AIOH 2018

Occupational Hygiene:
Challenges, Opportunities
& Solutions

1-5 December, Crown Melbourne

Australian Institute of Occupational Hygienists Inc
36th Annual Conference and Exhibition

AIOH AUSTRALIAN INSTITUTE OF OCCUPATIONAL HYGIENISTS

CONFERENCE PROCEEDINGS

https://www.aioh.org.au/aioh2018/

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1 – 5 December 2018

Crown Promenade
Melbourne, Victoria

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Editor

Rob Golec

www.aioh.org.au

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The Australian Institute of Occupational Hygienists Inc. is a non-profit organisation dedicated to the advancement of occupational hygiene and to the improvement of the knowledge, competence and standing of its practitioners. It is affiliated with the International Occupational Hygiene Association.

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A NOTE FROM THE 2018 AIOH PRESIDENT

On behalf of the Australian Institute of Occupational Hygienists (AIOH) council and staff, it is my pleasure to welcome you to the 36th AIOH annual conference and exhibition. AIOH 2018 provides the opportunity to continue the tradition established 36 years ago – to come together to learn, share and and renew acquaintances with delegates and guests from across the globe. I welcome all visitors to the wonderful city of Melbourne, voted the world's most livable city for seven consecutive years.

AIOH 2018 provides a tantalising scientific program spanning a range of professional education and development sessions to suit the needs of each delegate, intermingled with a lively social program and networking opportunities.

The scientific program includes a diversity of topics which may leave some difficulty in choosing which parallel session to attend. The keynote presentations and concurrent sessions will excite and challenge you, whilst providing the opportunity for career development and knowledge which will assist you in protection of worker health. For those delegates interested in learning about the occupational hygiene advances and activities occurring internationally, I highly recommend attending the sessions by International Occupational Hygiene Association (IOHA), Asian Network of Occupational Hygiene (ANOH) and the Occupational Hygiene Training Associates (OHTA).

In line with the theme for AIOH2018 – ensure you challenge yourself by attending the 'Speed Dating" meet and greet and other networking events. These opportunities allow you to meet national and international delegates from all over the world. You might meet a mentor, find the solution to a problem you have been trying to solve, or establish new professional connections and friendships.

The AIOH 2018 Trade Exhibition provides an opportunity for delegates to discuss occupational hygiene issues with a range of specialist service and equipment providers. With the rapid evolution of technology, you may find that the equipment you seek will be available sooner than you anticipate – so take the time to talk with the Exhibitors. You may even come across that elusive item of new equipment that you have been waiting for!

I would like to acknowledge the hard work of Yanel Lara and the AIOH 2018 Conference Committee in planning, preparing and delivering this conference. The time and effort that has gone into curating such a comprehensive program with such distinguished speakers, cannot be underestimated.

Finally, thank you to the AIOH 2018 conference and awards sponsors for your generosity in supporting the AIOH and its members. Your continued investment allows us to present this conference and provide opportunities for our members to further develop their professional skills. This also allows the AIOH, as a professional institute, to support members as they address challenges, identify opportunities and provide solutions for the protection of worker health.

Embrace your time in Melbourne and I wish you an enjoyable and informative conference.

Brian Eva
2018 AIOH President

A NOTE FROM THE 2018 ORGANISING COMMITTEE CHAIR

As Conference Chair and on behalf of the Conference Organising Committee, it is with pleasure that I welcome you all to our 36th Annual Conference and Exhibition of the Australian Institute of Occupational Hygienists. Our venue is the Crown Conference Centre, a purpose built, modern conference facility on the south bank of the Yarra River in cosmopolitan Melbourne. The Centre is close to cafes and restaurants, the cultural and arts precinct, stylish retailers and iconic sportive venues- one or all of which will please both Conference attendees and their partners.

Our Scientific Programme addresses our Conference Theme: Challenges, Opportunities & Solutions by bringing together speakers from across the globe and Australia to present on a wide variety of areas impacting on our Occupational Hygiene profession: trending and challenging issues such as PFAS, occupational lung disease, worker emotional and social health; opportunities to make a difference in areas such as recycling industries, the changing nature of work and fatigue management; and technological solutions found in emergency response, visual worker communication, exposure estimation and genetic susceptibility. The Concurrent Sessions, Posters and Exhibition together with Excite will complement this Conference theme by presenting the many practical aspects of our work as Occupational Hygienists.

This Conference, as in previous years, would not be a success without the financial support of our Conference Sponsors, Exhibitors and Professional Development Awards Sponsors, some of which have done so for many years. We appreciate your generosity and value your commitment to our profession. This year we recognise our exhibitors' efforts by setting aside more time for delegates to spend at the Exhibition.

Without a Conference & Events Manager and a Conference Committee, there would be no Conference so I thank them for their dedication and diligence in organising a successful event. I also would like to thank the AIOH Council and the AIOH staff for their support and assistance in our conference organising journey and its execution.

We are grateful for your attendance and support and we trust that you will be rewarded with plenty of opportunities to learn, challenge yourselves and find those solutions to make our workplaces healthier and safer.

Yanel Lara
2018 AIOH Conference Organising Committee Chair

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Enquiries should be directed to the AIOH Administration office.

BIOGRAPHICAL NOTES OF THE KEYNOTE SPEAKERS

PROFESSOR BRENDAN MURPHY

Professor Brendan Murphy is the Chief Medical Officer for the Australian Government and is the principal medical adviser to the Minister and the Department of Health. He also holds direct responsibility for the Department of Health's Office of Health Protection and the Workforce Division. Apart from the many committees he chairs, co-chairs and serves on, he is the Australian Member on the International Agency for Research on Cancer (IARC) Governing Committee and represents Australia at the World Health Assembly. Prior to his appointment, Professor Murphy was the Chief Executive Officer of Austin Health in Victoria. Professor Murphy is a Professorial Associate with the title of Professor at the University of Melbourne and an Adjunct Professor at Monash University, a Fellow of the Australian Academy of Health and Medical Sciences, a Fellow of the Royal Australian College of Physicians and Australian Institute of Company Directors.

DR KURT STRAIF

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Dr. Straif heads the section of Evidence Synthesis and Classification at IARC/WHO. He directs the WHO Classification of Tumours, the IARC Monographs and Handbooks of Cancer Prevention, serves as Director of the IARC Summer School and on national and international committees on primary and secondary prevention of cancer. He is board certified in Internal Medicine and Occupational, Environmental and Social Medicine and received his MPH and PhD in Epidemiology from the University of California, Los Angeles.

ASSOCIATE PROFESSOR DEBORAH YATES

Deborah Yates trained in Medicine at Cambridge University and completed her medical training at several London teaching hospitals. Later, she joined the Central Pneumoconiosis Panel in London and gained experience in a broad spectrum of occupational lung diseases including coal workers pneumoconiosis, silicosis, asbestos related disorders and occupational asthma. She completed an MSc in Occupational & Environmental Medicine at the London School of Hygiene and Tropical Medicine, including a thesis on asbestos-related diffuse pleural thickening, and also the AFOM (UK) and the Dip Occ Med. Since permanently moving to Australia in 1995, she has continued her research and clinical interest in occupational and obstructive lung diseases. She is a Senior Staff Specialist at St Vincent's Hospital, Sydney, Conjoint Associate Professor at UNSW and Co-Chair of the Coal Mine Dust Lung Disease (CMDLD) Collaborative Group and is active in the Thoracic Society of Australia and New Zealand (TSANZ) and Royal Australasian College of Physicians (RACP).

DR MICHAEL LOGAN

He has responded to more than 1500 HAZMAT incidents across Queensland, Australia and internationally. These have ranged from illicit labs, biological related releases, radiological, incidents chemical fires, spills, and explosions. He has a PhD in physical chemistry from the University of New South Wales and has been a Post Doctoral Fellow at the University of British Columbia. He also has various emergency management qualifications and is a HAZMAT specialist (NFPA 472). He has also been awarded the Australian Fire Service Medal. He coordinates a number of programs across the QFES including enhancing capabilities within QFES to manage HAZMAT incidents.

DANIEL DROLET

Daniel has worked 33 years at the Québec Research Institute in Occupational Health and Safety (IRSST) in Montréal, Canada. His main research activities deal with the development of laboratory analytical methods and exposure assessment strategies, adjustment of OELs to unusual work schedules, chemical mixtures management ... He has developed with many collaborators numerous applications for both laboratory and industrial hygiene uses, for the benefit of the industrial hygiene community (MIXIE, Heat Stress tools , ProtecPo , Saturisk). Daniel is also an active member of the AIHA Exposure Assessment Strategies Committee and has been involved in their "cool new tools" development (Multilanguage IHSTAT, IHMOD, IHEST and IH SkinPerm). He has been selected in 2012 by AIHA to receive the Edward J. Baier Achievement Award in recognition of his significant contribution to industrial hygiene in recent years.

DR JACK CARAVANOS

Dr. Jack Caravanos is Clinical Professor of Global Environmental Public Health at the College of Global Public Health at NYU. He is board certified in industrial hygiene (CIH) and author of the popular ACGIH study guide "Quantitative Industrial Hygiene". He prides himself as being a practicing field-based environmental and occupational health scientist and since 2005, has worked with the international NGO Pure Earth helping to create its Toxic Site Inventory Program and profiling chemical exposures. Having travelled to over 22 low and middle-income countries he has assessed dozens of sites where worker exposures continue to devastate families and communities. He is presently Director of Research at Pure Earth where he coordinates research activities based on assessment and remediation projects.

GEORGE HABIB

George Habib is a clinical psychologist and is employed as the Deputy Director of Psychology – Professional Partnerships at Monash Health. He currently maintains a clinical role in the area of psychological medicine and as part of Psychology and Specialist Services Design Team. Prior to his current role, George also held clinical leadership roles within Government, Health and the NGO sector. George is a current board member of the State Governments Therapeutic Treatment Board, and also sits on the Monash Care Steering Committee that is driving an organisation wide approach to the social and emotional wellbeing of its staff. George provides training on resilience and self-care, and is a trained peer supporter and critical incident responder.

ANDRE WINKES

In 1983 Andre started his career as a scientist at Lawrence Berkeley Laboratories in the USA on the topic of indoor air quality. Since 1984 he has been working as a consultant at Arbo Unie OHS in Arnhem in a range of functions, but always involved in projects in the field of occupational health and safety, for a broad range of organisations. Andre specialises in chemical exposure and health effects. From 1996 until 2004 he was the co-founder and board member of the Dutch Certification Authority for Industrial Hygienists. Since 2005 he has been involved in organizing the annual Dutch Occupational Hygiene Conference. In 2014 he became a member of the Dutch knowledge platform on Electromagnetic Fields. In 2016 he started as a member of the supervisory board for the Masters education "Safety" at the Technical University Delft. Since December 2017 he is a board member of the International Occupational Hygiene Society.

PROFESSOR DREW DAWSON

Prof Dawson undertook his PhD at Flinders University and completed post-doctoral fellowships at Harvard and Cornell Universities. He is an organisational psychologist who has spent the last 20 years building Australia's leading research centre for basic and applied psychology research. Over the last 20 years Prof Dawson has established one of Australia's leading research and consultancy groups in the area of shift work and labour relations. He has extensive experience in facilitating labour and management discussions around working time arrangements and fatigue risk management. He has worked as a bargaining agent facilitating labour negotiations for over 10 years.

DR DOUG BOREHAM

Dr. Boreham is also the principal scientist at Bruce Power, Manager of the Integration Department, and is the NOSM/Bruce Power Research Chair in Radiation and Health. Dr. Boreham is a recognized leader in the field of radiation health and environmental effects. He was selected as an expert Canadian delegate for the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) in 2012. He has earned several awards including: McMaster President's Award for Excellence in Instruction (2004),

Canadian Nuclear Achievement Award for outstanding Education and Communications (2005), Canadian Radiation Protection Association – Distinguished Achievement Award in Recognition of Outstanding Contributions in the Field of Radiation Protection (2009), The International Dose-Response Society selected Dr. Boreham as recipient of the 2015 Outstanding Leadership Award in the field of Dose Response.

ASSOCIATE PROFESSOR JODI OAKMAN

Jodi Oakman is an Associate Professor at the Centre for Ergonomics and Human Factors, La Trobe University. She is the Head of Department for Public Health. Her background is a mix of industry and academia. Jodi has worked extensively in industry across a range of sectors including health, manufacturing and logistics. Her PhD focussed on the ageing workforce and the impact of organisations on their employees' retirement intentions. Jodi is passionate about using evidence to change practice in organisations, and this underpins her research program in which she works closely with industry partners in order to facilitate change. She leads a program of research focused on the impact of the psychosocial work environment on musculoskeletal disorders (MSDs) and strategies to improve risk management in workplaces.

PROCEEDINGS INDEX

Concurrent Sessions

Soh Shi Hui and Susatyo Adi Wibowo, Tank Gauging: A Case Study in Health Risk Reduction

James Davies, Formaldehyde Exposure and Mortuary Workers: A Dead Cert Project!

Gregor Riese, Hazards associated with in-building decentralised wastewater treatment systems

Anita Aiezza, The important role of the occupational hygienist in establishing a collaborative global Asbestos Exhibit & Resource Centre

Candice Dix, Real-time dust monitoring to prioritise and assess control effectiveness in processing plants

Akemi Ichikawa, Comparison of the Analysis of Respirable Crystalline Silica in Workplace Air by X-ray Diffraction and Infrared Spectroscopy

Dr Berihun M Zeleke, Wi-Fi and base station exposure in Victorian workplaces

Venessa Thelan, Evolution of a Heat Stress management program at a large LNG operation in the Middle East – a Qatar Experience

Cameron Lawrence, Australian National Radiation Dose Register - A Review

Daniel Drolet, ProtecPo, a Web-based Tool Using the Hansen Solubility Parameters for the Selection of Protective Polymer Materials against Chemicals

Marcus Cattani, Development of injury risk management education for leaders

Dr Heike Neumeister-Kemp, Mould inside buildings, why does moisture protection go wrong

Marcus Cattani, Predicting incidents may never happen, but what about forecasting their risk?

Sandra McFadden, Mercury contamination in potable water - how can it happen. An Industry Share.

Shulan Liang, Work-Life Balance in Construction Workers

Brad Prezant, The consequences of poor indoor air quality - what is the associated morbidity and mortality?

Claire Bird, Climate change and Occupational Hygiene

Lauren Pickering, An Evaluation of airborne contaminants at a commercial composting facility

Jamie Ross, Melbourne Metro project

Doug Boreham, Occupational Exposure to McIntyre Powder and the Consequences.

Peter Knott, Creating Context in Real Time Measurement

Bhoopathy Sankaran, Assessment of work practices and exposure to perchloroethylene in small dry-cleaning workplaces in Sydney NSW.

Catherine Binghams, Managing workers exposure to emerging contaminants in environmental investigation and remediation programs.

Jennifer Hines, Linking Diesel Maintenance Personnel with Occupational Hygienists to Improve Worker Health

Melinda Gardner, Assessment of worker exposure to occupational organic dust in hemp processing facility

Mahinda Seneviratne, Preventing Silicosis: Exposure monitoring, Health surveillance and Hazard communication on respirable crystalline silica among engineered stone workers

Fouad Rizk, Development of a Hearing Protection Fit Testing Program

Roseanne Baxter, Investigation of Whole-body Vibration Exposure Levels in Dozer Operators Working at a Surface Coal Mining Operation.

Soyoung Lee, Blue light exposures of dental students using dental curing lamps: Scenario-based observations and experimental data

Venessa Thelan, Selecting the right Double Hearing Protection standard for a large LNG operation in the Middle East.

Dean Gleeson, H2O vs LEV: Which is best for reducing RCS in Rock Cutting?

Jane Whitelaw, Do PAPRs adequately filter DPM?

Helen Lingard, Reducing musculoskeletal injury in manual construction tasks: Objective measurement and work redesign

Ross Di Corletto, The evolving face of managing critical health risk in industry

Andrew Bennett, Managing fatigue at Shell Assets

Kate Cole, A program approach to managing occupational health and hygiene on Australia's largest public transport project, the Sydney Metro

Dr Robert McCartney, Mentally Healthy Workplaces - The Role of Occupational Hygienists and Occupational Physicians

Poster Abstracts


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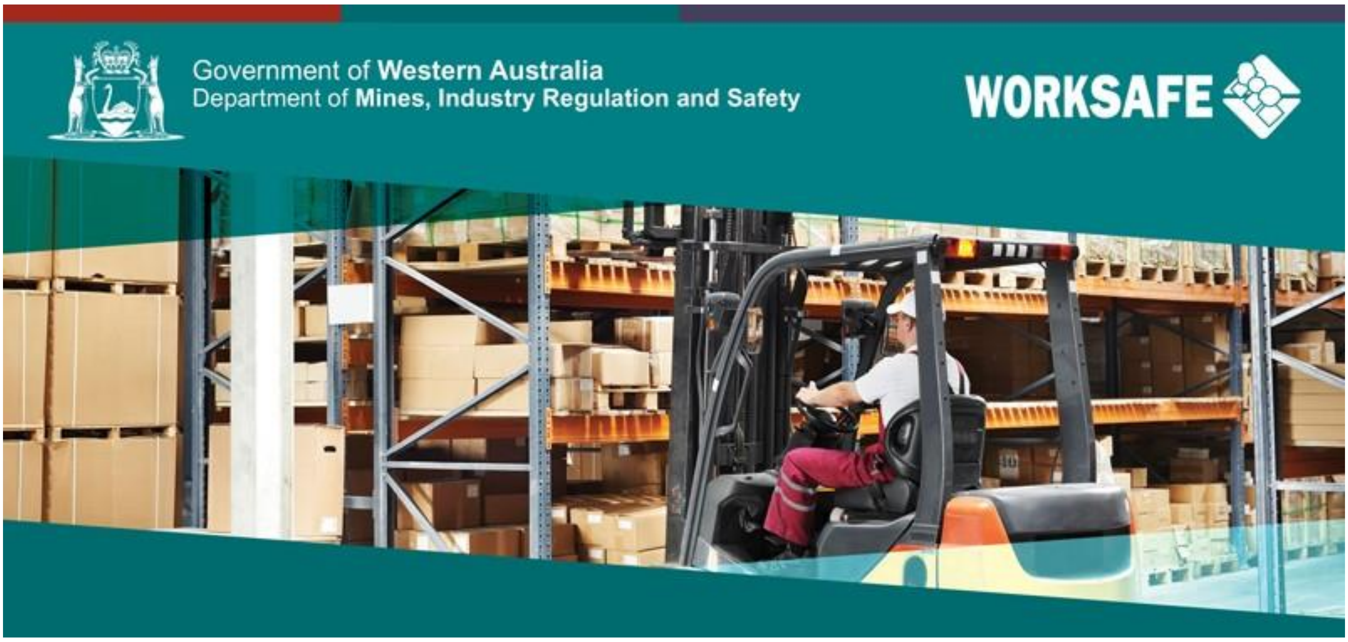
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KEYNOTE ABSTRACTS

ENVIRONMENTAL HEALTH – THE SCIENCE, EMOTION AND POLITICS

Professor Brendan Murphy

Chief Medical officer for the Australian Government

Whilst much of the responsibility and public health response to environmental health issues sits with the States and Territories, the Commonwealth CMO is drawn into this space when there are issues of national co-ordination, involvement of Commonwealth agencies and, often, where there is no other willing 'owner' of a particular issue. In nearly two years into this role, there has been considerable learning which can be shared. Most of the talk will use Per- and Poly-fluoroalkyl substances (PFAS) as the example, as this has dominated this space for the last 2 years and will do so for many years to come. Other examples will include an upcoming Parliamentary Enquiry into Biotoxin-related illnesses and proposals for a National Dust Diseases Register.

In the PFAS example, the absence of good human epidemiological data leads to a confused and emotionally charged space. Different countries and their agencies draw from the animal data and poor quality human data in diverse ways. There is little international consistency in recommendations and responses. Measurements in human blood, water and food take on an unwarranted significance. Given the inability, largely because of biological persistence, to provide definitive reassurance about health impacts, members of affected communities and elements of the media make unwarranted assumptions about conspiracies and cover-ups. This challenging PFAS journey will be the main focus of the presentation.

THE IARC MONOGRAPHS, THE BURDEN OF OCCUPATIONAL CANCER AND THE NEED FOR BETTER EXPOSURE ASSESSMENT

Dr Kurt Straif

Head, Section of Evidence Synthesis and Classification International Agency for Research on Cancer, WHO, Lyon, France

The IARC Monographs programme is the longest running program of cancer hazard identification, and is also on the cutting edge of the latest scientific developments. A short history of the evolution of the program with a focus on causal inference and changing contributions from the different scientific domains (exposure data, cancer bioassays, epidemiology and toxicology) will be followed by the latest developments in terms of systematic review, key characteristics of carcinogens, high through-put/high content data, and quantitative risk characterisation. The integration of evidence streams into an overall evaluation will be illustrated with a selected carcinogen. The Monographs' evaluations often serve as the basis for the estimation of the burden of occupational cancer. Refined and harmonized exposure data are critical for accurate global data on occupational cancer, and can also help to identify priorities for exposure control as well as document and benchmark our success in reducing the burden of occupational cancer.

CURRENT AND EMERGING OCCUPATIONAL LUNG DISEASES

Associate Professor Deborah Yates

Respiratory Physician in the Department of Thoracic Medicine at the St Vincent's Hospital in Sydney and a Conjoint Associate Professor at the University of NSW

Despite the widespread belief that occupational lung disorders have been largely prevented, there are disturbing trends worldwide with regard to the re-emergence of traditional dust diseases such as coal workers pneumonconiosis, and also description of new lung diseases from new exposures. Australia is not immune from these trends. This talk will outline current issues relevant to occupational lung disorders, which emphasize the need for vigilance, and the dangers of complacency.

WHAT DOES DETECTION AND SCIENCE HAVE TO DO WITH HAZMAT INCIDENT MANAGEMENT?

Dr Michael Logan

Director of the Queensland Fire and Emergency Services (QFES) Research and Scientific Branch

The Emergency Services within Queensland respond every day to incidents involving the release or threated release of hazardous materials such as ammonia, ammonium nitrate and organic solvents.They are often the result of an accident, or unintended consequences despite the volumes involved varying from a litre to many thousands of litres. In recent years there has been a growing interest in the manufacture of reactive materials outside industrial settings and their intended uses ranged from the curious application to deliberate use to harm others and all in between. Queensland has been no exception. These extremes even within Queensland have included methods for cold fusion, synthesis of gold using mercury and sulfur to manufacture of reactive materials like Triacetone Triperoxide (TATP). To assist the Emergency Services safely and effectively manage these incidents there are a variety of capabilities distributed across Queensland including detection supported by scientific specialists available 24 hours a day. Detection and identification of the hazard most often a chemical is essential to underpin risk based decision making including the selection and monitoring the performance of risk control measures to safely and effectively resolve and incident whilst protecting our responders and community. This presentation will highlight a journey being undertaken in Queensland involving detection capabilities and decision support software to improve its preparedness, and response to HAZMAT Incidents. The discussion will range widely from detection capabilities available within the Emergency Services to application of detection capabilities using case studies to highlight what works, does not work, and how we have extended these detection capabilities to areas even the manufacturers were not aware of. To demonstrate how far our journey has come and is ongoing we will highlight some research and development of decision support tools, such as the Emergency Response Decision Support Software using more real life examples. At the end of this presentation you will have a better appreciation of the detection challenges that confront the emergency service on a daily basis and how they are meeting these challenges.

IHSKINPERM/IHMOD

Daniel Drolet

Recently retired from the Québec Research Institute in Occupational Health and Safety (IRSST) in Montréal, Canada

Mathematical modeling to estimate exposures can be a powerful way to gain insights into past, current, or anticipated exposures. In the past, occupational hygienists have had limited options for easy to use modeling tools. Here, we present a new development, IH Mod 2.0, and outline the development approach, show the main contents, demonstrate the operational ease of this new tool and provide examples. This Microsoft Excel suite of air concentration models provides Monte Carlo Simulation (MCS) techniques and does not require any MCS software. IH Mod 2.0 runs the models in either deterministic or stochastic modes with intuitive interfaces throughout. The algorithms implemented are the same of IHMod version 1, but for key determinants of the model, the user selects either point values or the probability distributions and specifies the number of iterations for the simulation. Graphic data presentation includes point-in-time concentration curves or time-weighted averages at the 5, 25, 50, 75 and 95 percentiles of the results values' distribution. This new tool allows occupational hygienists to quickly and easily explore the probability distribution of exposures and risks, and understand how variability and/or uncertainty (or lack of knowledge) may affect the outcome. IH Mod 2.0 is available as freeware from the American Industrial Hygiene Association website, as is a companion support file. As translations are completed, IH Mod 2.0 will give the user a choice of language. The new IH SkinPerm version is now available in Spanish and Chinese and includes a new scenario allowing the user to estimate the absorption of airborne chemicals through the skin. This presentation will include live demonstration using examples from different workplace scenarios

THE GLOBAL BURDEN OF OCCUPATIONAL HEALTH DISEASE AND ITS IMPACT ON LOW AND MIDDLE-INCOME COUNTRIES

Dr Jack Caravanos

Clinical Professor of Global Environmental Health, College of Global Public Health, New York University and Professor Emeritus, City University of New York, School of Public Health

The global economy has shifted numerous jobs to low and middle-income countries; most especially the processing of recyclables. Electronic waste, plastics, and used-lead acid batteries, often find themselves in communities where peoples health and welfare is already stressed. Using a series of cases studies, significant exposure issues and challenges facing workers in several growing “industries” will be presented and reviewed. These case studies will showcase the findings of the recent Lancet report on Pollution and Health with specific interpretations and applications to occupational hygiene.

PSYCHOLOGICAL STRESS IDENTIFICATION AND SELF-MANAGEMENT

George Habib

Clinical Psychologist and Deputy Director of Psychology Professional Partnership, Monash Health

There is an increased focus within organisations on the social and emotional health of their employees. Current estimates in an Australian sample are that one in five people aged 16 to 85 years will experience one of the common forms of mental illness in any year (2007 National Survey of Mental Health and Wellbeing), and that people with mental health issues are also the least likely to be in the workforce with increasing economic costs including outlays by governments and health insurers. The rising costs of mental health issues within organisations has been highlighted in a range of reviews including with the Australian Defence Force, police, ambulance services and other organisations and has also led Worksafe to recently launch their $17 million Workwell Mental Health Improvement Fund   The current presentation will look at the state of play regarding organisational approaches to the social and emotional wellbeing of their staff and elaborate on the evidence informed and best practice approaches currently being used within organisations. George will also discuss learnings from an organisation wide approach within a major public hospital network.

VISUAL COMMUNICATION WITH THE EMPHASIS ON THE PIMEX METHOD

Andre Winkes

Senior Consultant Industrial Hygiene and Safety at Arbo Unie Expert Centre of Chemical Risk management, The Netherlands

At the moment we are confronted with a generation of workers that do not anymore read on a daily basis. New social media such as YouTube, Instagram etc. are almost completely visual. As a result it is getting more and more difficult to get the messages across by using traditional written word format.

On the other hand it is difficult for most workers to understand what exposure really means and what the effect of preventive measures are. So if exposure can be visualised there will be better understanding by workers of the hazards in their work. PIMEX is a video exposure monitoring technique which aims to make invisible hazards in the work environment visible and in this manner facilitate the reduction of hazards in workplaces. The name PIMEX is an acronym from the words **PI**cture **M**ix **Ex**posure. It implies that the method is based on mixing pictures, in this case from a video camera, with data on a worker’s exposure to different types of agents. In the Netherlands Pimex is a very successful tool for risk communication. At the moment more than 200 films are available and used by industry, the government and many different industry organizations. Most of them are used for training purposes and available on the internet. Pimex films have been made about different exposure types like noise, chemicals, vibrations, physical load, heat stress and nano particles. At the moment we are trying to modernize the technique together with our German and Swedish colleagues. A couple of films are translated in English and will be
shown. Pimex can be used worldwide to train workers to use control measures and PPE in the right manner. It will enlarge the knowledge of risks and can be used to motivate workers and management to use safe working procedures, to identify hazards and visualize good practices. Pimex has been proven as a strong, easy and cheap tool for risk communication

NEXT GENERATION FATIGUE MANAGEMENT; WORKING SAFELY WHILST FATIGUED.

Professor Drew Dawson

Director of the Appleton Institute based at Central Queensland University's Adelaide Campus

Traditionally, fatigue management has focussed on interventions that reduce the likelihood of fatigue by altering the working time arrangement (WTA). While potentially useful, changes to the WTA are often difficult. Operational constraints, labour contracts and employee expectations around overtime and income make changes politically challenging. From a risk-based perspective, risk can be reduced by either decreasing the likelihood of fatigue or by decreasing the consequence of a fatigue-related error. What we have labelled as 'fatigue-proofing'. In this paper we present a series of case studies describing informal protective behaviours that have evolved within workplaces to reduce the consequence of a fatigue-related error. Adopting Helmreich's principles of threat and error management, we demonstrate a novel methodology for eliciting common fatigue-related errors and re-proceduralising the task environment to prevent or attenuate adverse outcomes. This approach holds considerable promise for reducing fatigue-related risk in operational environments where fatigue is unavoidable including defence, emergency services, disaster relief, medical and health care services.

GENETIC SUSCEPTIBILITY TO OCCUPATIONAL EXPOSURES – HARM PREVENTION OR NOT?

Dr Doug Boreham

Professor at the Northern Ontario School of Medicine (NOSM) and Division Head for the Medical Sciences Division

Modern molecular technologies are changing the way human and environmental health can or should be monitored and protected. However, there are significant ethical and legal challenges when genetics are involved in understanding and adapting to occupational risks. An overview of the potential merits of genetic susceptibly testing for risks associated with workplace exposures will be presented. The absence of testing in the workplace will be addressed from the ethical, societal and legal perspectives. The merits and detriments of new legislation passed in Canada in 2017 to prevent genetic discrimination will be discussed.

FUTURE OF WORK FOR WORK HEALTH AND SAFETY PROFESSIONALS

Associate Professor Jodie Oakman

Associate Professor at the Centre for Ergonomics and Human Factors and Head of Public Health , La Trobe

The nature of work is changing. The impact of technology and increased automation is disrupting traditional forms of work. A workforce that is more dispersed, older and engaged in different ways of working provides some challenges for Work, Health and Safety (WHS) professionals. Whilst many traditional hazards managed by WHS professionals remain, new hazards are emerging which require attention. To explore this further, the Australian Safety & Health Professional Associations (ASHPA) commissioned La Trobe University to undertake research to identify current and future issues facing WHS professionals. Three professional associations, the AIOH, HFESA and SIA, all ASHPA members, participated in the research. Members of the three professional societies were invited to participate in a survey which explored past, current and future aspects of their work in WHS. This plenary will explore findings from this research in the context of the changing landscape of work and offer insights into what might be future challenges for WHS professionals.

TANK GAUGING: A CASE STUDY IN HEALTH RISK REDUCTION

Soh Shi Hui
Fouad Rizk, Norhamimi Mohd Yusof and Susatyo Adi Wibowo

Affilitation

Tank gauging is conducted monthly to ensure that inventories are accurate. For some products, Self-Contained Breathing Apparatus (SCBA) is needed. Carrying SCBA (typically 12 kg) up the stairs to the top of the tank requires some physical exertion and in tropical climate, heat stress can be an issue.

In this case study, tank gauging is a focus area for health risk reduction. Based on feedback from business line on the challenges in the use of SCBA for tank gauging, the need for SCBA was re-evaluated. The results were communicated to the risk owner who set up a team comprising of engineers, process technicians and the Industrial Hygienist to review options for exposure reduction that reduce reliance on SCBA. A semi-enclosed tank gauging system was proposed by the team. The solution was trialed in one business unit. Upon successful implementation, it was adopted at other business units.

This case study demonstrates the use of site feedback in risk discussion with the risk owner and how successful implementation in one unit can be replicated. By working closely with the business line, Industrial Hygienists can assist in finding risk-based and sustainable control solutions to enhance worker protection.

FORMALDEHYDE EXPOSURE AND MORTUARY WORKERS: A DEAD CERT PROJECT!

James Davies[1]
linda apthorpe[1], Jane Whitelaw[1] and Melanine Cocca[1]

[1] University of Wollongong

Formaldehyde is widely used in many workplaces. In the funeral industry, a diluted water soluble formulation (known as ‘Formalin’) is extensively used for embalming purposes as a disinfectant and a preservative agent. Formaldehyde has been classified under the GHS as a Category 1B carcinogen (IARC: Group 1 carcinogen); is a skin sensitisation agent; and is toxin which can have acute effects on the respiratory system and skin.

In the context of the funeral industry, various levels of embalming treatments are used to prevent decomposition based on the wishes of the deceased and their families. Depending on the requirements, small amounts of formalin may be used for short term and small area preservation (e.g. viewing) through to large amounts for long term ‘storage’ in crypts.

For some of these applications, significant amounts of formalin is used over long periods of time (up to 8 hours) with the opportunity for worker exposure high. In addition, there are a wide variety of workplace conditions and environments where mortuary work is undertaken which impact exposure. Morticians have reported adverse health effects such as respiratory illnesses including shortness of breath, bronchitis, chest tightness, wheezing and coughing.

This workplace research project investigates formaldehyde exposure for morticians with the intention of improving standards, implementation of practical controls to reduce exposure (including elimination of formaldehyde and replacement with glycerine) and increasing awareness of formaldehyde exposure for the Funeral Industry.

