack of redevelopment of a brownfield site can diminish a suburb's amenity and property values.[2]

Positive impacts of the re-development of brownfield sites

The redevelopment of brownfield sites has positive impacts for both the surrounding society and the developer. Such a project can improve a suburb's amenity and property values. Renewing older suburbs and past industrial areas is high on government planning agendas. It is already happening in Brisbane and southeast Queensland, with exceptional results for society and developers alike. In the United States, redevelopment of brownfield sites is encouraged by state-led voluntary brownfield clean-up programs.

Public perception

A survey of 47 respondents who work in the Brisbane central business district aimed to capture the general population's perception of brownfield sites and redevelopment in southeast Queensland. Definitions (summarised from the literature critique) of 'brownfield' and 'contaminated land' were given to respondents to ensure they had a clear understanding of the terms.

The majority of the population were not aware of any brownfield sites near their residence, and those who were aware showed very

TABLE 3 Contamination/remediation actions and their effect on decisions to live on a redeveloped site

	Respondents UNAWARE of nearby brownfields	Respondents AWARE of nearby brownfields
Did affect the decision	24 (52.17%)	14 (30.43%)
Did not affect the decision	6 (13.04%)	2 (4.35%)

little concern about their proximity to the site. The majority of respondents believed that petrol stations were the most likely source of brownfield status. Respondents' greatest concern was environmental damage, over and above degradation of character of the area and health risks (see Figure 1). Participants who were aware of existing of brownfield sites near their home showed a lower level of concern, regardless of whether they live on a redeveloped brownfield site (contaminated or not). However, participants unaware of a nearby brownfield site were more concerned about living on a redeveloped brownfield site, particularly one that had been contaminated (see Table 1). Table 2 illustrates the number of respondents who made purchasing or rental decisions based on an EMR or CLR search.

"The redevelopment of brownfield sites has positive impacts for both the surrounding society and the developer. Such a project can improve a suburb's amenity and property values."

Asked if they would conduct an EMR or CLR search if planning to purchase a property for use as a primary residence, most respondents (91%) said they would perform such a check. The 9% who responded 'no' were unaware of nearby brownfield sites. Around three-quarters (74%) of respondents indicated that they would not perform such a check on property they planned to rent. This discrepancy was expected, as renting is generally viewed as a short-term form of accommodation posing a shorter exposure period to the risks from contamination.

Contamination and remediation

Most (83%) respondents said that the type of contamination and remediation action would affect their decision to live on a redeveloped contaminated site (see Table 3).

Only around two-thirds (65%) of respondents were unaware of any contaminated land near where they live. There were slightly different attitudes between awareness related to decisions made for purchase and decisions made for renting. Those who were aware of any contaminated land indicated that any future decision to purchase their primary residence in future would include a check of the EMR or CLR. However, people were not overly concerned about such checks if they intended to rent.

Unfortunately, few people were aware of the existence of contaminated land, or knew how to minimise their risk by checking the EMR or CLR.

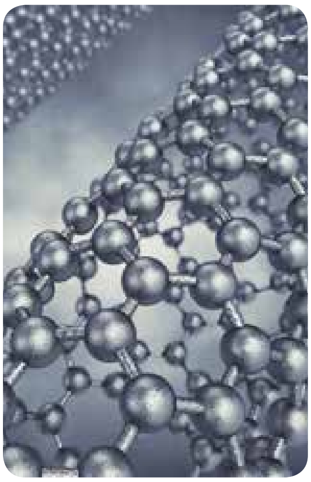
Redevelopment of brownfield sites is often drawn out when it comes to approving a remediation management plan and removal from the CLR. More realistic timelines may be achieved by gathering evidence of turnaround time and general fees through initial interviews with builders, developers and consultants, as well as a DEHP official.

