Issue 13 2013

Remediation Australasia

HOW TO CLEAN UP FOR A HOSPITAL

BETTER REGULATION

Australia's site contamination assessment guidelines updated

MERCURY

How do we manage this dangerous contaminant?

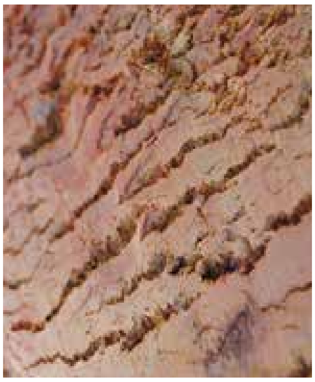
NULL AND (A)VOID

Statistics in contaminated land data assessment

CRC CARE

A safer, cleaner environmental future

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



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editor's note

Welcome to Issue 13 of *Remediation Australasia*.

It's hard to believe that already in much of Australia, we're rugging up in anticipation of winter – it seems barely weeks ago that we were sweltering under a late summer sun.

The past quarter has been a good one for CRC CARE, during which the centre continued to build on its reputation as a national and international centre of excellence at the forefront of innovative solutions for challenging contaminated site problems, capacity building, and policy and guidance.

It was particularly gratifying to see the revised Assessment of Site Contamination National Environment Protection Measure (NEPM) approved by the Council of Australian Governments Standing Council for Environment and Water. Working with a range of partners, CRC CARE made many important contributions to the new NEPM, which updates the original 1999 version and ensures that Australia's approach to the assessment of site contamination not only remains consistent, but also incorporates the latest, best-practice guidance. On behalf of CRC CARE, I would like to extend my appreciation to all those who contributed to this monumental effort, which will inform our work towards the delivery of a national remediation framework. You can read about the new NEPM on page 8 of this issue.

This issue also includes the final of a series of three articles on landfill mining in the context of sustainable materials management (pages 20–23). The series kicked off in Issue 11, our special landfills edition. This time, we look at landfill mining through the development of integrated resource recovery centres, which allow the recycling of various types of waste and recover energy from low-value combustible material.

Worldwide, the challenge posed by ever-growing landfills remains almost as intractable as it is costly. According to a recent report in *China Daily* (April 19–25, 2013), Beijing alone will spend around $16 billion over the next three years to improve sewage disposal, garbage treatment and air quality. As Asia's middle class grows and takes on an increasingly throw-away lifestyle, similar investments will be needed in cities across the entire region. The economics alone are staggering. Without a widespread and deep-seeded shift in the way we approach waste disposal – as embedded in technologies being developed at CRC CARE – the consequences for human and environmental health are dire.

Our next issue will include a focus on environmental legislation across countries – where it overlaps, where it varies, and what this means for the trade and transfer of remediation and management technologies. This issue will coincide with CleanUp 2013, the 5th International Contaminated Site Remediation Conference (see www.cleanupconference.com), to be held in Melbourne, Australia, on 15–18 September. I encourage anybody involved in contaminated site remediation to register for what is shaping up to be the biggest and best CleanUp yet.

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

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

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Editorial and production
Editor-in-chief
Ravi Naidu

Editor
Adam Barclay

Technical editor
Prashant Srivastava

Production editor
Victoria Leitch

Editorial enquiries
Adam Barclay, CRC CARE
08 8302 3925
Adam.Barclay@crccare.com

Cover photo: Remediation works at the site of the new Royal Adelaide Hospital. *Photo courtesy of FMG Engineering.*

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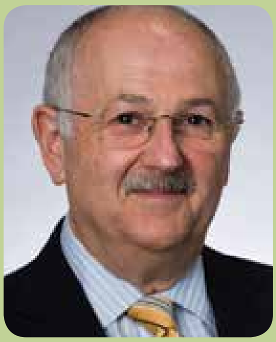
reMEDIAtion

Your guide to environmental contamination and remediation issues in the media

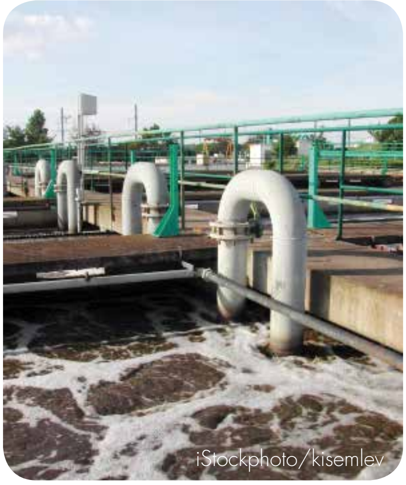


Orica announces new chair

Orica Chair Peter Duncan will step down at the company's next annual general meeting, in January 2014. His successor has been announced as Russell Caplan (pictured) – current director of Aurizon and Chair of The Melbourne and Olympic Parks trust and CRC CARE Board of Directors. Mr Duncan said that "Mr Caplan brings to the position both a wealth of experience and a deep knowledge of the company."

NSW EPA energy from waste policy

In an advance that will bring NSW into line with international standards, the NSW EPA has released a new 'energy from waste' policy, reports the *Business Environment Network* (bit.ly/10tDvBX; subscription only). The new policy relates to energy-recovery facilities and outlines criteria to be met by the facility. NSW Environment Minister, Robyn Parker stated that the policy is designed to 'maximise the recovery of energy and minimise harm to human health and the environment.'



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Sewage scheme for WA?

Following a 3-year trial that saw up to 2.5 billion litres of treated sewage added to an aquifer in Leederville, WA, Perth's Sunday Times reports that Water Corporation – WA's primary supplier of residential water – will recommend that the practice is continued (bit.ly/XhbwU7). This would make WA the first state in Australia to use recycled water as a source for household supply. The report notes that despite concerns from residents, Water Corporation plans to push on in an effort to drought-proof the state. In a response, Water Corporation issued a press release asserting that the water recycling trials were neither secretive nor publicly unpopular, with 76% public support for the scheme (bit.ly/15jiJvN).

Environmental risk reform

At present, there is no national body to oversee risk management decisions to protect the environment against harmful chemicals. As a consequence, the Council of Australian Governments Standing Council for Environment and Water (SCEW) has released a Consultation Regulation Impact Statement (RIS) on options for developing and implementing nationally consistent decisions to manage the environmental risks of industrial chemicals. SCEW is seeking feedback from people and organisations on the three reform options outlined in the RIS, with 28 June the closing date for submissions. Information on how to make a submission and the RIS document are available at bit.ly/119LQAl, along with details of a series of public forums to be held around the country in May and June.

Waste regulation stocktake

Differing regulations and guidelines across Australia causes much confusion about waste management. As a first step to strengthen and unify the waste-related regulations across Australia, the Australian Department of Sustainability, Environment, Water, Population and Communities (SEWPaC) has compiled a list of regulations from individual states and territories. The list is available at the SEWPaC website (bit.ly/XD81vK) and includes standards, specifications and guidelines from industries including e-waste, medical, organics and recycled materials. An initiative of the National Waste policy, the freely available stocktake will provide direction for further improvements in Australia's waste management systems.

Big plastic problem

A recent *Nature* editorial comment by Rochman et al reports that if our current rate of plastic use continues we could be inundated with another 33 billion tonnes by 2050 (bit.ly/X5tNqg). The report recommends reclassifying as hazardous plastics that are potentially toxic or difficult to recycle, in an attempt to reduce their production and give environmental authorities greater control over clean-up efforts. Citing the success of the Montreal Protocol and Stockholm Convention in eliminating the production of CFCs, the authors suggest that regulating the four most commonly used plastics (PVC, polystyrene, polyurethane and polycarbonate) would be a good first step.

Victoria to audit contaminated sites

Victorian Planning Minister Matthew Guy says the state government will develop a tougher approach to contaminated sites, *The Australian* reports (bit.ly/15elYCN). The Victorian Department of Planning and Community Development has called for further investigation into potentially contaminated sites – such as factories and petrol stations – to ensure they are not posing a public health risk.

New head for US EPA

President Obama has announced a successor to previous US EPA Administrator Lisa Jackson. The new head has been named as Gina McCarthy – previously Assistant Administrator for the Office of Air and Radiation. McCarthy was expected to be confirmed by the US Senate on 8 May.


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Standard for e-waste

Diverting e-waste from landfill is one of the driving factors behind the release of the joint Australian and New Zealand standard *AS/NZS 5377:2013 Collection, storage, transport and treatment of end-of-life electrical and electronic equipment* (bit.ly/10U1wT5). The standard, which is available from SAI Global (bit.ly/10quD0c), takes a hard line on using scientific uncertainty as an excuse for postponing measures. It also complements the Australian Government's National Television and Computer Recycling Scheme, which has been in effect for a year. SEWPaC recently released a discussion paper that suggested amendments to the scheme, such as altering product classes and co-regulatory arrangements (bit.ly/11Tvxmw).


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Cancer in your cupboard

An increasing trend of endocrine-related disorders, including cancer, has prompted the United Nations to release a list of approximately 800 chemicals that could be contributing to health conditions. Many of these are present in storage containers, cleaning products, electronics and even cosmetics, reports *ABC News* (bit.ly/11UCWXj). The World Health Organization has stated that many of the chemicals currently used in these common household products have not been tested, and that little is known about the effects of human or environmental exposure.

Groundwater modelling

A new method of computer simulation is allowing researchers at the National Centre for Groundwater Research and Training to model the speed and source of pollutants (bit.ly/14oxlK2). In a recent press release, Professor Craig Simmons stated that groundwater 'is increasingly polluted by pesticides, leaks from landfills and fuel dumps, residential and factory waste and other industrial contaminants which render it unusable and undrinkable'. It is hoped that the model allows more cost effective remediation.

Site contamination assessment guidelines updated

Bruce Kennedy, CRC CARE

Updates to Australia's National Environment Protection (Assessment of Site Contamination) Measure have been officially approved.

The National Environment Protection (Assessment of Site Contamination) Measure (or more commonly the Assessment of Site Contamination NEPM) was formulated in December 1999. As with other NEPMs, it established a nationally consistent, harmonised, approach to the assessment of site contamination to ensure sound environmental management practices throughout Australia. It comprised a set of guidelines for practitioners and regulators, and quickly became the 'bible' for the assessment of site contamination practice in Australia.

The development of the 1999 NEPM was managed by the National Environment Protection Council (NEPC) Service Corporation. It incorporated all contamination assessment guidance previously issued by various bodies in Australia up to that time, updated to meet contemporary requirements. Because the science and technology in contamination assessment and remediation was moving quickly, a five-year review clause was included in the NEPM.

The review, which commenced in 2005, recommended a substantial number of updates and improvements to the NEPM and its operation. Based on these recommendations, NEPC commenced a 'variation' process in 2007, to be completed in 2010. Many technical contributions to the variation came from several agencies outside NEPC, including the National Health and Medical Research Council, CRC CARE, CSIRO and the WA Health Department. The development of these contributions turned out to be more complex and time consuming than originally envisaged.

Inputs made by CRC CARE to the NEPM update, which are referenced in the NEPM and/or are available in the NEPM Toolbox, include:

- changes to reporting of petroleum hydrocarbon fractions and to related analytical methods
- characterisation of sites contaminated with petroleum hydrocarbons
- field assessment of petroleum hydrocarbon vapours
- biodegradation of petroleum hydrocarbon vapours, and Health Screening Levels for total petroleum hydrocarbons (visit www.crccare.com/publications/technical_reports/hsl_tech_report.html)
- contaminant bioavailability and bioaccessibility, and
- community consultation.

The associated documents can be found at both www.crccare.com/publications/technical_reports and www.ephc.gov.au/contam/toolbox.

NEPC, through the Council of Australian Governments Standing Council for Environment and Water (SCEW), approved the variation on 11 April 2013. The NEPM now incorporates updated methodologies for assessing human and ecological risks and site assessment methods in line with advances in Australia and overseas.

According to a SCEW communique issued on 11 April, "The amendment ensures [the NEPM] will remain the premier document for the assessment of site contamination in Australia, used by regulators, site assessors, consultants, environmental auditors, landowners, developers and industry."

CRC CARE, in conjunction with state and territory environmental protection regulatory agencies, will run a series of workshops around Australia in May 2013 on the implementation of the NEPM. Details of these events can be found at www.crccare.com/education/training/nepm/nepm_training.html

To further strengthen Australia's ability to deal with contaminated sites, CRC CARE is working with environmental agencies and industry to develop a nationally harmonised framework for the remediation and management of contaminated sites. Being designed to complement the NEPM, this national framework will support a harmonised system for both the assessment and remediation/management phases of site contamination. Harmonisation is sorely needed across states and territories, and will be of immense value to all people and organisations dealing with contaminated sites, from regulators to industry.

Assessment of Site Contamination NEPM workshops

CRC CARE is coordinating a national workshop series covering the changes, new elements and implementation of the recently amended Assessment of Site Contamination National Environment Protection Measure (NEPM).

Members of the NEPM Variation team, along with the technical experts involved in developing guidance for inclusion into the NEPM Schedules, will present a series of sessions that will help participants understand and apply the new guidance. Local jurisdictional representatives will also present on the transition and implementation plans relevant to their jurisdiction.

These workshops will be invaluable to anybody involved in assessing site contamination – regulators, site assessors, consultants, environmental auditors, landowners, developers and other industry practitioners.