ASSESSMENT OF AIRBORNE CONTAMINANT EXPOSURES AND OTHER WORKPLACE HAZARDS ASSOCIATED WITH IN-BUILDING SEWAGE TREATMENT SYSTEMS

Gregor Riese[1, 2] & Sue Reed[1]

1. Edith Cowan University – School of Medical and Health Sciences
2. Giant Hygiene Services – Sydney, Australia

INTRODUCTION

The rapid development of sewage treatment and water technologies, including membrane bioreactors and remote real-time monitoring of systems, has opened up sewer mining as a viable option for large commercial buildings to access treated sewage for non-potable building uses (e.g. cooling towers, toilet flushing). The development and installation of these systems into the urban environment and part of the push for greater environmental sustainability (e.g. Green Star and NABERS ratings) has created a unique work environment for the maintenance workers and building managers looking after these systems. Previously well-understood hazards and risk management methods associated with large-scale centralised sewage treatment and applied new technologies to create compact systems that fit into the basements of some of the most iconic buildings in our capital cities. This paper will present the results of a study into the workplace hazards associated with managing and maintaining onsite and decentralised wastewater systems in two large commercial buildings in Sydney.

SEWAGE WORKER HAZARDS

Technological developments in the treatment of sewage ('blackwater') and the use of membrane bioreactors (MBRs) over the past decade has allowed the use of small-scale sewage treatment plants (STPs) in a range of new locations and/or applications. These systems go by a number of different names depending on where they are deployed. In regional or remote areas, they are referred to as 'decentralised wastewater systems' as these typically residential customers are not serviced by centralised sewage collection systems. Alternatively, the installation of STPs in commercial environments are termed 'onsite wastewater systems'. Onsite wastewater systems are also often associated with "sewer mining" where sewage is collected from existing blackwater reticulation systems for treatment and reuse (Siegrist, 2013; Fisher & Conciatore, undated; Asano, 2009b).

This assessment examined general biological aspects associated with exposure to sewage for workers in typical modern facilities. Sewage worker are susceptible to a number of occupational infectious diseases including viruses (particularly Hepatitis A), parasitic diseases (*Cryposporidiosis, Giardiasis*), and bacterial infection (Douwes et al, 2003). A review of the literature on potential health hazards for sewage workers ranged from broad overviews of health impacts (Lundholm & Rylander, 1983; Thorn et al, 2002), to studies examining infection by specific diseases such endotoxins/bacteria (Cyprowiski et al, 2015; Friis et al, 1998; Hooste et al, 2010), midge allergies (Selden et al, 2013), hepatitis infection risk (Brugha et al, 1998; Venczel et al, 2003). The most notable observation from these studies is that disease-risk is very much a function of the STP design/management with an equal number of studies showing no significant risk to those showing higher disease incidence. Studies undertaken on sewage workers in developing countries typically show very high disease incident rates (e.g. Bener et al, 1998).

In relation to specific atmospheric hazards, hydrogen sulphide (H_2S) has been highlighted as a particular risk amongst sewage workers that is created by the decomposition of organic matter. With an odour similar to rotting eggs, H_2S has an extremely characteristic odour but above 100 to 150ppm a neurotoxic effect can set in where the odour is no detectable. H_2S can cause unconsciousness at concentrations above 250ppm and increasingly lethal at concentrations between 300-1000ppm (Forsgren et al., 2017; Austigard et al., 2018). The Australian STEL is 15ppm and the TWA 10ppm (Safework Australia HCIS). Fatalities caused by exposure to H_2S have been reported in sewage workers and is the second most common cause of fatal gas inhalation in the US (7.7% of the total) after carbon monoxide poisoning (Forsgren et al., 2017).

While the safety hazards associated with workers involved in sewage treatment are well understood, there is a far narrower range of publications which address the specific health and safety risks associated with water-reuse or sewer mining. This health and safety literature are predominantly grey literature and contained water engineering text books that are concerned with broader water reuse applications and technologies (Asano, 2009a; Chanan et al, 2014; Water Environment Federation, 2008). Because of their recent development, this literature review identified no specific studies examining the health and safety implications of STPs within the built urban environment.

PROJECT METHODOLOGY

The project methodology was planned to be undertaken in the following stages:

1. Review of the literature concerning health and safety impacts associated with operation of sewage treatment plants (STPs).
2. Initial site inspection accompanying a company service technician to characterise the workplaces and provide an initial hazard identification as well as:
    a. Identification and evaluation of any chemicals or substances used and/or stored at the workplaces for risk assessment (analysis/evaluation);
    b. Cataloguing routine and non-routine tasks undertaken by the service technician through interview and observation;
    c. Document the PPE used by service technicians and evaluate the adequacy/fit for purpose of the existing practices.
3. Undertake a minimum two further two site inspections to:
    a. Conduct static sampling within plant room over a minimum 24-hour period using calibrated airborne monitoring equipment sampling for Carbon dioxide, Carbon monoxide, Formaldehyde, Ozone, Nitrogen oxide, Nitrogen dioxide, and Total VOCs.
    b. Identify any sources of Hydrogen sulphide from existing processes/practices using a Photo Ionising Detector (PID) handheld probe with datalogging features.
    c. Characterise the ventilation systems of the plant rooms with a calculation of air-turnover under normal operations using a calibrated Hot Wire Anemometer and Smoke Tubes.
4. Collate data and prepare risk assessment of current work environment/practices including risk-analysis of equipment failure/shutdown systems and evaluate existing emergency response plans of the business.
5. Identify opportunities to improve work conditions and review the adequacy of existing procedures/PPE.

INITIAL RESULTS

At the time of writing this paper, initial workplace inspections have been undertaken at the two STP locations. Air monitoring results have not yet been analysed, however the inspections revealed the significant design challenges in allowing safe access for maintenance workers at both locations. Work areas were poorly lit, with difficult to access workspaces and inadequate ventilation. In this instance, both building management and the STP designer/plant owner share responsibility for ensuring maintenance workers have a healthy and safe work environment.

Particular hazards noted during initial inspections include potential for:

- Unsafe atmospheres
- Pathogen exposure (uncontained sewage and insect infestations)
- Confined space risks
- Falling from height risks
- Miscellaneous physical obstructions

INTERIM CONCLUSION

Initial inspections indicated poor ventilation in some areas of both plant rooms, as well as inadequate lighting and physical access in some areas. These design issues are the responsibility of the building owner and plant installers/ operators must ensure that an adequate physical environment is supplied by the building before accepting a plant room. Other hazards observed appeared to be the direct responsibility of the STP system designer/installer. Exposure to treated sewage was unavoidable at one site due to spillage from the membrane bioreactor tanks caused by excessive biological activity. This spillage is a commonplace and is a function of the system design. In addition, the lack of fall protection from the top of tanks at both locations would appear to be a design deficiency in the tank designer/manufacturer. This study highlights the important role of occupational hygienists in ensuring new and novel workplaces are evaluated for health and safety risks before the occurrence of incidents or injuries.

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THE IMPORTANT ROLE OF THE OCCUPATIONAL HYGIENIST IN ESTABLISING A COLLABORATIVE GLOBAL ASBESTOS EXHIBIT & RESOURCE CENTRE

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WHS Industry Services Pty Ltd – Asbestos Removal Risk Management Services (ARRMS)

Abstract: The eradication of asbestos from society is a positive outcome; however, along with this is the potential lost opportunity to preserve industrial history, enhance asbestos awareness, and to undertake research on the asbestos containing materials used widely in the past and in the present day, in Australia and throughout the world. There is also a risk that, through the passage of time, knowledge of the widespread use and legacy of such a hazardous material may also be eradicated and forgotten.

Many occupational hygienists have knowledge, skills and experience in asbestos use and risk management, including safe handling practices. They are often well connected with a broad range of groups that have an interest in asbestos, and are well placed to collect, record, preserve, handle and store asbestos minerals, materials and products.

This paper outlines current efforts by a Melbourne-based occupational hygienist to collect and preserve asbestos minerals, asbestos containing materials and products used across a broad range of environments, and related historic documentation. The current and potential uses and benefits of the asbestos collection are presented. These include enhanced awareness; improved identification for risk control and abatement purposes; identification of past and future asbestos exposed cohorts; identification of exposure sources that were unknown or forgotten and enhanced understanding of the context in which the production of asbestos containing materials were allowed to proliferate. Professions and groups envisaged to have an interest in the collection are identified and the vision for the establishment of a collaborative global *Asbestos Exhibit & Resource Centre* is discussed.

1. WHY AN ASBESTOS COLLECTION STARTED AND WHAT IS COLLECTED?

The mining of asbestos and the manufacture of asbestos containing products world-wide has left a legacy of suffering and disease. Thankfully, many countries, including Australia, are actively seeking to curb the infliction of asbestos-related diseases through bans, regulation and asbestos removal and abatement activities.

The eradication of asbestos from society will be a positive outcome; however, there is a risk that, through the passage of time, knowledge of the consequences of allowing the widespread proliferation of such a hazardous material may also be eradicated and forgotten. Every stone mined and every asbestos containing product made has been handled by workers and users; many of whom may have knowingly, or unknowingly, died of an asbestos-related disease.

It is for these reasons that six years ago efforts to collect and preserve asbestos minerals and products commenced. This privately funded collection comprises numerous mineral specimens and hundreds of manufactured asbestos-containing products from around the world. Many original books, catalogues, manufacturing specifications, brochures and advertisements have also been collected to give context to the historic asbestos-containing products.

The worldwide production and consumption of asbestos is still significant today in countries such as Russia, China, Brazil, Kazakhstan and India. The combined mine production within these countries totalled 1,310,000 metric tons in 2017[1] (Statistica, 2018). Despite the introduction of national bans on the import of asbestos into Australia, illegal imports have been found to occur most likely due to lack of awareness of the presence of asbestos in imported goods, incorrect documentation certifying products as asbestos free when they are not or due to oversees standards permitting products with low levels of asbestos to be categorised as 'asbestos free' (ASEA, 2017). Accordingly, the collection has been expanded to include asbestos minerals and materials from developing countries still involved in the mining and manufacturing of asbestos products. This will ensure that the collection reflects a complete picture of the use of asbestos to the present day, and may assist in identifying illegal imports.

[1] Compare with Australia's consumption of asbestos from 1920 to 2003 (over 83 years) which is estimated at a total of 12,000,000 tons or an average of 144,600 tons per year (ASEA, 2017 p.15).

2. HOW HAS THE ASBESTOS COLLECTION BEEN USED TO DATE?

So far, minerals and artefacts relevant to the built environment have been displayed extensively during the delivery of asbestos training to construction industry personnel, including site managers, project managers and tradespersons. The displays assist in enhancing the engagement of trainees and raising awareness of the potential presence of asbestos in their work environment. Photographs of a range of asbestos containing products found in different environments are also shown on a dedicated website (www.arrms.com.au) to provide insight into the extent of asbestos use throughout history and today, both in Australia and internationally.

The first formal asbestos exhibit was held in November 2017 at Old Parliament House, Canberra during the Asbestos Safety and Eradication Agency (ASEA) International Summit. It provided an opportunity to gauge interest and reactions, including any concerns about the presence of asbestos in the area where delegates congregate; noting that all asbestos artefacts were double-housed and in locked and labelled cabinets. There was considerable interest amongst delegates and with journalists reporting on the ASEA Conference. Various aspects of the exhibit were shown on WIN News Sydney and The Project and also appears on the ASEA video of Summit 2017 highlights (ASEA, 2017- video). Mr Peter Tighe, CEO at ASEA noted that:

> "The asbestos exhibit was well received by delegates and described as a 'great collection' and a 'great initiative' that contributes to the important work towards an overall goal of increased awareness of asbestos and its dangers"(Tighe, 2018).

The Australian Institute of Occupational Hygienists (AIOH) Conference 2018 provided a further opportunity to host an asbestos exhibit. The exhibit not only raises awareness about the asbestos collection amongst fellow occupational hygienists, but also demonstrates the contribution that occupational hygienists can make in advancing causes, such as asbestos disease prevention, beyond the workplace level.

Asbestos Exhibit held at Asbestos Safety and Eradication Agency (ASEA) Summit on the 26-28 November 2017 at Old Parliament House, Canberra, ACT

3. A VISION FOR A COLLABORATIVE GLOBAL *ASBESTOS EXHIBIT & RESOURCE CENTRE*

To date, various platforms have been used to display parts of the asbestos collection and associated historic documentation mainly for the purpose of raising awareness of the extensive use of asbestos throughout the world. However, mobile displays have limited reach and do not realise the full potential of an extensive asbestos collection.

The continual expansion of the collection stems from a strong desire to preserve, educate and research. In this regard, the vision is to establish a global *Asbestos Exhibit & Resource Centre* dedicated to asbestos awareness, education, research, disease prevention and the preservation of industrial history. The goal of the Centre is to preserve and provide resources to support the work of a broad group of potential users.

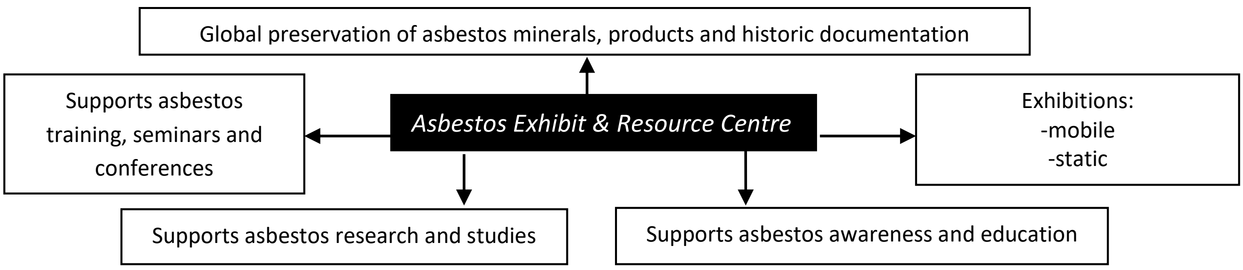

Figure 1: Goals of the proposed *Asbestos Exhibit & Resource Centre*

The goal of establishing a global *Asbestos Exhibit & Resource Centre* is a very ambitious one and realistically can only be implemented using a phased approach and with community support. The first stage is the establishment of an initial "virtual" Resource Centre through the use of a website, social media, collections catalogues and supported by ongoing mobile exhibits. The later stages of establishing a physical Resource Centre, to be also open to the public, requires considerable support and funding.

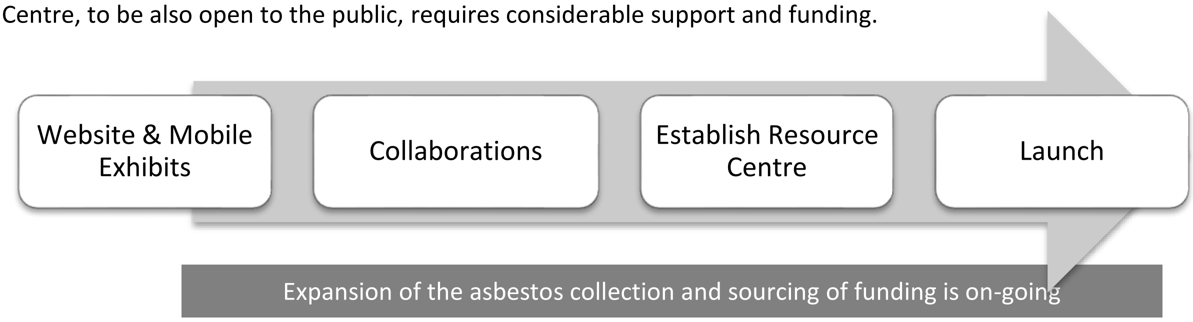

Figure 2: Proposed phases in the establishment of the *Asbestos Exhibit & Resource Centre*

Information about the project has been widely disseminated and support is being sought from both government and non-government institutions.

An additional avenue that can potentially contribute to the establishment of the Resource Centre is collaborations with institutions such as universities seeking work-integrated learning opportunities for final year undergraduate and post-graduate students. The potential for hands-on work experience are numerous and include –

- studies of past and current exposure from the manufacture and use of the asbestos-containing materials and identification of possible exposure cohorts (Studies in health sciences fields, including occupational hygiene and epidemiology)
- IT solutions to catalogue and link the items in the collection (Studies in Information Technology)
- creating and maintaining social media platforms (Studies in Media and Communications)
- promotion of events (Studies in Media and Communications & Event Management)
- managing events (Studies in Event Management)
- taking photos of asbestos collection items (Studies in Photography and Photo Imaging)
- publication of an asbestos picture book (Media and Communications and Arts/Humanities)
- development of strategies to overcome barriers created by people's fear of asbestos and which will entice them to visit an exhibit (Social Science & Communications)
- project management (Studies in Project Management)
- production of short film/documentary on use of asbestos – past and present (Studies in Film/Television)
- cataloguing and collection management (Diploma of Library and Information Services).

4. BENEFITS OF HAVING AN *ASBESTOS EXHIBIT & RESOURCE CENTRE*?

The potential benefits of an *Asbestos Exhibit & Resource Centre* include –

- An asbestos mineral repository that stores and records the types of asbestos mined around the world.
- Preservation and repository of asbestos containing products and associated documentation.
- Ready access to resources to support asbestos-related research, studies and educational activities.
- Accurate records of the use of asbestos containing products and it composition through analyses.
- Improved identification of asbestos containing material potentially resulting in reduced incidents of accidental exposures.
- Enhanced knowledge of the history and use of asbestos, the timelines of the manufacture and use of the asbestos containing products, and the methods used to market these products. This also provides an insight into the societal, political and regulatory context in which the uses of asbestos containing materials were allowed to proliferate.
- Increased awareness and education on the broad use of asbestos containing products across a range of environments (construction, manufacturing, hospitals, schools, domestic) industries, providing an enhanced insight into the possible avenues of past and present exposure and of exposed populations.

- Enables more tailored and enhanced questionnaires to be developed for surveying mesothelioma patients due to more detailed and accurate information about asbestos sources and exposed populations.
- Access to asbestos fibres to conduct quality-assured experiments on the exposure-effect mechanism of asbestos-related diseases.
- Maintenance of resources in one central location, and through collaborations and networks can be expanded further and accessed by those working in the asbestos field.

5. WHO WILL USE THE *ASBESTOS EXHIBIT & RESOURCE CENTRE*?

It is envisaged that an *Asbestos Exhibit & Resource Centre* would be of interest to a broad range of groups –

- Public/environmental health practitioners and researchers
- Epidemiologists
- Occupational hygienists
- Medical and clinical researchers
- Historians
- Social researchers
- Lawyers
- Educators
- Unions
- Employer associations
- Government authorities
- Asbestos support groups
- General public

It is anticipated that there would be considerable global interest in the establishment of a collaborative *Asbestos Exhibit & Resource Centre* and international cooperation is currently being explored.

6. THE IMPORTANT ROLE OF THE OCCUPATIONAL HYGIENIST IN THE ESTABLISHMENT OF A GLOBAL *ASBESTOS EXHIBIT & RESOURCE CENTRE*

Expertise

"Occupational hygiene is the science and art of anticipation, recognition, evaluation and control of hazards in, or arising from the workplace that can result in injury, illness, impairment, or affect the wellbeing of workers and members of the community" (AIOH, 2018). Occupational hygienists specialise in the assessment and control of chemical (including fibrous dusts such as asbestos), physical and biological hazards.

Occupational hygienists with relevant asbestos knowledge and experience are relied upon to –

- inform workplace parties on the health hazards associated with asbestos and the risk of health effects;
- conduct surveys to identify the presence of asbestos in both workplaces and the domestic environment and prepare Asbestos Registers;
- assess any exposure risks, including undertaking personal airborne asbestos monitoring;
- advise on risk control strategies in both the management and removal of asbestos, including developing Asbestos Management Plans
- advise on control measures, including safe work practices, when undertaking activities involving asbestos e.g. cutting, drilling, painting asbestos containing material
- conduct paraoccupational (static) airborne asbestos monitoring associated with asbestos removal activities and/or interpret analysis findings, and
- conduct clearance inspections following removal works and to certify a removal area as safe for re-occupation.

Indeed, SafeWork Australia *Model Code of Practice - How to Manage and Control Asbestos in the Workplace* (SWA, 2016 p. 13, 33) and *Model Code of Practice - How to Remove Asbestos Safely* (SWA, 2016 p.8) recognises occupational hygienists with relevant asbestos experience as "competent persons" for the purpose of asbestos identification, airborne asbestos monitoring and clearance inspections/certificates.

Some occupational hygienists have additional expertise in the identification of asbestos in bulk samples and the analysis of airborne fibre samples using microscopic methods prescribed in legislation.

Occupational hygienists are also often the trainers of asbestos courses, including those delivered through the Vocational Education and Training (VET) sector – asbestos awareness, licensed asbestos removal and supervision of licensed asbestos removal work.

On this basis, occupational hygienists with knowledge and practical skills in asbestos are well placed to lead and support the establishment of a global *Asbestos Exhibit & Resource Centre*, as they –

- are knowledgeable of the history of asbestos use;
- are knowledgeable of asbestos-related regulatory requirements;
- understand risks associated with asbestos, can undertake risk assessments associated with running such a Centre, and have risk in perspective;
- are skilled in the determination, implementation, management and maintenance of risk control strategies required for the safe handling, storage and transport of asbestos artefacts;
- can conduct analyses to identify the types of asbestos in the asbestos minerals and artefacts, where such analyses are carried out in a NATA[2] accredited laboratory;
- are in a position to identify and source asbestos-containing material while undertaking their work, by utilising connections within the asbestos industry, and through professional networks within Australia and overseas.

However, the maintenance and public display of any collection requires specialist skills beyond that normally expected of an occupational hygienist; skills that are collectively found in the array of professions that make up a museum. These skills include museum management, cataloguing, collections management, preservation, acquisitions and curating. Thankfully, there are a range of museum cataloguing software that can be readily purchased. Membership to Museums Australia has thus far provided the opportunity to participate in a range of workshops including on cataloguing, collection management, conservation, capturing quality catalogue images and exhibition skills. While not intended for achieving expert skill levels, the workshops are invaluable in assisting relatively small-scale collectors. It is likely that the establishment of an *Asbestos Exhibit & Resource Centre* will warrant other dedicated skilled professional(s) to supplement the role of the occupational hygienist.

<u>Connections between occupational hygienists and associated health sciences and asbestos interest groups</u>

The goal of, or interest in, asbestos disease prevention is not unique to occupational hygienists. Indeed, it is not unusual for occupational hygienists to liaise or work with public/environment health practitioners, toxicologists, epidemiologists, medical practitioners and other hygiene sciences, asbestos victim support groups and regulators for the purpose of protecting and preventing individuals and populations from harm and disease. It is these linkages that position the occupational hygienist as a key player in the establishment of a global *Asbestos Exhibit & Resource Centre*.

Occupational hygienists and environmental health practitioners are particularly strongly linked. In regard to asbestos this is illustrated by –

- asbestos hazards being a threat to both people at work and the community;
- the methodology used to identify asbestos, assess risk and determine exposure control strategies are the same for each practitioner;
- the scientific need to consider both occupational and community exposure in order to determine the risk of incurring an asbestos related disease;
- asbestos exposure control decisions often stemming from the broader view of each practitioner;
- the linkages between occupational and environmental health enhancing incentives within the political environment for the removal of asbestos from both the workforce and the community[3]
- the common appreciation of the contribution that epidemiology makes to understanding the effects of workplace and environmental exposure;
- human resources efficiencies that can be gained through collaborations.

In describing the benefits of linking occupational and environmental health, Yassi <u>etal</u> (2011) notes "... even where it is desirable for professionals to operate strictly in only one of these fields, having a good appreciation of the other enhances the credibility, knowledge base and effectiveness of the overall endeavour".

[2] NATA (National Association of Testing Authorities) is Australia's national accreditation body for the accreditation of laboratories, inspection bodies, calibration services, producers of certified reference materials and proficiency testing scheme providers throughout Australia (NATA, 2018)

[3] In Australia this is demonstrated by the establishment of the Asbestos Safety and Eradication Agency by the Federal Government. While in Victoria, this is demonstrated by the establishment of the Victoria Asbestos Eradication Agency whose mandate is to facilitate a risk based approach to the removal of asbestos from public buildings.

The fields of occupational hygiene and epidemiology are also tightly connected and overlapping fields which together seek to “positively influence the quality of human life...and together represent the fundaments of preventative medicine” (MEFANET, 2018). This is well illustrated in the work of epidemiologists to inform adopted occupational exposure limits that are so relied upon by occupational hygienists. The field based cross-sectional study of two-hundred and ninety-nine (299) miners and millers from Montana, Texas and North Carolina titled ‘An Epidemiological-Industrial Hygiene Study of Talc Workers’ provides a practical example of the synergy between occupational hygienists and epidemiologists (Gamble etal, 1980). This study involved an examination of lung function and X-rays, a review of work histories and personal respiratory dust sampling for each job. Cumulative exposure was calculated and symptoms of disease examined.

In general terms, the connections between occupational hygiene and the broad range of health science fields and stakeholders leads to an appreciation of the interests of each group and of the potential benefits that an *Asbestos Exhibit & Resource Centre* can deliver to all potential users. The idea of the occupational hygienist as a central part or glue that binds the related fields has been described well by Pityn (2008, p 165) who states “Simply put, hygiene is not a single scientific entity, but the collaboration of many human sciences, disciplines, professions and technologies, with the common purpose of protecting individuals and communities from harmful exposures”.

7. CONCLUDING REMARKS

The collection of asbestos minerals, artefacts and historic documentation preserves important industrial history and can potentially be used by a broad range of groups for increasing awareness, education, diseases prevention, scientific studies and research. The vision for the establishment of a collaborative global *Asbestos Exhibit & Resource Centre* can be realised through support from a range of institutions and with staged implementation. The expertise and connections of the occupational hygienist positions them well as a significant player in the establishment of such a *Resource Centre*.

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REAL-TIME DUST MONITORING TO PRIORITISE AND ASSESS CONTROL EFFECTIVENESS IN PROCESSING PLANTS

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Introduction

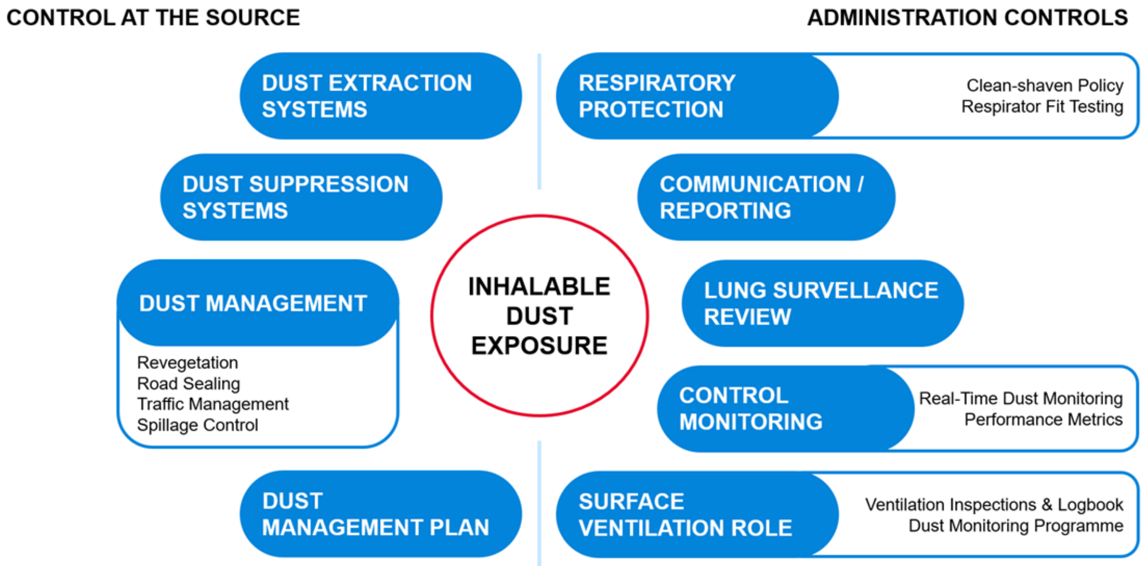
Dust is generated and dispersed into the air in mining operations through crushing, grinding, screening and material transfer. If not adequately controlled, airborne dust concentrations may exceed exposure standards and pose a health risk to those working in proximity to these processes. Workers exposed to inhalable dust are susceptible to irritation of the eyes, nose and throat (Australian Institute of Occupational Hygienists, 2014, p.3). Long term exposure above the occupational exposure limit (OEL) to *Dusts Not Otherwise Specified* may cause an inflammatory reaction in the lung, resulting in chronic obstructive pulmonary disease (COPD) (Cherrie et al 2013).

The focus of this paper is to identify and prioritise dust sources that may contribute to occupational exposures in processing plants. This is based on a comprehensive, real-time project that offers practical insights and applications for effective dust management.

In-depth real-time monitoring was conducted across several iron ore mine sites during 2017 and 2018. These sites use dry processing plants, meaning that no water is added to the ore across the processing circuit. As such, dry processing plants are typically associated with higher airborne dust levels compared to wet plants (Department of Health and Human Services 2012).

The primary focus of this paper is to share the process, practical application, considerations and outcomes for the real-time monitoring assessments. It is important to note that these assessments comprise only one aspect of a holistic inhalable dust improvement project. As is evident from Figure 1 below, this real-time dust monitoring forms a component of the 'control monitoring' element of the overarching inhalable dust project.

Figure 1: Components of the Inhalable Dust Project:



Health Effects of Low Toxicity Dusts

Low toxicity dusts include all poorly soluble, non-fibrous dusts that have an insignificant toxic effect on the body at low levels of exposure. However, if low toxicity dusts are inhaled in sufficient quantities, they can accumulate in the lung over time and cause injury to the terminal airways and proximal alveoli. This may lead to inflammation of the lungs and eventually to the development of COPD (Cherrie et al 2013). Exposure to low-toxicity dusts is also associated with pulmonary deficits including decline in the forced expiratory volume in one second (FEV1) and forced vital capacity (FVC) (Cowie et al 2006).

Low toxicity dusts impact on the health, comfort and safety of workers. Acute health impacts include unpleasant deposits in the eyes, ears and upper respiratory tract. From a safety point of view, excessive concentrations of low toxicity dust in the workplace may lead to poor visibility (Cherrie et al 2013).

Inhalable dust present in the Company's processing plants is considered to be low toxicity. This is based on both the Company safety data sheet for their iron ore product and personal monitoring results for asbestos and respirable crystalline silica that are significantly below the relevant OELs.

Limitations of Gravimetric Dust Sampling
Personal exposure monitoring is conducted to assess similar exposure group (SEG) conformance with respirable and inhalable dust exposure standards. Statistical analysis of Company personal monitoring results identified an increasing trend in the exposure of operators and maintainers to inhalable dust across the dry processing plants. As gravimetric sampling is limited to a single time weighted average result, it is challenging to identify contributing dust sources. Alternatively, real-time dust monitoring coupled with video recording is an effective means of identifying dust sources so that suitable solutions can be implemented.

Traditionally, analysis of the locations and tasks documented in sample field sheets can be used to identify trends and likely areas of elevated exposure. However, this information does not pinpoint the most significant dust sources. This is due to the numerous crushing, grinding, screening and material transfer points within each processing plant. Therefore, it is difficult to develop a business case that identifies prioritised sources for control implementation based solely on gravimetric sampling.

From an economic perspective, it can be beneficial to prioritise controls as it may not be practicable to control all potential dust sources.

Objectives of this Project
The following objectives identify and prioritise dust sources across the mine sites involved in this project.

Table 1: Real-time monitoring project objectives and measures

Objectives	Measures
1. *Site prioritisation:* prioritise the sites based on personal inhalable dust exposure data	Statistical analysis of personal sampling data
2. *Area prioritisation:* prioritise process plant areas at the sites identified through the site prioritisation	Real-time monitoring data (AM520)
3. *Dust source identification:* prioritise dust sources in each of the process plant areas assessed	Real-time monitoring data and video footage analysed using Enhanced Video Analysis of Dust Exposures (EVADE) software programme
4. *Recommendations:* prioritise control measures based on site and area priorities and dust sources identified	Recommendations based on visible dust sources (video footage) and prioritised based on quantitative real-time data
5. *Review:* demonstrate the effectiveness of control measures	Real-time monitoring pre- and post-control implementation
6. *Continuous improvement:* identify common area priorities and dust sources to improve future plant designs and specifications	Comparison of the real-time monitoring assessment outcomes across the operations assessed

Project Method
The real-time monitoring process developed by the Company Hygiene Specialist and Engineering Specialist is summarised in the following six steps:

1. Identification of Suitable Monitoring Equipment and Software
The TSI AM520 Personal Aerosol Monitor (TSI 2018), SKC Split2 Particulate Monitor (SKC 2015) and GoPro camera were trialled during the early stages of the project. The SKC Split2 Particulate Monitor was deemed unsuitable for this application as it is too bulky (requiring the addition of an active sampling pump). Moreover,

the supporting software was not as intuitive as the TSI AM520 software interface. A summary of the equipment trial outcomes is provided in the table below.

Table 2: Summary of equipment trial outcomes

Equipment	Key Features	Software	Considerations
SKC Split2 Particulate Monitor	• Inhalable fraction • Real-time & Gravimetric • Additional active sampling pump • Bulky	EDC DustComm Pro	• Counterintuitive • Difficulty downloading data • Technical issues • Not reliable 
TSI AM520 Personal Aerosol Monitor	• PM10 • Real-time only • Inbuilt pump • Lightweight	TSI TrakPro (version 5)	• Intuitive • Easy data download • User-friendly software • Data analysis capability • Reliable 
GoPro Camera	• Helmet mounted • Lightweight	HandBrake (compress files & remove audio)	• Video quality and angle • Large files and limited storage • No time stamp • Battery life 

The real-time personal dust monitoring assessments were conducted using TSI AM520 Personal Aerosol Monitors coupled with video footage from GoPro cameras mounted to workers' hard hats. The real-time dust and video data were imported into the EVADE software program (Centres for Disease Control and Prevention 2018) for simultaneously viewing.

2. Real-time Monitoring Assessment Preparation

In preparation for each assessment, the following data was gathered in advance for each site:

- Processing plant maps and engineering drawings (including locations of control measures)
- Processing plant shutdown schedule (to ensure that the assessment areas were planned to be fully operational during the assessment)
- Dust suppression and extraction system status
- Personal exposure field sheet analysis for inhalable and respirable samples to identify areas and tasks associated with elevated results
- Site contacts and escorts

3. Real-time Monitoring Assessment

The assessment conducted by the Hygiene and Engineering Specialists comprised a walk-through of all processing plant areas. During the walk-through, one member wore the personal AM520 monitor and helmet mounted GoPro camera while the other kept a log of recording times, locations, notable operating conditions and the status of control measures. The PM10 impactor was used on the AM520 monitor and the data logging function was set-up to record every second.

