Australia's leaders in the science of contamination and its remediation.

CRCCARE

A safer, cleaner environmental future

Annual Report

2020/21

Australian Government
Department of Industry, Science, Energy and Resources

Business Cooperative Research Centres Program

CRC CARE is a partnership of organisations dedicated to developing new ways of dealing with and preventing contamination of soil, water and air including solid and liquid waste management. We focus Australia's foremost expertise and resources on this issue and to develop close links with research partners at the cutting edge in this field around the world.

OUR GOALS

Solutions for industry

To develop cost-effective and commercially sustainable solutions and technologies within regulatory and policy frameworks for the identification and remediation of contamination problems of key importance to Australia and the Asia-Pacific region.

Innovative research

To deliver research quality that positions CRC CARE as a national centre of excellence with international standing and reputation, ensuring our outcomes are recognised and adopted globally.

Develop the business

To lead the development of a new export industry in environmental risk assessment and remediation through the delivery of solutions and technologies, and support their implementation with training programs that develop and improve the environmental management skills of the industry's labour force.

Deliver public benefits

To ensure the effective adoption of our solutions and technologies, leading to health, environmental and economic benefits to the Australian public through reduced exposure to toxic contaminants and improved amenity of our cities as a result of cost-effective remediation/management of urban land.

Capacity building

Through university and short-term training, educate a generation of researchers and practitioners highly skilled at solving and preventing the problems of contamination, solid and liquid waste management and create employment opportunities in the industry for these specialists.

COVER IMAGE

CRCCARE Managing Director and CEO Prof. Ravi Naidu (right) with researchers Dr Peter Sanderson and Dr Luchun Duan in a laboratory at the Global Centre for Environmental Remediation, University of Newcastle.

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CHAIRMAN'S FOREWORD

For 16 years, CRC CARE has played a unique and influential role in Australia's contaminated site sector. As a globally recognised research leader, we have brought together diverse – and at times opposed – stakeholders to vastly improve the national approach to the myriad challenges of environmental contamination.

The efforts of our scientific and technical experts, in concert with our end-user Participants, have helped grow the remediation industry tenfold and contributed more than $5.4 billion (and rising) of economic benefit to Australia. Crucially, this boost to the economy has gone hand in hand with better environmental outcomes, meaning safer, healthier urban and rural communities.

The 2020/21 reporting period was not only our last, but also one of the most difficult of the CRC's existence. The COVID-19 pandemic continued to disrupt personal and professional life worldwide. Furthermore, the logistical challenges were exacerbated by the cessation on 30 June 2020 of financial support from the Cooperative Research Centre (CRC) Program, as one of the conditions for our 12-month protracted exit (itself a product of the COVID disruption of 2020). In what was a huge vote of confidence, however, our Participants stepped up to ensure that we could continue our work and meet all Commonwealth milestones. I would like to thank all Participants for their support over the 10 years of our current term of funding, and particularly the Department of Defence (DoD), BHP and HLM Asia for their contributions in 2020/21.

Although much of our work in 2020/21 focused on completing projects and meeting our remaining milestones, our scientists also had the opportunity to perform exciting research. Highlights included: a suite of DoD projects such as PFAS remediation at RAAF Base Richmond and cleaning up contamination associated with the explosives facility at Mulwala, NSW; finalisation of a suite of online risk assessment tools; and progress on commercialisation of probeCARE™, a handheld device monitoring water quality in real time.

Another flagship project, The National Remediation Framework (NRF), which harmonises remediation approaches nationally, is getting impressive traction with the remediation industry. Following the launch in June 2020, the 25 NRF guidelines and around 50 associated resources have been downloaded more than 46,000 times. Significantly, the National Environment Protection (Assessment of Site Contamination) Measure and the NRF are underpinning the assessment and remediation of the former uranium mine at Rum Jungle in the Northern Territory.

So what next for CRC CARE? Although our bid for a new 'Clean Australia' CRC was not successful, our user-led Beyond 2020 Implementation Committee has worked tirelessly to develop a model that allows the CRC's crucial work to continue. I'm pleased to say that all major end-user Participants, as well as several new ones, have made in-principle commitments to fund the CRC's continuation for 10 years. Participant Agreements are close to being finalised and we expect to announce details very soon.

It is with mixed feelings that I present our final annual report as a CRC under the Australian Government's CRC program – and also mine as Chair. I am immensely proud of our achievements but recognise that a great deal remains to be done. Australia's contamination issues are far from resolved; we need a CRC CARE to focus our efforts and ensure that all parties are at the table, engaged in constructive dialogue and collaborative action.

My sincere thanks to everybody involved in CRC CARE so far – my fellow directors, our end-users, and all the staff, students and researchers who have together contributed to a safer, cleaner world. In particular, I want to commend our CEO Prof. Ravi Naidu for his vision and determination to bring the CRC to life and lead it to the heights it occupies today. Finally, a warm welcome to the incoming Chair, Sean Edwards. I wish him and the directors of the new entity every success.

Dr Paul Vogel AM
Chairman
CRC CARE

01 EXECUTIVE SUMMARY

MANAGING DIRECTOR AND CEO'S REPORT

The 2020/21 Annual Report marks the end of an era. CRC CARE came into existence in 2005, headquartered at the University of South Australia's Mawson Lakes campus. Now, a little over 16 years later, we are winding up as an organisation supported by the Australian Government's CRC Program. Most CRCs are lucky to last 10 years – our longevity is a testament to our success.

Although it is sad to end our tenure under the CRC Program, this is very much a new beginning, rather than an end. We can be proud of the CRC's achievements and its major contributions to not only environmental and human health, but also substantial benefits to the Australian economy (including nearly $9 return on every dollar invested by government and industry). But there is much work to be done. Australia is still home to around 200,000 potentially contaminated sites (not to mention millions globally). Many industrial processes, although ever-improving, continue to pollute soil, water or air. Newly developed chemicals emerge regularly as potential hazards.

For years, CRC CARE has been the focal point for the diverse stakeholders that deal with contaminated sites – site owners, regulators, environmental consultants, all levels of government, and affected communities. We have ensured that these groups see eye to eye and can work together towards a common goal. If the CRC were to disappear, the remaining vacuum could be disastrous, threatening the progress and momentum of the last two decades. So I am very happy to say that CRC CARE will be continuing, thanks to the support of existing and new end-user Participants. We will announce more details soon.

The 2020/21 reporting period was as challenging a year as I can recall. With the shock arrival of the COVID-19 pandemic in early 2020, we have had to deal with major logistical problems due to lockdowns and border closures. With this impeding our ability to meet some milestones, the CRC Program generously granted us a 12-month protracted exit unto 30 June 2021. Understandably, this additional year did not include core funding, but the support of our end-user Participants – particularly DoD, BHP and HLM Asia – allowed us to operate and, indeed, meet all of our Commonwealth milestones.

Despite the disruption, we had a productive year. Highlights included:

- Extremely pleasing uptake of the NRF, with more than 46,000 downloads of the 25 NRF guidelines and around 50 associated resources to 30 June 2021.
- The continued success of our Industry Training Program after being forced by COVID-19 to adopt a purely online model during the reporting period. We helped boost the skills and knowledge of around 400 professionals via:
  - From Risk to Remediation 2020: CRC CARE Online Masterclass on Contaminated Site Assessment, Management and Communication
  - Online Masterclass: Light Non-Aqueous Phase Liquids (LNAPLs) Natural Source Zone Depletion (NSZD)
  - CleanUp Emerging Contaminants Symposium 2021
  - Vapour Intrusion Online Workshop.
- Another 10 PhD graduates, making more than 80 throughout our second term of funding (from 2011) and more than 160 since we launched in 2005.
- The development of a suite of online resources including risk assessment tools and contaminant databases (these will be publicly available in 2021/22).
- Progress in the potential commercialisation of our probeCARE™ real-time water quality monitoring tool, including discussions with a Melbourne-based small-to-medium enterprise (SME) with a memorandum of understanding (MoU) currently in development.

I am proud of what we have achieved over the past 16 years. As we move into our next phase of existence, I would like to extend an enormous vote of thanks to all those who have been with me throughout the journey – my directors, the CRC CARE staff, our Participants, and all of the researchers – from students to postdocs and senior professors – without whom we would not be where we are today.

Ravi Naidu

Laureate Professor Ravi Naidu
Managing Director and CEO
CRC CARE

02
HIGHLIGHTS AND ACHIEVEMENTS

2.1. AWARDS AND RECOGNITION

Despite the impact of the COVID-19 pandemic and the focus on winding up operations under the CRC Program, several CRC CARE staff and researchers were honoured in 2020/21. Highlights included:

- CRC CARE's reputation as an honest broker of expert information on contamination issues was recognised by the Australian Parliament via **Professor Ravi Naidu's** invitation to participate as an expert witness in Joint Standing Committee on Foreign Affairs, Defence and Trade's inquiry into the elimination and remediation of per- and polyfluoroalkyl substances (PFAS)-related impacts in and around Defence bases. Prof. Naidu fronted the inquiry on 9 November 2020, answering questions from Senators Mehreen Faruqi (NSW), Malarndirri McCarthy (NT), Sam McMahon (NT) and David Fawcett (SA) and Meryl Swanson MP, Member for Paterson, NSW.
- RMIT University PhD student **Will McCance's** project "Novel groundwater tracers for delineating groundwater contamination from wastewater treatment plants" – supported by CRC CARE, Melbourne Water, Western Water and Gippsland Water – won the Australasian Land & Groundwater Association (ALGA) 2020 Annual Industry Excellence Award for "Innovation that has advanced the practice of contaminated site assessment". Dr McCance has since completed his PhD.
- **Prof. Naidu** was recognised by the University of Newcastle, which bestowed upon him the title of Laureate Professor, awarded to the university's most distinguished academics in recognition of their achievements and outstanding contribution to their field of scholarship and the University of Newcastle. Prof. Naidu also won the Global Engagement Excellence Award for both the Faculty of Science and the university overall in recognition of his work to advance the university's international engagement capability and profile – particularly in leading the Global Centre for Environmental Remediation (GCER), which has established research partnerships across Australasia-Pacific (including China, India, Bangladesh, South Korea and Thailand), USA, UK and Europe.
- GCER's **Danidu Kudagamage** won the 2020 University of Newcastle Faculty of Science Professional Staff Rising Star Award, presented to a staff member who commenced at the university in the previous 5 years and who has demonstrated outstanding capacity to contribute meaningfully within the early stages of their career at the university. Danidu's work included remediation of PFAS-contaminated DoD sites.
- **Prof. Naidu** was again included in the Clarivate Web of Science list of Highly Cited Researchers, in the cross-field category. He and Program 4 Leader **Prof. Megh Mallavarapu** also ranked in the top 1% of environmental researchers globally in a Stanford University analysis of more than 150,000 scientists worldwide.
- CRC CARE-supported PhD student (GCER) **Scott Warner** was employed as Principal Hydrogeologist, California-Western US Regional Leader – Expert Witness/Litigation Support with BBJ Group, a leading US environmental consultancy. Previously Principal Hydrogeologist at Ramboll USA, Scott's PhD is on remediation and climate change.
- **Prof. Naidu** was elected:
  - a Fellow Ahurei of the Royal Society Te Apārangi (formerly the Royal Society of New Zealand) for his "revolutionary work in the field of environmental contamination and remediation"
  - a Foreign Fellow of the Indian National Academy of Agricultural Science – the only Foreign Fellow elected in 2020.

2.2. RESEARCH

2.2.1. Program 1: Best Practice Policy

Interim Program Leader:
Dr Joytishna Jit, CRC CARE

CRC CARE's Best Practice Policy program develops the principles, indicators and strategies to support the development of policy by environmental regulators and other agencies, as well as a national guidance framework, for remediation of site contamination.

The program's key research areas are:

- guidance for emergent and priority contaminants prioritised for end users and regulators
- use of contaminant flux for assessing and managing groundwater contamination
- a national guidance framework for remediation in Australia (the NRF)
- classification and ranking of incentives for remediation and for the reduction of 'title blight'
- decision-making strategies for selecting remediation technologies based on available technologies, cost and effective community engagement.

PROGRAM HIGHLIGHTS

National Remediation Framework

CRC CARE has completed and released a harmonised NRF to complement the National Environment Protection (Assessment of Site Contamination) Measure ('the ASC NEPM'). The NRF aims to achieve greater certainty in environmental outcomes and promote consistent implementation of guidance across Australia. In November 2019, the Heads of Environment Protection Authorities Australia and New Zealand (HEPA) endorsed the NRF as best practice.

In June 2020 CRC CARE launched the NRF as an independent, user-friendly website (www.remediationframework.com.au), which makes freely available 25 NRF guidelines and a suite of associated resources including relevant CRC CARE Technical Reports.

Feedback on the NRF has been very positive, with clear evidence that contaminated land professionals are using the resource widely. From launch until 30 June 2021, the 25 NRF guidelines plus around 50 associated resources have been downloaded more than 46,000 times. The most popular guideline was CRC CARE Technical Report 43: Practitioner guide to risk-based assessment, remediation and management of PFAS site contamination, with more than 2,000 downloads.

CRC CARE Interim Program Leader Dr Joytishna Jit presented on the NRF at the RemTech Europe Conference in September 2020 and was subsequently invited to join the RemTech Europe Scientific Committee.

Key issue: Providing certainty on the continuation of the NRF beyond CRC CARE's wind up.

Incentives for remediation and reduction of title blight

Contaminated sites, and even remediated sites, may suffer title blight – loss of local amenity and environmental values as well as reduced property prices. Identifying the barriers to remediation and redevelopment, as well as the extent of the impact of these barriers, will create a significant knowledge base from which to develop intervention measures.

CRC CARE-supported PhD student Ms Kerry Scott (University of Newcastle) was awarded her PhD on title blight in 2020/21 after completing her thesis *Classification and ranking of incentives for remediation and reduction of title blight.*

Key issue: Developing practical strategies for the amelioration and management of title blight.

Community engagement

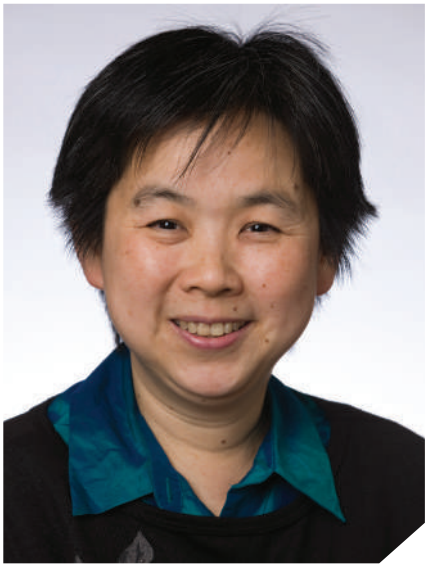
In 2019/20 CRC CARE published Technical Report 45: *Societal perceptions on remediation technologies: guidance for engagement with residents*, which includes both guidance and a tool to assist remediation service providers, auditors, local governments, health professionals and environmental regulators to develop and implement plans for remediation using an evidence-based understanding of residents' perceptions and acceptance of remediation technologies.

In early 2020, NSW Trust released the complementary step-by-step *Guide for Creating Stakeholder Engagement Plans for Contaminated Sites in NSW*. The launch of the step-by-step guide and Technical Report 45 was scheduled to take place in 2020/21 but was postponed due to COVID-19 restrictions. It was agreed that the launch would be rescheduled again to a date that permitted an in-person event.

Key issue: the longer-term challenge is for the guidance to help develop practical strategies for effective community engagement when selecting remediation strategies.

2.2.2. Program 2: Better Measurement

Program Leader:
Dr Cheryl Lim, National Measurement Institute (NMI)



The Better Measurement Program's goal is to ensure that Australia's key environmental contaminants can be characterised with enough certainty so that end users can make informed decisions. End users include site assessors, remediation practitioners and policy-makers.

Our ability to manage the environment depends heavily on the extent to which we can reliably identify and quantify environmental contamination within a reasonable amount of resources. CRC CARE's Better Measurement Program develops next-generation analytical methods and innovative field technologies to provide fast and more efficient assessment of site contamination. A major target is to replicate laboratory outcomes in the field using newly developed real-time monitoring tools. The program also seeks to improve end-user confidence in environmental data by:

- contributing to CRC CARE guidance on environmental analysis, optimisation and validation of common analytical methods
- developing quality assurance tools such as proficiency testing and reference materials
- engaging proactively with end users to ensure that research is driven by their needs and delivers the outcomes required by industry and government alike.

The key research areas for this program are:

- sensitive analytical techniques for emerging and priority contaminants
- novel assessment and remote online monitoring systems
- integrated information management tools
- standards for sampling contaminated material.

PROGRAM HIGHLIGHTS

- The joint ChemCentre/Commonwealth Scientific and Industrial Research Organisation (CSIRO) project Mine Pit Lakes – Their Characterisation and Assessment for In-Situ Metal Recovery Opportunities and Cost Effective Environmental Management has been completed. The project has compiled a novel dataset of mine pit lake water quality in WA that includes commodities mined across that state and covers mine pit lakes of a variety of ages and environmental conditions. The data will better inform government policy and regulatory guidance on what is required from industry to assess the long-term environmental impact of mine pit lakes and hence facilitate mine-site closure. Water data analysis from mine pit lakes and leaching tests on solid samples from mine pits and pit lakes were also used to identify whether any of the sites showed potential for in-situ metal recovery opportunities.
- probeCARE™, a tool that allows agricultural irrigators to monitor water quality in lakes and streams through real-time measurement of metal ions in solution, entered the commercialisation phase. The GCER research team successfully demonstrated probeCARE™ for sodium, potassium, calcium and nitrate, and developed a number of prototypes for testing.

- Efforts are also continuing into the commercialisation of irCARE™, a handheld Fourier transform infrared (FTIR) spectroscopy tool for monitoring the presence of total petroleum hydrocarbons (TPH) in surface and subsurface soils. When coupled with handheld FTIR, the non-destructive irCARE™ method can be applied for 1) rapid in-field quantification of TPH in the soil; and 2) rapid in-situ classification of dominant petroleum hydrocarbon fractions in the soil. irCARE™ can also be used for product quality control, such as content analysis and materials testing. Without any analytical experience, users can upload infrared spectrum data and immediately receive analytical results.
- The riskCARE™/infoCARE™ online system provides information on health-based investigation levels for all hazardous chemicals listed by the ASC NEPM. Users can directly calculate the hazard quotient (the ratio of the potential exposure to a substance to the level at which no adverse effects are expected) for contaminated site assessments. If the hazard quotient is less than 1, no adverse health effects are expected as a result of exposure; if greater than 1, adverse health effects are possible. Progress continued on development of an online tool, which is expected to be launched in 2021/22.
- NMI ran a PFAS proficiency testing workshop in November 2020. This popular workshop series builds end-user understanding and confidence in the overall data quality and reliability of results. The workshop included an update on the results of NMI's fifth annual PFAS proficiency study, which was also its first investigation of the Total Oxidisable Precursor (TOP) Assay. The workshop had its largest ever audience (nearly 250 registrations), while Dr Hunter Anderson (US Air Force) provided a technical keynote direct from the US.

AWARDS/RECOGNITION

RMIT University's Novel Tracers project concluded well, with the successful PhD candidature of primary researcher Dr Will McCance. The project received the ALGA 2020 award for "Innovation that has advanced the practice of contaminated site assessment" and Dr McCance and his team published 2 peer-reviewed papers in highly regarded scientific journals.

KEY ISSUES CONFRONTING THE RESEARCH

Measurement is a vital link in the chain of knowledge that underpins effective environmental management. There is a need for measurement solutions which provide accurate, reliable and comparable data, especially for emerging and priority contaminants. Field and remote analysis present their own challenges, with the need for robust measurement technologies able to address issues such as environmental and matrix variability. Strong engagement among scientists and end users is equally critical in ensuring that measurement data are used as effectively as possible, and that policymakers and practitioners alike are provided with the tools and evidence to support their decisions.

2.2.3. Program 3: Minimising uncertainty in risk assessment

Program Leader:
Dr Yanju Liu, The University of Newcastle

Health risk assessment has its origins in toxicology: the classical statement that 'the dose makes the poison' remains true today. Contemporary environmental and health risk assessments required by regulators, industry and health agencies demand a refined, evidence-based approach. Risk assessment based on total contaminant concentration has a high degree of uncertainty, which may lead to unnecessarily stringent and costly remediation, or remediation of sites that do not require it.

Program 3 aims to improve the certainty of risk assessment by considering:

- the fate of chemical contaminants in the environment
- the influence of ageing, weathering and soil properties
- the bioavailability of contaminants (to achieve a more refined exposure assessment).

It also focuses on the risk characterisation and assessment of contaminant mixtures, with particular reference to matrix properties and mixture interactions, and how their effects on bioavailability lead to adverse health effects.

Program outcomes aim to help regulators, industry, environmental consultants and risk assessors make informed decisions with reduced uncertainty, and thus better protect human and ecological health at sites with complex mixtures of contaminants. The program focuses on:

- the fate of chemicals in the main Australian soil types
- quantifying toxicity and bioavailability of individual and mixed contaminants
- quantifying pathways of exposure and transient risks
- creating databases for prioritised and emerging contaminants
- developing a robust risk and compliance model.

The program develops new technologies, methods and knowledge that minimise uncertainties in assessing human health and environmental risks and contribute to creating the next generation of health-screening levels and risk assessment approaches.

PROGRAM HIGHLIGHTS

- *Create a database for prioritised and emerging contaminants*
  We have developed a fully operational stand-alone relational database package (infoCARE™) comprising more than 1,000 chemicals, with a corresponding suite of more than 8,000 rows of chemical and toxicological data. Categories of chemicals include, but are not limited to, metals, herbicides, insecticides, growth promoters, hormones, antibiotics/antimicrobial agents, industrial pollutants and solvents of both classical and emerging contaminants. The database will be made freely available via a web-based application, which has been developed and is scheduled for launch in 2021/22.
- *Minimising uncertainty in human health risk assessment – inorganic contaminants*
  CRC CARE researchers at GCER conducted in vitro and in vivo studies aimed at developing a standard operating procedure for assessing mixed metal(loid) bioavailability (the proportion of a substance that enters the circulation when introduced into the body). The CRC is also developing a predictive tool to estimate mixed metal(loid) bioavailability based on total metal content and soil properties. In 2020/21, two papers were published for inorganic compounds. Given constraints on in-vivo studies due to COVID-19 border closures, the standard operating procedure's expected delivery was delayed until 2021/22.
- *Assessing the risk to human health and the environment from PAH-contaminated soils*
  This project, a collaboration with the SA Health and Medical Research Institute, is investigating bioavailability of polycyclic aromatic hydrocarbons (PAHs) in soils with the aim of improving human health risk assessment. Rat models are used to estimate bioavailability of PAH contaminants that are: mixtures that originate from different contaminant sources; aged; at different remediation stages; or have been treated with different remediation approaches. Following animal studies in 2019/20 to improve the in vitro bioaccessibility models (which can be used to predict risks from PAH exposure), work in 2020/21 was limited to preparation of research manuscripts, given COVID-19 restrictions.
- *Bioaccessibility of PAHs in soil: investigations into the potential risks associated with exposure to residual PAHs in soil*
  The traditional approach to risk, for which assessment assumes that contaminants in soils are 100% bioavailable, has contributed to the expensive nature and slow pace of contaminated site clean-up. The alternative risk-based approach to clean-up is more realistic, faster and more cost-effective, but uncertainties constrain its adoption by environmental regulators globally. One such uncertainty is whether highly sequestered PAHs in soils pose risks to human and ecological health. This project, which seeks to minimise this uncertainty, demonstrated that PAH non-extractable residues were highly sequestered in aged soils, meaning that only very small quantities remobilised in the soils, bioaccumulated in earthworms, or were released into a simulated human gut fluid (to simulate cancer risk). Hence, PAH non-extractable residues in long-term contaminated soils are unlikely to cause significant harm, and do not need to be considered in routine risk assessments. In 2020/21, one PhD on PAH non-extractable residues was awarded.

- *Toxic effects of PFAS on terrestrial and subterranean environmental biota*
  This project is investigating the toxic effects of priority PFAS compounds on terrestrial and subterranean bioindicators. A lack of PFAS toxicity data has constrained the derivation of ecological screening levels (ESLs) for priority PFAS, especially perfluorohexane sulfonate (PFHxS), using the sensitive species distribution approach. In 2020/21, researchers exposed a wide range of plants and soil biota to PFHxS to determine toxicity. The information will support the derivation of ESLs for contaminated soils.
- *Fate and transport of PFAS in contaminated sites*
  This project investigated the occurrence of PFAS in contaminated sites – including soil, groundwater, plants and sediment – to better understand the behaviour of PFAS in long-term contaminated soils. PFAS was identified at sites subject to historical use of aqueous film-forming foam (AFFF) use. Researchers also investigated: the potential presence of precursor compounds; the leaching and release of PFAS from contaminated soils; sorption and retention of PFAS from different surface soils; and the influence of groundwater chemistry on the behaviour of PFAS.
- *Ecological assessment of PFAS contaminated groundwater*
  This project investigated the presence of PFAS and stygofauna in a groundwater system, particularly the toxic effects of perfluorooctanesulfonate (PFOS) on typical stygofauna groups. Researchers are using the results to develop ecological indicators for groundwater risk assessment, as well as toxic threshold values for PFOS for one stygofauna group.

KEY ISSUES FACING RESEARCH

Environmental and health risk assessments are largely based on toxicological data. However, there is a scarcity of data on both mixtures of contaminants and emerging contaminants of concern. Without sufficient data, risk assessment is based on assumptions, resulting in large uncertainties. CRC CARE has generated limited but significant data that fill some of these knowledge gaps. It is important to acknowledge that it is impossible to generate comprehensive datasets for many more mixture combinations or emerging contaminants within the current term of the CRC's funding.

Progress in Program 3 was continuously constrained in 2020/21 by COVID-19 restrictions, which limited researchers' access to laboratories and other resources.

2.2.4. Program 4: Cleaning Up

Program Leader:
Professor Megharaj Mallavarapu, University of Newcastle

The Cleaning Up Program aims to develop, evaluate and demonstrate the technologies, indicators and strategies for in-situ management of contamination issues experienced by industry, government and the community. It addresses the limitations of existing assessment and remediation technologies for effective reduction of risks to human and environmental health, and develops sustainable and 'green' remediation technologies. The green approach seeks to exploit the unique properties of biological material (e.g. plants or microorganisms) rather than potentially dangerous synthetic chemicals that may pose a subsequent risk to people or the environment. The program also promotes techniques that reduce greenhouse gas and other pollutant emissions by, for example, reducing the need to transport contaminated soils to landfills or using renewable energy (including solar power) to power remediation infrastructure.

The program also establishes the parameters for effective risk reduction via manipulation of contaminant bioavailability in unique Australian soils and aquifers. It is the engine room for technologies scaled up and demonstrated in the field as part of the CRC's DoD, BHP, China and Petroleum demonstration programs. Program 4's work is particularly important when we consider that a mere 10 to 15% of Australia's 200,000 potentially contaminated sites have been remediated. There are several reasons for this slow rate of remediation, including the complex nature of contaminated sites (and associated commercial drivers) along with the heterogeneous nature of surface and subsurface environments. Furthermore, contamination is occurring and legacy contaminated sites are being identified at a pace that far exceeds that of the improvement in remediation approaches and technologies.

Key research areas include:

- novel remediation technologies for emerging and priority contaminants
- development, testing and validation of sustainable and green remediation technologies
- novel bioremediation tools for nitrogen-contaminated groundwater.

The CRC's National Contaminated Sites Demonstration Program (NCSDP; see page 11) also oversees and scales up projects that address Program 4 utilisation milestones.

PROGRAM HIGHLIGHTS

With CRC CARE winding up its activities under the CRC Program, most of Program 4's projects were completed by 30 June 2020.

The program's main achievements in 2020/21 included:

- A study on bioremediation of PAH-contaminated soils, which showed that initial soil microbial diversity is the most dominant factor in determining the biodegradation potential of a soil, and that nutrient availability is one of the main rate-limiting factors influencing degradation rates. The work provides a holistic view and systematic understanding of the importance of initial soil microbial diversity, nutrient amendment and plant presence when considering approaches to enhance bioremediation potential in natural soils (Western Sydney University).
- Development of a method to recapture energy and nutrients from solid organic wastes through hydrothermal carbonisation, and generate energy (methane) from both solid and liquid wastes through anaerobic digestion (Southern Cross University).
- Development of an algal-based technology to ameliorate acidic soils (University of Newcastle).
- Work to isolate and characterise the purple non-sulfur bacteria for their ability to detoxify PAH contaminants (University of Newcastle).
- Development of a microalgae- based system for remediation of brewery wastewater with simultaneous energy generation (University of Newcastle).

Program 4 also had considerable success in field application of several new or improved technologies through the NCSDP, including our BHP, Australian Institute of Petroleum (AIP) and DoD programs.

KEY ISSUES CONFRONTING THE RESEARCH

Environmental contamination with emerging contaminants such as PFAS continues to be a major human and environmental health issue. Additionally, microplastics alone or as a vector for persistent contaminants have recently emerged as potential threats to human and ecological health. These chemicals are designated as emerging contaminants of environmental concern. Developing next-generation, sustainable remediation technologies for such contaminants continues to be a challenge, and requires novel approaches and considerable funding.