Workshop topics

ASC NEPM Overview	• Overview highlighting key changes • Organisation of the schedules and supporting documents • Implementation arrangements and implications for state/territory policies
Site characterisation	• Informed decision making – the role of CSMs and DQOs • Analysis of site data
Ecological risk assessment	• Overview of ERA • Applying the new ERA methodology for terrestrial ecosystems • Soil and groundwater assessment levels
Health risk assessment	• Asbestos – overview of assessment framework and application • Overview of HRA • HRA methodology – what's changed • Soil, groundwater and vapour assessment levels • Vapour assessment framework • Key differences – petroleum and chlorinated organic hydrocarbons
Assessment of petroleum hydrocarbons	• Applying the HSLs, ESLs and management limits

Workshop venues

Canberra	6 - 7 May	Rex Hotel, 150 Northbourne Ave, Braddon, Canberra
Brisbane	7 - 8 May	Rydges South Bank, Cnr. Grey and Glenelg St, Brisbane
Sydney	8 - 9 May	SMC, 66 Goulburn Street, Sydney
Darwin	9 - 10 May	Holiday Inn Esplanade, 116 The Esplanade, Darwin
Hobart	20-21 May	Hobart Function and Conference Centre, 1 Elizabeth St, Hobart
Melbourne	21 - 22 May	Novotel Melbourne on Collins, 270 Collins St, Melbourne
Adelaide	22 - 23 May	Hilton Adelaide Hotel, 233 Victoria Square, Adelaide
Perth	23 - 24 May	Novotel Perth Langley, 221 Adelaide Terrace, Perth

Program, fees and registration available at
www.crccare.com

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Contaminated land data assessment – the fundamentals

David Coutts, Sinclair Knight Merz

Without accurate data assessment it's difficult to make the right decisions about how to manage contaminated land.

The population, samples, and uncertainty

According to the *Australian Standard Guide to the investigation and sampling of sites with potentially contaminated soil* (AS 4482.1-2005; Table E1), samples from a minimum of 13 locations are required to be taken from a 1/2-hectare site – roughly the area of a soccer pitch. Assuming that we are just interested in surface soil samples, we will be making decisions on the nature and extent of contamination from around 0.0026%[1] of locations that could be sampled. Making inferences about site contamination from such a small sample is fraught with uncertainty.

If the Australian Standard is followed, most practitioners will take a few more samples for quality assurance/quality control (QA/QC) purposes, to check that results from the primary laboratory analyses are useable within the assessment. QA/QC sections in reports with calculated relative percent differences are thus considered to be a normal part of the contaminated land report. This practice is to examine sampling and laboratory error – both of which can be considered technical errors.

The assessment of sample strategy uncertainty is rarely considered and discussed.

The importance of the null hypothesis

The null hypothesis is simply the baseline hypothesis that is being tested. A typical null hypothesis could be 'the site is contaminated', with the alternative being 'the site is uncontaminated'. We are presuming that the site is 'guilty' and through sampling and assessment, we are looking at proof of safety. We therefore undertake the site investigation to see if there is evidence that the concentrations of contaminants are greater than the appropriate assessment criteria[2], and in this case we either accept the (null) hypothesis that the site is

Drilling work at an old landfill at Malabar Headland. Work for Department of Finance and Deregulation, managed by UGL and undertaken by SKM.
Tom Hoole, SKM

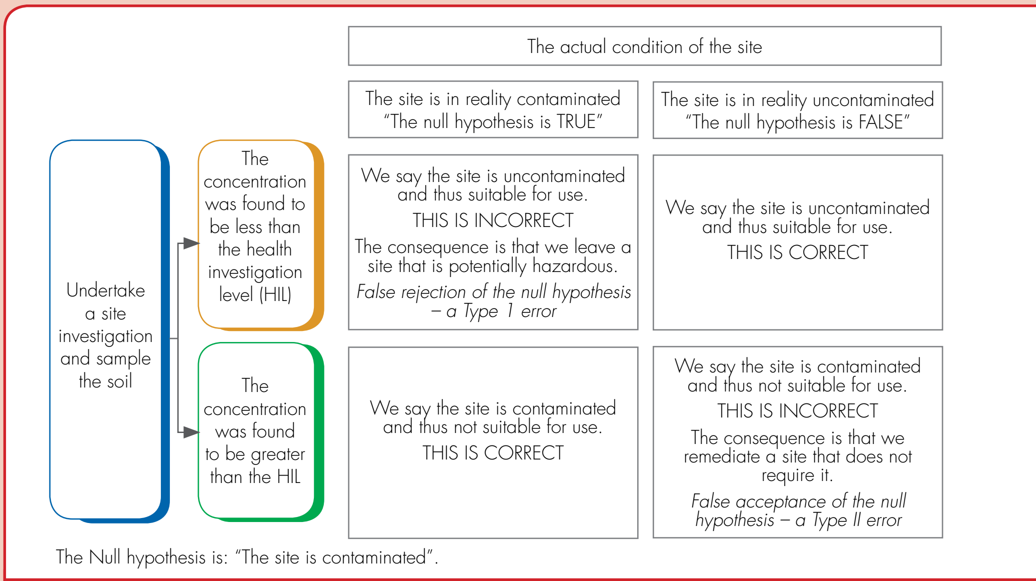
contaminated, or reject it and say that the site is not contaminated.

However, in making this assessment against the hypothesis, we could be making a mistake, as illustrated in Figure 1.

Two types of error are possible:

- Type I error – false rejection, which is also known as the level of significance of the test; and
- Type II error – false acceptance, which is also known as the power of the test.

Of the two errors noted above, the false rejection of the null hypothesis is a very poor decision and could result in hazards to human health. The false acceptance is also not desirable although the consequences are not as severe (e.g. delays or unnecessary costs).



		The actual condition of the site	
		The site is in reality contaminated "The null hypothesis is TRUE"	The site is in reality uncontaminated "The null hypothesis is FALSE"
Undertake a site investigation and sample the soil	The concentration was found to be less than the health investigation level (HIL)	We say the site is uncontaminated and thus suitable for use. THIS IS INCORRECT The consequence is that we leave a site that is potentially hazardous. *False rejection of the null hypothesis – a Type 1 error*	We say the site is uncontaminated and thus suitable for use. THIS IS CORRECT
	The concentration was found to be greater than the HIL	We say the site is contaminated and thus not suitable for use. THIS IS CORRECT	We say the site is contaminated and thus not suitable for use. THIS IS INCORRECT The consequence is that we remediate a site that does not require it. *False acceptance of the null hypothesis – a Type II error*

The Null hypothesis is: "The site is contaminated".

Figure 1: Illustration of potential errors in decision making.

Handling the upper confidence level

Most regulatory authorities require that the average contaminant concentration is compared with an assessment criterion in order to evaluate whether a site is contaminated. The average (or 'central estimate') is recommended because this is most representative of the concentration to which individuals would be exposed over time, and is in turn linked to the way risks are evaluated.

The 'best' central estimate is actually the time-averaged concentration. However, because this is commonly approximated using the spatial average, reduction in chemical concentrations over time are not usually taken into account. For example, if the medium is contaminated soil, then the spatially averaged concentration can be used to approximate the time-averaged concentration if one assumes that the exposed individual moves randomly across the area being exposed at one time to high concentration and at other times to a low concentration.

The average is simply a calculation based on the laboratory data and the samples gathered. However, as noted in the opening paragraph, there is considerable uncertainty over whether this sample average is representative of the true population average (i.e. how similar is the average of 13 random samples to the true population average?).

To assist in this evaluation, rather than rely on the average of the samples, an estimate of the true average can be made by calculating a confidence interval. Because we tend to be interested only in what the upper extent of the interval is, this is expressed as an upper confidence level (UCL). The UCL is defined as the value that, when calculated repeatedly for randomly drawn subsets of site data, equals or exceeds the true average a certain percentage of the time. UCLs are

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1 This is illustrative only and will depend on the actual volume of soil in an individual sample.

2 In this article assessment criteria is assumed to be a health investigation level

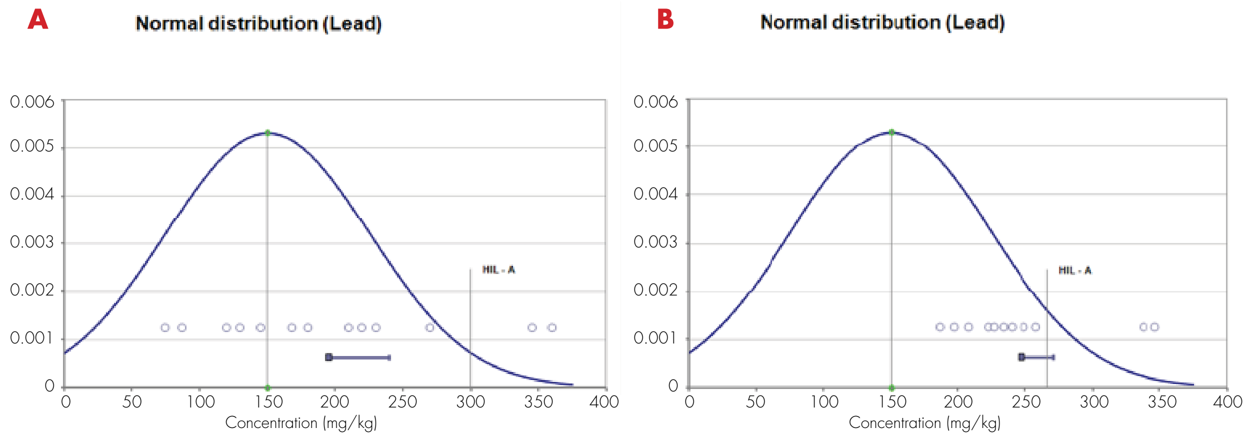

Figure 2: Illustration of normal distribution of data, posted results from 13 samples (circles). A) the sample average (square) and the UCL (bar). Correct decision is made. B) the sample average (square) and the UCL (bar). Incorrect decision is made.

generally calculated at the 95% level of significance – in other words, 95 times out of a hundred, this 95% UCL will exceed or equal the true average. It thus provides a conservative estimate of the true average with the UCL tending to move closer to the true average as the sample size increases.

In Figure 2a, the true concentration of lead is 150 mg/kg with a standard deviation of 75 mg/kg, generating the normal distribution (which has been truncated at 0). This demonstrates that although the average is well below the health investigation level (HIL) of 300 mg/kg, in some cases – the upper 2% of the data in this hypothetical case – values can exceed the HIL. Therefore, if 13 samples yield results ranging from 75 mg/kg to 360 mg/kg and these results are plotted onto the graph, two of the samples exceed the HIL. The sample average is 208 mg/kg and the 95% UCL is 250 mg/kg. If we are using the UCL as the estimate of the 'true average', we will conclude that the site is uncontaminated; we will be correctly rejecting the null hypothesis.

If the sampling exercise is repeated many times, it is possible that, by chance, samples may register at the higher end of the normal distribution (Figure 2b). In this case the sample average is 278 mg/kg and the 95% UCL is 304 mg/kg and thus we will conclude (wrongly) that the site is contaminated; we will be incorrectly accepting the null hypothesis. This type of error will only occur rarely.

The upper confidence level as a means to consider error

While in simple terms the UCL is used only as a means to assess whether a site is potentially contaminated, it also provides useful information on both Type I and Type II errors:

- As we are interested in only the one-sided UCL, the higher the confidence level the more the UCL gets 'pushed to the right'. The 99% UCL will be a higher value than the 90% UCL; this in turn is analogous to the false rejection rate.
- The smaller the width of the interval, the higher the power of the test or the false acceptance. The wider the confidence limit the more chance there is of saying that an uncontaminated site is actually contaminated. This is equivalent to the false acceptance rate.

FURTHER READING

1 CIEH (2008) Guidance on Comparing Soil Contamination data with a Critical Concentration

2 Gilbert (1987) Statistical Methods for Environmental Pollution Monitoring

3 USEPA (2002). Calculating Upper Confidence Limits for Exposure Point Concentrations at Hazardous Waste Sites. OSWER 9285.6-10

4 USEPA (2007). ProUCL Version 4 Users Guide

5 Michigan Department of Environmental Quality (2002) Sampling Strategies and Statistics Training Materials for Part 201 Clean up criteria

Calculating the upper confidence level

There are several questions we need to ask before the UCL can be calculated:

Can you follow a statistical approach?	This guidance for calculating UCLs describes statistical methods that are based on the assumption of random sampling. At many contaminated land sites, however, sampling is focused on areas of suspected contamination. In such cases, it is important to avoid introducing bias into statistical analyses. While random sampling can achieve this, it can sometimes lead to poor coverage of the site. Reducing bias can also be achieved through stratified sampling, such as square, triangular and off-set Herringbone grid patterns. So long as the statistical analysis is constructed properly (i.e. samples are not mixed across different populations) bias can be minimised and a statistical approach followed.
Are the samples from one averaging area?	A key assumption in contaminated-land risk assessments is that the receptor (humans using the site) will tend towards an average exposure, which is related to both the contaminant profile at the site and the receptor habits. An example of an averaging area might be the whole of the surface soils of the site or an area 20 m in radius around a former tank. Viewing the data within a geographic information system (GIS) can be very helpful in assessing patterns in the data that might not be apparent otherwise.
Have you got enough samples?	Sample size is especially important when there is large variability in the underlying distribution of concentrations. Clearly the more samples the better, however, as described at the start of this article, datasets from contaminated-land investigations tend to be relatively small. Very little guidance is available on recommendations for minimum sample size. The US Environmental Protection Agency states that datasets with fewer than 10 samples provide poor estimates of average concentrations (i.e. there tends to be a large difference between the sample average and the UCL).
Are there any nondetects?	Nondetects – or censored data – are data that are considered by the laboratory to be below the practical limits of quantitation. The presence of nondetects is commonly seen with contaminated-land investigations. In the first instance nondetects can be substituted with a value of either zero, half, or equal to that of the minimum detection limit. If there are more than 50% nondetects then an average (or UCL) should not be calculated, and the assessor must resort to using the maximum or a percentile as an estimate of the central value.
What is the distribution of the data?	Environmental populations tend to follow either a normal (bell-shaped) or log normal (skewed) distribution. The distribution type is important as this will determine how some of the statistical tests and calculations are performed. Sometimes it is not possible to determine what the distribution is and thus 'distribution free' tests can be done. These tend to provide more conservative results.
Are there any extreme values, stragglers or outliers?	The data should be assessed using a number of standard outlier tests such as Grubbs' test, Rosner's test, Tukey's interquartile rule and the median absolute deviation test. Visual assessment of normal probability plots or box plots can also indicate the presence of outliers. If any potential outliers are flagged, the characteristics of the outlying sample should be assessed to determine any reasons why it could be anomalous. Does it look different, does it have any other chemical properties that stand it out, or is it from near a potential source (as opposed to being just part of the rest of the site)? If the sample is identified as an outlier it should be removed from the dataset for further assessment. If not, it should be retained and simply considered as a high value.
THEN **Calculate the UCL**	**The UCL can then be calculated using the verified data set with the appropriate calculation method.**

A critical aspect of following the above is to iterate the process. This iteration should be undertaken until a final dataset is arrived at for UCL calculation. The data assessment effort is following the steps in the table above – the UCL calculation is easy!