The following contextual variables were identified and captured as potential extraneous influences on real-time dust data:

- Weather conditions (temperature, wind speed, relative humidity and rainfall)
- Processing plant production levels and operational status
- Shutdowns in progress
- Vehicle traffic

4. Data Interpretation and Reporting

Following the walk-throughs, data from the personal AM520 was downloaded to the TSI TrakPro 5 software package and exported to Excel for analysis. Data from each area was separately interpreted and combined to produce a site-specific graph that illustrates priority areas based on peak dust recordings (refer to section 4.2).

Videos from the GoPro camera were downloaded and the 'Handbrake' application (Handbrake 2018) was applied to compress the video files and remove the audio recordings. EVADE software (Centres for Disease

Control and Prevention 2018) was used to merge video files and logged real-time data files. This enabled the project team to simultaneously view, identify and prioritise dust sources.

The Engineering Specialist identified sources of peak dust readings within each area of the processing plants. Still photos and descriptors were included on the area specific graphs to highlight dust sources. Corresponding recommendations are included for each area in the site report.

Real-time data is a snap shot in time and several contextual factors were considered when interpreting this data including:

- The percentage of time that workers spend in each area
- Task versus plant dust sources (i.e. task exposures should also be captured)
- Weather conditions
- Plant production rates at the time of assessment
- Ore / material characteristics
- Plant / equipment operational status
- Control status (including dust suppression and extraction systems)
- Elevated results that are not relevant or are due to the survey process

4.1 Site Prioritisation (Objective 1)

Sites were prioritised based on annual statistical analyses of inhalable dust sampling results. Inhalable dust samples were collected in accordance with the Australian Standard 3640-2009 for *Workplace atmospheres – Method for sampling and gravimetric determination of inhalable dust* (Standards Australia 2009). The OEL was shift-adjusted for the various site rosters based on the Quebec Model weekly adjustment for substances that produce effects following long-term exposure (Drolet 2015).

Results for each site were extrapolated from Cority, the Company hygiene data management system, (Cority 2018) and entered into the IHSTAT for analysis. IHSTAT is a tool developed by the American Industrial Hygiene Association (AIHA) to enable statistical analysis of occupational hygiene measurement data. All data sets had a lognormal distribution with the exception of two data sets that were neither normal nor lognormal. The sites were ranked in order of priority using the 95% upper confidence limit for lognormal distributions and the mean was used for the two data sets that did not conform to a lognormal or normal distribution.

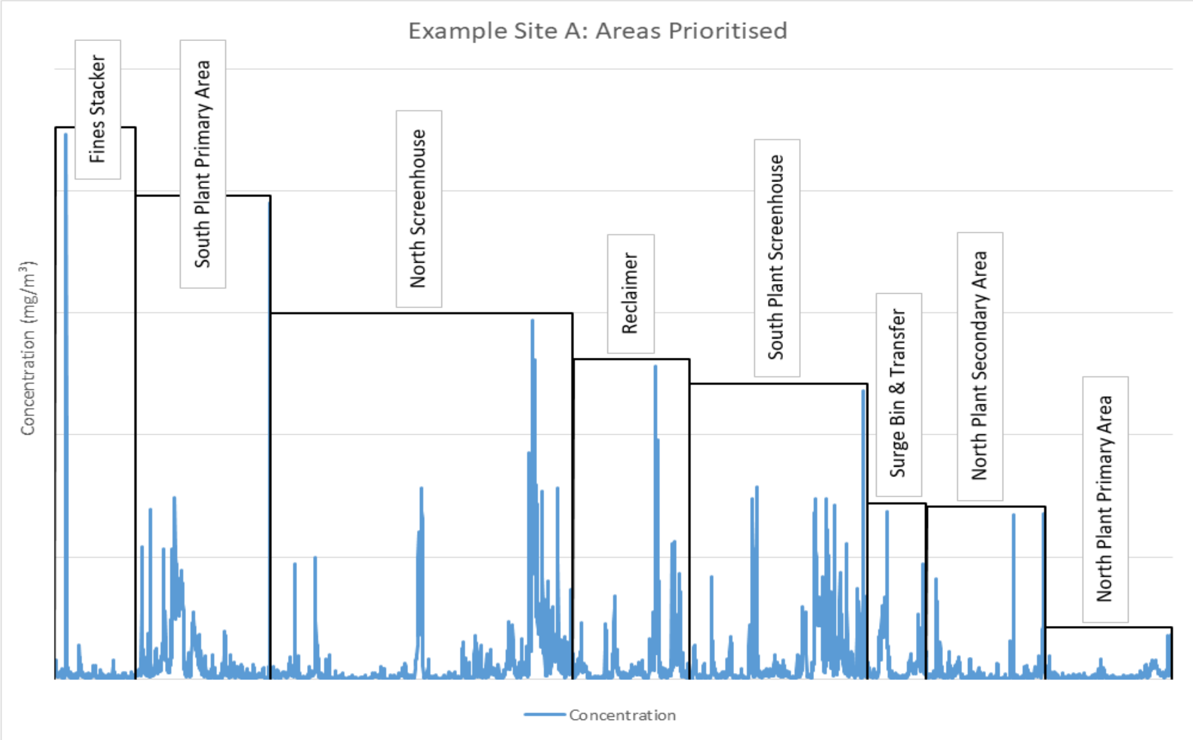
The following data points from the IHSTAT analysis were considered in the site prioritisation process:

- Number of workers in each SEG
- Date range for the data
- Number of samples collected
- Distribution (lognormal, normal or neither)
- Geometric standard deviation
- 95% Upper Confidence Limit
- Mean

4.2 Area Prioritisation (Objective 2)

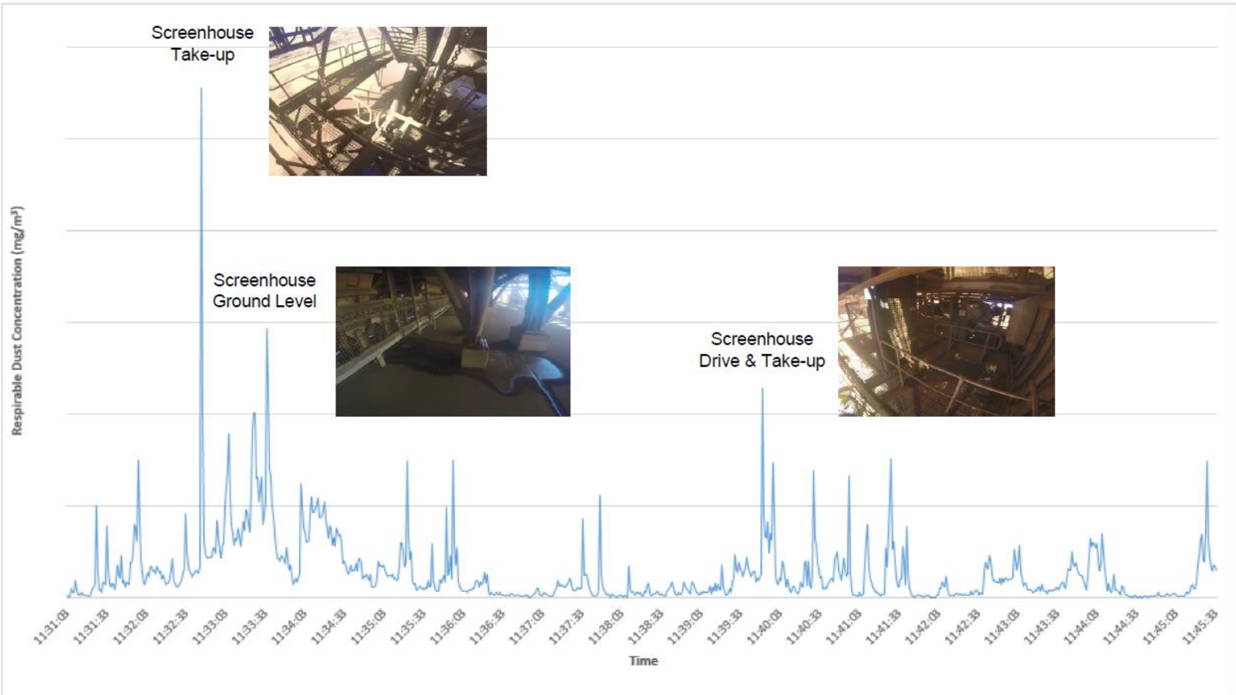
All real-time monitoring data was analysed into a combined spreadsheet and areas were ranked based on the singular highest recording for each area. All peak recordings were verified through review of the footage to identify a valid dust source. High recordings where a dust source could not be verified were eliminated from the data set. Below is an example of an area prioritisation graph for Site A.

Graph 1: Example Site A – Site Prioritisation of Processing Plant Areas



4.3 Dust Source Identification and Recommendations (Objective 3 & 4)
Real-time data for each area of the processing plant was deconstructed and graphed to identify peaks and to prioritise recommendations. A still photo and label is included in the graph to illustrate the dust source for each peak. Below is an example of an area-specific graph with sources of the peak readings identified for Site B.

Graph 2: Example Site B – Area Specific Graph (Screenhouse)



The Excel data analysis spreadsheet, videos and EVADE files were provided to each site engineering team to support the site report.

5. Review and Assessment of Control Effectiveness (Objective 5)

The real-time nature of this approach lends itself to assessing control effectiveness. Confirmation of control effectiveness is advanced by taking measurements pre- and post-control implementation under similar weather and operating conditions to assess the impact of the control measure. If possible, the assessment should be conducted on the same day, initially without and then with the control measure in operation.

Control effectiveness assessments are underway, however, the method of analysing and reporting the outcomes is yet to be finalised.

Once the site action plans have been implemented, personal inhalable and respirable exposure baseline monitoring will be repeated to assess the impact that control measures have on SEG exposures.

6. Common Real-time Survey Findings and Continuous Improvement (Objective 6)

Based on the real-time monitoring assessments conducted across numerous sites, the most common sources of elevated dust levels were:

- Screenhouses (particularly the ground level)
- Tunnels (particularly in the vicinity of the discharge conveyor)
- Apron feeders (particularly those that are not fully enclosed)
- Transfer points
- Primary crushers
- Secondary crushers
- Reclaimers

The Engineering Specialist provided the common area and dust source recommendations to the project design team so the requirements and specifications for control measures can be improved for new processing plants.

Project Limitations

1. Data cannot be used to assess personal exposure

Data collected by the AM520 monitor (up to PM10) does not represent the inhalable fraction and cannot be used to assess personal exposure data with reference to an OEL. However, the data for each mine area can be compared for control prioritisation purposes as each processing plant was assessed during a single shift and under similar weather and operating conditions. It is also difficult to make an accurate comparison across the sites assessed as operating conditions varied. Therefore, personal exposure data collected in accordance with AS 3640-2009 was exclusively used for exposure assessments and to prioritise the sites.

2. Site reports collected over a limited number of shifts

Site reports were based on data collected over a limited number of shifts and does not reflect all operating or seasonal conditions. The project team was aware of these limitations and attempted to ensure that each survey was conducted during usual plant operating conditions, when production levels were at full capacity and when there had been no rainfall in the days leading up to or during the survey.

3. Contextual factors may influence exposure data

There are a number of factors that may influence real-time data measures. This includes weather conditions (particularly rainfall), production rates and the status of control measures (extraction and suppression systems).

4. Area prioritisation is based on peak dust readings

Peak or maximum readings were used to prioritise the areas and dust sources. Site leaders were advised to consider the duration that personnel work in the vicinity of the dust source, whether the source of dust is continuous or intermittent and the extent of affected area. These factors should also be considered when developing the site action plan.

Communication Strategy

A comprehensive communication strategy was developed in the early stages of the project in consultation with the communication team. Regular and targeted communication is integral to the effective implementation of these recommendations and to develop an appropriate action plan. In addition, a compelling communication strategy is essential to gain support and funding from the leadership team. Key stakeholders include the

Managing Director, Site General Manager, Processing Plant Manager, Engineering teams, Processing Plant Operators and Maintainers and Health and Safety teams. Regular updates were provided at management meetings and the Hygiene and Engineering Specialists met with each site Processing Plant Manager and General Manager individually to present the site report and recommendations.

As part of the communications package, a professional and compelling video was developed and rolled out to all operational teams to educate workers of the negative health impacts of inhalable dust exposure and to reinforce effective control measures.

Conclusions

1. Real-time technology offers a best practice approach in identifying dust sources and prioritising dust management strategies in occupational settings. This informs the development of targeted control plans to limit dust emissions and reduce occupational dust exposure.

2. A collaborative approach to execute real time dust assessments is essential to ensure the prioritisation of improvement initiatives and resource deployment across the system. It is necessary to work closely with engineering teams to accurately interpret the data and formulate appropriate and practical recommendations.

3. Effective and regular communication with key stakeholders is integral to implementing suitable control measures and sustaining focus and utilisation of these controls.

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COMPARISON OF X-RAY DIFFRACTION AND INFRARED SPECTROSCOPY METHODS FOR THE ANALYSIS OF RESPIRABLE CRYSTALLINE SILICA OF WORKPLACE AIR SAMPLES.

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Abstract

Excessive exposure to Respirable Crystalline Silica (RCS) can result in the development of a range of adverse health effects, including silicosis and lung cancer. Internationally, RCS occupational exposure limits are being lowered, putting pressure on the capabilities of the analytical techniques used. X-ray Diffraction (XRD) or Fourier Transfer Infrared Spectroscopy (FT-IR) are the two predominant techniques used to determine the amount of crystalline silica (α-Quartz) in air. Therefore, it is timely to evaluate these two techniques.

Pure analytical standards of α-quartz and more than 200 real workplace air samples from a variety of locations were analysed by the "direct on filter" method using XRD and FT-IR techniques.

This paper compared the analytical test results on the basis of sensitivity, the effects of the loading of total dust on the filter, the linearity and range of the techniques and the interferences encountered in each technique.

In conclusion, the comparison of the "direct on filter" method using both analytical techniques gave similar limits of detection (LOD) of 0.010 mg/sample. However, the XRD showed better results due to:

i) Less interferences from common matrixes found in Australian workplace samples
ii) 33% of workplace samples failed the FT-IR peak ratio criteria for valid analysis
iii) XRD could handle up to twice the sample loading (2 mg) of an FT-IR and could correct for overloading

Keywords: α-quartz, crystalline silica, respirable dust in air, silica exposure, FT-IR, XRD

Introduction

Excessive exposure to Respirable Crystalline Silica (RCS) can result in the development of a range of adverse health effects, including silicosis and lung cancer (Safework 2013). Internationally, RCS occupational exposure limits are being lowered, putting pressure on the capabilities of the analytical techniques used. X-ray Diffraction (XRD) or Fourier Transfer Infrared Spectroscopy (FT-IR) are the two predominant techniques used to determine the amount of crystalline silica (α-Quartz) in air.

The report from a Round Robin of α-Quartz in air of the international interlaboratory proficiency program organised by the Laboratory of the Government Chemist (LGC) in the UK is shown in Table 1 (LGC 2017). Six methods were used to analyse crystalline silica in air. The most utilized method is the "direct on filter" method with 66% of laboratories using it as it requires less sample preparation and is therefore more accurate as it has experiences less analyte losses than other more complex analytical methods. Analysis of pure α-quartz by the "direct on filter" method gave robust standard deviations better than the "indirect" method in the loading range of 78-181 µg.

Real workplace airborne dust samples can have considerable interference from the sample matrix. The "Indirect" method is employed when necessary to reduce this interference by more extensive sample preparation including ashing, acid and alkaline treatments thus giving an improved analytical response from the dust samples (NMAM7603, Reut 2007). The disadvantage is that there is a risk of loss from the samples, resulting in larger variability between laboratories. Other advantages are the readily available different size of filters (e.g. 37mm) and lower limits of detection. When the dust is redeposited onto a small area (e.g. 3mm KBr pellet) the sensitivity improves while the maximum measurable amount may become to less than 1 mg (Ojima 2003, NMAM7603).

In this paper, we present a comparison between the "direct on filter" method using X-ray Diffraction (XRD) and "direct on filter" method using Fourier Transfer Infrared Spectroscopy (FT-IR).

Table 1. Robust standard deviation of methods for the analysis of respirable crystalline silica from LGC UK international interlaboratory proficiency program (LGC2017)

Method	Sample Preparation	Analytical Sampling Device	Analytical Technique	Number of labs.	Robust standard distribution between laboratories for α-quartz analysis using pure α-quartz samples (μg)			
					Loaded 78 μg	Loaded 99 μg	Loaded 134 μg	Loaded 181 μg
"Direct on filter" using FT-IR	Not required	PVC filter	FT-IR	9 (28%)	3.3	8.2	18.2	22.8
"Direct on filter" using XRD		PVC filter	XRD	12 (38%)	9.4	6.4	13.1	6.8
"Indirect-KBr" using FT-IR	Ashing/ Acid treatment/ Alkaline treatment	KBr pellet	FT-IR	7 (22%)	14.2	13.8	39.1	22.7
"Indirect on filter" using FT-IR		Re-deposited PVC filter	FT-IR	1 (3%)	-	-	-	-
"Indirect on filter" using XRD		Re-deposited PVC filter	XRD	1 (3%)	-	-	-	-
Other	-	-	-	2 (6%)	-	-	-	-

Methodology

The respirable portion of pure α-quartz Certified Reference Materials (NIST SRM 1878a, A9950) was deposited onto a 25mm PVC filter (GLA5000) from a dust generator through a cyclone sampler under the same conditions as real sampling to obtain the respirable dust fraction as real dust samples. The amount of α-quartz was measured by gravimetric analysis using a 6-digital Mettler Toledo XP6 microbalance (AS 2985: 2009, MDHS 101/2 2014). The interlaboratory proficiency program test samples for Workplace Analysis Scheme for Proficiency (WASP HSL) and (LGC UK) were also used as pure α-quartz samples.

Three types of simulated samples (α-quartz & kaolinite, α-quartz & cristobalite, α-quartz & graphite) were prepared with the same deposition method for α-quartz. An amount of α-quartz was deposited on the filter and weighed, this was followed by an amount of each interfering material (kaolin/cristobalite/ graphite) and subsequently weighed.

Real workplace air samples (*n* = 219) were assembled from a cross section of different worksites and industries. They were collected from 30 different sampling sites in various Australian industries such as mining, construction and engineering. The compositions of the dust are similar in the same sampling site, but different between individual sampling sites. The ratio of α-quartz in the respirable dust is shown in Fig. 1. It shows the variety of real workplace samples that were measured in this study.

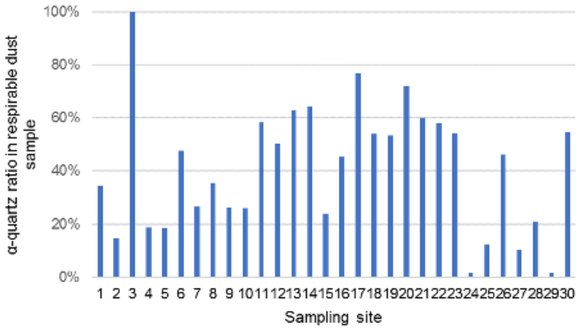

Fig. 1. The ratio of α-quartz in the respirable dust samples from 30 workplaces

Method for analysis

FT-IR measurements were performed using a Perkin Elmer Spectrum Two at resolution of 4 cm^{-1}. The absorbances of infrared energy at Si-O vibration at 800 and 780 cm^{-1} were used to measure the α-quartz. The IR beam diameter at 800 cm^{-1} was about 8 mm. The number of scans used was 32 and the spectra were averaged to reduce the signal noise. The sample filter was fixed onto a sample holder and placed vertically in the apparatus. Blank correction was performed using a pre-scanned spectrum of similar weight of the blank filter.

XRD measurements were performed using a Panalytical X'Pert Pro with a X'celerator detector and a Cu-target X-ray tube. The α-quartz (101), (100) and (112) crystalline lines were measured to analyse α-quartz. The sample filter was loaded onto a sample holder, which was rotated during the measurement to obtain homogenized sample area to give a more complete analysis of the sample. The X-ray beam power was 45kV & 40mA and the X-ray beam diameter was 21 mm almost covering the entire filter.

Results

Estimation of the LOD

Figures 2 and 3 show the α-quartz calibration curves for XRD and FT-IR. The curves for XRD and FT-IR showed good linearity with r^2 = 0.999 in the range between 0 to 2 mg and r^2 = 0.996 in the range between 0 to 1 mg, respectively.

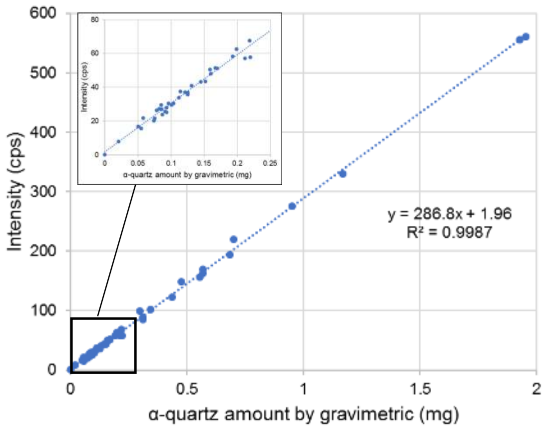

Figure 2. α-quartz calibration curve for XRD

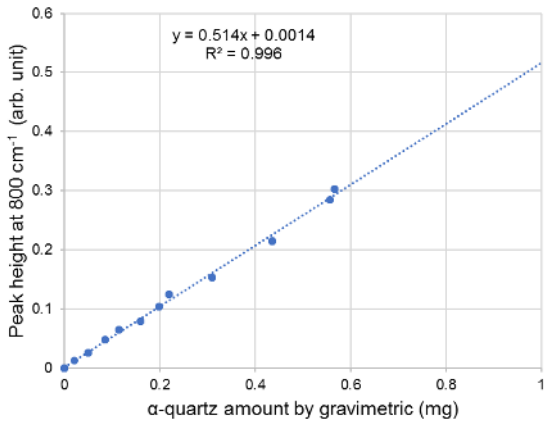

Figure 3. α-quartz calibration curve for FT-IR

Table 2. The comparison of the standard deviations of blank filters by XRD and FT-IR

	Condition	XRD (µg/filter)	FT-IR (µg/filter)
Repeatability (within day)	10 measurements of same blank filter	2.5	0.030
Intermediate precision (between days)	10 measurements of same blank filter over 3 months	3.1	0.34
Variability between filters	10 different blank filters	2.8	3.45 (9.2*)
Estimated LOD (3 x *s*)		10	10 (30*)

* blank correction performed by spectrum with average weight

Table 2 shows the variability of each method by comparison of the standard deviations (SD) between both methods in three different ways. Blank PVC filters were used to obtain the SD. The SD from 10 measurements of one blank filter within a day was measured and expressed as the repeatability. The SD from 10 measurements of the same blank in between days was measured as the intermediate precision. The variability between filters was measured using 10 different blank filters on the same day. In XRD method, the variability under the three conditions is reasonably constant. This is because the major contribution to the standard deviation is the background noise of the signal response, other factors such as the variability between filters or between days are negligible.

However, in FT-IR, the variability between filters is high even though the repeatability standard deviation and intermediate precision are quite small. The variation in the analysis of PVC filters can be attributed to a large absorption of PVC between the analytical infrared wavenumbers of 1100 to 500 cm^{-1}. Moreover, there is a large variation of absorption between individual filters due to the varying thickness of the filters which can vary in weight from 5 to 8 mg. In this study, the PVC absorption peaks were subtracted by using the spectrum of PVC filters of a similar weight as a blank correction. If the pre-weight data was not available, a spectrum with an average weight was used. This reduced the standard deviation by approximately three times.

Estimated LODs by multiplying the standard deviation of blank results by 3 are 10 µg/filter in both methods. However, if a blank correction was not performed the LOD was increased by a further factor of three. however, the major factors to determine the value are different.

Figure 4 shows increasing standard deviation with increasing amounts of α-quartz by XRD and FT-IR methods. Each data point was calculated from three measurements using three different samples with approximately equal α-quartz loading of a pure α-quartz CRM. The standard deviation of XRD and FT-IR are the similar, but the level for XRD shows slightly better at lower loadings.

Figure 5 shows the relationship between α-quartz amount in pure α-quartz samples measured with XRD and FT-IR. This shows good agreement with $r^2 = 0.9918$.

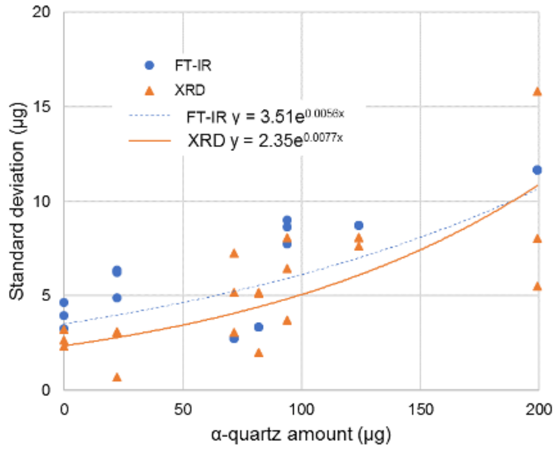

Figure 4. The repeatability standard deviation (within day) of the analysis of α-quartz by XRD and FT-IR

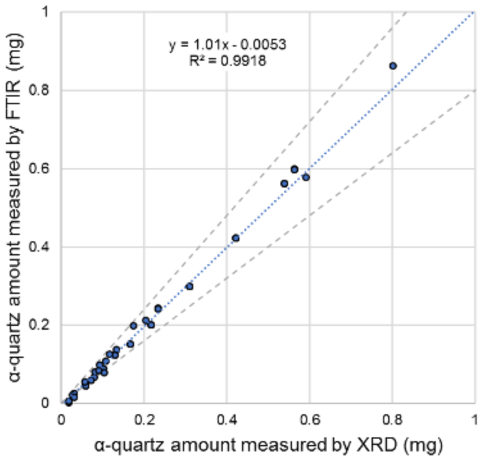

Figure 5 The relationship between α-quartz amount in pure α-quartz samples measured with XRD and FT-IR

Comparison of analytical results by using real workplace samples

Figure 6 shows the relationship between α-quartz amount in 219 real workplace samples measured with XRD and FT-IR. The regression analysis shows good correlation with r^2 =0.894, however there are many unacceptable outliers falling outside of the ± 20% shown by the dashed lines. If the outlining samples that show low infrared absorption are excluded then a general positive bias in the FT-IR results can be seen. Further analysis to determine the other crystalline components of the material revealed crystalline phases of calcite, graphite, halite, kaolinite, illite, anorthite, cristobalite and their mixtures. These phases may have contributed to the FT-IR absorbances giving the positive bias results.

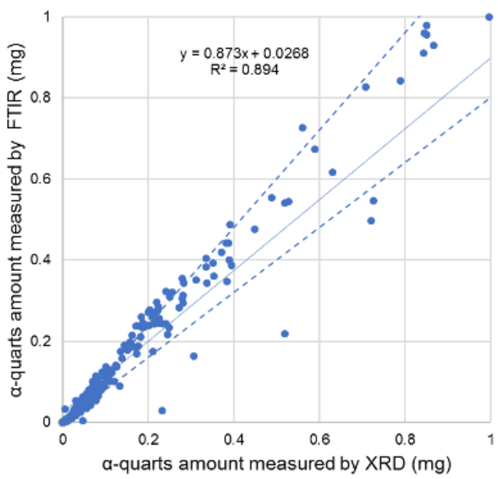

Figure 6. The relationship between α-quartz amount in 219 real work place samples measured with XRD and FT-IR

Figure 7 shows the same samples as presented in Figure 6 with outliers (n = 72) removed. They showed improved correlation between XRD and FT-IR test results with r^2 = 0.972. However, the regression curve shows an 11% positive bias in the reporting of test results from FT-IR.

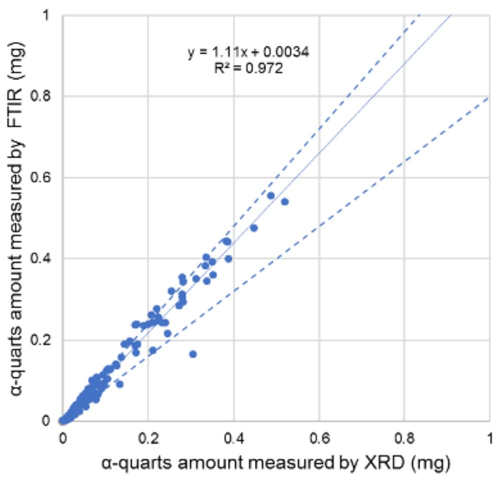

Figure 7 The relationship between α-quartz amount in 147 real work place samples measured with XRD and FT-IR. The interfered data points were removed from data points shown in Figure.6.

The outlier FT-IR test results were removed based on the HSL UK criteria of calculating the peak height ratio of 800 and 780 cm^{-1}wave numbers, and determining if the ratio returns a number between 1 to 1.4 to be a valid analytical result. The total dust on the filter should also be less than 1 mg in weight (MDHS 101/2 2014). The number of data points removed was 72, which was 33% of the total 219.

Interferences in XRD were identified by the criteria in NH&MRC which uses the response of three crystalline phase lines not displaying a variance not more than 10% of the average value (NH&MRC 1984). When the main line (101) has unacceptable interference, the second (100) or third line (112) is used to analyse. The number of data points that showed interference was for (101), (100) and (112), 1 (less than 0.5%), 16 (7%) and 4 (2%), respectively. There were no samples which showed interference on all three lines.

Interferences from matrix

To investigate the interferences further, simulated samples with interfering matrixes were prepared and analysed. The three most common matrixes kaolinite, cristobalite, and graphite were selected to investigate. Figure 8 shows the relationship between α-quartz amount in simulated samples with interfering materials measured with XRD. All the data had less than ± 20% of the 45° line as shown by the dashed lines. XRD results show less interferences from common matrixes found in real workplaces samples.

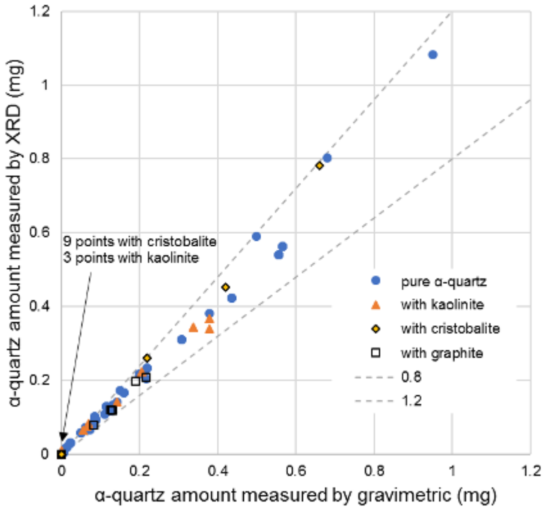

Figure 8. The relationship between α-quartz amount in simulated samples with interfering materials measured with XRD

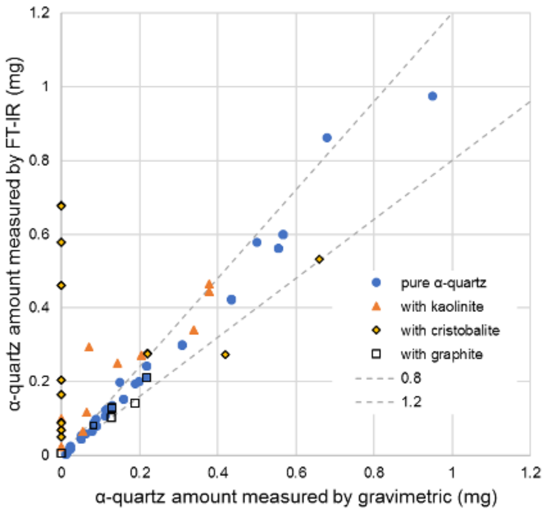

Figure 9. The relationship between α-quartz amount in simulated samples with interfering materials measured with FT-IR

Figure 9 shows the relationship between α-quartz amount in simulated samples with interfering materials measured with FT-IR. When kaolinite was included in the dust samples absorbances were seen to overlap the α-quartz peaks, resulting in a positive bias. In the case of cristobalite, the effect is more severe. The cristobalite peaks overlapped the α-quartz peaks at 800 and 780 cm^{-1}, positive or negative bias was observed depending on how detorted the absorbances at 800 and 780 cm^{-1} wave numbers were, resulting in erratic integration. When graphite was included, it showed no peak but increase of absorption level across wavelength was observed. This gave a negative bias in the samples with a large amount of incurred graphite.

Discussion

International OELs for silica are being reduced due to the increasing awareness of the risk of health effects occurring at lowers exposure levels. This trend calls for a lower analytical LOD. A LOD of 10 µg/sample will not be sufficient to adequately test for compliance to a lower OEL (Stacey 2007).

Interference from other common components of the samples means that FT-IR is unreliable for a large proportion of samples. The peak ratio method of the wavenumber bands 800 and 780 cm^{-1} needs to be utilised to ensure valid results.

In "direct on filter" method with FT-IR, the main influencing factor to determine the LOD is the difference between blank filters since the PVC filter has a large absorbance in the measurement range 1100 to 500 cm^{-1} and a blank correction is required for every sample. If every blank filter is scanned before the sampling and the spectrum is used for a blank correction, the difference becomes smaller. This is because each filter has an individual spectrum and is best used for the correction while double cost for the analysis.

In "direct on filter" method with XRD, the main influencing factor to determine LOD is the signal to noise ratio of the measured diffractogram. Interference from the PVC filter is small. The signal to noise ratio can be improved by using slower scan rate. A four times slower scan rate can provide a two times better signal to noise ratio. Another solution is to introduce a more sensitive detector. Current technologies can provide at least a two times better signal to noise ratio according to literature from major XRD manufactures (Panalytical 2018, Bruker 2017, Rigaku 2018).

