

# Remediation Australasia



ISSUE 20/2018



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policy making

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remediation  
strategies

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its remediation  
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# Master of Environmental Risk Assessment and Remediation

Are you an environmental practitioner or consultant who is concerned about the risks (human and ecological) associated with environmental pollution and want to be involved in providing creative solutions to minimise those risks? The University of Newcastle's Master of Environmental Risk Assessment and Remediation can be the pathway to that position you've been dreaming of.

## Overview

Providing you with specialised training in risk assessment and environmental remediation designed for the growing needs of the remediation industry both nationally and globally, this hands on practical and research-focused program will help prepare you for your dream job.

Using a balanced approach that includes both hands on and case studies, you'll examine the core concepts, principles and techniques underlying environmental risk assessment and remediation. You'll learn how to assess a contaminated site including following guidelines for contaminated site assessment (eg NEPM-ASC) and jurisdictional legislation regulating management of contaminated land; carry out desktop research for preliminary site investigation (PSI), develop conceptual site models, produce a sampling plan for a detailed site investigation using data quality objectives (DQOs) and evaluate contaminated site data to identify contaminant fate and pathways and assess the risk presented by the contaminant(s) detected on site and determine the need for further investigation or remediation.

On completion, you'll be able to provide full site assessment reports that exceed clients expectations, provide innovative solutions to remediation and/or risk assessment problems, and bring remediation projects to a successful conclusion.

## Is it for you?

Environmental practitioners can have different backgrounds and their previous experience and

knowledge often help shape the future direction of their careers. You may have a bachelor's degree in science or applied science (engineering) and now want to expand your skills and move into the growing field of environmental remediation. Or you may want to start a research career in the field of environmental chemistry, toxicology and technology.

## Career opportunities

The University of Newcastle's Master of Environmental Risk Assessment and Remediation will prepare you for managing contaminated site(s) projects and developing remediation action plans for both private and public organisations. With a core focus on environmental risk assessment and remediation, you will have specialised and instrumental skills that will be highly valued by mining, property development and industrial sectors. Your capacity to work internationally will be supported by the University's own reputation in the field. Distance study may be possible; for more information contact [ravi.naidu@newcastle.edu.au](mailto:ravi.naidu@newcastle.edu.au).

**To register your interest in this program, visit [gs.edu.au](http://gs.edu.au)**





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### Editorial and production

EDITOR-IN-CHIEF

Ravi Naidu

EDITOR

Adam Barclay

TECHNICAL EDITORS

Carrie DeHaan, Biotext Pty Ltd  
Prashant Srivastava, CRC CARE

DESIGN AND WEBSITE

Biotext Pty Ltd  
[www.biotext.com.au](http://www.biotext.com.au)

EDITORIAL AND ADVERTISING

ENQUIRIES:

Adam Barclay, CRC CARE

02 4033 9439

[Adam.Barcly@crccare.com](mailto:Adam.Barcly@crccare.com)

### Cover photo

Coal dust being generated at a coal mine. Coal dust is of concern to many communities as an air pollutant, often as a component of urban dust, and is discussed in this issue of *Remediation Australasia*.

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## Editor's note

It's my pleasure to welcome you to issue 20 of *Remediation Australasia*. This issue of the magazine takes a look at a range of topics that we – and, we hope, you – find fascinating. We're putting plastics under the microscope (sometimes literally), with an article on the increasingly urgent problem of microplastics. We also examine particulate plastics in soil, where the news might not be all bad. Also, biochar is receiving more and more attention for a range of uses, such as boosting carbon sequestration and soil health. In this issue, we review its potential for soil and water remediation.



We update readers on progress with CRC CARE's probeCARE™ system, which provides cost-effective, in situ, real-time monitoring of pollutants in soil. I'm confident that this technology will also help drive improved management of cropping via optimised fertiliser application and other soil amendments.

At several locations in Australia, coal dust causes significant community concern. This issue reports on an improved method of analysing dust samples to provide information about quantity, composition and size distribution – data that are critical for understanding the best ways of reducing dust concentrations. We also dive into how contamination practitioners communicate risk associated with contaminated sites to community members who live or work close to the contamination. The latest research tells us that experts' ability to inform about risk – and therefore enable affected residents to participate in the decision-making process – has potentially large social and economic ramifications.

I want to remind readers about the 1st Global CleanUp Congress, which will take place in Coimbatore, India, from 21 to 25 October this year. We've secured some of the world's leading contamination experts to share their knowledge and we'll be running some excellent workshops for delegates who want to advance their professional development. Visit the [Global CleanUp Congress India 2018 website](http://GlobalCleanUpCongressIndia2018.com) for more information.

Lastly, I'm excited to let you know about CleanUp Korea 2019, which will be held from 25 to 27 March in Seoul. This event has a Korea focus, but will be sufficiently broad to be of global interest. Its themes include: innovative in situ and ex situ remediation technologies; chlorinated hydrocarbons; PFAS assessment, remediation and management; regulatory constraints for emerging contaminants; and more. Find out more about at the [CleanUp Korea website](http://CleanUpKorea.com).

### Professor Ravi Naidu

Managing Director and CEO, CRC CARE

Editor-in-chief, *Remediation Australasia*



# reMEDIAtion

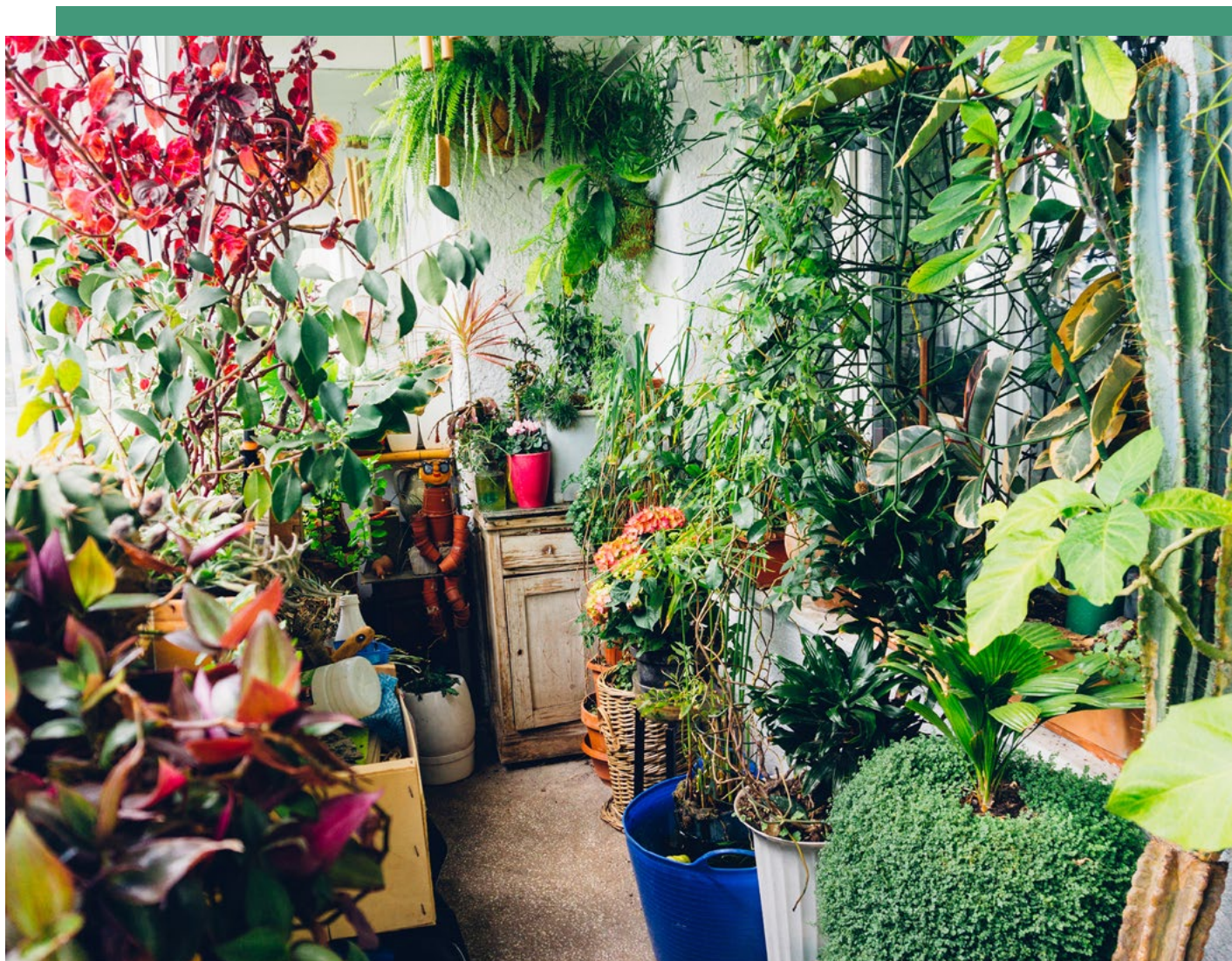
A snapshot of recent contamination and remediation issues in the media.

## There's an app for that: how to improve your plant-life balance

You have no doubt heard that a good work-life balance benefits overall health and wellbeing, but did you know you could be improving your plant-life balance as well? Not sure how? That's OK, because researchers at RMIT University and the University of Melbourne have established

the Plant Life Balance Index, which has been converted into an innovative, virtual reality app called Plant Life Balance. Indoor plants can remove 75–90% of air pollution and can benefit your overall wellbeing.

Users can use the app to assess their current plant-life balance, based on the size of the room and the number of plants in it, and then identify plants that can improve their plant-life balance. The RMIT University website reported on the award-winning app in May 2018.



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## Air pollution in Asian countries is increasing alongside the number of vehicles on the road

Pedestrians and car drivers in Asia are exposed to far more air pollution than their counterparts in Europe or the United States, a recent study has found. The study was reported in *Science Daily* and first published in *Atmospheric Environment*. Researchers found that the levels of fine and ultrafine particles, and black carbon were 1.6–9.0 times higher in large Asian cities than in European or American cities. This is related to the increasing number of vehicles on the road – for example, the number of vehicles in Beijing increased from 1.5 million in 2000 to more than 5 million in 2014. Even larger increases are expected for New Delhi from 2010 to 2030. Although researchers caution against directly comparing different cities and regions as this study did, the results are still significant – the World Health Organization has reported that about 88% of premature deaths in low- and middle-income Asian countries can be attributed to air pollution. To understand the true nature of the problem, more research is needed. The accuracy of air pollutant monitoring needs to be improved, and monitoring needs to be extended to smaller cities, and to rural and semirural areas.