Conclusions

- Application of statistics requires careful consideration.
- Look at the data – do they make sense?
- The data should be reviewed and only when a 'usable' data set is defined can a UCL be calculated. This review process is likely to require iteration.
- Write about sample size error in the report – it is by far the largest source of error in undertaking contaminated land site investigations.

To sum up, the science of statistics is not a substitute for common sense. Or, to paraphrase the US mathematician John Tukey, an approximate answer to the right problem is worth a good deal more than an exact answer to an approximate problem.

Dr David Coutts is Practice Leader, Contaminated Land Investigation, for Sinclair Knight Merz Pty. Ltd., Melbourne. He specialises in contaminated land site investigation, quantitative risk assessment and environmental statistics, and has been involved in environmental pollution assessment, environmental impact assessments and regulatory reviews.

Contaminated site data collection can be fraught with uncertainty.
iStockphoto/Bartco

Opinion

How reliable are commercial laboratory analyses?

Ray Correll, Centre for Environmental Risk Assessment
and Remediation, University of South Australia

Commissioning a commercial laboratory to perform a contaminant analysis should yield a reliable report, right? Not necessarily.

I write this article as an environmental statistician. Over several decades I have had unfortunate experiences with some laboratory results. Discussion with Swedish colleagues has shown that problems with laboratory analyses also occur in Europe.[1] Problems are especially likely when the required sensitivity of an analysis is near the reporting limit. This article outlines the reasons for many inaccuracies, and suggests how to detect and possibly control this variation.

Poor definition of the analysis

Problems can occur as a result of how the analysis is defined. Some definitions may seem trivial but they can be very important – take, for example, a mass balance trial that required both fresh and dry weights of a material. The fresh weight of the produce was measured but laboratory data were expressed on a dry-weight basis, with no measure of moisture content. In another case, there was doubt over whether the weights of meal samples were collected as fresh or dry.

Confusion over units of measurement can also cause problems. For example nitrate concentration may be expressed as NO3- or as nitrate-N. In one case, this caused a major source of variation even though the same models were run by experienced modellers using the same data sets.[2]

Bungles

When plotting log mercury content against tuna length I found a series of points exactly one log unit below the majority. Reanalysis of those samples gave concentrations 10 times higher suggesting a systematic dilution error had occurred. Another example of a systematic error is shown in Figure 1. Both cases indicate a dilution or calculation error occurred in the laboratory.

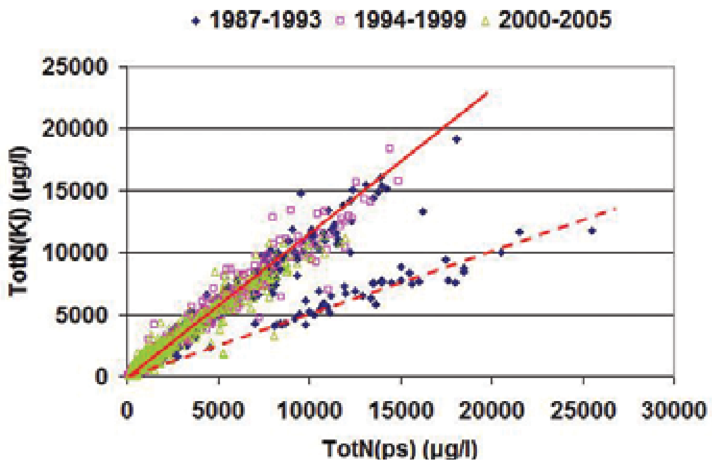

Figure 1. Scatter chart of Tot-N(Kj) plotted against Tot-N(ps) for a sample of 7540 water samples collected in 34 rivers in Sweden. The slope of the dashed line is exactly half of that of the solid line (after Whalin and Grimvall, 2008).

Sampling and other random errors

It is surprisingly difficult to take a representative subsample in the laboratory. Generally these errors contribute to noise so taking more samples will reduce the problem. This is of little comfort where decisions are made on individual samples rather than on the sample mean. This type of random error can be quantified by comparisons between laboratory duplicates and split samples.

Laboratory drift

'Laboratory drift' becomes very important in monitoring studies. In theory, if standard samples are included in runs, this should not occur. Unfortunately the reality is otherwise. Analyses of a heavy metal in seawater by two different laboratories on four occasions (Figure 2) reveal clear inconsistencies between the laboratories that changed with time. This indicates that results from at least one (and probably both) laboratories drifted. There was no reason to believe that the true concentration in the seawater changed over the duration of the survey.

Another example of laboratory drift is an analysis that demonstrated changes in phosphate levels in a lake (Figure 3). The reported changes were considered an artefact of the measurement process.[1]

Contamination

Sample contamination can be a major problem in environmental sampling, especially with water samples. See, for example, the outliers in Figure 4, which shows concentrations of a heavy metal in seawater. These outliers were likely due to contamination. In the current case there appeared to be more contamination of samples sent to Laboratory B, suggesting the source was in the laboratory.

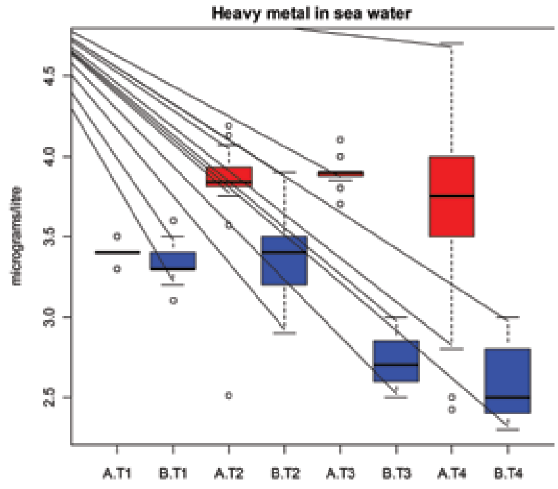

Figure 2. Box plots of results from analyses by two laboratories (A and B) over four times (T1 to T4) of a heavy metal in seawater. The variation in results indicates laboratory drift.

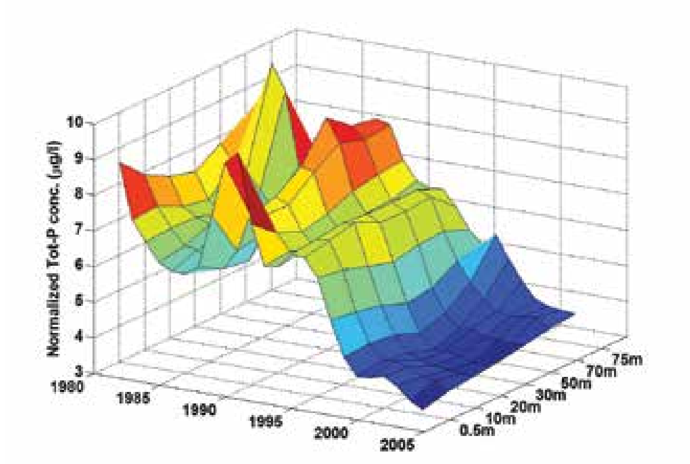

Figure 3. Temporal trends in temperature-normalised concentration of total phosphorus at Jungfrun in Lake Vättern, Sweden. Trend surface for samples collected at different depths (0.5 – 75 m) (after Whalin and Grimvall 2008).

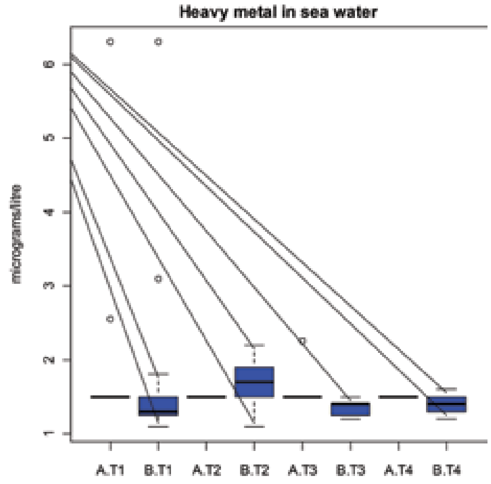

Figure 4. Box plots of results from analyses by two laboratories (A and B) over four times (T1 to T4) of a heavy metal in seawater. The outliers are likely a result of sample contamination.

This is a serious matter as the outliers triggered further – probably unnecessary – investigation.

Typically contamination creates positive outliers. The outliers inflate the mean (at times they dominate it) and thus create an upward bias. Outliers also increase the variability, which in turn decreases statistical power. At times the outliers may represent true values, so they should not be automatically discarded – if sufficient sample remains the sample should be re-analysed in triplicate.

Incomplete extraction

Problems can arise when there is incomplete extraction of a sample. An example of this I have encountered was extraction of heavy metals from animal tissue by a commercial laboratory, which led to an underestimate of the contaminant concentration. Generally this should not be a problem as details of the extraction process should follow some published protocol.

Avoiding errors

The effect of errors in an analysis fall into two classes – those that affect precision only and those that also cause a bias. Sampling variation and machine variation affects precision – increased replication will reduce that component of error. Other errors, such as laboratory drift and contamination, will cause bias – no amount of replication will remove that bias so a mean from those data can never be accurate.

Improving accuracy

Increased replication – increasing the number of samples will yield a more precise estimate of the mean.

Field blanks (e.g. adding distilled water in the field to a collection bottle) can be used as a check for contamination.

Triplicate samples are three independent samples taken from the same point. The difference between these triplicates is a measure of both field sampling variation and laboratory variation.

Split samples – a sample that has been collected in the field is split and both halves sent for analysis.

The difference between the two halves measures laboratory variation (including subsampling variation).

Laboratory duplicates – a comparison of laboratory duplicates provides a measure of the laboratory precision. Duplicate analyses are often carried out on the same extract as they do not include subsampling or extraction variation.

Surrogate recovery – a known amount of a compound is added to the extractant and the fraction recovered is recorded (this is equivalent to spike recovery). Surrogate recovery is a measure of accuracy for that surrogate.

Certified reference material – analyses of certified reference material will provide a measure of the accuracy of the laboratory analysis.

There is no easy way of ensuring accurate results. All of the examples discussed in this article come from laboratories that had National Association of Testing Authorities (NATA) accreditation. Some control can be obtained by including field blanks, which could detect sources of contamination (e.g from the containers themselves). Surrogate recovery, laboratory duplicates and split samples should be within the limits prescribed by the National Assessment Guidelines for Dredging (NAGD).[3] The NAGD state that recovery rates should be in the range specified for that analysis (typically 75–125%) duplicates should agree within the specified relative percent difference for the method (typically ±30–35%). Further, if certified reference material is included in every 10 to 20 sample series, the analysis should give a value of 80–120% of the certified value.

The effect of the lack of precision varies among applications. For dredging, the 95% confidence interval of the mean is important[3] and the effect of sampling errors can be reduced by increasing replication. However toxicants are treated differently in the Australian and New Zealand Environment and Conservation Council / Agriculture and Resources Management Council of Australia and New Zealand guidelines[4] where a single high value can trigger further investigation.

In conclusion, while most analyses in my experience have been repeatable, there have been cases where data from a NATA-accredited chemistry laboratory could have caused an incorrect decision. It is important to incorporate sufficient control and reference samples to ensure the accuracy of the analyses.

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Case Study

Land fit for a Royal (Hospital)

Jeremy Clapp, FMG Engineering

Remediation Australasia takes a look at how Adelaide's old rail yards were cleaned up for the construction of the new Royal Adelaide Hospital.

The Adelaide rail yards circa 1930.
Wikicommons

In 2011 construction of the new Royal Adelaide Hospital (RAH) began at the western end of North Terrace on the old Adelaide Rail Yards. The site was chosen for several reasons, including its proximity to the city and ease of access (with good road, rail and tram connectivity). One of the key criteria was that sufficient space was available to create a new hospital on a clean slate. Replacing the existing RAH, which opened in 1840, the new version will be Australia's most advanced hospital. Scheduled for completion in 2016, it is also the largest infrastructure project in the South Australia's history.