Therefore, it is considered that the two "direct on filter" methods leave room for improvement of the LOD.

Conclusion

Both XRD and FT-IR show good linearity and LODs on pure α-quartz samples provided that a blank correction for each PVC filter is performed with FT-IR and the sample loading is below 1 mg for FT-IR and 2 mg for XRD.

However, FT-IR does not perform well when samples include other common constituents such as kaolinite, graphite or cristobalite. Of the real workplace samples analysed 33% did not comply with the 1 to 1.4 peak ratio rule proposed by MHDS 101/2 to ensure valid analytical results. When such constituents are encountered test results are erratic showing false positive and negative results.

It is uncommon for XRD to suffer from these inferences and when such an interference occurs two other diffraction peaks can be used to avoid erroneous results. Therefore, for the most accurate analysis of real workplace samples XRD is the preferred method of choice.

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WI-FI AND BASE STATION EXPOSURE IN VICTORIAN WORKPLACES

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As part of a study investigating risk perception to Radio Frequency Electromagnetic Energy (RF-EME) in the community, we completed an RF dosimetry survey of participants (N=63) in various workplaces in Melbourne, Victoria. These workers were not designated as RF exposed workers and the workplaces consisted of mainly office and administrative jobs. Measurements were undertaken with ExpoM RF dosimeters measured across 16 bands of the RF spectrum as part of a 24 hour measurement. The sampling rate was one sample every 10 seconds.

Mean (SD) exposures for office workers and healthcare workers to Wi-Fi of ISM 2.4GHz was 64.6 (14.9) $\mu W/m^2$ and 26.6(22.2) $\mu W/m^2$, respectively. For base station exposure at GSM 900MHz downlink, mean exposure for Office workers and healthcare workers were 28.8(18.6) $\mu W/m^2$ and 25.7(20.0) $\mu W/m^2$, respectively.

We found that the levels of exposure were similar to those reported in recent surveys in kindergartens and schools in Melbourne, Victoria. All RF broadband and narrow band measurements resulted in less than 1% of the “General Public limit”, specified in the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) RPS3 Guidelines: “Maximum Exposure Levels to Radiofrequency Fields- 3kHz to 300 GHz”.

EVOLUTION OF A HEAT STRESS MANAGEMENT PROGRAM AT A LARGE LNG OPERATION IN THE MIDDLE EAST – A QATAR EXPERIENCE

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Afiya Osunwoke[2,3,4] and Bufford Ang[4,5] [1] AIOH, [2] IOSH, [3] BSCP, [4] AIHA, [5] ACGIH
Laing O'Rourke

Introduction

The State of Qatar is located in the Persian Gulf in the Middle East, at Latitude 25.26954° N, Longitude 51.21277° E, with a maximum height above sea level of 15 meters (US Library of Congress 2018) – see Figure 1. The annual climate in Qatar includes long summers characterized by intense heat, with temperatures reaching 50 degrees Celsius (°C) (Casey & Vine 1991) and the average humidity in August reaching 59% (Weather 2 2018).

Figure 1: Qatar Geolocation (*Source: Maphilll.com n.d.)*

These extreme environmental conditions during Qatar's summer months (April to September) present a significant health risk for many thousands of outdoor workers, predominantly expatriates from Bangladesh, India, Pakistan, Nepal, Egypt and the Philippines (Snoj 2017). Exposure to extreme heat can result in occupational illnesses and injuries ranging from heat rashes and/or heat cramps, to heat exhaustion or heat stroke (Centers for Disease Control and Prevention 2018). This paper provides an overview of an evolving Heat Stress Management Program (HSMP) that mitigates the risk of these injuries and illnesses, at a large Liquefied Natural Gas (LNG) operation (the Company) in the State of Qatar in the Middle East.

As the second largest LNG operation in Qatar, the Company assets extend across a geographical area of more than 4000 square kilometres (km_2); with two operating plants incorporating nine LNG trains, three helium plants, two offshore platforms and 13 remote wellheads. The Company is located at the north eastern coastal tip of Qatar, within the Ras Laffan Industrial City, and is administered by the State owned Qatar Petroleum.

Qatar Climate

A general review of climate data for Qatar, based on weather reports collected between 1985 – 2015, shows temperate averages above 40°C in the peak summer months (June, July and August), with minimums above 30°C for the same period (Time and Date 2018) – see Figure 2.

Whilst it seems to be generally accepted that summers are getting hotter each year, irrespective of what part of the world is considered, there are several articles suggesting that the Middle East specifically may become unsuitable for human habitation by the end of this century (Warrick 2015). One particular article in *The Guardian*, 26 October 2015, states that 'at wet bulb temperatures (WBTs) above 35°C, the high heat and humidity make it physically impossible for even the fittest human body to cool itself by sweating, with fatal consequences after six hours' (Shaheen 2015). WBT is a measure of how much moisture is available in air and is one of several methods for measuring the Heat Index (HI). HI is described as how hot the weather 'feels' (US OSHA 2018), and is a single value that takes both temperature and humidity into account. HI is considered a better measure than air temperature alone for estimating the risk of heat related illness and injury.

Managing this risk through sustained monitoring and communication of the HI was a key success factor in the Company's HSMP.

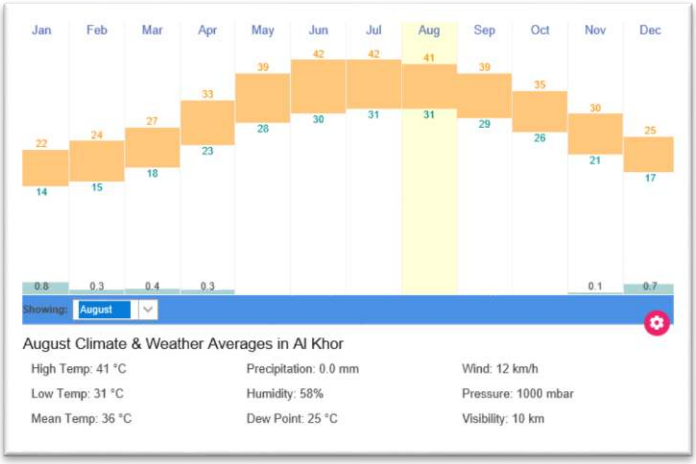

Figure 2: Annual Weather Averages – Doha International Airport (*Source: Time and Date 2018*)

Legislation & Governance

While heat stress management practices were in place prior to 2004, it is considered that the 2004 Minister of Civil Service & Housing Decision No 16 – *Specifying Working Hours in Open Places in Open Areas During the Summer* triggered the need for a more 'formal' program (Qatar Minister of Civil Service Affairs and Housing 2007). This law specifically prohibits workers working outside between 1130am and 3pm daily from June 15th to August 31st each year. To confuse things slightly, Article 3 of this same law states that '*The provisions of this Decision shall not apply to activities performed by companies working in the oil and gas projects'*. So it would seem that this one piece of protective legislation was not applicable to the large LNG operation.

To overcome this 'exclusion' and ensure the health and safety of oil and gas workers, as the governing body for Oil and Gas Producers (OGP) in Qatar, Qatar Petroleum's (QP) Health, Safety and Environment (HSE) Directorate, released a memorandum to all Managers, Company Directors, Joint Ventures and Subsidiaries stating that in relation to the Ministers decision;

- All Company's and sub-contractors must operate within the control framework of a Health Risk Assessment approved by their respective Health and Safety Staff
- All cases of heat illness must be fully investigated and findings forwarded to the QP HSE Directorate, and
- Individuals who suffer from a heat illness must be subject to a fitness for work assessment, counter-signed by the end-user Company Health & Safety Advisor prior to that individual returning to work (Qatar Petroleum 2007)

These memoranda continue to be released annually in April and now require that all necessary controls to mitigate heat related illness are documented within the Health Risk Assessment; that adherence to these controls is strictly managed by end-user Company HSE staff, and that heat illness statistics are reported to the HSE Directorate on the 1st and 15th of each month (Qatar Petroleum 2012). These memoranda demonstrate at the highest corporate level, a commitment to ensure that heat stress is effectively managed by all OGPs in Qatar. In addition to these annual reminders, the HSE Directorate's Health and Healthcare Division produced a *Guideline for Heat Stress Management in the Oil and Gas Sector* based on the OGP International Petroleum Industry Environmental Conservation Association (IPIECA) – *Health Aspects of Work in Extreme Climates (2008)*, applicable to all stakeholders in the Qatar Oil and Gas Sector (HSE Regulations and Enforcement Directorate, 2013). Compliance with this Guideline was considered the *minimum* standard required to maintain the health and welfare of OGP employees without unnecessary compromise to the rate of development in the Oil and Gas Sector.

Company Procedures

By 2003 the Company had already developed a Heat Stress Management Standard of its own that outlined the health risks associated with exposure to high heat and humidity and included some basic controls such as the need for regular fluid intake and working in shade etc. (McDonald, Shanks & Fragu 2008). In 2007/2008 this was updated to a Procedure based on the HSE Directorate's Guideline which provided more information around incident classification, reporting requirements, monitoring equipment, training and acclimatisation. Importantly this procedure included a HI calculation chart and 'Preventative Heat Stress Work Practices to Minimize the Effect of Heat Exposure' – see Figure 3.

This table included the following notes* which became the source of vigorous discussions in the ensuing years;

1. *For Heat Index >54 Safety / Integrity Critical Activities will be allowed to continue subject to maximum 20 min of work and minimum 20 min rest as per approved risk assessment and proper controls measures in place, and*
2. *Exclusion applies to all emergency response teams.*

PREVENTIVE HEAT STRESS WORK PRACTICES TO MINIMIZE THE EFFECT OF HEAT EXPOSURE

HEAT INDEX	WORK : REST PERIOD (Minutes)		WATER REQUIREMENTS (1 cup = 250 ml)	CONTROLS
27 - 31	50	:10	1 Cup every 20 Minutes	Continuous Visual monitoring of workers in direct sun and heavy work
32 - 38	40	:10	1 Cup every 20 Minutes	No Working alone
39 - 49	30	:10	1 Cup every 15 Minutes	Work under Shade
50 - 53	20	:10	1 Cup every 10 Minutes	Elevated and Confined Space Work Stopped
> 54	–		–	All Work Stopped*

Figure 3: HSE Directorate *Guide for Preventative Heat Stress Work Practices*, 2013

Challenges to the stop work requirements were raised repeatedly, usually by Operations and Maintenance personnel with key responsibilities for ensuring plant integrity and/or commercial supply. As with many health risks, the challenge for the occupational hygienist is to work with stakeholders to help them find a way to meet these responsibilities whilst not any worker.

Heat Stress Index

Danger category	Heat index	Heat syndrome
IV. Extreme danger	≥ 54	Heat stroke or sunstroke imminent
III. Danger	39-53	Sunstroke, heat cramps or heat exhaustion likely. Heat stroke possible with prolonged exposure and physical activity.
II. Extreme caution	32-38	Sunstroke, heat cramps or heat exhaustion possible with prolonged exposure and physical activity.
I. Caution	27-31	Fatigue possible with prolonged exposure and physical activity.

***Note.** Degree of heat stress may vary with age, health and body characteristics.*

Relative Humidity

Air Temp (°C)	10%	20%	30%	40%	50%	60%	70%	80%	90%
50	54	>54	>54	>54	>54	>54	>54	>54	>54
49	47	54	>54	>54	>54	>54	>54	>54	>54
48	45	53	>54	>54	>54	>54	>54	>54	>54
47	44	51	>54	>54	>54	>54	>54	>54	>54
46	43	49	>54	>54	>54	>54	>54	>54	>54
45	42	47	54	>54	>54	>54	>54	>54	>54
44	41	46	52	>54	>54	>54	>54	>54	>54
43	40	44	49	>54	>54	>54	>54	>54	>54
42	39	42	47	54	>54	>54	>54	>54	>54
41	38	41	45	51	>54	>54	>54	>54	>54
40	37	39	43	48	54	>54	>54	>54	>54
39	36	38	41	46	52	>54	>54	>54	>54
38	35	37	39	43	49	54	>54	>54	>54
37	34	35	38	41	46	51	>54	>54	>54
36	33	34	36	39	43	48	54	54	>54
35	32	33	35	37	41	45	50	54	>54
34	31	32	33	35	38	42	47	52	>54
33	31	31	32	34	36	40	43	48	54
32	30	30	31	32	34	37	40	44	49
31	29	29	30	31	33	35	38	41	45
30	28	28	29	30	31	33	35	38	41
29	27	27	28	29	30	31	33	35	37
28	27	27	27	28	28	29	31	32	34
27	26	26	26	27	27	28	29	30	31
26	25	25	26	26	27	27	27	28	28

***Note.** Adapted from U.S. NOAA National Weather Service Heat Index.*

Figure 4: HSE Directorate Guide – Heat Index Calculator, 2013

The requirement to stop all work at a heat HI of 54 was questioned even further during a major construction project at the Company that commenced in 2011 and ran through to 2015, during which more than 28,000 workers were on site. The definition of Safety / Integrity Critical Activities provided a bone of contention for both the Health and Safety team, and Construction Managers alike, but the discussion was warranted as the HI was regularly exceeding 54 when calculated from Company's HI calculation chart – see Figure 4.

The outcome from these discussions was the introduction of the following dispensations for certain construction activities;

1. Where the elevated work is being done on construction plant / structures that have been fully checked and enclosed by rails, such that fall and PPE equipment is not required to address the hazard of falling, the risk of working at heights between a HI of 50 – 54 is considered to have been mitigated and therefore this work can continue
2. In relation to Confined Space work, if the HI as measured within the confined space is below 50 and the HI outside of the Confined Space (where the

Hole Watch and other support personnel are located) is below 54, the conditions are accepted to fall within the allowable limits and the confined space work can continue, and

3. Identified safety / integrity critical work can continue above a HI of 54 with a risk assessment, but only to a maximum HI of 60.

These dispensations were eventually absorbed into the Company Procedure, however additional risk assessment and approval documentation was also added in the form of a Heat Stress Critical Task - Certificate (HSCT-C) for critical and essential jobs required to continue above a HI of 54. The HSCT-C requires the requestor to consider all possible options before submitting it for approval, such as re-scheduling or delaying the task until the HI drops. If the task must continue the requestor must identify the increased risk and identify and implement additional controls to mitigate this risk. Finally, the HSCT-C must be reviewed and approved by the Permit Holder, at least one Health and Safety Professional, and the Asset's Head of Operations. Additional training was also provided to the people approving HSCT-Cs to ensure they could fully appreciate the risk of continuing the work.

Since that time the Company has progressively improved the procedure to include unique features, such as;

- A requirement for work health assessments every two years to confirm physical fitness for work in 'heat stress' environments
- The requirement for more detailed risk assessment, workshops, specific Safe Work Procedures and approval by the Company Chief Operations Officer for activities that may need to continue above a HI of 60
- Requirements to schedule shutdowns and maintenance activities to minimise outdoor work during the summer months
- Requirements to implement air-conditioned rest shelters, and
- An effective system for communication of HI values to all employees

The Company's 2018 Procedure has evolved into a comprehensive yet easy to read document that requires confined space activities and work at heights to cease when the HI reaches 50, and all other work to cease at HI of 54 unless deemed safety / integrity critical. Explicit instruction is provided for exceptions, including a decision making flowchart to help Supervisors and Managers determine if a given task really is safety / integrity critical. Further guidance is also provided for activities deemed so critical they cannot be stopped even once the HI reaches 60, including the requirement for a workshop led by the HSE Manager.

Additional Requirements for Contractors

In addition to compliance with the Company's Heat Stress Management Procedure, contractors must provide a Health and Safety Plan for review by the HSE team that specifically details how the Contractor will manage the risk of heat stress. This plan must include provisions for additional staff to account for increased work/rest ratios required as the HI rises. The Contractor must outline how they will manage worker fatigue which is increased due to the extreme heat and longer working hours during shutdowns, and must detail how they will ensure new workers are properly acclimatized to prevent injury or illness. Further, the Contractor must describe how they will ensure fasting workers are protected from the risk of heat stress during Ramadan and how they will manage the work packets given the reduced working hours for Muslim workers during the Ramadan period. In accordance with Qatar Labour Law No. 14, Article 73, working hours during the holy month of Ramadan are reduced by at least two hours per day (Qatar Embassy 2010).

The Company's comprehensive Heat Stress Management Procedure, together with Contractors Health and Safety Plans greatly influence the implementation of controls that actively reduce the risk of a heat illness or injury.

Work Planning

As with any large LNG operation, shutdowns are planned so that numerous routine maintenance activities can be performed in the shortest possible time with the least impact on business operations. Large shutdowns can take several weeks and can involve thousands of additional contract workers, some of whom may not have worked in the country before.

One of the most valuable improvements to the HSMP has been a major shift in how the Company schedules its shutdowns. Throughout the 2000's, shutdowns occurred regularly throughout the year irrespective of environmental conditions, however in the past few years stakeholders from Operations, Maintenance, Projects and Joint Ventures have workshopped various options to enable them to be scheduled outside the summer months. This significant change in is not without other risks, but it is a major feature of the HSMP as it effectively eliminates the risk of heat stress for many thousands of contract workers.

Despite this superb outcome, there are still hundreds of workers who remain at risk during summer. Operator rounds must continue, reactive maintenance is required if something breaks, LNG vessels must be loaded and drilling operations cannot always be stopped. Thus a robust and extensive HSMP remains essential to prevent a heat related injury or illness. Increased focus of the importance of heat stress management at the highest level has led to increased demand for the Company to ensure everyone is ready for summer well in advance, and that lessons learned at the end of each season are effectively used to improve work practices and planning in the following years. In the IH Department alone, the HSMP has expanded considerably, requiring sustained effort throughout the year. Some key activities that the IH Department manages in contribution to the HSMP are shown in Table 1.

Activity	Start Date	Completion Date
Calibration of Weatherlink equipment & confirmation of live data upload to intranet	March	April
SMS recipient list updated & delivery system confirmed (i.e. EMS and Safety Advisors or other mechanism for regular notifications)	February	April
Heat Stress Procedure updated to reflect lessons learned from previous year	January	February
Heat Stress Awareness training package updated to reflect heat Illness cases from previous year, any lessons learned, any new requirements – and released to Assets for review and input	February	March
Promotional material designed, ordered and ready for installation	February	April
Preparation of Annual Campaign Kick-Off Message for release by HSEQ Manager	February	April
Communication to all Assets to ensure Heat Stress Readiness (i.e. that Assets have ordered sufficient water bottles, installed rest shelters, arranged for water coolers etc.)	February	April
Heat Stress Readiness Presentation to HSE Leadership and Executive Leadership Teams	March	March
Issue of portable HI monitoring equipment & training of users	March	April
Release of training package for Safety Advisor delivery to workforce	March	April & July
Receipt and collation of HSCT-C, review of activites and reporting to weekly HSE Leadership meetings	April	Ongoing to September
Management of reports / complaints regarding HI data, equipment failure, clarification of procedural requirements etc.	April	Ongoing to September
Weekly data download all Weatherlink sites, analysis and reporting to weekly HSE Leadership Meetings, including week ahead forecast	April	Ongoing to September
Return of portable monitoring equipment and dispatch to the UK for calibrations	October	March
Review of lessons learned (feedback from workforce during the season, incidents, equipment issues, legislation updates etc.)	October	November
Review of No. of HSCT-C prepared by Asset and task	October	November
Presentation of season performance to HSE Leadership including recommendations	November	December
Workshop for identified HSCT-C issues (i.e. activities that occur regularly, tasks that should not have been authorized to proceed) – to enable improved work planning	November	December

Table 1: IH Department Heat Stress Program Activity Snapshot

Of these activities, perhaps the most useful is the HSCT-C Workshop, where Operations and Maintenance personnel and the HSE Team come to together to discuss alternative ways to do work. The Company is *very* focused on reducing the number of activities that are approved to continue above a HI of 54 and especially above 60. Stakeholders are challenged to consider earnestly, how they can make changes to eliminate the need to do the work when conditions are hazardous to health.

Training & Awareness

Heat stress was originally covered in the mandatory site induction as a five minute discussion around how summer is really hot, heat stress can be fatal, and the controls involve drinking a lot of water and staying in the shade when possible. As appreciation of the health risk has grown, so too has the Company's suite of training material around heat stress prevention, which now includes additional specific training for Supervisors and Safety Advisors, increased content in the site induction package, and a comprehensive heat stress awareness presentation for delivery to the workforce at the beginning of each summer. These presentations are mandatory for all workers and are delivered in April as summer kicks off, and then again in July as the hotter months arrive. When Ramadan falls in summer there are additional training sessions highlighting the need to maintain fluid intake even when fasting. Training delivery and attendance has become a key performance indicator (KPI) for both the Safety and Operations teams, however the Company relies heavily on its Safety Officers to ensure that appropriate information reaches employees and contractors.

Recognition that support staff, although predominantly office-based, are also at risk of heat stress has led to development of a heat stress awareness video attached to an on-line training system, made mandatory in 2018 for non-operational personnel. The system allows 'office-based' personnel to watch the video at any time during the month of April and record their training in the system, and contributes to an improved cultural awareness of the risk. The added advantage of this system is that non site-based workers, particularly ex-patriates new to Qatar and arriving in summer, are provided with enough information to ensure they can protect themselves from a heat related illness or injury either at work or at home.

To complement these face-to-face and video delivery systems, IH designed pull-up banners promoting fluid intake and installed them in high thoroughfare locations around the plant. Informative posters were translated into multiple languages including English, Arabic, Hindi, Urdu, Nepali, Tamil and Thai and installed in key locations in all buildings across the operation, and heat stress prevention slides were added to TV monitors in the mess halls, waiting rooms and other key locations. Guides to Dehydration Urine charts were placed in every washroom facility, and to ensure that supervisors in particular could have relevant information at hand small cards were printed showing the HI table, applicable controls and when they must stop work.

The visibility of promotional material throughout the plant, in languages applicable to the workforce, accompanied by 'ready-reckoner' cards, TV displays and mandatory training for all workers has contributed appreciably to the success of the HSMP.

Monitoring Equipment & Workforce Communication Strategies

Another improvement has been the introduction of dedicated fixed and portable HI monitoring equipment in 2013. These include the Weatherlink® for Vantage Pro® from Davis Instruments, and portable Quest heat stress monitors, Models 34, 36, 44 and 46.

The Weatherlink has static meteorological stations equipped with wind, temperature and humidity sensors that can measure inside and outside temperatures, humidity, barometric pressure, wind speed and direction. Sensors data are fed into a data logger and can be stored in a computer, with capacity for remote access from several key computer terminals across the site. As at May 2018 the Company had four Weatherlink units in place: one at Main Plant Medical Centre; another at the Marine Terminal; a third at the Company's second operating plant, and a fourth on the main offshore platform. Key users were identified by IH, such as Shift Superintendents and Safety Leads, and the software was subsequently installed onto their PCs and linked back to the relevant unit.

In areas where Weatherlink data cannot be transmitted, the Company makes use of short message service (SMS) notifications which are initiated by either a Safety Officer or an Emergency Control Room Operator (ECRO) with PC access, in response to changes in the HI. Specific announcement text is pre-defined by the IH team for each of the HI bands shown in Figure 3, and training provided to personnel in how to use the notification system. Prior to April each year, IH initiates a call for SMS users and updates the notification list for each Weatherlink site so that the relevant HI information is received for a specific work area. In addition to the SMS notifications a public address general alarm (PAGA) system is used to make announcements advising the HI band and the required controls. In 2017 changes were made to the frequency of PAGA and SMS notifications to better fit with the work demands of Panel Operators and ECROs. Announcements previously made every hour were reduced to occur within one hour of any on-coming shift, within one hour of meal breaks and at any change in the HI band (see Figure 3), maintaining effective risk communication whilst improving work conditions for key personnel.

In 2018 access to HI data was further improved by linking live Weatherlink data to the Company's intranet portal, making it a click away for most employees in Supervisory positions. An added advantage to this is that a person in charge of multiple workgroups across the large site can 'check' the HI at all locations in just a few seconds and respond to conditions on the ground.

One of the issues with the Weatherlink units however, is that they only reflect the conditions within a few meters of the sensors at best. Workers in the plant area and at remote wellheads, sometimes several kilometers away, often experience very different environmental conditions to that being reported. The proximity of large steel structures in the plant area, restrictions on wind movement, differences in elevation etc., all influence the local HI. To account for these differences and allow the workforce a level of local control, the Company invested in more than 40 portable Quest wet bulb globe temperature (WBGT) heat stress meters that are capable of recording indoor and outdoor temperatures, humidity, WBGT temperatures, as well as the HI. Prior to 2018 these units were issued to any requesting Asset at the beginning of the Heat Stress season, with specific training provided in equipment use and maintenance. In 2018 however, with access to live data available to almost everyone via the intranet, the portable units were restricted to remote areas including Wellheads and Projects, with several units on standby for use with approved critical tasks.

The combined use of fixed and portable HI monitoring equipment, intranet access to real-time HI data, PAGA announcements and SMS notifications, as well as radio communications and a colour coded flag system implemented on some Project sites, provides broad coverage of the Company's widely distributed Assets, whilst still allowing a level of local control. Nevertheless, no system is without its complications and issues such as Weatherlink failures during high humidity events, portable equipment getting damaged, live data not updating and/or SMS notifications being sent incorrectly or not at all etc. require ongoing attention and maintenance. In the search for a more reliable way to measure and communicate HI to all personnel, in 2018 the Company investigated and agreed to trial a Qatar Research led new '*Smart Heat Stress Management Solution'*.

This system makes use of temperature and relative humidity sensors; a light emitting diode (LED) tower which is made up of four different colors (i.e., red, orange, yellow and green) to denote the HI level, and an electric horn to warn an individual to cease work if HI is significantly high. The monitoring device has two types of sensors: one for sensing and display, and another one for relay. The system can be installed using a portable installation or can be fixed in multiple locations throughout the plant area (for example) with LEDs displaying the relayed HI. Further, the solution includes live intranet data and a Phone App that provides live data for all installation sites, enabling personnel to access important safety and health information from any location. Figure 5 provides an overview of this system which, if successful, could eliminate the current manually intensive monitoring and reporting system, and replace it with a fully automated and externally managed alternative.

The sustained effort to improve how HI data is communicated to the workforce is an example of an effective continual improvement process.

Figure 5: Smart Heat Stress Management Solution (*QMIC 2018)*

Heat Index Monitoring

Prior to 2017, data from the four Weatherlink stations was downloaded weekly and incorporated into HSE Leadership presentations as recognition of heat stress as a business risk. In 2017 the IH team started to really analyse the data for more detail, such as;

- The number of times the HI exceeded 54 in the daytime versus nighttime
- The time of day the HI was highest
- The duration of excursions above 54

- The number and duration of excursions above 50, and
- Which months had the most excursions above 54

Further, data from the Company's Weatherlinks was compared to equivalent units at neighbouring OGPs, and to data collected from environmental units, with the exercise extended backwards to consider trending for the previous three years – see Figure 6. These graphs show the average heat index per hour for the months June, July, August and September, and the individual HI events above 54 and 60 for the years 2014 – 2017. They demonstrate the following results;

- August most often the hottest month
- August most often has the greatest number of HI events above 54
- The HI begins to rise rapidly from ~ 6am, and does not begin to fall until ~ 7pm
- The coolest period is most often between midnight and 6am
- HI events above 54 or 60°C may still occur between midnight and 6am
- 2015 had the greatest number of HI events exceeding 54 and 60 (reflecting workforce feedback that 2015 was an extremely hot summer)

This type of information was found particularly useful by Maintenance schedulers as it provided increased visibility of an additional environmental condition with significant impact on production. In 2018 this data was already being utilised for planning decisions relating to shutdowns for the next five years, and was driving conversation around a possible change to summer working hours for dayshift operators and support personnel. A shift in the start time from 7am to 5am for example, would see increased opportunities to complete outdoor activities before the HI rises. However, one complication would be the potential for delays actually getting to the site, as the country also experiences extreme early morning fogs during the summer months.

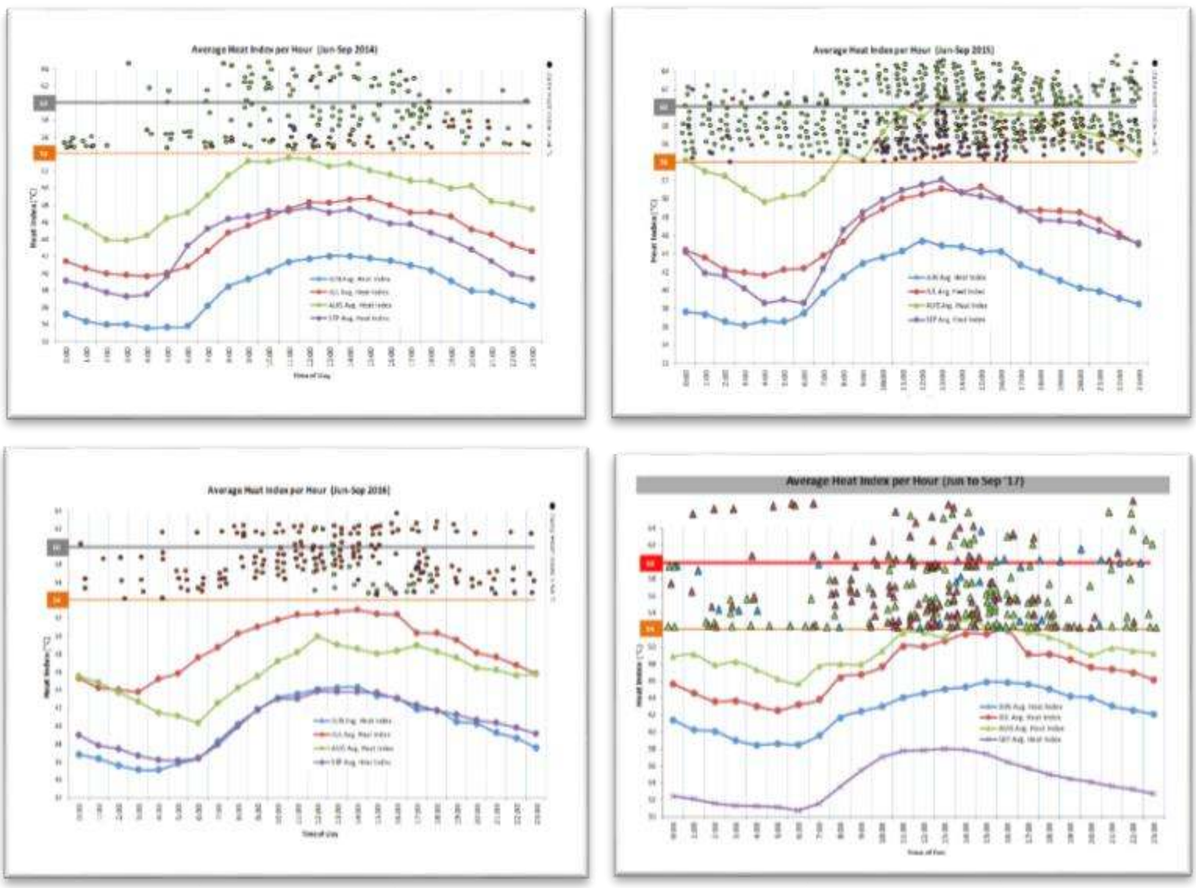

Figure 6: HI Data at the Company's Main Plant Weatherlink site – June, July, August & September 2014 – 2017
(*V. Thelan 2006, pers. Comm. 02 May)*

Personal Protective Equipment (PPE) and Engineering Controls

Over the years various items of PPE have been issued and trialled at the Company, including 25,000 evaporative bandanas in 2007 (McDonald, Shanks & Fragu 2008) and 30,000 evaporative and phase change cool vests in 2014 (Dehart R 2014). In 2016 and 2017 these cool vests were borrowed from project reserves and trialled in offshore and offsite settings with mixed results. The high humidity during summer limits the effectiveness of the cool vests and requirements for 'recharging' mean that additional logistics are necessary, thus they are not recommended by the IH team. Balaclavas and head scarves are used extensively by expatriate workers to protect them from the sun, however these interfere with the use of other PPE like earmuffs and respiratory protection, and so to try and combat this issue, in 2018 hardhat brims and neck flaps were being trialled as alternatives.

Water bottles as mandatory PPE were introduced during the major construction years (2011 – 2015) and a *No Water No Work* policy was introduced toward the end of this period. This requirement is now considered one the most critical controls for reducing the risk of heat stress. Supplementing individual water supplies, numerous and easily accessible cool water stations are installed across the plant during summer and workgroups are supplied with larger cool water iceboxes, date and time stamped to ensure they are replenished and cleaned daily. Water stations are located in proximity to rest shelters which must be no further than 50m from any work location, and rest shelters have also improved over time, evolving from scaffold structures covered in shade cloth with open sections below 1m in height to allow airflow, to portable air-conditioned plug-&-play units that can be hired annually and connected directly to Plant power supplies.

This combination of the right PPE and good quality engineering controls are required to complement the overall HSMP.

Heat Related Illnesses

From 2005 an increasing number of strategies have been implemented to achieve a decrease in the number of heat related illnesses. Some of these have been discussed in this paper however additional efforts by the Medical and Emergency Response teams have also contributed to improved worker readiness and first aid treatments, leading to fewer recordable injuries. Figure 7 shows the number of recordable heat stress cases each year between 2008 and 2016. 2017 (not shown) also had only one recordable injury, the investigation finding that the individual did not follow the requirements of the HSMP, did not implement basic controls, and did not notify when they first felt unwell. This unfortunate incident demonstrates that while the HSMP is admirable, there are still opportunities for improvement, particularly in the areas of communication, training and supervision. Every incident is fully investigated to understand how and why it occurred and findings are shared at upper management meetings and at toolbox talks across all Assets. The Company's goal is to achieve zero heat related incidents, including first aid treatments.