Progress in Program 4 was constrained in 2020/21 by the COVID-19 global pandemic, which limited researchers' access to laboratories and other resources.

AWARDS/RECOGNITION

- Profs Naidu and Bolan were listed in the Clarivate Highly Cited Researchers list.
- Prof Naidu and CRC CARE researcher Dr Bhaba Biswas were lead authors of *Chapter 6: Status of soil pollution in Asia and the Pacific* in the Food and Agriculture Organization of the United Nations report *Global assessment of soil pollution* (part of the UN's Towards Zero Pollution initiative). Prof Naidu presented on this topic at the 4 June launch.
- Prof Naidu was invited by Elsevier to write a "Global Compendium of Contaminated Sites", which will total 4 volumes and 150 Chapters.

- Prof. Naidu was invited to make several virtual presentations at major international events, including:
  - Tamil Nadu Agricultural University Golden Jubilee Celebrations International Webinar Series on 25 August 2020, speaking on "Soil: the critical zone for sustainability"
  - a keynote address on "Chemical pollution: a growing peril and potential catastrophic risk to humanity" at the 4th International and 23rd National Conference on Environmental Health, hosted by the Iranian Association of Environmental Health in Tehran in October 2020
  - "Advances in PFAS remediation" at the PFAS – Dealing with Contaminants of Emerging Concern conference in December 2020 in Berlin, following an invitation from the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety
  - University of Guelph PFAS Universities Forum on "PFAS: An Australian Perspective" in June 2021
  - a keynote address on "Cleaning up the soil" at the Delivering the Human Future Conference in March 2021.

2.2.5. National Contaminated Sites Demonstration Program

The NCSDP demonstrates integrated multidisciplinary solutions to complex and highly challenging soil, groundwater and air contamination problems faced by a number of CRC CARE Participants. Projects address issues that require extensive laboratory research. Once solutions are generated, the project is extended to the field. Such an approach provides an opportunity for engineers, scientists and consultants to test, validate and optimise operating conditions for new site assessment and remediation technologies. Along with tackling technical problems, the NCSDP develops guidance in collaboration with industry and regulators. Demonstration projects within the program are co-sponsored by AIP, BHP and DoD.

2.2.5.1. Petroleum Program

AUSTRALIAN INSTITUTE OF PETROLEUM PROGRAM

Program Coordinator:
Dr Prashant Srivastava, CRC CARE

The petroleum industry is represented by AIP, a founding Participant of CRC CARE. The AIP Demonstration Program was initiated to address policy and guidance issues related to the assessment, risk characterisation and remediation of sites contaminated with petroleum hydrocarbons and other related compounds associated with the industry. It also addresses constraints to site characterisation and remediation from policy guidance perspectives. The program seeks guidance and advice from jurisdictions (e.g. regulatory agencies) on the development of policies and guidance documents relating to petroleum hydrocarbon-contaminated sites. The Project Advisory Group established under the AIP Program – which includes industry, jurisdiction and research representatives – develops scope, invites tenders and advises on the development of guidance documents.

Petroleum Program projects include:

- Endpoints for petroleum LNAPL remediation technology performance and risk reduction (ongoing)
- Analysis of weathered hydrocarbons using a silica gel clean-up method (completed)
- Methodologies to assess LNAPL NSZD (completed)
- Management of sites impacted by LNAPL using NSZD approach (completed)
- Demonstration of LNAPL NSZD (completed).

All AIP Program projects were completed in 2019/20.

BHP PROGRAM

Program Coordinator:
Dr Sreeni Chadalavada, CRC CARE

This program reflects BHP's strong support for environmental sustainability and recognition that mining activities can impact the so-called critical zone, which includes both soil and groundwater. While focussing on contaminated site assessment, risk characterisation and remediation, BHP is also prioritising artificial intelligence and machine learning with a view to improving characterisation of contaminated sites. To this end, in 2019/20 BHP funded projects that employ these exciting new approaches, as well as traditional methods, to assess sites and investigate the fate and dynamics of contaminants. The following provides a summary of BHP initiatives during the current reporting period.

Enhanced phytoremediation of hydrocarbon-contaminated soils using native Australian plant species

Work on phytoremediation of hydrocarbon-contaminated soils continued, with the focus being cost-effective amendments to enhance phytoremediation technologies using the selected plant species, with good progress made on methodology establishment. Rather than using native plant species, we focused on maize due to its fast growth rates, drought tolerance and applicability to phytoremediation.

Natural attenuation of hydrocarbons in the vadose zone

CRC CARE established laboratory-based analytical methods for analysing volatile petroleum hydrocarbons. The research team found that both the amount and rate of vapour taken up by soil depends on the fractions of soil organic matter and secondary soil mineral (clay) fractions. For sites where the contaminant source is underneath uncontaminated soil with greater clay and/or soil organic matter contents, vapour equilibrium models tend to overestimate the human risk due to vapour intrusion.

Identify the chemistry and transport mechanisms of the ingredients of AFFF in soil and groundwater

CRC CARE completed sampling of groundwater and surface and subsurface soils from BHP sites in Newman and Port Hedland, WA. The samples were analysed to determine any correlation between soil properties and PFAS in soils, including PFAS mobility. The results suggest stronger mobility of short-chain PFAS. The leaching concentration of PFOS + PFHxS exceeded the interim landfill acceptance criteria for unlined landfill sites for one sample, and perfluorooctanoic acid (PFOA) concentrations were within the interim landfill acceptance criteria.

PFAS toxicity on terrestrial organisms in an AFFF-impacted area in WA

Following a detailed review of PFAS toxicity on terrestrial organisms, CRC CARE conducted glasshouse studies on the terrestrial ecotoxicity of PFAS. Based on these studies, we developed permissible criteria for select PFAS constituents, with the resulting report reviewed externally for both publication and guidance documents. The team also completed a toxicological analysis of PFAS with various bio-indicators in soils in the Pilbara region. A guidance document is under development.

Formation of hexavalent chromium by natural process in the Pilbara

In 2019/20 we completed the biogeochemical characterisation of Pilbara soils for chromium contamination. Chromium was naturally present at elevated concentrations in the Pilbara due to the mineralogy of the region. In south-eastern Pilbara, relatively low levels of hexavalent chromium (Cr(VI)) were found in soil, despite elevated concentrations of total chromium. We also completed research that explained the mechanisms involved in the formation of Cr(VI), with manganese oxide (MnO_2) identified as the main oxidiser of chromium in the environment. A guidance document on delineation of geogenic Cr(VI) from anthropogenic Cr(VI) has been written and shared with BHP.

FTIR spectroscopy method for the analyses of weathered hydrocarbon mixtures in standard solutions

CRC CARE completed the development of a handheld FTIR method for the analyses of weathered petroleum hydrocarbon mixtures in standard solutions. Through this BHP-funded project, the CRC developed irCARE™, which integrates novel algorithms and methods of using FTIR, allowing rapid in-field quantification of TPH and rapid in-situ classification of dominant petroleum hydrocarbon fractions in soils for contaminated site risk assessment. Hydrocarbons with longer the carbon chains are considered to be heavier fractions, which have higher viscosity, density and boiling points, and longer residence times in soil, compared with lighter fractions. Knowledge of the carbon fractions in a petroleum hydrocarbon-contaminated site provides valuable information for site assessment and remediation.

rankCARE II™ site ranking software

rankCARE II ™ is a user-friendly graphical interface, designed to identify risk factors at individual contaminated sites and compare human health risk factors across multiple sites. In 2019/20, CRC CARE completed the beta version of the web-based software tool, which is currently being validated.

Electrokinetic remediation of subsurface hydrocarbon-contaminated soils

Bench-scale electrokinetic remediation of PH-contaminated soils revealed extremely positive results, with PH concentrations decreasing from more than 80 mg/L to less than 7 mg/L in 90 days. This work is ready to be scaled up to field validation of the technology.

Aging effect on natural attenuation of diesel in contaminated soil

In 2019/20 we identified chemical (decrease of different TPH fractions) and microbial (soil enzyme activity) indicators of natural attenuation of soils contaminated with diesel-related petroleum hydrocarbons. We are currently undertaking laboratory studies with the aim of developing protocols for analysing natural petroleum hydrocarbon attenuation at contaminated sites.

Co-disposal of hydrocarbon-contaminated soils with mine waste

When disposing of petroleum hydrocarbon-contaminated soils mixed with mine waste, bioremediation (via microbial activity) can be limited due to the waste having low levels of nutrients – particularly nitrogen – for microbes. CRC CARE is developing a remediation approach that supplements mine waste with organic amendments, especially nitrogen. The amendments to be trialled include compost (1.07 % nitrogen), cow manure (1.71% nitrogen) and liquid fertiliser (3.5 % nitrogen). This work is continuing.

2.2.5.2. Department of Defence Program

Program Coordinator:
Dr Sreeni Chadalavada, CRC CARE

The Australian DoD sponsors a demonstration program focused on contaminants commonly found at DoD sites. This multidisciplinary program involves laboratory and field investigations of potentially contaminated sites, and the testing and validation of innovative technologies developed for site assessment and remediation. CRC CARE technologies and applications are now operational at several DoD sites. Highlights from 2020/21 are outlined here.

Portable gas chromatography–mass spectrometry (GC-MS) for in-situ real-time monitoring of volatile organic compounds at contaminated sites

CRC CARE installed three horizontal soil vapour sampling probes at a DoD site at Edingburgh, SA, resulting in successful detection of significant trichloroethylene (TCE) concentrations. The probes were thus validated as functional for soil vapour sampling and monitoring. A nearby demolished factory was identified as a potential TCE source.

Risk-based management of petroleum hydrocarbon-contaminated groundwater in Williamtown, NSW

Petroleum hydrocarbon metabolites at environmentally relevant concentrations revealed toxicity to microalga according to new endpoints such as oxidative stress and lipid perodioxidation, rather than chlorophyll, which has been the conventional endpoint for many decades. Further, analysis of stygofaunal communities across two seasons showed that TPH and its metabolites were responsible for declined stygofaunal population in an upstream contaminated well.

Accelerated remediation of TCE contamination in groundwater at Edinburgh, SA

In-situ chemical oxidation was used to successfully accelerate remediation of TCE contamination. At all monitoring wells, significant TCE concentrations (above 500 ug/L) were rapidly reduced to below the detection limit (5 ug/L). Subsequent monitoring results several months later confirmed that TCE concentrations at all wells remained below guideline levels.

Field-scale research for parameter optimisation of shooting range remediation technology

The CRC completed the successful remediation of contaminated soil at Mount Stuart Training Area, QLD, using a heavy particle concentrator (HPC) machine. Subsequently, DoD requested remediation of 200 m^3 of lead-contaminated soil from Lavarack Barracks, Townsville.

Pilot-scale trials of PFAS remediation using matCARE™ technology at RAAF Base Richmond, NSW

Work continued on this project, which uses an innovative horizontal-reactor permeable reactive barrier treated with CRC CARE's matCARE™ adsorbent, coupled with active pumping whereby the contaminated water is passed through the reactive media.

Diffusion assessment of Upper Shepparton clay (feasibility study), Mulwala Explosives and Chemical Manufacturing Facility, Mulwala, NSW

The project team analysed groundwater and soil samples for pH, electrical conductivity, and concentrations of nitrate, sulfate, ammonium and other inorganic elements. This information will provide a detailed picture of the distribution and diffusion of these properties relative to geology, depth and the presence and location of soil types including floodplain sand, dune sand, Upper Shepparton clay and Shepparton sand. The study will help predict diffusion and back diffusion with the soils and aquifers, as well as improve the remediation approaches for the Mulwala site.

2.2.6. China Program

Program Coordinator:
Dr Luchun Duan, University of Newcastle

CRC CARE's China Program is run in partnership with HLM Asia Group Ltd, Huazhong University of Science and Technology (HUST), Wuhan, and Shaoguan University, Guangdong.

In 2020/21, the outbreak of the COVID-19 pandemic in Wuhan significantly curtailed progress on ongoing projects.

CRC CARE–China (HUST) Communication Program

Initiated in 2005, the CRC CARE–China 'Commun' Communication Program provides annual opportunities for CRC CARE and its collaborator universities in China to exchange ideas about environmental science, focusing on contamination monitoring, remediation and risk assessment. CRC CARE organises annual communication workshops that bring together all researchers working on research funded by CRC CARE. This includes Masters and PhD students.

As in 2019/20, the program did not take place due to COVID-19.

CRC CARE researchers prepare pilot-scale trials of PFAS remediation using matCARE™ technology at RAAF Base Richmond, NSW.

Research projects

CRC CARE funded four major projects, which included both laboratory-based study and field scale-up of new technologies for testing and validation:

- Waste management via bio-conversion of wastes to energy – completed.
- *Red mud and degraded mine-site rehabilitation* – lab and glasshouse study has been completed with the project now extended to field-based phytoremediation of mine-site degraded land.
- Algae farming using piggery wastewater and conversion of algae to energy – completed.
- *Lake remediation* – lab- and bench-scale technology has been delivered with the project extended to a contaminated lake.

Two new projects were formed based on previous outcomes: 1) lake remediation using Phoslock (to lock nutrient phosphate) coupled with biofilm (for the removal of nitrate), and 2) phytoremediation of heavy metal–contaminated mine site soils. Progress in both projects has been significantly curtailed by COVID-19.

Piggery waste remediation project – pooCARE™

Piggery waste is a major source of environmental pollution in China. Developed in collaboration with HUST, CRC CARE's pooCARE™ is a piggery waste remediation system capable of converting pig waste into biogas and nutrient-rich fertiliser. This project also included a demonstration of an 'underground river' bioreactor. pooCARE™ is currently in use for piggery farm waste management in Wuhan.

Algae as renewable energy

Naturally occurring algae, especially blue–green algal blooms (which can result from excess nutrients in water), can pollute large water bodies and devastate local fish populations. It can also be toxic to humans. This project aims to harvest algae and produce clean energy from the biomass.

CRC CARE has focused on algae produced using effluent from piggery waste, and investigated conversion routes from algae to fuel. Previous research identified *Diplosphaera* sp. as a promising algal strain. Current research focuses on using the Automatic Methane Potential Test System II to estimate biomethane potential of different algal biomasses.

Rehabilitation of red mud

Red mud is a highly alkaline waste generated during alumina production. There are many old red mud storage sites around the world and it is estimated that 100 million tonnes are produced globally every year. Hybrid giant Napier grass is a fast-growing species that tolerates the alkalinity at old red mud storage sites. The grass is cultivated to cap the surface soil and prevent dust generation. Furthermore, the biomass from Napier grass can be fed back into the soil to improve soil health, or collected to produce biochar for carbon sequestration and soil improvement. This approach allows red mud residue to be gradually rehabilitated. Excess biomass can also be used to generate energy and thus, potentially, income.

Field trials of phytoremediation of metal-contaminated soil began in June 2018. The project has moved to phase two, where combinations of soil amendments for plant growth and rehabilitation are being tested in the field. Ultimately, we will transfer the Napier grass system to highly contaminated soils for phytoremediation.

Along with field trials using Napier grass, alternate uses of the contaminated area were assessed by converting part of the red mud–impacted area into a solar farm to harvest solar energy, with the energy generated sold to a photovoltaic company. This was a highly successful initiative, which will be expanded to enable local farmers impacted by red mud to use their farms to supply solar energy and generate income.

Due to COVID-19, very little progress was made on the field study in 2020/21.

Removal of phosphate from East Lake using Phoslock® coupled with biofilm

Phoslock is a commercially available product that removes phosphates from water. Sorption to Phoslock converts phosphate into a stable form (rhabophane). This project aims to combine Phoslock application with biofilm technology to manage eutrophication (excessive richness of nutrients, often because of fertiliser run-off) and algal blooms in lakes.

Preliminary laboratory studies using Phoslock showed its capacity to immobilise nearly 10,000 µg of phosphate per gram of Phoslock used. The research team also: (a) isolated some aerobic denitrifiers that were highly efficient in nitrogen removal; and (b) developed a microbial biofilm technology that can be used for in-situ lake remediation. An in-situ remediation device was installed at a small contaminated lake in 2019. Monitoring of lake water phosphate and nitrogen has been ongoing.

However, COVID-19 restrictions prevented significant progress in 2020/21.

Phytoremediation of heavy metal-contaminated mine-site soils

CRC CARE conducted lab- and field-based research on phytoremediation of heavy metal-contaminated mine-site soils using Napier grass. The study included a small plot design with a control (no treatment) and plots treated with metal-locking amendments. This approach was very effective in remediating the contaminants while also establishing Napier grass as a source for biochar, paper pulp, fibre and biomass-to-energy.

As a potential alternative use for degraded land, we also established a solar power plant (photovoltaic panels) for harvesting energy for placement into the grid. This was successful, allowing a local company to generate income from solar farming.

Collaboration

The China Program Coordinator has developed collaborations with local governments and private companies. These initiatives have led to a number of meetings and work is in progress to develop joint projects that benefit CRC CARE and companies in China. CRC CARE signed a MoU with the Ecology Institute of Shandong Academy of Sciences in 2017. Since then, the two parties have had frequent scholar exchange and initiated joint research projects. Prior to the COVID-19 pandemic, three scholars visited CRC CARE for further collaboration. Subsequent planned travel of CRC CARE researchers to China has been postponed.

2.3. COLLABORATION

In addition to SME engagement, CRC CARE has built strong collaborations in all aspects of its research program, including proposal development, advisory panels, research, demonstration sites and industry training programs. CRC CARE's research and demonstration nodes are distributed widely across Australia, with hubs in NSW, SA, WA, Victoria and Queensland. For international collaboration, see the list below.

Significant collaborations are undertaken through the NCSDP with CRC CARE's partners DoD, BHP and AIP (see *National Contaminated Sites Demonstration Program* on page 11 for further details). Dedicated CRC CARE coordinators manage the projects associated with these organisations, drawing on universities, consultants, SMEs and end users to deliver research objectives. The unique structure of the demonstration program is mutually beneficial for researchers and industry alike – industry partners can investigate and assess potential clean-up options for their sites, while CRC CARE researchers fast-track the application of science to the field by working directly with industry in contaminated environments to test scientific ideas and new technologies.

This reporting period also saw CRC CARE collaborate with:

- The NSW Department of Planning and Environment to develop a methodology for management of health and environmental risks associated with contaminated derelict mine sites in NSW.
- The Victorian water industry (South East Water, Melbourne Water, Gippsland Water and Western Water) on two RMIT-based projects:
- Novel tracers for groundwater remediation
- Novel bioremediation tools for nitrogen-contaminated groundwater.
- The NSW dairy industry (Richmond Dairies and Norco Cooperative Ltd with Richmond Valley Council) on optimising technologies to extract energy and nutrients from milk processing wastes, and from biosolids generated at sewage treatment plants. Three solid-waste treatment methods (anaerobic digestion, pyrolysis and hydrothermal carbonisation) are being trialled and optimised for the production of energy and soil ameliorants from solid sludge waste generated by project partners.
- The Australian Department of Agriculture, Water and the Environment to develop marine water guideline values for PFOS for inclusion in the Australian Water Quality Strategy.
- The Minerals Research Institute of WA on the project Mine Pit lakes – their characterisation, assessment and management to inform mine site closure and for in-situ remediation opportunities.
- Airservices Australia on remediation of PFAS-contaminated wastewater in Darwin.
- Veolia on remediation of PFAS-contaminated wastewater in Townsville.
- Spotless Australia on maintenance of a treatment plant for PFAS-contaminated water at RAAF Townsville.

INTERNATIONAL LINKS

CRC CARE researchers continue to collaborate extensively with international scientists, leading research and development on contamination assessment and remediation. Part of this involves extensive work in China via our China Program (see pages 13-14), although this was curtailed substantially in 2020/21 due to COVID-19 restrictions. This collaboration includes work with overseas researchers based in their home countries as well as numerous visiting scientists, who spend three to six months with CRC CARE researchers in Australia. The reporting period's record number of visiting scientists provides evidence of the global recognition that CRC CARE has established.

In addition to direct project work, CRC CARE maintains an international presence on its Research and Technology Committee, which includes internationally renowned researcher Prof. Ming H. Wong (Hong Kong Institute of Education) as a member. Other international collaborations established through the CRC, and which continued into the 2018/19 financial year, are outlined below.

Bangladesh

The CRC has linked with Dhaka Community Hospital and the Bangladesh Agricultural Research Institute to investigate arsenic contamination in drinking water and the local food supply. An estimated 35 million people are exposed to water with an arsenic concentration above 50 micrograms per litre in Bangladesh, and a further 4.2 million people are exposed in West Bengal, India. Many people in these two regions suffer from arsenic-related diseases. Journal papers based on the work continue to be published.

China

CRC CARE continues to further build and strengthen collaboration with Prof. Xiao Bo (HUST) and Prof. Lena Ma (Nanjing University). Research on bioavailability of contaminants continues. The CRC supports a number of PhD scholarships at HUST and CRC CARE staff (including the Managing Director) and board member Charles Wong visited HUST in June 2019 for the annual 'Commun' event, which helps build the capacity of students to communicate their science in English. In 2019/20 the CRC also continued collaboration with the Chinese Academy of Sciences to collaborate on bioavailability of arsenic and other metal(loid)s.

Germany

Active collaboration continues with the German research agency RUBIN and remediation experts Mull and Partners gmbh in the deployment of permeable reactive barrier technology for the treatment of groundwater contaminated with chlorinated hydrocarbons and heavy metals. Prof. Volker Birke, at Ostfalia University of Applied Sciences, has been actively involved with CRC CARE since 2008 and contributes his expertise to a number of DoD projects.

India

Established collaborations with Tamil Nadu Agricultural University, Pandit Deendayal Petroleum University, Gujarat, and PSG Institute of Technology, Coimbatore.

Japan

Program 3 Leader Prof. Jack Ng continued his work with Prof. Tetsuya Suzuki from the Graduate School for the Creation of new Photonics Industries on utilising Euglena species as a model single-celled in vivo organism for developing a unicellular cell tool for the toxicity assessment of metals and metalloids (pure or mixtures) – the 'cell-on-a-chip' concept.

Korea

Extensive collaboration is occurring with Prof. Yong Sik Ok (Kangwon National University) and Dr Kwon Rae-Kim (Gyeongnam National University of Science and Technology) on synchrotron-based studies.

Malaysia

The Honourable Mrs Zuraida Kamaruddin MP, Malaysian Minister of Housing and Local Government, attended the CleanUp 2019 Conference to present the Brian Robinson memorial lecture. Subsequent discussions resulted in an invitation for CRC CARE to host, with the Malaysian Government's support, the 2nd Global CleanUp Congress, which will take place in November 2021 in Kuala Lumpur under the theme of "Trash to cash".

Netherlands

Collaboration on bioavailability continues with Dr Joop Harmsen from the Alterra Research Institute at Wageningen University and Research Centre. In 2014/15, this work led to a joint European COST (Cooperation in Science and Technology) Action proposal involving more than 12 scientists. The proposal was resubmitted in 2017/18, with a funding decision pending.

Nigeria

After establishing a MoU with Nigerian company Contec Global Agro Ltd in 2016/17, both parties are developing a project on bioremediation of hydrocarbon-contaminated soils. Collaboration was also established with Professor Obinna Chukwu, University of Lagos, on heavy metal contamination.

Singapore

CRC CARE researchers and the National University of Singapore continue to work together on nanomaterials, including the characterisation of clays and synthetic materials potentially used for wastewater and soil remediation.

Spain

Collaboration on bioavailability continues with Prof. José-Julio Ortega-Calvo from the Spanish National Research Council.

Sweden

Collaboration established with Prof. Ian Cousins, Stockholm University, on PFAS dynamics in the context of assessing and remediating PFAS-contaminated sites.

Taiwan

Collaboration on soil and groundwater remediation has been undertaken with Prof. Zueng-Sang Chen from National Taiwan University. Prof. Chen is also leading an Asian soil and groundwater research cluster, which involves collaboration with CRC CARE.

United Kingdom

CRC CARE continues to work with Cranfield University on risk communication activities, in particular with risk management expert Prof. Simon Pollard. Prof. Naidu continued his collaboration with Prof. Paul Nathaniel (University of Nottingham and Land Quality Management Ltd), Dr Mark Cave (British Geological Survey) and Prof. Kirk Semple (Lancaster University) on bioavailability and risk assessment.

United States of America

US company EthicalChem continues to be involved in the CRC's research into the use of chemical oxidation techniques for groundwater remediation, in conjunction with the Australian DoD. The CRC works closely on training on dense non-aqueous phase liquid (DNAPL) contamination with the Interstate Technology & Regulatory Council (ITRC), a public-private coalition working to reduce barriers to the use of innovative environmental technologies that reduce compliance costs and maximise clean-up efficacy. Through ITRC's Integrated DNAPL Site Strategy Team Lead, Naji Akladiss, collaboration continued with the Maine Department of Environmental Protection, where Mr Akladiss is a NAPL site project manager. The CRC is also working with Dr Kurt Pennell from Brown University, Rhode Island, on PFAS fate and transport.

Vietnam

CRC CARE continued its collaboration with Thai Nguyen University of Agriculture and Forestry following a MoU in 2017/18 to:

- promote collaboration on a joint education program between the two universities, focusing on a Masters in Environmental Assessment and Clean-up After Mining
- with GCER, provide support to Vietnamese students including those studying the Masters program.

2.4. SMALL-TO-MEDIUM ENTERPRISE ENGAGEMENT

CRC CARE pays particular attention to building the mechanisms and structures to engage with not only our 28 Participants, but also the broader industry, especially Australian SMEs. SMEs are seen as risk takers and hence have a crucial role in the Australian economy as leaders in innovation. This recognises the strategic value to Australia of having an internationally competitive, innovative and highly skilled local industry to protect both human and environmental health and grow sustainable Australian businesses.

Our means of engaging with SMEs include: face-to-face meetings, technical guidance reports, industry training workshops, seminars and webinars, hosting and participating in stakeholder and policy groups, industry-focused print and online publications, national and international conferences, our website, project reports, newsletters, and other methods of direct contact including face-to-face meetings.

Since its establishment, CRC CARE has had a long-standing relationship with the Australian Contaminated Land Consultants Association (ACLCA), ALGA, and the Australasian College of Toxicology and Risk Assessment – member-based organisations that represent contaminated land consultants, risk assessors, and environmental and laboratory service providers. We work with ACLCA (a CRC Participant) and ALGA to disseminate knowledge of the CRC's strategic activities and projects to consulting and service-providing SMEs throughout the industry.

Contamination assessment and remediation is a highly contested space, with stakeholders often holding competing interests. CRC CARE provides an independent evidence base enabling these interests to come together and be mediated. In this context, stakeholder engagement in general, and SME engagement in particular, is at the core of our operations and central to our success.

One measure of CRC CARE's impact on SMEs is the role our work has had in growing the value of the remediation industry in Australia. In the late 1990s, before CRC CARE was established, the remediation industry was valued at $300 million per annum. Since that time, and in part due to the CRC's efforts to not only develop the industry but also bring it into the mainstream, this value has grown ten-fold to now be estimated at over $3 billion. This has driven an exponential increase in the number of SMEs involved with contaminated sites assessment and remediation, with a commensurate surge in SME-based employment.

Despite COVID-19 limiting opportunities for SME engagement in 2020/21, highlights included:

- Continued collaboration with StygoEcologia, a consultancy that provides expertise in surface and groundwater biology, on sampling and analysis of stygofauna (animals, mostly small crustaceans, that live in groundwater systems or aquifers) for environmental risk assessment and management. CRC CARE researchers received training from StygoEcologia on sampling techniques and sample preservation.
- Continued collaboration with Hunter Water on sample analysis and water treatment, with Hunter Water supplying water samples to facilitate the research activities.
- Engagement on potential commercialisation of probeCARE™ with a Melbourne-based SME with expertise in managing water quality and water treatment processes.

WORKSHOPS, CONFERENCES AND SEMINARS

CRC CARE organises workshops and webinars with and/or for SMEs, both directly and via industry groups. In 2020/21, our scheduled series of events was heavily disrupted by COVID-19 restrictions. The CRC ran several online events: two workshops, an emerging contaminants symposium and the From Risk to Remediation Online Masterclass (see *End-user training* on page 22), all of which were well attended by SME personnel.

2.5. COMMERCIALISATION

'Utilisation' in the CRC context means the deployment of research outputs and encourage take-up by end-users. It includes: technology transfer and take up by end-users; the manufacture, sale, hire or other exploitation of a product or process developed by the CRC; or the provision of a service, which may also incorporate intellectual property (IP) developed by the CRC. 'Commercialisation is one aspect – typically the most demanding – of utilisation.

To enhance utilisation by end users of research outputs, around 400 environmental managers attended CRC CARE workshops, seminars, webinars or conferences during the reporting period. Furthermore, 10 PhD students completed their study, enabling their entry into the workforce and thus facilitating the take-up of research outputs.

CRC CARE progressed its assessment of commercialisation/utilisation arrangements with industry. This includes engaging SMEs and other end users that are candidates to adopt several technologies. This assessment has provided a platform for development in future years.

Further information on the specific utilisation and commercialisation activities of CRC CARE can be found in relevant sections of this report. A summary of these activities includes:

- the production of technical guidance reports, publicly and freely available on the CRC CARE website
- workshops and training offered to industry professionals
- the submission and maintenance of patent applications
- activities of the NCSDP (see page 11)
- support provided to PhD, Masters and Honours students, who work in conjunction with CRC CARE researchers on research activities
- the publication of journal papers and presentation of conference papers (a full list for the financial year can be found in the Publications section of this report).