In summary, a majority of respondents (65%) were unaware of any brownfield sites near their homes, but those who knew of such sites were less concerned about the idea of living on them. People looking to purchase a primary residence were more motivated to investigate contamination than potential renters. However, relatively few people were aware of the existence of contaminated land or how to minimise their risk by checking the registration through EMR/CLR. It is likely that a better-informed public would lead to less contentious decisions at all stages, from developing a property through to buying a home. ■

Research RoundUp

Research Roundup aims to keep you up-to-date with current research on environmental contamination assessment and remediation in Australia. By keeping content succinct and focusing on particular projects, *Remediation Australasia* makes it easier for you to find the time to read about areas which are relevant to you. In this issue, the focus is on CRC CARE funded projects.

CRC CARE's second term of operation commenced in July 2011, and the research programs have an increased focus on helping to develop uniform national standards for assessing and remediating contamination. The outputs from the research programs will fill knowledge gaps and allow adoption of remediation that balances health and environmental protection with economic and social considerations. With this in mind, the CRC has funded the following projects:



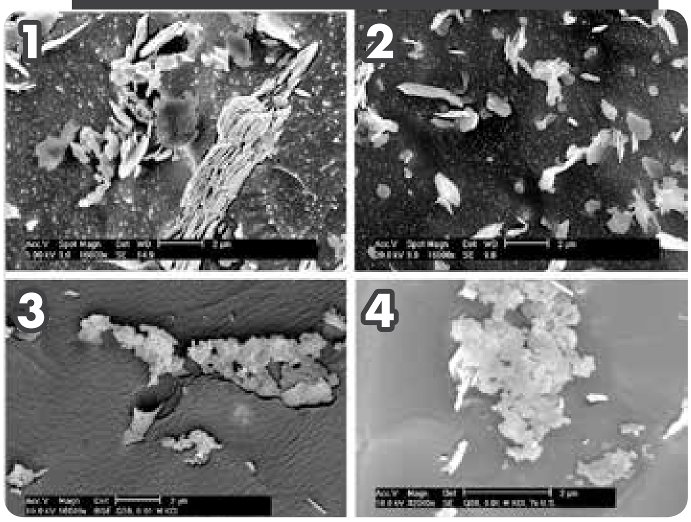
Environmental risk assessment of nanomaterials for soil and groundwater remediation

Contaminant transport by naturally occurring nanoparticles (i.e. colloids) has been identified In recent years as a key process underlying the unexpected movement of low-solubility environmental contaminants away from their source. It is likely that this type of unwanted transport may be further facilitated by the addition of manufactured nanomaterials to the environment. This project aims to reduce the uncertainties regarding the potential side effects of manufactured nanomaterials designed for use in soil/groundwater remediation. The project will focus on nanomaterials already employed or being developed specifically for remediation (e.g. nanoscale zerovalent iron and pther nanomaterials close to the commercialisation stage). The knowledge gained will support the design of effective yet sustainable nanomaterials; it will also help remove impediments to commercialisation by strengthening industry and regulator confidence, and ensuring that inadequate risk assessment does not disrupt market growth. The outputs will increase certainty that the target technologies are safe for commercial scale application. ■

Ultrasonic equipment

In the last decade, new high power ultrasonic treatments to improve thickening in food technology and in industrial and sewage wastes have been highly successful. This technology has not yet been applied to mineral processing concentrates and wastes but offers major potential in this field. A project with Rio Tinto, UniSA, High Power Ultrasonics P/L and CRC CARE investigated using ultrasonic treatment to enhance thickener performance in increased settling rates, consolidation rates, underflow solids density and water recycle with tailings containing significant clay content. Tests showed that settling rates at the same flocculant dosage could be increased by up to 40% and underflow solids densities by 20% for both commercial kaolin and real high-clay tailings. On these results translated into practice, estimates at one Rio Tinto mine would give 3.5 gigalitres p.a. water saving worth more than A$5.5 million to that operation. Dr Jason Du working with Prof. Roger Smart identified, by understanding the changes in aggregate structure of the clays, how and where in the thickening sequence the ultrasonics need to be applied for maximum benefit. This is critical to effective dewatering and now protected in the joint patent with CRC CARE. ■