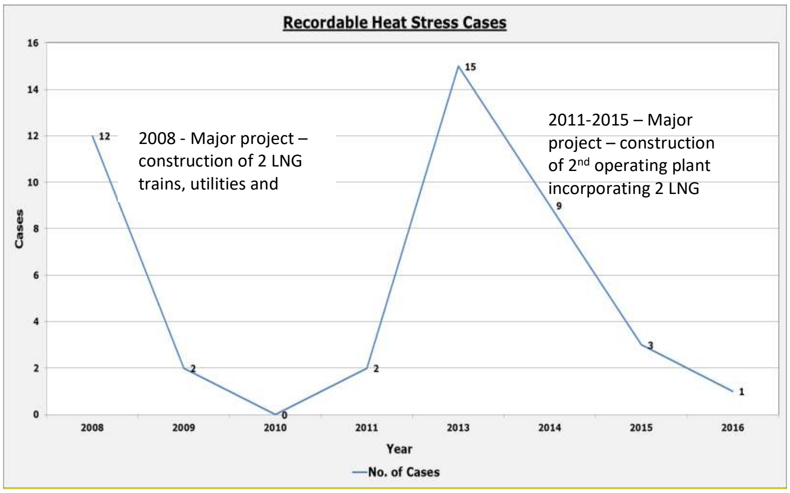

Figure 7: No of Recordable Heat Stress Cases by Year

Figure 7 shows a reduction in the number of recordable heat related illnesses over time, with spikes in 2008 and 2013 correlating to major construction projects where the number of workers swelled from approximately 4000 to more than 30,000.

Conclusion

This paper has described the many and varied improvements made over several years to produce what is arguably now a World Class Best Practice HSMP.

The success of this program is evidenced not just by a reduction in the number of recordable heat related injuries and illnesses, but by the demonstrated willingness and capacity of a large LNG operation to change the way it does business.

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AUSTRALIAN NATIONAL RADIATION DOSE REGISTER – A REVIEW

Cameron Lawrence & Ben Paritsky

Australian Radiation Protection and Nuclear Safety Agency

Introduction

Recording and maintaining occupational exposure records are important aspects of any radiation protection program to demonstrate compliance with occupational dose limits and to facilitate dose optimisation. International safety standards require that records of individual occupational doses of workers are kept and made available to the relevant regulatory authority and individuals for the long-term (IAEA 2014).

The Australian National Radiation Dose Register (ANRDR) is a database designed to store and maintain radiation dose records for workers who are occupationally exposed to radiation. The ANRDR is maintained and managed by the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA).

Originally established for the uranium mining and milling industry, the ANRDR is now open to receive dose records from all industries with occupationally exposed workers, including the mining, medical, education, research and government sectors.

The ANRDR has been approved by the Commonwealth, state and territory radiation regulators as Australia's approved central record keeping agency for the dose records of occupationally exposed workers (ARPANSA 2016).

Background on the ANRDR

Prior to the establishment of the ANRDR, a worker's doses were assessed, recorded and maintained exclusively by the employer. Whilst this ensured that dose records were maintained at the worksite, there was no system in place to monitor the cumulative dose received by a worker who moved between different employers, industries or jurisdictions. The ANRDR has been developed to overcome this gap in the management of dose records. Employers will still be required to maintain radiation dose records for workers in compliance with relevant state, territory or Commonwealth law, however, there may also be a requirement to report dose records to the ANRDR, as is the case with Commonwealth entities.

Although the ANRDR is currently voluntary for most organisations under state or territory regulatory authority, participation is considered international best practice and is highly encouraged by all radiation regulators in Australia.

The purpose of the ANRDR is to ensure that radiological dose records of occupationally exposed workers are maintained in a national database in order to:

- allow workers to have access to their cumulative radiation dose history, regardless of where in Australia they have worked, or for whom
- provide assurance that radiological dose records are maintained and retrievable for the long-term in accordance with requirements outlined in the Code for Radiation Protection in Planned Exposure Situations, Radiation Protection Series C-1 (ARPANSA 2016)
- perform statistical analyses of industry dose trends to facilitate dose optimisation.

Benefits

The ANRDR allows workers to access their personal dose histories from one location, regardless of where they have worked or for whom. A worker whose records have been provided to the ANRDR by their employer can request their personal dose history report from ARPANSA free of charge.

The data contained in the ANRDR will assist in developing better work practices to improve safety for occupationally exposed workers in Australia by facilitating optimisation of radiation protection programs. Periodic analysis of data provides information on exposure trends across jurisdictions, industries and workgroups. This data analysis provides valuable information to industry on the effectiveness of radiation safety programs and enhances the regulatory capabilities of radiation regulators.

The ANRDR is also able to notify employers and regulators if an individual exceeds any occupational exposure limits. This is a particular benefit when workers change employers or jurisdictions, or those who work for multiple employers with separate monitoring programs.

De-identified ANRDR data may also be provided to international organisations such as the International Atomic Energy Agency (IAEA) and the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) to facilitate understanding of global dose trends and to help inform international guidance on radiation protection.

Privacy

The ANRDR is a system that incorporates a secure web-based portal and database. Employers upload data files containing workers' radiation dose records through the secure web portal in quarterly intervals, in accordance with ANRDR specifications. All dose records are maintained in compliance with the requirements of the *Privacy Act 1988* (Cwlth) (the Privacy Act). Data files are automatically processed and checked for integrity during the submission process before being accepted into the database. Typically, the nominated radiation safety officer or similar would be the appropriate person to have access to the web portal.

ARPANSA does not alter any data submitted. If errors are found in the file, or if the file does not meet the specific ANRDR requirements, an error report is automatically produced. The user will be required to address the issues identified in the error report and resubmit the data. ARPANSA does not perform calculation checks on doses submitted.

In addition to dose data, the ANRDR also requires the submission of some personal details to ensure that doses are matched to the correct worker. This personal information includes:

- Full name
- Date of birth
- Gender

The thirteen Australian Privacy Principles (APPs), as defined in the Privacy Act, outline how most Australian Government agencies and private sector organisations (collectively defined as 'APP entities') must handle, use and manage personal information. The Office of the Australian Information Commissioner (OAIC) has determined that for private organisations, the disclosure of exposure records that form part of an employee record are exempt from the APPs. The ANRDR has relevant policies and procedures in place to manage personal information that meet the requirements of the APPs.

The published data analyses will not identify or reveal personal information about individuals or details about employers who are registered with the ANRDR.

Data Analysis

The ANRDR maintains information on quarterly-assessed radiation doses for a range of dose types and exposures. The data is used to monitor individual doses and generate annual statistics related to exposure trends for industries and workgroups. This assists with the optimisation of radiation protection practices for workers.

The ANRDR currently holds dose records for more than 43 000 individuals from the uranium and mineral sands industries, and government organisations. This section provides an up-to-date analysis of data from these industries. Although the pilot phase for our expansion to the medical sector has been completed, we are currently unable to present an analysis of medical workers' exposures, as only one medical facility has submitted data to the ANRDR.

While annual effective doses continue to remain low (71% of all workers are below 1 mSv) for all industries in the ANRDR, a notable increase in both the average doses and workforce numbers was observed for uranium processing workers in 2017, compared with the previous year. We understood this to be a result of maintenance work undertaken at a number of processing facilities, and not the result of poor work practices.

A challenge has been identified with the reporting of doses to the ANRDR that are below the minimum reportable dose (<MRD). Dosimetry service providers in Australia report monitoring results in different ways. ARPANSA's Personal Radiation Monitoring Service (PRMS), for example, does not report results below 100 µSv due to the high uncertainty associated with results below that level. Due to the high uncertainty, which below 100 µSv is around 100%, the results become meaningless. Many database systems, including the ANRDR,

require a numerical dose to be entered. As a result, a zero dose value is commonly substituted for the '<MRD' result, skewing the results. The ANRDR is considering a number of options to minimise the impact of this issue on data analysis. These may be implemented in future data analyses.

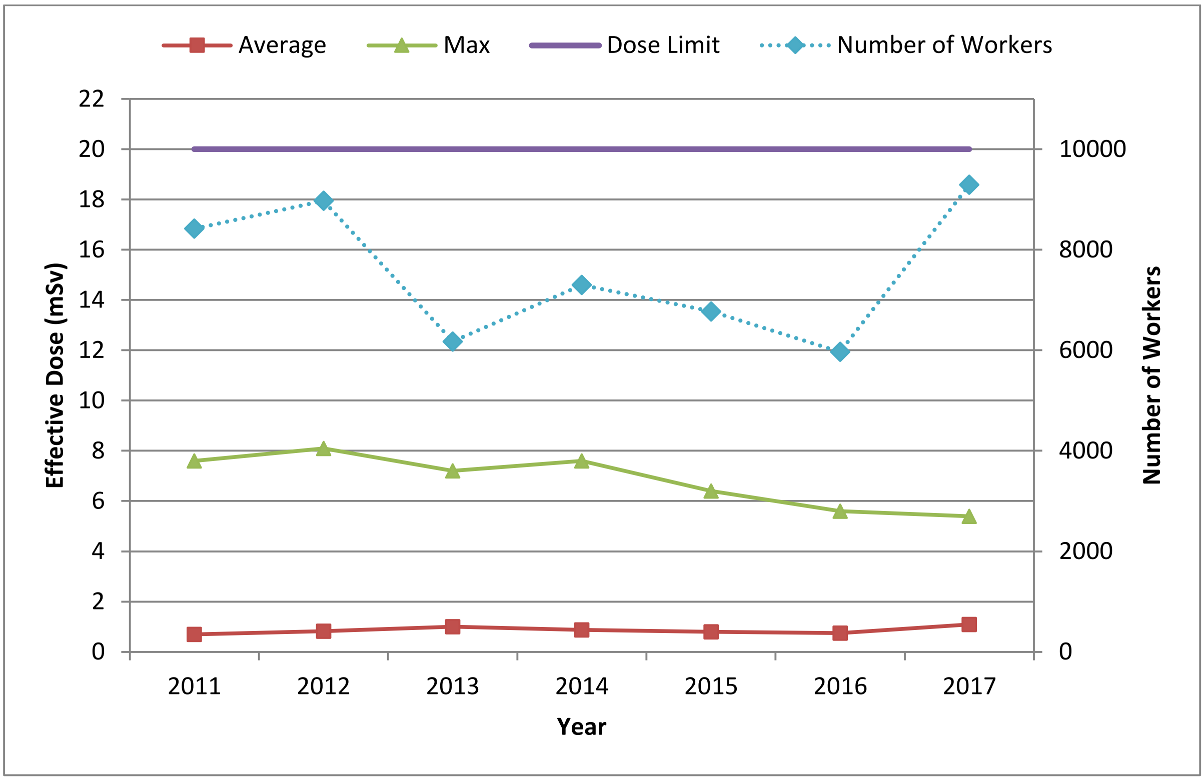

Figure 1: Uranium industry average and maximum effective doses with workforce numbers (2011 – 2017)

The ANRDR has coverage of all licenced Australian uranium operators with exposure records for all operations from 2011.

Figure 1 shows that the average annual effective doses have remained consistently low (averaging less than 1 mSv) over the past seven-year period. The maximum effective doses have seen a steady decrease over the same period. A notable increase in the number of workers in the industry was also observed for 2017, which accounted for the slight increase in the average effective dose for that year (1.09 mSv).

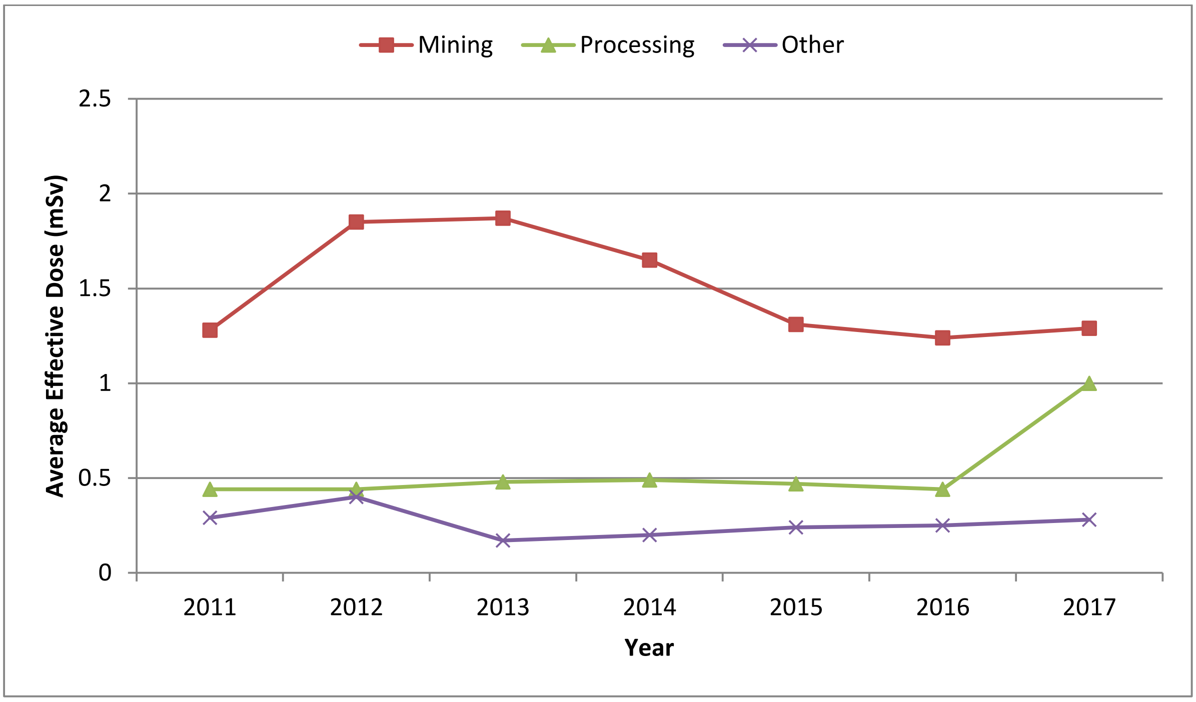

Figure 2: Uranium industry average effective doses by worker categories (2011 – 2017)

Figure 2 shows an increase in the average effective dose for all of the work categories used by the ANRDR for the uranium industry. The largest increase is observed in processing workers, which has more than doubled from 0.44 mSv in 2016 to 1 mSv in 2017.

Review of this analysis led to further investigation of the 2017 industry data in order to understand the increase in exposure and worker numbers. It was observed that in 2017 there were 4018 people employed in worker categories that were classed as 'shutdown', compared with only 1241 in 2016.

Shutdown work typically involves the closure of a process to allow for the cleaning and repair or replacement of critical equipment. This work commonly involves higher exposures than normal operations, as exposure controls move to the use of personal protective equipment.

Shutdown work is typically performed for short periods. Assessment of worker duration in the uranium industry is compared against Commonwealth organisations (organisations under ARPANSA's regulatory authority) in **Figure 3**.

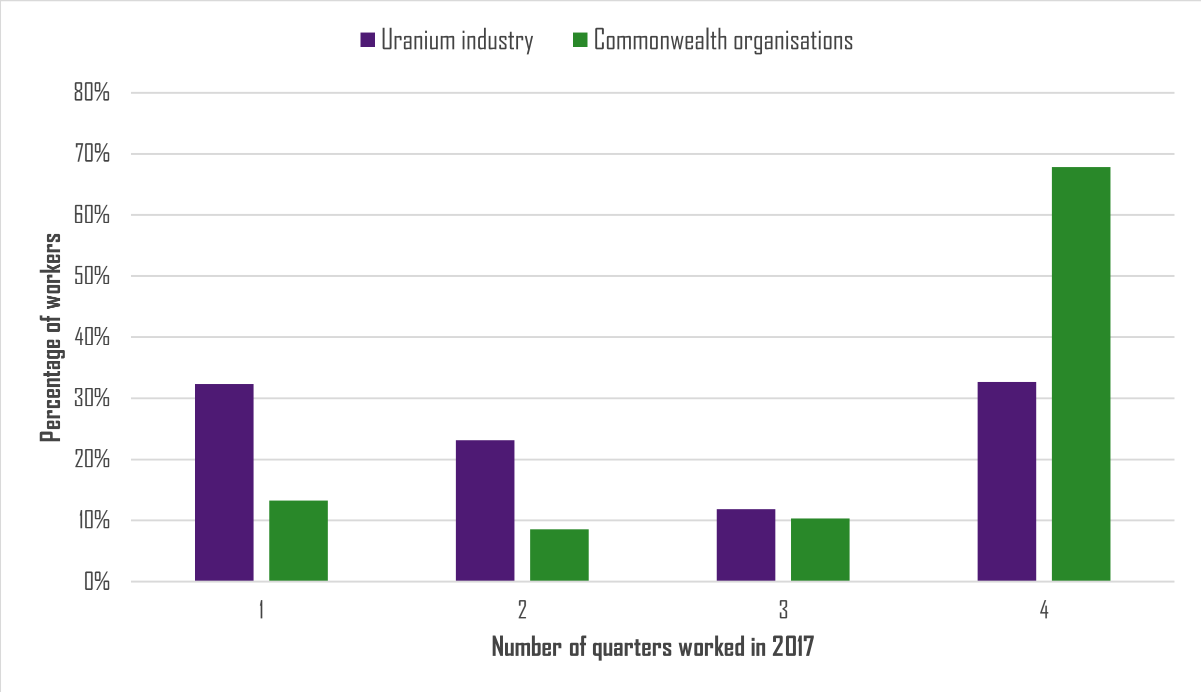

Figure 3: Comparison of the number of quarters worked for workers in 2017 (Uranium industry vs. Commonwealth organisations)

Figure 3 shows that only a third (33%) of uranium workers had worked in this industry for all four quarters in 2017. Additionally, a third of uranium workers had doses recorded for only one quarter. This analysis indicates that the majority of individuals who worked in the uranium industry last year were temporary maintenance workers. In comparison, Commonwealth facilities, who have more of a permanent workforce, had double the percentage (68%) of workers who worked all four quarters.

The collective effective dose can be used as a comparative tool for the optimisation of radiation protection practices. It has been used by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) for reporting and comparing exposures from different practices around the world (UNSCEAR 2008).

The collective effective dose is simply the sum of the individual doses incurred by a group, and is expressed as 'man-sieverts' (man Sv), to distinguish the collective dose from the individual dose (IAEA 2007). The collective effective doses from the uranium industry are shown in **Figure 4**. As discussed previously, a substantial increase in temporary uranium workers was observed in 2017 to support the 'shutdown' maintenance work. Figure 4 shows that the majority of these workers were employed in processing facilities.

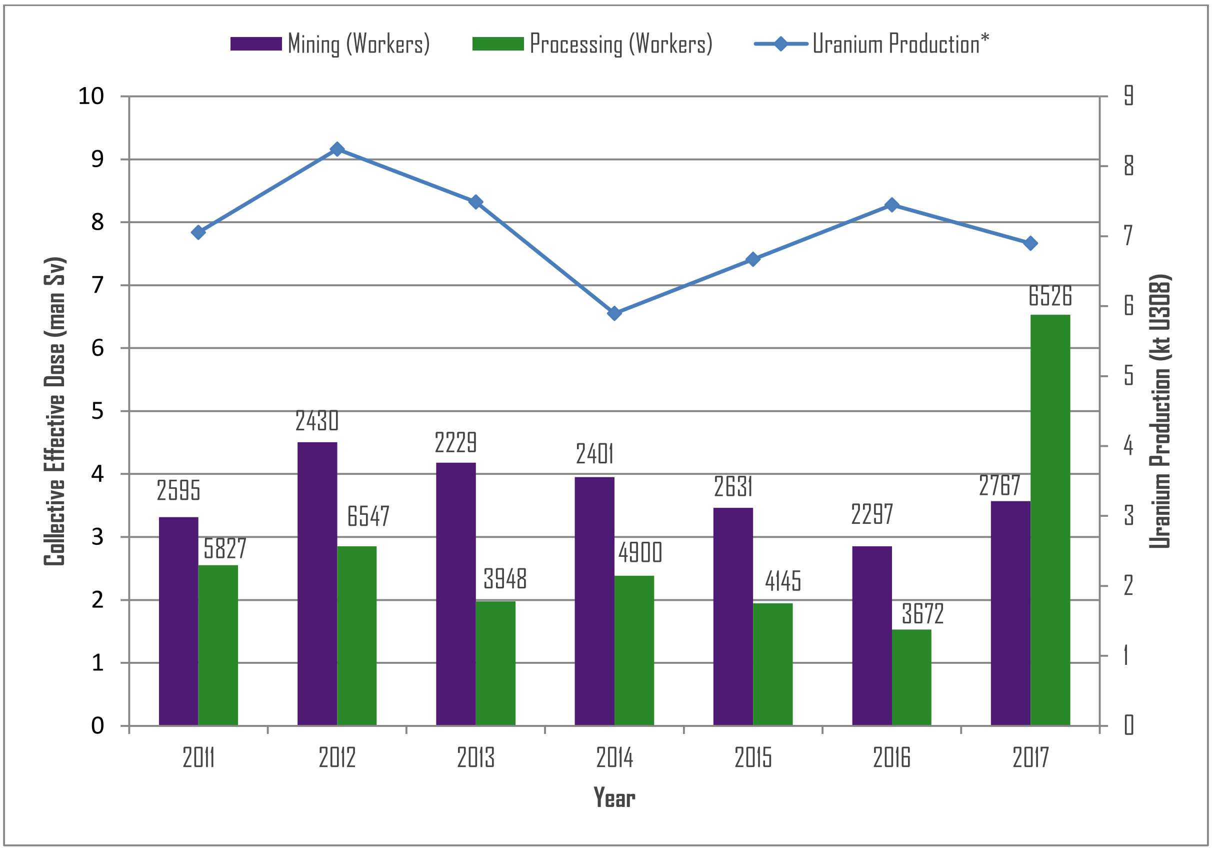

Figure 4: Australian uranium industry collective effective dose and uranium production, with worker numbers above columns (2011 – 2017)

The data for all organisations contributing to the ANRDR has been analysed to produce a dose distribution histogram for 2017 in **Figure 5**. The dose distribution histogram is an effective way to demonstrate the distribution of occupational doses, as it eliminates the skewing effect on the average effective doses of the <MRD doses that have been reported as zero doses.

This analysis shows that more than 71% of occupationally exposed workers in the ANRDR received an annual effective dose in 2017 of 1 mSv or less. This increases to more than 84% for annual effective doses of 2 mSv or less. Less than 3% of occupationally exposed workers received an annual effective dose greater than 3 mSv and the maximum annual effective dose recorded was 5.4 mSv.

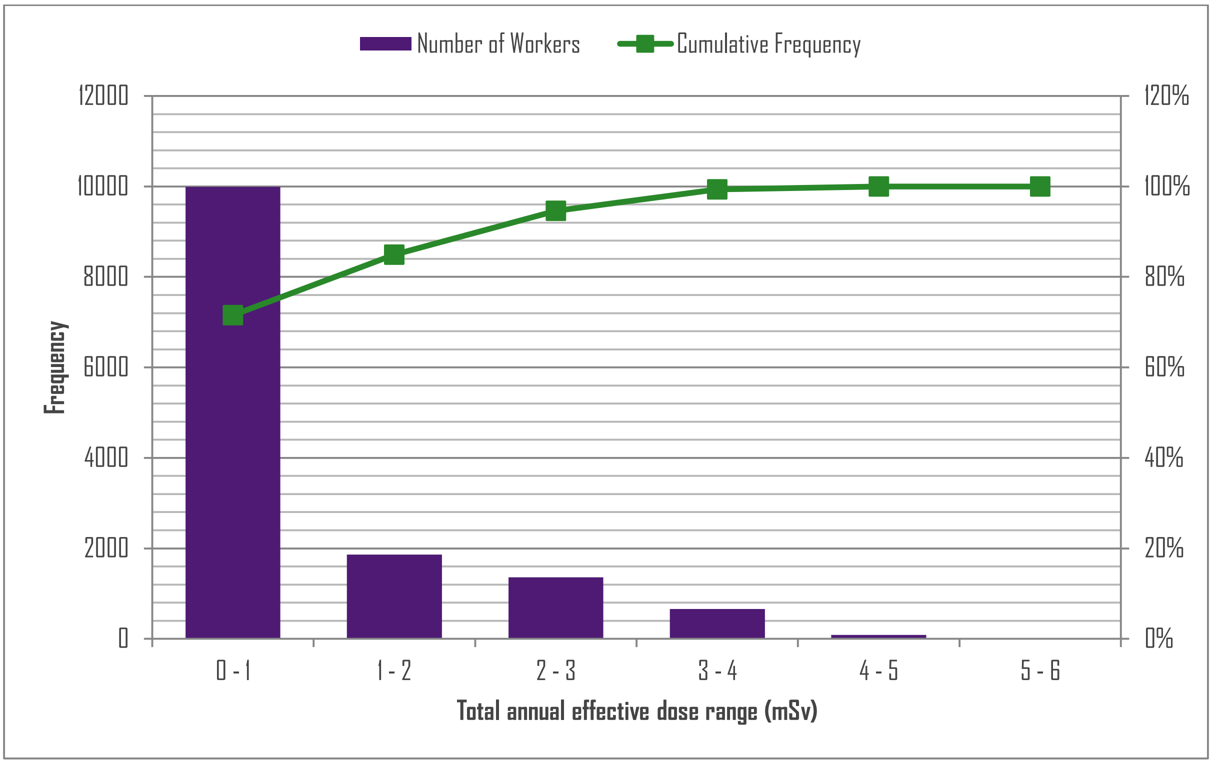

Figure 5: 2017 Dose distribution histogram for all ANRDR data

Conclusion

The ANRDR is a centralised database designed for the storage and maintenance of radiation dose records of occupationally exposed workers. In line with international best practice, these records must be maintained for the long-term.

The ANRDR provides a single uniform national approach to the management of radiation dose records and safeguards their longevity in a central location to ensure they remain available to workers on request. The analysis of data in the ANRDR provides valuable information for regulators and industry to facilitate optimisation of radiation protection programs.

The aim of the ANRDR is to have coverage of all occupationally exposed individuals in Australia. This will align the ANRDR with international best practice for national dose registers. The ANRDR team is continuing its engagement with all relevant industries and regulators to advance this work.

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PROTECPO, A WEB-BASED TOOL USING THE HANSEN SOLUBILITY PARAMETERS FOR THE SELECTION OF PROTECTIVE POLYMER MATERIALS AGAINST CHEMICALS

Daniel Drolet

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ProtecPo is a Web-based tool that allows to select the most appropriate polymeric material(s) candidate(s) for skin pro-tection against a chemical or mixture of chemicals. The recommendations are based on the calculation of physicochemi-cal interactions between chemicals and protective polymeric materials. They are based on the principle that the more a polymer material is soluble in a chemical, the less resistant the material will be. The Hansen three-dimensional solubility parameters (HSP) theory, based on the calculated differences between Dispersion, Polar and Hydrogen bond forces from a chemical (or mixture) and a polymer, was used. A database of HSP values and the ones of five of the most used protective polymer materials that were experimentally obtained in this study were used in the predictions. An algorithm was developed and validated by comparing ProtecPo's predictions with experimental results from the scientific literature or in guides published by glove manufacturers. The predictions were also compared to experimental data originated from this project. The new version of ProtecPo includes the following new features:

- 9,000 new chemicals have been added to the previous version and now contain over 10,300 substances.
- Even if the first version of ProtecPo classified material as resistant, intermediate resistance and nonresistant, the rec-ommendation given was presented as Resistant and Non-Resistant. The new version of ProtecPo classifies the mate-rial resistance in four categories: HIGH, MEDIUM, LOW and NON-RESISTANT, with each category being color-coded.
- An experimental database has been set up to refine the results. Expandable over time, it will store information on the resistance of a given material to a given chemical (documented either by recognized laboratory testing or in reviewed scientific publications). This presentation will include live demonstration using examples from day-to-day life.

DEVELOPMENT OF INJURY RISK MANAGEMENT EDUCATION FOR LEADERS

Marcus Cattani[1]
Russell Jones[1] and Jessica Boylan[1]

[1] Edith Cowan University

Whilst the development of a West Australian response to the model Work Health and Safety legislation is ongoing, some work has commenced to prepare organisations for the changes this legislation is likely to bring. This paper describes the outcomes of the research concerned with the identification of educational needs from 1288 participants from the WA Government Mines Safety Roadshow over 2 years. Participants indicated their perception of their own effectiveness and their employers' effectiveness in a range of disciplines associated with the implementation of WHS legislation. In addition, participants informed on a variety of issues concerning their training needs, and preferred delivery mode. Participants indicated a strong need for an educational program which not only informed them of the new legislation, but also the fundamentals of work health and safety, such as hazard identification, and disciplines such as leadership and culture, and emergency management.

In response, in 2017 two modules of a 10-module training package were developed and published using an online publishing platform, and distributed to Roadshow participants, prior to completing a survey. Due to the broad educational needs identified, each module includes a variety of techniques to encourage learning at different educational levels, including an introductory video, participation using review questions and more in depth study and ongoing education. The whole program is structured as a 'journey' which communicates both how each module fits into the overall program, and where the participant is in the program. Feedback (n=637) indicated participants valued the 'journey' analogy, the training materials and the online mode of delivery, although a 'hard copy' participant and facilitator materials will also be developed for off line delivery. The results of these surveys will assist the development of additional materials to educate people in a range of disciplines aiming to assist implementation of the new WA legislation.

MOULD INSIDE BUILDINGS, WHY DOES MOISTURE PROTECTION GO WRONG

Heike Neumeister-Kemp[1] Sam Athanasios[1]

[1] Mycotec Pty Ltd

A selection of the most common sources of mould proliferation in buildings is presented. Mould grows when viable spores, free water, energy and nutrients are present. Typically, the only variable that can be easily controlled in a building is the amount of moisture available, which provides a source of free water.

Based on many (1000's) of inspections in Australasian buildings, we present a selection of pertinent cases, where mould growth within the structure of a building has occurred.

Examples of factors considered are:

- Leaky facades and/or windows allowing direct water/moisture ingress
- Leaky facades and/or windows allowing moisture laden air ingress, especially in humid environments
- Inter-tenancy walls between warm/cool apartments (internal temperature differentials)
- High humidity levels in internal spaces such as apartments resulting in condensation (free water) at different points in the daily temperature cycle
- “Swimming Pool" effect; when moisture is trapped after flooding and/or other water ingress
- Water ingress/condensation in HVAC ducting
- Maintenance issues with HVAC systems

Further, the legal and health aspects will be discussed, along with why an understanding of mould ecology is so important to the prevention/limitation of mould proliferation.

PREDICTING INCIDENTS MAY NEVER HAPPEN, BUT WHAT ABOUT FORECASTING THEIR RISK?

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Abstract:
There appears to be some frustration concerning the reduction in the rate of safety performance improvement, in Australia and overseas. Whilst the total number of lower severity incidents reported appears to be reducing, higher severity incidents do not appear to be following the same trend. The Australian State Governments are the custodians of several databases of workplace incident notifications, as employers are obliged to notify them of serious workplace injuries and other occurrences. Most medium sized or larger organisations also collect and store data and information on their occupational health and safety performance, relating to their safety management system risk management and incidents and injuries. It is hypothesised that since we learn from experience the incident data and information databases could be used to indicate future performance. This project reviewed several incident databases. The project aimed to develop a statistical process to describe the gap in performance defined by risk criteria and the current level of risk performance. The current performance was calculated from organisations effectiveness to manage the risk of injury and incidents over time. This paper outlines a new process to convert data and information into an injury risk index. A demonstration website allows organisations to trial the process with their own data (www.injuryalarm.com). Perhaps one day any organisation will be able to proactively manage unacceptable risk?

1 INTRODUCTION

There is a dramatic contrast in injury and incident performance between countries, industries and organisations. The International Labour Organisation has recently updated their global safety statistics which indicate an unimaginable number of fatalities and serious injuries. With over 3 million fatalities and 317 million serious injuries per year at a cost of 4% of global GDP the world's safety performance still has a long way to go, despite some impressive performance improvements in some jurisdictions (ILO, 2018).

In brief, the International Standard "Risk Management – Principles and Guidelines" (ISO, 2009) describes a generic risk management architecture, commencing with an organisation committing to a risk based approach, then embarking on a cycle of risk management improvement, which in theory continues until its risk criteria are met. Once the management team have committed to a risk based approach, the organisation defines a series of risk criteria defining desired performance, and design and implement processes to improve performance relative to the risk criteria. In effect, the risk criteria define the desired future performance and the risk improvement process compares the current level of risk to the criteria. The management team provides the required resources and motivation to address this gap.

Whilst this theoretical approach appears logical, the following example shows how it can be applied to a practical situation. The Australian offshore oil and gas industry Regulator, the National Off-shore Petroleum, Safety and Environmental Management Authority ('NOPSEMA') have reported for the first time that there were no fatalities in their operations for the 2016 reporting period, and in addition, there were no major investigations by them in response to serious events. This is a remarkable outcome considering the previous performance of the industry, somewhat defined by the Piper Alpha disaster in 1988 when 167 people were killed. The Cullen Public Enquiry following this incident recommended a series of changes to the off shore oil and gas industry, notably concerning its regulation. Of particular note was the introduction of the "safety case regime" which required the facility owner to demonstrate to the Regulator their risk based safety management system approach would be effective and the proposed facility would be operated safely, before the licence to construct the facility is granted. Once in operation both the Operator and the Regulator are obliged to monitor the effectiveness of the risk management controls, ensuring they meet the agree risk criteria. The safety case regime was adopted by Australia and other jurisdictions in their off shore safety legislation.

In effect, the safety case regime is an example of an effective risk based approach to the management of incident risk. The safety case requires the organisation to demonstrate an effective safety management system before production can commence, which results in strong management team commitment. The safety management system defines a series of controls (i.e. risk criteria) which must be in place to prevent incidents, and the effectiveness of these controls are monitored on an ongoing basis (i.e. Operator and Regulator risk monitoring). The oil and gas industry emphasis on proactively managing risk by requiring safe design, safe operation and the on-going Regulator review of the effectiveness of the operator to manage risk to an acceptable level appears to have been a successful approach to preventing serious incident for this industry.