CRC CARE'S PATENTED TECHNOLOGIES AND TRADE MARKS

The following tables summarise CRC CARE's pending patent and trade mark families. A selection of our technologies are described on the following pages. Highlights in 2020/21 included:

PATENTS AND PATENT APPLICATIONS HELD
A method and system for quantifying a concentration of anionic surfactants in a sample
Patent application filed (2017331805)
A method of determining petroleum hydrocarbon fractions in a sample
PCT application filed (PCT/AU2019/050912)
Amine-modified clay sorbents (matCARE™)
National phase applications in Australia (AU2010330678) and the USA (9,284,201)
Australia and USA – granted
Modified clay sorbents (matCARE™)
Patent granted in Australia (2009326853), Canada (2,746,067), Germany (2376221), France (2376221) and UK (2376221)
Analyte ion detection method and device (probeCARE™)
Patent granted in Australia (2011349050), Canada (2,822,876), USA (10,119,927), Germany (2656059), France (2656059) and UK (2656059)
Anionic surfactant detection (astkCARE™)
Patent granted in Australia (2008310306, 2014200985), Japan (5523324) and USA (9,103,797)
Contaminant separating method using a modified palygorskite clay sorbent
Patent granted in USA (9,199,184)
Method, composition and system for degrading a fluorinated organic compound
Patent application filed in Australia (2017320329)
A method of recalibrating a device for assessing concentration of at least one analyte ion in a liquid (probeCARE+™)
Patent accepted – USA (15/558,982) / Patent granted – France, Germany, UK (3271712)

TRADE MARKS HELD
CleanUp (logo) – image mark (Class 41)
Registered in Australia (1765036), China (1329303), India (3516206) and internationally under the Madrid Protocol, (1329303); accepted in Nigeria (F/TM/O/2016/109960)
CleanUp – word mark (Class 41)
Registered in Australia (1765037) , China (1329304), India (3518752) and internationally under the Madrid Protocol, (1329304); accepted in European Union (1329303) and Nigeria (F/TM/O/2016/109959); accepted in European Union (1329303) and Nigeria (F/TM/O/2016/109959)
CRC CARE – combined word and image mark
Registered in Australia (1150159)
globalCARE – word mark (Class 35, 40, 41, 42)
Registered in Australia (1637278), USA (5,314,281) and internationally under the Madrid Protocol (1323742)
matCARE – word mark
Australian registered trade mark (1352133)
pooCARE – word mark (Class 11, 40)
Registered in Australia (1487165) and China (11607975, 11607976)
irCARE – word mark (Class 9)
Registered under the Madrid Protocol (1522221); accepted in Australia (2030005); pending in USA (79/281,908) and China (1522221)
probeCARE – word mark (Class 9, 42)
Registered in Australia, the European Union and internationally under the Madrid Protocol (2007409); pending in China (1503533), India (1503533) and USA (79/274,133)
svbCARE – word mark (Class 9)
Registered in Australia (2007410)

Amine-modified clay sorbents (matCARE™)

CRC CARE developed matCARE, an amine-modified clay, to remove toxic contaminants such as PFAS found in some AFFFs and those on the Stockholm Convention list. matCARE has undergone field trials and has now been dispensed to or utilised by DoD at four sites, and to Airservices Australia at one site. matCARE™ removes PFAS from wastewater and soil.

Modified clay sorbents (matCARE™)

This remediation product is being developed for removal of problematic pollutants, including some of those featured in the Stockholm Convention on Persistent Organic Pollutants. These contaminants represent serious hazards to humans and animals. This technology is cheap, effective and easy to use; uses recoverable materials; requires the use of standard industrial plant, low-skill operators and low-cost equipment; and is applicable to major remediation problems and contaminated brownfield sites.

Analyte ion detection method and device (probeCARE™)

probeCARE offers a novel technique for the real-time measurement of metal ions in solution. It allows common ions such as sodium, potassium and calcium to be measured in complex solute matrices, even in coloured solutions. This is of value to agricultural irrigators and for monitoring water quality in lakes and streams. Existing techniques utilise laboratory equipment that is too large and heavy for in-field measurements, leading to time and cost constraints. probeCARE supports cost-effective, in-situ, real-time monitoring, together with improved management strategies for cropping, improved fertigation (applying fertilisers or other amendments through an irrigation system), effective use of recycled water, and monitoring for possible pollutants to ensure regulatory standards are met. Internet connectivity will support remote sensing and continuous monitoring of resources.

probeCARE+ determines analyte concentrations in unknown samples. It is particularly practical for end users because it can be recalibrated with a small number of standard solutions.

CRC CARE recently entered into discussions with a Melbourne-based water management SME on potential commercialisation of probeCARE™.

Anionic surfactant detection (astkCARE™)

The anionic surfactant test kit provides a safe, sensitive and reliable method for detecting and measuring the concentration of highly toxic surfactants in the environment. These surfactants can come from a range of sources including industrial cleaning solutions and effluent, AFFFs, and personal hygiene products (e.g. soaps, shower gels and domestic cleaning solutions). astkCARE is simple to use, does not require highly skilled operators and can be used in the field. It achieves rapid results, is cheaper and safer than established techniques that rely on hazardous solvents, and has high specificity and reliability. CRC CARE is developing colour-response strips and electronic sensing. The technology is at an early stage of commercialisation.

Contaminant separating method using a modified palygorskite clay sorbent

CRC CARE developed a modified palygorskite clay sorbent, which can be used for separating different contaminants in a mixture through sorption of chemical compounds. The sorbent has particular application for the sorption of anionic and/or hydrophobic compounds. The modified palygorskites possess several properties that make them desirable as sorbents, including nanoscale fibrous or acicular (needle-shaped) particle morphology and high initial surface area. These properties are particularly advantageous for sorption of organic contaminants where fast kinetic rates are required for successful application.

A method of determining petroleum hydrocarbon fractions in a sample (irCARE™)

Coupled with a handheld FTIR spectrometer, irCARE allows rapid in-field quantification of TPH and rapid in-situ classification of dominant petroleum hydrocarbon fractions in soils for contaminated site assessment. Conventional ex-situ methods for petroleum hydrocarbon fraction analysis are highly labour-intensive and time-consuming, have a high skill requirement, and provide only a snapshot in time. Accordingly, these methods require frequent sampling intervals to provide representative temporal variations in petroleum hydrocarbon levels. irCARE provides rapid predictions that support fast-reacting, risk-based contaminated site assessment. The method is non-destructive, does not require sample preparation or solvent extraction, and is easy to use with minimal training.

2.6. EDUCATION AND TRAINING

Through its Education Program, CRC CARE provides scholarship stipends and operational funding for high-calibre PhD and Honours students. The program also provides additional training to help students develop skills desired by prospective employers. One of the Education Program's main aims is to ensure that the CRC's graduates are industry-ready. In some cases, this is achieved by having students co-supervised by end users.

The CRC's Industry Training Program is designed to ensure that research outcomes and technical knowledge are disseminated to all stakeholders, from industry professionals to government regulators. The CRC uses a number of approaches to share this knowledge, including seminars, webinars, workshops and conferences.

2.6.1. Education Program

In 2020/21, 10 PhD students completed their study, with one continuing as of 30 June 2021. It has been pleasing to see the level of student participation in the CRC's industry training program, which supports the CRC's objective of developing the students' transferable and functional skills expected by future employers.

CRC CARE STUDENTS IN 2020/21

Programs

1. Best Practice Policy
2. Better Measurement
3. Minimising Uncertainty in Risk Assessment
4. Cleaning Up

PhD GRADUATES

Student name	Program	University	Country of origin	Thesis topic
Kerry Scott	1	UON	Australia	Classification and ranking of incentives for remediation and reduction of title blight
Kate Hughes	1	UTS	Australia	The socially literate expert – a new model of risk communication and social engagement – bridging content and bridging process
William McCance	2	RMIT	Australia	Novel tracers for groundwater management
Jonás García Rincón	2	UTS	Spain	Evaluating high-resolution site characterisation tools and multiphase modelling to predict LNAPL distribution and mobility
Shruti Sharma	3	UON	India	Indigenous communities' dietary intake and associated health implications
Rangana Kulathunga	3	UON	Sri Lanka	Identification of factors affecting chronic kidney disease of unknown aetiology prevailing in North Central Province of Sri Lanka
Justin Morrissey	4	RMIT	Australia	Bioremediation for nitrogen management in groundwater
Exhaussée Boukaka	4	SCU	Congo	Nutrient recapture from solid waste
Simranjit Kaur	4	WSU	India	Plant-microbiome interactions and communication
Ramesh Jayaramaiah	4	WSU	India	Metagenomics approaches to predict efficiency of bioremediation

CONTINUING PhD STUDENTS

Student name	Program	University	Country of origin	Thesis title	Expected completion
Scott Warner	4	UON	USA	Impact of climate change on groundwater systems.	2021/22

RMIT = RMIT University; SCU = Southern Cross University; UON = University of Newcastle; UTS = University of Technology Sydney; WSU = Western Sydney University

2.6.2. End-user training

CRC CARE's Industry Training Program builds the capacity and knowledge base of the Australian contamination industry. The program provides opportunities for hundreds of contamination experts every year and boosts the professionalism of this field across Australia and beyond. In 2020/21, we continued to be heavily disrupted by COVID-19, necessitating a purely online program. Nevertheless, more than 400 Participants attended our events over the reporting period. The pandemic has forced us to rapidly increase our capability for online delivery, which has opened up opportunities such as self-paced courses, which Participants can start and complete at the time and speed of their choosing.

From Risk to Remediation 2020: CRC CARE Online Masterclass on Contaminated Site Assessment, Management and Communication

Given the overwhelmingly positive feedback of From Risk to Remediation 2019, CRC CARE had planned to run this week-long, face-to-face course again in March 2020. Given COVID-19 restrictions, however, the CRC postponed the event to June. When it became clear that a face-to-face event would be impossible, we converted the course to a fully online, 8 week, 4 module, self-paced course for early- to mid-career professionals who manage, regulate, investigate, remediate, or are affected by contaminated sites. A series of live webinar Q&A sessions punctuated each module. Beginning on 20 July 2020, the course received a high level of interest with around 100 registrations.

Online Masterclass: LNAPL NSZD

This self-paced online course covered the science of NSZD of LNAPLs, including measurement techniques/methodologies and options for incorporating NSZD into LNAPL conceptual site model development and site management strategy. It draws on CRC CARE Technical Reports 44, 46 and 47. The course also provided Participants with an understanding of LNAPL – NSZD processes, as well as evolution of LNAPL site management toward more sustainable risk and science-based practices, NSZD assessment, and where and when NSZD can be applied to site management. Participants gained an awareness of the different methods available for evaluating NSZD, along with the advantages and limitations of each method. More than 110 Participants from Australia and overseas attended the course.

CleanUp Emerging Contaminants Symposium 2021

This 2-day online symposium focused on the latest developments in the detection, fate and transport, risk assessment, clean-up, and regulation of emerging contaminants (ECs). It brought together experts and leaders from academia, government, the regulatory community, site owners, private consulting agencies, and other environmental sectors. The Symposium supported and promoted science that underpins risk-based management of ECs and hosted interactive forums that identified the major constraints to their effective remediation. The event was attended by 65 Participants from Australia and across the globe (including Sweden, USA, UK, Switzerland, Italy and Belgium).

Vapour Intrusion Online Workshop

This workshop took place in June 2021 and offered contaminated land practitioners, regulators, and researchers insights into the predictability of vapour intrusion exposure for non-traditional building structures and geologically complex land contaminated with volatile organic compounds. Participants benefited from panel discussions and case studies on VI investigations and associated health risk evaluations for 'odd' building structures. The workshop was organised and sponsored by CRC CARE, GCER, and the Office of the NSW Chief Scientist & Engineer. It was attended by 116 Participants from Australia and New Zealand.

CleanUp Conference series

After beginning preparation for the 9th International Contaminated Site Remediation Conference (Cleanup 2021), COVID-19 restrictions and uncertainties prompted the CRC to postpone the conference to September 2022. CleanUp 2022 will take place in Adelaide on 11-15 September under a hybrid (face-to-face and virtual) structure.

Preparation also continued on the 2nd Global CleanUp Congress, which was similarly postponed until 2022. It will take place on 20-21 September in Kuala Lumpur, Malaysia.

Prof. Ravi Naidu (centre) with GCER PhD students and researchers from 15 countries at CRC CARE headquarters at the University of Newcastle's Callaghan campus.

03
CASE STUDIES

Please refer to the following case studies in the Highlights and achievements report:

Successful commercialisation of CRC CARE research outputs:

- matCARE™ – cleaning up PFAS contaminants (page 39).

Participants working together to make an impact that would not have been achievable without the CRC collaboration:

- Risk-based remediation and bioremediation of contaminated soil for BHP in WA (page 45)
- Health screening levels for petroleum hydrocarbons (page 45)
- A National Framework for Remediation and Management of Contaminated Sites in Australia (page 45).

CRC CARE education programs influencing the uptake of new knowledge, products or processes:

- ASC NEPM Roadshow (page 49).

Also see the *Snapshot summary* on page 53.

04
RISKS AND IMPEDIMENTS

COVID-19 was again the major impediment to the CRC's activities in 2020/21, as it was in the previous reporting period. The COVID-safe workplace practices implemented in 2019/20 (in line with those undertaken at our research provider organisations) mitigated risk to our research staff. However, lockdowns and border restrictions severely compromised our researchers' ability to complete laboratory activities and fieldwork. This was exacerbated by Australia's relatively slow uptake of a vaccination program. With CRC CARE likely to continue as an end-user-funded centre (see *Future plans and transition arrangements* on page 27), ongoing COVID-related disruption remains a risk, but we are hopeful that this will be mitigated as a result of increasing vaccination rates and associated relaxation of restrictions.

Another impediment in 2020/21 was CRC CARE's requirement to operate without any funding from the CRC Program, which ceased on 30 June 2020. However, as a result of COVID-19 disruption and attendant challenges in meeting some milestones, the CRC Program permitted a 12-month protracted exit, without further funding. The shortfall was to some extent met by our end-user Participants – particularly DoD, BHP and HLM – although this had a material impact on our budget for management and administration. Consequently, a number of staff (directly employed by CRC CARE and supported staff at research Participant organisations) obtained employment elsewhere, reducing capacity and increasing workload for remaining staff.

The cessation of CRC CARE's CRC Program funding remains a significant challenge. There is potential for Australia to lose significant expertise in tackling pressing pollution problems associated with existing and emerging contaminants such as PFAS. Prior to CRC CARE, remediation was achieved largely through costly and risky excavation and transport to landfills. The CRC's work has led to the development of policy guidance and remediation technologies that have helped clean up around 5% of the contaminated sites in Australia. The complex nature of not only contaminants themselves, but also the soil environment, requires robust science that underpins both innovative technologies and policy guidance. If CRC CARE were to cease operating, there is a real risk that the progress of the past 15 years will dissipate, with dire consequences for the Australian and global economies, our environment and human health.

05
PARTICIPANTS AND THIRD PARTIES

PARTICIPANTS

CRC CARE's 28 Participants as at 30 June 2021:

PARTICIPANT	PARTICIPANT TYPE	AUSTRALIAN BUSINESS NUMBER (ABN)	ORGANISATION TYPE
Agilent Technologies Australia Pty Ltd	Supporting	29 088 510 605	Industry/private sector
ACLCA Incorporated	Supporting	36 533 132 904	Industry association
Australian Institute of Petroleum Ltd	Core	11 005 152 581	Industry/private sector
BHP Billiton Iron Ore Pty Ltd	Supporting	46 008 700 981	Industry/private sector
ChemCentre (WA)	Supporting	40 991 885 705	Industry/private sector
Chevron Australia Pty Ltd	Core	29 086 197 757	Industry/private sector
CSIRO	Supporting	41 687 119 230	Australian Government
Curtin University	Supporting	99 143 842 569	University
Department of Defence	Core	68 706 814 312	Australian Government
Department of Environment and Science (Qld)	Supporting	46 640 294 485	State government
Department of Industry, Science, Energy and Resources – National Measurement Institute	Supporting	74 599 608 295	Australian Government
EPA Victoria	Supporting	85 899 617 894	State government
EthicalChem	Core	International	Industry/private sector
FibreCell Australia Pty Ltd	Supporting	60 114 025 759	Industry/private sector
GHD Pty Ltd	Core	39 008 488 373	Industry/private sector
HLM Asia Group Limited	Core	International	Industry/private sector
JBS&G Pty Ltd	Supporting	62 100 220 479	Industry/private sector
Master Builders Australia Ltd	Supporting	68 137 130 182	Industry/private sector
RMIT University	Core	49 781 030 034	University
SA EPA	Core	85 393 411 003	State government
Southern Cross University	Core	41 995 651 524	University
Technological Resources Pty Ltd (Rio Tinto)	Supporting	12 002 183 557	Industry/private sector
University of Newcastle	Core	15 736 576 735	University
University of Queensland	Core	63 942 912 684	University
University of South Australia	Core	37 191 313 308	University
University of Technology Sydney	Core	77 257 686 961	University
Western Sydney University	Core	53 014 069 881	University
WA Dept of Water and Environmental Regulation	Supporting	38 052 249 024	State government

THIRD PARTIES

In 2020/21, CRC CARE worked with the following third parties, which provided resources (cash or in-kind) to support our activities:

THIRD PARTY	ABN	ORGANISATION TYPE
National Energy Resources Australia (NERA)	24 609 540 285	Australian Government
Minerals Research Institute of WA	86 779 457 072	Research organisation
NSW Department of Planning, Industry and Environment	38 755 709 681	State government
Department of Agriculture, Water and the Environment	34 190 894 983	Australian Government
Airservices Australia	59 698 720 886	Australian Government
Richmond Valley Council	54 145 907 009	Local government
Richmond Dairies	79 106 445 881	Large industry
Norco Foods (a division of Norco Co-operative Ltd)	17 009 717 417	Large industry
Spotless Australia	83 072 293 880	Large industry
Veolia	20 051 316 584	Large industry
South East Water	89 066 902 547	State government
Melbourne Water	81 945 386 953	State government
Gippsland Water	75 830 750 413	State government
Western Water	67 433 835 375	State government
NSW EPA	30 841 387 271	State government
TAS EPA	58 259 330 901	State government
ACT EPA	n/a	State government
NT EPA	n/a	State government

06 INTELLECTUAL PROPERTY MANAGEMENT

During the 2020/21 reporting period, CRC CARE had the following patent families and applications:

- Six patent families registered:
  - *Amine modified clay sorbents* (Australia, USA)
  - *Analyte ion detection method and device* (Australia, Canada, France, Germany, UK, USA)
  - *Anionic surfactant detection* (Australia, Japan, USA)
  - *Contaminant separating method using a modified palygorskite clay sorbent* (USA)
  - *Modified clay sorbents* (Australia, Canada, France, Germany, UK)
  - *A method of recalibrating a device for assessing concentration of at least one analyte ion in a liquid* (France, Germany, UK).
- One patent family accepted and awaiting the grant:
  - *A method of recalibrating a device for assessing concentration of at least one analyte ion in a liquid* (USA).
- Two patent families at the PCT application stage:
  - *A method and system for quantifying a concentration of anionic surfactants in a sample* (Australia)
  - *A method of determining petroleum hydrocarbon fractions in a sample* (Australia)
- One patent family under examination:
  - *Method, composition and system for degrading a fluorinated organic compound* (Australia).

The CRC has seven trade marks registered in Australia (pooCARE, matCARE, globalCARE, probeCARE, svbCARE, CleanUp – word and image, and CRC CARE – word and image), and one (irCARE) accepted in Australia. Two marks (CleanUp and pooCARE) have been registered in China. globalCARE is also registered as a trade mark in USA, Australia and under the Madrid protocol. CleanUp (word) and CleanUp (logo) have been registered as trade marks in Australia, China, Europe, India and USA, and accepted in Nigeria.

Existing trade marks:

- matCARE (Australia)
- CleanUp (Australia, China, India, Europe, Madrid Protocol)
- CleanUp (Logo) (Australia, China, India, Europe, Madrid Protocol)
- globalCARE (Australia, USA, Madrid Protocol)
- irCARE (Madrid Protocol)
- pooCARE (Australia, China)
- probeCARE (Australia, European Union, Madrid Protocol)
- svbCARE (Australia).

Pending trademarks:

- CleanUp (Nigeria)
- CleanUp (Logo) (Nigeria)
- irCARE (Australia, China, USA)
- probeCARE (China, India, USA)

All of CRC CARE's new technologies have potential for commercial application. The focus to date has been on securing appropriate agreements with end users – such as site operators, remediation contractors, manufacturers and suppliers of equipment – for evaluation. Continuing protection of IP is important until the commercial potential has been fully assessed.

Details of CRC CARE patents are available on the IP Australia website (https://ra.sourceip.ipaustralia.gov.au).

CRC CARE has the essential mechanisms in place to ensure adherence to the National Principles of IP Management. Provisions within the Commonwealth and Participants' Agreements provide the key elements for IP management. In addition to the Agreements, CRC CARE has implemented appropriate policies and procedures, including those for:

- identification and disclosure of IP
- assessment of existing IP
- protection of IP
- record keeping via an IP register
- business case development and approval
- benefit sharing.

Although no registered IP was sold, transferred or licensed for commercialisation during the reporting period, two of the CRC's products (matCARE and probeCARE) are being considered for possible commercialisation by local SMEs.

07
FUTURE PLANS AND TRANSITION ARRANGEMENTS

CRC CARE pursues its aims through a range of focused initiatives and activities, summarised as:

- industry-wide and public-good objectives
- industry partner and commercial objectives.

CRC CARE's funding under the CRC Program ceased on 30 June 2020, but we continued operating until 30 June 2021 (with Participant support) following approval from the CRC Program for a protracted exit. Given Australia's ongoing need for an organisation that is able to play CRC CARE's unique role, in 2012 we established an end-user-led Beyond 2020 Implementation Committee to develop strategies for the CRC's continuation. The committee reviewed three options:

a. applying for a continuation of CRC CARE under the CRC Program (not permitted under current guidelines)
b. a model of funding that ensures continuing support from Participants
c. a commercial mode of operation.

The committee concluded that option (c) was not suitable and favoured option (b) as the priority strategy unless option (a) became a possibility through changes to CRC Program rules. However, the impact of the COVID-19 pandemic thwarted progress on option (b), resulting in a change of strategy.

Given widespread end-user recognition that waste and emerging contaminants pose major challenges to Australia's prosperity and health, the committee decided to bid for an entirely new 'Clean Australia' CRC, which aims to prevent, reduce and deal with hazardous waste and pollution. The bid was submitted in application round 22 in July 2020 but was not shortlisted.

With the failure of Clean Australia CRC bid, the Beyond 2020 Committee refocused on option (b), a centre funded by end users. This was supported in principle by all of CRC CARE's major end-user Participants, as well as several new partners that had been part of the Clean Australia CRC bid (including the water industry, represented by water corporations from all mainland states. As of 30 June 2021, CRC CARE had gained sufficient in-principle support to continue operating as a centre of excellence in contaminants, with negotiations to finalise funding commitments progressing well.

THE BEYOND 2020 IMPLEMENTATION COMMITTEE

The committee was formed in 2013 with Prof. Max Brennan as Chair and Paul Barrett (AIP) as Deputy Chair. With Prof. Brennan's retirement in 2017, Mr Barrett assumed the Chair role with Dr Mark Bowman (DoD) as Deputy. In March 2020, Dr Bowman assumed the Chair's role after Mr Barrett stepped down as Chair to focus on COVID-related disruption to the petroleum industry.

BEYOND 2020 IMPLEMENTATION COMMITTEE MEMBERS IN 2020/21:

Name	Role/representing	Organisation
Mark Bowman	Chair	Director Environmental Remediation Programs, DoD
Paul Barrett	Deputy Chair	CEO, AIP
Gavin Price	Minerals industry	BHP (Head of Environment, Minerals Australia)
Tony Circelli	Regulators	CEO, SA EPA
Anthony McGregor	Commonwealth Government	Department of Agriculture, Water and the Environment
Tim Eaton	Regulators	EPA Executive Director Assessments, EPA Victoria
Peter Gniel	Petroleum industry	General Manager Policy, AIP
Andrew Pruszinski	Regulators	Head, Contaminated Sites, SA EPA
Ross McFarland	Environmental consultants	AECOM
Bryan Jenkins	Remediation practitioners	Environment Institute of Australia and New Zealand
Ravi Naidu	CRC CARE	CRC CARE
Stuart Rhodes	Minerals industry	Rio Tinto

08
GOVERNANCE – BOARD, COMMITTEES AND KEY STAFF

8.1. COMPANY STRUCTURE

CRC CARE Pty Ltd (the Company) is an incorporated venture established on 13 September 2005 to carry out the activities of CRC CARE. The Company is a limited liability entity with 14 shareholders. Voting and dividend rights are determined by the value of contributions by shareholders ('Core' Participants) in the relevant financial year. Voting rights and the payment of returns from any commercialisation of IP for 'Supporting' (non-shareholder) Participants of CRC CARE are provided for through the ownership of shares in projects.

The Company is governed by a shareholder-elected skills-based board. The maximum number of directors is 10, with the majority of members required to be independent of the shareholders, and with a further and more specific requirement for the Chairperson to be independent of Participants (Core and Supporting) as well as the management of CRC CARE and CRC CARE Pty Ltd. In 2020/21 the CRC's Board had nine directors.

The Chairperson is elected at each annual general meeting (AGM) with the balance of Directors serving a term of two years, after which they are eligible to seek another term. During 2020/21 the Board met five times. The AGM took place on 19 November 2020 in Newcastle.

8.2. THE CRC CARE BOARD

The following table presents details of the members of the CRC CARE Board in 2020/21:

NAME	ROLE	KEY SKILLS	INDEPENDENT/ORGANISATION
Dr Paul Vogel AM	• Independent Chair of Board • Remuneration & Succession Committee • Commercialisation Committee • Audit & Risk Management Committee (observer)	Regulatory	Independent
Prof. Ravi Naidu	• CEO and Managing Director • Remuneration & Succession Committee • Project Advisory Group • Policy Advisory Committee • Management Committee • Commercialisation Committee • Beyond 2020 Committee • Audit & Risk Management Committee (observer)	Research leadership, regulatory policy, management, commercial, policy and end-user linkages	CRC CARE
Dr Rod Lukatelich	• Board Director • Remuneration & Succession Committee (Chair) • Policy Advisory Committee • Commercialisation Committee (Chair) • Beyond 2020 Committee	Petroleum industry, research, environmental management	Independent
Ms Anthea Tinney	• Board Director • Audit & Risk Management Committee • Remuneration & Succession Comittee • Policy Advisory Committee (Chair)	Regulatory, policy and governance	Independent
Mr Charles Wong	• Board Director • Audit & Risk Management Committee • Commercialisation Committee	Venture capital/finance	Independent
Mr Ralph Hardy	• Board Director • Audit & Risk Management Committee (Chair)	Finance	HLM Asia Group Ltd
Mr Tony Circelli	• Board Director • Beyond 2020 Committee	Regulatory	Independent
Prof. Alan Broadfoot	• Board Director • Audit & Risk Management Committee • Remuneration & Succession Committee	Research, academic and management	University of Newcastle
Company Secretary			
Ms Cathy Cooper	• Board • Audit & Risk Management Committee • Remuneration & Succession Committee	Legal	Independent

The Board's roles include:

- appointing the CEO and Managing Director
- providing strategic direction to the Company
- overseeing the financial management of the Company
- ensuring that effective governance practices are in place, including an integrated and detailed approach to risk management
- monitoring senior management performance
- developing succession plans
- ensuring that the Company adheres to a high ethical standard.

The Board provides the overall strategic direction necessary to ensure that the above roles are carried out, and exercises stewardship of the Company's resources in a manner that enables its objectives to be met.

Where particular agreements apply (e.g. the Commonwealth Agreement and the Participants' Agreement), the Board will use its best endeavours to ensure that the objectives, policies, strategies and plans applicable to the Company are met.

In 2020/21, Board meetings were held in September, October, November, March, May and June. Attendances were as follows:

BOARD MEMBER	NUMBER OF MEETINGS ELIGIBLE TO ATTEND	NUMBER OF MEETINGS ATTENDED
Dr Paul Vogel	6	6
Prof. Ravi Naidu	6	6
Mr Tony Circelli	6	5
Dr Rod Lukatelich	6	6
Mr Charles Wong	6	5
Ms Anthea Tinney	6	6
Mr Ralph Hardy	6	6
Prof. Alan Broadfoot	6	5

DR PAUL VOGEL AM
CHAIRMAN

Paul Vogel was elected to the position of Chairman of CRC CARE at the AGM of shareholders in December 2015. He has a PhD in chemistry from the University of WA. From 2007 to 2015, Dr Vogel was Chairman of the WA Environment Protection Authority (EPA) and prior to that he was the inaugural Chief Executive and Chairman of SA EPA.