Aggregate structure before flocculant addition. 1 & 3: Without ultrasonic pre-treatment. 2 & 4: With ultrasonic pre-treatment



Arsenic bioavailability, biomagnification, detoxification in aquatic systems and eco-toxicological validation

Besides soil contamination, aquatic systems (particularly freshwater bodies) have been contaminated by arsenic in many countries from natural and anthropogenic sources. Arsenic is one of the deadly toxic elements ubiquitous in the environment; its toxicity is associated with its speciation and concentration.The Mole River mine is a well-known point-contamination source of arsenic in Australia. Mining and processing of arsenopyrite ore at several localities in northern NSW and southern Queensland in the 1920s and 1930s have resulted arsenic contamination of freshwaters in these areas. Aquatic microorganisms contribute to the occurrence of thermodynamically unstable arsenite and methylarsenic compounds in natural waters, which are then converted to less toxic organoarsenic compounds. In order to provide a complete toxicological assessment of arsenic detoxification to limit its toxicological impacts in aquatic systems, it is thus important to assess the persistent forms of arsenic and their bioavailability. In natural aquatic systems, phytoplankton plays an important role in the detoxification of highly toxic inorganic arsenicals to less toxic methylarsenicals and organoarsenic compounds such as arsenosugars, arsenobetaine. This project will provide validation of arsenic detoxification mechanism (metabolism of highly toxic methylarsenicals to organoarsenic compounds) by phytoplankton as an effective remediation technique, and thus, having potential for the advancement of bioremediation technology. The specific objectives are to- (i) characterize arsenic pollution and its biological impacts in Australian aquatic systems, (ii) investigate the bioavailability and trophic transfer of arsenic in aquatic food webs, (iii) calibrate the response of relevant dominant phytoplankton to arsenic in relation to the concentration and chemistry, develop an in situ bioassay procedure to evaluate arsenic toxicity using phytoplankton, and assessing the competence of As-detoxification by calibrated phytoplankton, and (iv) arsenic uptake in Australian native aquatic plants grown in contaminated aquatic systems to evaluate their potential for phytoremediation. ■

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Training and events calendar

October

3 **Environmental management plans – Who reads** *ALGA* / Sydney
www.landandgroundwater.com/#/events/calendar

10 **Introduction to environmental site assessment (CPD training, module 8)**
ACLCA / Melbourne
www.aclca.org.au/cms-events/index.phps

10 – 12 **Occupational Health and Safety 3 Day Course**
ACLCA / Melbourne
www.aclca.org.au/cms-events/event-registration.phps

17 **Olympic Dam expansion (Groundwater issues/innovations/etc)**
ALGA / Adelaide
www.landandgroundwater.com/Industry%20Calendar.html

17 **SuRF and sustainable remediation - The great debate**
ALGA / Melbourne
www.landandgroundwater.com/Industry%20Calendar.html

22 **Petroleum vapour intrusion (PVI) Assessment training course**
CRC CARE & ALGA
http://bit.ly/PVIinvitation

23 – 26 Australian Groundwater Modelling School using GMS
SRIT / Perth
www.srit.com.au/course_details.php?id=32

24 **Petroleum vapour intrusion (PVI) Assessment training course**
CRC CARE & ALGA
http://bit.ly/PVIinvitation

26 **Petroleum vapour intrusion (PVI) Assessment training course**
CRC CARE & ALGA
http://bit.ly/PVIinvitation

29 **Oct – 1 Nov Groundwater modelling using ArcHydro GW**
SRIT / Perth
www.srit.com.au/course_details.php?id=41

November

13 **Expert witness seminar – State administrative tribunal. Neutral expert within?**
ALGA / Perth
www.landandgroundwater.com/#/events/calendar

14 – 16 **Sustainable Remediation 2012**
EURODEMO+, US EPA & CL:AIRE / Vienna
www.umweltbundesamt.at/sustainable_remediation2012

15 **A look back on the first year of the *National Environmental Standard for Managing Contaminants in Soil***
ALGA / Auckland
www.landandgroundwater.com/#/events/calendar