## Chinese workers are suffering to feed the world's appetite for mobile phones

China produces about 90% of the world's electronics. In an episode of *Four Corners*, the ABC revealed that Chinese workers in mobile phone factories have been exposed to poisons and are paying the price with their health. Workers have been diagnosed with various illnesses, such as leukaemia and



Image credit: TimeStopper – stock.adobe.com

nervous system conditions, and have finally realised that these illnesses are directly linked to the chemicals they are exposed to at work. In response to this revelation, Apple banned the use of benzene and *n*-hexane in the production of its phones, but the ban does not apply to its subcontractors, which produce about two-thirds of the parts. There are also no bans on the use of dangerous chemicals in electronics manufacturing in other developing countries. Affected workers are now fighting for compensation.

## The power of poo and other waste

Researchers in New South Wales are looking at ways to turn poo into power and profit. Although the technologies used to produce biosolids are old, the ways of using them and the starting materials are new. Dairy processing solids and human waste are the current targets for starting materials, *ABC News* reports.

Biosolids are essentially organic matter and bacteria, both of which contain chemical energy. This can be used to produce biogas for energy, but it can also be heat treated and then used as a soil improver. Benefits of using waste this way include cheaper fertilisers for farmers and less waste to landfill, and savings in energy and landfill costs. For example, the Norco ice-cream factory in Lismore, New South Wales, currently sends about 12 tonnes of heavy waste to landfill, which could be converted to biosolids. Its landfill bill is \$100 000 per year.

Richmond Dairies has spent millions of dollars treating wastewater, but is looking at capturing the methane produced from this process and converting it to energy for the factory. The project – led by researchers from Southern Cross University in Lismore, and funded by CRC CARE, Richmond Dairies and the Richmond Valley Council – is moving to small-scale field trials next year.

## CARE catch-up

# Validating probeCARE™ in field tests

**Dr Liang Wang, Professor Ravi Naidu**

GLOBAL CENTRE FOR ENVIRONMENTAL REMEDIATION, UNIVERSITY OF NEWCASTLE

CRC CARE developed probeCARE™ to support cost-effective, in situ, real-time monitoring of water. This is used to improve management strategies for cropping and fertigation, using recycled water effectively and monitoring for possible pollutants to meet environmental protection agency standards.

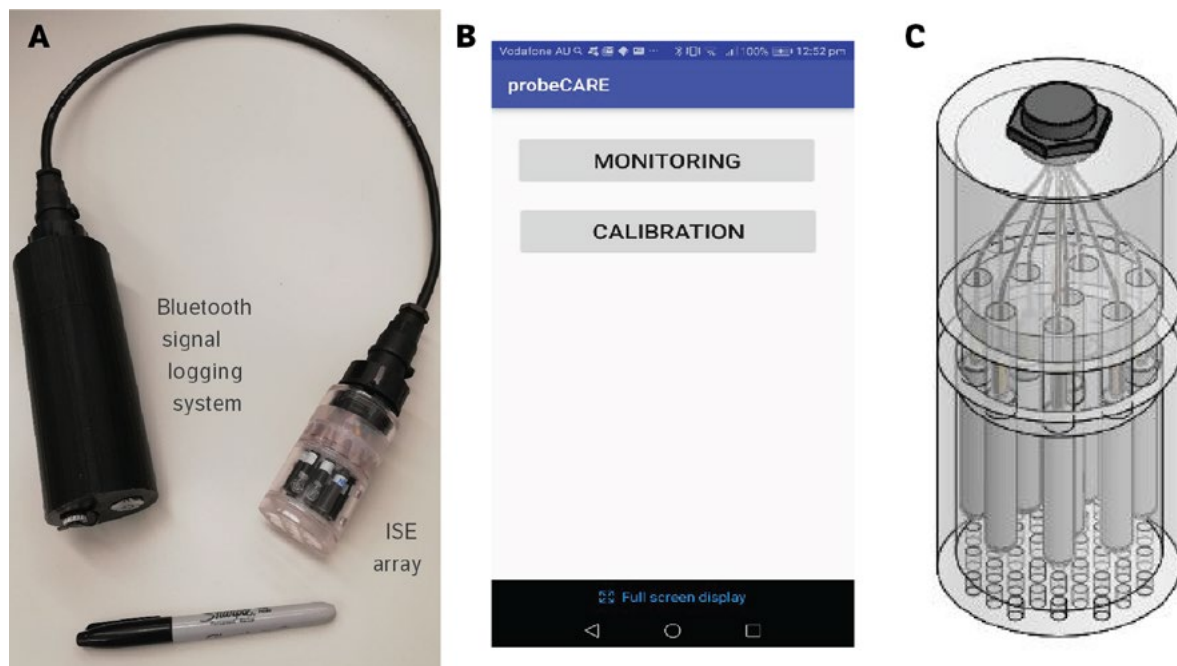
## probeCARE and its function

probeCARE is an ion-selective electrode (ISE) array, coupled with a Bluetooth signal logging device and a smartphone app (see Figure 1 for the new prototype). The miniature ISEs used – 30 mm long and 6 mm wide – have a solid-state electrode body with different ion-selective membranes. A housing unit can hold up to 12 ISEs, including a reference

electrode, in an array. The data-logging system can simultaneously record and send all the signals from the ISE array to the smartphone app via a Bluetooth connection with a 1-second interval. The smartphone app has patented algorithms to simplify the ISE array calibration, and improve the prediction accuracy by eliminating the interference from undesired ions.<sup>1,2</sup>

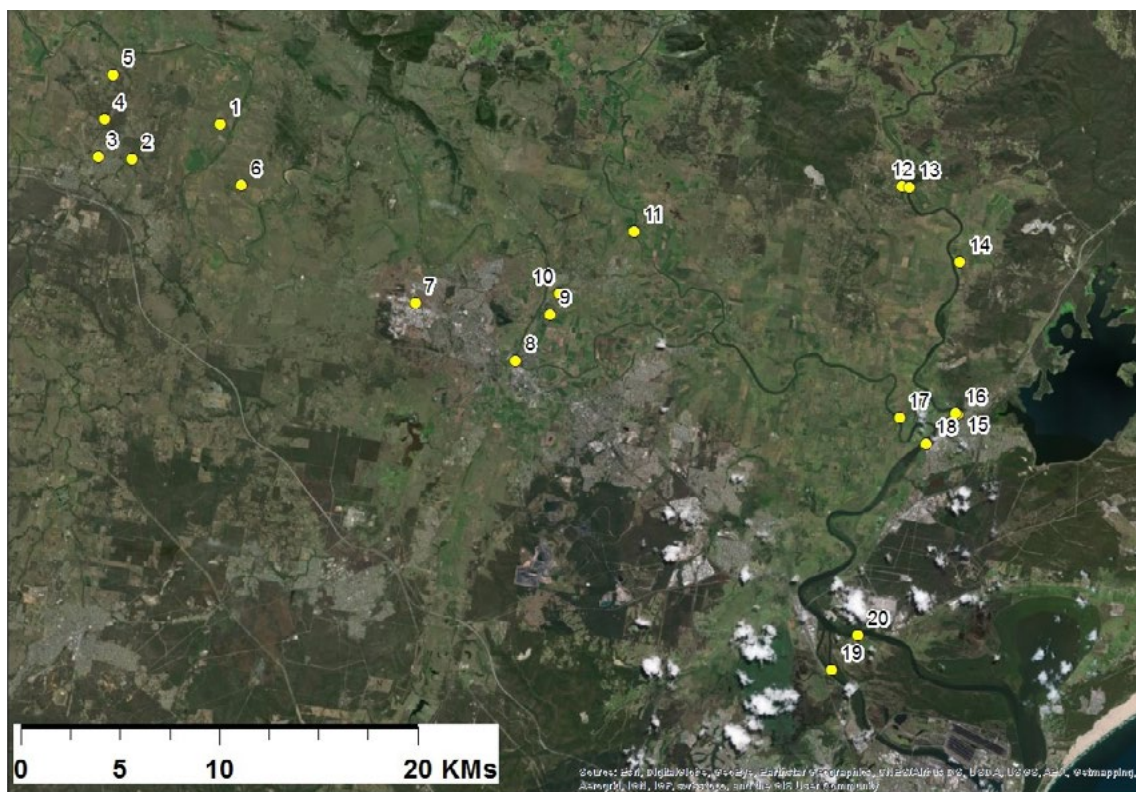
## Field validation

To validate the field performance of probeCARE, we used it to measure 4 exchangeable cations – sodium (Na), potassium (K), calcium (Ca), magnesium (Mg) – in 20 surface water sources from the Hunter region, New South Wales (see Figure 2). Six different creek waters (samples 1–3, 5, 6 and 14) and 6 reserved or pond waters (samples 4, 7, 9, 10, 12 and 15) were also measured in situ using probeCARE. Furthermore, water from the Hunter River was also measured in several locations. The upper Hunter River is



ISE = ion-selective electrode

**Figure 1** probeCARE prototype a) probeCARE system; b) probeCARE app; c) ISE housing unit



**Figure 2** Sampling points in the Hunter region, New South Wales

separated into 3 different rivers: the Williams, Peterson and Hunter rivers. The waters of these 3 rivers have been tested at Seaham (sample 13), Woodville (sample 11) and Maitland (sample 8), respectively. The 3 rivers merge into the Hunter River at Raymond Terrace (samples 16–18). The Hunter River is separated into 2 channels (south as sample 19 and north as sample 20) before it reaches the Pacific Ocean.