Dr Vogel has been and continues to be a key advisor to governments on the environmental acceptability of development and on important environmental issues. He has extensive knowledge and experience of the environmental issues and regulatory regimes in WA, SA and the Northern Territory and their interaction with Commonwealth environmental legislation, and in engaging key industry, government and community stakeholders. In 2016 Dr Vogel was appointed Chairman of the Northern Territory EPA. He holds directorships of Global Aquatica (Australia) Pty Ltd and the Australian Technology Network of Universities Research Impact Advisory Board, and is a member of the Australian Institute of Company Directors. In 2019, Paul was named a Member (AM) in the General Division of the Order of Australia for "significant service to public administration through environmental leadership roles".

LAUREATE PROFESSOR RAVI NAIDU
CEO AND MANAGING DIRECTOR

Ravi Naidu has been a research leader in environmental contaminants, bioavailability and remediation for over 30 years. He is co-author of more than 700 technical publications and co-editor of 11 books in the field of environmental science including field remediation of contaminated sites. He was the initiator and inaugural director of the Centre for Environmental Risk Assessment and Remediation where he conceived, developed and led the successful bid for CRC CARE in 2004. He was also the initiator and founding managing director/CEO of CRC CARE, having engaged significant local and international collaboration, and led the successful bid for CRC CARE's nine-year extension in 2010. Prior to joining the University of South Australia in December 2002, Prof. Naidu was Chief Research Scientist and Leader of the Remediation of Contaminated Environments Program at the CSIRO Land and Water Division, and Component Coordinator of CSIRO's Land and Water Sector. He is a University of Newcastle Global Innovation Chair and the initiator and inaugural director of GCER.

Prof. Naidu was awarded a Gold Medal in environmental science in 1998 by Tamil Nadu Agricultural University, has been awarded the status of Chartered Chemist, and is a Fellow of the Soil Science Society America (elected in 2000), the Soil Science Society of New Zealand (2004), the American Society of Agronomy (2006) and the American Association for the Advancement of Science (2012). He was elected in 2016 as a member of the European Academy of Sciences and Arts, and in 2017 as a Fellow of the Royal Australian Chemical Institute, Fellow of the Royal Society of Chemistry, and Fellow of the Australian Academy of Technological Sciences and Engineering. Ravi is Chair of the International Committee on Bioavailability and Risk Assessment and a sitting member of the EPA Victoria Contaminated Sites Auditor Panel. He has also been Chair of the Standards Australia Technical Committee on Sampling and Analyses of Contaminated Soils (1999–2000), Chair of the International Union of Soil Sciences Commission for Soil Degradation Control, Remediation and Reclamation (2002–10), and President of the International Society on Trace Element Biogeochemistry (2005–07).

PROFESSOR ALAN BROADFOOT

Professor Alan Broadfoot is the Executive Director of the Newcastle Institute for Energy and Resources (NIER) at the University of Newcastle, a position he has held since 2010. At NIER, Alan leads an ambitious agenda linking industry and academia for transformational research in energy and resources. Under Prof. Broadfoot's leadership, NIER has grown to host over 360 staff across 19 research centres. Alan holds a Doctor of Philosophy, Master of Engineering and Bachelor of Electrical Engineering (Honours) from the University of Newcastle. An Electrical Engineer in various roles from 1985, Prof. Broadfoot joined electrical design and manufacturing company Ampcontrol in 1991 and held senior management positions, including Managing Director and CEO from 2005 to 2010. He is a Fellow of the Institution of Engineers Australia and in 2006 he was awarded Engineers Australia's Professional Engineer of the Year. He was Chair of the Australian Industry Group Hunter Manufacturing Council from 2004 to 2009. Prof. Broadfoot is a Graduate of the Australian Institute of Company Directors, a Fellow of The Royal Society of NSW, and Director of the NSW Energy and Resources Knowledge Hub. He is also a Board member of TUNRA (The University of Newcastle Research Associates) and sits on a number of executive industry and research advisory committees including NTCP (India) Energy Technology Research Advisory Council.

MR TONY CIRCELLI

Tony Circelli is Chief Executive of the SA EPA. Having worked at the EPA since its establishment in 1995, he has led national and state policy and strategy development, EPA operations, and corporate governance. He has significant knowledge and experience in regulatory science and building better regulatory practice into EPA policy, operations and organisational culture. Mr Circelli has overseen reform to site contamination services in SA, including strengthened risk communication protocols and capabilities to better build trust and confidence with affected communities. Under his leadership, the EPA established Australia's first formal government-led program to manage health risks associated with orphan sites.

Mr Circelli has an honours degree in Mechanical Engineering from the University of Adelaide and a Master of Business Administration from Deakin University. He is a Director of the SA EPA Board, the national Asbestos Safety and Evaluation Council, and Presiding Member of the SA Radiation Protection Committee. He is also a member of SA's Senior Management Council and the Australian Institute of Company Directors, and a Fellow of SA's Governor's Leadership Foundation.

MR RALPH HARDY

Ralph Hardy is a senior manager with extensive finance, commercial, and systems experience in the manufacturing and service industries. He currently leads multinational finance teams for the Ampcontrol Group, a role which provides the strategic direction, finance policies and governance framework to all companies in the Group. He holds functional responsibility for provision of consolidated financial and management accounting support and reports, multinational shared service centres, treasury, finance funding, tax compliance, statutory compliance and mergers and acquisitions, together with financial management and advice. Mr Hardy has strong experience in ensuring statutory compliance, internal control, risk management, business planning, systems technology design, systems implementation, staff development and leadership in a number of jurisdictions including Australia, Hong Kong, UK and Singapore.

DR ROD LUKATELICH

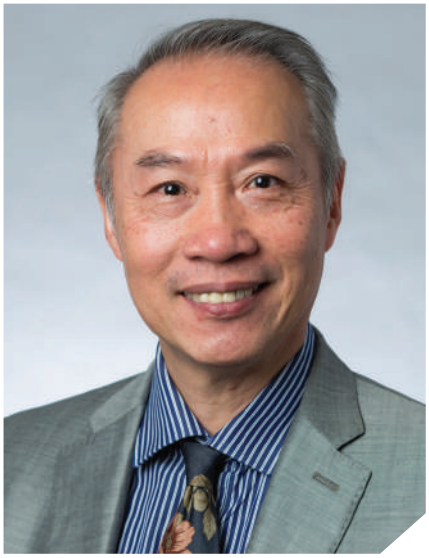
Rod Lukatelich's career has spanned academia, environmental consulting and industrial environmental management. As a lecturer/ research officer (1982–89) at the Centre for Water Research at the University of WA his research included studies on the impacts of eutrophication on algae and seagrasses in lakes and estuaries; development of ecological models; and the relationships between hydrodynamics and water quality in reservoirs, rivers and estuaries. In 1989 Dr Lukatelich joined Kinhill Engineers as Senior Aquatic Ecologist and in 1990 joined BP Refinery Kwinana as Environmental Manager. In various roles at BP he led a team of environmental engineers and was responsible for environmental management systems, monitoring and reporting emissions, wastewater treatment, environmental impact assessment for major projects, solid waste management, groundwater production, soil and groundwater remediation, dangerous goods management, and Major Hazardous Facility Safety Reports. He has also supported BP's global refining businesses as a Senior Environmental Technologist (1995–97) and as Water Technology Advisor (2004–06) in the areas of contaminated site assessment and remediation, and wastewater treatment, respectively.

Dr Lukatelich has broad experience in regulatory systems, having completed major contaminated site remediation projects in Asia, Europe, the Americas and the Middle East. He retired from BP in 2014 and now works part time as an environmental consultant. He has published more than 50 refereed papers and book chapters in environmental science. He has been a director of CRC CARE since its inception and director of Perth Racing since 2017. He is a member of CSIRO's Oceans and Atmosphere Strategic Advisory Committee. He chaired the Great Australian Bight Research Program Management Committee and was a member of the Environmental Protection Authority of WA (2009–14). Dr Lukatelich was appointed to the Northern Territory Environmental Protection Authority in January 2019.

MS ANTHEA TINNEY

Anthea Tinney has wide board experience including as Chair of the Marine Estate Expert Knowledge Panel (NSW), a director on the NOPSEMA Advisory Board and Chair and/or independent member of public sector audit committees. She was previously Chair of the Sydney Harbour Federation Trust, the Australian National Commission for the United Nations Educational, Scientific and Cultural Organization (UNESCO), Chair of Land and Water Australia and a member of the Australian Government's Independent Communications Committee.

Ms Tinney was a deputy secretary in the federal environment portfolio and, prior to leaving the Australian Public Service, was appointed as the Interim CEO of the National Film and Sound Archive. Her public service career also included a period as the head of the Cabinet Office in the Department of Prime Minister and Cabinet and some years in the Treasury. Ms Tinney has served on several boards and has wide experience in government administration and advising on public policy. She has a Bachelor of Economics degree and was awarded a Public Service Medal in 1995 for services to the Australian Cabinet system.



MR CHARLES WONG

Charles Wong is a professional engineer who worked in the telecommunications industry in Canada for over 25 years until his move in late 2005 to work as a project manager at HLM Asia Group Ltd Hong Kong, a financial consulting and investment firm with offices in Hong Kong and Beijing. His responsibilities in the telecommunications industry included research and development, manufacturing, marketing and product management for a multinational telecommunication company. He has a BASc from the University of Toronto. Mr Wong's main focus with HLM Asia Group includes corporate financing, mergers and acquisitions, investment fundraising, and initial public offerings. HLM has significant involvement in traditional and renewable energy businesses in the People's Republic of China. Mr Wong is currently overseeing CRC CARE's research activities in China.

8.3. BOARD COMMITTEES

The CRC CARE Board has several subcommittees to oversee aspects of the Company's strategic planning and decision making. Chaired by directors from the Board, the following committees have been delegated powers as detailed below:

- Audit and Risk Management Committee
- Remuneration and Succession Committee

With the CRC transitioning to a wind-up phase in 2020/21, the Research and Technology Committee was discontinued on 30 June 2020, with its work performed by the Board on a by-exception basis.

AUDIT AND RISK MANAGEMENT COMMITTEE

The primary purpose of the Committee is to assist the Board in fulfilling its responsibilities relating to the financial reporting and risk management practices of the Company.

In particular, the Committee:

- oversees, coordinate and appraise the quality of the external audit, and recommend appointment, and the terms of such appointment, of the external auditor to the Company
- maintains, through regular meetings, open lines of communication between the Board and the external auditors to exchange views and information as well as to confirm their respective authority and responsibilities
- serves as an independent and objective party to review the financial information submitted by management to the Board for issue to members and regulatory authorities
- oversees compliance with the Commonwealth and Participant Agreements and the requirements of the Corporations Act as they apply to the operations of the Company
- reviews the adequacy of the reporting and accounting controls
- reviews the Company's overall risk profile to ensure that material risks are dealt with appropriately, including in conjunction with other Board committees where required
- oversees the development and maintenance of policies and practices to identify, assess, monitor and report risk.

The Audit and Risk Management Committee meets five times a year.

AUDIT AND RISK MANAGEMENT COMMITTEE MEMBERSHIP:		
Name	Role	Independent/organisation
Mr Ralph Hardy	Chair	Independent
Prof. Alan Broadfoot	Member	University of Newcastle
Ms Anthea Tinney	Member	Independent
Mr Charles Wong	Member	HLM Asia Group Ltd
Ms Cathy Cooper	Company Secretary	

REMUNERATION AND SUCCESSION COMMITTEE

The Committee:

- ensures that levels of remuneration are sufficient to attract and retain executives of the quality required to successfully manage the Company
- ensures that a succession plan is in place for the Company, noting that some of the key individuals may not be in the direct employ of the Company
- reviews and recommends to the Board remuneration policies and packages for the Managing Director and senior executives directly reporting to the Managing Director so as to link remuneration to corporate and individual performance
- recommends to the Board any changes in remuneration policy including superannuation, and remuneration structure for executives identified above
- ensures there is a proper performance-management process in place throughout the organisation and that it is operating effectively
- reviews and recommends to the Board any changes to non-executive directors' fees.

The Remuneration and Succession Committee comprises four Company directors (including the Chair) and during 2020/21 was chaired by Dr Rod Lukatelich. The Committee meets as often as is required by the Board or as the Committee may determine, but generally not less than once a year.

REMUNERATION AND SUCCESSION COMMITTEE MEMBERSHIP:		
Name	Role	Independent/organisation
Dr Rod Lukatelich	Chair	Independent
Ms Anthea Tinney	Member	Independent
Prof. Alan Broadfoot	Member	University of Newcastle
Dr Paul Vogel	Member	Independent
Ms Cathy Cooper	Company Secretary	

8.4. NON-BOARD COMMITTEES

COMMERCIALISATION COMMITTEE

The Commercialisation Committee advises on opportunities and sets strategies for commercialising CRC CARE–developed technologies. It comprises Rod Lukatelich (Chair), Ravi Naidu, Paul Vogel, Charles Wong and Alan Broadfoot.

BEYOND 2020 IMPLEMENTATION COMMITTEE

The Beyond 2020 Implementation Committee advises develops CRC CARE's strategy and transition arrangements for post-CRC Programme activity. See *Future plans and transition arrangements* (page 27) for the list of committee members.

OTHER NON-BOARD COMMITTEES

With the CRC transitioning to a wind-up phase in 2020/21, the Policy Advisory Committee and Management Committee were discontinued on 30 June 2020.

8.5. CRC CARE STAFF AND PROGRAM LEADERS

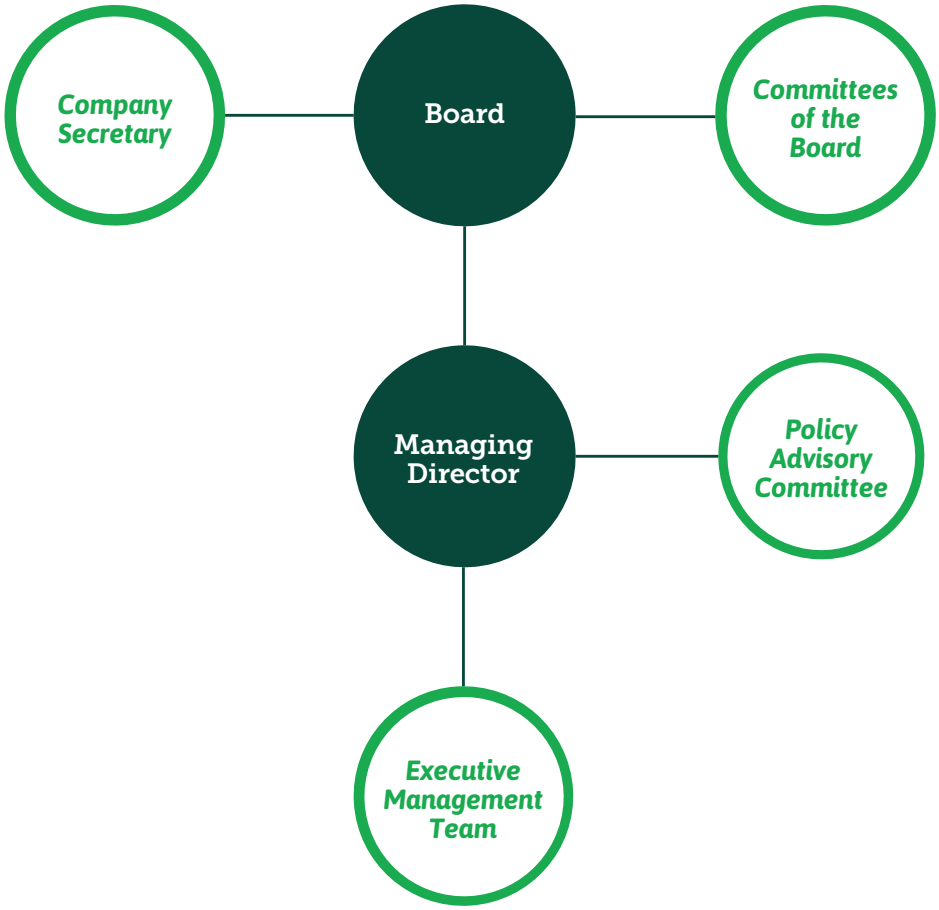
Key CRC CARE staff and Program Leaders during 2020/21 were:

KEY STAFF		
Name	Organisation	CRC CARE position/role
Prof. Ravi Naidu^	CRC CARE	CEO, Managing Director and Chief Scientist
Dr Joytishna Jit^^	CRC CARE	Program 1 Leader
Dr Cheryl Lim	NMI	Program 2 Leader
Dr Yanju Liu	University of Newcastle	Program 3 Leader
Prof. Megharaj Mallavarapu	University of Newcastle	Program 4 Leader
Dr Prashant Srivastava	CRC CARE	Business Manager
Mr Mark Flick	CRC CARE	Finance Manager
Dr Sreenivasulu Chadalavada	CRC CARE	Research Manager and Principal Hydrogeologist
Mr Adam Barclay	CRC CARE	Communication Director
Ms Caryn McArthur	CRC CARE	Executive Personal Assistant to the CEO

^ 0.2 EFT Director of GCER (University of Newcastle).

^^ Dr Jit left CRC CARE on 16 January 2021, with Prof. Naidu assuming responsibility for Program 1.

8.6. ORGANISATIONAL STRUCTURE



09
HIGHLIGHTS AND ACHIEVEMENTS REPORT

9.1. ECONOMIC, ENVIRONMENTAL AND COMMUNITY BENEFITS FOR AUSTRALIA

Since its creation in 2005, the Cooperative Research Centre for Contamination Assessment and Remediation of the Environment (CRC CARE) has consistently provided a unique resource to Australia that has delivered enormous economic and environmental benefits to the nation's key growth industries, communities, governments, small-to-medium enterprises (SMEs), and regulatory agencies.

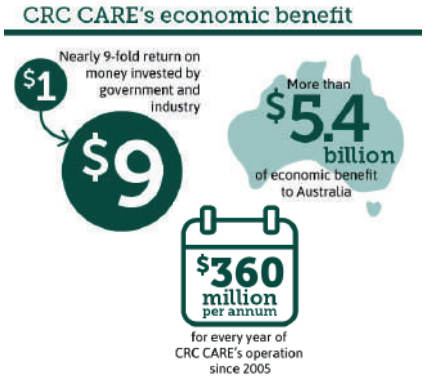
- ✓ **More than $5.4 billion of economic benefit to Australia**
- ✓ **Nearly $9 return on every dollar invested by government and industry**

In 2018/19, CRC CARE commissioned an independent economic impact review, which was conducted by Consulting & Implementing Services (CIS), Melbourne. This section of the Highlights and Achievements Report summarises the CIS review.

During the 15-year period from its initiation, the economic benefit due to practical roll-out and application of CRC CARE research now exceeds $5.4 billion.[1] This amounts to a cost-benefit ratio of 8.6 on the total cash and in-kind investment made by the Commonwealth and CRC CARE industry and research partners.

By focusing Australia's contamination research and development capabilities, the CRC has been central to establishing Australia's enviable global reputation as a leader in research on contaminated site assessment and remediation. CRC CARE's work has boosted the sector's professionalism and fostered a more skilled and internationally well-regarded industry. The CRC's international collaboration, including a dedicated research node in China, has forged global connections and opened up potential trade opportunities for the sector.

In addition to the direct economic benefits of the CRC for its partners and target industries, there are significant and broad flow-on benefits as a result of CRC CARE's work. The application of the CRC's research nationally has unlocked the productive potential of contaminated land and provided communities with confidence that land has been restored to a state that will not threaten their health and safety.



CRC CARE HAS DRIVEN IMPROVEMENTS TO AUSTRALIAN CONTAMINATED SITE REGULATIONS

The CRC has generated extensive knowledge from 14-plus years of research to enable government, environmental regulatory agencies and businesses – large and small – to effectively manage established and emerging high priority contaminants.

- CRC CARE's best practice strategies and guidance for managing sites contaminated with per- and poly-fluoroalkyl substances (PFAS) have improved the national effort to assess and remediate these high-priority emergent contaminants. The CRC's work, which complements and informs the PFAS National Environmental Management Plan, has delivered significant direct economic benefits for industry. This includes more than $200 million through reduced need for remediation of PFAS that – based on the CRC's risk-based approach – does not pose an environmental or health threat. In addition, sectors relying upon PFAS clean-up are now able to commence or accelerate project operations on this land, reducing their costs of development and spurring new economic activity.

As a national leader in PFAS management, CRC CARE has developed:

- ✓ **technologies for analysing and cleaning up PFAS contamination**
- ✓ **best practice strategies for managing PFAS-contaminated sites.**

- CRC CARE developed health screening levels (HSLs) for petroleum hydrocarbon remediation, which provide a minimum concentration of contaminant that triggers further action (including monitoring and clean-up). The HSLs, as well as other best practice strategies for managing petroleum hydrocarbon contamination, were incorporated into national legislation known as the National Environment Protection (Assessment of Site Contamination) Measure ('the ASC NEPM'), ensuring that they were adopted by all regulators (environment protection authorities) across Australia. This work has already resulted in, and will continue to allow, substantial reductions in remediation costs for the mining, petroleum, defence and other sectors. The total benefits to industry and government so far amount to more than $1.3 billion.

CRC CARE's health screening levels for petroleum hydrocarbons have:

- ✓ **been incorporated into national regulatory frameworks**
- ✓ **been adopted by all regulators nationally**
- ✓ **provided a $1.3 billion (and growing) benefit to industry and government.**

[1] Figures are cumulative over a 15-year period from the beginning of CRC CARE's current term of funding in 2013. Figures are risk-adjusted and provided in present value terms at a discount rate of 5%.

- CRC CARE's research on heavy metalloid bioavailability (the proportion of a substance that enters the circulation when introduced into the body) has provided substantial benefits to industry and the Commonwealth. The increased understanding of bioavailability (lower bioavailability implies lower risk) has reduced the need for remediation of some contaminants and allowed limited resources to be focused on priority sites, resulting in reduced costs of $60 million.
- The CRC's National Remediation Framework (NRF), which has recently been recognised by the Heads of EPAs, ensures consistent best practice approaches to contaminated site clean-up across all Australian states and territories. The Framework will make it easier to identify the sites needing remediation, provide advice on the most effective clean-up approaches, and create certainty for companies and regulators nationally. These benefits will drive savings across the remediation sector. The efficiencies gained are forecast to deliver a minimum 5% reduction in total costs, amounting to more than $200 million through to the end of the 15-year impact period.

INNOVATIVE ASSESSMENT, MONITORING AND REMEDIATION TECHNOLOGIES

In addition to the knowledge harnessed from significant and comprehensive research that has been translated into public policy, the CRC has delivered a range of highly innovative remediation strategies and technologies

Innovative remediation technologies developed by CRC CARE are forecast to provide nearly $1 billion of savings for industry and government by 2026.

CRC CARE has conceived and developed a wide range of assessment, monitoring and remediation technologies. These are trademarked and/or at an industry demonstration stage, with expected widespread uptake beyond the life of the CRC.

Examples include:

- matCARE™ and pfasCARE™ for PFAS remediation
- astkCARE™ for PFAS detection and analysis
- pooCARE™, developed at CRC CARE's China node, for piggery waste remediation and biofuel production
- leadCARE™ for in-situ remediation of lead-contaminated soils at shooting ranges and munitions facilities
- Permeable reactive barriers and other technologies for groundwater contamination.

These technologies have provided substantial benefits to CRC partners and end users, with anticipated further uptake expected to generate for industry and government cumulative benefits of over $950 million through to the end of the 15-year impact period.

The CRC has continued to develop, trademark and is in the process of licensing further technologies with flow-on benefits to other industries. An example of this is probeCARE™ for real-time, in-situ detection of metal ions in water, with applications for crop management. The forecast annual savings to greenhouse growers through more efficient fertiliser management amount to $2.5 million p.a. nationally with additional benefits in improved productivity of crops and potential savings in wastewater monitoring and management.

CRC CARE HAS CREATED A SKILLED INDUSTRY WORKFORCE

By the end of its current funding term, CRC CARE will have completed more than 150 PhDs since it was launched in 2005. This is the most of any CRC to date and greatly exceeds our own targets:

- An estimated 40% of these graduates are, or will be, employed in industry-based roles and will achieve an earnings premium of $19,000 to $26,000 higher than comparable graduates. Cumulatively, this amounts to $4.7 million in additional earning power.[2]

- CRC CARE has driven substantial improvements in the skilled workforce available to service Australia's remediation and contamination needs across industries of national importance, and has significantly advanced remediation research capacity in the public sector.
- Furthermore, CRC CARE developed Site Contamination Practitioners Australia, a professional certification scheme (now operated by a third-party) that has contributed to a more skilled and professional industry. This in turn has resulted in benefits to site developers through reduced assessment times and reduced need for assessment rework. This scheme has resulted in an expected benefit of $63 million through to the end of the 15-year period.[3]

[2]In risk-adjusted net present value terms

[3]risk-adjusted net present value

STEWARDSHIP OF A RAPIDLY GROWING SECTOR, WITH MUCH MORE TO BE DONE

In the past two decades, the size of Australia's remediation industry has grown exponentially from around $300 million per year to more than $5 billion per year. Based on CIS's economic impact review, it is clear that a significant portion of this growth is directly linked to CRC CARE's activities since its launch in 2005. Had the CRC not existed, not only would Australia's remediation sector be smaller, less professional and less organised, but industry and government would also have borne substantially higher costs in their efforts to deal with contamination issues – costs that would compound into the future. Furthermore, and perhaps most importantly, the Australian people and environment would be exposed to greater and more persistent contaminant threats that they are now. Despite these achievements, Australia's legacy of more than 200,000 potentially contaminated sites and the constant recognition of emerging contaminants mean that much work remains to be done.

Background and context

In 2015, Consulting & Implementation Services (CIS) conducted the four-year midterm review of CRC CARE. CIS has been engaged to conduct a final review of CRC CARE's impact. The figures provided result from revision of existing modelling and new impact assessment based on consultations with industry and research CRC CARE stakeholders across the four research programs. The revised benefits have exceeded the expected benefits during the midterm review. Consultations indicated the successful delivery of outputs having been achieved, and the provided insight on the retrospective level of adoption of these outputs into industry. Consequently, the associated probability of achieving certain outputs and their usage in revised modelling have also been adjusted to reflect this more likely realisation of research translation.

CASE STUDY OF THE SUCCESSFUL COMMERCIALISATION OF CRC CARE RESEARCH OUTPUTS

matCARE™ – cleaning up PFAS contaminants

CRC CARE has worked closely with the Australian Department of Defence (DoD) to develop matCARE™ – a modified natural clay that irreversibly locks up potentially toxic PFAS in wastewater, groundwater and soil that have been contaminated as a result of firefighting foam use.

PFAS are extremely stable chemical compounds. Their stability gives them very useful properties for multiple industrial uses, including in firefighting foams, nonstick cookware, food packaging, insecticides, and waterproof and fire-resistant fabric. But this same property also means that they don't break down easily and therefore accumulate in the environment. They are now so widespread that almost every person on Earth has been exposed to PFAS and has them in their blood. PFAS can enter ecosystems and move up food chains, accumulating in animal and human tissue, including the liver and blood. They have been linked to bladder and liver cancer, endocrine disruption and developmental and reproductive toxicity (including neonatal mortality).

Many PFAS contaminated sites are located at and adjacent to firefighting training areas, especially at Air Force and commercial airports, country and metropolitan fire services, and industrial sites such as mining and petroleum facilities. In some cases, the chemicals have leached into groundwater, affecting residential areas and causing considerable community concern.

Working with DoD, CRC CARE has so far remediated on-site more than 2 million litres of wastewater at three RAAF bases, reducing annual clean-up costs by 90%. As a result of this success, the CRC has initiated commercialisation efforts. Although these are still at an early stage, we have already performed commercial clean-up operations for Airservices Australia at one civilian airport. The CRC is also in discussions with a commercial resources company regarding supplying the raw matCARE™ clay. CRC CARE plans to expand its commercialisation and marketing activities in 2019/20, and to this end has commissioned a marketing agency to carry out a pilot campaign to test national and international markets.

In 2018/19, the CRC developed a related product, nano-matCARE™. This employs a nanoparticle slurry of the matCARE™ modified clay material, which can be applied to contaminated concrete (such as the slabs often found at fire training sites) to immobilise the PFAS molecules and prevent them from leaching into the surrounding soil or groundwater. The CRC is investigating the potentially significant untapped market for this application.

9.2. CRC CARE'S IMPACT ON INDUSTRY COLLABORATION

BREAKDOWN OF PARTICIPANTS AND COLLABORATIONS OVER THE LIFE OF THE CRC

As well as working closely with its 29 Participants, CRC CARE has a strong record of collaboration with research and industry partners both in Australia and internationally. The following table lists our non-Participant collaborators over the current funding period (for our current list of Participants, see page 25).