This project aims to provide the leadership teams of any organisation with risk information, in particular the organisations performance relative to a series of risk criteria, to allow them to make proactive decisions to improve and sustain the performance of their organisation.

2 RISK BASED APPROACH

If establishing management commitments, risk criteria and a performance monitoring process are required for a successful operation, an unsuccessful operation can also be defined. Organisations which have not committed to a risk based approach, or which have not set risk criteria or which do not have a process to monitor risk are therefore more likely to have uncontrolled or unacceptable risk, therefore more likely to have an undesirable event. Without internal processes to monitor the level of risk relative to risk criteria, this type of organisation may only improve its management of risk when obliged to do so after an incident is reported externally, for example, after an employee attends a medical practitioner in response to a serious injury. The Regulator will then determine whether the organisations performance exceeds legislative standards (i.e. risk criteria) and whether action will be taken to improve performance (i.e. prosecution).

Organisations therefore need internal processes to monitor their level of risk relative to a series of criteria to warn them of potential unacceptable risk, rather than allowing the risk of injury to unknowingly increase until an event gains the attention of the Regulator. Ironically, organisations which are most in need of management commitment, risk criteria and risk monitoring processes are also those most likely to not have these in place.

3 PERFORMANCE MONITORING: WHERE ARE WE NOW?

All Australian and many overseas occupational health and safety ('OHS') jurisdictions oblige organisations to report serious incidents and potential serious incidents. Subsequently the Regulator can decide whether to take further action such as to investigate the incident and if necessary prosecute the organisation for a breach of the legislation. In Part 3 of The Australian Model Work Health and Safety Bill organisations are required to notify their Regulator of a death, serious injury or illness or a dangerous incident. Previous and other Australian States' legislation have had similar requirements. In addition, the Australian State's workers compensation legislation require organisations to inform them of serious workplace incidents and injuries. Thus over many years databases of incident notifications and incidents have accumulated in each State.

In this project, several sections of the West Australian mining operations incident notification database, Work Cover WA database and a construction organisation database were reviewed following Research Ethics approval. All databases contained only unidentifiable data i.e. all names of organisations and people were replaced with a code.

The databases were presented in spreadsheets comprising a series of column headings (i.e. variables), including date and time of incident, job role of injured person, task at time of injury, injured body part, and some incident description free text, as defined by the relevant legislative requirement. Although some data cleansing to adjust for missing data was required, most incidents contained data in all the variables, representing a near complete dataset.

The Government databases contained the equivalent of approximately 100 serious incidents per day over several years, around 250,000 incidents in 7 years. The construction industry organisation had approximately 15,000 incidents, of all severities, over 14 years i.e. approximately 3 per day.

Review of the Government databases showed that several organisations had reported many incidents but most had reported very few. There was also variation in the frequency of reporting of categories of incident, for example manual handling and mobile equipment incidents were reported more frequently than others. Due to the limited information for each organisation (i.e. generally less than 5 serious incidents) in the Government database, an industry collaborator, with multiple construction sites, donated 14 years of their safety data and information to allow the development and testing of the process. The construction organisation unidentifiable safety data and information, including their safety incidents of different severities and associated information were reviewed.

4 RISK CRITERIA: A FUNCTION OF LEADERSHIP

Recent reviews of the Government databases in Western Australia has resulted in useful interpretations of the data and are available for use by any organisation to assist in the prevention of future events. The West Australian Government reviews of fatalities and significant incidents, and hazard registers are a particularly useful insight into causes of serious incidents and fatalities (DMIRS, 2017) and will assist organisations learn from others (DMIRS, 2017). However, unless these reviews concern similar operations or hazards to an organisation, they can only provide some generic risk criteria or risk controls, and are unlikely to provide a risk monitoring process or initiate management commitment.

It was assumed that organisations that reported an injury to the Government did not want to do so, as their intention was to keep their employees free from harm, and protect their organisation from prosecution. Reporting an incident therefore exceeded a risk criteria and created a gap in performance which the organisation needed to address. In the absence of reported incidents which define the risk criteria, the leadership team must set the risk criteria based on their commitment to improve performance.

To accommodate the absence of event reporting two risk criteria were established to enable the gaps in performance to be modelled:

- Tolerated risk criteria is the level of risk which initiates action to improve (i.e. an undesirable event or behaviour which is no longer 'tolerated'), and,
- Acceptable risk criteria is the desired level of risk in the future which prompts the organisation to sustain and improve efficiency of the associated controls, and to develop new risk criteria to drive performance improvement.

5 RISK MONITORING: SAFETY INTELLEGENCE FOR LEADERSHIP

Defining tolerated and acceptable risk criteria enabled the development of statistical modelling of performance using the incident databases. Each incident reported represented either an omission or act in the development or implementation of a risk control, thus every incident provided information on the risk criteria or the organisations capability to achieve them.

A statistical risk monitoring process was developed by determining an organisations effectiveness to control the recurrence of incidents over time. The change in the effectiveness of an organisation to control a hazard over time enabled a series of scenarios to be developed to explain this outcome. For example, if an organisation reported a serious manual handling incident in year 2000 and then did not report another one for 18 years, it was assumed the organisation was effective in the control of these hazards. If an organisation reported a series of serious mobile equipment incidents each of 18 years from year 2000, it was assumed the organisation was less effective at implementing controls for this hazard.

A review of all variables and all categories of incident over all years of the database enabled a risk profile to be created for each organisation each year over the duration of the database.

6 DISCUSSION: INJURY ALARM

The use of the terminology from the international standard and existing reported incident data resulted in a process which does not require an organisation to implement a new process, a benefit to all in the present economic environment.

Establishing the two risk criteria and the subsequent modelling using the incident databases provided insight into the relative performance of organisations over time.

Testing with the construction organisation data showed an increase in the risk two years risk prior to a catastrophic event, a positive indication of the potential of this process.

The statistical model was developed into a web site called Injury Alarm (www.injuryalarm.com) to communicate the new process to the community. The aim of the website is to gauge interest in the process, and provide feedback to users who upload their data and information on whether their risk performance exceeds their risk criteria, thus an alarm “sounds”! The Injury Alarm website was launched by the West Australian Government Minister responsible for safety regulation, in time for World Day for Safety and Health, 2017.

The interest and feedback from users has enabled the further development of the process. Future versions will include a series of machine learning algorithms to forecast the risk, and provide users with recommendations on how to improve their risk performance, based on their own previous capability and effectiveness to improve.

7 CONCLUSION

Gaining the leadership team commitment, whether by Regulatory action or exceeding the tolerated risk in an organisation is essential to the development of risk based performance. Subsequently, the leadership team need risk monitoring information to enable decisions to allocate resources to manage unacceptable risk. A statistical process to monitor the level of risk in an organisation, relative to the risk criteria has been shown to be effective in one organisation. A free website called Injury Alarm communicates these ideas and allows organisations to upload their data for analysis and reporting.

8 ACKNOWLEDGEMENT

Thank you to the West Australian Government agencies Department of Mines, Industry Regulation and Safety, Work Cover Western Australia, and the construction organisation for donating their data.

MERCURY CONTAMINATION IN POTABLE WATER - HOW CAN IT HAPPEN. AN INDUSTRY SHARE

Sar McFadden

Site potable water sampling returned an unexplained high Mercury result at a processing site in NSW. Water results in the low lying areas of the system varied from at the ADWG heath limit of ~ 0.001 mg/L to 0.0104 mg/L.

Investigations with regards to the source of Mercury contamination have been extensive throughout a 12 month period and currently failed to identify the source.

Initially it was thought to be due to a catastrophic failure of a UV tube in the disinfection system discharging Mercury into the processing plant potable water supply. This significant risk was not identified as a potential source of heavy metal exposure through the supply of water to crib areas and ice machines.

The lamp contained ~110mg Mercury per tube in an amalgam which passed through the system and thought to have settled at the physical low point of the pipework. Fortunately the water is only used for crib washing not as drinking water. Previous UV lamp failures with Mercury release have been reported but have been presented as Environmental concerns, not as a health issue.

Treatment of Mercury contaminations is complex and requires a multi-disciplinary management plan. This paper presents solutions and risk management for UV systems failure in a potable water system. The presentation would be an ideal industry share during the AIOH conference where we highlight Challenges, Opportunities & Solutions.

WORK-LIFE BALANCE IN CONSTRUCTION WORKERS: A PILOT MODEL FOR MANUAL LABOURS

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Abstract

A work-life imbalance is identified as a vital determiner for attracting the young generation to join the construction industry. This paper explored the factors affecting the work-life balance (WLB) in construction manual workers. It investigates the most critical factors that impact on workers' work-life balance. In addition, it proposes a model of factors, work-life balance, job satisfaction, and turnover intention of different types of construction manual workers. The pilot model depicts the potential factors and moderators affecting the work-life balance of the manual workers in the construction industry. It also links up the factors and organisational issues such as commitment and turnover intention. The findings would help to enhance understanding on this issue and helps to make informed suggestions for improving work-life balance in the construction industry.

Introduction

In Hong Kong, there were increasing job vacancies in building and civil engineering sites between 2010 and 2015 (Vocational Training Council, 2015). With labour shortage comes wage increase. According to the Census and Statistics Department (2017), the construction industry has the third highest increase (46.1%) in accumulative year-on-year median monthly wages from 2010 to 2015, after estate management, security & cleaning services (51.3%) and miscellaneous activities (47.3%). The largest number of vacancies occurred at the skilled and semi-skilled worker levels and in the decoration/repair/maintenance sector, as well as special trades contractors, e.g. electrical work, painting, heating and air-conditioning, etc. The reasons why the construction industry, especially the manual job, is not attractive to young people have been well documented. The manual construction work suffers from numerous problems, e.g. adverse image with hardship at site, long work hours, income inequality between trades, poor safety and lack of job security and future prospects, etc. One critical problem of the manual job is poor work-life balance. This study examined the issues of work-life balance (WLB) as perceived by construction workers. Based on their perception, policies and strategies will be recommended to enhance WLB for construction workers to attract the younger generations to join the industry.

Work-life balance

SafeWork SA (2017) defined Work-life balance as "individual choices that enable businesses and workers to manage the interaction between work and the demands of life that affect health, families and communities." Fagan et al. (2012) stated that work-life balance is "work life integration". Work-life balance is how an individual deals with his/her work and personal life. Although there is abundant research on WLB, there are few studies focusing on manual workers, in particular, manual labours in construction and mining sectors. In a recent review of the qualitative research on work–family aspects from management field, Beigi and Shirmohammadi (2017) concluded that the occupations with high expectation but low profiled, e.g. mineworker, were under-studied.

Employees in these occupations were restricted to devote their time and energy to activities outside the workplace. It is therefore claimed that there exists an urgent need for research in this field. One of the critical elements of work-life balance/ work-life conflict is work-related stress. Job stress is often associated with poor work-life conflict. Bell et al. (2012) found that perceived work-related stress was associated with poor WLB and increased the conflict between studied subjects' work and personal life. Construction site work is well known for its high physical demand and unpleasant working environment. To understand the level of job stress perceived by manual employees and their relationship with site workers' work-life balance, the antecedents of site-work stress should be explored.

Antecedents of work-related stress in the construction industry

Job demands

Job demands are a cause of stress. They are also crucial elements of work to family conflict. Wallace and Montreuil (2005) found that job demands significantly contribute to work-to-life conflict. In addition, they found that control over working hours decreased the level of work-family conflict in lawyers. However, the samples from their study were lawyers instead of manual workers. The real impacts of job demand variables for WLB and work life conflict still need to be established and explored.

Physical demand

Intensive physical demanding is an essential job nature of the site works. Site works often involves high force (e.g. pushing, heavy lifting, and gripping tools), contact stress (e.g. handling tools), awkward postures (e.g. when blending, carrying and twisting), vibration of hands and whole body with power equipment, which all involve high repetition and long duration(School of Medicine Washington University, 2014). Working under such heavy workload, requirement for individuals' physical fitness would be high. Few aged workers could continue to work on site due to decreased fitness. The hardship of site works could lead to unpleasant work experience. Thus, the physical demand of manual work was employed as a variable in the current study.

Working time arrangement
One important cause for job stress of construction employees is awkward working time arrangement. It is also a critical factor affecting the level of WLB. There are two primary standards for weekly working hours limits across nations by the mid-twentieth century. At the end of World War I, the 48-hour limit was usually legislated as national standards (Lee et al., 2007). Later in 1962, the 40-hour limit was adopted as the international standard. This limit was evident as national measures in the International Labor Organization (ILO) review on and legislation of working time. Out of 93 countries, 35 had 48-hour limit while the others adopted the lower 40-hour limit for weekly work. Lee et al. (2007) reported that most Asia countries used to adopt the 48-hour limit, but then generally conformed to the lower statutory hours during the 20th century, e.g. China adopted the 40-hour limit in 1995. To date, the 40-hour limit is the most prevalent standard worldwide (Lee et al., 2007). As Tucker and Folkard (2012) commented, "(a) standard day work is from 7 to 8 am, and 5 to 6 pm, from Monday to Friday". Working over 8 to 9 hours a day, and more than a total of 40 hours a week can be regarded as working extended hours (Tucker and Folkard, 2012). However, there are still a large number of workforces working for more than 40 hours per week. With reference from the data of the Third EU Survey on Working Conditions in 15 European countries, there were 84% of the employed and 44% of the self-employed working more than 40 hours weekly (Costa et al., 2004). In addition, it was reported from the labour statistics 2005 that nearly one-third of the workforces in the United States regularly worked over 40 hours per week (Tucker and Folkard, 2012).

Increasing evidence suggests that bad health and poor well-being can be attributed to long working hours. Sparks et al. (1997) found that health symptoms were significantly correlated with the length of working hours, and longer working hours were associated with poorer well-being. Additionally, long working hours contributed to increased risk of physical health (Dembe et al., 2008). Further, long working hours was reported to be associated with unhealthy lifestyles (Burke and Cooper, 2008). Based on the Third and Fourth Europe Working Conditions Surveys, it was found that there was a significant positive correlation between the frequency of reported problems and number of working hours (Boisard et al., 2003, Burchell et al., 2007). Long working hours, particularly more than 48 hours weekly, may lead to increased risk of occupational health (Boisard et al., 2003, Burchell et al., 2007). Further, long working hours may lead to fatigue, which was identified as the most critical factor resulting in accidents in oil and gas construction (Chan, 2011). Overtime work (over 40 working hours per week) was found to have increased the occurrences of occupational injury, with 61% more injury rate when compared with non-overtime work (Dembe et al., 2005). Moreover, working overtime was identified to have clearly increased occupational accident rates (Occupational Safety and Health Council et al., 2003). The ILO suggested that employees should not work over 48 hours weekly (Tucker and Folkard, 2012).

Long working hours not only attribute to adverse impacts on health (Dembe et al., 2008, Burchell et al., 2007, Boisard et al., 2003, Sparks et al., 1997), but also contribute to hostile site conditions and difficulty in recruitment. With reference to the data (2010-2015) from the Vocational Training Council of Hong Kong, job vacancies in building and civil engineering sites have been growing although more workforces have entered the field

(Vocational Training Council, 2015). Skilled and semi-skilled workers were in highest demands, as well as those working for decoration/repair/maintenance contractors, and for special trade contractors e.g. electrical work, painting, heating and air-conditioning, etc. With a labour shortage comes a wage increase. Not only Hong Kong but also Australia and Canada are facing construction labour shortage and ageing problems. In Alberta of Canada, according to Alberta Human Resources and Employment (2006), their labour force was also ageing. In the five years following 2006, the population of those more than 45 years of age would grow twice as fast as those younger, and the population in the “55 to 64” age group would grow the fastest. All these places face the same difficulties in recruiting enough young people, the Generation Y, to join the industry. The latter is not interested in working six days or more a week. Instead, they would demand more flexible work practices and opportunities to achieve WLB. Working long and “un-social” hours are not conducive to the recruitment of young people who are in general more educated, and have more career choices open to them than before. The problem is becoming acuter especially when there is a construction boom going on as in the case of Hong Kong.

Lack of job security /Uncertain prospects of the industry and Career Development

Job insecurity and project discontinuity could lead to the uncertain prospects of the industry and career development. The fluctuant construction market and policy of the authority may have a great impact on labour demand. Take Hong Kong for an example, the gross value of construction work at constant (2000) market prices in both public and private construction sites dropped from the year 1995 to 2006, when the industry went into regression (Census and Statistics Department, 2017). During the regression period, a large number of construction workers had to change their jobs into other occupations for a living. Furthermore, it was reported that the filibustering in the local Legislative Council had prevented from public projects getting their necessary approvals to start work (Li, 2016). Launching construction projects evenly will assist the sustainable development of the industry and guarantee sustainable job supply. Chiang et al. (2015) revealed that a limited career path and inadequate training courses were barriers to attract young labour to join the construction industry. Provision of plans for sustainable career development, such as adequate training, and fulfilling the expectation for the employees may lower the experienced emotion exhaustion (Chih et al., 2016). Thus, the perceived job security perceived career development was assessed in current research.

Income

Income is considered as one dimension of work rewards. The level of payment could be associated with job satisfaction. In addition, the relationship between work and family could impact on the satisfaction in life and job. Researchers found that less work-family conflict could carry positive impacts from personal life to work (Adams et al., 1996, Qu and Zhao, 2011). Wei et al. (2016) revealed that job satisfaction could partially mediate the relationship between drivers’ safety participation and work-to-family conflict. Thus, we employed income as a mediating variable in the study.

Hostile work environment

Construction work is susceptible to the adverse physical environment because of its outdoor and confined workplace. Site work contains several of hazards, e.g. dust and poor air quality from construction materials, lack of sufficient ventilation, chemical particles generate from building procedures, noise, and heat stress from the hot climate and bright sunshine, etc. Excessive exposure to occupational irritants, extremely thermal stress and inadequate lighting can contribute to the low response to the treatment of psychiatric symptoms, e.g. mood disorders (Woo and Postolache, 2008). Temperature, airflow and humidity can greatly affect the thermoregulation. They are also critical factors for mood disorder (Woo and Postolache, 2008). Construction workers in Hong Kong suffer from high risk of heat stress and extreme humidity during the summer, in particular, from outdoor working. Melamed et al. (1992) found that exposure to noise was associated with increased sickness absence and incidents. Noise becomes a crucial stressor for predicting anxiety, irritability, as well as depression. Chiang et al. (2015) indicated that improving site facilities such as more bathrooms, mobile toilets and lifts for workers is one of the most important measures to attract the young generation to join the industry. In terms of psychosocial work environment, construction workers also face several stressors in their workplace such as tight project schedule, heavy job demands, adversarial culture, and lack of organizational and other support from supervisor and co-workers, etc. All these results in a hostile work environment for site labours and increase the risk of work-life conflict. In addition, construction work is infamous for its poor safety record. Workers need to stay highly focused during work. Thus, high attention and extreme focus are required when performing the dangerous work, which can be considered as another source of job demands.

Life variables of WLB

"Life" is another essential facet of work-life balance. Results from the National Work-Life Conflict (WLC) Study of Canada illustrated that the level of family life interfacing work depended on the demands from personal life and was predicted by the hours spending on childcare. It suggested that individuals with responsibilities of elder care and/ or childcare were under a high risk of this kind of WLC (Duxbury and Higgins, 2009). In terms of the young generation who do not have children, life variables can be the leisure time or any other time they spend outside the workplace. The more responsibilities they have and the more important role they assume with their family and friends, the more demand they are likely to hold. Demands introduce the risk of WLC. Thus, the life variables will be assessed in the study.

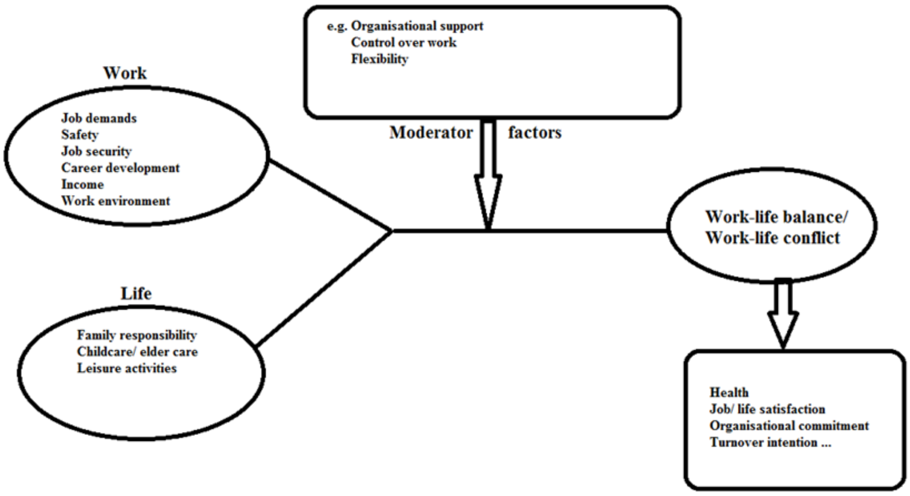
Moderator variables of work life balance
Organizational support, Control over work and Flexibility

Organizational support is identified as facilitator for WLB. The sector of the organisation may have impacts on employees' WLB. Compared with employees from the public sector, private sector employees may experience relatively higher levels (Francis and Lingard, 2004). In addition, organizational culture, management support and policy were reported as factors of work-life balance (Lester, 2015, Julien et al., 2011). Supportive work environment can increase WLB. Blue-collar labours were reported to have lower level of work life conflict under family-supportive work environment (Grandey et al., 2007). Flexible working hours is considered another organisational factor that might facilitate WLB. Flexibility in work schedule to some extent reflects the availability of employees' control over their work arrangement. Therefore, provision of flexibility in work time arrangement and increase in employees' control over their work might be considered to enhance WLB without effecting total workload and output in the construction industry.

Emotional intelligence
"Emotional intelligence" was identified as one of the main factors affecting WLB (Kumarasamy et al. (2015). It was found in particular to have positive effects on enhancing WLB, at an individual level. Emotional intelligence can be referred to as the ability to perceive, understand and manage emotions (Kumarasamy et al. (2015). It could assist individual's thinking and actions to achieve and maintain a good WLB. In addition, personality is also reported to be a predictor for work-life conflict (Leka and De Alwis, 2016). Leka and De Alwis (2016) found that neuroticism was a strong predictor of work-life conflict, suggesting that one's personality could suggest the extent the particular individual would be prone to experience work-life conflict. However, this is not within the scope of the present study.

Therefore, the proposed relationship between the variables and work-life balance is shown as follow. Job demands, safety, job security, career development, income and work environment are variables of "work". Likewise, family responsibility, childcare and leisure activities are variables of "life". "Work" and "life" work together to contract the integration of work-life balance or work-life conflict. During the contracting process, moderator factors such as control over work, flexibility and organisation support would affect the process. The interaction of work and life could have impacts on individual's health, work or life satisfaction. It would further affect employees' commitment and turnover intention. The pilot model depicts the potential factors and moderators affecting the work-life balance of the manual workers in the construction industry. It also links up the factors and organisational issues such as commitment and turnover intention, which would be utilised for the policy-making for the industry and the manual labours. It should be assessed in the future research for its accuracy.

Figure 1 work-life balance in the contruction industry



Conclusion

Work-life balance is a vital issue for construction manual workers. It relates to the quality of an individual's "work" and "life" and has effects on the statues of health. It might also impact on the turnover intention of workers. Thus, policy and measures should be formulated with the above variables to address such issue.

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THE CONSEQUENCES OF POOR INDOOR AIR QUALITY - WHAT IS THE ASSOCIATED MORBIDITY AND MORTALITY?

Brad Prezant

The last 50 years has seen a dramatic shift in the design and construction of the buildings we occupy. Reduced ventilation, increased humidity, and changing building materials have created more attractive homes, but unintended health consequences have accompanied these changes. In the developed world, poor indoor air quality has profound consequences on public health, particularly on the incidence and severity of asthma and other respiratory disease. Cockroaches, rodents, dust mites, and indoor moisture are all significant contributors to disease with large financial implications to society. Although Australia has few areas with significant radon exposures, data from other developed countries suggest that estimated population attributable risk of lung cancer due to radon exposure is between 10% and 20% of total cases in smokers and non-smokers (both are at additional risk).

In portions of the less developed world, more than 90% of people rely on biomass to meet their domestic energy needs - globally over 3 billion people, with 4.3 million deaths annually as a result. 500,000 children under 5 years of age die annually as a result of pollution from cooking. These exposures are among the top 10 preventable contributors to the global burden of disease.

Indoor air quality has a profound impact on disease. A significant portion of the $28 billion expense we incur in Australia annually due to asthma is due to the indoor environment, and a significant portion of that amount is preventable.

CLIMATE CHANGE AND OCCUPATIONAL HYGIENE

Claire Bird

There is an urgent need to improve our building practices to perform better under a changing and sometimes unpredictable meteorological future. This presentation examines the triangle of climate change, the wellness movement and the demands placed on the construction industry. It examines the resultant impact on indoor and construction site workplaces. It looks at how hygienists can engage in new areas where self-awareness rather than traditional workplace exposure risks is driving work absenteeism, and ultimately the perceived health of workplaces.

There is demand for healthier workplace environments; buildings with Indoor Environment Quality certifications attracts elevated prices at sale and rental. There is ironically equal pressure to construct buildings with cheaper building materials, such as substandard plumbing and electrical fittings, and materials that may contain asbestos, that may generate workplace exposure risks. Current construction practice is also exposing internal structures to inclement weather before completing the façade and/or roofing. Wet cellulosic materials allow fungal growth and hence result in exposure to potential odours, allergens and asthmatogens during handling of materials by building operatives and post-occupancy. Conversely, encasing the occupied space within an airtight envelope leads to health risks from build-up of indoor contaminants and moisture that reduce the quality of life for occupants, and can lead to health complaints despite conditions being compliant with National Exposure Standards.

Two case studies are examined that demonstrate the impact of sub-toxic level contaminants on workers in two offices whereby long-term absence were the result of odour complaints and faulty building design or operation.

COMPOST WORKER EXPOSURE TO INHALABLE AND RESPIRABLE DUSTS

Lauren Pickering and Sue Reed
Edith Cowan University

ABSTRACT:
This project aimed to quantify occupational exposures to inhalable and respirable dust at a commercial composting facility whilst staff undertook their normal daily duties. The results indicate that the workers at the compost facility are exposed to higher levels of the inhalable dust fraction rather than the respirable fraction. At no point during the monitoring period was the Safe Work occupational exposure limit of 10mg/m^3 exceeded. The adopted trigger value of 5mg/m^3 was exceeded on three occasions. The adopted respirable trigger value of 1mg/m^3 was not exceeded during the monitoring period.

The variable nature of the roles undertaken at the facility, tasks conducted, work practices and the effect of weather have all impacted on the levels of inhalable and respirable dust. While mobile plant cabins and filtration systems are effective in reducing occupational exposures. Further work and recommendations to reduce worker exposure include the development of a health surveillance program and an educational program to improve worker behaviour and work practices. While proven methods of dust suppression such as wetting down should be considered at the site.

1. INTRODUCTION:

Commercial composting is a growing industry driven by a shift to reduce and recycle waste, resulting in the establishment of large-scale composting facilities and increased employment in this sector (Kumar et al. 2011). Compost workers are potentially exposed to many occupational health hazards that can have the potential to adversely affect a worker's health, including airborne contaminants such as inhalable and respirable dust. While there have been many studies (Persoons, Parat, Stoklov, Perdrix & Maitre, 2010; Sykes, Allen, Wildsmith & Jones, 2009; van Tongeren, van Amelsvoort & Heederik, 1997; van der Werf, 1996) in the northern hemisphere predominantly focusing on bioaerosol exposure; few occupational studies have been conducted at composting facilities in the southern hemisphere that utilize windrow systems and in-vessel composting techniques and focus on employee exposure to inhalable and respirable dust.

The aim of the project was to establish an occupational exposure profile of workers in a commercial composting facility to inhalable and respirable dusts.

To meet this, aim the project had the following objectives:

- Measure the levels of exposure to inhalable and respirable dust at a composting facility; and
- Determine if the current control methods utilized at the site reduce occupational exposures.

2. POTENTIAL HEALTH IMPACTS:

During the composting process movement, mixing of feedstock, screening and turning of the compost, generates dust. Inhalable dusts (<100 µm) can be deposited in the upper respiratory tract, and are considered to be nuisance dusts, which could be potentially harmful in high concentrations (AIOH, 2016). The respirable dust fraction, which includes dusts for which 98% are less than 10µm, with a 4µm median cut point, can penetrate into the gas exchange region of the lungs (AIOH, 2016). Compost workers who are potentially exposed to organic dusts may experience a number of adverse health effects. Adverse health effects may include mild symptoms such as irritation of the eyes, nose and throat to more severe effects such as pulmonary inflammation (acute inflammation, hypersensitive pneumonitis) occupational asthma and chronic bronchitis (Domingo & Nadal, 2009). In addition, it has been reported that compost workers that have been exposed to organic dusts experience increased symptoms of organic dust toxic syndrome (ODTS), which results in a number of symptoms such as cough, chest tightness, dyspnea, muscle ache, joint pain, fatigue and headache (Perez, Frank, & Zimmerman, 2006; Poulson, Breum, Ebbehoj, Hanson, Ivens, van Lelieveld et al., 1995). In addition to the increased ODTS symptoms and diseases of the airways, it has been reported that compost workers experience an increase in diseases of the skin including eczema, dermatomycosis (Perez, Frank, & Zimmerman 2006).

3. STUDY SITE:
The study site was a large scale EPA licensed compost facility that receives up to 220 000 tonnes of waste per year to produce approximately 50 000 tonnes of compost per year (D Key, personal communication, March 2018). The site accepts both prescribed and non-prescribed waste. Typical prescribed waste include industrial wash waters, interceptor waste, dairy wastes, eggs and contaminated soils. Non-prescribed waste consists of green waste, and biosolids. The non-prescribed waste are batched in order to get the correct mixture. This batching process involves moving feedstock's and loader work to get the mixture correct which is then formed into windrows. Using temperature and moisture content of the compost windrows as a guide, each windrow is periodically aerated to ensure aerobic conditions are maintained throughout the composting process. The final product is screened to remove large debris and sold as an agricultural soil conditioner. Overall the process takes approximately 12 weeks.

The site employs approximately 20 people consisting of management, technical, and operational personnel. The staff working within the composting facility work a 9-day fortnight consisting of 8-hour shift lengths with over time as required. Currently staff preforming operator roles, are rotated every 6-months (D Key, personal communication April 2018). A mechanical contractor is based at the site full time, working a 4-day working week consisting of 8-hour days. Table 1 outlines the work activities performed by the staff across the composting facility.

Table 1: Work Activities conducted across the composting facility

Work Area	Job Title	Work Tasks
Non-prescribed waste	Loader & Truck Operators	- Batching, mixing and forming windrows - Majority of shift spent in cabin
	Aerator Operator	- Aerate compost windrows - Majority of shift spent in cabin
	Rousie (rouse-about)	- Works behind the aerator - dragging hoses & keeping water up to the aerator - Operating mobile plant including loaders and skid-steers
	Screen Operator	- Loading trucks with final product - In and out of loader cabin - Attending to the screen - including attending to blockages - Attending to conveyors and conduct
Prescribed waste	Operators	- Work in a series of sheds - Unloading liquid waste from trucks - Attend to silo's and in-vessels - Mixing of waste - Cleaning vessels & sheds - Limited time spent in mobile plant
	Mechanic	- Conducts regular routine maintenance of all mobile plant including the aerator - including the replacement of cabin filters - Maintenance and break down maintenance of screens and conveyors - Tasks such as welding and grinding
	Scientific & QA Officer	- Office and lab based work - Conduct moisture and temperature readings of compost windrows
	Operations Manager	- Office based work - Occasionally out in the composting facility talking to staff

4. METHODOLOGY:

Across the composting facility a repeated sampling regime was implemented using the following similar exposure groups (SEG's):

- Non-Prescribed Operators;
- Prescribed Operators;
- Mechanic;
- Technical; and
- Operations Manager.

4.1 Occupational Exposure Monitoring:
Inhalable dust monitoring was undertaken in accordance with AS 3640 using SKC IOM sampling heads located within the workers breathing zone. The sampling heads were attached to either SKC Airchek 5000 (Serial Number 82490) or SKC Touch (Serial Numbers 15126, 15282, 15368, 15425, 15427, 15319, 15320, 15413, 15423, 15437) pumps using flexible tubing. The air sampling pumps were calibrated at 2 L/min, using a DryCal Calibrator (Serial Number 108770).

Respirable dust monitoring was undertaken in accordance with AS 2985 using SKC cyclone (SKC Catalog Number 225-62-25) sampling heads loaded with PVC fliters were attached within the workers breathing zone. The cyclone sampling heads were connected to SKC touch sampling pumps (Serial Numbers 15126, 15282, 15368, 15425, 15427, 15319, 15320, 15413, 15423, and 15437) using flexible tubing. The air sampling pumps were calibrated at 2.2 L/min, using a DryCal Calibrator (Serial Number 108770).

Inhalable exposure results were statistically analysed and compared to the occupational exposure standard for inhalable dust of 10 mg/m^3 measured as an 8-hour time weighted average (TWA) and the AIOH recommended trigger level for inhalable NOC dust of 5mg/m^3 measured as a 8-hour TWA (AIOH 2016). Respirable occupational exposures were statistically analysed and compared to the AIOH recommended trigger level for respirable NOC dust of 1mg/m^3 measured as an 8-hour TWA (AIOH 2016).

4.2 Area Monitoring
Static monitoring of inhalable and respirable dust occurred across the facility to identify high contaminant areas/tasks that may contribute to occupational exposures. Sampling heads were attached to SKC Aircheck 5000 air-sampling pumps (Serial Numbers 49761, 77143, 77607, 80715, 82331, 82392, 82490 and 82686) were placed at fixed locations over the monitoring period at a height of 1 to 2 metres.