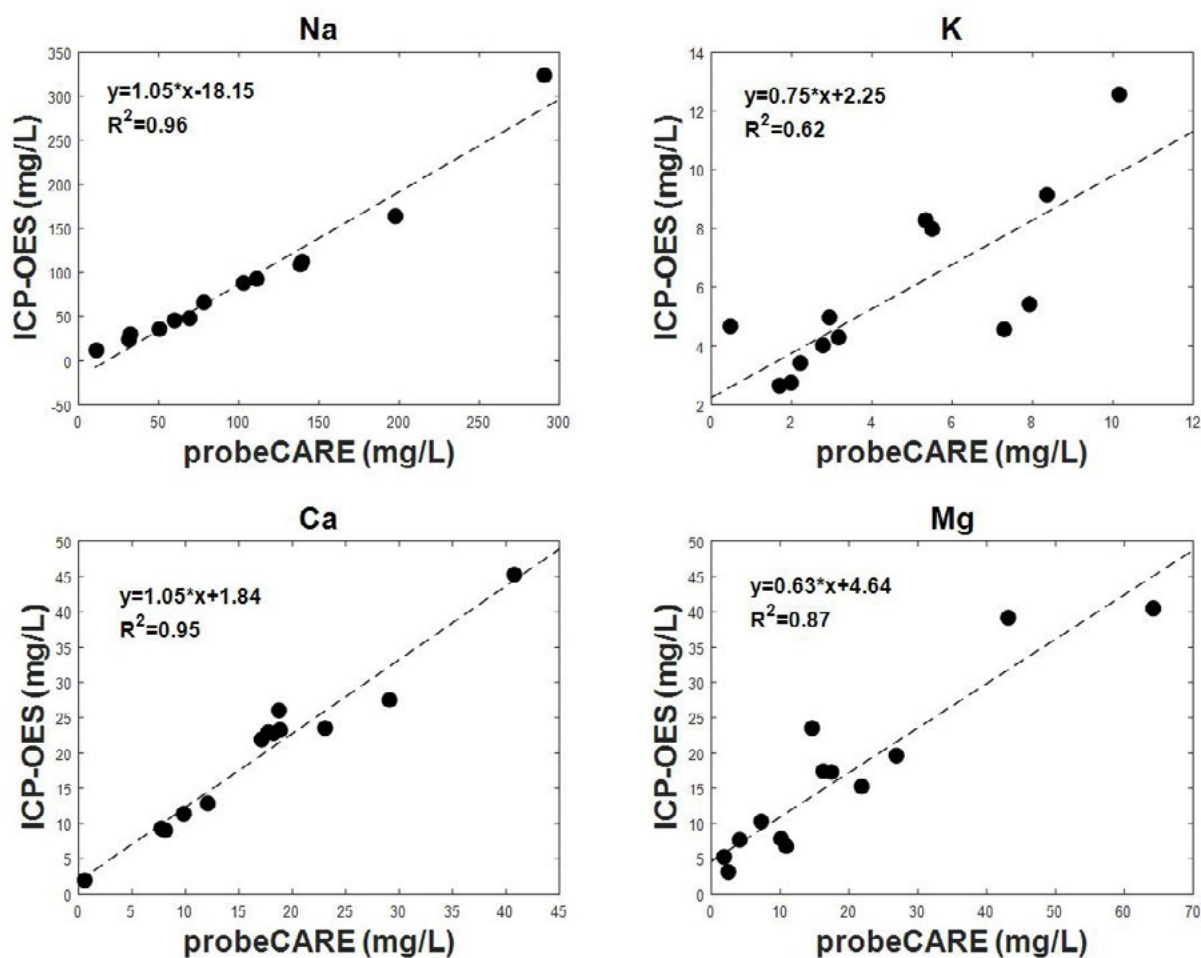
For comparison, 2 samples from each water source were collected and sent to the Global Centre for Environmental Remediation, University of Newcastle, to be measured using conventional inductively coupled plasma optical emission spectrometry

(ICP-OES). Figure 3 compares the results from probeCARE and ICP-OES. Samples 15–20 are salty water samples, with high sodium chloride concentrations that are not suitable for irrigation. Therefore, the results for these 6 samples are not shown. For the rest of the samples, the results showed that:

- Na concentrations were around 10–300 mg/L
- K concentrations were <10 mg/L
- Ca and Mg concentrations were <100 mg/L.

Figure 3 shows the linear relationships between the ICP-OES and probeCARE results.





ICP-OES = inductively coupled plasma optical emission spectrometry

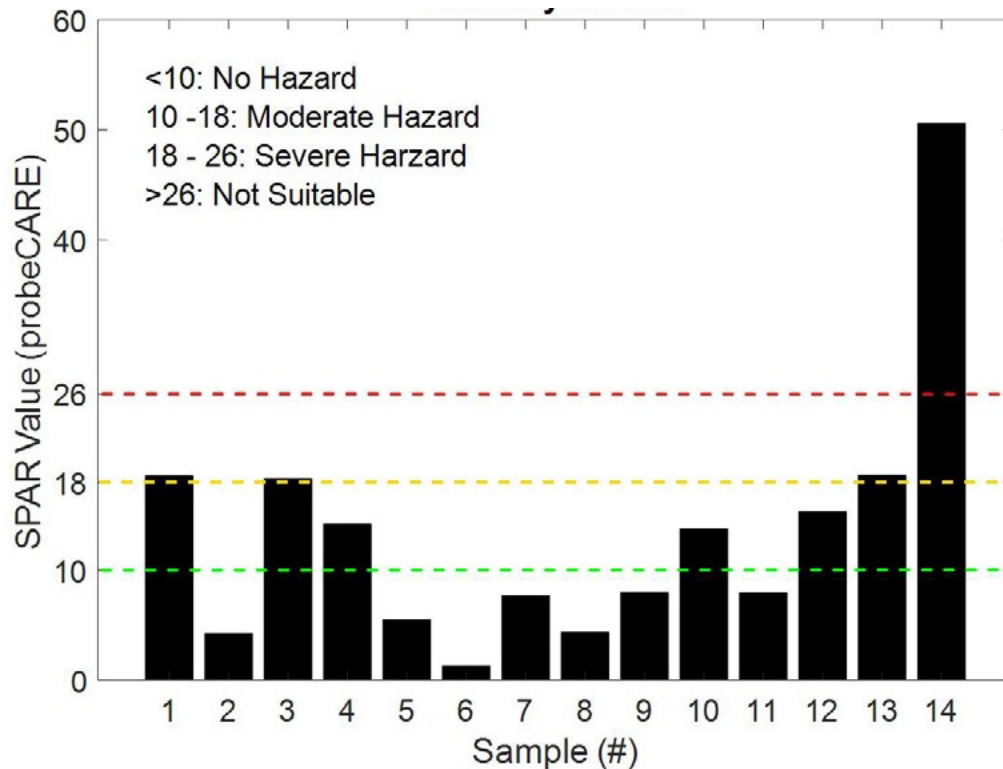
**Figure 3** Prediction results for probeCARE and ICP-OES for sodium, potassium, calcium and magnesium

## Sodicity hazard estimation

A major problem concerning the quality of irrigation water is the level of monovalent cations (Na and K) in the water. This is known as sodicity hazard, and it influences the structural stability of clay minerals and potential for dispersion, erosion and drainage.<sup>3</sup> It can be indicated by the sodium–potassium adsorption ratio (SPAR), in terms of the relative proportion of monovalent cations, compared with bivalent cations (Ca and Mg) in solution.<sup>4</sup> If the bivalent cations are more dominant in the solution than the monovalent cations, the danger is minimal – and vice versa. The SPAR values calculated using probeCARE are shown in Figure 4. Most of the water samples were within the no or moderate sodicity hazard zone. High SPAR values were detected from samples 14–20, which indicates these water sources are not suitable for irrigation.

## Conclusion

The interference from undesired ions is a major challenge of using ISEs. For instance, in our results, Na concentration varies from one to hundreds of mg/L in the water samples we measured. According to our previous studies,<sup>1,2</sup> Na can significantly interfere with ISE measurements, especially when Na dominates in highly saline water. Since the results from both measurement systems closely align, we show that probeCARE can eliminate the interference from Na and provide accurate measurements.



SPAR = sodium–potassium adsorption ratio

Notes:

<10: no hazard (below the green line)

10–18: moderate hazard (between the green and the yellow line)

18–26: severe hazard (between the yellow and the red line)

>26: not suitable (above the red line)

**Figure 4** Sodicity hazard of the water samples measured for probeCARE

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## From the fringe

# Dandelions, cotton balls and swimming pools: how poor risk communication endangers our health and costs us money, and what we can do about it

**Dr Kate Hughes**

INSTITUTE FOR SUSTAINABLE FUTURES, UNIVERSITY OF TECHNOLOGY SYDNEY

Dandelions, cotton balls and swimming pools – what do they have in common? They are all terms used by Australian experts to explain science to the public. A scientific concept such as density might be explained by comparing, say, a piece of glass with a snow-flake. A description of water management might invoke a drop of a dangerous substance in an Olympic-size swimming pool. Explaining the risk from asbestos exposure may draw on its form, with flaky asbestos distributed in the air like the seeds of a blown dandelion. These are all issues that must be accounted for during land clean-up. Some experts explain them very well, but sometimes their efforts to communicate fall well short – and this can cause problems. So what does it take for experts to do a good job communicating risks about remediation to non-experts, and how important is it that they do so?

Contaminated sites need to be cleaned up. When companies start projects to do this, they need to communicate with the local community. After all, it is residents living near a contaminated site that are asked to take on any risks around remediation. Whether it's a huge stack burning contaminated soil or a dredging process that could affect water quality, remediation has to be performed to a very high standard. Remediators need to explain how and why their technology is safe and effective.

So how good are experts at risk communication? Some communicate well and others don't. Does it matter? Well, yes, since there are real-world consequences of poor risk communication, including delays to projects, increased health risks and added costs.

New Australian research identifies shortcomings in expert risk communication and suggests where improvements can be made.

## The research

Kate Hughes' research draws on the experiences of Australian remediation experts at 7 contaminated sites, including Sydney Olympic Park, Homebush Bay, Botany Industrial Park, Breakfast Point and Barangaroo.

The Cooperative Research Centre for Contamination Assessment and Remediation of the Environment (CRC CARE) supported the project, which was undertaken at the Institute for Sustainable Futures, University of Technology Sydney.



How could an expert explain empirical risk in this situation?

Dr Hughes identifies deficiencies in the way experts communicate, and provides guidance on how they can improve. Her research shows that it is not simply a matter of experts being able to explain scientific concepts using lay language. To really get the message across, they must adopt narrative language – that is, they must tell a story. The story will convey the context of a situation, whether it be about a notorious contaminant such as dioxin, lesser known emerging contaminants such as per- and poly-fluoroalkyl substances (PFAS) that have been used in firefighting foams, or other ingredients in all manner of consumer products.

Telling the story of how dangerous chemicals contaminated our environment helps people get a feel for the risks the contaminants pose and allows them to understand these risks better. When armed with this knowledge, people are better able to participate in the decision-making process.

## What did the research find about language and its power to communicate meaning?

Words matter in risk communication, and experts' choice of words is critical when remediation risks are being explained to non-experts: there's active vs passive voice, verbs vs nouns, analogy, context and comparison. These elements of language all help to paint a visual picture and get the essential message across to those who need to know about a risk. After all, when contamination is discovered on or near a residential site, the results can range from disruptive to devastating. In the worst-case scenario, people are forced to give up their homes.

Contamination at brownfield sites – former industrial sites slated for redevelopment – provides a double economic hit. Not only are such sites costly to remediate, but this can also cause lengthy delays in an industry where time is money. When the site is adjacent to existing suburbs, delays can easily blow out because genuine consultation with the local community can take a long time.