Building the hospital on old rail yards poses particular engineering challenges from both quality and technical perspectives. The rail yards were used as a maintenance facility for the metropolitan railway lines for over a century. Along with underground diesel storage tanks and pipelines criss-crossing the site, other potential hazards included old pavements, concrete slabs, train wash bay facilities and plumbing. Over half a million tonnes of soil had to be removed from the site to excavate to the future basement level. Because hospitals by their nature must be very sensitive to environmental health considerations, the site was also under the auspices of an Environmental Protection Agency SA auditor.

Following the project's announcement, FMG Engineering was engaged to develop a detailed site investigation plan followed by a remediation management plan, which together would identify, confirm and manage contamination. Ultimately these plans needed to satisfy both the human health risk on site during the construction phase as well as the hospital's operation once completed.

The initial investigation works began in July 2011 with remediation earthworks commencing in October. For six months prior to contract finalisation, FMG Engineering analysed previous data and reports

Remediation works at the site of the new Royal Adelaide Hospital. *FMG Engineering.*

from the site to establish a scope for the remediation site works. Overall, this included air quality monitoring, due diligence, environmental site histories, environmental site assessment, groundwater assessment and remediation, waste classification, validation of site remediation, and regulatory compliance issues. Other hazards considered included soil contamination and groundwater contamination, vapour management, stormwater and runoff management, and dust monitoring. Remediation was completed in just under a year, in September 2012.

All of the above considerations contributed to on-site human health risk assessment and contamination management. For construction, the site had to be remediated to a state where there is no risk to the health of construction workers whereas the long-term aim for the site is to have no adverse impact on the operation of the hospital in terms of remnant contamination or vapour intrusion to the hospital.

To manage the half-million tonnes of surplus material being removed from the site, it was necessary to accurately determine the extent of contamination of these materials. Boreholes were drilled throughout the site to confirm areas of contamination, including leakage and seepage from the diesel fuel tanks and train wash bays. These holes were drilled at depths of up to 12 m, allowing for accurate characterisation of contamination. This drilling also determined appropriate disposal options for removing surplus soils from the site. To assist in this process, FMG Engineering used military-grade tablet computers in the field, allowing real-time logging of samples with exact coordinates. In addition to this, mining visualisation software was used to create a three-dimensional contamination model of the site. Contaminated soil was logged and tracked according to legal requirements, to account for all soil and fill relocated or removed from the site.

It was crucial to track soil as it left the site, and to accurately log soil as it was moved around the site. Contaminated soil was stockpiled in monitored areas, and classified before being taken to licensed landfill. Pre-classification allowed FMG Engineering to deal with the large volumes of contaminated soil, as well as its varying levels of contamination. Leaking diesel fuel tanks have provided a further degree of complexity to the remediation of the site. Fate and transport modelling was conducted to model the potential movement of diesel plumes under the site. Contaminant plumes were shown to be contained within the site boundaries. Overall, the area was remediated to around 4.5 m, ensuring that future construction or maintenance works can be carried out safely.

As the site is located next to the River Torrens, which runs through the City of Adelaide and into surrounding suburbs from the hills to the beach, a stormwater detention basin was set up to manage stormwater runoff and potential contamination risks. Dust management was also a key concern as the site is located on the corner of three major arterial roads, with associated pedestrian and vehicle traffic and public transport. Air quality was monitored to observe dust levels in the air, and weather stations were employed to ensure that air quality remained at a suitable level.

As works progress towards completion, FMG Engineering will continue to monitor the site as the piling, foundations and in-ground services are constructed to ensure that all surplus soil is managed in accordance with site protocols and plans.

LANDFILL SERIES
PART 3

Integrated resource recovery: a better way to mine landfill

Piles of compost in maturation yard at a German mechanical biological treatment facility
All photos: Paul Clapham

Paul Clapham, Sinclair Knight Merz

Integrated resource recovery centres bring together energy recovery, recycling and storage for a more complete approach to landfill mining.

This is the third and final article in a series that has looked at landfill mining in the context of sustainable materials management. Landfill mining, which recovers value from previously discarded material through recycling and/or energy recovery from the waste, helps to close the loop in materials management, conserving virgin materials and saving energy. These concepts were described in detail in the first article of this series;1 while the second article focused the technology's history and application, and provided an assessment process to help determine whether landfill mining is applicable in a particular situation.[2]

This instalment explores enhanced landfill mining through the development of integrated resource recovery centres (IRRCs). These are landfill-based facilities that allow the recycling of contemporary municipal solid waste, commercial and industrial (C&I) waste, and construction and demolition (C&D) waste. They also recover energy from the low-value combustible material present in the waste. At IRRCs, recycling and energy recovery processes are closely coupled with the temporary storage of waste materials for which there is no current market demand, or for which a viable, cost-effective recycling or recovery technology does not yet exist.

The concept of resource recovery parks is not new, and there are many examples of materials recovery facilities that separate and sort specified materials (e.g. metals, plastics, paper and garden waste) from commingled recyclables collected from households, at recycling centres (often known as 'bring sites'), or from C&I or C&D waste streams.

At a more advanced level, complex waste treatment facilities such as mechanical biological treatment (MBT) plants have been designed to recover materials and energy from residual municipal waste (material left over after householders have separated out the more common types of recyclables such as glass bottles, paper, metal cans, and hard plastics). MBT plants effectively sort the residual waste into different material types, typically recovering the remaining ferrous and non-ferrous metals, hard plastics, glass, paper and cardboard, together with an organic fraction (made up of garden and food waste). The more valuable of these material types (typically the metals and hard plastics) are then baled and sold to reprocessors. The paper, cardboard, and soft plastics are often blended to produce a refuse-derived fuel (RDF), which can be either burnt in an energy recovery plant (typically a mass burn incinerator), or thermally decomposed in a gasifier, pyrolysis unit or plasma gasifier to produce an energy-rich 'syngas'. The syngas can be burnt in an internal combustion engine or furnace to produce electricity or heat for space heating. The organic fraction (the green and garden waste) can be either digested anaerobically to produce a methane rich biogas that can be burnt to produce electricity or heat, or composted to produce a low-grade soil improver.

Piles of recovered timber to be shredded as mulch, Australia

In continental Europe there are many examples of MBT facilities that are located at landfills. Many of the early European facilities were designed to reduce the biodegradability (the volatile carbon content) of the organic fraction of the waste so that the risk of greenhouse gas production was minimised once the waste was placed in the landfill. Later MBT designs have focused on producing an RDF from selected components of the waste (usually the organic fraction, soft plastics, and the badly contaminated paper and cardboard). The RDF is then usually combusted on-site (or processed through an advanced thermal treatment facility) to produce the electricity needs of the MBT with any excess electricity being sold to the grid.

One of the advantages of co-locating MBT plants at landfill is that the processing facility can often operate under the existing site licence and is situated well within the required separation distances from sensitive surrounding land uses. Another advantage is that the residues from the process – those materials that have no market value as recyclable materials, such as off-specification

Piles of recovered glass for use as road base before refining, Australia

plastic polymers, contaminated organic material or soil, and construction waste (concrete, road sweepings, etc) – can be deposited in or used to restore the landfill, used as daily cover for landfill, or used in on-site road construction.

This description of an MBT-based resource recovery facility is an example of the ideal design, where the majority of the waste being received by the facility is recovered either as recyclate, compost or energy. The reality can be somewhat different. The principal bugbear in the system is the volatility of markets for recyclable materials. The history of resource recovery is replete with tales of boom and bust. Scarcity of particular material types, such as paper or metals, has encouraged municipalities and private contractors to invest heavily in the types of materials-recovery equipment described above. As the number of processing facilities increases, the market price for recyclates typically begins to fall (a situation that is exacerbated during periods of economic downturn). Eventually the more marginal recovery operations (usually those located furthest from the reprocessors or those employing old or inefficient equipment) enter liquidation, the waste material is ultimately sent to landfill, and the facility is either mothballed or dismantled.

If we take a step back and consider resource recovery more holistically, rather than as a reactive response to market demand, we can begin to identify ways to strengthen the integrity of the resource recovery system. The key to this is the effective use of landfill as a temporary repository for materials. Although the stockpiling of recyclables has gained a poor reputation in the waste and materials recovery sector because of its association with 'sham recovery' – spurious claims by an operator that materials have been recycled when all that has happened is that they have been separated from the residual waste, baled and dumped – there is an argument for the legitimate storage of sorted material pending the right market conditions for their dispatch to a reprocessor. Similar approaches are used for other commodities including foodstuffs, minerals and wood products.

For material storage to work in the waste and resource recovery sector, careful thought will need to be given to the adoption and deployment of appropriate controls. Of paramount importance will be the need to protect human health and the environment. Thus medium- or long-term storage of organic waste (garden and food waste) should not be permitted, as these materials will naturally begin to decompose, producing odours and greenhouse gases (carbon dioxide and methane), and possibly attracting vermin (e.g. flies and rodents). Thus organic waste should either be composted or used for energy recovery (either through anaerobic digestion or as part of an RDF).

Plastic polymers can degrade when exposed to sunlight, so to protect the integrity of these materials they should be stored under cover in designated areas. While burying bales of plastic could provide a solution, this approach should not be promoted in anything other than dry climates, as infiltration of rainwater can leach out chemicals, which in an unlined landfill can contaminate ground and surface waters. Thus plastics are best stored in sheds or warehouses. Similarly, ferrous metals will degrade if buried in landfills in wet climates, and should therefore be baled and stored under cover.

So what types of waste should be buried in the landfill? The most obvious answer is hazardous waste (sometimes known as prescribed industrial waste) that has been treated in some way to stabilise the material and then placed in a suitable container. Once treated, this waste would be placed in an engineered cell with its description and location recorded. Such cells would then act as repositories for the waste material, which could be retrieved should a need be identified or a new recovery process developed. The remainder of the landfill void space would be filled with low-value inert waste including bottom ash from the energy recovery facility and overburden from mineral excavation.

Future landfills could therefore look very different to their current counterparts, where mixed waste is generally dumped in cells, compacted and then covered. Taking the concept to the next level, we could look to redevelop existing landfills along these principles by progressively mining the existing waste mass (as described in the previous two articles in this series). The mined material would provide additional feedstock for the operation of an on-site MBT plant and energy recovery facility, while at the same time releasing real estate for the construction of storage sheds and new landfill cells. Indeed the landfill could become a hive of activity that could include workshops for dismantling or refurbishing items such as furniture, electronic equipment and end-of-life vehicles. The on-site energy recovery plant coud provide the energy to operate these workshops. Where necessary, the fuel supply for the energy recovery plant could be supplemented with a proportion of the stored combustible waste (e.g. plastics, wood, paper, cardboard, used oils and solvents) – particularly if this material was approaching its use-by date.

The economics of an enhanced landfill or integrated resource recovery centre would be a little more complex than is the case for many of today's landfills. Many landfills operate on a gate fee basis (a charge being made by the operator of the landfill per tonne of waste received) to cover operational costs, applicable landfill taxes and emissions charges, plus a suitable profit margin. Gate fees for municipal waste are typically established through service contracts. For an enhanced landfill or IRRC, a different financial model could be adopted – one that is made up of a 'base gate fee' that would cover operational costs, and a flexible tariff that could reflect the market value of recyclable materials and any energy that is exported from the site to the grid. Such an approach would require the development of contracts between the service provider and the municipality that provides for the sharing of risk and profit. For C&I and C&D wastes, a spot market approach could be adopted by individual landfill operators so that the price charged for receiving a tonne of waste would be based on the composition of that waste and its market value – a higher gate fee would be charged by the landfill operator to cover the storage costs associated with waste types that do not have a sufficiently high market value to justify their immediate reprocessing.

The enhanced landfill mining model provides an opportunity for the waste and resource recovery sector to adopt a 21st-century approach to managing the residues from society. There are a number of examples where the principles of enhanced landfill mining are already being adopted. In Flanders (Belgium), Group Machiels is in the early stages of recovering value from 15 million tonnes of waste that has been deposited in landfill since the 1970s, using gas plasma technology provided by Advanced Plasma Power to process the waste. In Western Australia, New Energy Corporation is developing its concept design for resource recovery in the Pilbara region. Similar interest is being shown in communities in Canada and Southeast Asia.

The twin concepts of enhanced landfill mining and integrated resource recovery centres have application at a range of scales and could be deployed at existing landfills located near metropolitan areas (thereby helping to extend the remaining life of the landfill). The same principles can also be applied at more remote landfills, and can help overcome some of the frustration that exists in rural communities where existing economies of scale tend act as barriers to recycling or recovering value from waste.

If enhanced landfill mining is to become the norm, municipalities, regulators and waste management contractors will need to embrace new ways of doing business. To succeed, this fresh approach will need to recognise the inherent value of different material types and the varying demands of the commodities markets.

Bales of recovered plastic bottles, Germany

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2. Landfill mining technologies: part 2 (pages 38–41 of *Remediation Australasia* Issue 12)

East Perth: Socially and transit-friendly remediation.
Garry Smith

Sustainable remediation in Australia and New Zealand

Garry Smith, SuRF ANZ

The time has come to consider social, as well as environmental and economic, factors in our approach to remediation.

Why adopt sustainable remediation?

Sustainable remediation (SR) is currently a topic of intense interest and debate in Australia and New Zealand (ANZ). In other countries that have formed national Sustainable Remediation Forums (SuRFs), notably the USA and UK, SR initiatives have shown immediate benefits. These include improved remediation methodology decisions, reduced carbon and water footprints, better social inclusion, and improved targeting of remediation costs.

ANZ remediation practitioners, regulators and other stakeholders began discussing SR around 2009. The Sustainable Remediation Forum of Australia and New Zealand – SuRF ANZ – was officially launched in 2012.