5. RESULTS:
5.1 Inhalable Dust
Over the monitoring period 30 occupational inhalable dust samples were collected (Table 2). Overall, employee exposure to dust was found to be low (min 0.06 mg/m^3; max 7.40 mg/m^3). Of the 30 inhalable dust samples collected none exceeded Safe Work Australia's occupational exposure limit for rough dust of 10 mg/m^3. Three samples were found to exceed the AIOH's recommended trigger value for inhalable NOC dust of 5 mg/m^3. Overall the Non-Prescribed Operators were exposed to higher levels of inhalable dust (MVUE 2.51 mg/m^3) followed by the Mechanic (MVUE 2.19 mg/m^3) and the Non-Prescribed Operators (MVUE 1.24 mg/m^3) (Table 3). The Technical and Operations Manager SEG's recorded low levels of exposure to inhalable dust with MVUE of 0.18 mg/m^3 and 0.45 mg/m^3 respectively.

Table 2: Results of inhalable dust exposures

Similar Exposure Group		Inhalable Dust Concentrations (mg/m³)				
Non Prescribed Operators	1	0.68	1.89			
	2	1.57	1.41	7.40	3.31	
	3	0.81	0.23	Invalid		
	4	2.86	6.00	1.46	1.43	2.46
Prescribed Operators	1	1.21	0.33	0.63	0.33	
	2	3.12	0.28	2.96		
Mechanic		2.04	0.75	0.61	5.67	
Technical	SO	0.06	0.18	Invalid	0.09	
QA		1.46				
Operations Manager		0.45	0.73			

Table 3: Descriptive Statistics for Inhalable Dust Exposure - Safe Work Australia occupational exposure limit for inhalable dust of 10 mg/m³ 8-hr TWA and the adopted trigger value of 5mg/m³.

Similar Exposure Group	No. Samples	Min	Max	AM/ MVUE	GSD	OEL of 10mg/m³		Adopted Trigger Value of 5mg/m³	
						95th Percentile	95% Level %>OEL	95th Percentile	95% Level %>OEL
Non Prescribed Operators	13	0.23	7.40	2.51	2.50	7.77	2.70	5.32	12.2
Prescribed Operators	7	0.28	3.12	1.24	2.82	4.43	0.80	6.88	3.90
Mechanic	4	0.61	5.67	2.19	2.79	8.19	3.30	8.19	12.2
Technical Staff	3	0.06	0.18	0.11	1.74	0.25	0.00	0.25	0.00
Operations Manager	2	0.07	0.45	0.26	3.73	1.55	0.10	1.55	0.60

5.2 Respirable Dust

A total 25 occupational respirable dust samples were collected with occupational exposures ranging from 0.02 mg/m³ to 0.44 mg/m³ (Table 4). The respirable dust (NOC) trigger value of 1 mg/m³ was not exceeded during the monitoring period. The highest respirable dust exposure was less than 50% of the adopted value with the calculated MVUE ranging from 0.1 mg/m³ to 0.2 mg/m³ across the SEG's (Table 5).

Table 4: Results of Respirable Dust Exposures

Similar Exposure Group		Respirable Dust Concentrations (mg/m^3)			
Non Prescribed Operators	1	0.06	0.21		
	2	0.02	0.43		
	3	0.31	0.12	0.06	0.02
	4	0.27	Invalid		
Prescribed Operators	1	0.10	0.13	0.39	
	2	0.04	0.12	0.07	
Mechanic		0.08	0.22	0.20	
Technical	SO	0.06	0.16	0.11	
	QA	0.13	0.09		
Operations Manager		Invalid	0.37	0.10	

Table 5: Descriptive Statistics for Respirable Dust Exposure - Adopted trigger value of 1 mg/m^3.

Similar Exposure Group	No. Samples	Min	Max	AM/ MVUE	GSD	95th Percentile	95% Level %>OEL
Non Prescribed Operators	9	0.02	0.43	0.18	3.17	0.68	2.40
Prescribed Operators	6	0.04	0.39	0.14	2.20	0.34	0.20
Mechanic	3	0.08	0.22	0.17	1.71	0.38	0.00
Technical	5	0.06	0.16	0.11	1.48	0.19	0.00
Operations Manager	2	0.10	0.37	0.24	2.52	0.88	3.70

5.3 Area Static Monitoring

Static monitoring (Table 6) results varied across the site with tasks such as screening resulting in significant levels of inhalable dust (max 68.22 mg/m^3). Respirable dust levels in the non-prescribed wastes area ranged from 0.06 mg/m^3 to 3.61 mg/m^3. Inhalable dust levels in the prescribed wastes area ranged from 0.19 mg/m^3 to 27.15 mg/m^3, while respirable dust levels ranged from 0.07 mg/m^3 to 0.98 mg/m^3 (Table 7).

Table 6: Area Static Monitoring - Non-prescribed waste

Location	Date	Inhalable Dust Concentration (mg/m^3)	Respirable Dust Concentration (mg/m^3)
Internal Loader 4	15/02/2018	1.77	-
Screen Area West Boundary Fence	15/02/2018	Invalid	0.05
External Loader 4	27/02/2018	19.54	3.61
Internal Loader 4	27/02/2018	0.00	0.06
Internal Loader 8	01/03/2018	1.51	0.24
Screening Area - East Boundary Fence	01/03/2018	5.99	0.18
Screen Area West Boundary Fence	09/03/18	Invalid	0.46
Screen Area West Boundary Fence	22/03/2018	68.22	0.23
East Brew Room Entry	22/03/2018	27.15	-

Table 7: Area Monitoring - Prescribed waste

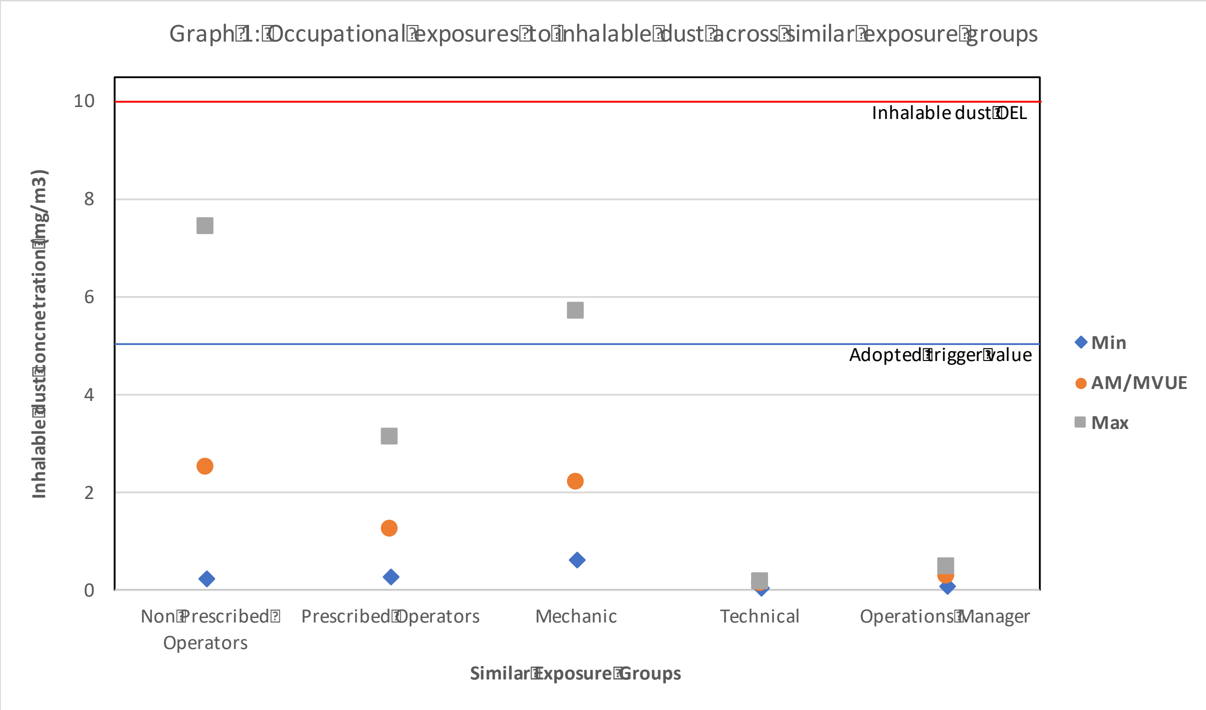
Location	Date	Inhalable Dust Concentration (mg/m^3)	Respirable Dust Concentration (mg/m^3)
Soils Shed - Mixing Bay	15/02/2018	0.19	0.07
Soils Shed - Mixing Bay	27/02/2018	2.66	0.10
Soils shed - Mixing Bay	9/03/2018	0.20	0.98
Unloading Bay	22/03/2018	27.15	0.31
In-vessel Shed -East Entry	22/03/2018	16.68	-

6. DISCUSSION:

The monitoring occurred during the summer months during an unusually dry period, with rainfall being below average for both February and March, with recorded rainfalls of 15.8 mm in February and 18.8 mm in March, which is significantly below the historical averages of 42.1 mm and 48.4 mm respectively (Bureau of Meteorology BOM 2018). These weather conditions along with operational constraints over the monitoring period also resulted in difficulties in maintaining the moisture content of the compost as a result it would be expected that occupational exposures to airborne dust may have been at the worst. (D Key, personal communication April 2018).

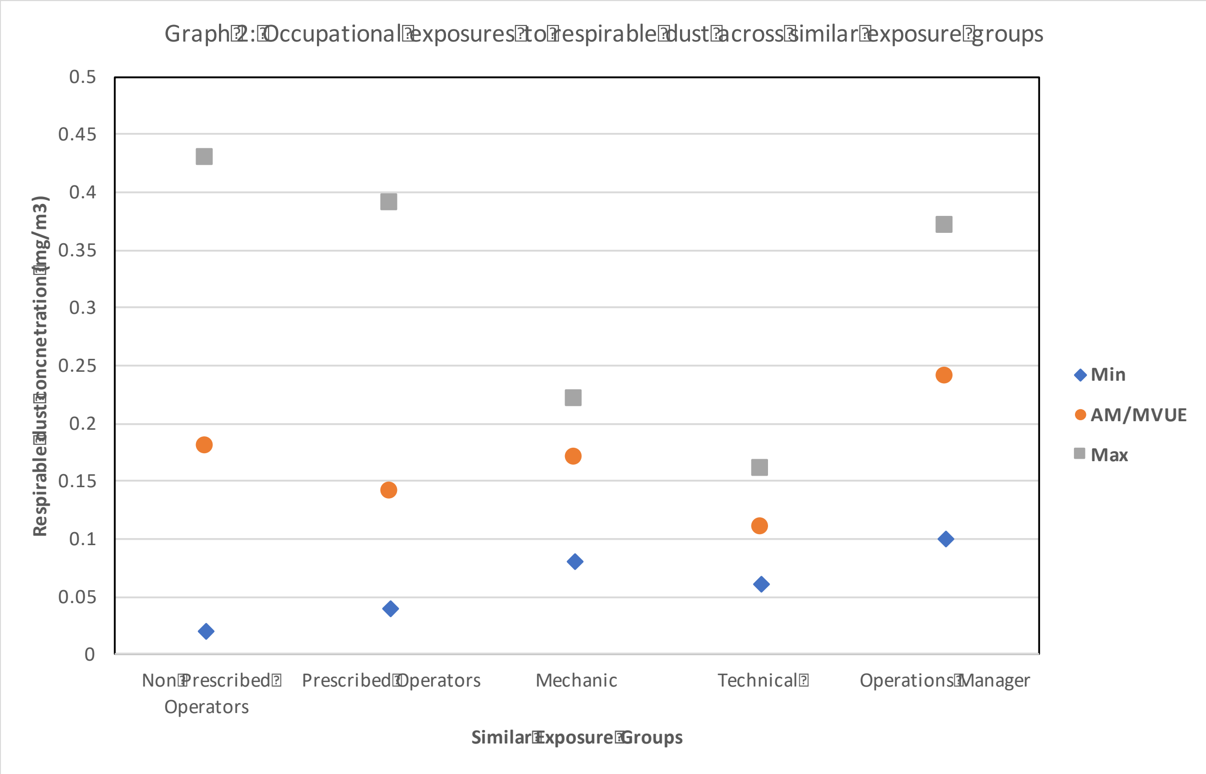
6.1 Inhalable dust:

The results of both the personal and area monitoring suggest that there is potential for personnel to be exposed to inhalable dust levels that can exceed the adopted trigger value; with the Non- Prescribed Operators and the Mechanic exceeding this level on 3 occasions (Graph 1). Tasks performed by the Non-Prescribed Operators such as screening and fulfilling the role of Rousie resulting in higher occupational exposures.



6.2 Respirable dusts:

The results of the occupational exposure monitoring across the compost facility suggests that it is unlikely that operators across all SEG's will be exposed to respirable dust levels that would exceed the adopted trigger value of 1mg/m^3 - with the highest levels recorded (0.43 mg/m^3) by the operator in the Non-Prescribed Operators SEG undertaking the role of Rousie. Respirable dust levels for the prescribed operators were found to be similar to the Non-Prescribed Operators and were all found to be below the adopted trigger value of 1mg/m^3 with the MVUE of 0.14 mg/m^3 (Graph 2).



6.3 Controls Measures:
Control measures employed at the site consist of predominantly engineering controls such as ventilation systems, and high efficiency cabin filtration systems. In addition to this staff working with in facility are required to wear mandatory gas badges. Respiratory protection was only worn by staff when conducting asbestos related work.

At no point during the monitoring period was wetting down of the unsealed gravel-clay hardstand employed as a method for reducing airborne levels of dust, despite high traffic areas and activities such as the screening of final product creating significant amounts of dust especially if the weather conditions are conducive. During high winds not only is there a potential for elevated occupational exposure, but large volumes of airborne dust creates a significant visibility hazard - with the operator reporting poor visibility within the final product area during high wind days. Dust suppression techniques such as mist sprays or wetting down the hardstand have been proven to lower the airborne dust levels within composting facilities (Epstein et al 2001).

The main method of controlling occupational exposures at the site for the majority of the staff working at the site is the cabins of the mobile plant. All of the mobile plant cabins are pressurized and have been retrospectively fitted with Breathe Safe HEPA / activated carbon filtration systems. Given the occupational exposures of the operators and the static monitoring that occurred within the cabins highlights that these systems are effective in reducing occupational exposures.

6.4 Limitations:
While the study was conducted over a two-month period it is hard to use the collected data to completely characterise the workers exposure to inhalable dust levels. Factors such as, limited time to sample and volunteers' not being available on monitoring days has resulted in a small data set. This small data set has resulted in high variability and uncertainty. In addition to this external factors that have impacted on the results of this study include seasonal variability, day-to-day variability and possible changes in worker activities. Ideally, to produce a more meaningful data set a minimum of six samples should have been collected from each SEG for each contaminant of concern. To fully understand the exposure profile of the site occupational exposure monitoring should occur over a greater timeframe to incorporate temporal changes, differing feedstock, and to account for worker variability - however this is often difficult to achieve.

7. CONCLUSION AND RECOMMENDATIONS:

The results of the investigation demonstrated that the occupational exposures were similar to previous studies assessing worker exposure to dust in composting facilities conducted overseas. The results of this study demonstrated that the compost workers monitored were exposed to greater levels of the inhalable dust rather than respirable dust. Two Non-Prescribed Operators and the Mechanic were found to exceed the adopted trigger value of 5 mg/m^3. While one prescribed operator was found to exceed 50% of this value on two occasions. The statistical analysis highlighted the variation between the SEG's and also within SEG's. The variable nature of the roles undertaken at the facility, tasks conducted, work practices and the effect of weather have all impacted on the levels of inhalable and respirable dust. Mobile plant cabins and filtration systems appear to be well maintained and are effective in reducing occupational exposures to both inhalable and respirable dusts.

Further work and recommendations to reduce worker exposure include:

- The development of a health surveillance program. This program should include lung function tests and targeted routine monitoring for inhalable dusts for the Rousie Worker, Screen Operator and Mechanic.
- Provide training to staff about how their behaviour and work practices can result in inhalable dust exposure. Employees across the site should be encouraged to limit their use of compressed air when cleaning down plant and cabins.
- Consider applying water to the hardstand during dry windy days in particular in the screening area. The high dust levels not only can result in elevated occupational exposures, but results in poor visibility creating a potentially hazardous situation and an increased risk of an accident occurring in this area

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MELBOURNE METRO PROJECT

Jamie Ross

Metro Tunnel Project

The Melbourne Metro Tunnel is an $11 billion city-shaping project, setting a new standard for high capacity and efficient public transport in the city. Five state-of-the-art train stations connected by twin 9km tunnels will be constructed in the heart of the city. With works now underway, the impacts on the workforce and the public are being carefully managed to ensure the project is as successful during it's construction as it will be in improving Melbourne's rail network. This presentation will provide an overview of the project, and details on the leading-practice approaches to managing health and safety risks during construction, and achieving the project's vision of getting the workforce, public and passengers home safe and healthy every day.

OCCUPATIONAL EXPOSURE TO MCINTYRE POWDER AND THE CONSEQUENCES

Dr. Doug Boreham

Northern Ontario School of Medicine (NOSM) and Division Head for the Medical Sciences Division

It is known that exposures to toxic agents inherent to the mining environment (arsenic, diesel exhaust and fumes, silica and mycotoxins) modify the risk of lung cancer. However one agent that has never been considered is McIntyre Powder. McIntyre Powder is a fine aluminum oxide powder that was used from 1943 to 1979 in the majority of gold and uranium mines in Canada (Ontario, Quebec, Manitoba, Saskatchewan, British Columbia, Northwest Territories), the United States, Mexico, Chile, Belgian, Congo and Western Australia. The powder was used as a potential “prophylactic” treatment for silicosis. Most miners were not given a choice and were forced to inhale the powder in specialized areas of the mine. Recently, a program began to investigate some of the biological consequences of McIntyre Powder exposure. This presentation will provide an overview of the history of McIntrye Powder and discuss some of the concerning health conditions arising in miners from exposure to large quantities of aluminum along with all the other toxic agents that were present at the time.

CREATING CONTEXT IN REAL-TIME MEASUREMENT

Peter Knott COH, Anthony Bamford MAIOH Senior Occupational Hygiene Consultants GCG Health Safety Hygiene

Abstract: Video Exposure Monitoring (VEM) has received renewed vigour with improvements in portability, a wider range of devices, lower cost and readily available software such as the NIOSH EVADE program. The deployment of Helmet-CAM analysis in a range of workplaces is demonstrated, applied to a variety of contaminant exposures. Additional insights from wearers and occupational hygienists reviewing the results lead to a deeper awareness of the behavioural and physical elements contributing to exposure and improved focus on the optimum means for effective control. We performed additional statistical analysis of real time data aimed at providing greater descriptive information of the results beyond simple TWA's, which permitted the investigation of changes in the pattern and intensity of exposures. These efforts combined provide greater understanding of the time varying nature of exposures, permit workers to understand the factors which contribute to their exposures and reassure employers of the effectiveness of implemented controls.

1. INTRODUCTION

The availability and range of direct reading instruments for measurement of contaminants in workplaces has increased significantly in the past 30 years. There has also been a corresponding reduction in the size and weight of instruments. These developments have enabled worker-mounted measurements to be performed unobtrusively. Unfortunately, the ready availability of data and time-history logging creates an issue: how to accurately identify the reasons for peaks during monitored periods? Even when the exact time is known, unless the hygienist is present and taking careful notes, the particular contributors to that exposure often go unnoticed. The advent of low cost portable video cameras in the 1980's then enabled researchers and workers to "see" the factors contributing to exposure and the first implementation; Picture Mix and Exposure (PIMEX), was born (Rosen and Lundström, 1987).

Following to the development of PIMEX, researchers at facilities around the world have continued to develop the technology into a range of implementations (Gressel et al., 1993, Walsh et al., 2002, Bromwich, 1995). All have the same intention: to increase the engagement of researchers, hygienists and workers in understanding the contributors to exposures and develop solutions to these items (Rosen et al., 2005). The use of video as a medium to communicate has its benefits by increasing the support from workers involved, provide a first-hand account of the activities surrounding the exposure and creating a lasting record available for others. These factors have proven to be valuable in changing attitudes to dust exposure (Haas et al., 2016). For hygienists, VEM provides us with visual clues to the reasons why an exposure occurred, it gives us something no other technique can;

> **Context** *"The circumstances that form the setting for an event, statement, or idea, and in terms of which it can be fully understood. "*

Along with the visual process the collection of large quantities of direct reading data brings its own difficulties; what does one do with all that information? Are there methods which can make use of this information to convey additional information to risk managers? Can alternative measures of exposure such as peak profiles, frequency and duration (Preller et al., 2004), sufficiently characterise the time varying nature of exposures? When dealing with continuous data such as that obtained from direct reading instruments, particularly when it is characterised by a small number of high readings, conventional statistics based on normal or lognormal distributions may be inadequate and more sophisticated statistical means such as time series analysis (Klein Entink et al., 2011, O'Shaughnessy and Cavanaugh, 2015) are required. For many real time measurements, the data can best be described as having a highly skewed distribution. This type of distribution is not unique to workplace measurements, highly skewed data exists nature as daily rainfall values, wind speed measurements and is a characteristic of many financial analyses of stock markets (Reiss and Thomas, 2007). Extreme Value Analysis is a statistical technique which derives inferences from asymptotic statistical theory to model distributions of extreme events from historical data (Coles et al., 2001). In essence, the tails of skewed distributions are selected and specific distributions are fitted to those tails. This permits calculations to be made of the probability of events at those extreme ends of the distribution.

2. METHODS

2.1 Video Exposure Monitoring Software

Since 2013, we have used NIOSH's **E**nhanced **V**ideo **A**nalysis of **D**ust **E**xposures (EVADE) software in its Beta (Reed, 2013), V1.0 (Reed et al., 2014) and V2.0 (NIOSH, 2016) updates for Helmet-CAM surveys. Whilst the software has undergone improvements and adaptions to cater for a range of input files, our work has mainly used the universal file format, where real time data is converted to a .csv file in a standard format and then imported into an EVADE project.

2.2 Respirable Dust Investigations

Respirable Dust investigations were conducted using either a TSI® AM510 or AM520 Aerosol Monitors fitted with 10 micron (µm) Dorr-Oliver cyclones. The units were configured to log in one (1) second intervals, and were within calibration, as specified by the manufacturer. The flow rate of the unit was checked and adjusted using a secondary flow calibrator to 1.7L/min, as specified by the manufacturer to best measure the respirable dust size fraction. The units were zeroed prior to use, using the supplied HEPA filter. A K-Factor of 1 was used for all investigations as only the relative concentrations were used and no site specific aerosol corrections were used.

2.3 Diesel Particulate Investigations

Diesel Particulate investigations were conducted using TSI® AM510 Aerosol Monitors fitted with 10 micron (µm) Dorr-Oliver cyclones and a 1um impactor inlet. The Dorr-Oliver cyclone was used as a pre-classifier to reduce the particle concentration entering the impactor to improve its longevity of use in the field. The units were configured as per the description in section 2.1.1.

2.4 Video Collection

Video was collected using GoPro Hero3+, Hero5 and Cube action cameras. GoPro cameras were selected for their waterproof housings and low EV range to enable video capture in low light conditions. These were either body mounted with a chest mount, or in the case of vehicle operators, mounted inside the cabin. We configured the cameras to record in high resolution (1080P), low frame rate (24fps), ISO 1600 limit and the inbuilt lowlight mode activated for use underground. Raw Video files were imported into iMovie or VLC, merged and converted into an .mp4 file before being exported for use in EVADE.

2.5 Statistical Analysis

Consistent with the approach proposed by NIOSH (Gressel et al., 1992), a 3–tiered level of statistical analysis was applied in various instances as appropriate.

Approach	**Techniques**
Descriptive	Frequency Distribution Plots; Median, 90,95,99th percentiles, Duration>OEL, 3xOEL(30min), 5xOEL, Non-parametric hypothesis testing.
Regression	Univariate Extreme Value Analysis using the Generalized Pareto Distribution (GPD), for modelling exceedances over a threshold (Pickands III, 1975).
Time-Series Analysis	A Generalised AutoRegressive Conditional Heteroskedasticity (GARCH) approach to model the volatility of exposure across time (Becketti, 2013). Conventional time series assumes a constant variance (homoskedastic), whereas in a GARCH model, periods of high and low variance are incorporated into the model.

These analyses were performed in STATA v15.1 (StataCorp, 2017) using the inbuilt statistical functions for Descriptive analyses and time-series analyses and the ssc package EXTREME for regression analysis ((Roodman, 2017).

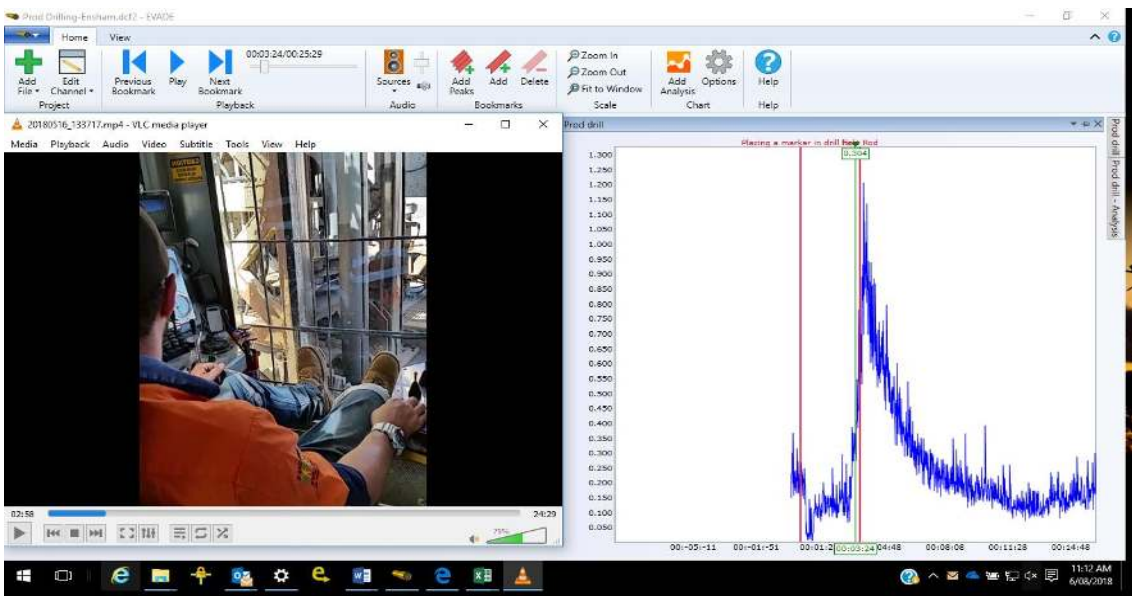
3. RESULTS

3.1 Respirable Dust

3.1.1 Open Pit Production Drilling

In this example during production drilling at an open pit coal mine, the sample was placed on worker inside cabin, with the worker spending limited time outside when placing drilled hole markers. The real time data showed an increase in dust is noticeable, but we could not determine if this was due to leakage (engineering) or door being opened by an operator (behavioral). Both the operator and supervisors were of the opinion that the cabin was not dusty, and therefore not a significant source of exposure. Data indicated that dust did enter the cabin and the reason for not appearing dusty is probably due to the fine nature of respirable dust. The context obtained from Real Time + Evade showed that exposure was mainly due to emissions during the first couple of drill rods; thereafter the dust lingered in the cab and took some time to be diluted/ removed by make-up air. There was no obvious correlation between drilling rod changes and dust generated from the 4th rod onwards. The air conditioning system (A/C) had ineffective recirculation filters, hence respirable dust concentrations in the cab did not quickly decay. Exposure from outside activities could be distinguished from exposure while sitting inside and operating the drill.

Figure 1:Production Drilling dust exposure



In this case, engineering improvements to the A/C intake, recirculation filters and pressuriser were warranted. Future control effectiveness will be monitored by means of differential pressure sensors that will verify cabin pressure is maintained.

3.1.2 Reverse Circulation (RC) Drilling

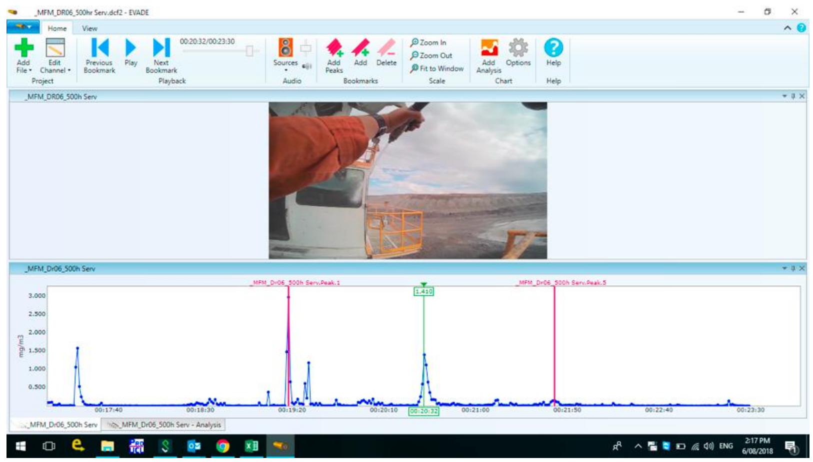
An Investigation of exploration drilling activities using a reverse circulation method revealed both engineering and behavioural contributors to exposures which would not have been obvious without the added context provided by VEM. The sample was worn within the BZ of the worker during entire time to drill and sample one hole. The data obtained from Real Time clearly identified periods of very high respirable dust exposure which is easily noted from normal observation. However, “secondary” peaks occurred when the cyclone was operating normally. Additional insight obtained from Real Time + Evade revealed the high exposures were related to periods of time when both sample valves were opened simultaneously, using air to “clear” out the cyclone. Secondary exposure sources were generated from the sampling buckets billowing dust into the breathing zone (BZ) whilst carrying samples, from tapping the base of sample buckets to remove residue and stacking empty buckets, generating a piston effect to produce dust close to the BZ.

In this case, significant contributors to exposure were from behavioural factors, in addition to some engineering fixes on the drill and cyclone.

3.1.3 Maintenance Activities

In an investigation into the contributors of exposure to field maintenance employees at an open cut mine, exposures during routine servicing were examined. The data indicated that background dust concentrations were very low, interspersed by short sharp exposures of 5-10 second in duration with a cluster of high exposures toward end of monitoring task. From visual observation some sources were from handling dusty tools or equipment but for other exposures there are no obvious sources.

Figure 2: Maintenance Dust Exposures



The EVADE analysis showed peaks were associated with the following events: Operation of small diesel powered pump – exposure to DPM not respirable dust, Hosing dust from surfaces around cabin (Figure 2) and rotating machinery, Handling dust covered equipment and dust on overhead storage compartments dislodged when opening/closing.

In this case the significant factors were due to engineering factors. Recommendations for control included; changing hose nozzles from jets to adjustable spray/jet to wet surfaces prior to washing away deposited dust and perform a wash down of the upper deck prior to commencing maintenance work.

3.2 Diesel Particulate

3.2.1 Underground Mine Truck Driver

In an investigation of the contributors of exposure to truck and loader drivers in an underground gold mine the performance of in cabin air conditioning systems and cabin integrity was examined. It was believed that doors and windows were being opened underground contributing to exposure. The real time data showed high peaks which decayed over the course of the monitoring periods. The regular peaks with decay are indicative of a sudden intake of contaminant into the cabin and progressive dilution through the AC system, supportive of the opinion that the driver is opening door / window. Also a general increase in background concentrations occurs during the middle of the monitoring period.

Figure 3: DPM Gold Mine Truck Driver

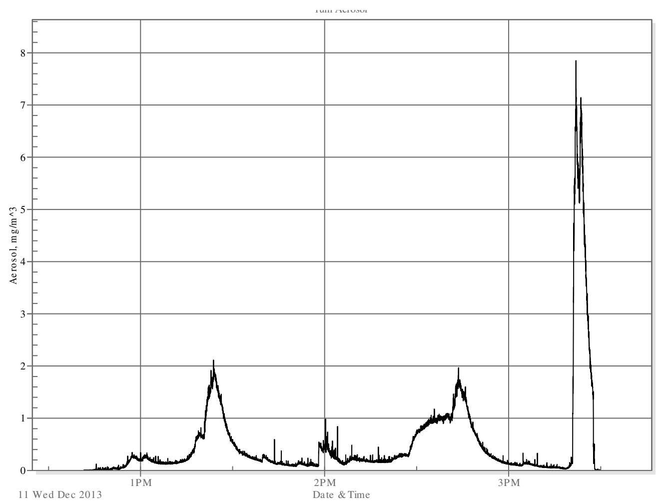
Context provided by RT + EVADE analysis showed that regular peaks were associated with 2 types of event; Reversing truck in to passing bay off decline and intake of exhaust into the A/C system, and, passing fresh air rises where high concentrations of DPM are abruptly diluted with cleaner air (Figure 3). No doors or windows were opened during the period of monitoring dispelling the opinion that driver behaviour was a contributor.

In this case, significant efforts to change the mine ventilation system as well as changing the cabin A/C filters from HEPA to MERV 16 efficiency were noted. The previously held belief that entry of contaminants into the cabin was from actions such as opening doors or windows was dismissed.

3.2.2 Caterpillar AD55 Underground Mine Truck

In an underground copper mine investigation, the measurement was obtained inside the vehicle cabin to identify effectiveness of existing cabin ventilation. The real time data showed 2 periods of increased exposure (Figure 4). The vehicle completed 2 runs from the surface to underground; the increase in exposures are related to time spent U/G. However, toward the very end of the monitoring period an exposure up to 7.8mg/m^3 was noted.