No matter how long it takes, however, remediation experts need to communicate. Experts need to



Differing perceptions about persistent organic pollutant remediation risks

explain what the project involves, how long it will take, and how it could affect the local community. They need to make clear any potential economic, environmental and health risks and – if they're smart – they'll explain the benefits as well. These include less pollution, improved amenity and, very often, increased home values. If remediation is performed to the right standard, these benefits will balance out any risks.

The results of the research are published as:

Hughes K (2017). Do remediation experts have what it takes to explain empirical uncertainty? *Remediation* 28:73–86.

## About the researcher

Dr Kate Hughes is an environmental advocate and researcher with an interest in hazardous chemicals and remediation. During her early career in the independent non-government sector, she campaigned for reform in the assessment and use of hazardous chemicals. Kate works in the remediation industry, providing guidance on scientific communication and community engagement. She has written and edited books about pollution so that the public can better understand its risks. She believes that education and a renewed focus on values is the key to a safer and more just future. Kate holds a PhD in Politics and has recently completed second doctoral research project into risk communication in the remediation industry at the Institute for Sustainable Futures, University of Technology Sydney.

## More information

Dr Kate Hughes, University of Technology Sydney, (02) 4568 2118, [katehughes27@bigpond.com](mailto:katehughes27@bigpond.com)



## Regulator Roundup

# Regulator Roundup 20

This edition of Regulator Roundup includes information about EPA Victoria's new board, the South Australian ban on PFAS.

## New EPA Victoria board

After the 2016 review of Environment Protection Authority (EPA) Victoria, state Environment Minister the Hon. Lily D'Ambrosio announced eight members of the new board in May 2018.

Ms Cheryl Batagol, who had been chairing the EPA's interim advisory board, stays on as chair of the new board. Mr Greg Tweedly – a director of Melbourne Health, Chair of Dorsavi Ltd and Chair of the Personal Injury Foundation – is the new deputy chair. The other members are:

- Professor Rebekah Brown, Director of the Monash Sustainable Development Institute at Monash University
- Ms Monique Conheady, a commissioner with the Taxi Services Commission, a director with the Victorian Responsible Gambling Foundation, and a co-founder and director of DC Power Co
- Mr Graeme Ford, former Chief Executive Officer of the Victorian Farmers Federation
- Mr Ross Pilling, Chair of Swinburne University's Industry Research Advisory Committee and the Victorian Government's Advanced Manufacturing Advisory Council
- Ms Debra Russell, a member of the Department of Justice Audit and Risk Committee, and the Surf Coast Shire Audit and Risk Committee
- Professor Joan Ozanne-Smith AO, Head of Injury Prevention Research at the Department of Forensic Medicine at Monash University.

## South Australia bans PFAS firefighting foams

The South Australian Government has banned the use of firefighting foams that contain per- and poly-fluoroalkyl substances (PFAS). The ban follows amendments to the Environment Protection (Water Quality) Policy 2015, making South Australia the first state to ban the use of potentially hazardous fluorinated firefighting foams through legislation.

EPA South Australia's Chief Executive, Tony Circelli, said the ban on fluorinated firefighting foams will effectively negate further environmental and human health risks associated with their use.

‘The changes will provide the community and industry with certainty around the use of these products’, he said. ‘The EPA will work directly with industry needing to transition through licensing, guidance and the development of environment improvement programs.’

## New Western Australia guidance on monitored natural attenuation

In April 2018, the Western Australian Department of Water and Environmental Regulation (DWER) issued a draft state guideline on the use of monitored natural attenuation (MNA) for groundwater clean-up.

The draft guideline requires that MNA should result in a decrease in the concentration or mass of contamination, and there must be geochemical and biochemical indicators of natural attenuation.

Adoption of MNA as a remediation strategy must include a contingency plan in the event that natural attenuation is unsuccessful. The guideline gives DWER the right to ensure that the organisation applying for approval MNA can fund such contingencies.

The consultation period closed on 8 June 2018. DWER is analysing submissions and will revise the draft guideline accordingly.

## United States EPA budget maintained

Despite an uncertain environment for the United States (US) EPA, its funding was maintained in new Financial Year Budget announcements in March 2018.

President Trump proposed cuts to the US EPA, which the US Congress rejected. This maintained EPA’s total funding at its 2017 level – US\$8.1 billion. Within that total, funding for science and technology was also maintained at US\$706 million.

US Congress also allocated US\$7 million to the Pentagon for a nationwide study on the health effects of PFAS in drinking water, focusing on PFOS and PFOA. The Agency for Toxic Substances and Disease Registry will conduct the research.

# GLOBAL CLEANUP CONGRESS INDIA 2018

CRC CARE, with Tamil Nadu Agricultural University, is proud to present the 1st Global CleanUp Congress as part of its globalCARE initiative.

globalCARE aims to change the way we think about, approach and solve contamination issues.

**21–25 OCTOBER 2018, COIMBATORE, INDIA**

Register now: **[gcc2018.cleanupconference.com](http://gcc2018.cleanupconference.com)**





# Using microscopy to characterise coal dust in urban samples

**Carrie DeHaan**

BIOTEXT PTY LTD

**Dr Graham O'Brien, Dr Karryn Warren, Dr Silvie Koval**

CSIRO ENERGY

**Dr Mark Hibberd**

CSIRO OCEANS AND ATMOSPHERE

Coal dust – which may be a component of urban dust – is of concern to many communities, particularly those near coal mines, railroads and ports. To reduce dust concentrations, we need to first understand where the particulates originate from by characterising the particles that comprise the dust. This should be done in a way that is acceptable to community groups, residents and experts, to result in evidence-based policy.

## Why do we need to investigate urban dust?

Communities, industry, government and academic bodies, and politicians are concerned about the health effects of urban dust. To create effective policies to reduce dust concentrations in the air, the amount, composition and size distribution of the particles in urban dust need to be characterised consistently and accurately.

Coal dust is fine, powdered coal, formed when coal is crushed or pulverised during mining and transportation. Coal dust can sometimes be a component of urban dust, which may also contain soot, dirt, metal, paint, and insect and plant detritus. Coal dust is an issue of community concern, particularly associated with the handling of coal on railways and ports in urban environments.

Urban dust samples can be qualitatively and quantitatively characterised using chemical and microscopic methods. This article looks at reflected light microscopy methods – the manual

point counting method and the automated imaging analysis method. These methods can distinguish carbon-based particles, such as rubber, organic material and diesel soot, in addition to coal particles.

## How can we characterise urban dust samples?

The collected dust sample is mixed with a polyester resin and allowed to cure; the set block is then cut and polished to a mirror finish. When prepared this way, the samples can be studied using a high magnification (500×) so that the different urban dust particles can be identified visually by an expert petrographer. Dust particles can also be characterised by their reflectance histogram using an imaging system.

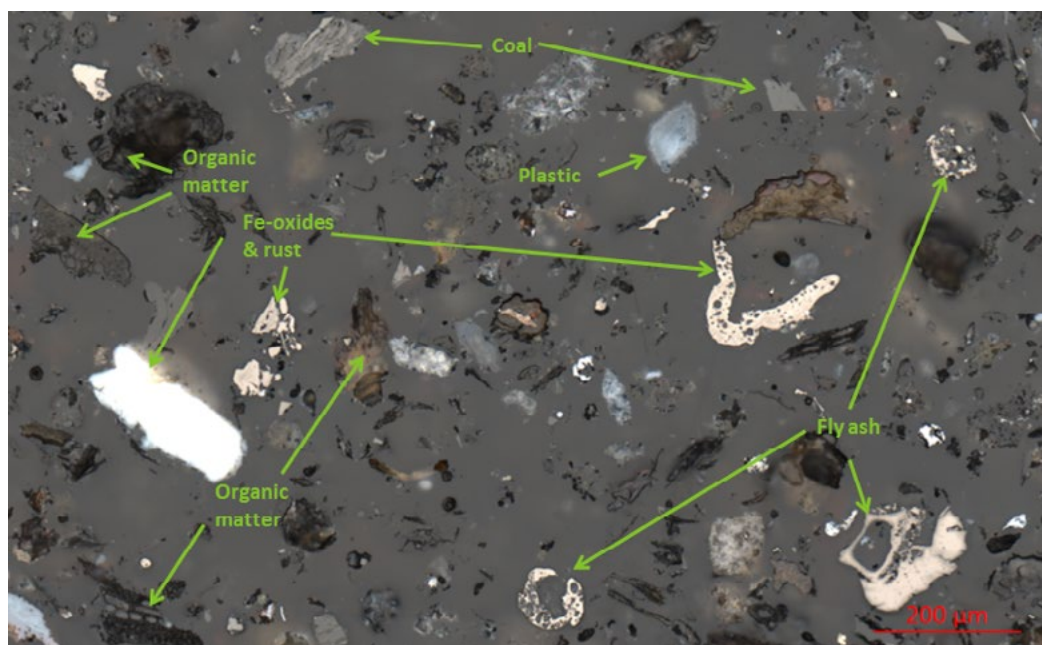
### Manual point counting method

The manual point counting method requires a petrographer to manually identify different components of an urban dust sample under a microscope (see Figure 1), using the Diessel classification method.<sup>1</sup> The manual point counting method needs an extremely skilled operator to correctly identify the particles.

For this article, the manual point counting method was used to characterise a sample collected from a rooftop near the coal port in Gladstone, Queensland.

### Reflected light imaging analysis method (coal grain analysis)

Coal grain analysis (CGA) uses image processing software that combines high-resolution colour images derived from optical reflected light microscopy. The software creates a reflectance



**Figure 1** Optical reflected light photomicrograph of an urban dust sample; components are identified using the manual point counting method

histogram, or fingerprint, for each individual particle in the image of each sample. The fingerprint is then used to differentiate the coal and non-coal particles.

CSIRO prepared a reference library of about 30 different types of particulates that could be found in urban dust, including coal particles. A subset of the particulates in this reference library (Figure 2) shows the different appearances of the different types of particles, which serve as reference points for different urban dust samples. Additional work done at the Australian Synchrotron verified this method, and showed that samples that appeared different did indeed have different chemical compositions.