NATIONAL	
Organisation name	Organisation type
AECOM	Industry/private sector
Ramboll Australia	Industry/private sector
Spotless Australia	Industry/private sector
Richmond Dairies	Industry/private sector
Norco Foods	Industry/private sector
Thiess Services (now Ventia)	Industry/private sector
Coffey Environments	Industry/private sector
URS (since acquired by AECOM)	Industry/private sector
Veolia	Industry/private sector
Australasian Land & Groundwater Association	Industry representative body
South East Water	Water authority
Melbourne Water	Water authority
Gippsland Water	Water authority
Western Water	Water authority
SA Water	Water authority
Airservices Australia	Australian Government
WA Department of Health	State government
NSW EPA	State government
NT EPA	State government
ACT EPA	State government
TAS EPA	State government
NSW Department of Planning, Industry and Environment	State government
SA Health	State government
Minerals Research Institute of WA	State government/research
Salisbury Council, SA	Local government
Brisbane City Council, QLD	Local government
Kogarah City Council, NSW	Local government
Richmond Valley Council, NSW	Local government
James Cook University	University

INTERNATIONAL		
Organisation name	Organisation type	Country
Dhaka University	University	Bangladesh
Environment and Climate Change Canada	Government	Canada
Huazhong University of Science & Technology	University	China
Nanjing University	University	China
Shaoguan University	University	China
Chinese Academy of Sciences	Government/research	China
Ecology Institute of the Shandong Academy of Sciences	Government/research	China
Jiangxi Nuclear Industry Geological Bureau	Government/research	China
Mull and Partners gmbh	Industry/private sector	Germany
Ostfalia University of Applied Sciences	University	Germany
Wismar University	University	Germany
RUBIN (German Permeable Reactive Barrier Network)	Industry/private sector	Germany
Indian Institute of Soil Science (Indian Council of Agricultural Research)	Government/research	India
Indian Institute of Technology	University	India
Tamil Nadu Agricultural University	University	India
Pandit Deendayal Petroleum University	University	India
Bharatiar University	University	India
PSG Institute of Technology	University	India
University of Rome Tor Vergata	University	Italy
Graduate School for the Creation of new Photonics Industries	Research	Japan
Kangwon National University	University	Korea
Gyeongnam National University of Science & Technology	University	Korea
HUNIC, the Hub University of Industrial Collaboration	University	Korea
Alterra Research Institute at Wageningen University and Research Centre	Research	Netherlands
Contec Global Agro Ltd	Industry/private sector	Nigeria
University of Lagos	University	Nigeria
National University of Singapore	University	Singapore
Hub University of Industrial Collaboration	University	South Korea
Instituto de Recursos Naturales y Agrobiología de Sevilla (Spanish National Research Council)	Government/research	Spain
Stockholm University	University	Sweden
National Taiwan University	University	Taiwan
US Environmental Protection Agency, Maine	Government/regulatory	USA
Interstate Technology & Regulatory Council	Regulatory	USA
Brown University	University	USA
Lancaster University	University	UK
Cranfield University	University	UK
University of Leeds	University	UK
University of Nottingham	University	UK
British Geological Survey	Government/research	UK
Land Quality Management Ltd	Industry/private sector	UK
Thai Nguyen University of Agriculture and Forestry	University	Vietnam

NUMBER OF PUBLICATIONS PUBLISHED WITH/FOR PARTICIPANTS DURING THE AGREEMENT PERIOD			
Year	Public	Confidential^	Total
2020/21	0	1	1
2019/20	27^^	15	42
2018/19	4	15	19
2017/18	2	11	13
2016/17	8	14	22
2015/16	4	9	13
2014/15	3	6	9
2013/14	7	11	18
2012/13	2	13	15
2011/12	7	8	15
Total	64	102	**167**

^Some reports are kept confidential at the Participants' request for commercial reasons.

^^Includes the 25 NRF guidance documents.

NUMBER OF PEER-REVIEWED ACADEMIC PUBLICATIONS DURING THE AGREEMENT PERIOD

CRC CARE-supported researchers published nearly 1,000 peer-reviewed papers in academic journals, as well as more than 50 book chapters and 8 books. These publications build on the global body of knowledge on contamination science and underpin our end-user focused guidance and technology development.

NUMBER OF PUBLICATIONS PUBLISHED WITH/FOR PARTICIPANTS DURING THE AGREEMENT PERIOD			
Year	Journal papers	Books	Book chapters
2020/21	71	0	3
2019/20	46	1	4
2018/19	68	0	4
2017/18	103	0	4
2016/17	129	0	7
2015/16	120	1	7
2014/15	111	1	5
2013/14	128	3	5
2012/13	112	2	13
2011/12	105	0	2
Total	993	8	**54**

INDUSTRY GROWTH CENTRES WITH WHICH CRC CARE WORKED DURING THE AGREEMENT PERIOD

CRC CARE has worked with National Energy Resources Australia (NERA) on two projects:

- Weathered petroleum hydrocarbons (silica gel clean-up)
- Guidance for LNAPL natural source zone depletion (NSZD).

THE VALUE THAT PARTICIPANTS PLACE ON BEING PART OF CRC CARE

CRC CARE sought statements from four key Participants:

- **GHD Pty Ltd**, one of the world's leading professional services companies operating in the global market sectors of water, energy and resources, environment, property and buildings, and transportation. GHD represents the environmental consulting industry, whose role is to manage and clean up contaminated sites.
- **South Australian Environment Protection Authority** (SA EPA), representing government environmental regulators.
- **Australian Department of Defence** (representing industry in the sense that they are owners of contaminated sites, which need to be remediated).
- **Australian Institute of Petroleum** (representing the petroleum and oil industries).

GHD statement

We see it to be very important to be a participant in CRC CARE, and also for CRC CARE to exist. In terms of being a participant, it gives us an opportunity to participate in leading edge research in collaboration with leading scientists and policy makers, particularly in our case in the preparation of guidance on new approaches and thinking in the industry, and for the increased capability that this provides to our company and its ability to win work and provide effective services to our clients. It also promotes our company's involvement in activities that are associated with the CRC, such as conferences, seminars and meetings, and benefiting from the learning and networking opportunities that flow from this.

All in all, we consider that our involvement in CRC is important and essential, that the investment (both in cash and in kind) that we make in this is well spent, that we have obtained significant value from being a participant and that it has significantly contributed to the success of our business in this field of endeavour. With regard to the importance to the industry more generally: we consider that CRC CARE has made a significant contribution in advancing the industry. We consider that, if CRC CARE did not exist, the field would be significantly held back, the industry would not be able to respond as effectively and efficiently to the contamination problems that it faces, and there would be a significantly greater cost to our community in dealing with contamination problems.

Dr Peter Nadebaum, *Principal and Senior Technical Director – Environment*

SA EPA statement

CRC CARE has played a crucial role in strengthening the response to contaminated environments, through supporting policy development, pursuing technology R&D, and capacity building, providing leadership both here in Australia and with international site contamination networks. CRC CARE's guidance development work is based on a collaborative approach with regulators and practitioners, with the goal of improving assessment, remediation and management of site contamination using leading edge approaches across national and international jurisdictions.

Cash contributions alone from EPAs have leveraged substantial co-investment from CRC CARE to deliver national site contamination guidance and robust and innovative solutions to serious site contamination problems and issues identified by end-users. Over the past 13 years, EPAs including the WA Department of Water and Environment Regulation have contributed $2.25 million into projects worth $12.43 million. This equates to a leverage of 5.5 times the investment. There has also been significant in-kind investment from senior technical staff of EPAs from across the country.

CRC CARE has enabled the South Australian EPA to deliver work at best practice, to collaborate with international researchers and to rely on world class technical documents that have been adopted nationally. That is, the benefits of working with CRC CARE have been significant.

Andrew Pruszinski, *Manager Site Contamination*

Australian Institute of Petroleum statement

The Australian Institute of Petroleum (AIP), and its members (BP, Caltex, Mobil and Viva Energy), have benefited substantially from CRC CARE since becoming a foundation participant. The CRC's Petroleum Demonstration Program was created to address policy issues related to the assessment, risk characterisation and remediation of sites contaminated with petroleum hydrocarbons and related compounds. AIP has also benefited from other CRC CARE programs, including its world-leading research on the management and remediation of per- and poly-fluoroalkyl substances (PFAS). AIP's engagement with the CRC has been extremely valuable to the petroleum industry while also delivering excellent outcomes for other industries, government, the environment and human health.

Paul Barrett, *CEO*

Department of Defence statement

See next page.

Department of Defence statement

UNCLASSIFIED

Australian Government
Department of Defence
Estate and Infrastructure Group

Dr Mark Bowman
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ASEE-ID/OUT/2019/BS3917868

Professor Ravi Naidu
Cooperative Research Centre
Contamination Assessment & Remediation of the Environment
University of Newcastle
Callaghan, NSW, 2308

Dear Ravi,

Statement from the Department of Defence for CRC CARE II Exit Report

The Department of Defence has been a partner with CRC CARE since the first agreement in 2003. Over that time we have had a close working relationship with Professor Ravi Naidu and his dedicated research teams achieving many positive outcomes for Defence. Through the CRC CARE research efforts, we have been able to better understand the fate and transport of contaminants in the environment and apply practical risk based solutions to many of our challenging contaminated sites across our estate.

CRC CARE has also supported us in other aspects of contaminated land management and we would particularly like to mention their education and training program. CRC CARE has trained many Defence personnel in aspects of contaminated land management thereby increasing our capacity to be an informed buyer of services from our industry partners. In a reciprocal way we have also been able to build capacity within CRC CARE by imparting knowledge of managing Defence specific contaminants and provide access to real world examples to validate research outcomes.

The value we place on our relationship with CRC CARE is evidenced by our participation in two agreements and our continuing support of the CRC model. Your efforts to bring together the diversity of participants from industry, government and academia, to create a centre of excellence, sharing knowledge for the common good, is exceptional. The Department of Defence has benefited by our relationship with CRC CARE.

Yours sincerely,

Dr Mark Bowman
Director Contamination Assessment & Remediation Management
Environment and Engineering Branch

19 August 2019

CASE STUDIES ILLUSTRATING HOW PARTICIPANTS WORKING TOGETHER LED TO AN IMPACT THAT WOULD NOT HAVE BEEN ACHIEVABLE WITHOUT THE CRC COLLABORATION

1. Risk-based remediation and bioremediation of contaminated soil for BHP in WA

To remediate hydrocarbon-contaminated soil at multiple sites in the Pilbara, WA, BHP was required to meet regulatory criteria that were practicably unachievable in the local environmental conditions. Accordingly, the size and cost of BHP's landfarms (areas of contaminated soil where contaminants undergo microbial degradation) were growing rapidly. At one site alone, the assessment and management costs were around $600,000 per year and rising. BHP commissioned CRC CARE to develop a risk management framework that ensured no increase in risk to people or the environment. This was presented to and subsequently endorsed by the WA regulator. In addition, CRC CARE and BHP trialled bioremediation through 'biopiling' – piling contaminated soil in conditions that allow microbial activity to reduce concentrations of contaminants – as a means to attain contaminant concentrations that met risk criteria. This was achieved in less than three months (half the originally predicted time). Over the life of the affected mines, port and railways, the CRC's approach has reduced treatment costs to less than 30% compared with previous methods, saving BHP millions of dollars and achieving a better result for the environment.

This outcome would have been virtually impossible if not for CRC CARE's ability to: (a) bring together stakeholders from all sectors; and (b) ensure that guidance on contaminated site assessment and remediation is underpinned by robust science, such that it is acceptable to all parties.

Key collaborating organisations:

- BHP (site owner; CRC Participant)
- WA Dept of Water & Environment Regulation (state government regulator; CRC Participant)
- UniSA (research partner; CRC Participant)
- Centrals (civil engineering – responsible for constructing the biopile)
- JBS&G (environmental consulting; CRC Participant)
- Otek (now Fyfe – environmental consulting).

2. Health screening levels for petroleum hydrocarbons

Much of CRC CARE's guidance – which is developed in collaboration with EPAs, contaminated site owners, and the environmental consulting sector – has been incorporated into national legislation. A prime example of this is the development of CRC's HSLs for total petroleum hydrocarbons (TPHs), which provide a minimum concentration of contaminant that triggers further action (including monitoring and clean-up). The TPH HSLs were included in the National Environment Protection (Assessment of Site Contamination) Measure ('the ASC NEPM'), ensuring that they were adopted by all Australian regulators. By ensuring that limited resources are committed only to contamination that represents an environmental or human health threat, this work has already resulted in, and will continue to allow, substantial reductions in remediation costs for the mining, petroleum, defence and other sectors. The CRC's recent environmental impact review estimated total benefits to Australian industry and government so far amount to $1.3 billion.

Collaboration was crucial to the success of this initiative: for HSLs to be developed and applied, comprehensive understanding and agreement was required on multiple fronts, including health impacts, regulatory implications, and analytical approaches and clean-up approaches.

Key collaborating organisations:

- GHD (environmental consulting; co-developed the HSLs)
- CSIRO research partner; CRC Participant
- All state and territory EPAs (regulators; Victoria, SA, WA, Queensland as CRC Participants)
- Federal and State health departments
- Site owners (Participants): Rio Tinto, AIP (representing BP, Caltex, Mobil and Shell), Chevron
- Research partners: Monash University, University of Technology Sydney, University of South Australia, University of Queensland (all Participants except for Monash University)
- Analytical labs: ALS, Envirolab, NMI (a CRC Participant).

3. A National Framework for Remediation and Management of Contaminated Sites in Australia

CRC CARE's National Remediation Framework (NRF) was endorsed as best practice by the Heads of EPAs in October 2019. Launched in June 2020, the NRF currently comprises 25 guidance documents and an Excel-based cost-benefit and sustainability analysis tool, all of which are freely available via the NRF website (www.remediationframework.com.au). Users also have free access to a suite of associated resources including relevant CRC CARE Technical Reports.

"HEPA is pleased to endorse the National Remediation Framework as best practice"
Letter from Heads of EPAs Australia & New Zealand, 8 November 2019

The NRF, which harmonises approaches to contaminated site clean-up across all Australian states and territories, is forecast to deliver a minimum 5% reduction in total costs, amounting to more than $200 million through to 2026.

The NRF is based on existing guidance, expertise and hard-won experience, and provides practical guidance for both the remediation of contaminated sites and the long-term management of remediated sites. Its development was overseen by the NRF Steering Group, which comprises senior representatives from industry, government and communities.

Any attempt at an NRF would have been doomed to fail if it did not have widespread support from its target users. Such support is predicated on all stakeholder groups having the opportunity to contribute to the NRF's development – as was achieved via the NRF Steering Group. It is fair to say that CRC CARE is the only organisation with sufficient established networks and trust across all relevant sectors to be able to bring together stakeholders to develop such a significant, sorely needed and widely accepted resource. HEPA recognised the significant efforts of CRC CARE to deliver the framework, mentioning that it is a "significant body of work" and that it is a "considerable achievement to finalise 25 guidelines" after "extensive consultation".

"ALGA considers that the NRF is a valuable document in providing guidance on the requirements for remediating contaminated land and groundwater in Australia. It will assist in achieving a more consistent approach to remediation of contaminated land and groundwater across the various Australian jurisdictions. As such, ALGA sees that the preparation of the document is to be applauded..."
Australasian Land & Groundwater Association

Feedback on the NRF has been very positive to date, with clear evidence that contaminated land professionals are using the resource widely. From launch until 30 June 2021, the 25 NRF guidelines plus around 50 associated resources have been downloaded more than 46,000 times.

9.3. IMPACT OF EDUCATION PROGRAMS ON INDUSTRY, THE SECTOR, AND SKILLS DEVELOPMENT

POSTGRADUATE INFORMATION OVER CRC CARE'S CURRENT TERM OF FUNDING

Total number of postgraduates and PhD graduates

From the start of its second term of funding in July 2011 until 30 June 2021, CRC CARE has had a total of 101 graduates, including:

- 14 Honours
- 6 Masters
- 82 PhDs

One PhD student is due to complete his studies by 30 June 2022. When the CRC's first term of funding is included, the total number of PhD students exceeds 160.

Total number of postgraduates taking up employment in the industry

The CRC's recent economic impact review, conducted by CIS, estimated that 40% of our graduates are, or will be, employed in industry-based roles and will achieve an earnings premium of $19,000 to $26,000 higher than comparable graduates. Cumulatively, this amounts to $4.7 million in additional earning power for these graduates.

At the time of writing, at least 4 honours, 14 PhD graduates and 1 PhD student were employed by industry, with the majority of the remainder working for universities on end-user projects.

THE KEY EDUCATIONAL OUTPUTS, INCLUDING DETAILS OF ANY COURSES DEVELOPED

CRC CARE education and training

Since the start of its current term of funding in 2011, CRC CARE has conducted more than 60 conferences, workshops, seminars, webinars and symposia, with a total of almost 10,000 Participants. A number of these have supporting educational resources, including the ASC NEPM and petroleum hydrocarbon HSLs. The CRC has published almost 50 technical guidance documents that are available for free download from the CRC CARE website. A CRC CARE educational book on community engagement, *Engaging the community: a handbook for professionals managing contaminated land*, is also available for sale. The CRC also played a significant role in the development of the University of Newcastle's Masters in Environmental Risk Assessment and Remediation course.

EDUCATION AND TRAINING EVENTS				
Event name	Type of event	Location	Month	Number of Participants
2020/21				
1. From Risk to Remediation 2020: CRC CARE Online Masterclass on Contaminated Site Assessment, Management and Communication	Course	Online	July/August	99
2. Online Masterclass: LNAPL NSZD	Workshop	Online	October	111
3. CleanUp Emerging Contaminants Symposium 2021	Webinar	Online	March	63
2019/20				
4. Vapour Intrusion Online Workshop	Workshop	Online	June	116
5. 8th International Contaminated Site Remediation Conference (CleanUp 2019)	Conference	Adelaide	September	700
6. CleanUp Korea 2019	Conference	Seoul, Korea	December	150
7. Launch of the NRF	Webinar	-	June	300
8. Impact of COVID-19 on the contaminated land sector	Webinar	-	May	195
9. Petroleum hydrocarbon risk assessment in the 2020s.	Webinar	-	February	56
2018/19				
10. Human Health Risk Assessment	Workshops (3)	Perth, Melb, Syd	June	37
11. Mined Land Rehabilitation Conference 2019	Conference	Newcastle	June	285
12. From Risk to Remediation 2019: CRC CARE Summer School on Contaminated Site Assessment, Management and Communication	Workshop	Newcastle	March	62
13.National Remediation Framework Roadshow	Seminars / Q&A (8)	All capitals	February	300
14. Establishing remediation Objectives, Performing Cost-Benefits and Sustainability Analysis	Workshop	Perth	November	9
15. Principles of Remediation Costing	Webinar	-	November	30
16. 1st Global CleanUp Congress	Conference	India	October	350
17. Assessment and management of benzo[a]pyrene-contaminated land	Webinar	-	September	37
18. Societal Perception and Acceptance of Remediation Technologies (SPART)	Workshop (2)	Perth, Syd	September	12
19. Comprehensive and Innovative guidance for DNAPL site characterisation and remediation	Workshop (2)	Melb, Syd	August	11
20. Technical and Regulatory Issues resulting from the use of PFAS contaminated sites	Workshop (2)	Melb, Syd	August	47
21. Designing a site Investigation from conceptual model to sampling and analytical strategy	Webinar	-	August	21
2017/18				
22. Contaminated Land Management of Local Governments	Webinar	-	May	22
23. Emerging Contaminants – What are they and what do we do about them?	Webinar	-	May	41
24. Human Health Risk Assessment	Workshops (5)	Adel, Melb, Syd, Bris, Perth	March	64
25. The NRF – What's new and what to expect in 2018	Webinar	-	March	44
26. CleanUp 2017 Conference	Conference	Melbourne	September	650
27. LNAPL NSZD	Workshop	Sydney	August	17
28. LNAPL NSZD	Workshop	Perth	August	13
2016/17				
29. CleanUp Indonesia 2017	Conference	Bandung, Indonesia	May	100
30. Human Health Risk Assessment	Workshops (5)	Adel, Melb, Syd, Bris, Perth	March	93
31. CleanUp India 2016	Conference	Coimbatore, India	December	540
32. Dealing with Derelict Mines 2016 – International Summit on Derelict Mines	Conference	Singleton	December	99
33. CleanUp Conference in China 2016	Conference	Beijing, China	October	575
34. PFAS Contamination from AFFFs: Toxicity, Sampling, Remediation and Management	Workshop (5)	Adel, Melb, Syd, Bris, Perth	September	135
35. Guidance on Methyl Tert-Butylene (MTBE) in Groundwater	Webinar	-	August 2016	44
36. Statistics for Environmental Practitioners	Workshop	Melbourne	July	9
37. Statistics for Environmental Practitioners	Workshop	Sydney	July	19

EDUCATION AND TRAINING EVENTS				
Event name	Type of event	Location	Month	Number of Participants
2015/16				
38. Risk Ranking of Contaminated Sites	Webinar	-	June	64
39. Life Cycle of Petroleum Biodegradation Metabolite Plumes and Implications for Risk Management at Fuel Release sites	Webinar	-	February	78
40. Environmental Forensics – Utilisation of Established and Evolving Techniques	Workshop	Sydney	November	13
41. CleanUp 2015	Conference	Melbourne	September	650
2014/15				
42. National Workshop on Nuclear Energy for Australia	Workshop	Adelaide	June	28
43.Analysis, Management and Remediation of LNAPL in Australia	Workshops (5)	Adel, Melb, Syd, Bris, Perth	May	69
44. Who do People Trust? A Resident's perception of Risk communication on Industrial Contamination	Seminar/ webinar	Adelaide + national	May	31
45. Recent Advances in Risk Assessment for Mixed Contaminants	Seminar/ webinar	Adelaide + national	April	46
46. Recent Advances in the Measurement Accuracy for Total Recoverable Hydrocarbon Analysis	Workshop	Sydney	November	15
47. Launch of Site Contamination Practitioner Australia Certification Scheme	Seminar/ webinar	Adelaide + national	November	116
48. Acid Sulfate Soil: The World's Nastiest Soil	Seminar/ webinar	Adelaide + national	October	33
49. DNAPL and LNAPL workshops	Workshops (2)	Melb, Syd	October	59
50. Best practice approaches for ensuring successful bioremediation outcomes	Seminar/ webinar	Adelaide + national	September	15
51. Communicate 2014	Conference	Adelaide	September	107
52. Biogas Basics Seminar	Seminar	Adelaide	August	13
53. A unified approach for the analysis, management and remediation of LNAPL in Australia	Seminar/ webinar	Adelaide + national	August	37
54. Technical writing workshop	Workshop	Adelaide	July	31
2013/14				
55. A technical guide for demonstrating monitored natural attenuation of petroleum hydrocarbon in groundwater	Seminar	Adelaide	June	99
56. Contaminants of emerging concern	Seminar	Adelaide	May	93
57. National Remediation Framework	Seminar	Adelaide	April	175
58. Certification of Site Contamination Practitioners Scheme	Seminar	Adelaide	March	221
59. CleanUp 2013	Conference	Melbourne	September	600
2012/13				
60. ASC NEPM Roadshow	Workshops (8)	All capitals	May	620
61. Unlocking soil's secrets to open the door to agricultural productivity gains	Symposia (4)	Syd, Bris, Adel, Perth	November	195
62. All State and Territory capitals Petroleum Vapour Intrusion assessment	Workshops (3)	Syd, Melb, Perth	October	200
63. International Workshop on the Risk Assessment of Manufactured Nanomaterials	Workshop		October	69
64. Communicate 2012	Conference	Adelaide	September	122
2011/12				
65. Health-based screening levels for petroleum hydrocarbons	Workshops (5)	Perth, Syd, Adel, Bris, Melb	November	202
TOTAL NUMBER OF PARTICIPANTS				**9,457**

THE IMPACT OF EDUCATION AND TRAINING PROGRAMS IN AREAS OF SKILL SHORTAGES

CRC CARE tailors its education and training program around industry, government and academia needs, particularly where skill shortages exist. Examples include:

National Remediation Framework training

CRC CARE led the development of a national framework for the remediation of contaminated sites (NRF), which aims to achieve greater certainty in environmental outcomes and promote consistent implementation of guidance across Australia. The NRF, which was recognised and supported by the Heads of EPAs in October 2019, will complement ASC NEPM. In performing the role of national harmonisation, the NRF effectively identifies areas of skill shortage. In response to this, CRC CARE ran a series of workshops that focus on NRF-related topics, including: establishing remediation objectives; performing cost-benefit and sustainability analyses; and stakeholder engagement. Furthermore, as part of the consultation process, the CRC held an NRF roadshow that included presentations and Q&A sessions in all State and Territory capital cities in February 2019. With the NRF officially launched in June 2020, CRC CARE is planning a modular course based on the components of the framework.

Management of PFAS-contaminated sites

In recent years, a class of chemicals known as per- and poly-fluoroalkyl substances (PFAS) have emerged as contaminants of concern, especially at fire-training sites where years of use of firefighting foams that contain PFAS have resulted in soil and groundwater contamination. As is the case with most so-called emerging contaminants, industry and government have limited understanding of the effects of PFAS and how to clean it up. CRC CARE has been a leader in developing knowledge of and tools for PFAS remediation. One of our roles in this area has been to host a series of workshops around the country on *Technical and regulatory issues resulting from the use of PFAS* and *PFAS contamination from AFFFs: toxicity, sampling, remediation and management*.

SCP Australia professional certification scheme

During its current term of funding, CRC CARE worked with industry-wide stakeholders to develop, launch and manage Site Contamination Practitioners Australia (SCP Australia) – Australia's first certification scheme for contaminated site professionals. SCP Australia aimed to improve the professionalism of the industry as a whole by using a recognised certification process to ensure that those dealing with contaminated site issues have the necessary level of knowledge, expertise and skill. The impetus for creating SCP Australia was wide recognition that there was an unacceptable level of variation in the quality of and approach to contaminated site management among practitioners in the private sector.

In 2018/19, SCP Australia merged with the Environment Institute of Australia and New Zealand Certified Environmental Practitioner scheme to allow certification to be directly managed by the sector and ensure the initiative's enduring future. While it operated under CRC CARE's management, SCP Australia awarded 77 certificates and attracted 183 subscribers.

LNAPL NSZD for cost-effective contaminated site management

Research led by CRC CARE and supported by NERA has found that allowing LNAPLs to degrade naturally via NSZD is often the most effective approach for remediating sites contaminated with petroleum hydrocarbons, particularly after 3-5 years of active remediation. Applying this world-first research will deliver improved environmental outcomes and potentially save end users $320 million over the next 10 years through more effective remediation. The results of the study, which compared six contaminated sites across Australia, are presented for environmental professionals in three CRC CARE Technical Reports, available for free download:

- CRC CARE Technical Report 44: *Technical measurement guidance for LNAPL natural source zone depletion*
- CRC CARE Technical Report 46: *The role of NSZD in the management of LNAPL contaminated sites*
- CRC CARE Technical Report 47: *Australian case studies of LNAPL NSZD rates compared with conventional active recovery efforts.*

To help industry adopt the findings of the research, CRC CARE and NERA are running a self-paced online course that covers the science of LNAPL NSZD, including measurement and options for incorporating NSZD into LNAPL conceptual site model development and site management strategies.

NEPM Roadshow

See case study below.

CASE STUDY THAT ILLUSTRATES HOW CRC CARE EDUCATION PROGRAMS HAVE INFLUENCED THE UPTAKE OF NEW KNOWLEDGE, PRODUCTS OR PROCESSES

ASC NEPM Roadshow

The NEPM is the national guideline on contaminated land assessment in Australia. It was first released in 1999, and was varied in May 2013. CRC CARE contributed to the variation of the ASC NEPM by developing guidelines on a range of issues, including PHs (particularly focusing on human health–based screening levels and site characterisation).

In May 2013, when the varied NEPM was released, CRC CARE, in partnership with state EPAs, organised a national roadshow to provide regulators, site assessors, consultants, environmental auditors, landowners, developers and industry practitioners with an opportunity to come together and gain an understanding of the changes, new elements, and implementation of the NEPM. Members of the NEPM variation team, along with the technical experts involved in developing guidance for inclusion into the NEPM Schedules, presented the changes and identified new aspects of the amended NEPM.

The workshops aimed to help people involved in the industry to interpret the guidance so as to enable its uptake and application. Local EPA representatives also presented on the transition and implementation plans relevant to their jurisdiction. A total of 620 delegates attended the roadshow, which spent two days in each State and Territory.

The varied NEPM has had a major impact on contaminated site assessment nationally, helping to save millions of dollars annually in site assessments alone. The CRC CARE roadshow played a significant role in in educating the environmental professional sector and building the capacity of Australian contaminated land industry. To further support the roadshow, a DVD of the workshop presentations was made available via the CRC CARE web site and YouTube.

9.4. SNAPSHOT SUMMARY

Chemical contamination of the environment, and its threat to human health, is one of the most intractable problems facing all nations. Conservative estimates suggest that there are more than 5 million potentially contaminated sites globally that threaten the wellbeing of hundreds of millions of people and ecosystems globally, including more than 200,000 in Australia. Since its launch, CRC CARE has performed ground-breaking research, developed innovative technologies, and provided practical guidance to tackle this challenge. CRC CARE is a unique in the contaminated site sector as the only body globally that brings together government, regulators, industry, contaminated site owners, environmental practitioners, research, science, and engineering.

CRC CARE's influence on Australia's approach to contaminated sites has:

- allowed all stakeholders – industry, government, research and community – to work together to solve problems in more transparent, efficient and cost-effective ways
- driven a shift to a risk-based, in-situ approach to managing contaminated sites – cleaning up contamination where it lies, rather than the traditional 'dig and dump'
- demonstrated that contaminants only pose a risk if they can be absorbed by humans, animals and plants, leading to more rational, effective and affordable clean-up
- supported exponential growth in the Australian remediation industry from $300 million per year in 2005 to over $3 billion per year now
- boosted Australia's global standing in the contaminated land sector through education and training.