It is clear from both international and ANZ experience that by including relevant sustainability considerations in project planning and implementation, a project is more likely to meet 'triple bottom line' criteria (this approach assesses performance against social and environmental, as well as economic, measures). Recognising this, in 2012 the International Organisation for Standardisation (ISO) approved a working party, with SuRF ANZ a participant, to formulate an informative (guidance) not normative (prescriptive) ISO standard on SR.

Several sessions and a workshop at the CleanUp 2013 Conference in Melbourne in September 2013 (see www.cleanupconference.com for more information) will include discussion on just what SR involves, what remedial solutions may be acceptable, whether SR offers tangible benefits in our region, and where existing regulatory systems and policies may already be sufficient. Discussions may also include consideration of how an SR framework will interface with the emerging Australian National Remediation Framework, including requirements of regulators in relevant ANZ jurisdictions.

What is sustainable remediation?

A working definition of adopted by SuRF ANZ (based on that of SuRF UK) states that sustainable remediation is "a remediation solution selected through the use of a balanced decision-making process that demonstrates, in terms of environmental, economic and social indicators, that the benefit of undertaking remediation is greater than any adverse effects."

A framework for SR

A draft Framework for Sustainable Remediation prepared for SuRF ANZ (available at www.surfanz.com.au) can be used to inform local projects. The framework considers application of SR approaches at a range of scales, from regional to site-specific. Other SuRF ANZ draft working papers available at the website consider remediation planning, remediation metrics (e.g. carbon and water usage) and some preliminary case examples from ANZ. Links to international SuRFs and their working papers are also available.

Australia has well-established statutory systems involving independent third-party auditors drawn from the private sector and delegated by state government regulatory agencies to assess the results of remediation and to formally certify that land is suitable for use. Work is carried out in accordance with detailed guidelines issued by regulatory agencies. In New Zealand there is over-arching legislation for environmental compliance and a new National Environmental Standard for contamination.

Both Australia and New Zealand have used a generally accepted 'clean up to the extent practicable' approach that considers the technical feasibility, logistics and financial aspects of pursuing clean-up, including groundwater contamination. This has resulted, where appropriate, in regulatory acceptance of remedial solutions that cannot practically achieve complete clean up. Such an approach is compatible with consideration of the principles of sustainability during selection of remedial strategies. The audit system as practiced in Australia can, for example, allow for effective retention and long-term management of contamination on sites using appropriate risk assessment-based decision making.

SR practice as applied in the region has important contributions to make to emerging cross-disciplinary sustainable development practices in land-use planning (brownfields development), urban design (urban renewal) and transport (transit-oriented development).

SR versus Green SR

There is considerable discussion in the government regulatory context within some international jurisdictions about the applicability of 'Green and Sustainable Remediation' (GSR) – described somewhat simplistically as developing more sustainable approaches to complying with set clean-up endpoints – versus SR (remediation plans which balance environmental, social and economic endpoints).

Regulatory governance norms in ANZ, based on well-established jurisdictional legislation and guidance, have in practice established workable positions on government, industry and public approaches to some aspects of sustainability principles in remediation. Indeed, GSR and SR may be considered complementary rather than conflicting. The issue is really what is deemed to be mandatory. When regulatory requirements make reaching a particular clean-up endpoint mandatory, then effort is typically directed to achieving a sustainable and balanced approach to the achievement of that endpoint. This is effectively GSR. If however a jurisdiction does not require a fixed endpoint (for example, source treatment, monitored natural attenuation or containment could be options, so long as beneficial uses are protected and the risk level of each is considered acceptable), then effort is directed to determining which option provides the most sustainable solution. This is SR.

In Australia, for example, 'beneficial uses protection' is an essential regulatory requirement. Deviation from this requirement generally occurs only when it can be formally demonstrated that complete protection of uses is not practicably achievable, and that the resulting level of risk is low and acceptable. There is growing recognition that whether the outcomes of remediation are or will be acceptable depends on the acceptability of the risk to stakeholders – both the risk that implementing the remedial method presents, and the risk that is associated with the ultimate solution. This approach considers the likelihood (of an event occurring) and the severity of effect (should the events occur). It is essential that stakeholders deem the risk acceptable. Larger projects are typically required to confirm that acceptability has been agreed upon.

A requirement for financial assurances in situations where clean-up has not been completed is now increasingly evident and may be applied more widely than is currently the case. It is likely that other principles and indicators of sustainability will be defined, with reference to those already present in ANZ environmental legislation, and that their quantitative consideration will be required but not mandated.

The urban renewal attributes, and the environmental, social and economic benefits of SR will ultimately resonate with public stakeholders, and therefore with environmental regulators in ANZ. Remediation outputs developed and applied in ANZ can thus expect to be publicly endorsed if they include social and economic components as well as environmental components – i.e. if they are offered in an SR (as opposed to the more singular GSR) framework. Therefore SuRF ANZ considers that SR frameworks for remediation are ultimately most protective of the environment, and will better achieve sustainable development goals, when viewed from a holistic viewpoint. Ultimately, sustainability will be widely included in remediation decision making because it offers a balanced solution that benefits site owners.

Rhodes Peninsula, Sydney, Australia, (see www.surfanz.com.au).
SuRF ANZ / Thiess Services

We conclude that the concepts of GSR and SR are complementary. GSR focuses on achieving a particular remediation endpoint. SR has a broader focus, which includes wider endpoint options. SR practice depends on what is mandatory versus what is optional. This can vary depending on the particular situation, and on particular regulatory and stakeholder requirements.

Regulatory approaches to SR

Finalisation of an ANZ SR Framework will benefit from further discussion of regulatory approaches to SR, consistent with the regulatory agencies' mandate for consideration of ecologically sustainable development. This might include clarification of what is legally allowable in legislation in each jurisdiction, and of the definitions of 'sustainable' and 'practicable' among jurisdictions. Development of the National Remediation Framework in Australia provides a valuable opportunity to undertake this discussion and for harmonization of state-based regulatory requirements.

SR practice includes:

- identifying the timing for a remediation project
- considering opportunities for implementing sustainable technologies
- minimising risk to receptors (humans using the site or the surrounding environment) through source removal, in situ treatment, isolating contaminated areas or excluding receptors
- restoring or enhancing a site to meet the local community's vision.

Consideration of timeframes must include commercial imperatives alongside health and environmental risk. SR practice also requires consideration of both the current and future life cycle attributes of a site. The ANZ standard *AS/NZS ISO 14040 Life Cycle Assessment* series specifies principles, requirements and a general framework for conducting and reporting life cycle assessments. Once SR opportunities and drivers are identified, potential technologies can be chosen on the basis of their ability to satisfy the remedial drivers and to respond to sustainability opportunities (e.g. reducing the carbon footprint of remediation).

Including sustainability principles in decision making requires a balance of different viewpoints on relevant site and project factors and indicators. As such, it compels consultation. A key benefit of considering sustainability in remediation is that it takes different viewpoints into account and can therefore lead to a more balanced solution (compared with simply the viewpoint of a proponent, for example).

Tools for SR

SuRF ANZ research has identified a large number of metric tools which integrate sustainability concepts into remediation technology selection. These can be loosely defined as:

- Qualitative tools: Broad ranging and look at environmental, economic and social indicators (often referred to as 'triple bottom line').
- Quantitative tools: Typically calculating the impacts of a specific technology or action relative to an indicator group (environmental, economic and

social). Economic and social parameters can be difficult to quantify and hence the tools tend to focus on the metrics associated with environmental factors.

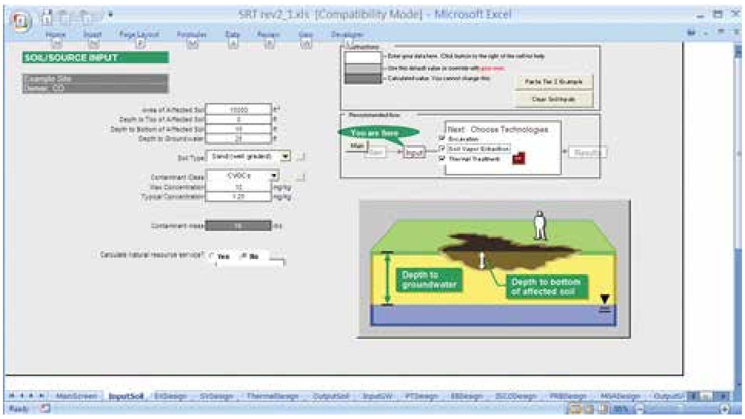
Well-established tools being used in the remediation industry include life-cycle assessment methodologies, the Sustainable Remediation Tool, SiteWise (available at the SuRF ANZ website, www.surfanz.com.au) and more qualitative tiered assessment processes. The tools are primarily US based, with some consultancies adapting them to build their own in-house tools. At time of writing a number of consultancies within ANZ are actively applying sustainable metrics. Although similarities exist in applying these, there is no single consistent method or approach. Cost of clean-up remains a fundamental factor in most cases.

It is unlikely that specific tools will be mandated in ANZ. More likely, a list of indicators (such as that devised by SuRF UK) will be made available for consideration, with a narrative. This would build upon the current State regulatory guidance relating to 'clean up to the extent practicable'. A tiered approach may evolve, involving an initial screening of options to understand the important factors that determine the decision, with more detailed analysis following as required.

SuRF ANZ is currently considering which existing tools apply to regional conditions, the issue of testing site tools' suitability to ANZ conditions, and the feasibility of developing tools appropriate for such conditions. Useful shareware resources, including initial tools for SR practice and links to overseas information on SR are available at www.surfanz.com.au.

SR for international development

From SuRF ANZ's perspective,it is important to consider the potential role of SR in addressing environmental, social and economic aspects of urban development in developing countries. This also has important implications for global climate change mitigation efforts. Over half the global human population is now urbanised, with the most rapidly growing cities located in the developing world. Urban sprawl continues to disperse urban travel destinations, thereby generating high carbon emissions from cities, particularly in urbanising developing nations.



Example page from the shareware SRT metrics tool (see www.surfanz.com.au).

Important and largely under-appreciated aspects of remediation include:

- Brownfield development's evolution from a tool for ongoing environmental and public health protection to a tool for sustainable urban renewal and urban carbon emission reduction
- The potential for brownfields development to contribute to carbon emission mitigation methods in developing countries while supporting urban development
- The importance of designing remediation to be energy and carbon efficient.

Abandoned, idle, and underused industrial and commercial land, where redevelopment is complicated by environmental contamination, is a substantial problem throughout the developing world. Large urban slums, for example, cause local pollution including petroleum, municipal waste and sewage infiltration to soil and groundwater, and thus require remediation on public health grounds. Current development-based aid financing (e.g. UN Habitat) is directed towards improving slum conditions, including making them habitable. This issues surrounding such sites reinforce that, by its very nature, brownfield development is inseparable from social and economic development.

As SR practice in ANZ develops, key case studies (e.g. the Rhodes Peninsula site in Sydney, which is taken from a case study available at the SuRF website; see photo on page 26) will highlight how adoption of the SR framework can provide real-world benefits. By illustrating applicable tools, it will also demonstrate how an SR framework can be practically implemented.

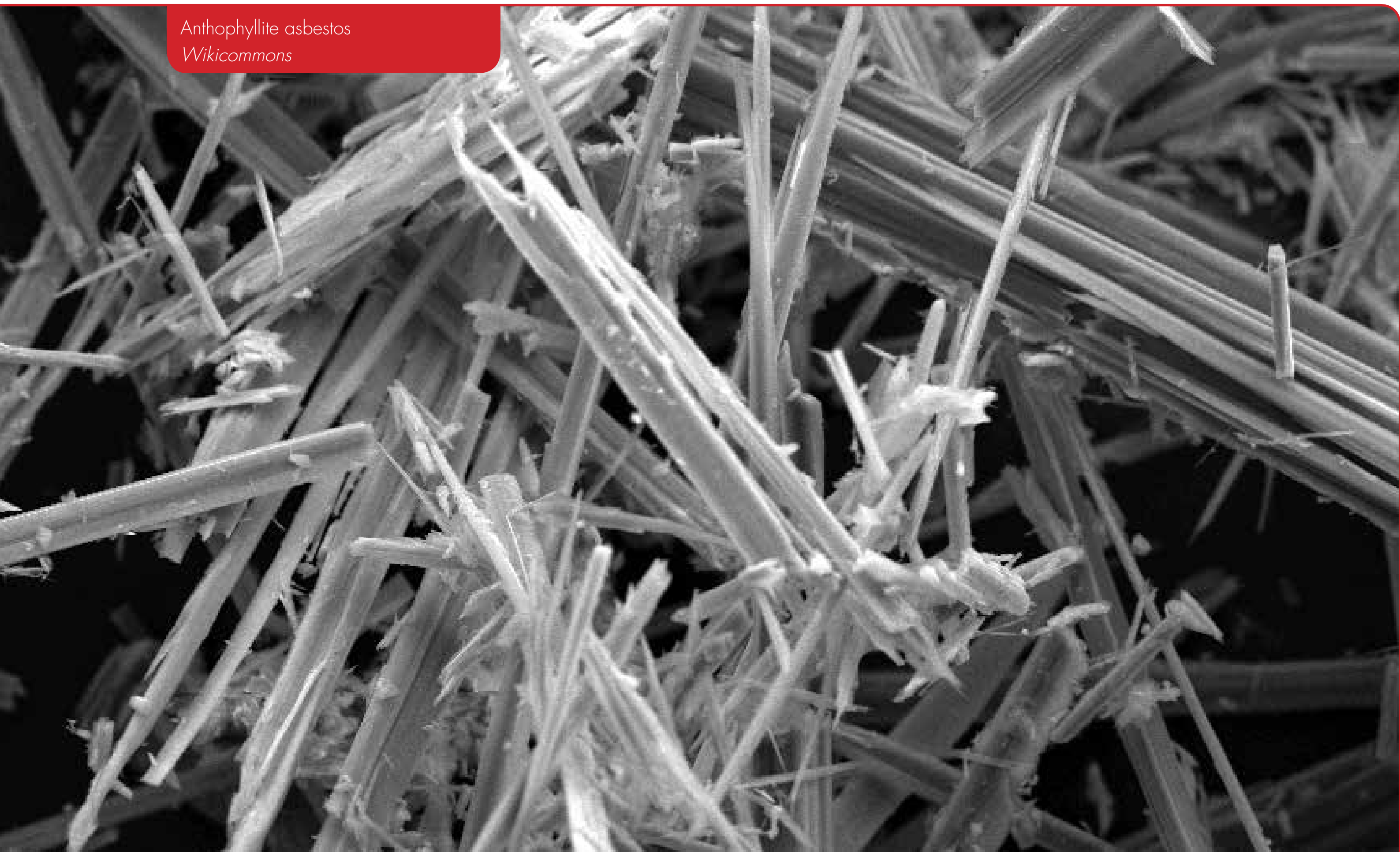
Dr Garry Smith is chairman of SuRF ANZ. He can be contacted at smithenvironm@gmail.com. The SuRF ANZ secretariat can be contacted at secretariat@surfanz.com.au.