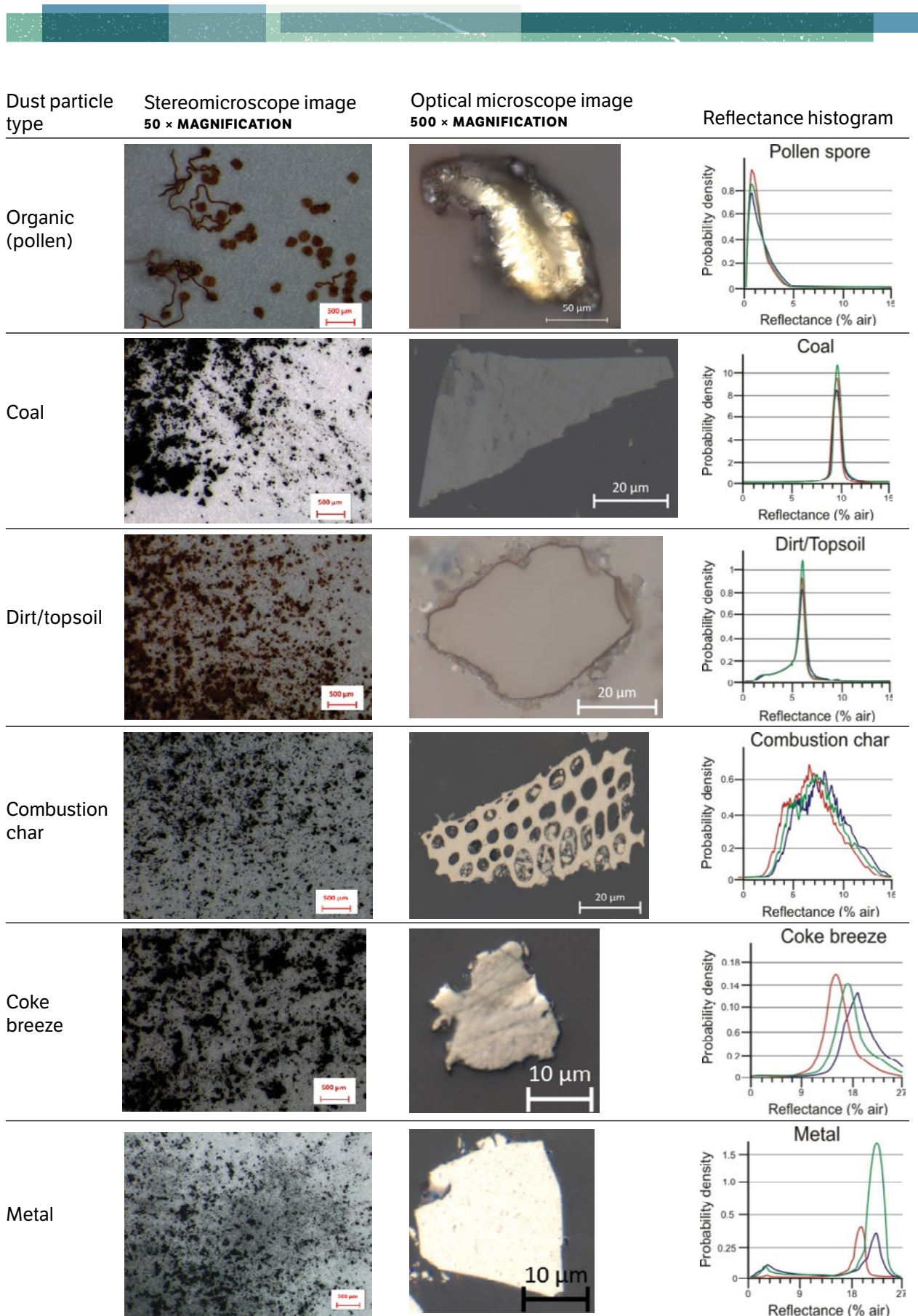
The verification step was automated by creating reflectance fingerprints from the CSIRO known reference samples (see Figure 3). After the software classifies each particle in the image, a skilled petrographer then validates the characterisation of each particle. The Australian Coal Association Research Program is funding work to develop 'optical dust markers' that use the reflectance fingerprints of the samples in the CSIRO reference library to speed up and improve this validation step.

CGA was used to analyse 49 samples from 5 different locations in the Mackay region in Queensland, and an additional 19 samples from Newcastle, New South Wales.

## Results of the urban dust characterisations

The manual point counting method found that one of the Queensland dust samples contained coal from a range of sources consistent with the known vitrinite reflectance fingerprints of the coals shipped through the Gladstone port. Vitrinite is one of the primary components of coal.

In one of the Newcastle samples, CGA identified size and composition information for 2912 individual particles (Box 1). The sample was found to contain particles of clays, quartz and organic material; iron particles; and small amounts of soot and rubber.



Note: The low-magnification (50×) images collected on unset particulates were visually similar. The high-magnification (500×) images and the reflectance histograms were collected on polished grain-mounted samples.

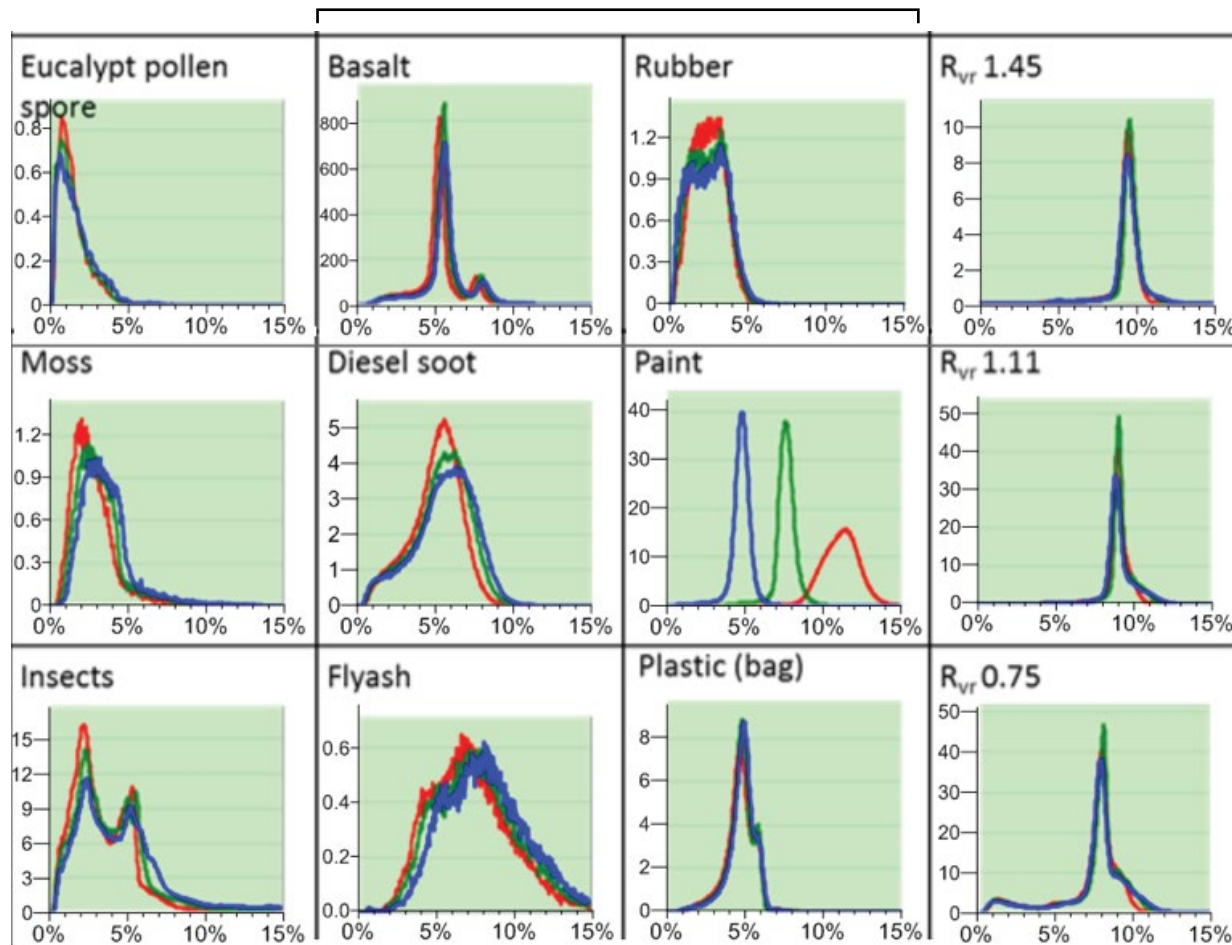
**Figure 2** Optical photomicrographs of a subset of the dust particulates in CSIRO's reference library



Organic particles

Inorganic particles

Coal particles



Note: The x axis represents the reflectance in air from 0 to 15% for each particle and the y axis represents the estimated probability density for the red-green-blue measurements.

**Figure 3** Reflectance fingerprints for different types of particles found in urban dust

## Why do we need two different characterisation methods?

Information from the manual point counting method and the reflected light imaging analysis method can be used side by side to complement each other. The advantage of the manual analysis is that a skilled petrographer can identify more of the non-coal particulates than can currently be identified by an imaging system. They can also use vitrinite reflectance information to determine the possible origin of the coal. However, an imaging analysis method, such as CGA, can characterise far more particulates in a sample than a manual method. Imaging analysis methods can provide particle size information for every particle greater than 1 micron.

Therefore, combining the methods will provide a more quantitative analysis.

### Box 1 CSIRO software to characterise dust samples

CSIRO has developed specialised software that identifies the composition of dust samples and the amount of different particle types in the sample. Researchers can upload images from the CGA to a website. Figure 4 shows results for the Newcastle sample:

- dark material particles (predominately dirt, sand, rubber, some plastic and paint, and organic material) are shown as red
- coal particles are shown as dark green
- combustion biochar particles are shown as yellow
- unclassified particles are shown as pink
- bright material (predominately iron flakes, and some plastics and paint) are shown in light blue.



**Figure 4** Sample from Newcastle, New South Wales, uploaded to the imaging website

This article was based on:

- O'Brien G, Warren K, Koval S and Hibberd M (2017). Quantifying coal dust in urban samples. In: *Proceedings of the 40th Symposium on Advances in the Study of the Sydney Basin: weathering change*, Pokolbin, New South Wales, 27–28 April 2017.
- Koval S, Krahenbuhl G, Warren K, O'Brien G (2017). Optical microscopy as a new approach for characterising dust particulates in urban environment. *J Environ Manage* 223:196–202.

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# Particulate plastics in soil: friend or foe?

**Hasintha Wijesekara, Lauren Bradney, Dr Anitha Kunhikrishnan, Professor Nanthi Bolan**

GLOBAL CENTRE FOR ENVIRONMENTAL REMEDIATION, UNIVERSITY OF NEWCASTLE, NSW

**Dr Aravind Surapaneni**

SOUTH EAST WATER, FRANKSTON, VICTORIA

**Professor Wang Hailong**

SCHOOL OF ENVIRONMENT AND CHEMICAL ENGINEERING, FOSHAN UNIVERSITY, GUANGDONG 528000, CHINA

**Professor Yong Sik Ok**

DIVISION OF ENVIRONMENTAL SCIENCE AND ECOLOGICAL ENGINEERING, KOREA UNIVERSITY, REPUBLIC OF KOREA

Plastics can pollute the air, land and water during all stages of their life cycle from manufacture to disposal. Synthetic plastics do not biodegrade and tend to accumulate in the environment. Particulate plastics of varying physical size fractions are becoming major sources of pollutants in terrestrial and aquatic ecosystems.