MAJOR ACHIEVEMENTS

- *Economic benefit for Australia:* CRC CARE's industry guidance and policy insights coupled with risk-based management of, and new insights into, both conventional and emerging contaminants (including PFAS) allows limited resources to be directed to where they are needed most. CRC CARE's work has saved its industry Participants millions of dollars annually. A 2019 economic impact review estimated that spread across the entire sector this amounts more than $5.4 billion of economic benefit to Australia – a return of more than $8.50 on every dollar invested by government and industry.
- *A national approach to best practice clean-up:* CRC CARE's National Remediation Framework (NRF) was endorsed as best practice by the Heads of EPAs in October 2019. Launched in June 2020, the NRF currently comprises 25 guidance documents and an Excel-based cost-benefit and sustainability analysis tool, all of which are freely available via the NRF website (www.remediationframework.com.au). The NRF, which harmonises approaches to contaminated site clean-up across all Australian states and territories, is forecast to deliver a minimum 5% reduction in total costs, amounting to more than $200 million through to 2026. Feedback on the NRF has been very positive to date, with clear evidence that contaminated land professionals are using the resource widely. From launch until 30 June 2021, the 25 NRF guidelines plus around 50 associated resources have been downloaded more than 46,000 times.

- *Improving the national approach to managing PFAS contamination:* In recent years, there has been a steep increase in community concern over contamination of soil and water with PFAS, a component of some firefighting foams. CRC CARE's best practice strategies and guidance for managing PFAS-contaminated sites have improved the national effort to assess and remediate these high-priority emergent contaminants. The CRC's work, which complements and informs the PFAS National Environmental Management Plan, has delivered significant direct economic benefits for industry. According to the CRC's recent economic impact review, this includes more than $200 million through reduced need for remediation of PFAS that – based on the CRC CARE's risk-based approach – does not pose an environmental or health threat. In addition, sectors relying upon PFAS clean-up are now able to commence or accelerate project operations on this land, reducing their costs of development and spurring new economic activity. In 2018/19, the CRC CARE published Practitioner guide to risk-based assessment, remediation and management of PFAS site contamination. Freely available via the CRC's website (www.crccare.com/knowledge-sharing/pfas-practitioner-guide), this guide details current best practice in this area. This guideline is also available via the NRF website, from where it was downloaded more than 2,000 times in 2020/21.

RESEARCH

- *Restoring wetlands devastated by acid sulfate soils*: CRC CARE's work on innovative acid sulfate soil remediation at East Trinity, Queensland, turned badly acidified land into a place where mangroves, native birds and other wildlife again flourish. The 774-hectare site became an environmental disaster in the 1970s after being drained to create a sugarcane farm. The CRC optimised a remediation approach known as lime-assisted tidal exchange (LATE). Compared with conventional methods, which would have used nearly $80 million in lime alone, LATE reduced lime use to less than 5% of the original requirements. Accordingly, the CRC has provided a blueprint for the affordable rejuvenation of similarly affected wetlands globally.
- *Driving innovative clean-up technologies:* The Global Centre for Environmental Remediation (GCER) at the University of Newcastle, Australia, is the engine room for the development of CRC CARE's innovative contamination clean-up technologies. State-of-the-art laboratories allow CRC CARE-supported researchers to carry out research that is only possible at a small handful of labs worldwide.

COMMERCIALISATION AND UTILISATION

- *Health screening levels for petroleum hydrocarbons mean huge savings for industry:* CRC CARE developed HSLs for total petroleum hydrocarbons, which provide a minimum concentration of contaminant that triggers further action (including monitoring and clean-up). The HSLs were included in the National Environment Protection (Assessment of Site Contamination) Measure ('the ASC NEPM'), ensuring that they were adopted by all Australian regulators. By ensuring that limited resources are committed only to contamination that represents an environmental or human health threat, this work has already resulted in, and will continue to allow, substantial reductions in remediation costs for the mining, petroleum, defence and other sectors. The CRC's recent environmental impact review estimated total benefits to Australian industry and government so far amount to $1.3 billion.

- *matCARE™ technology for remediating PFAS from firefighting foams:* Working with the Department of Defence (as well as Airservices Australia), CRC CARE developed matCARE technology to remediate PFAS contamination from firefighting foams. matCARE is a modified clay substance that irreversibly locks up PFAS molecules in contaminated soil, water or concrete. To date, the CRC has remediated on-site more than 3 million litres of wastewater, reducing annual clean-up costs by 90%.
- *Reducing BHP's environmental management costs and protecting human health:* To remediate hydrocarbon-contaminated soil at multiple sites in the Pilbara, WA, BHP was required to meet regulatory criteria that were practicably unachievable in the local environmental conditions. Accordingly, the size and cost of BHP's landfarms (areas of contaminated soil where contaminants undergo microbial degradation) were growing rapidly. At one site alone, the assessment and management costs were around $600,000 per year and rising. BHP commissioned CRC CARE to develop a risk management framework that ensured no increase in risk to people or the environment. This was presented to and subsequently endorsed by the WA regulator. In addition, CRC CARE and BHP trialled bioremediation through 'biopiling' – piling contaminated soil in conditions that allow microbial activity to reduce concentrations of contaminants – as a means to attain contaminant concentrations that met risk criteria. This was achieved in less than 3 months (half the originally predicted time). Over the life of the affected mines, port and railways, the CRC's approach has reduced treatment costs to less than 30% compared with previous methods, saving BHP millions of dollars and achieving a better result for the environment.
- *A better way to clean up shooting range soils:* Our improved technology for cleaning up shooting range soils contaminated with lead and other toxic metals has helped the Department of Defence clean up more than 100 tons of contaminated soil at major weapons ranges in WA and Queensland. The remediated soil is clean enough for reuse, while the economic value of the recycled lead offsets the cost of remediation.

SME ENGAGEMENT

- *Opening up opportunities for SMEs:* Small-to-medium enterprises (SMEs) have been major beneficiaries of CRC CARE's collaboration with industry. Commercialisation of CRC CARE technology along with the roll-out of its guidance on policies, procedures and protocols, have catalysed growth in Australian SMEs in the contaminated site sector and beyond. The growth of the sector over the past 20 years has delivered an attendant increase in employment and opened up unprecedented opportunities for SMEs in the environmental consulting sector – such as JBS&G, one of the CRC's Participants – to establish themselves and thrive. SMEs in other sectors, from development and construction to minerals and resources, also benefit through:
  - unlocking the productivity of billions of dollars of previously disused real estate at brownfield and other industrial sites such as derelict mines
  - improvements in contamination analysis and measurement that have created opportunities for analytical laboratories.
- *Raising the professionalism of the contaminated site remediation sector:* For many years there was widespread recognition that the contaminated site remediation sector suffered from a lack of standardisation and variable levels of professionalism. To address this, at the request of end users, CRC CARE initiated Site Contamination Practitioners Australia (SCP Australia) – the nation's first certification scheme for contaminated site professionals. SCP Australia was designed to improve:
  - outcomes for all stakeholders involved in the contaminated land industry
  - the professionalism of the industry as a whole by using a recognised certification process to ensure that those dealing with contaminated site issues have the necessary level of knowledge, expertise and skill.

The success of SCP Australia has been a major contributor to more consistent and higher standards throughout the sector. Recognised industry-wide, such certification benefits environmental consulting businesses by allowing them to demonstrate that their employees have achieved a minimum level of knowledge and skill. This has benefitted SMEs in particular by levelling the playing field and helping them compete with larger operators.

In 2018, after awarding 77 certificates and attracting 183 subscribers, SCP Australia merged with the Environment Institute of Australia and New Zealand's Certified Environmental Practitioner scheme. The two schemes were consolidated to allow certification to be directly managed by the sector and ensure the initiative's enduring future.

EDUCATION AND TRAINING

- *CleanUp conferences – world-leading knowledge exchange:* CRC CARE's CleanUp Conference series features the biennial International Contaminated Site Remediation Conference. In 2019, 700 delegates from more than 25 countries, representing industry, research and government, attended the 8th CleanUp Conference in Adelaide, Australia. The event included a program of professional development workshops, 260 oral presentations, 50 posters and the 2nd International PFAS Conference. CleanUp is considered one of the world's foremost forums for knowledge exchange on environmental contamination and its remediation.
- *Fostering the next generation of contamination science leaders:* In its current term of funding, CRC CARE has supported more than 70 PhD graduates. Since the CRC was launched in 2005, this figure exceeds 150. As well as representing a substantial proportion of all Australian PhD graduates in the field of contamination science, these students work directly with end users on real-world problems, ensuring that they enter the workforce 'industry-ready'. Further, the CRC's recent economic impact review estimated that 40% of CRC CARE graduates are, or will be, employed in industry-based roles and will achieve an earnings premium of $19,000 to $26,000 higher than comparable graduates. Cumulatively, this amounts to $4.7 million in additional earning power.

SPIN-OFF COMPANIES AND INVENTIONS

- *Real-time analysis of irrigation water for better crop management:* CRC CARE's probeCARE™ system allows farmers and agriculturalists to take real-time measurements of common ions (e.g. sodium, potassium and calcium) in irrigation water, providing vital information on water quality that informs decisions on crop management.
- *Faster, more cost-effective soil vapour analysis:* CRC CARE has developed a portable, retractable soil vapour bore for sampling volatile organic compounds in soil vapour from subsurface soils. The tool, named svbCARE™, improves the efficiency and speed of vapour intrusion assessments. Traditional methods are not as portable, involve lengthy installation, and require samples to be sent to a lab for costly analysis. When used in conjunction with portable GC-MS equipment, svbCARE allows 30 to 50 samples to be measured and analysed per day on site at greatly reduced cost, with results comparable to those of a commercial laboratory.

INTERNATIONAL ENGAGEMENT

- *Exporting Australian know-how to build capacity in China:* CRC CARE engages with organisations globally, with the most significant collaboration based in China via our China Program. The program is run in partnership with HLM Asia Group Ltd, Huazhong University of Science and Technology, Wuhan, and Shaoguan University, Guangdong. China Program highlights include:
  - Piggery waste remediation (pooCARE™) – piggery waste is a major source of environmental pollution in China. Developed in collaboration with HUST, pooCARE employs a specially designed bioreactor to convert pig waste into biogas and nutrient-rich fertiliser.
  - Using Hybrid giant Napier grass to remediate red mud, a highly alkaline waste generated during alumina production.
  - Clean-up of a lake contaminated with phosphate as a result of agricultural chemical runoff. This project combines Phoslock (a commercially available product that removes phosphates from water) with biofilm technology to manage eutrophication (excessive richness of nutrients, often because of fertiliser run-off) and algal blooms.

Via the China Program, CRC CARE also builds local capacity via numerous training opportunities for Chinese scientists and practitioners. In 2018/19, for example, 13 staff from Jiangxi Nuclear Industry Geological Bureau were hosted at GCER, University of Newcastle, to complete a three-month risk assessment and remediation training course.

10 GLOSSARY OF TERMS

ACLCA
Australian Contaminated Land Consultants Association

AFFF
Aqueous film-forming foam

AGM
Annual general meeting

AIP
Australian Institute of Petroleum

ALGA
Australasian Land & Groundwater Association

ASC NEPM
National Environment Protection (Assessment of Site Contamination) Measure

CEO
Chief executive officer

CRC
Cooperative Research Centre

CRC CARE
CRC for Contamination Assessment and Remediation of the Environment

COVID
Coronavirus disease

Cr(VI)
hexavalent chromium

CSIRO
Commonwealth Scientific and Industrial Research Organisation

DNAPL
Dense non-aqueous phase liquid

DoD
Department of Defence

EPA
Environment Protection Authority

ESL
Ecological screening level

FTIR
Fourier transform infrared

GCER
Global Centre for Environmental Remediation

GC-MS
Gas chromatography–mass spectrometry

HEPA
Heads of EPAs Australia & New Zealand

HSL
Health screening level

HUST
Huazhong University of Science and Technology

IP
Intellectual property

ITRC
Interstate Technology & Regulatory Council

LATE
Lime-Assisted Tidal Exchange

LNAPL
Light non-aqueous phase liquid

MoU
Memorandum of understanding

MP
Member of Parliament

NCSDP
National Contaminated Sites Demonstration Program

NERA
National Energy Resources Australia

NIER
Newcastle Institute for Energy and Resources

NMI
National Measurement Institute

NRF
National Remediation Framework

NSW
New South Wales

NSZD
Natural source zone depletion

NT
Northern Territory

PAHs
Polycyclic aromatic hydrocarbons

PCT
Patent Cooperation Treaty

PFAS
Per- and polyfluoroalkyl substances

PFHxS
Perfluorohexane sulfonate

PFOA
Perfluorooctanoic acid

PFOS
Perfluorooctanesulfonate

RAAF
Royal Australian Air Force

SA
South Australia

SCP Australia
Site Contamination Practitioners Australia

SCU
Southern Cross University

SME
Small-to-medium enterprise

TCE
Trichloroethylene

TPH
Total petroleum hydrocarbons

UK
United Kingdom

USA
United States of America

UTS
University of Technology Sydney

WA
Western Australia

WSU
Western Sydney University

11 PUBLICATIONS

JOURNAL PAPERS

Abbasi, S, Lamb, DT, Kader, M, Naidu, R & Megharaj, M 2021, 'The influence of long-term ageing on arsenic ecotoxicity in soil', *Journal of Hazardous Materials*, vol. 405, art. 124819.

Abbasi, S, Moore, F, Keshavarzi, B, Hopke, PK, Naidu, R, Rahman, MM, Oleszczuk, P & Karimi, J 2020, 'PET-microplastics as a vector for heavy metals in a simulated plant rhizosphere zone', *Science of the Total Environment*, vol. 744, art. 140984.

Abinandan, S, Perera, IA, Subashchandrabose, SR, Venkateswarlu, K, Cole, N & Megharaj, M 2020, 'Acid-adapted microalgae exhibit phenotypic changes for their survival in acid mine drainage samples', *FEMS Microbiology Ecology*, vol. 96, iss. 11.

Abinandan, S, Praveen, K, Subashchandrabose, SR, Venkateswarlu, K & Megharaj, M 2020, 'Life cycle assessment for the environmental sustainability of the immobilized acid-adapted microalgal technology in iron removal from acid mine drainage', *ACS Sustainable Chemistry & Engineering*, vol. 8, no. 41, pp. 15670–15677.

Amin, MA, Sobhani, Z, Liu, Y, Dharmaraja, R, Chadalavada, S, Naidu, R, Chalker, JM & Fang, C 2020, 'Recent advances in the analysis of per- and polyfluoroalkyl substances (PFAS)—A review', *Environmental Technology & Innovation*, vol. 19, art. 100879.

Anantha, MS, Olivera, S, Hu, C, Jayanna, BK, Reddy, N, Venkatesh, K, Muralidhara, HB & Naidu, R 2020, 'Comparison of the photocatalytic, adsorption and electrochemical methods for the removal of cationic dyes from aqueous solutions', *Environmental Technology & Innovation*, vol. 17, art. 100612.

Bagherifam, S, Brown TC, Fellows, CM, Naidu, R & Komarneni, S 2021, 'Highly efficient removal of antimonite (Sb(III)) from aqueous solutions by organoclay and organozeolite: kinetics and isotherms', *Applied Clay Science*, vol. 203, art. 106004.

Bagherifam, S, Brown, TC, Wijayawardena, A & Naidu, R 2021, 'The influence of different antimony (Sb) compounds and ageing on bioavailability and fractionation of antimony in two dissimilar soils', *Environmental Pollution*, vol. 270, art. 116270.

Basak, BB, Sarkar, B & Naidu, R 2020, 'Environmentally safe release of plant available potassium and micronutrients from organically amended rock mineral powder', *Environmental Geochemistry and Health*, vol. 43, pp. 3272–3286.

Bekele, DN, Liu, Y, Donaghey, M, Umeh, A, Arachchige, CSV, Chadalavada, S & Naidu, R 2020, 'Separation and lithological mapping of PFAS mixtures in the vadose zone at a contaminated site', *Frontiers in Water*, vol. 2.

Besha, AT, Liu, Y, Fang, C, Bekele, DN & Naidu R, 'Assessing the interactions between micropollutants and nanoparticles in engineered and natural aquatic environments', *Critical Reviews in Environmental Science and Technology*, vol. 50, iss. 2, pp. 135–215.

Bhattacharjya, S, Sahu, A, Phalke, DH, Manna, MC, Thakur, JK, Mandal, A, Tripathi, AK, Sheoran, P, Choudhary, M, Bhowmick, A, Rahman, MM, Naidu, R & Patra, AK 2021, 'In-situ decomposition of crop residues using lignocellulolytic microbial consortia: a viable alternative to reside burning', *Environmental Science and Pollution Research*, vol. 28, pp. 32416–32433.

Bidast, S, Golchin, A, Baybordi, A, Zamani, A & Naidu, R 2020, 'The effect of non-stabilised and Na-carboxymethylcellulose-stabilised iron oxide nanoparticles on remediation of Co-contaminated soils', *Chemosphere*, vol. 261, art. 128123.

Bolan, S, Seshadri, B, Grainge, I, Talley, NJ & Naidu, R 2021, 'Gut microbes modulate bioaccessibility of lead in soil', *Chemosphere*, vol. 270, art.128657.

Chowdhury, MI, Sana, T, Panneerselvan, L, Dharmarajan, R & Megharaj, M 2021, 'Acute toxicity and transgenerational effects of perfluorobutane sulfonate on Caenorhabditis elegans', *Environmental Toxicology and Chemistry*, vol. 40, iss. 7, pp. 1971–1980.

Deb, AK, Biswas, B, Goswami, N, Hilder, E, Naidu, R & Rahman, MM 2021, 'Synthesis of environmentally benign ultra-small copper nanoclusters-halloysite composites and their catalytic performance on contrasting azo dyes', *Applied Surface Science*, vol. 546, art. 149122.

Duan, Q, Duan, L, Liu, Y, Naidu, R, Zhang, H & Lei, Y 2020, 'A novel in-situ passive sampling technique in the application of monitoring diuron in the aquatic environment', *Environmental Technology & Innovation*, vol. 20, art. 101073.

Eugenio, NR, Naidu, R & Colombo, CM 2020, 'Global approaches to assessing, monitoring, mapping, and remedying soil pollution', *Environmental Monitoring and Assessment*, vol. 192, art. 601.

Fang, C, Sobhani, Z, Zhang, D, Gibson, CT, Tang, Y, Luo, Y, Megharaj, M & Naidu, R 2021, 'Capture and characterisation of microplastics printed on paper via laser printer's toners', *Chemosphere*, vol. 281, art. 130864.

Fang, C, Sobhani, Z, Zhang, X, Gibson, CT, Tang, Y & Naidu, R 2020, 'Identification and visualisation of microplastics/nanoplastics by Raman imaging (ii): smaller than the diffraction limit of laser?', *Water Research*, vol. 183, art. 116046.

Fang, C, Sobhani, Z, Zhang, X, McCourt, L, Routley, B, Gibson, CT & Naidu, R 2021, 'Identification and visualisation of microplastics/nanoplastics by Raman imaging (iii): algorithm to cross-check multi-images', *Water Research*, vol. 194, art. 116913.

Gao, Y, Du, J, Bahar, MM, Wang, H, Subashchandrabose, S, Duan, L, Yang, X, Megharaj, M, Zhao, Q, Zhang, W, Liu, Y, Wang, J & Naidu, R 2021, 'Metagenomics analysis identifies nitrogen metabolic pathway in bioremediation of diesel contaminated soil', *Chemosphere*, col. 271, art. 129566.

Gerdelidani, AF, Towfighi, H, Shahbazi, K, Lamb, DT, Choppala, G, Abbasi, S, Bari, ASMF, Naidu, R & Rahman, MM 2021, 'Arsenic geochemistry and mineralogy as a function of particle-size in naturally arsenic-enriched soils', *Journal of Hazardous Materials*, vol. 403, art. 123931.

Halim, MA, Rahman, MM, Megharaj, M & Naidu, R 2020, 'Cadmium immobilization in rhizosphere and plant cellular detoxification: role of plant-growth-promoting rhizobacteria as a sustainable solution', *Journal of Agricultural and Food Chemistry*, vol. 68, no. 47, pp. 13497–13529.

Hassan, M, Liu, Y, Naidu, R, Du, J & Qi, F 2020, 'Adsorption of perfluorooctane sulfonate (PFOS) onto metal oxides modified biochar', *Environmental Technology & Innovation*, vol. 19, art. 100816.

Hassan, M, Liu, Y, Naidu, R, Du, J, Qi, F, Donne, SW & Islam, MM 2021, 'Mesoporous biopolymer architecture enhanced the adsorption and selectivity of aqueous heavy-metal ions', *ACS Omega*, vol. 6, pp. 15316–15331.

Islam, MR, Sanderson, P, Johansen, MP, Payne, TE & Naidu, R 2021, 'The influence of soil properties on sorption-desorption of beryllium at a low level radioactive legacy waste site', *Chemosphere*, vol. 268, art. 129338.

Khodabakhshloo, N, Biswas, B, Moore, F, Du, J & Naidu, R 2021, 'Organically functionalized bentonite for the removal of perfluorooctane sulfonate, phenanthrene and copper mixtures from wastewater', *Applied Clay Science*, vol. 200, art. 105883.

Kulathunga, MRDL, Wijayawardena, MAA & Naidu, R 2021, 'Heavy metal(loid)s and health risk assessment of Dambulla vegetable market in Sri Lanka', *Environmental Monitoring & Assessment*, vol. 193, no. 4, p. 230.

Kulathunga, MRDL, Wijayawardena, MAA, Naidu, R, Wimalawansa ,SJ, & Wijeratne, AW 2020, 'Association between body mass index and estimated glomerular filtration rate in patients with chronic kidney disease of unknown aetiology in Sri Lanka', *Environmental Geochemistry and Health*, vol. 42, no. 9, pp. 2645–2653.

Kundu, S, Patel, S, Halder, P, Patel, T, Marzbali, MH, Pramanik, BK, Paz-Ferreiro, J, de Figueredo, CC, Bergmann, D, Surapaneni, A, Megharaj, M & Shah, K 2021, 'Removal of PFASs from biosolids using a semi-pilot scale pyrolysis reactor and the application of biosolids derived for the removal of PFASs from contaminated water', *Environmental Science: Water Research & Technology*, iss. 3.

Kuppusamy, S, Venkateswarlu, K & Megharaj, M 2020, 'Examining the polyphenol content, antioxidant activity and fatty acid composition of twenty-one different wastes of fruits, vegetables, oilseeds and beverages', *SN Applied Sciences*, vol. 2, art. 673.

Lal, MS, Megharaj, M Naidu, R & Bahar, MM 2020, 'Uptake of perfluorooctane sulfonate (PFOS) by common home-grown vegetable plants and potential risks to human health', *Environmental Technology & Innovation*, vol. 19, art. 100863.

Liu, W, Su, Y, Liu, J, Zhang, K, Wang, X, Chen, Y, Duan, L & Shi, F 2021, 'Determination of cyflufenamid residues in 12 foodstuffs by QuEChERS-HPLC-MS/MS', *Food Chemistry*, vol. 362, art. 130148.

Liu, W, Yang, X, Duan, L, Naidu, R, Yan, K, Liu, Y, Wang, X, Gao, Y & Chen, Y 2021, 'Variability in plant trace element uptake across different crops, soil contamination levels and soil properties in the Xinjiang Uygur Autonomous Region of northwest China', *Scientific Reports*, vol. 11, art. 2064.

Logeshwaran, P, Sivram, AK, Surapaneni, A, Kanna, K, Naidu, R & Megharaj, M 2021, 'Exposure to perfluorooctanesulfonate (PFOS) but not perflurooctanoic acid (PFOA) at ppb concentration induces chronic toxicity in Daphnia carinata,' *Science of the Total Environment*, vol. 769, art. 144577.

McCance, W, Jones, OAH, Cendón, DI, Edwards, M, Surapaneni, A, Chadalavada, S, Wang, S & Currella, M 2020, 'Combining environmental isotopes with contaminants of emerging concern to characterise wastewater derived impacts on groundwater quality', *Water Research*, vol. 182, art. 116036.

McCance, W, Jones, OAH, Cendón, DI, Edwards, M, Surapaneni, A, Chadalavada, S & Currell, M 2021, 'Decoupling wastewater impacts from hydrogeochemical trends in impacted groundwater resources', *Science of the Total Environment*, vol. 774, art. 145781.

Meftaul, IM, Venkateswarlu, K, Dharmarajan, R, Annamalai, P & Megharaj, M 2020, 'Sorption-desorption of dimethoate in urban soils and potential environmental impacts', *Environmental Science: Processes & Impacts*, iss. 11.

Murtaza, G, Rehman, MZ, Qadir, M, Shehzad, MT, Zeeshan, N, Ahmad, HR, Farooqi, ZR & Naidu, R 2021, 'High residual sodium carbonate water in the Indian subcontinent: concerns, challenges and remediation', *International Journal of Environmental Science and Technology*, vol. 18, pp. 3257–3272.

Naidu, R, Biswas, B, Willett, IR, Cribb, J, Singh, BR, Nathanail, CP, Coulon, F, Semple, KT, Jones, KC, Barclay, A & Aitken, RJ 2021, 'Chemical pollution: a growing peril and potential catastrophic risk to humanity', *Environment International*, vol. 156, art. 106616.

Naidu, R, Nadebaum, P, Fang, C, Cousins, I, Pennell, K, Conder, J, Newell, CJ, Longpré, D, Warner, S, Crosbie, ND, Surapaneni, A, Bekele, D, Spiese, R, Bradshaw, T, Slee, D, Liu, Y, Qi, F, Mallavarapu, M, Duan, L, McLeod, L, Bowman, M, Richmond, B, Srivastava, P, Chadalavada, S, Umeh, A, Biswas, B, Barclay, A, Simon, J & Nathanail, P 2020, 'Per- and poly-fluoroalkyl substances (PFAS): Current status and research needs', *Environmental Technology & Innovation*, vol. 19, art. 100915.

Nematollahi, M, Keshavarzi, B, Moore, F, Saravi, HN & Rahman, MM 2021, 'Hydrogeochemical and ecological risk assessments of trace elements in the coastal surface water of the southern Caspian Sea', *Environmental Monitoring & Assessment*, vol. 193, art. 452.

Perera, IA, Abinandan, S, Subashchandrabose, SR, Venkateswarlu, K, Cole, N, Naidu, R & Megharaj, M 2021, 'Extracellular polymeric substances drive symbiotic interactions in bacterial–microalgal consortia', *Environmental Microbiology*.

Perera, IA, Abinandan, S, Subashchandrabose, SR, Venkateswarlu, K, Naidu, R & Megharaj, M 2021, 'Microalgal-bacterial consortia unveil distinct physiological changes to facilitate growth of microalgae', *FEMS Microbiology Ecology*, vol. 97, iss. 3.

Rahman, MA, Lamb, D, Rahman, MM, Bahar, MM, Sanderson, P, Abbasi, S, Bari, ASMF & Naidu, R 2021, 'Removal of arsenate from contaminated waters by novel zirconium and zirconium-iron modified biochar', *Journal of Hazardous Materials*, vol. 409, art. 124488.

Rahman, MA, Rahman, MM, Bahar, MM, Sanderson, P & Lamb, D 2021, 'Antimonate sequestration from aqueous solution using zirconium, iron and zirconium-iron modified biochars'. *Scientific Reports*, vol. 11, art. 8113.

Rahman, MM, Alauddin, M, Alauddin, ST, Siddique, AB, Islam, MR, Agosta, G, Mondal, D & Naidu, R 2021, 'Bioaccessibility and speciation of arsenic in children's diets and health risk assessment of an endemic area in Bangladesh', *Journal of Hazardous Materials*, vol. 403, art. 124064.

Ramakrishnan, B, Maddela, NR, Venkateswarlu, K & Megharaj, M 2021, 'Organic farming: does it contribute to contaminant-free produce and ensure food safety?', *Science of the Total Environment*, vol. 769, art. 145079.

Rathnayake, IVN, Megharaj, M & Naidu, R 2021, 'Green fluorescent protein based whole cell bacterial biosensor for the detection of bioavailable heavy metals in soil environment', *Environmental Technology & Innovation*, vol. 23, art. 101785.

Saini, A, Bekele, DN, Chadalavada, S, Fang, C & Naidu, R 2021, 'Electrokinetic remediation of petroleum hydrocarbon contamination soil (I)', *Environmental Technology & Innovation*, vol. 23, art. 101585.

Samarasinghe, SVAC, Krishnan, K, Aitken, RJ, Naidu R & Megharaj, M 2021, 'Persistence of the parabens in soil and their potential toxicity to earthworms, '*Environmental Toxicology and Pharmacology*, vol. 83, art. 103574.

Shahriar, S, Haque, MM, Naidu, R & Rahman, MM 2021, 'Concentrations of toxic elements and health risk assessment in arum grown in arsenic-contaminated areas of Bangladesh', *Food Control*, vol. 129, art. 108240.

Shanthakumar, S, Abinandan, S, Venkateswarlu, K, Subashchandrabose, SR & Megharaj, M 2021, 'Algalization of acid soils with acid-tolerant strains: improvement in pH, carbon content, exopolysaccharides, indole acetic acid and dehydrogenase activity', *Land Degradation & Development*, vol. 32, iss. 11, pp. 3157–3166.