The author gratefully acknowledges the important contributions to this article of a number of SuRF ANZ working groups and members, notably Dr Peter Nadebaum of the SuRF ANZ Forum Committee.

The trouble with Asbestos disposal

Tony Nocito , ABCOV

Hailed as a miracle mineral because of its superior fire resistance and tensile strength, asbestos was installed abundantly into our built environment for over 200 years. However, once it was established that this undeniably useful resource was a dangerous carcinogen, Australia and many other countries enacted strict regulations for handling asbestos and asbestos-containing material (ACM). These regulations created an asbestos abatement industry worth billions of dollars worldwide annually, and which will continue to generate millions of tons of asbestos waste long into the future.



Anthophyllite asbestos
Wikicommons

Corporations and insurance companies have paid out billions of dollars in asbestos claims and have increased their reserves by billions of dollars to cover present and future incalculable loses pertaining to asbestos lawsuits. Much of the cement board that permeates Australian residential, commercial, school and government buildings is a prominent example of such a product.

The installation and presence of these building products has caused many construction trade workers – including plumbers, pipefitters, boilermakers, carpenters and installers – to contract mesothelioma and other asbestos-related diseases. Besides the construction trades, the people who live and work in buildings containing asbestos are potentially exposed to toxic froms of asbestos. Consequently, the ACM mining, manufacturing and installation industries have created great liability issues for the producers, installers, end users and their associated insurance companies.

From 1950 to 1970, Australia was the highest per capita user of asbestos in the world,1 and vast numbers of domestic dwellings built before 1982 contained – or still contain – asbestos.

Australian bans on asbestos:

1967	crocidolite (blue asbestos) – considered the most dangerous of the asbestos minerals.
1989	amosite, (brown asbestos), banned from building products (and from other products in 2003).
2003	chrysotile (white asbestos).
2004	the remaining asbestos minerals, tremolite, actinolite and anthophyllite.

Sources: Asbestos Disease Awareness Organization (www.asbestosdiseaseawareness.org); Australian Council of Trade Unions

Whereas most countries banned the use of asbestos in building products by 1980, Australia's relatively late bans are likely to lead to more asbestos-related exposures and diseases many years into the future. Australia already has one of the world's highest rate of mesothelioma deaths, as well as many other asbestos-related cancers. These late bans will feed the asbestos abatement industry and the disposal of asbestos and ACMs, as well as contribute strongly to ongoing contraction of asbestos diseases.

In Tasmania, the Australian Workers Union has developed a plan to remove all the ACM by 2030, 17 years from now. But this raises difficult questions. Will all ACM on substrates will be removed? Where will the ACM be stored (noting that asbestos never really goes away, even when landfilled).

US laws make the owner or generator of asbestos or ACM a 'Potential Responsible Party', who is responsible for the cradle-to-grave liability for asbestos stored in a landfill through perpetuity. This means that when the landfill fails and must be cleaned up, the Potential Responsible Party or Parties, become responsible to pay for clean-up. In Australia there is no such regulation, with taxpayers meeting much of the financial burden for clean-up.

Let us explore the disposal options presently available for asbestos and ACMs.

Landfilling

Eventually, all landfills will fail. Modern day landfill liners last around 30 years. What happens when the liners are punctured or deteriorate?

Although landfilling is the cheapest and most convenient disposal option for asbestos or ACM, it it is not the most cost effective – in the long run someone will have to pay to re-abate the asbestos from the landfill before it pollutes the surrounding area.

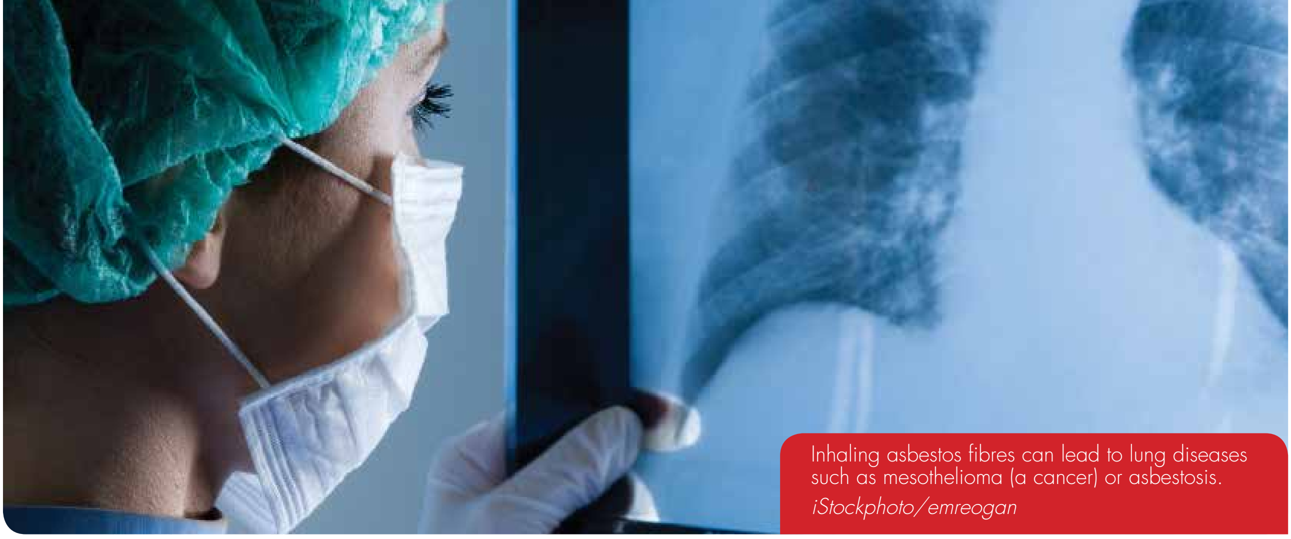
So what happens to asbestos or ACM when it is landfilled? By regulation, asbestos and ACM must be wrapped in plastic or a double polythene bag. Every package of asbestos must be clearly marked with a proper shipping name, including UN number, packaging group number, hazchem code and class label. The polythene bags are loaded on to a bin or trailer and driven to the landfill. The vehicle carting the ACM to the landfill must display a placard that is placed at the front and rear of the vehicle stating 'Miscellaneous Dangerous Goods'. Next, the polythene bags are dumped from the height of a trailer or container into the landfill. The dumped asbestos polythene bags must then be covered with 15 to 30 cm of non-asbestos covering pushed over by heavy construction equipment.

What are the possible consequences of this method of disposal? Bags can break, allowing asbestos fibers to become airborne and migrate to the water table. An example of problems encountered in Australia with landfilling asbestos is Wyong Council's landfill at Shelly Beach, New South Wales. Because ACMs have surfaced above its cover due to erosion and weather conditions, it will cost $12 million to clean up the asbestos dumped into the landfill during the 1970s. Also, there is no way to tell how many people who live and work around Shelly Beach have been exposed to the surfaced asbestos.

Thermal options

There are presently three thermal options to destroy and permanently rid asbestos from our environment: vitrification, plasma torch, and Asbestos Recycling, Inc.'s hearth oven.

All thermal processes require high heat and high energy to destroy asbestos, because they need to run at 1500 to 2000 °C to glassify the asbestos. The asbestos is fed into the thermal unit for a required residence time. Following this, the end product must be cooled before



Inhaling asbestos fibres can lead to lung diseases such as mesothelioma (a cancer) or asbestosis.
iStockphoto/emreogan

testing. If no asbestos is detected by transmission electron microscopy, the end product can be recycled or sent to a non-regulated landfill. If asbestos is detected, then the whole previously treated batch must be put back through the thermal unit.

The high temperatures require substantial electricity at high cost, along with high maintenance costs on the refractory – the inner brick lining of furnace, which over time cracks and wears out due to the high temperature required to destroy the asbestos – which causes approximately 25 to 30% down time. Furthermore, the thermal unit must have an extensive and efficient scrubber system that prevents the escape of potentially harmful byproducts (e.g. furans, dioxins and nitrogen oxides).

Chemical options

There are several chemical options for the permanent disposal for asbestos.

Soaking chrysotile asbestos in sulfuric acid for an extended period of time destroys the chrysotile, but is slow in its destruction reaction time. Once the reaction is complete, the acid is neutralised with a base, such as lime or baking soda.

W.R.Grace, Inc. developed an in situ non-thermal chemical process to destroy asbestos-containing spray-on fireproofing containing chrysotile. The spray-on fireproofing (trade name Monokote) was developed and sold by Grace when asbestos was still permitted in building materials. When asbestos was banned, Grace developed an in situ chemical asbestos destruction process that destroyed only chrysotile. The process requires a full negative air containment with four air changes per hour, but not high electrical use. Ultimately, Grace encountered two problems: 1) for a building with hundreds or thousands of square feet of sprayed-on fireproofing, it was difficult and costly to prove that all the asbestos was destroyed; and 2) the process did not fall under the relevant US Federal Environmental Protection Agency (EPA) regulation; therefore Grace could not secure EPA approval for the process. (The aforementioned thermal options are EPA approved, because they do fall under the relevant regulation).

The ABCOV® Method of asbestos destruction is a non-thermal, EPA-approved mixing process that chemically and physically destroys all forms of asbestos in all ACM. The process is performed under negative air containment and employs size reduction of the ACM and high speed dispersion mixing with ABCOV® chemicals, which are contained in a mild acidic solution.

The asbestos destruction is able to be tested, using polarized light microscopy, as the asbestos is being destroyed, allowing no asbestos to leave the process equipment until completely inert.

The process requires the negative air containment to have six air changes per hour. There is minimal electrical usage and a negative air scrubber system that includes an activated carbon filter and a high-efficiency particulate air filter that will provide six air changes per hour (as opposed to the four air changes per hour that is required for a typical asbestos abatement project performed under negative air containment.

Innovative waste treatment technologies are the future of the waste industry – not only for asbestos, but for all hazardous wastes that cannot be recycled.

Disclaimer: Tony Nocito works for ABCOV®; Description of proprietary technologies does not imply endorsement by *Remediation Australasia*.

FURTHER READING

- www.asbestos.com
- Asbestos Disease Awareness Organization (www.asbestosdiseaseawareness.org)
- United States Federal Environmental Protection Agency (www.epa.gov)
- Australian Industrial Waste Resource Guidelines: Asbestos Transport and Disposal (http://bit.ly/12EwRvY)

REFERENCES

1. NSW Government: Cabinet Office 2004. Report of the special commission of inquiry into the medical research and compensation foundation. 'Asbestos and James Hardie', Annexure J., p.117.
2. National Occupational Health & Safety Commission 2005. Code of Practice for the Safe Removal of Asbestos 2nd Edition [NOHSC:2002 (2005)].

Training and events calendar

May

20-21 Assessment of site contamination NEPM workshop

CRC CARE/Hobart

www.crccare.com/education/training/nepm/nepm_training.html

21-22 Assessment of site contamination NEPM workshop

CRC CARE/Melbourne

www.crccare.com/education/training/nepm/nepm_training.html

22-23 Assessment of site contamination NEPM workshop

CRC CARE/Adelaide

www.crccare.com/education/training/nepm/nepm_training.html

23-24 Assessment of site contamination NEPM workshop

CRC CARE/Perth

www.crccare.com/education/training/nepm/nepm_training.html

28-30 Water in mining

CIWEM/Brisbane

http://bit.ly/13QSQ1M

29-31 Demystifying contaminants

UTS/Sydney

www.science.uts.edu.au/courses/csarm.html

June

11-13 Fundamentals of environmental management for the resources sector

JKTech/Perth

http://bit.ly/164t8uO

12-14 Implementation of sustainability in management of contaminated land

NICOLE/ Lisbon, Portugal

www.nicole.org/pagina/18/Next_Workshop.html

16-20 International conference on the biogeochemistry of trace elements

ISTOB/Athens, USA

http://198.124.230.16/home

18-20 Northern Territory Mining

Austmine/Darwin

http://bit.ly/106m3Sk

18-20 Mine closure and environmental impacts

Waste management association of Australia/Brisbane

http://bit.ly/YqMNmj

July

31-2 (August) Contaminants and toxicity

University of Technology, Sydney

www.science.uts.edu.au/courses/csarm.html

August

6–8 Australian Mine Rehabilitation Workshop

JKTech/Adelaide

www.jktech.com.au/amr2013

September

11-13 Risk based site assessment

University of Technology, Sydney

www.science.uts.edu.au/courses/csarm.html

15-18 CleanUp Conference

CRC CARE & ALGA/Melbourne

www.cleanupconference.com

November

6-8 Remediation principles and closure

UTS/Sydney

www.science.uts.edu.au/courses/csarm.html

Can environmental insurance promote a healthier environment?