Particulate plastics are synthetic polymer particles measuring less than 5 mm in diameter. There are two types of particulate plastics that can enter the environment. Primary particulate plastics are manufactured and are a direct result of anthropogenic use of plastic-based materials (eg microbeads in cosmetics). Secondary particulate plastics are plastic fragments derived from the breakdown of larger plastic debris. An example of secondary particulate plastic input to soil is the breakdown and weathering of plastic mulch used mainly in agricultural and horticultural crops (Figure 1).



Slavko Sereda – stock.adobe.com

**Figure 1** Breakdown and weathering of plastic mulch is an important source of particulate plastic input to soil



Both particulate plastics persist in terrestrial and aquatic ecosystems. Because plastics do not breakdown readily, they can be ingested and incorporated into the tissues of some terrestrial and aquatic organisms.

## Sources of particulate plastic contamination

Particulate plastics reach terrestrial ecosystems through their indiscriminate disposal in landfills, and through compost and biosolids application. Although medium and large-sized plastic materials are generally segregated during the composting process, a significant portion of small-sized plastics make it through the sieve and are still composted. Because compost is subsequently milled, most plastics end up as microplastics or nanoplastics. There has been renewed interest in the large-scale application of composts to soil, mainly to increase soil health and to improve carbon sequestration in soil.

Biowastes – including biosolids (treated sewage sludge) and composts – are excellent sources of nutrients and organic matter for agricultural and degraded soils. Although biowastes offer agronomic benefits, they also contain a number of contaminants, including heavy metals, pharmaceuticals, per- and poly-fluoroalkyl substances and particulate plastics. Particulate plastics end up in soils when biowastes are applied to land. It was estimated that more than 280 billion particulate plastics entered the Australian soils through biowaste application in 2017.<sup>1,2</sup>

The terrestrial ecosystem is a major source of the particulate plastics that reach aquatic ecosystems, through sediment transfer during soil erosion.

## Impacts of particulate plastics in soil

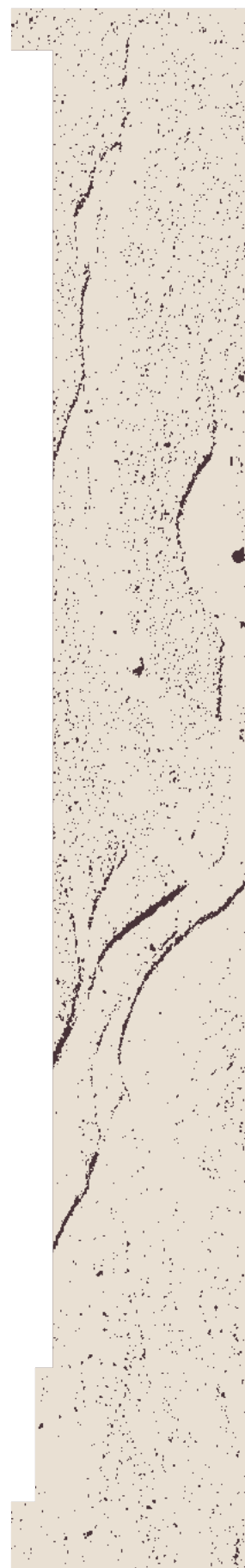
Particulate plastics input to terrestrial ecosystem can have both beneficial and detrimental impacts on soil characteristics and organisms. For example, polyacrylamide is used to promote flocculation (particle clumping) and soil aggregation, thereby mitigating soil erosion.<sup>3</sup> Particulate plastics in soils can serve as a hidden source of carbon sequestration, thereby contributing to climate change mitigation. However, since particulate plastics are introduced through human activities, it may not be considered a ‘direct action’ approach to mitigate climate change.

Most research on particulate plastics has focused on their detrimental effects in aquatic environments. The results indicate that particulate plastics can act as a vector for pollutants, and transport them long distances to affect aquatic environments.

## Our research

Although particulate plastics are recognised as emerging contaminants in soils, their impact in the soil environment remains largely unclear, particularly on microbial functions and contaminant mobility. We quantified the amount of particulate plastics in biosolid samples. We also conducted a laboratory incubation study to examine the impact of particulate plastics on microbial activity and contaminant mobility in soil.

Particulate plastics were extracted from a number of biosolid samples. Two types of particulate plastics, pristine polyethylene (PPP) and surface-modified plastics (BSPPs), were used in the laboratory incubation study. The PPP (size ~100 µm – Microscrub®) was purchased. The BSPPs were prepared by spiking biosolids with PPP, facilitating the adsorption of



biosolids-derived dissolved organic carbon onto PPP. Sandy soil samples collected from Grenfell, Sydney, New South Wales, were spiked with copper (500 mg copper/kg soil) and equilibrated for 2 weeks. Both the pristine and copper-contaminated soil samples were treated with PPP and BSPPs. These soil samples were subsequently analysed for bioavailable copper concentration, soil basal respiration, microbial biomass carbon and dehydrogenase activity.

The amounts of particulate plastics in the biosolids samples tested were:

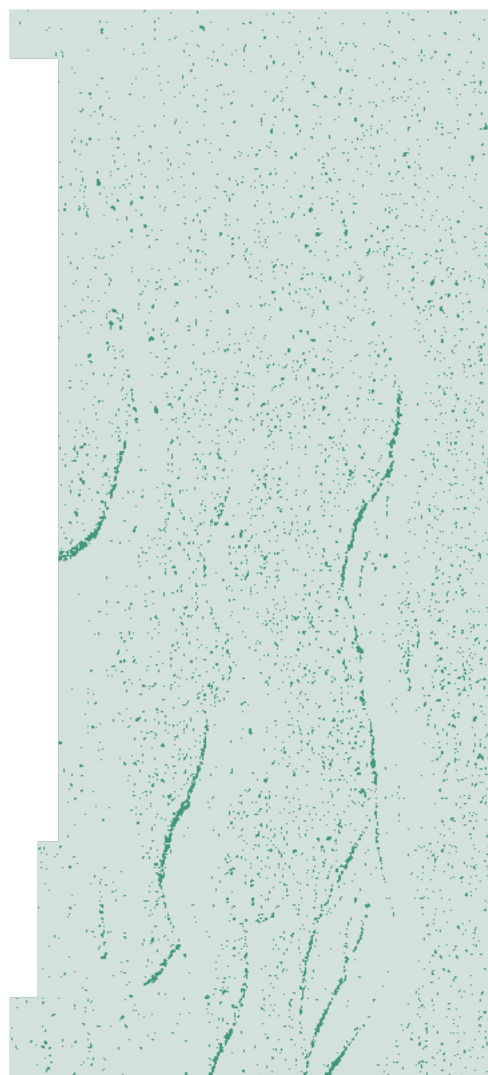
- 352 particles/kg for the <50 mm size fraction of particulate plastics
- 146 particles/kg for 50–100 mm
- 324 particles/kg for 100–250 mm
- 174 particles/kg for 250–1000 mm.

The incubation study indicated that the bioavailability of copper in contaminated soil decreased with the addition of both PPP and BSPPs. The effect was more pronounced with the BSPP addition. This may be attributed to the adsorption of copper by the dissolved organic matter associated with the particulate plastics.

The results also showed that there was less soil basal respiration in copper-contaminated soil samples, suggesting copper is toxic to soil microbial activity. Adding particulate plastics resulted in an increased soil respiration in both uncontaminated and contaminated soils. The increase in microbial respiration due to the particulate plastic was higher in the BSPP-treated soil than in the PPP-treated soil. This suggests that soil microorganisms used the BSPP – the organic matter that had sorbed to particulate plastics – to increase their microbial activity. BSPPs are likely to interact with and retain the contaminants, thus reducing the toxicity to soil microorganisms. The improved soil aeration (porosity) caused by adding PPP or BSPPs could be another reason for the increase in the microbial activity.<sup>4</sup> Similar to the soil respiration observations, copper contaminated and uncontaminated soils treated with particulate plastics appear to increase dehydrogenase activity and microbial biomass carbon.

## Conclusions

Particulate plastics in terrestrial ecosystems can have both beneficial and detrimental effects on soil health. Our observations on soil basal respiration, dehydrogenase activity and microbial biomass carbon indicate that adding particulate plastics helps modulate contaminant toxicity on soil microbial activity. However, it is important to examine the long-term effects of particulate plastics on the microbial activity in soil health.



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# Biochar – what is its potential for environmental remediation?

## Professor Nanthi Bolan

GLOBAL CENTRE FOR ENVIRONMENTAL REMEDIATION, UNIVERSITY OF NEWCASTLE

## Dr Sanchita Mandal

FUTURE INDUSTRIES INSTITUTE, UNIVERSITY OF SOUTH AUSTRALIA

## Professor Wang Hailong

SCHOOL OF ENVIRONMENT AND CHEMICAL ENGINEERING, FOSHAN UNIVERSITY, GUANGDONG 528000, CHINA

## Professor Yong Sik Ok

KOREA UNIVERSITY

## Professor Dan Tsang

HONG KONG POLYTECH UNIVERSITY

## Dr Qiao Li

NANJING UNIVERSITY OF SCIENCE AND TECHNOLOGY

Applying biochar to soil has been shown to improve carbon sequestration and soil health, and remediate contaminated soil and water resources. Biochar is valuable as a nutrient source and a soil amendment, to remediate contaminated soil and aquatic ecosystems. In this article, we present an overview on the synthesis and characteristics of biochar, and how designer biochar may help remediate contaminated soil and water.

## Biochar synthesis

Biochar is charcoal made thermochemically from biomass. The starting material can be various carbon-based sources, including woody biomass, crop residues, animal litter, composts and biosolids. Thermochemical processes used include pyrolysis, torrefaction and hydrothermal carbonisation.

### Pyrolysis

Pyrolysis is an inexpensive and robust technology, which can thermochemically decompose organic matter into non-condensable syngases, condensable bio-oils and solid residual products – biochar. The end product of pyrolysis can be controlled by altering the pyrolysis parameters, such as

temperature and length of the process. For example, increasing the pyrolysis temperature increases gas yield and decreases biochar production.

### Torrefaction

Torrefaction is a modified pyrolysis technique. Here, biomass is slowly heated within a specified temperature range (200–300 °C) and held for a certain duration to remove the moisture, carbon dioxide and oxygen from feedstocks (raw materials). The torrefaction environment must be inert or have limited oxygen. Torrefaction temperature is the most important parameter that influences the biomass weight loss, and the chemical and thermophysical properties of biochar. The torrefied biomass has properties similar to that of raw biomass and biochar, because torrefaction is first stage of the pyrolysis process and the torrefied biomass still contains some volatile organic compounds.