Siddique, AB, Rahman, MM, Islam, MR & Naidu, R 2021, 'Varietal variation and formation of iron plaques on cadmium accumulation in rice seedling', *Environmental Advances*, vol. 5, art. 100075.

Siddique, AB, Rahman, MM, Islam, MR, Mondal D & Naidu, R 2021, 'Response of iron and cadmium on yield and yield components of rice and translocation in grain: health risk estimation', *Frontiers in Environmental Science*, vol. 9, art. 716770.

Sivaram, AK, Logeshwaran, P, Surapaneni, A, Shah, K, Crosbie, N, Rogers, Z, Lee, E, Venkatraman, K, Kanna, K, Naidu, R & Naidu, R 2020, 'Evaluation of cyto-genotoxicity of perluorooctane sulfonate (PFOS) to Allium cepa', *Environmental Toxicology and Chemistry*, vol. 40, iss. 3, pp. 792–798.

Sivaram, AK, Subashchandrabose, SR, Logeshwaran, P, Lockington, R, Naidu, R & Mallavarapu, M 2020, 'Rhizodegradation of PAHs differentially altered by C3 and C4 plants', *Scientific Reports*, vol. 10, art. 16109.

Sobhani, Z, Fang, C, Naidu, R & Megharaj, M 2021, 'Microplastics as a vector of toxic chemicals in soil: enhanced uptake of perfluorooctane sulfonate and perfluorooctanoic acid by earthworms through sorption and reproductive toxicity', *Environmental Technology & Innovation*, vol. 22, art. 101476.

Sobhani, Z, Panneerselvan, L, Fang, C, Naidu, R & Mallavarapu, M 2021, 'Chronic and transgenerational effects of polystyrene microplastics at environmentally relevant concentrations on earthworms (Eisenia fetida)', *Environmental Toxicology*, vol. 40, no. 8, pp. 2240–2246.

Umeh, AC, Naidu, R, Shilpi, S, Boateng, EB, Rahman, A, Cousins, IT, Chadalavada, S, Lamb, D & Bowman, M 2021, 'Sorption of PFOS in 114 well-characterized tropical and temperate soils: application of multivariate and artificial neural network analyses', *Environmental Science & Technology*, vol. 55, no. 3, pp. 1779–1789.

Usese, AI, Chukwi, LO, Naidu, R, Islam, S & Rahman, MM 2020, 'Arsenic fractionation in sediments and speciation in muscles of fish, Chrysichthys nigrodigitatus from a contaminated tropical lagoon, Nigeria', *Chemosphere*, vol. 256, art. 127134.

Uz-Zaman, KA, Biswas, B, Rahman, MM & Naidu, R 2021, 'Smectite-supported chain of iron nanoparticle beads for efficient clean-up of arsenate contaminated water', *Journal of Hazardous Materials*, vol. 407, art. 124396.

Wang, L, Cheng, Y, Naidu, R, Chadalavada, S, Bekele, D, Gell, P, Donaghey, M & Bowman, M 2021, 'Application of portable gas chromatography-mass spectrometer for rapid field based determination of TCE in soil vapour and groundwater', *Environmental Technology & Innovation*, vol. 21, art. 101274.

Wang, X, Luo, X, Qang, Q, Liu, Y & Naidu, R 2020, 'Predicting the combined toxicity of binary metal mixtures (Cu–Ni and Zn–Ni) to wheat', *Ecotoxicology and Environmental Safety*, vol. 205, art. 111334.

Wu, H, Wang, J, Xiang, Y, Li, L, Qie, H, Ren, M, Lin, A & Qi, F 2021, 'Effects of tetrabromobisphenol A (TBBPA) on the reproductive health of male rodents: A systematic review and meta-analysis', *Science of The Total Environment*, vol. 781, art. 146745.

Zazouli, MA, Dehbandi, R, Mohammadyan, M, Asrabi, M, Dominguez, AO, Kelly, FJ, Khodabakhshloo, N, Rahman, MM & Naidu, R 2021, 'Physico-chemical properties and reactive oxygen species generation by respirable coal dust: implication for human health risk assessment', *Journal of Hazardous Materials*, vol. 405, art. 124185.

Zhang, D, Ding, A, Li, T, Wu, X, Liu, Y & Naidu, R 2021, 'Immobilization of Cd and Pb in a contaminated acidic soil amended with hydroxyapatite, bentonite, and biochar', Journal of Soils and Sediments, vol. 21, pp. 2262–2272.

Zhang, J, Hu, H, Wang, M, Li, Y, Wu, S, Cao, Y, Liang, P, Zhang, J, Naidu, R, Liu, Y, Man, YB, Wong, MH, Zhang, C & Shan, S 2021, 'Land application of sewage sludge biochar: Assessments of soil-plant-human health risks from potentially toxic metals', Science of The Total Environment, vol. 756, art. 144137.

Zhang, J, Jin, J, Wang, M, Naidu, R, Liu, Y Man, YB, Liang, X, Wong, MH, Christie, P, Zhang, Y, Song, C & Shan, S 2020, 'Co-pyrolysis of sewage sludge and rice husk/bamboo sawdust for biochar with high aromaticity and low metal mobility, 'Environmental Research, vol. 191, art. 110034.

Zhang, J, Wu, S, Xu, J, Liang, P, Wang, M, Naidu, R, Liu, Y, Man, YB, Wong, MH & Wu, S 2021, 'Comparison of ashing and pyrolysis treatment on cadmium/zinc hyperaccumulator plant: Effects on bioavailability and metal speciation in solid residues and risk assessment', Environmental Pollution, vol. 272, art. 116039.

BOOKS AND BOOK CHAPTERS

Naidu, R, Biswas, B, Chen, ZS, Jit, J, Rahman, MM, Duan, L, Lee, K, Niazi, NK & Wijayawardena MAA 2021, 'Chapter 6: Status of soil pollution in Asia and the Pacific', in *Global assessment of soil pollution: Report*, FAO and UNEP, Rome, Italy.

Naidu, R, Megharaj, M, Dillon, P, Kookana, R, Correl, R & Wenzel, WW 2020, 'Pollution: nonpoint source', in *Wetlands and Habitats*, 1st Edition, CRC Press, Boca Raton, USA.

Umeh, AC, Naidu, R, Owojori, OJ & Semple, KT 2020, 'Bioavailability and bioaccessibility of hydrophobic organic contaminants in soil and associated desorption-based measurements', in *The Handbook of Environmental Chemistry*, Springer, Berlin, Germany.

CONFERENCE PRESENTATIONS/ABSTRACTS

Linge, KL, Black, S & Allen, DA 2021, 'Mine pit lakes: characterisation of water quality and geochemistry to inform mine closure', in Proceedings of *the Tenth Australian Workshop on Acid and Metalliferous Drainage*, The University of Queensland (online), pp.172–182.

Linge, KL, Black, S & Allen, DA 2021, 'Mine pit lakes: characterisation of water quality and geochemistry to inform mine closure', presented at *the Tenth Australian Workshop on Acid and Metalliferous Drainage*, online, 22–25 June.

Linge, KL, Black, S & Firns, G 2021, 'Developing a mine pit lakes database to inform mine closure', presented at the *2020 Goldfields Environmental Management Group conference*, Kalgoorlie, WA, 19–21 May 2021.

Naidu, R 2021, 'Innovative technologies for the remediation of PFAS-contaminated water and soil', presented at the *CleanUp Symposium Emerging Contaminants 2021, online*, 24–25 March.

FINANCIAL STATEMENTS

CRC CARE PTY LTD ACN 113 908 044

COOPERATIVE RESEARCH CENTRE

FOR CONTAMINATION ASSESSMENT AND REMEDIATION OF THE ENVIRONMENT

FINANCIAL STATEMENTS FOR THE YEAR ENDED 30 JUNE 2021

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CRC CARE Pty Ltd

ACN 113 908 044

Directors' Report

30 June 2021

The directors present their report on CRC CARE Pty Ltd (the 'Company' or "CRC CARE") for the financial year ended 30 June 2021.

Directors

The names of each person who has been a director during the year and to the date of this report are:

Dr Paul Vogel, Chairman
Mr Sean Edwards, Deputy Chairman - Appointed 22 June 2021
Prof Ravi Naidu, CEO & Managing Director
Dr Alan Broadfoot
Ms Anthea Tinney - Resigned 22 June 2021
Ms Frances Joy Kay-Lambkin - Resigned 11 September 2020
Mr Charles Wong
Mr Ralph Hardy
Dr Rod Lukatelich
Mr Tony Circelli - Resigned 22 June 2021

Directors have been in office since the start of the financial year to the date of this report unless otherwise stated.

Principal activities

The principal activity of CRC CARE Pty Ltd during the financial year was to manage and govern the Cooperative Research Centre for Contamination Assessment and Remediation of the Environment ("the Centre").

The objective of the Centre is to promote research and capacity building for the development and extension of advanced technologies and methods for:

a) assessing contamination risks to the land, groundwater and air;
b) preventing, managing and/or remediating contamination;
c) developing safe options for land use and the reuse of wastes on land;
d) developing solutions that are acceptable to regulatory agencies and the public; and
e) capacity building.

No significant changes in the nature of the Company's activity occurred during the financial year.

Dividends paid or recommended

No dividends were paid or declared since the start of the financial year. No recommendation for payment of dividends has been made.

Review of operations

The Company specialises in research and development of technologies to overcome and prevent contamination of soil, water and air. During the year, the Company received cash contributions of $6,698,000 (2020: $8,509,000) and in-kind contributions of $4,766,408 (2020: $9,252,013).

Costs directly attributable to Research expenditure totalled $9,574,049 (2020: $17,606,722) which is reflective of the research performed in order to complete the projects of the Company.

CRC CARE Pty Ltd

ACN 113 908 044

Directors' Report
30 June 2021

Significant changes in state of affairs

On 10 June 2020, the Company had received approval from the Department of Industry, Science, Energy & Resources to undertake protracted wind-up activities until 30 June 2021. Accordingly, the prior year financial statements were prepared on a realisation basis.

On 10 September 2021, the Company signed agreements with key participants to receive funding for at least three years to provide for the continuation of research activities.

Accordingly, the 2021 financial statements have been prepared on the going concern basis, which assumes assets will be utilised and liabilities will be extinguished in the ordinary course of business.

Events after the reporting date

Subsequent to year end, a number of CARE industry participants agreed to continue funding the Company for the next three years. This funding will allow the Company to continue its research programs and will allow the Company to continue to operate as a going concern.

Except for the above, no other matters or circumstances have arisen since the end of the financial year which significantly affected or could significantly affect the operations of the Company, the results of those operations or the state of affairs of the Company in future financial years.

Future developments and results

Likely developments in the operations of the Company and the expected results of those operations in future financial years have not been included in this report as the inclusion of such information is likely to result in unreasonable prejudice to the Company.

Environmental issues

The Company's operations are subject to significant environmental regulations under the laws of the Commonwealth and State of Australia, briefly discussed below:

(i) The Company is subject to regulation relating to the testing of contaminated sites and the formulation of proposals for the remediation of contamination in the environment;

(ii) Personnel of the entity and entities providing research services to the Company are required to conform to the site specific Environmental Health and Safety plans when entering and working on contaminated sites.

There have been no breaches of such environmental regulations or plans that have a material effect on the financial statements.

Indemnification and insurance of officers and directors

During the financial year, the Company paid a premium of $7,772 (2020: $4,599) to insure Directors and Officers of the Company.

The liabilities insured are legal costs that may be incurred in defending civil or criminal proceedings that may be brought against Directors and Officers in their capacity as officers of the Company, and any other payments arising from liabilities incurred by the officers in connection with such proceedings. This does not include such liabilities that arise from conduct involving wilful breach of duty by the officers or the improper use by the officers of their position or of information to gain advantage for them or someone else to cause detriment to the Company.

CRC CARE Pty Ltd

ACN 113 908 044

Directors' Report
30 June 2021

Auditor's independence declaration

The lead auditor's independence declaration in accordance with section 307C of the *Corporations Act 2001*, for the year ended 30 June 2021 has been received and can be found on page 4 of the financial report.

Signed in accordance with a resolution of the Board of Directors:

Chairman of Board of Directors: .....
Dr Paul Vogel

CEO & Managing Director: .....
Prof Ravi Naidu

Dated 8 October 2021

PKF

CRC CARE Pty Ltd
ACN 113 908 044

Auditor's Independence Declaration under Section 307C of the Corporations Act 2001 to the Directors of CRC CARE Pty Ltd

I declare that, to the best of my knowledge and belief, during the year ended 30 June 2021, there have been:

(i) no contraventions of the auditor independence requirements as set out in the *Corporations Act 2001* in relation to the audit; and

(ii) no contraventions of any applicable code of professional conduct in relation to the audit.

PKF

MARTIN MATTHEWS
PARTNER

8 OCTOBER 2021
NEWCASTLE, NSW

PKF(NS) Audit & Assurance Limited Partnership
ABN 91 850 861 839

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CRC CARE Pty Ltd

ACN 113 908 044

Statement of Profit or Loss and Other Comprehensive Income

For the Year Ended 30 June 2021

	Note	2021 $	2020 $
Revenue from continuing operations	4	11,054,898	20,706,270
Consultants fees		(70,971)	(322,100)
Employee benefit expense		(692,230)	(863,176)
IT expenses		(33,661)	(84,098)
Lease expenses		(14,306)	-
Legal expenses		(99,257)	(83,572)
Research expenditure - cash		(4,807,641)	(8,354,709)
Research expenditure - in-kind		(4,766,408)	(9,252,013)
Travel expenses		(10,368)	(82,582)
Finance costs		(5,914)	(9,706)
Other expenses	5	(567,246)	(1,649,930)
(Loss)/profit before income tax		(13,104)	4,384
Income tax benefit/(expense)	6	13,104	(4,384)
Other comprehensive income for the year, net of tax		-	-
Total comprehensive income		-	-

The accompanying notes form part of these financial statements.

CRC CARE Pty Ltd

ACN 113 908 044

Statement of Financial Position
As At 30 June 2021

	Note	2021 $	2020 $
ASSETS			
CURRENT ASSETS			
Cash and cash equivalents	7	2,579,939	3,066,102
Trade and other receivables	8	326,497	663,212
Other assets		104,798	91,978
Non-current assets held for sale		-	74,781
TOTAL CURRENT ASSETS		**3,011,234**	**3,896,073**
NON-CURRENT ASSETS			
TOTAL ASSETS		**3,011,234**	**3,896,073**
LIABILITIES			
CURRENT LIABILITIES			
Trade and other payables	9	448,890	353,849
Current tax liabilities		-	19,108
Employee benefits	10	-	306,006
Other liabilities	12	1,334,641	2,030,466
Other financial liabilities	11	1,227,693	1,186,630
TOTAL CURRENT LIABILITIES		**3,011,224**	**3,896,059**
TOTAL LIABILITIES		**3,011,224**	**3,896,059**
NET ASSETS		**10**	**14**
EQUITY			
Issued capital	13	10	14
Accumulated losses		**-**	-
TOTAL EQUITY		**10**	**14**

The accompanying notes form part of these financial statements.

CRC CARE Pty Ltd

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Statement of Changes in Equity
For the Year Ended 30 June 2021

2021

	Ordinary Shares	Accumulated Losses	Total
	$	$	$
Balance at 1 July 2020	**14**	**-**	**14**
Loss for the year	**-**	**-**	**-**
Share buy-back	**(4)**	**-**	**(4)**
Balance at 30 June 2021	**10**	**-**	**10**

2020

	Ordinary Shares	Retained Earnings	Total
	$	$	$
Balance at 1 July 2019	14	-	14
Profit for the year	-	-	-
Balance at 30 June 2020	14	-	14

The accompanying notes form part of these financial statements.

CRC CARE Pty Ltd

ACN 113 908 044

Statement of Cash Flows
For the Year Ended 30 June 2021

	Note	2021 $	2020 $
CASH FLOWS FROM OPERATING ACTIVITIES:			
Cash contributions received from Commonwealth (inclusive of GST)		-	834,900
Cash contributions received from all Participants (inclusive of GST)		6,955,520	8,525,000
Payments to suppliers and employees		(7,822,828)	(13,977,459)
Income tax refunded/(paid)		13,104	(4,384)
Interest received		772	59,360
Training fees received		132,894	1,108,012
Other income received		182,888	582,648
Grant income received		51,491	89,916
Net cash provided by/(used in) operating activities	21	**(486,159)**	**(2,782,007)**
CASH FLOWS FROM INVESTING ACTIVITIES:			
Net cash provided by/(used in) investing activities		**-**	**-**
CASH FLOWS FROM FINANCING ACTIVITIES:			
Share buy-back		**(4)**	-
Net cash provided by/(used in) financing activities		**(4)**	-
Net increase/(decrease) in cash and cash equivalents held		**(486,163)**	**(2,782,007)**
Cash and cash equivalents at beginning of year		**3,066,102**	**5,848,109**
Cash and cash equivalents at end of financial year	7	**2,579,939**	**3,066,102**

The accompanying notes form part of these financial statements.

CRC CARE Pty Ltd

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Notes to the Financial Statements

For the Year Ended 30 June 2021

The financial report covers CRC CARE Pty Ltd as an individual entity. CRC CARE Pty Ltd is a for-profit proprietary Company limited by shares, incorporated and domiciled in Australia.

The functional and presentation currency of CRC CARE Pty Ltd is Australian dollars.

1 Basis of Preparation

In the Directors opinion, the Company is not a reporting entity since there are unlikely to exist users of the financial statements who are not able to command the preparation of reports tailored so as to satisfy specifically all of their information needs. This special purpose financial report has been prepared to meet the reporting requirements of the *Corporations Act 2001.*

The financial statements have been prepared in accordance with the recognition and measurement principles of all applicable Australian Accounting Standards and Interpretations issued by the Australian Accounting Standards Board and the *Corporations Act 2001.*

Historical cost convention

These financial statements have been prepared under the historical cost convention.

On 10 June 2020, the Company received approval from the Department of Industry, Science, Energy & Resources to undertake protracted wind-up activities until 30 June 2021. Accordingly the comparative financial statements were prepared on a realisation basis.

On 10 September 2021, the Company signed agreements with key participants to receive funding for at least three years to provide for the continuation of research activities.

Accordingly, the 2021 financial statements have been prepared on the going concern basis, which assumes assets will be utilised and liabilities will be extinguished in the ordinary course of business.

2 Summary of Significant Accounting Policies

(a) Revenue and other income

Revenue is measured at the fair value of the consideration received or receivable. Amounts disclosed as revenue are net of returns, trade allowances, rebates and amounts collected on behalf of third parties.

The Company recognises revenue when the amount of revenue can be reliably measured, it is probable that future economic benefits will flow to the entity and specific criteria have been met for each of the Company's activities as described below. The Company bases its estimates on historical results, taking into consideration the type of customer, the type of transaction and the specifics of each arrangement.

Grant revenue

Grants from the government are recognised at their fair value where there is a reasonable assurance that the grant will be received and the Company will comply with all attached conditions.

Government grants relating to costs which have not yet been incurred are included in deferred revenue in current liabilities and are credited to the statement of comprehensive income in the period necessary to match them with the costs that they are intended to compensate.

Government grants relating to the purchase of property, plant and equipment are included in non-current

CRC CARE Pty Ltd

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Notes to the Financial Statements
For the Year Ended 30 June 2021

2 Summary of Significant Accounting Policies (cont'd)

(a) Revenue and other income (cont'd)

Grant revenue (cont'd)
liabilities as deferred revenue and are credited to the statement of comprehensive income over the expected lives of the related assets.

Participants' contributions

Contributions received in cash (recorded as deferred revenue on receipt - for further information refer note 12) and in-kind from the Participants during the financial year are applied to expenditure incurred in carrying out the affairs of the Company under the terms of the Participants Agreement between the Company and the entities who have undertaken to provide contributions to the Company (other than the Commonwealth of Australia).

Contributions received in-kind are recognised as detailed in note 2(b) and comprise material, labour and other costs, when sufficient documentation and information has been received to quantify the cost with reasonable certainty.

Contributions as detailed in note 15 are calculated on a cash basis for reporting purpose to Commonwealth of Australia.

(b) In-kind contributions

In-kind contributions of staff by research providers are valued in accordance with the Commonwealth Agreement, as per Table 1 of the Schedule 4 of the Agreement.

Non-staff in-kind contributions are valued on the following bases:

1. Buildings - a reasonable estimate of the commercial rental value related to the area and time period of occupation related to the activities of the Company.

2. Capital equipment - either an allocation of the replacement cost of the equipment apportioned over the proportion of the useful life utilized by the activities of the Company or an agreed value determined with reference to the cost of an equipment service from a commercial operator.

Office and laboratory accommodation is provided by the University of South Australia and the University of Newcastle as part of the Participants Agreement and are treated as in-kind contributions.

Where a value cannot be readily obtained by applying the policy rules set out above, a Directors' valuation is used.

(c) Cash and cash equivalents

Cash and cash equivalents includes cash on hand, deposits held at call with financial institutions, other short-term, highly liquid investments with original maturities of three months or less that are readily convertible to known amounts of cash and which are subject to an insignificant risk of changes in value.

(d) Financial instruments

Financial instruments are recognised initially on the date that the Company becomes party to the contractual provisions of the instrument.

CRC CARE Pty Ltd

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Notes to the Financial Statements
For the Year Ended 30 June 2021

2 Summary of Significant Accounting Policies (cont'd)

(d) Financial instruments (cont'd)

On initial recognition, all financial instruments are measured at fair value plus transaction costs (except for instruments measured at fair value through profit or loss where transaction costs are expensed as incurred).

Financial assets

All recognised financial assets are subsequently measured in their entirety at either amortised cost or fair value, depending on the classification of the financial assets.

Classification

On initial recognition, the Company classifies its financial assets into the following categories, those measured at:

- amortised cost
- fair value through profit or loss - FVTPL
- fair value through other comprehensive income - equity instrument (FVOCI - equity)
- fair value through other comprehensive income - debt investments (FVOCI - debt)

Amortised cost

The Company's financial assets measured at amortised cost comprise trade and other receivables and cash and cash equivalents in the statement of financial position.

Subsequent to initial recognition, these assets are carried at amortised cost using the effective interest rate method less provision for impairment.

Impairment of financial assets

Impairment of financial assets is recognised on an expected credit loss (ECL) basis for the following assets:

- financial assets measured at amortised cost
- debt investments measured at FVOCI

When determining whether the credit risk of a financial assets has increased significantly since initial recognition and when estimating ECL, the Company considers reasonable and supportable information that is relevant and available without undue cost or effort. This includes both quantitative and qualitative information and analysis based on the Company's historical experience and informed credit assessment and including forward looking information.

The Company uses the presumption that an asset which is more than 60 days past due has seen a significant increase in credit risk.

CRC CARE Pty Ltd

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Notes to the Financial Statements
For the Year Ended 30 June 2021

2 Summary of Significant Accounting Policies (cont'd)

(d) Financial instruments (cont'd)

Financial assets (cont'd)

The Company uses the presumption that a financial asset is in default when:

- the other party is unlikely to pay its credit obligations to the Company in full, without recourse to the Company to actions such as realising security (if any is held); or
- the financial assets is more than 90 days past due.

Credit losses are measured as the present value of the difference between the cash flows due to the Company in accordance with the contract and the cash flows expected to be received. This is applied using a probability weighted approach.

Trade receivables

Impairment of trade receivables have been determined using the simplified approach in AASB 9 which uses an estimation of lifetime expected credit losses. The Company has determined the probability of non-payment of the receivable and multiplied this by the amount of the expected loss arising from default.

The amount of the impairment is recorded in a separate allowance account with the loss being recognised in finance expense. Once the receivable is determined to be uncollectable then the gross carrying amount is written off against the associated allowance.

Where the Company renegotiates the terms of trade receivables due from certain customers, the new expected cash flows are discounted at the original effective interest rate and any resulting difference to the carrying value is recognised in profit or loss.

Other financial assets measured at amortised cost

Impairment of other financial assets measured at amortised cost are determined using the expected credit loss model in AASB 9. On initial recognition of the asset, an estimate of the expected credit losses for the next 12 months is recognised. Where the asset has experienced significant increase in credit risk then the lifetime losses are estimated and recognised.

Financial liabilities

The Company measures all financial liabilities initially at fair value less transaction costs, subsequently financial liabilities are measured at amortised cost using the effective interest rate method.

The financial liabilities of the Company comprise trade payables, current tax liabilities and accrued expenses.

CRC CARE Pty Ltd

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Notes to the Financial Statements
For the Year Ended 30 June 2021

2 Summary of Significant Accounting Policies (cont'd)

(e) Impairment of assets

Assets that are subject to depreciation or amortisation are reviewed for impairment whenever events or changes in circumstances indicate that the carrying amount may not be recoverable. An impairment loss is recognised for the amount by which the asset's carrying amount exceeds its recoverable amount. The recoverable amount is the higher of an asset's fair value less costs to sell and value in use. For the purposes of assessing impairment, assets are grouped at the lowest levels for which there are separately identifiable cash flows (cash generating units).

(f) Plant and equipment

Plant and equipment is stated at historical cost less depreciation. Historical cost includes expenditure that is directly attributable to the acquisition of the items.

Subsequent costs are included in the asset's carrying amount or recognised as a separate asset, as appropriate, only when it is probable that future economic benefits associated with the item will flow to the Company and the cost of the item can be measured reliably. The carrying amount of any component accounted for as a separate asset is derecognised when replaced.

Depreciation is calculated using the straight line method to allocate their cost or revalued amounts, net of their residual values, over their estimated useful lives.

Plant and equipment is depreciated over the useful life of 10 years.

The assets' residual values and useful lives are reviewed, and adjusted if appropriate, at the end of each reporting year.

An asset's carrying amount is written down immediately to its recoverable amount if the asset's carrying amount is greater than its estimated recoverable amount (note 2(f)).

Gains and losses on disposals are determined by comparing proceeds with carrying amount. These are included in profit or loss.

(g) Trade Creditors

All trade creditors unpaid as at the reporting date are recognised at the amount invoiced, net of any applicable taxes. The Company's policy is to pay trade creditors no more than 30 days from the date of invoice.

(h) Employee benefits

(i) Wages and salaries, annual leave and sick leave

Liabilities for wages and salaries, including non-monetary benefits, accumulating sick leave and annual leave expected to be settled within 12 months of the reporting date are recognised in respect of employee's services up to the reporting date and are measured at the amounts expected to be paid when the liabilities are settled.

Liabilities for non-accumulating sick leave are recognised when the leave is taken and measured at the rates paid or payable.

CRC CARE Pty Ltd

ACN 113 908 044

Notes to the Financial Statements
For the Year Ended 30 June 2021

2 Summary of Significant Accounting Policies (cont'd)

(h) Employee benefits (cont'd)

(ii) Long service leave

The liability for long service leave is measured at the present value of expected future payments to be made in respect of services provided by employees up to the end of the reporting period using the projected unit credit method. Consideration is given to the level of service provided by the employee, the length of employment contracts, expected future wage and salary levels, and the experience of employee departures.

Expected future payments are discounted using market yields at the end of the reporting period of corporate bonds with terms and currencies that match, as closely as possible, the estimated future cash outflows. Remeasurements as a result of experience adjustments and changes in actuarial assumptions are recognised in profit or loss.

(i) Share capital

Ordinary shares are classified as equity. Incremental costs directly attributable to the issue of new shares or options are shown in equity as a deduction, net of tax, from the proceeds.

(j) Research expenditure

Research expenditure are recognised as incurred and consist of costs incurred as part of day to day research and development activities for research programs. The main items of expenditure are salaries, equipment, consumables and travel costs.

Salaries relate to research and non-research staff working directly on research programs. In some instances salary costs may be allocated between research expenditure and employee benefits when it is identified that time can be specifically attributed to research programs.

Equipment costs relate to expenses incurred in the procurement of equipment to assist directly with the research programs undertaken. Consumable and travel costs are incurred on an ongoing basis and relate to day to day expenses incurred as part of the research activities. Research expenditure is accounted for on an accrual basis.

(k) Income Tax

The income tax expense or revenue for the year is the tax payable/(receivable) on the current period's taxable income based on the notional income tax rate adjusted by changes in deferred tax assets and liabilities attributable to temporary differences between the tax bases of assets and liabilities and their carrying amounts in the financial statements, and to unused tax losses.

Deferred tax assets and liabilities are recognised for temporary differences at the tax rates expected to apply when the assets are recovered or liabilities are settled, based on those tax rates which are enacted or substantively enacted for each jurisdiction.

CRC CARE Pty Ltd

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Notes to the Financial Statements
For the Year Ended 30 June 2021

2 Summary of Significant Accounting Policies (cont'd)

(k) Income Tax (cont'd)

The relevant tax rates are applied to the cumulative amounts of deductible and taxable temporary differences to measure the deferred tax asset or liability. An exception is made for certain temporary differences arising from the initial recognition of an asset or a liability. No deferred tax asset or liability is recognised in relation to these temporary differences if they arose in a transaction, other than a business combination, that at the time of the transaction did not affect either accounting profit or taxable profit or loss. Deferred tax assets are recognised for deductible temporary differences and unused tax losses only if it is probable that future taxable amounts will be available to utilise those temporary differences and losses.