Firefighters at the scene of the Deepwater Horizon oil rig explosion. *Wikicommons*

Anthony Saunders, Envirosure

By encouraging carbon emission abatement – the goal of the new carbon tax – environmental insurance can contribute to environmental sustainability.

Without such insurance, the costs of rectifying unabated pollution can weigh too heavily on society's ability to afford to compensate victims of environmental harm.

It is important to identify potential environmental liabilities in the process of risk mitigation because an entity should assess if they are sufficiently asset rich to financially provide for adverse environmental impact or if they should take out insurance to offset their potential liability. This is because the process highlights the investment necessary to exact precautionary measures to protect the environment.

Take for example, the Deepwater Horizon oil rig, which in 2010 in the Gulf of Mexico suffered an explosion that killed 11 crew and is to this point the largest criminal resolution in US history, with BP fined $4 Billion (see postscript). Had environmental liability insurance been in place, it can be argued that the incident would never have occurred, because insurance requirements would have mandated that robust risk protection measures needed to be deployed prior to exploration. It is not the cost of environmental insurance that is the stumbling block in such cases, but the precautionary measures that need to be undertaken.

'Remediation' is well known as a term used to describe environmental clean-up. In insurance terminology, remediation would be defined as: "Reinstatement subject to commercial consideration to limit the amount an entity would need to invest within their legal bounds." (Re-mediation also suggests that the influence of pollution will slowly attenuate, compromising the extent to which reinstatement may be exercised.)

'Reinstatement' implies returning the environment to its condition prior to the incident. However, because of the difficulty in cleaning up toxic spills and waste, the process can be complex and in some communities the clean-up can take scores of years. It is therefore unlikely that resilience levels relating to the speed of ecosystem recovery had not been determined for a worst-case scenario in the Gulf of Mexico. Depending on the environmental laws that prevail, remediation techniques will also vary according to the resilience of ecosystems affected.

Accounting for the costs of remediation in any industry poses a risk for all stakeholders if they fail to consider the potential risks related to litigation as a result of failing to account for externalities (consequences of a commercial activity that are not reflected in the cost of the commercial product). If 'self-insurance' is defined as acting in the same capacity as if you were the insurer, then a business must account for its externalities. This is possible through integrated reporting (see below).

Let us consider the threat of serious or irreversible environmental damage as a matter of fact but not of law. Even if a project is sustainable as a matter of law, it may not be sustainable as a matter of fact: the threat of serious or irreversible environmental damage exists simply by failing to make the project sustainable as a matter of fact. Indeed, our current consumption levels of energy and water already exceed the sustainable yield thresholds for these resources.


Environmental insurance may encourage carbon emission abatement.
shutterstock/Mark William Richardson

Furthermore, the threat of serious or irreversible environmental damage as a matter of fact but not of law poses no legal obligation for an engineer to reduce the environmental impact of a development. Knowingly causing serious damage to the environment, however, could incur future liabilities, both professional and legal. In this case, it may be prudent to seek legal advice on reducing future liabilities associated with the environmental damage.

It is possible to tap into a community's environmental concerns by providing developers with several design options that not only meet legal requirements but also reduce the ecological footprint of a development. Good design can be both cost effective and environmentally friendly.

Losses due to environmental damage are potentially catastrophic. Dealing with environmental liabilities is commonly achieved through financial indemnities or by holding back the purchase price in an escrow account (held by a third party on behalf of the other two parties until certain conditions are met). However, these approaches do not cover the maximum liability of environmental damage or deal with the risk-adjusted environmental damage (where the cost of the environmental damage is multiplied by the probability of likelihood).

Integrated reporting incorporates risk-adjusted environmental damage. Without environmental insurance, 100% of the risk-adjusted environmental damage must be anticipated and reserved, with no discount for the probability applying to uncertain catastrophe. Risks that have, for example, a probability of only 10% would require 100% coverage. In comparison, environmental insurance can robustly cover the risk-adjusted environmental damage in the form of an insurance premium that is insignificant compared with a fully funded indemnity or escrow hold-back of the sales price.

To conclude, as the nature of environmental liabilities has become clearer and more quantifiable, environmental insurance has evolved to provide protection at reasonable cost.

This article was adapted from the original, published by Lexis Nexis in the international Environmental Law Community and the Insurance Law Community.

Mercury: a global issue

Dawit N Bekele and Ravi Naidu, Centre for Environmental Risk Assessment and Remediation, University of South Australia

To effectively combat mercury contamination, we need a better understanding of the dynamics of this dangerous pollutant.

Mercury (Hg) is a toxic pollutant that is released to the environment from natural geologic sources and human activities such as mining and other industrial uses (e.g. manufacturing chlorine-based products, paints and batteries), as well as medicine and dentistry. Since the beginning of the industrialised period, emissions from human activities have substantially increased global atmospheric mercury. The associated pollution and contamination are persistent and pose a public health concern worldwide.

Much early gold mining involved separating gold from the crushed ore using elemental mercury to form an amalgam (an alloy of mercury with another metal). The gold-mercury amalgam was then burned at high temperature, which resulted in pure gold being released. At least 100 million people in over 55 countries depend on small-scale gold mining for their livelihood, mainly in Africa, Asia and South America. As a consequence of poor practices, mercury amalgamation in these mines results in the discharge of 650 to 1000 tonnes of mercury per year, equivalent to one third of all human-caused (anthropogenic) mercury releases into the environment. This makes small-scale gold mining the single largest anthropogenic source of mercury pollution in the world. Asia alone has become the largest contributor of anthropogenic atmospheric mercury, responsible for over half of global emissions.

In 1956 in Minamata, Japan, large numbers of people suffered mercury poisoning after consuming fish and shellfish that had accumulated organic mercury (or methyl mercury, MeHg) from industrial wastewater released into the ocean from the Chisso Corporation's chemical factory. Another outbreak of so-called Minamata disease occurred in Niigata, Japan, in 1965, as a result of mercury-contaminated waste discharged from a chemical factory owned by Showa Denko Corporation. Both incidents were attributed to the MeHg (which is the

What is mercury?

In its elemental form, mercury is a dense, silvery-white, shiny metal, which is liquid at room temperature and boils at 357 °C. At 20 °C. The vapour pressure of the metal is 0.17 Pa (0.0013 mm Hg), and a saturated atmosphere at this temperature contains 14 mg/m3. Mercury compounds differ greatly in solubility; at 25 °C, the solubilities of metallic mercury, mercurous chloride and mercuric chloride in water are 60, 2 and 69 g/litre respectively.

An abandoned mercury processing plant in Western Nevada, USA. *Dreamstime/Neillockhart*

most bioavailable form of mercury) that was generated in the process for producing acetaldehyde using mercury as a catalyst. These were the first recorded cases of mercury poisoning via the food chain. Prior to the Minamata outbreak, poisoning generally occurred as a result of the direct contact by people who engaged in organic mercury handling occupations or who were exposed accidentally.

Although large-scale gold mine operations with amalgam process have been phased out in developed countries; mercury demand in small-scale gold mining continues to increase in developing countries.

Despite the adoption of alternative technologies – such as cyanidation or gravity separation – in developed countries, the trans-boundary movement of mercury pollution means that it remains a global problem. As such, efforts to implement alternative technologies worldwide must be seen as a global obligation.

Mercury pollution can travel long distances through the atmosphere and has an enduring half-life when deposited geologically. For example, atmospheric transport and deposition of mercury from lower latitudes to the Arctic poses environmental and human health risks, despite few sources within the Arctic itself. Understanding the chemistry and transport of atmospheric mercury is thus vitally important for managing mercury pollution.

Mercury in the terrestrial environment

The historical lack of appropriate management strategies at old gold mining sites has resulted in off-site contamination of both soils and river systems. In addition, soil erosion due to rainfall can worsen surface-water contamination. This is especially the case in humid regions, especially where rainfall intensity can be high. One pathway of the mercury flux (movement) in the environment is evaporation (termed 'off-gassing') from soils. Some of the volatile and non-volatile forms of mercury may evaporate from soil directly or by co-distillation with evaporating water.

The mobilisation of mercury from mine sites into aquatic systems presents a major risk. Transport of mercury from catchment soils and atmospheric depositions to surface waters leads to increased mercury – especially MeHg – in the aquatic ecosystem. Although inorganic total mercury is the main form of mercury in atmospheric deposition, the dominant form in fish is MeHg. The transformation of inorganic mercury to MeHg occurs naturally via microbial action in anoxic (oxygen-depleted) environments, such as water-saturated zones in petlands, riparian areas and sediments. The most toxic form of mercury, MeHg is more readily absorbed by the gastrointestinal tract than other forms.

The major effects of mercury in aquatic life, soils and sediments have been found where whole ore-mercury amalgamation has been combined with the cyanidation process. This combined use exacerbates the methylation of mercury, which, once methylated, can rapidly move through the food chain, causing problems downstream. The interaction of mercury and cyanide is a complex issue and its complexity becomes greater when these substances interact with other elements along rivers and watersheds.

Fate of mercury in the environment

Mercury is a persistent toxicant that bio-accumulates, making the risk it poses to humans and the environment all the more complex. It exists in a number of forms (species) depending on

Liquid mercury 'beads' due to high surface tension. *flickr.com/Ignacia Conejo*

> "Mercury's ability to bio-accumulate makes the risk it poses to humans and the environment all the more complex."

environmental conditions, with its environmental mobility and toxicity in a soil profile depending on its speciation. Understanding the mechanisms of mercury evaporation from the soil to the atmosphere is necessary for tracing its fate and for assessing potential health effects and the impact of anthropogenic mercury emissions on the environment. The volatility of mercury species differs considerably, with elemental mercury and dimethyl mercury being by far the most volatile compounds.

To trace the fate of the mercury emitted into the environment and predict its toxic consequences, it is important to investigate local mercury fluxes. This includes quantifying the mercury that is already biologically available in the ecosystem (e.g. sorbed to soils or sediments), and the mercury that is released from geological sources (e.g. background sources).

Mercury volatilisation from soil depends on:

1. the distribution of mercury in the soil profile
2. the places for formation of volatile mercury species
3. the physical migration of the mercury species within the soil,
4. the physical and chemical sorption of mercury vapour (including all mercury species)
5. the presence of appropriate microbes, and
6. a slightly acidic soil pH.

Mercurous mercury precipitates with chloride (Hg_2Cl_2), phosphate (Hg_3PO_4), carbonate (Hg_2CO_3), and hydroxide ($Hg_2(OH)_2$). At concentrations of mercury commonly found in soil, only the phosphate precipitate is stable. In alkaline soils, mercuric mercury precipitates with carbonate and hydroxide to form a stable (but not exceptionally insoluble) solid phase. At lower pH and high chloride concentration, soluble mercuric chloride ($HgCl_2$) is formed. Mercuric Hg(II) also forms complexes with soluble organic matter, chlorides and hydroxides that may contribute to its mobility

Biotic mediated mercury evaporation occurs when mercury-resistant soil microorganisms detoxify their environment by transforming inorganic and organic Hg(II) to volatile mercury species, which subsequently evaporate quickly into the atmosphere.

The bioavailability and toxicological effects of mercury are strongly dependent on its chemical speciation. Methylation of inorganic mercury is an important process, and can fundamentally change mercury's bioavailability and toxicity.

Impact on human health

Human exposure pathways for mercury include: inhalation of mercury vapours or contaminated dust, consumption of food including fish and shellfish; skin exposure or absorption of metallic mercury through the skin; and ingestion of soil. Humans may be exposed to mercury in three chemical forms: inorganic compounds (combined with chlorine, sulfur, oxygen and other noncarbon groups); elemental, or metallic, mercury (uncombined with other elements); and organic mercury (combined with methyl, ethyl or other carbon groups).

Elemental mercury vapour has the greatest immediate impact on health. MeHg is arguably the most important form for exposure to mercury because of its pervasiveness in fish and its neurotoxicity. Exposure to mercury causes severe, potentially lethal neurological disturbances such as ataxia (loss of full control of bodily movements), tremors and other coordination problems. Toxic effects can be at the biochemical, cellular or organ level. High levels of MeHg can be detrimental to organisms directly contaminated, as well as to those higher on the food chain through bio-accumulation.

The most common pathway for human exposure to mercury is by eating fish containing MeHg. Less common pathways include inhalation of its colourless and odourless vapours (the primary exposure pathway to metallic mercury); and dermal exposure or absorption of metallic mercury through the skin. Exposure in the general population is believed to occur almost entirely through consumption of fish or seafood. MeHg and metallic mercury off-gassed from amalgams is absorbed through inhalation. This is a major exposure pathway compared with metallic mercury absorbed by ingestion or absorbed through skin contact.

Conclusion

Our understanding of the fate and dynamics of mercury in the terrestrial environment is incomplete. The extent to which mercury is transported is a function of regional and/or site biogeochemistry, land use and climate. However, much of the information published on the biogeochemistry of mercury arises from research conducted on mercury outputs from watersheds, where the importance of the terrestrial runoff can vary from slight to high depending on the intensity of rainfall. There is incomplete information on the biogeochemical behaviour of mercury in arid environments, where land is subject to marked seasonal variations in average daily temperature and precipitation.