### Hydrothermal carbonisation

Hydrothermal carbonisation (HTC) is an exothermic process in which feedstock is heated in water in a confined system. HTC offers advantages for biochar production, including high-conversion efficiency and relatively low operating temperature (150–250 °C), and it does not use an energy-extensive drying process. The composition and structure of the biochar (hydrochar) from HTC differs substantially from that of pyrolysis biochar. The



chemical structure of hydrochar closely resembles natural coal, with higher hydrogen:carbon (H:C) and oxygen:carbon (O:C) ratios than biochar from pyrolysis.

## Characteristics of biochar

### Physical characteristics

Physical characteristics, such as surface area and porosity of biochar, are key parameters controlling the magnitude of interactions between biochar and contaminants. The physical and chemical properties of biochar are affected by several factors, including:

- feedstock types
- production conditions such as pyrolysis temperature
- gas flow
- presence of gases, such as carbon dioxide or nitrogen.

For example, higher temperatures during biochar synthesis result in the biochar-pore infillings releasing volatile matter. This produces biochar with maximum surface area and microporosity. Resulting pore sizes differ, and the relative distribution of pore size affects interactions between biochar and the environmental solutes, including contaminants.

### Elemental characteristics

Biochar is made up of elements such as carbon, hydrogen, sulfur, potassium, oxygen and nitrogen, as well as minerals in its ash component. The elemental composition of biochar also depends on its production conditions and feedstock types. Elemental molar ratios, such as H:C and O:C, of biochar are used to measure its aromaticity and maturation. Aromaticity is defined as the fraction of carbon in biochar that forms aromatic bands. Biochar with dense aromatic structures is more resistant to oxidation and microbial degradation. Therefore, the degree of aromatic condensation in biochar is related to its recalcitrance in the environment. Low-temperature biochar is likely to have lower aromaticity than high-temperature biochar.

### pH and Eh of biochar

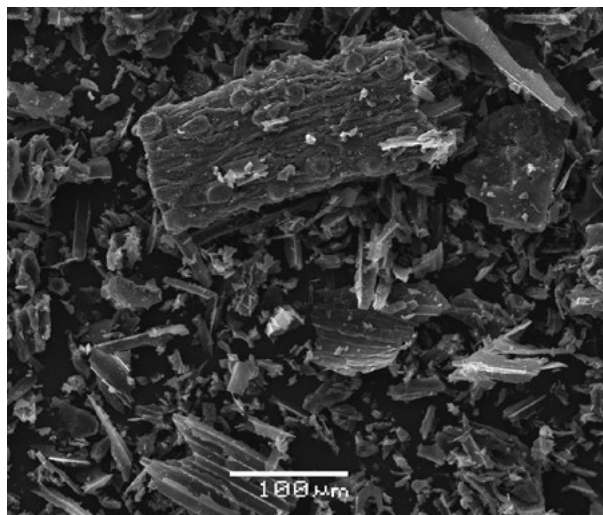
Biochar is typically alkaline, but this depends on the original feedstock and the preparation conditions. A higher ash content results in a biochar with a higher pH. Functional groups, such as carboxylic

and phenolic groups, in biochar determine its surface charge and redox properties, and play an important role in the retention of cations and anions in soil and water. Biochar can donate, accept or transfer electrons to or from their surrounding environments, thereby influencing the redox reactions of contaminants.

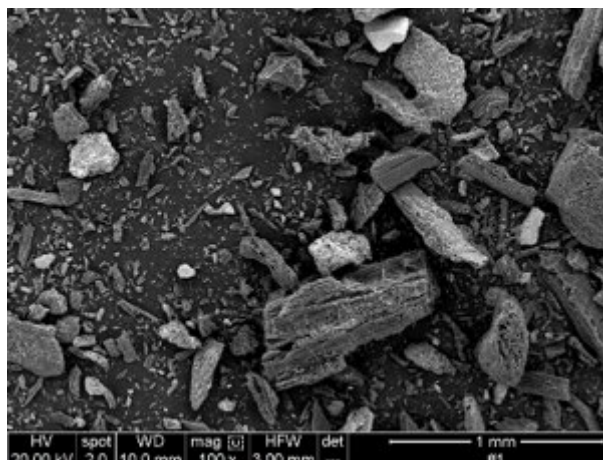
Elemental composition, cation-exchange capacity, surface functional groups, and pH and Eh of biochar are important properties that control the interactions between biochar and contaminants.

## Making designer biochar


Recently, the concept of designing biochar for a specific purpose has been proposed. Using designer biochar is reported to be more effective than simply



Biochar made from macadamia nut shell  
(photo credit: Dr Naser Khan)



Biochar made from wood shavings  
(photo credit: Dr Fangjie Qi)



applying biochar indiscriminately. For example, modifying the biochar surface aims to improve the physicochemical and sorptive characteristics of biochar for novel uses such as heavy metal binding, organic pollutant sorption and water purification. Various approaches are used to modify biochar surface properties. Here, we discuss impregnation, oxidation and grafting.

## Impregnation

Impregnation is a process where elements (usually metals) are incorporated into the biochar surface through prolonged wet contact. Biochar modification by impregnation is likely to make them more active in terms of retaining heavy metals from aqueous solution. Nitric acid is often used to remove intrinsic ash and tar from biochar before impregnation.

## Oxidation

Oxidation is another modification process where liquid or gaseous compounds (eg inorganic acids) are used to modify and purify biochar. Two types of oxidation, liquid-phase oxidation and gas phase oxidation, are generally used.

In the liquid-phase oxidation process, the following have been used to modify or purify biochar:

- strong acids such as nitric acid
- a mixture of nitric and sulfuric acids
- strong oxidisers, such as potassium permanganate, in an acid solution
- other chemical mixtures, such as hydrogen peroxide/sulfuric acid and hypochlorite solution.

Gaseous phase oxidation uses carbon dioxide and oxygen gas to modify the biochar. Using potassium hydroxide increases the biochar's porosity and surface area.

Oxidation can modify biochars in 2 different ways:

- it opens the pores in char products and then fills the pores with metals
- it adds new functional groups on the surface of biochars.

Acid and base chemical activation modifies biochar through both dehydration and oxidation. The feedstock is usually mixed or soaked in a solution of acids and bases before pyrolysis and activation. Strong oxidisers also can be used to modify or purify biochar.

## Grafting

Grafting can also modify biochar, by fusing guest molecules or elements onto the functional groups of

the char surface, using the condensation reaction. Grafting can be done with or without pre-oxidation. There are several compounds or materials that can be used to graft biochar. Grafted biochar has many potential applications, such as in biomaterials, bioengineering and emerging biotechnology.

## Biochar-assisted remediation of heavy metals

Biochar application is effective in the remediation of heavy metal-contaminated soil and aquatic ecosystems. Various mechanisms have been proposed to explain how biochar remediates heavy metal contamination, but chemisorption is the dominant process involved in removing heavy metals such as cadmium and lead in soil and aquatic systems.

Biochar-mediated redox reactions controlling the (im)mobilisation and subsequent bioavailability of heavy metals have been reported. For example, although chromium(III) is strongly retained onto soil particles, Cr(VI) is very weakly adsorbed and is readily available for plant uptake and leaching to groundwater. Thus, reduction of Cr(VI) to Cr(III) can affect the (im)mobilisation and bioavailability of chromium. Although oxidation of Cr(III) to Cr(VI) is mostly mediated abiotically through oxidising agents – such as manganese oxide and, to a lesser extent, ferric oxide – reduction of Cr(VI) to Cr(III) is mediated through abiotic and biotic processes. Chromate can be reduced to Cr(III) in environments that have electrons available. Biochar provides a source of electrons, thereby enhancing the reduction of Cr(VI) to Cr(III) and subsequent immobilization of Cr(III) – mitigating the environmental toxicity of chromium.

## Conclusions

Applying biochar to soil has been shown to improve carbon sequestration, soil health and agricultural productivity. Currently, the focus of biochar research is on its potential value in mitigating the toxicity of contaminants in soil and groundwater resources. Its favourable physicochemical characteristics – such as high surface area, porosity and surface charge density of biochar – are key parameters enabling its potential application to remediate contaminated soil and aquatic ecosystems.

# Phthalate contamination in China – a review of sources, distribution and trends

**Carrie DeHaan**

BIOTEXT PTY LTD

**Ming Hung Wong**

SCHOOL OF ENVIRONMENTAL SCIENCE AND ENGINEERING, SOUTHERN UNIVERSITY OF SCIENCE AND TECHNOLOGY, SHENZHEN, CHINA

Phthalates (also known as phthalic acid esters, or PAEs) are used as plasticisers in many consumer products, such as plastics and polyvinyl chloride (PVC), and as solvents in adhesives, cosmetics and paints. Phthalates are one of the most common organic contaminants in the environment, but data about human exposure to them are limited. This article reviews the sources, levels and distribution of phthalate contamination in China, and compares the results with other countries.

China is a major producer and user of phthalate-containing products, and such products are used ubiquitously worldwide. As a result, phthalates are a common environmental contaminant, and human exposure is unavoidable. But how much we are exposed to is not well known, especially in China.

The health effects from phthalate exposure are also poorly defined. Several studies have shown that phthalates are endocrine-disrupting chemicals, which have negative effects on human health. Some, such as di-(2-ethylhexyl)phthalate (DEHP), are possible carcinogens. Other ill health effects associated with phthalate exposure include reproductive toxicity and metabolic disorders.

A number of countries have classified phthalates such as DEHP as 'priority pollutants'. Many countries have banned the use of DEHP in materials, but many developing countries still use it.

## How are people exposed to phthalates?

There are many routes for exposure to phthalates, which is not surprising given their widespread use. People can be exposed to phthalates by breathing contaminated air or drinking polluted water. Phthalate-contaminated soil also offers several sources of exposure, and people may be exposed internally through plastic-based medical devices. Babies can be exposed to phthalates through breastmilk.

This article outlines the common exposure routes and sources of contamination in China.

## Air contamination

In China, increased levels of phthalates are found in the air around facilities used for plastic waste recycling and municipal waste incineration. e-waste is particularly high in phthalates. Recycling and incineration processes release phthalates into the air, water and soil, thus also leading to soil and water contamination.

## Dust and personal product contamination

Phthalates are found in many common household and personal products in China, such as PVC flooring, vinyl wallpaper, ceiling materials, hair gels and sprays, cosmetics (including nail polish), body lotions, fragrances and deodorants. Such products can release phthalates that end up in dust, and dermal exposure can occur through any substance that is directly applied to the skin.