Current and deferred tax balances attributable to amounts recognised directly in equity are also recognised directly in equity.

(l) Comparative figures

When required by Accounting Standards, comparative figures have been adjusted to conform to changes in presentation for the current financial year.

3 Critical Accounting Estimates and Judgments

The preparation of financial statements requires the use of certain critical accounting estimates. It also requires management to exercise its judgement in the process of applying the Company's accounting policies. Estimates and judgements are continually evaluated and are based on historical experience and other factors, including expectation of future events that may have a financial impact on the entity and that are believed to be reasonable under the circumstances.

The areas involving a higher degree of judgement or complexity, or areas where assumptions or estimates are significant to the financial statements are detailed below.

Key estimates - In-kind contributions

Staff contributions are valued in accordance with guidelines and the multiplier set by the Commonwealth of Australia and as detailed in note 2(b). The actual time recorded on project work requires a certain level of estimate and judgement by project leaders. In applying that judgement, consideration is given to project budgets and agreements, as set out and approved by Participants and the Company.

The capital and equipment rates and useful lives used for contributions are based on estimations and agreements as calculated by project Participants and the Company. Valuations are generally based on estimates of the percentage utilisation of capital and equipment depreciation directly related to project output. The Company believes that the estimates and assumptions in relation to in-kind contributions result in recognition of amounts that represent the fair value of contributions received.

4 Revenue and Other Income

	2021 $	2020 $
Contributions Revenue		
- Allocated contributions from Participants/Commonwealth - Cash	5,914,985	9,667,289
- Allocated contributions from Participants - In-kind	4,766,408	9,252,013
Total Contributions Revenue	**10,681,393**	**18,919,302**

CRC CARE Pty Ltd

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Notes to the Financial Statements
For the Year Ended 30 June 2021

4 Revenue and Other Income (cont'd)

	2021 $	2020 $
Other Revenue		
- Interest received	772	59,360
- Training fees	120,813	1,108,012
- Other income	137,610	529,680
- Grant income	46,810	39,916
- Government grants	67,500	50,000
Total Other Revenue	**373,505**	**1,786,968**
Total Revenue	**11,054,898**	**20,706,270**

5 Other expenses

Education and training expenses	188,280	968,359
Board expenses	161,748	253,315
Insurance premium	91,627	90,846
Compliance costs	30,808	30,664
Communication expenses	80,394	229,947
Other expenses	14,389	76,799
Total Other Expenses	**567,246**	**1,649,930**

6 Income Tax Expense

Local income tax (benefit)/expense	(13,104)	4,384

7 Cash and Cash Equivalents

Cash on hand	128	128
Bank balances	141,110	99,544
Deposits at call	2,438,701	2,966,430
Total Cash and Cash Equivalents	**2,579,939**	**3,066,102**

Included in Cash and Cash Equivalents is restricted cash of $3,489 for use with respect to NESP, $90,827 for use with respect to Clean Australia CRC and $38,999 for use with respect to Waste 5.0 CRC (2020: $30,440 for use with respect to NESP and $44,076 for use with respect to Clean Australia CRC), refer to note 9.

CRC CARE Pty Ltd

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Notes to the Financial Statements
For the Year Ended 30 June 2021

8 Trade and Other Receivables

	2021 $	2020 $
CURRENT		
Trade receivables	326,497	663,212

9 Trade and Other Payables

CURRENT		
Trade payables	218,819	224,930
Monies held in trust	133,315	74,516
GST payable	63,617	14,195
Other payables	33,139	40,208
Total Trade and Other Payables	**448,890**	**353,849**

10 Employee Benefits

CURRENT		
Provision for employee benefits	-	306,006

Current provision for employee benefits includes accrued annual leave and long service leave. Long service leave covers all unconditional entitlements where employees have completed the required period of service and also those where employees are entitled to pro-rata payments in certain circumstances. There is no provision at 30 June 2021 since all employee contracts expired on 30 June 2021. All employee entitlements have been classified as accrued expense and paid subsequent to 30 June 2021.

11 Deferred Revenue

CURRENT		
Contributions from Participants	1,193,049	840,570
Other deferred revenue	34,644	346,060
Total Deferred Revenue	**1,227,693**	**1,186,630**

As per the accounting policy in note 2, contributions from the Commonwealth of Australia and Participants (both cash and in-kind) are treated as deferred revenue until matched against expenditure in the course of the Company's activities.

In the event of a wind up of the Company, any deferred revenue not matched against expenditure is required to be returned to the Commonwealth of Australia and individual Participants in accordance with the terms of the Agreements.

Deferred revenue arising from obligations to make contributions to the Company and not allocated to program expenses at balance date has been included as a current liability as it is anticipated that the relevant sum will be matched against expenditure during the next financial year.

CRC CARE Pty Ltd

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Notes to the Financial Statements
For the Year Ended 30 June 2021

12 Other Liabilities

	2021 $	2020 $
CURRENT		
Accrued expenses	**1,334,641**	2,030,466

13 Issued Capital

10 (2020: 14) Ordinary shares	10	14

(a) Movement in ordinary share capital

	2021 No.	2020 No.
At the beginning of the reporting period	14	14
Shares bought back during the year	**(4)**	-
At the end of the reporting period	**10**	**14**

Ordinary shares entitle the holder to receive notice of and to attend and vote at all general meetings of the Company. On a show of hands, a member is entitled to one vote. On a poll, the number of votes is in proportion to the total level of contribution to CRC CARE Pty Ltd, as of the financial year prior to which the vote is taken.

If the Company is wound up, any assets remaining after payments of the debts and liabilities of the Company, inclusive of intellectual property, will be divided amongst Participants proportionate to their contributed percentage as at the date of the division of assets.

14 Participants' contributions (Cash basis ex GST as per note 2(b))

	2021 $	2020 $	Cumulative 2005 to 2019 $	Total $
Agilent Technologies Australia Pty Ltd				
Cash contributions	-	-	25,000	25,000
In-kind contributions				
- Salaries	-	91,500	197,000	288,500
- Other	-	197,000	1,085,204	1,282,204
Total	-	288,500	1,307,204	1,595,704

CRC CARE Pty Ltd

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Notes to the Financial Statements

For the Year Ended 30 June 2021

14 Participants' contributions (Cash basis ex GST as per note 2(b)) (cont'd)

	2021	2020	Cumulative 2005 to 2019	Total
	$	$	$	$
Alcoa World Alumina Australia				
Cash contributions	-	-	150,000	150,000
In-kind contributions				
- Salaries	-	-	94,750	94,750
- Other	-	-	-	-
Total	-	-	244,750	244,750
Australian Institute of Petroleum				
Cash contributions	-	250,000	3,200,000	3,450,000
In-kind contributions				
- Salaries	-	-	1,034,499	1,034,499
- Other	-	-	55,385	55,385
Total	-	250,000	4,289,884	4,539,884
BHP				
Cash contributions	1,750,000	1,031,000	7,063,158	9,844,158
In-kind contributions				
- Salaries	-	-	1,402,924	1,402,924
- Other	-	-	366,600	366,600
Total	1,750,000	1,031,000	8,832,682	11,613,682
CSIRO				
Cash contributions	-	-	-	-
In-kind contributions				
- Salaries	-	561,000	3,018,759	3,579,759
- Other	-	115,000	55,000	170,000
Total	-	676,000	3,073,759	3,749,759
Chemistry Centre Department of Industry and Resources (Western Australia)				
Cash contributions	-	156,000	1,728,750	1,884,750
In-kind contributions				
- Salaries	-	-	2,133,426	2,133,426
- Other	-	-	1,030,855	1,030,855
Total	-	156,000	4,893,031	5,049,031

CRC CARE Pty Ltd

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Notes to the Financial Statements
For the Year Ended 30 June 2021

14 Participants' contributions (Cash basis ex GST as per note 2(b)) (cont'd)

	2021	2020	Cumulative 2005 to 2019	Total
	$	$	$	$
CH2MHill Australia Pty Ltd				
Cash contributions	-	-	180,000	180,000
In-kind contributions				
- Salaries	-	-	53,962	53,962
- Other	-	-	-	-
Total	-	-	233,962	233,962
Coffey Environments Ltd				
Cash contributions	-	-	90,000	90,000
In-kind contributions				
- Salaries	-	-	38,850	38,850
- Other	-	-	-	-
Total	-	-	128,850	128,850
Curtin University of Technology				
Cash contributions	-	150,000	1,963,100	2,113,100
In-kind contributions				
- Salaries	-	54,000	3,631,174	3,685,174
- Other	-	-	288,879	288,879
Total	-	204,000	5,883,153	6,087,153
Department of Defence				
Cash contributions	4,155,000	3,005,000	36,443,982	43,603,982
In-kind contributions				
- Salaries	-	440,000	1,335,330	1,775,330
- Other	-	-	3,000	3,000
Total	4,155,000	3,445,000	37,782,312	45,382,312
Department of Environment Regulation (Western Australia)				
Cash contributions	-	-	2,068,444	2,068,444
In-kind contributions				
- Salaries	-	-	342,312	342,312
- Other	-	-	-	-
Total	-	-	2,410,756	2,410,756

CRC CARE Pty Ltd

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Notes to the Financial Statements
For the Year Ended 30 June 2021

14 Participants' contributions (Cash basis ex GST as per note 2(b)) (cont'd)

	2021	2020	Cumulative 2005 to 2019	Total
	$	$	$	$
Environment Protection Authority (South Australia)				
Cash contributions	-	-	1,300,000	1,300,000
In-kind contributions				
- Salaries	-	33,700	288,344	322,044
- Other	-	-	-	-
Total	-	33,700	1,588,344	1,622,044
Environment Protection Authority (Victoria)				
Cash contributions	-	-	678,000	678,000
In-kind contributions				
- Salaries	-	-	641,078	641,078
- Other	-	-	4,000	4,000
Total	-	-	1,323,078	1,323,078
Fibrecell Pty Ltd				
Cash contributions	-	-	-	-
In-kind contributions				
- Salaries	-	-	80,000	80,000
- Other	-	-	-	-
Total	-	-	80,000	80,000
GHD Pty Ltd				
Cash contributions	-	20,000	529,227	549,227
In-kind contributions				
- Salaries	-	27,000	443,440	470,440
- Other	-	-	1,606	1,606
Total	-	47,000	974,273	1,021,273
HLM Asia Group Limited				
Cash contributions	125,000	375,000	7,000,000	7,500,000
In-kind contributions				
- Salaries	-	2,602,500	19,663,143	22,265,643
- Other	-	-	-	-
Total	125,000	2,977,500	26,663,143	29,765,643

CRC CARE Pty Ltd

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Notes to the Financial Statements

For the Year Ended 30 June 2021

14 Participants' contributions (Cash basis ex GST as per note 2(b)) (cont'd)

	2021	2020	Cumulative 2005 to 2019	Total
	$	$	$	$
James Cook University				
Cash contributions	-	-	300,000	300,000
In-kind contributions				
- Salaries	-	-	352,038	352,038
- Other	-	-	-	-
Total	-	-	652,038	652,038
Southern Cross University				
Cash contributions	-	100,000	1,425,000	1,525,000
In-kind contributions				
- Salaries	-	716,300	7,419,557	8,135,857
- Other	-	154,000	5,368,732	5,522,732
Total	-	970,300	14,213,289	15,183,589
Technological Resources Pty Ltd (formerly Rio Tinto Services)				
Cash contributions	-	50,000	687,000	737,000
In-kind contributions				
- Salaries	-	-	426,193	426,193
- Other	-	-	44,629	44,629
Total	-	50,000	1,157,822	1,207,822
The University of Queensland				
Cash contributions	-	150,000	1,800,000	1,950,000
In-kind contributions				
- Salaries	-	-	3,811,083	3,811,083
- Other	-	-	4,450,638	4,450,638
Total	-	150,000	10,061,721	10,211,721
University of South Australia				
Cash contributions	-	100,000	3,200,000	3,300,000
In-kind contributions				
- Salaries	-	-	12,517,808	12,517,808
- Other	-	-	12,413,350	12,413,350
Total	-	100,000	28,131,158	28,231,158

CRC CARE Pty Ltd

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Notes to the Financial Statements

For the Year Ended 30 June 2021

14 Participants' contributions (Cash basis ex GST as per note 2(b)) (cont'd)

	2021 $	2020 $	Cumulative 2005 to 2019 $	Total $
University of Technology, Sydney				
Cash contributions	-	150,000	1,500,000	1,650,000
In-kind contributions				
- Salaries	-	-	7,169,461	7,169,461
- Other	-	-	1,460,467	1,460,467
Total	-	150,000	10,129,928	10,279,928
Victorian Urban Development Authority (VICURBAN)				
Cash contributions	-	-	120,000	120,000
In-kind contributions				
- Salaries	-	-	-	-
- Other	-	-	-	-
Total	-	-	120,000	120,000
VERUTEK				
Cash contributions	-	-	37,312	37,312
In-kind contributions				
- Salaries	-	-	15,000	15,000
- Other	-	-	-	-
Total	-	-	52,312	52,312
Chevron Australia				
Cash contributions	-	50,000	467,000	517,000
In-kind contributions				
- Salaries	-	-	7,950	7,950
- Other	-	-	-	-
Total	-	50,000	474,950	524,950
Mobil Australia (Third party)				
Cash contributions	-	-	1,617,103	1,617,103
In-kind contributions				
- Salaries	-	-	-	-
- Other	-	-	-	-
Total	-	-	1,617,103	1,617,103

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Notes to the Financial Statements
For the Year Ended 30 June 2021

14 Participants' contributions (Cash basis ex GST as per note 2(b)) (cont'd)

	2021	2020	Cumulative 2005 to 2019	Total
	$	$	$	$
Queensland Department of Environment and Resource Management				
Cash contributions	-	-	1,493,088	1,493,088
In-kind contributions				
- Salaries	-	-	2,290,794	2,290,794
- Other	-	-	1,654,436	1,654,436
Total	-	-	5,438,318	5,438,318
Other Commonwealth (Third Party)				
Cash contributions	-	-	213,615	213,615
In-kind contributions				
- Salaries	-	-	-	-
- Other	-	-	-	-
Total	-	-	213,615	213,615
Scholarship Support (Third Party)				
Cash contributions	-	-	-	-
In-kind contributions				
- Salaries	-	-	233,750	233,750
- Other	-	-	-	-
Total	-	-	233,750	233,750
National Measurement Institute (NMI)				
Cash contributions	-	-	-	-
In-kind contributions				
- Salaries	-	352,100	2,705,726	3,057,826
- Other	-	119,000	544,691	663,691
Total	-	471,100	3,250,417	3,721,517
Hort Resources (Third Party)				
Cash contributions	-	-	-	-
In-kind contributions				
- Salaries	-	-	6,400	6,400
- Other	-	-	25,000	25,000
Total	-	-	31,400	31,400

CRC CARE Pty Ltd

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Notes to the Financial Statements

For the Year Ended 30 June 2021

14 Participants' contributions (Cash basis ex GST as per note 2(b)) (cont'd)

	2021 $	2020 $	Cumulative 2005 to 2019 $	Total $
Lasse and Rumbaugh (Third Party)				
Cash contributions	-	-	-	-
In-kind contributions				
- Salaries	-	-	-	-
- Other	-	-	10,400	10,400
Total	-	-	10,400	10,400
JBS&G (Soil & Groundwater)				
Cash contributions	-	-	87,500	87,500
In-kind contributions				
- Salaries	-	-	-	-
- Other	-	-	-	-
Total	-	-	87,500	87,500
Other (Third party)				
Cash contributions	668,000	1,665,000	1,767,193	4,100,193
In-kind contributions				
- Salaries	-	-	53,550	53,550
- Other	-	-	-	-
Total	668,000	1,665,000	1,820,743	4,153,743
Capital Technic Group Pty Ltd				
Cash contributions	-	-	160,000	160,000
In-kind contributions				
- Salaries	-	-	8,000	8,000
- Other	-	-	-	-
Total	-	-	168,000	168,000
Worsley Alumina Pty Ltd				
Cash contributions	-	-	150,000	150,000
In-kind contributions				
- Salaries	-	-	13,500	13,500
- Other	-	-	-	-
Total	-	-	163,500	163,500

CRC CARE Pty Ltd

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Notes to the Financial Statements
For the Year Ended 30 June 2021

14 Participants' contributions (Cash basis ex GST as per note 2(b)) (cont'd)

	2021	2020	Cumulative 2005 to 2019	Total
	$	$	$	$
University of Western Sydney				
Cash contributions	-	50,000	300,000	350,000
In-kind contributions				
- Salaries	-	-	432,049	432,049
- Other	-	-	457,014	457,014
Total	-	50,000	1,189,063	1,239,063
Royal Melbourne Institute of Technology				
Cash contributions	-	100,000	500,000	600,000
In-kind contributions				
- Salaries	-	275,100	803,925	1,079,025
- Other	-	64,000	118,008	182,008
Total	-	439,100	1,421,933	1,861,033
University of Newcastle				
Cash contributions	-	313,000	1,125,500	1,438,500
In-kind contributions				
- Salaries	2,455,460	1,137,600	5,041,762	8,634,822
- Other	2,310,948	2,312,213	6,799,716	11,422,877
Total	4,766,408	3,762,813	12,966,978	21,496,199
ACLCA				
Cash contributions	-	5,000	10,000	15,000
In-kind contributions				
- Salaries	-	-	-	-
- Other	-	-	-	-
Total	-	5,000	10,000	15,000
Pacific Environment				
Cash contributions	-	-	-	-
In-kind contributions				
- Salaries	-	-	18,000	18,000
- Other	-	-	-	-
Total	-	-	18,000	18,000

CRC CARE Pty Ltd

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Notes to the Financial Statements

For the Year Ended 30 June 2021

14 Participants' contributions (Cash basis ex GST as per note 2(b)) (cont'd)

	2021 $	2020 $	Cumulative 2005 to 2019 $	Total $
Master Builders Australia				
Cash contributions	-	30,000	30,000	60,000
In-kind contributions				
- Salaries	-	-	-	-
- Other	-	-	-	-
Total	-	30,000	30,000	60,000

	2021	2020	Cumulative 2005 to 2019	Total
Total Commonwealth Contributions				
Cash contributions	-	759,000	55,341,000	56,100,000
Total Contributions				
Cash contributions	6,698,000	8,509,000	134,813,972	150,020,972
In-kind contributions				
- Salaries	2,455,460	6,290,800	77,725,836	86,472,096
- Other	2,310,948	2,961,213	36,237,567	41,509,728
Total	**11,464,408**	**17,761,013**	**248,777,375**	**278,002,796**

15 Remuneration of Auditors'

	2021 $	2020 $
Remuneration of the auditor for:		
- auditing or reviewing the financial statements	**26,250**	24,500

CRC CARE Pty Ltd

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Notes to the Financial Statements
For the Year Ended 30 June 2021

16 Commitments for expenditure

At balance date the entity had the following commitments for expenditure:

- Funding obligations in relation to the appointment of research staff to address research areas that are relevant to the Company's obligations under the terms of the Commonwealth Agreement is $nil (2020: $3,960,306). Funding obligations relevant to the Company's obligations to its Participants after exiting the CRC Program is $825,171 (2020: $nil).
- Non-staff component of Research projects to the extent of cash $nil (2020: $1,076,660) subject to satisfactory performance as evaluated on a 3 monthly basis.
- Funding obligations for the secondment of employees to provide services to the company for the period to 30 June 2021. The total sum of the obligations are $184,477 (2020: $386,923).
- Funding obligations for lease of office space in Adelaide commencing on 1 July 2021 and ending on 30 June 2022. The total sum of obligations is $29,640 (2020:$nil).

	2021	2020
	$	$
Payable within 1 year	**1,039,288**	5,423,889

17 Contingencies

CRC CARE Pty Ltd had the following contingent liabilities at the end of the reporting period:

Under the terms of the Participants Agreement entered into by the Company on 6 July 2011, certain Participants, who are not shareholders of the Company, have agreed to make defined contributions (both cash and in-kind) to the Company in return for an interest in any intellectual property and income from commercialisation arising from the projects to which the Company applied the relevant contributions.

At balance date, the interest of Participants, other than shareholders, in any intellectual property and income from commercialisation arising from projects funded by the Company is calculated to be 36.74% (2020: 16.45%) based on total contributions, both cash and in-kind, from the inception of CRC CARE in 2005.

18 Related Party Transactions

(a) Research and consultancy services

The Company engaged related parties that are either shareholders and/or Participants to carry out research activities funded by the Company.

The Company also, on occasion, engages related parties to provide consultancy services to the Company.

The Company's commitments in relation to research and consultancy services provided or to be provided by Participants are included in note 17 .

CRC CARE Pty Ltd

ACN 113 908 044

Notes to the Financial Statements
For the Year Ended 30 June 2021

18 Related Party Transactions (cont'd)

(b) Management services

Subsequent to the move of operations of CRC CARE to the University of Newcastle, the Managing Director is engaged via a secondment agreement from the University of Newcastle, a Participant. The agreement provides for the Managing Director to act as the Founding Director of the Global Centre for Environmental Remediation ("GCER") for 20% of his time. The balance of the Managing Director's time remains dedicated to the Company.

The Company has appropriate governance protocols and appropriate delegation of operational duties to deal with this relationship.

(c) In-kind transactions

The Company receives in-kind contributions, both staff and non-staff from Participants and applies these contributions to assist related parties to carry out research contracts entered into with the Company. During the year ended 30 June 2020 staff and non-staff in-kind contributions from Participants totaled $(4,766,408) (2020: $(9,252,013)).

19 Subsequent events

As indicated within the Directors' Report, subsequent to year end, a number of CARE industry participants agreed to continue funding the Company for the next three years. This funding will allow the Company to continue its research programs and will allow the Company to continue to operate as a going concern.

20 Economic Dependency and continuance of operations

The Company depends upon continued support from Participants for its ongoing operations. During the period ending 30 June 2021 approximately 100% (2020: 91%) of the Company's cash contributions of $6,698,000 (2020: $8,509,000) was sourced from Participants and nil (2020: 9%) from the Commonwealth of Australia.

CRC CARE Pty Ltd

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Notes to the Financial Statements
For the Year Ended 30 June 2021

21 Cash Flow Information

(a) Reconciliation of net cash flows from operating activities to operating profit after income tax

	2021 $	2020 $
Profit for the year	-	-
Impairment/ Depreciation	74,781	14,437
Reclassification of non-current assets	-	74,781
Changes in assets and liabilities:		
- decrease in trade and other receivables	322,520	192,454
- increase in assets held for sale	-	(74,781)
- (increase)/decrease in other current assets	(12,820)	211,957
- (increase)/decrease in tax liability	(19,108)	25,000
- increase/(decrease) in payables	109,236	(688,663)
- (decrease)/increase in provisions	(306,006)	37,401
- (decrease)/increase in accrued expenses	(695,825)	92,164
- increase/(decrease) in deferred revenue	41,063	(2,666,757)
Cashflows from operations	**(486,159)**	**(2,782,007)**

22 Statutory Information

The registered office and principal place of business of the company is:
CRC CARE Pty Ltd
IDC Building
University of Newcastle
Callaghan NSW 2308

CRC CARE Pty Ltd

ACN 113 908 044

Directors' Declaration

The directors have determined that the Company is not a reporting entity and that this special purpose financial report should be prepared in accordance with the accounting policies described in Note 2 to the financial statements.

The directors of the Company declare that:

1. The financial statements and notes, as set out on pages 5 to 30, are in accordance with the *Corporations Act 2001* and:

   (a) comply with Accounting Standards as stated in Note 1; and

   (b) give a true and fair view of the Company's financial position as at 30 June 2021 and of its performance for the year ended on that date in accordance with the accounting policies described in Note 2 to the financial statements.

2. In the directors' opinion, there are reasonable grounds to believe that the Company will be able to pay its debts as and when they become due and payable.

This declaration is made in accordance with a resolution of the Board of Directors.

Chairman of Board of Directors .....
Dr Paul Vogel

CEO & Managing Director .....
Prof Ravi Naidu

Dated 8 October 2021

INDEPENDENT AUDITOR'S REPORT

TO THE MEMBERS OF CRC CARE PTY LTD

Report on the Financial Report

Opinion

We have audited the financial report of CRC CARE Pty Ltd (the Company), which comprises the statement of financial position as at 30 June 2021, the statement of profit or loss and other comprehensive income, statement of changes in equity and statement of cash flows for the year then ended, and notes to the financial statements, including a summary of significant accounting policies, and the directors' declaration.

In our opinion, the accompanying financial report of the Company is in accordance with the Corporations Act 2001, including:

(a) giving a true and fair view of the Company's financial position as at 30 June 2021 and of its performance for the year then ended; and
(b) complying with Australian Accounting Standards to the extent described in Note 1, and the Corporations Regulations 2001.

Basis for Opinion

We conducted our audit in accordance with Australian Auditing Standards. Our responsibilities under those standards are further described in the Auditor's Responsibilities for the Audit of the Financial Report section of our report.

We believe that the audit evidence we have obtained is sufficient and appropriate to provide a basis for our opinion.

Emphasis of Matter – Basis of Accounting

We draw attention to Note 1 to the financial report, which describes the basis of accounting. The financial report has been prepared for the purpose of fulfilling the directors' financial reporting responsibilities under the Corporations Act 2001. As a result, the financial report may not be suitable for another purpose. Our opinion is not modified in respect of this matter.

Independence

We are independent of the Company in accordance with the auditor independence requirements of the Corporations Act 2001 and the ethical requirements of the Accounting Professional and Ethical Standards Board's APES 110 Code of Ethics for Professional Accountants (including Independence Standards) (the Code) that are relevant to our audit of the financial report in Australia. We have also fulfilled our other ethical responsibilities in accordance with the Code.

PKF(NS) Audit & Assurance Limited Partnership
ABN 91 850 861 839

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Responsibilities of the Directors for the Financial Report

The directors of the Company are responsible for the preparation of the financial report that gives a true and fair view and have determined that the basis of preparation described in Note 1 to the financial report is appropriate to meet the requirements of the Corporations Act 2001 and is appropriate to meet the needs of the members. The directors' responsibility also includes such internal control as the directors determine is necessary to enable the preparation of a financial report that gives a true and fair view and is free from material misstatement, whether due to fraud or error.

In preparing the financial report, the directors are responsible for assessing the Company's ability to continue as a going concern, disclosing, as applicable, matters relating to going concern and using the going concern basis of accounting unless the directors either intend to liquidate the Company or to cease operations, or have no realistic alternative but to do so.

Auditor's Responsibilities for the Audit of the Financial Report

Our objectives are to obtain reasonable assurance about whether the financial report as a whole is free from material misstatement, whether due to fraud or error, and to issue an auditor's report that includes our opinion. Reasonable assurance is a high level of assurance, but is not a guarantee that an audit conducted in accordance with the Australian Auditing Standards will always detect a material misstatement when it exists. Misstatements can arise from fraud or error and are considered material if, individually or in the aggregate, they could reasonably be expected to influence the economic decisions of users taken on the basis of this financial report.

As part of an audit in accordance with the Australian Auditing Standards, we exercise professional judgment and maintain professional scepticism throughout the audit. We also:

- Identify and assess the risks of material misstatement of the financial report, whether due to fraud or error, design and perform audit procedures responsive to those risks, and obtain audit evidence that is sufficient and appropriate to provide a basis for our opinion. The risk of not detecting a material misstatement resulting from fraud is higher than for one resulting from error, as fraud may involve collusion, forgery, intentional omissions, misrepresentations, or the override of internal control.

- Obtain an understanding of internal control relevant to the audit in order to design audit procedures that are appropriate in the circumstances, but not for the purpose of expressing an opinion on the effectiveness of the Company's internal control.

- Evaluate the appropriateness of accounting policies used and the reasonableness of accounting estimates and related disclosures made by the directors.

- Conclude on the appropriateness of the directors' use of the going concern basis of accounting and, based on the audit evidence obtained, whether a material uncertainty exists related to events or conditions that may cast significant doubt on the Company's ability to continue as a going concern. If we conclude that a material uncertainty exists, we are required to draw attention in our auditor's report to the related disclosures in the financial report or, if such disclosures are inadequate, to modify our opinion. Our conclusions are based on the audit evidence obtained up to the date of our auditor's report. However, future events or conditions may cause the Company to cease to continue as a going concern.

- Evaluate the overall presentation, structure and content of the financial report, including the disclosures, and whether the financial report represents the underlying transactions and events in a manner that achieves fair presentation.

CRC CARE PARTNERS

Agilent Technologies Australia Pty Ltd
Australian Contaminated Land Consultants Association Incorporated
Australian Institute of Petroleum Ltd
BHP
ChemCentre (WA)
Chevron Australia Pty Ltd
CSIRO
Curtin University
Department of Defence
Department of Environment and Resource Management (Queensland)
Department of Industry, Science, Energy and Resources – National Measurement Institute
Environment Protection Authority (SA)
Environment Protection Authority (Victoria)
EthicalChem
FibreCell Australia Pty Ltd
GHD Pty Ltd
HLM Asia Group Limited
JBS&G Pty Ltd
Master Builders Australia
Royal Melbourne Institute of Technology (RMIT)
Southern Cross University
Technological Resources Pty Ltd (Rio Tinto)
University of Newcastle
University of Queensland
University of South Australia
University of Technology, Sydney
University of Western Sydney
WA Department of Environment Regulation

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