21 **Landfill BEPM**
ALGA / Melbourne
www.landandgroundwater.com/#/events/calendar

TBC **Introduction to environmental site assessment** (CPD training, module 8)
ALGA / Melbourne
www.landandgroundwater.com/#/events/calendar

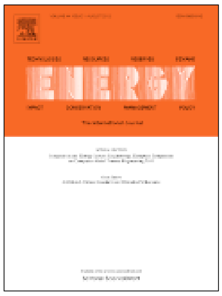
December

2 – 7 **Joint ASSSI and NZSSS Soil Science Conference: Soil Solutions for Diverse Landscapes**
ASSSI & NZSSS / Hobart www.soilscience2012.com/

Publications Update

This section contains publications that have been published in the last 3 months (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 **aric@crccare.com**.

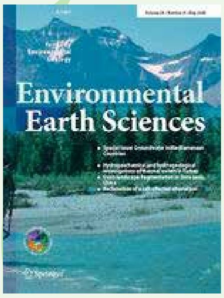
Use of inorganic and organic wastes for in situ immobilization of Pb and Zn in a contaminated alkaline soil Zhou, Haynes & Naidu 2012, *Environmental Science and Pollution Research*, vol. 19, iss. 4, pp. 1260–70.



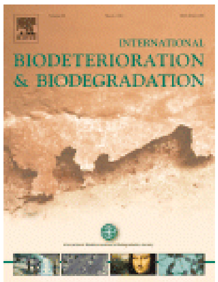
Gasification of biomass micron fuel with oxygen-enriched air: Thermo-gravimetric analysis and gasification in a cyclone furnace Cheng, He, Xiao, Hu, Liu, Zhang & Cai 2012, *Energy*, vol. 43, iss. 1, pp. 329–333.

Degradation of p-nitrophenol by immobilized cells of Bacillus spp. isolated from soil
Sreenivasulu, Megharaj, Venkateswarlu & Naidu 2012, *International Biodeterioration & Biodegradation*, vol. 68, pp. 24–27.

Urinary excretion of bilirubin oxidative metabolites in arsenite-treated mice
Arthur, Ng, Lang & Abu-Bakar 2012, *Journal Toxicological Sciences*, vol. 37, iss. 3, pp. 655–661.



Comparison of the effects of conventional organic amendments and biochar on the chemical, physical and microbial properties of coal fly ash as a plant growth medium
Belyaeva & Haynes 2012, *Environmental Earth Science*, vol. 66, iss. 7, pp. 1987–1997.



Optimal identification of groundwater pollution sources using feedback monitoring information: A case study
Chadalavada, Datta & Naidu 2012, *Environmental Forensics*, vol. 13, iss. 2, pp. 140–153.

Effect of synthetic dairy factory effluent containing different acids (H3PO4, HNO3 and CH3COOH) on soil microbial and chemical properties and nutrient leaching
Liu & Haynes 2012, *Biology and Fertility of Soils* doi: 10.1007/s00374-012-0678-1.

Organoclays reduce arsenic bioavailability and bioaccessibility in contaminated soils
Sarkar, Naidu, Rahman, Megharaj & Xi 2012, *Journal of Soils and Sediments*, vol. 12, pp. 704–712.

Metabolism of bilirubin by human cytochrome P450 2A6
Abu-Bakar, Arthur, Wikman, Rahnasto, Juvonen, Vepsäläinen, Raunio, Ng & Lang 2012, *Toxicology and Applied Pharmacology*, vol. 261, iss. 1, pp. 50-58.

Bioavailability of lead in contaminated soil depends on the nature of bioreceptor
Ming, He, Lamb, Megharaj & Naidu 2012, *Ecotoxicology and Environmental Safety*, vol. 78, pp. 344–350.

Interactions between Ca, Mg, Na and K: Alleviation of toxicity in saline solutions
Kopittke 2012, *Plant Soil*, vol. 352, pp. 353–362.

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For further project related information, please contact:

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