## Soil contamination

Studies have shown that phthalates are widely found in both urban and agricultural soils in China. Several practices can lead to phthalate soil contamination:

- Urbanisation and industrialisation – Phthalates are widely used in industrial processes and products. From these sources, phthalates can be released to the environment during all stages of production and product degradation.
- Plastic film used in agriculture – Mulching with plastic film is common agricultural practice, especially in arid or semi-arid regions, and phthalates are a major component of plastic films. Phthalates can end up in the soil by leaching, migration and abrasion from the plastics.
- Fertiliser application – Applying fertiliser is another common agricultural practice, and China is a world leader in the use and production of fertilisers. Phthalates are a common component of synthetic fertiliser.
- Wastewater irrigation – Severe water shortages in China have led to irrigation with wastewater. Wastewater contains several contaminants, including phthalates.
- Sewage sludge application – Sewage sludge is used worldwide as a fertiliser and soil amendment. However, sewage sludge contains organic contaminants, including phthalates.

## Food and water contamination

Food and water contamination is the most common method of exposure for people in China – called dietary exposure. Phthalates can bioaccumulate in food sources higher in the food chain. Further, plastic food storage containers contain phthalates, which could leach and migrate into the food or liquid. Contaminated water can lead to contaminated seafood. Finally, crops grown in phthalate-contaminated soil can take up phthalates, which in turn can be eaten by humans.

## Medical contamination

Plastic-based medical devices, such as those used in blood transfusions and haemodialysis, could be a source of phthalate contamination.

## How serious is phthalate contamination in China?

Relative to other countries, the phthalate contamination of soil, water and air in China is moderate to severe, depending on the exposure route. There are not a lot of data available, however.

As mentioned, exposure through diet is common, and an important route for phthalate exposure in China. In addition to eating contaminated plants, such as vegetables and cereals, soil itself can be ingested and inhaled. Aquatic foods are also highly contaminated with phthalates in China, especially fish from the Pearl River Delta.

## Regional variation

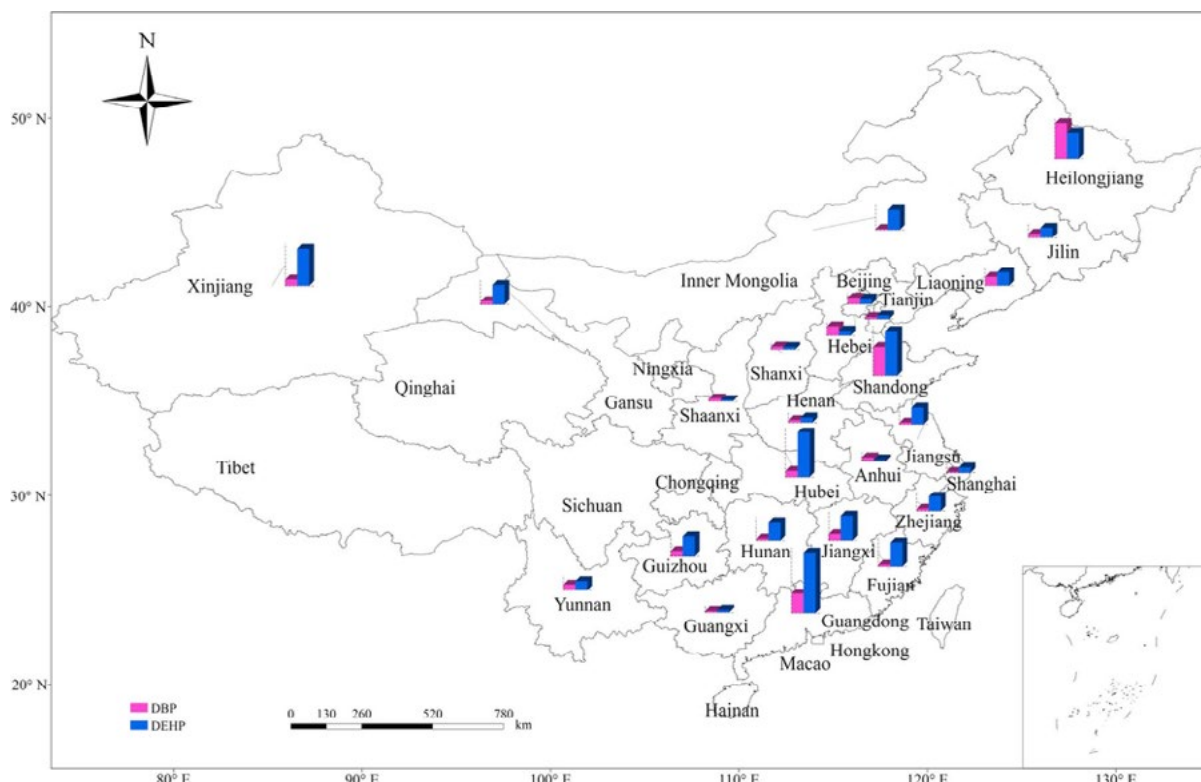
In China, the levels of phthalate exposure vary from region to region. This variation could be real, but – because there are so few data from some areas – it is more likely due to estimation errors and other biases. For example, places of intense manufacturing, such as the Pearl River Delta, have been studied more than other regions, thus possibly skewing results.

As an example of the national variance in levels of soil contamination, Figure 1 shows the average concentrations of dibutylphthalate (DBP) and DEHP in samples taken from across China. For reference, the Pearl River Delta is in the Guangdong, Hong Kong and Macau regions.

Other variances in phthalate distribution patterns could be due to temperature differences (for air contamination), and seasonal differences and depth of sample (for soil contamination).

## How do exposure and source levels in China compare with other countries?

Indoor levels of phthalates (from dust and personal care products) in China are comparable to other Asian countries, and moderate compared with other parts of the world. Air and foodstuff contamination in Chinese cities are low compared with other global cities. The levels of phthalates in Chinese soils are at the high end of the global range. China also has a high dietary exposure compared with other countries, but with a lot of regional variability.



DBP = dibutylphthalate; DEHP = di-(2-ethylhexyl)phthalate

**Figure 1** Average concentrations of DBP and DEHP (in mg/kg) in soil samples from China

Although some phthalate contamination sources and exposure levels in China were around the global average, there are not a lot of data available on which to base solid conclusions. Also, phthalate use is increasing, and the human exposure trend is unknown. Phthalate contamination is widespread and could be getting worse, not better.

## What questions still need to be answered?

In China, we need to examine regional discrepancies in phthalate exposure levels and collect more samples, to ensure that all segments of the population are represented in studies. Does exposure depend on income, age or area of residence? Studies also need to include subpopulations – for example, do workers at recycling plants have higher exposure levels than other subpopulations?

In addition, the health effects of phthalate exposure and routes of exposure need to be determined, again in different populations. Does the health effect depend on the route of exposure and the type of phthalate? Do different types of phthalates have different human exposure routes?

Until some of these questions are answered, it will be difficult to assess the health of the Chinese population as a result of phthalate contamination. More information is also needed about the extent of phthalate contamination across China. Making phthalates a research priority could lead to changes to manufacturing policies and to remediation strategies.

This article was based on 2 reviews:

- Lü H, Mo CH, Zhao HM, et al (2018). Soil contamination and sources of phthalates and its health risk in China: a review. *Environ Res* 164:417–429.
- Wang W, Oi Wah Leung A, Chu LH, Wong MH (2018). Phthalates contamination in China: status, trends and human exposure – with an emphasis on oral uptake. *Environ Pollut* 238:771–782.

# Training and events calendar

## 2018

### 27 and 30 August

#### WORKSHOP

Technical and regulatory issues resulting from the use of PFAS at contaminated sites

CRC CARE / Sydney (27 August) and Melbourne (30 August)

[www.crccare.com/  
knowledge-sharing/  
upcoming-training-and-events](http://www.crccare.com/knowledge-sharing/upcoming-training-and-events)

### 28 and 31 August

#### WORKSHOP

Comprehensive and Innovative guidance for DNAPL site characterisation and remediation

CRC CARE / Sydney (28 August) and Melbourne (31 August)

[www.crccare.com/  
knowledge-sharing/  
upcoming-training-and-events](http://www.crccare.com/knowledge-sharing/upcoming-training-and-events)

### 21 and 25 September

#### WORKSHOP

Societal perceptions and acceptance of remediation technologies

CRC CARE / Sydney (21 September) and Perth (25 September)

[www.crccare.com/  
knowledge-sharing/  
upcoming-training-and-events](http://www.crccare.com/knowledge-sharing/upcoming-training-and-events)

### 26–28 September

What's the matter? Toxicity and health effects of particulates – size or composition

Australasian College of Toxicology and Risk Assessment / Perth

[events.clems.com.au/  
QuickEventWebsitePortal/  
actra-asm-2018/welcome](http://events.clems.com.au/QuickEventWebsitePortal/actra-asm-2018/welcome)

### 3–4 October

Waste Expo Australia  
Reed Exhibitions / Melbourne  
[www.wasteexpoaustralia.com.au](http://www.wasteexpoaustralia.com.au)

### 21–25 October

1st Global Contamination CleanUp Congress

CRC CARE and Tamil Nadu  
Agricultural University / Coimbatore,  
Tamil Nadu, India

[gcc2018.cleanupconference.com](http://gcc2018.cleanupconference.com)

## 2019

### 4–8 March

1st Australian Summer School:  
Contaminated site assessment,  
management and communication

CRC CARE / Newcastle

[www.crccare.com/events/1st-  
australian-summer-school-newcastle-  
contaminated-site-assessment-  
management-and-communication](http://www.crccare.com/events/1st-australian-summer-school-newcastle-contaminated-site-assessment-management-and-communication)

### 25–27 March

CleanUp Korea 2018

CRC CARE and Korea University /  
Seoul, Republic of Korea

[korea2019.cleanupconference.com](http://korea2019.cleanupconference.com)



# Is your site contaminated by firefighting foam?

Known as aqueous film-forming foams (AFFFs), some firefighting foam used for many years at airports and fire training facilities contained the potentially toxic chemicals PFOS and PFOA. In many cases, these chemicals have spread to groundwater, drinking water, plants and animals.

This is affecting local communities and is the focus of investigations by regulatory bodies.

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**matCARE™** does a far better job than granular activated carbon and other technologies currently available, with a much smaller amount required. Around 90% cheaper than landfill, **matCARE™** remediation is a cost-effective solution. And with CRC CARE's scientific foundation, **matCARE™** provides the safest solution to ensure toxins are removed from soil and water, protecting everyone who comes in contact with the facility.

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