Hg(II) is the predominant form depositing to ecosystems and Hg(0) represents the majority of emissions. Understanding the oxidation and reduction reactions that control the speciation of mercury is necessary to better constrain where and when deposition is most likely to occur. A better understanding of where and under what conditions Hg(II) is formed can help in tracing pollutants from source to receptor as well as identifying gaps in measurements in potentially affected ecosystems.

Though concentrations of mercury in the atmosphere are low, it is atmospheric transport that makes mercury a global pollution concern. To support relevant environmental policies, we need better integration and analysis of the fate of atmospheric mercury across local, regional, and global scales. More effort is required to understand the biogeochemistry cycle of mercury and its associated health effects.

Although safer alternatives and cleaner technologies already exist in industries that formerly relied on mercury, they must be effectively implemented to reduce mercury emissions. Finally, new and improved remediation technologies are required to clean up the widespread mercury contamination that threatens the health of people and the environment.


Fish are a common pathway for human exposure to mercury.

Regulatator RoundUp

New South Wales

Jessica Dorricott, Niall Johnston, John Coffey and Arminda Ryan, EPA NSW

NSW EPA prosecutes consultant for false information on waste reports

The NSW EPA recently prosecuted an environmental consultant and two of its employees for providing false information in relation to asbestos in a stockpile of waste on residential land in the Hawkesbury region. It was intended to reuse the asbestos waste in landscaping on that land but, after the NSW EPA issued a clean-up notice, the waste was disposed of to landfill.

The NSW Waste Regulations prohibit the re-use or recycling of asbestos waste.

The defendants pleaded guilty and the NSW Land and Environment Court convicted and ordered the consultant and the two employees to pay penalties totalling $45,000, as well as the EPA's legal costs. The fact that the consultants had been convicted of a similar offence in Queensland in 2003 was considered by the Court as an aggravating factor during sentencing.

The Court emphasised the need for accuracy by environmental consultants in reporting on the nature of waste material and Justice Craig noted that failures of this kind can "have the potential to create serious environmental harm".

The assessment and management of asbestos is a widespread issue for regulators in NSW and across Australia. The impending variation to the National Environment Protection (Assessment of Site Contamination) Measure is anticipated to provide additional guidance for addressing the identification and management of asbestos in soils.

South Australia

Belinda Scott, EPA SA

New Executive Director Operations

SA's EPA Chief Executive Dr Campbell Gemmell recently welcomed the appointment of the new Executive Director Operations Andrew Wood (pictured).

Mr Wood was previously the Deputy Director of Operations for the England and Wales Environment Agency, where he leads the Agency's National Operational teams and is responsible for 1,800 full-time staff. He has worked for the Environment Agency for more than 17 years and prior to that was the Head of Fisheries for the National Rivers Authority in England.

He holds a BSc in Zoology and an MSc in Applied Fish Biology, and is widely experienced in delivering change both locally and nationally. He will complement the already highly experienced EPA Executive team and contribute to the considerable work already undertaken in the past 12 months in transforming the EPA into a leading-edge regulator.

Mr Wood shares a passion and enthusiasm for the environment and for managing the interface between the environment, communities and industry. Dr Gemmell, the Executive and EPA staff look forward to working with him.

New EPA vision

Robust regulation, sound science and genuine engagement will be strategic priorities for the EPA in the next three years.

Released in December 2012, the 2012–15 Strategic Plan outlines the highest-level commitments and strategies for the EPA. The plan was drafted and refined over nine months through feedback and discussions, including Chief Executive Dr Campbell Gemmell's meetings with individual stakeholders, the Round-table Conference in June 2012, and the 2012 stakeholder survey.

With the vision of 'a better environment – protected for all South Australians', the plan is aligned with the SA Government's priorities and SA's Strategic Plan.

The strategies focus on robust regulation, sound science, strategic influence and partnerships, genuine engagement, and being an adaptive organisation. This provides the framework for prioritising work programs, ongoing program reform, and implementing the EPA's current change program.

For more information, visit the EPA Website at bit.ly/13c0Ewd.

EPA SA's windfarm study found that infrasound levels were generally below the level of human perception. *All photos: EPA SA*

EPA study of windfarm infrasound levels

There has been considerable interest, locally, nationally and even internationally, in an EPA study of windfarm infrasound levels. The EPA recently released the findings of the study, conducted in conjunction with Resonate Acoustics, on infrasound levels near windfarms and in other environments.

Measurements were undertaken over a period of approximately one week at seven locations in urban areas and at four locations in rural areas, including two residences approximately 1.5 kilometres away from the wind turbines.

Overall infrasound levels at rural locations both near to and at a distance away from the wind farm were no higher than infrasound levels measured at urban locations.

The study also showed that both indoor and outdoor infrasound levels were well below the perception threshold and that the most obvious difference between urban and rural locations was that human activity and traffic appeared to be the primary source of infrasound in urban locations, while localised wind conditions are the primary source of infrasound in rural locations.

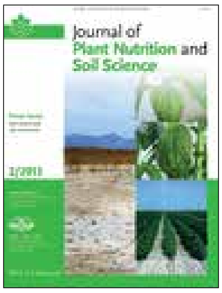
Further testing is being undertaken by the EPA at four locations near the Waterloo Windfarm in the Clare Valley from April to May. These results will provide longer-term data that, along with this current study, will help the EPA better understand the nature of any impacts on the community and whether existing guidelines need to be reviewed.

The report of the study and more information on the EPA's position on windfarm issues is available on the EPA website at bit.ly/Xqq18D.

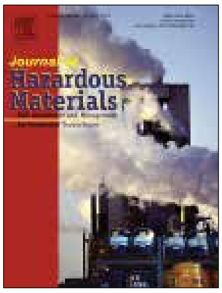
Publications update

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 **victoria.leitch@crccare.com**.

Donner, E, de Jonge, MD, Kopittke, PM & Lombi E 2013, **Mapping element distributions in plant tissues using synchrotron x-ray fluorescence techniques**, *Methods in Molecular Biology*, vol. 953, pp. 143-159.



Haynes, RJ, Belyaeva, ON & Kingston G 2013, **Evaluation of industrial wastes as sources of fertilizer silicon using chemical extractions and plant uptake**, *Journal of Plant Nutrition and Soil Science*, vol. 176, iss. 2, pp. 238-248.



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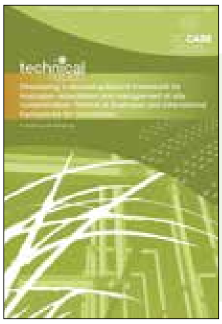

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Zhou, Y, Kuang, Y, Li, W, Chen, Z, Megharaj, M and Naidu, R 2013 **A combination of bentonite supported bimetallic Fe/Pd nanoparticles and biodegradation for the remediation of p-chlorophenol in wastewater**, *Chemical Engineering Journal*, vol. 223, pp. 68-75.

Research RoundUp

Research roundup keeps you up to date with current research on environmental contamination assessment and remediation in Australia. Issue 13 of Research roundup provides a short summary of some of the recent publications that have been generated by research funded by CRC CARE and its partners.

Bioavailability of barium to plants and invertebrates in soils contaminated by barite


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Exposure to barium causes a raft of health issues in humans, and is toxic to plants and soil invertebrates. The effect of barite – a less soluble mineral form of barium – is less well understood, with current studies, which largely assess artificially spiked soil, failing to fully reflect real-world contamination. To better ascertain the effect of barite in plant and invertebrate tissue, this study analysed soil samples collected from field sites 'naturally' contaminated as a result of barite mining.

Contrary to results seen in existing literature, it was found that barite contamination of soil had a negative impact on the health of plant and invertebrate experimental samples. Differences between this study and the existing literature may indicate that future barium bioavailability studies need to take an approach that is more complete than simply spiking soil with barite.

Lamb, DT, Matanitobua, VP, Palanisami, T, Megharag, M & Naidu, R 2013, 'Bioavailability of Barium to plants and invertebrates in soils contaminated by Barite', *Environmental Science and Technology*, in press, doi: 10.1021/es302053d.

Carbon storage in a heavy clay soil landfill site after biosolid application

The role of carbon (C) in global climate change has driven researchers to look for alternative measures to mitigate the influence that the C cycle can have in the atmosphere. Soil C sequestration can reduce CO_2 levels, improving atmospheric CO_2 and therefore aiding in the prevention of climate change. Additionally, this soil-bound C improves soil fertility.

The practice of capping landfill is gaining popularity, with evidence that it may prevent further environmental impacts from the landfill. It was not known, however, how phytocapping affects the ability of the soil to sequester C. This study used in-depth analysis of soil constituents and properties to measure the effect of phytocapping on soil C sequestration. Although the level of sequestration varied between plant species, the application of bilosolid did enhance the rate of C sequestration in.

Bolan, NS, Kunhikrishnan, A & Naidu, R 2013, 'Carbon storage in heavy clay soil landfill site after biosolid application', *Science of the Total Environment*, in press, doi: 10.1016/j.scitotenv.2012.12.093.

Consumption of arsenic and other elements from vegetables and drinking water from an arsenic-contaminated area of Bangladesh

This study assessed the risk of ingestion of toxic heavy metals from food and water in a district in Bangladesh known to be contaminated with arsenic, lead, copper, cadmium and a number of other toxic metals. Collection of a number of soil, vegetable and water samples showed that the average adult consumes 839 micrograms of arsenic daily – with the large majority of this coming directly from the water supply. Variation between different types of vegetables in the study also confirmed the need to regularly test a range of foods in the region.

Rahman, MM, Asaduzzaman, MD & Naidu, R 2013, 'Consumption of arsenic and other elements from vegetables and drinking water from an arsenic-contaminated area of Bangladesh', *Journal of Hazardous Materials*, in press, doi: 10.1016/j.jhazmat.2012.06.045.


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Session topics:

- Advanced site characterisation
- Advanced remediation methods
- Advances in bioremediation
- DNAPL management & remediation
- Decision tools for engaging communities in the management of land contamination
- Emerging contaminants
- Ex situ soil remediation
- In situ remediation
- LNAPL remediation & management
- Metal(loid) assessment & remediation in groundwater
- Mine site remediation & revegetation
- Nanotechnologies for remediation
- National remediation framework
- Sediment management & remediation
- Sustainability & remediation
- Unconventional gas
- Urban renewal
- Plus more...

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15-18 September 2013

This year CleanUp is moving *to the Crown Melbourne*! Located next to the award-winning Crown Towers, Crown Metropol and Crown Promenade Hotels, the Crown Conference centre provides world-class facilities. This change in venue constitutes the next stage in the conference's extraordinary growth after four successful events in Adelaide.

CleanUp 2013

Tours and workshops

Details for technical tours and conference workshops have now been confirmed and are being added to the conference website. Registration links will be open soon.

Thank you to everyone who submitted an abstract, the reviewing process has begun and you will notified of the status of your application soon.

Key dates:

- Registration opens:
  1 June 2013
- Earlybird registration close:
  30 June 2013
- Standard registration close:
  11 August 2013
- Late registration open:
  12 August 2013

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Here is a taste of the invited speakers for the 5th International Contaminated Site Remediation Conference – visit the conference website for information on all of our invited speakers.

Ben Mork
Regenesis, USA
Presentation topic: Advancing technologies for soil and groundwater remediation

Naji Akladiss
ITRC Integrated DNAPL Site Strategy Team Lead, Maine Department of Environmental Protection, USA
Presentation topic: The USA's intrastate technology and regulatory councils approach to advancing innovative clean up solutions

Rao Y. Surampalli
US Environmental Protection Agency
Presentation topic: Emerging contaminants in landfill leachate: sustainable management

Ashok Mulchandani
The University of California, Riverside
Presentation topic: Nanobiotechnological approaches to environmental remediation

For more information visit www.cleanupconference.com

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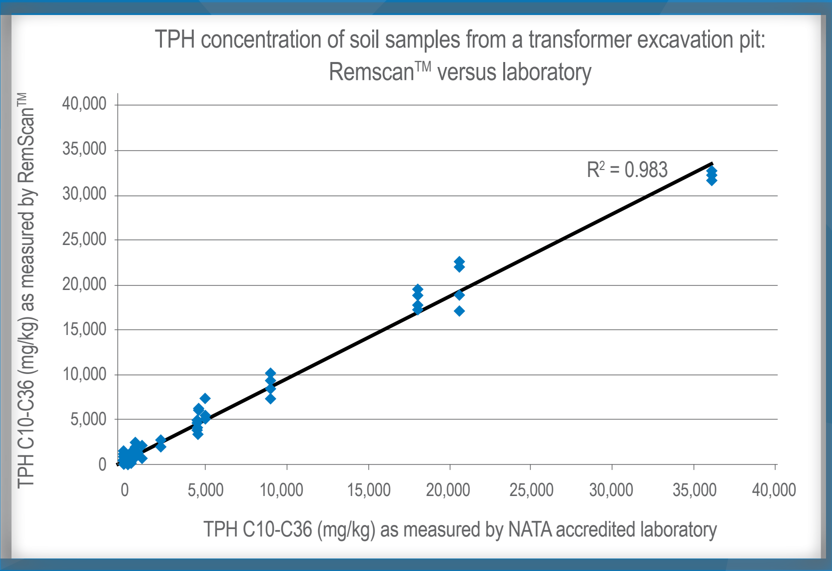
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