Figure 4: Copper mine DPM



Context obtained from Real Time + Evade showed in the 2 periods of increased exposure the shoulder of the 2 main peaks is related to trucks idling and waiting to be loaded, the peak occurs when being loaded (idling + increased DPM in proximity to loader). The extreme peak occurred as the truck was heading out of the mine toward the portal with no obvious cause; the video does not show any behaviours by the driver such as smoking, but following review of the video and investigation it was found the truck directly ahead on decline experienced transmission/engine failure just before the portal exit resulting a short, intense release of fine particles.

3.3 Statistical Analysis

An example of the statistical treatment of Real time respirable dust data from the RC drilling investigation is described. Two different drilling rigs were examined with different crews. The mineralogical make-up of the area was similar; however, one rig was fitted with dust control equipment (Rig 5).

3.3.1 Descriptive Analysis

Table 1: Descriptive Statistics for Rig 3 & 5 Tasks

TASK	n	Median (mg/m^3)	90th%ile (mg/m^3)	95th%ile (mg/m^3)	99th%ile (mg/m^3)	Max (mg/m^3)	t>OEL (s)	3x OEL (30min)	5x OEL?
Rig #3 Offsider	1065	0.111	1.027	3.035	17.467	19.000	55	N*	Y
Rig #3 Offsider	1299	0.072	1.367	4.851	19.000	19.136	87	Y*	Y
Rig #3 Offsider	2576	0.112	0.775	1.435	4.908	18.382	49	N*	Y
Rig# 5 Offsider	2051	0.028	0.261	0.7	3.995	19.907	27	N*	Y
Rig#5 Offsider	2739	0.03	0.103	0.189	0.806	6.428	5	N*	N

* Assuming 10 holes / day

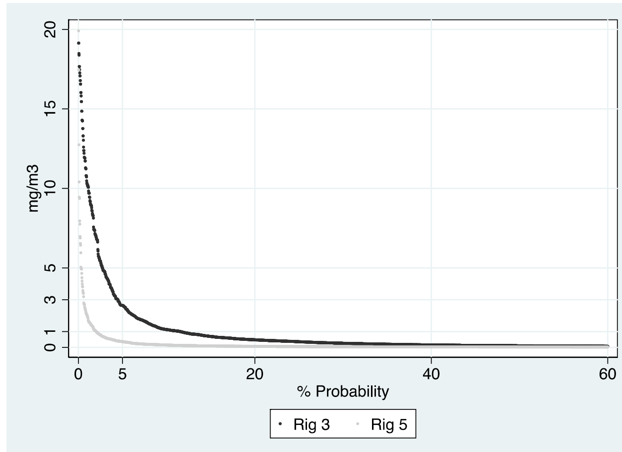
Table 1 contains a descriptive comparison of five task based samples listing measures of the distribution and rudimentary examination of excursion limit compliance. A comparison shows the medians of Rig 5 to be lower than Rig 3, with 90 and 95th%iles also lower. The sample durations >OEL are also lower, lending support to a supposition that Rig 5 exposures are likely to be lower than Rig 3.

A formal comparison of all the data points from each rig using the non-parametric equality of median test (Mood's test) (Mood, 1954) of both data sets revealed a significant difference between the two rigs ($p<0.01$). Mood's test is robust to outliers with no assumptions about the distribution as long as the shape of the distribution of both data sets are similar, in this case all assumptions hold and is an appropriate test for this application.

3.3.2 Extreme Value Analysis

Fitting the data from each group to a probability distribution revealed a pattern similar to Figure 5 where the likelihood of an exposure to concentrations greater than a threshold concentration of, for example, 3mg/m^3 is considerably greater in Rig 3 (darker points) than Rig 5 (lighter points). This was also indicated by the shape factor (xi, ξ) for each distribution (Rig 3 = 1.07, Rig 5 = 0.54) indicating the tail of Rig 3 being much heavier or containing larger values, than Rig 5.

Figure 5: Probability Distributions Rig 3 and Rig 5

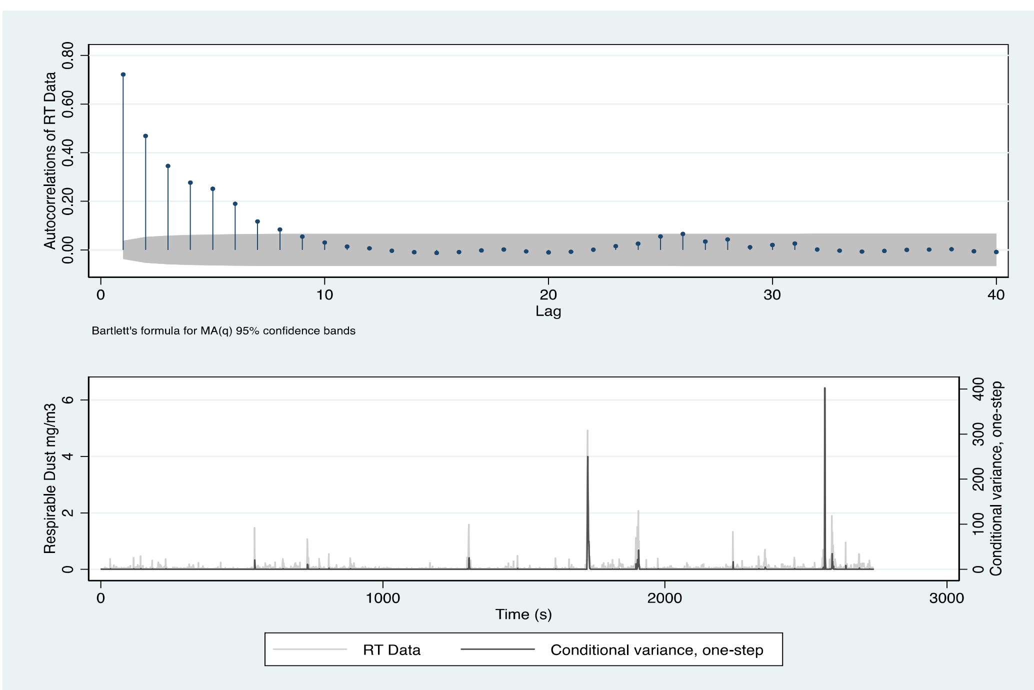


3.3.3 Time-Series Analysis

The autocorrelation analysis in the upper graph of Figure 6 shows the effect of prior measurements on subsequent readings, where up to 5 seconds of lag is strongly correlated. In order to remove this serial dependence on the previous readings data the GARCH model variances were predicted for the time series.

The GARCH model of the real time data provided additional insights into the periods during the sample time where increased variance in the time-series data was present and the effects of autocorrelation were minimised. In simple terms it permits the significant events in the time series to stand out from the noise. The solid line in the lower graph of Figure 6 shows when periods of high variance are encountered indicating periods of unstable concentrations. Matched with the video data in EVADE the significant events are easy to identify.

Figure 6: GARCH Model Autocorrelation and Variance



3. CONCLUSIONS

Whilst VEM has been in the toolkit for 30 years, developments in portable video imaging and smaller more capable real time instruments have extended our ability to understand the factors contributing to exposure in a way previously only accessible by limited means. In instances described within, the insights provided by VEM have challenged strongly held views on the contributors of exposure, whilst for others, previously unknown conditions have shown themselves to be noteworthy. With the ready availability of statistical tools, the data collected during real time measurement should no longer be reduced to simple measures, it can be examined to shed light on the likelihood of exceedances above a threshold and give risk managers meaningful probabilistic data from which to make decisions (Waters et al., 2015). Complex data sets can be examined to filter out noise from autocorrelation and allow users to see the trees from the forest. Whilst VEM can generate high levels of engagement with workers, its contribution to increasing the understanding and skills of occupational hygienists is also important (Rosén and Andersson, 2002). It should become a mainstay of investigative tools for those wishing to improve the workplace into the future as technology becomes available.

4. ACKNOWLEDGEMENT

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ASSESSMENT OF WORK PRACTICES AND EXPOSURE TO PERCHLOROETHYLENE IN SMALL DRY-CLEANING WORKPLACES IN SYDNEY NSW.

Bhoopathy Sankaran
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Perchloroethylene (PERC) is most commonly used in the dry-cleaning industry. PERC is classified by IARC as a possible carcinogen (Group 2) associated with bladder cancer, non-Hodgkin lymphoma, and multiple myeloma. PERC can be easily absorbed by inhalation, through the skin or by ingestion.

Twelve small dry cleaning workplaces in Sydney were investigated. Walk-through observational evaluations of exposure controls, work practices, worker knowledge, instruction, training, equipment maintenance regimes and personal protective equipment (PPE) were conducted. The assessment included personal air monitoring and biological monitoring of exposure to PERC of 34 workers on the first, third and the fifth day of their work week.

Personal air sampling was compared to the Safe Work Australia, Workplace Exposure Standard, 8-hour Time Weighted Average (TWA) for PERC of 50 ppm. The workplaces recorded PERC air concentrations of between 0.075 to 6.21 ppm with a Geometric mean
(GM) of 1.05 ppm. This is significantly below the TWA and gave a student *t*-test *p* value << 0.05. The test results of urine analyses were also assessed for exposure to PERC by comparison to the Biological Occupational Exposure Limit (BOEL) of SafeWork NSW of 0.02 mmol TCA/L and showed no significant difference between pre-shift and post-shift urine test results with a GM of 0.001 mmol/L across the time-period of the assessment. Work practices were also assessed and recommendations were provided to ensure the general health and safety of the dry-cleaning workers.

MANAGING WORKERS EXPOSURE TO EMERGING CONTAMINANTS IN ENVIRONMENTAL INVESTIGATION AND REMEDIATION PROGRAMS

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Abstract: There are many interesting challenges when working at contaminated sites, with complex ground conditions and competing stakeholder interests, but fundamentally when on site undertaking the work, the safety of our workers and those around us is our top priority. Our investigation and remediation staff and subcontractors regularly work on sites with environmental contaminants, and one aspect of managing their health and safety is a need to understand and manage potential exposures to these contaminants. The health risks and exposure management procedures for some contaminants maybe complex but are well understood, but some such as newly emerging or unique contaminants can present challenges due to limited information. The investigation and remediation of emerging and unique contaminants present special challenges with respect to identifying and understanding the hazards prior to work commencing, and the development of management programs on site to address health risks to workers. However, the basic approach and principles behind the management of potential exposures to contamination remain the same regardless of the complexity and the level of real or perceived health risk. This paper explores the approach taken to understand and manage contaminant exposure via a case study of per-and polyfluorinated alkyl substances (PFAS).

1. CONTAMINANTS IN THE ENVIRONMENT

Investigation and remediation of contaminated land is generally undertaken to make the site fit for purpose for its current or future use in terms of impacts to human health due to the occupants potential exposure to chemicals in the environment. The assessment of health risks and development of clean up or remediation strategies are typically focused on understanding and mitigating chronic health effects; however, acute (or sub chronic) chemical risks to workers during the investigation and remediation stage must also be managed.

There are some key differences in assessing and managing worker exposures to contaminants in the environment when compared to other occupational settings. The most significant of these are the limited information about the presence and nature of the contamination and the relatively uncontrolled nature of the exposure. Preparation for our work requires collation of as much information as we can about the possible type of contaminants, the likely location and concentration and an assessment of the potential pathways of exposure. These will each inform the specific heath and safety measures adopted, however given the significant uncertainty and potential for unexpected finds, the process and procedures to assess the risk remain relatively the same for the range of remediation projects.

An additional factor to consider is the public perception of risk from the likely contaminants. Some issues have been raised in the media and the is a broader public awareness of the potential health risks. This may prompt particular concern from stakeholders, including the client or subcontractors or members of the public, about their individual health risk. Whilst we need to be acutely aware and consider these concerns, the process to assess risk and develop the Health, and Safety, Security and Environment Plan appropriate to the risk largely remain the same as for any other less high profile project.

2. PER AND POLY FLUOROALKYL SUBSTANCES (PFAS)

PFAS are a group of manufactured chemicals that have been used since the 1950s, and due to their unique attributes to make products resist heat, stains, grease and water, they have been used widely in consumer products such as carpets and textiles, food packaging and plastics and also in aqueous film forming foams (AFFF). There is world wide interest in these compounds due to their wide spread use, persistence in the environment and the potential for PFAS to bioaccumulate in the food chain (EPA, 2018).

Due to increased regulatory and public interest, PFAS compounds are more regularly being tested in, and found in, soil and water (both surface water and groundwater) at brownfields redevelopment sites. Where encountered, PFAS exposures to workers need to be assessed and managed appropriately, particularly in instances where investigation and remediation or redevelopment works will include movement of significant quantities of soil or worker exposure to contaminated water. The recent publicity about potential PFAS exposures in workers who used PFAS compounds in the past, particularly AFFF, and in communities living in areas near facilities that used PFAS. Consequently, contractors and their employees were particularly concerned abut the potential health risks, above and beyond those regularly managed as part of a typical remediation or redevelopment project.

As noted in the PFAS National Environmental Management Plan (HEPA, 2018), "clear and consistent communication is vital to increasing the community's understanding of the PFAS issue". This is complicated however by the seemingly conflicting messages received by communities affected by PFAS and the significant media exposure for this particular contaminant.

We note that the science on PFAS and health effects is currently inconclusive. In May 2018, the Australian Department of Health Expert Health Panel for Per- and Poly-Fluoroalkyl Substances (PFAS) released their report to the Minister. The panel's key finding as highlighted in their summary report was as follows:

> *"The Panel concluded there is mostly limited or no evidence for any link with human disease from these observed differences. Importantly, there is no current evidence that supports a large impact on a person's health as a result of high levels of PFAS exposure. However, the Panel noted that even though the evidence for PFAS exposure and links to health effects is very weak and inconsistent, important health effects for individuals exposed to PFAS cannot be ruled out based on the current evidence."*

Regardless of the above, there is a need for health and safety procedure to respond to worker perception of health impacts from PFAS exposure. As with all works on contaminated land, a Health and Safety Plan needs to be developed to document the known information regrading contamination at the site and recommended appropriate management procedures to minimise exposure. The Health and Safety Plan needs to be clearly communicated to all workers on the site, including straight forward information about the nature and extent of contamination to provide context for the required management measures.

A site specific health risk assessment can be used to establish the soil and water concentrations above which specific management of worker exposure to PFAS is required. As a result, the majority of the works maybe deemed not to require specific measures, and standard hygiene, including the wearing of gloves during works involving soil and groundwater and the washing of hands prior to eating maybe sufficient to mange the potential exposure risks.

In areas of the site with higher concentrations or where for example groundwater was to be intersected, additional controls maybe recommended to mange possible incidental ingestion of soil or groundwater. These included additional personal protective equipment such as:

- Use of water-proof disposable nitrile gloves
- Use of P2 dust masks

As well as personal hygiene controls, including the provision of adequate washing facilities near the works area to enable:

- Washing of hands and face prior to eating, even if gloves are worn
- Cleaning of contaminated clothes on a daily basis, preferably on site (contaminated clothing not to leave site)

No further monitoring, such as air monitoring, is routinely recommended as this generally does not represent a significant exposure pathway. Given the chemical properties of PFAS, the likelihood of vapours being generated is low. Although dust inhalation is considered to present negligible exposure risks in comparison to the incidental ingestion of soil or water, where works are likely to generate significant dust, standard dust suppression (not using PFAS impacted water) and monitoring would be appropriate.

Although worker concern regarding exposure risk maybe high due to wider community publicity about PFAS contamination, the recommended management measures are relatively familiar and are typically recommended for any earthworks were contamination may be present in soil or groundwater. The measures are relatively straight forward to implement and easily understood by the workers. Despite the unknows regarding nature and extent of the contamination, or the potential health effects, based upon the current scientific knowledge about the toxicity and behaviours of PFAS compounds, the management of the incidental ingestion exposure pathway is considered sufficient to manage risk to an acceptable level. Our experience is that given the heightened concerns that exist regarding the potential impacts of exposure to PFAS there is an increasing need to provide clear information to workers on the potential risks and how they should be appropriately managed.

4. CONCLUSIONS

Workers at contaminated sites are in a workplace where there is often limited information about the presence and nature of the contamination. The case studies presented highlight the range of approaches from a highly managed and monitored process for the chemical warfare agents, to a relatively simple and easily implemented approach for PFAS. Both address the health risks and potential exposures and the measures recommended and adopted commensurate with the level of risk presented by exposure to the contamination.

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Linking Diesel Maintenance Personnel with Occupational Hygienists to Improve Worker Health

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Diesel maintenance personnel are responsible for the repair and maintenance of diesel engines. They detect faults and damage in diesel engines. They measure parts to ascertain the extent of the damage and wear and tear and then repair or replace the parts. Much of the work requires meticulous adherence to standards and specifications. This type of job description makes them a perfect candidate to understand their engine even more intimately and actively maintain them with the wider goal of reducing exposure to workers.

There are ongoing developments within the Mining Industry for the ability to measure diesel engine exhaust, and to interpret the results from the workshop at the time of measurement, allowing immediate improvements to the atmosphere the workers breathe. One term used for this process is Emissions Based Maintenance (EBM).

This presentation will go into detailed findings of a site based, practical PhD where EBM was implemented at one site, compared to another site where no additional maintenance was conducted. It will cover material on how this was achieved, the outcomes and productivity gains as well as how it can be done elsewhere while reducing the pain of pitfalls. It will cover surprises found along the way and inform the audience of the real value of implementing EBM and working with fitters to achieve the results.

ASSESSMENT OF WORKER EXPOSURE TO OCCUPATIONAL ORGANIC DUST IN HEMP PROCESSING FACILITY

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ABSTRACT
The cultivation and processing of industrial hemp, *Cannabis sativa* L., is a developing industry in Australia. Exposure to hemp dust is demonstrated as producing reactive and respiratory health effects, potentially causing permanent lung disease/damage. The aim of this study was to assess the average airborne organic dust concentrations generated in an Australian hemp processing facility. Personal sampling, in the breathing zone of exposed workers for respirable dust, and parallel static sampling for airborne concentrations of inhalable and respirable dust fractions were measured. Static sampling showed respirable dust concentrations (mg/m^3) (M = 1.33) (range 0.07 – 3.67), dusts exceeded the maximum level of the recommended Australian Institute of Occupational Hygienists (AIOH) applicable allowable concentration of 1mg/m^3 (respirable fraction) for dusts not otherwise specified. In addition, t-tests ($p < 0.05$) confirmed that there is no statistically significant difference between mean airborne concentrations between size fractions throughout the facility, nor in each of sampled processing areas. The analysis of results from personal respirable sampling (M = 4.49, SD = 4.49) (range 0.77 - 11.08 mg/m^3), showed exposed workers greatly exceed the AIOH recommended OEL of 1 mg/m^3 (respirable fraction) for dusts not otherwise specified. Workers in this industry are at risk of developing permanent and disabling respiratory disease due to high hemp dust exposure. There is no Australian OEL for hemp dust. It is recommended further research is needed and industry specific guidance material or model code of practice developed to effectively control exposures.

KEYWORDS: hemp, dust, occupational health, byssinosis, lung disease

INTRODUCTION

Cannabis sativa L., commonly referred to as industrial hemp, has been cultivated, processed and utilised for many millennia (Abel, 1980). The difference between industrial hemp and other varieties of hemp plants is they are bred to have negligible quantities of tetrahydrocannabinol (THC) (Small, & Marcus, 2003). In the majority of the western world, industrial hemp has a THC content that must not exceed 0.3% (Small, & Marcus, 2003). Thus, this means that these plants do not typically elicit the psychoactive response in the general population, as other species of cannabis (Small, & Marcus, 2003).

Sir Joseph Banks introduced cannabis to Australia by sending the plants on the First Fleet (State Library New South Wales, 2016). This was with the view of cultivating enough hemp to manufacture rope for the British Navy (State Library New South Wales, 2016). Nowadays, hemp has various and diverse uses including but not limited to fibre, body care products, biofuel, therapeutic goods, medicine, livestock bedding and building and paper products.

In recent years, industrial hemp has been experiencing a resurgence and has become a developing industry in Australia. As of November 2017, new legislation was enacted in Australia allowing hemp to be grown and sold as a nutritional supplement (Hendy, 2018). Due to the introduction of these new laws the Australian hemp industry is expected to experience significant growth (Hendy, 2018). However, hemp dust is associated with respiratory response, illness and/or disease in exposed textile and rope worker populations (Barbero & Flores, 1967; Vali , Ž kin, Walford, Ker ić, & Pauković, 1968; Bouhuys, Barbero, Schilling, & Van de Woestijne, 1969).

Throughout all stages of hemp processing potentially harmful dust particles are released from the plants into the ambient air, which when inhaled, may lead to debilitating respiratory disease (Vali et al., 1968). Organic dusts in the agricultural industry are biologically active mixtures that frequently contain plant cell fragments, insect/mite parts, fungal spores, actinomycetes and bacteria and their constituents such as endotoxins and mycotoxins (Fishwick, Allan, Wright, & Curran, 2001). The association between respiratory illness and occupational exposure to organic dust, including hemp dust, was initially observed and documented in the early 18th century by the father of occupational medicine, Bernardino Ramazzini (Er et al., 2016). Subsequently, both acute and chronic exposures to airborne hemp dust have been further clinically demonstrated as causing detrimental respiratory health effects in workers (Vali & u kin, 1972; Valić et l., 1968).

Following a single shift workers exposed to high hemp dust concentrations may experience a significant reduction in forced expiratory volume (FEV) and forced vital capacity (FVC) (Valić et al., 1968). Additionally, exposures may elicit airway inflammatory response and/or disease including but not limited to hypersensitivity pneumonitis, mucous membrane irritation, occupational, allergic and non-allergic asthma, organic dust toxic syndrome (ODTS), emphysema, bronchitis, chronic obstructive pulmonary disease (COPD) and byssinosis, colloquially referred to as 'Monday fever' or 'brown lung disease' (Valić et al., 1968; Health and Safety Executive [HSE], 2018; Decuyper et al., 2017; Mapp, 2001).

Byssinosis was the first recorded example of occupational COPD (Baxter & Hunter, 2000). It is characterised by symptoms of cough, dyspnoea and chest tightness with onset occurring upon entry into an environment where hemp, or other vegetable fibres, are present (Altin, Ozkurt, Fisekçi, Cimrin, Zencir, & Sevinc, 2002). Initially, symptoms dissipate overnight, reducing on subsequent days; by week's end workers are generally asymptomatic (Schilling, Hughes, Dingwall-Fordyce, & Gilson, 1955). Following approximately 48 hours absence from an environment where hemp dust is present symptoms typically return upon re-exposure (Altin, 2002).

It was not until the mid-twentieth century when epidemiological studies began to concentrate on byssinotic symptoms in hemp worker populations (Barbero & Flores, 1967; Vali et al., 1968). Valic and Zuskin (1972) compared the prevalence of byssinotic symptoms in natural fibre textile workers and discovered hemp workers had a greater prevalence of byssinosis than cotton workers (44% and 27% respectively). Exposure to hemp dust is considered more potent in producing acute and chronic respiratory symptoms, potentially leading to permanent lung damage, than cotton dust (Ž kin Kanceljak, Pokrajac, Schachter, & Witek, 1990). However, the majority of these early studies reported on the inhalable fraction of dust concentrations with the respiratory fraction largely ignored (Vali et al., 1968; Ž kin et al., 1990; Er et al., 2016). With the introduction of modern machinery and equipment in processing facilities the field of occupational hygiene has largely neglected worker exposure to hemp dust in recent decades (Davidson, Reed, Gardner, & Dennis, 2018; Davidson et al., In Press).

As the hemp industry is still in its infancy in Australia no studies on worker exposure to hemp dust have previously been published; average airborne concentrations still remain unknown in the hemp processing industry in this country. Moreover, there is no hemp specific guidance material for the industry to follow regarding acceptable worker exposure levels other than Safe Work Australia's (SWA's) 8-hour time weighed average (TWA) of 0.2 milligrams per cubic metre (mg/m^3) for raw cotton dust based on static sampling of thoracic fraction with vertical elutriator, or the Australian Institute of Occupational Hygienists (AIOH) dusts not otherwise specified recommended TWA of 5 mg/m^3 (inhalable fraction) and 1mg/m^3 (respirable fraction) exposure standard (Safe Work Australia [SWA], 2013; Australian Institute of Occupational Hygienists [AIOH], 2016). With the hemp industry gaining momentum, the potential for the incidence and prevalence of hemp induced occupational illness also increases.

The aim of this study was to establish typical airborne concentrations of organic dusts in a modern day hemp processing facility in Australia. In particular, this study aimed to determine the concentrations of both inhalable (equivalent aerodynamic diameter [EAD] of 100 micrometres (µm) or less) and respirable (10 µm or less with a median cut point of 4.0 µm) (AIOH, 2016) organic dusts present in hemp facilities during normal operations. Personal sampling was used to assess respirable dust size fractions and parallel static sampling was used to assess both inhalable and respirable dust size fractions.

METHODOLOGY

The hemp facility and process

The selected hemp processing facility was located in regional Victoria, Australia. This facility manufactures hemp building products, such as, particleboard. The majority of previous studies conducted on hemp dust generation were concentrated in the textile industry. The interior layout of operations was open plan with equipment and machinery placement representing the processing areas. Six areas of the facility were characterised as follows:

- dry hemp stalk storage;
- course hurd storage;
- fine hurd storage;
- decorticator fibre stripping;

- hurd sieving (of both course and fine hurd to remove dirt and debris), and;
- hammer mill operations to crush the course hurd to fine.

Of importance is the hemp processing facility was not fully operational during sampling. On the third day, all operations were shut down as the decorticator was undergoing maintenance during the sampling period.

Personal and static sampling

Airborne dust sampling was undertaken for approximately two to four hours over four non-consecutive days, to allow for separation of tasks. Individual breathing zone concentrations of respirable dust were measured in two (n = 2) hemp processing workers. Parallel static sampling occurred in the following process areas:

- dry hemp bale storage area;
- hurd sieving processing area;
- course hurd storage area, and;
- feed entry of hammer mill.

Sampling trains consisted of SKC Airchek 52 and SKC Airchek XR5000 flow pump units. Samples were collected on equilibrated pre-weighed GLA5000 25 millimetres (mm) diameter filters with a pore size of 5 µm. SKC conductive plastic cyclones, with pump flow rate set to 2.2 litre per minute (L/m) ± 0.2 L/min, and SKC conductive plastic Institute of Occupational Medicine (IOM) sampling heads, with pump flow rate set to 2.0 litre per minute (L/m) ± 0.2 L/min, were used for sample collection.

All sampling, conditioning of filters and pre- and post-weighing was undertaken according to Australian Standards *AS 2985:2009* Workplace atmospheres - Method for sampling and gravimetric determination of respirable dust and *AS 3640:2009* Workplace atmospheres - Method for sampling and gravimetric determination of inhalable dust.

Statistical analysis

For static sampling results, the assumption of normality was made by conducting the Shapiro-Wilks test with Levene's test used to determine the assumption of homogeneity of variance. Concentration measurements were then analysed with an independent t-test, two sample assuming equal variance, to determine whether there was any statistically significant difference in total inhalable airborne organic dust concentrations compared to total respirable airborne organic dust concentrations present throughout the processing facility. Multiple independent t-tests, adjusting the alpha value ($p = 0.0125$) using the Bonferroni correction factor to reduce type I errors, were also used to determine whether there were any statistically significant differences between inhalable and respirable airborne dust concentrations in each of the four sampled processing areas. All the t-tests used an alpha equal to 0.05 ($p < 0.05$) as criterion for significance. Personal sampling of respirable hemp dust results were analysed using the American Industrial Hygiene Association (AIHA) IHSTAT+ (v. 235) exposure assessment software to determine whether there are any current or potential over-exposures regarding the applicable exposure standards.

RESULTS

Personal sampling for respirable organic dust levels

The concentrations for personal respirable organic sampling were analysed using IHSTAT+ (v. 235) exposure assessment software using both the occupational exposure levels (OEL) of AIOH's dusts not otherwise specified recommended TWA of 1 mg/m^3 (respirable fraction) and the SWA's TWA of 0.2 mg/m^3 for raw cotton dust.

The summary of the personal organic dust concentrations (mg/m^3) for the respirable size fraction are shown in Table 1.

Table 1: Summary of respirable organic dust concentrations using personal samplers

Personal Respirable Dust Concentration (mg/m^3)	
Mean	4.49
Number of Samples	5
Median	4.05
Standard Deviation	4.49
Minimum	0.77
Maximum	11.80
Geometric Mean	2.78
Geometric Standard Deviation	3.21
Lognormal 95% Percentile	18.90

The analyses identified personal respirable sampling results (M = 4.49, SD = 4.49) (range 0.77 - 11.08 mg/m^3), using the OEL of 1 mg/m^3, are presently 60% above the OEL. The lognormally distributed statistics showed approximately 81% of exposed process workers will exceed the OEL with a 95% percentile of 18.9 which also exceeds the OEL. The data analysis showed 100% of the hemp process workers exceeded the OEL of 0.2 mg/m^3 for raw cotton dust, as stipulated by SWA, based on the thoracic fraction.

General static inhalable and respirable concentrations

The mean concentration of the total hemp dust generated was 2.02 (range 0.07 - 11.15) mg/m^3 with a mean inhalable fraction of 2.72 (range 0.26 - 11.15) mg/m^3 and a mean respirable fraction of 1.33 (range 0.07 – 3.67) mg/m^3.

The summary of the airborne organic dust concentrations (mg/m^3) for inhalable and respirable size fractions are shown in Table 2.

Table 2: Summary of airborne organic dust concentrations using static samplers

	Static Inhalable Airborne Conc. (mg/m^3)	Static Respirable Airborne Conc. (mg/m^3)
Mean	2.72	1.33
Number of Samples	13	13
Median	2.09	0.91
Standard Deviation	2.93	1.09
Minimum	0.26	0.07
Maximum	11.15	3.67
Geometric Mean	1.66	0.88
Geometric Standard Deviation	2.98	2.94
Lognormal 95th Percentile	9.98	5.19

It is assumed the two size fractions had homogeneity of variance and the Levene's test did not violate this assumption by returning a non-significant result ($p = 0.09$). The assumption of normality was made by conducting the Shapiro-Wilks test; however, the static inhalable size fraction ($p = 0.003$), violated this assumption. Therefore, an independent t-test was conducted. Results from the t-test confirmed that there is no statistically significant difference between mean airborne concentrations of inhalable (M = 2.72, SD = 2.93) and respirable (M = 1.33, SD = 1.09) dust fractions $t(24) = 1.61$, $p = 0.12$, 95% CI [1.15, 2.90] in the sampled hemp processing facility.

Inhalable and respirable concentrations per processing areas

A comparison was made between the two size fractions in four different processing areas of the facility with concentrations shown in table 3.

Table 3: Comparison summary of inhalable and respirable dust concentrations by processing area

Processing area	Sampling time (min)	Inhalable dust (mg/m^3)	Respirable dust (mg/m^3)
Coarse hurd storage area	230	2.35	1.44
	250	2.74	0.47
Dried hemp hurd sieve processing area	158	3.31	3.67
	159	2.09	
	224	5.02	2.98
	247	0.88	0.39
Dry hemp bale storage area	140		0.59
	144	11.15	1.81
	160	4.01	1.49
	228	0.34	0.89
	257	0.26	0.07
Entry feed of hammer mill	153	1.57	2.15
	222	1.04	0.91
	243	0.56	0.36
Mean		2.72	1.33
Median		2.09	0.91
Geometric Mean		1.66	0.88

It is assumed both the inhalable and respirable dust levels for all four processing areas had homogeneity of variance and the Levene's test did not violate this assumption by returning non-significant results of ($p = 0.10$) and ($p = 0.14$) respectively. The assumption of normality was made by conducting the Shapiro-Wilks test with all except the course hurd storage area, due to an insufficient number of viable samples, not violating this assumption. To determine whether there is a difference between inhalable and respirable dust concentrations in each processing area multiple independent t-tests were completed, adjusting the alpha value ($p = 0.0125$) using the Bonferroni correction factor. Results from t-tests confirmed there was no statistically significant difference between inhalable and respirable dust size fraction concentrations in each of the four hemp processing areas.

DISCUSSION

This small preliminary study has demonstrated that workers in hemp processing have the potential to be exposed to high levels of inhalable and respirable organic dusts. Personal sampling, for respirable dusts, demonstrated a mean concentration of 4.49 mg/m^3 (range 0.77 - 11.08 mg/m^3). These measurements are greater than the maximum level of the applicable allowable concentrations of 0.2 mg/m^3 and 1mg/m^3 for respirable raw cotton dust and dusts not otherwise specified, respectively. Previous studies by Zuskin et al. (1990) and Fishwick et al. (2001) also showed high levels of organic dust exposures in hemp processing facilities overseas. Additionally, the study by Zuskin et al. (1990), identified that there was a high prevalence of byssinosis, up to 66.7%, discovered in the hemp workers surveyed. These workers also had a statistically significant reduction in ventilatory capacity across a single working shift (Zuskin et al. 1990).

Inhalable dust static measurements showed a mean concentration of 2.72 mg/m^3 with a range of 0.26 - 11.15 mg/m^3. The mean concentration for inhalable dusts was in excess of the 50% action level of 5 mg/m^3 (inhalable) for dusts not otherwise specified, as recommended by the AIOH. Furthermore, the maximum level recorded was approximately 200% of the recommended OEL. Static measurements for the respirable fraction of organic dusts had a mean concentration of 1.33 mg/m^3 with a range of 0.07 – 3.67 mg/m^3. These measurements identified mean concentrations were above the 1mg/m^3 OEL, as recommended by the AIOH, with the maximum level recorded more than 350% of the OEL.

In addition, an applicable exposure standard, as stipulated by SWA, of 0.2 mg/m^3 for raw cotton dust was greatly exceeded for both the inhalable and respirable dust fractions. This study also showed there was no statistically significant difference between the concentrations of inhalable and respirable dust particles both overall and in each in the four sampled processing areas.

Although this study had a limited sampling strategy, when the processing facility was not fully operational and measurements should be considered an underestimation of typical exposures, it does provide a quantified indication of organic dust exposures in the Australian hemp industry where no measurements had been undertaken previously. At full operating capacity, workers have the potential to be exposed to much greater concentrations of hemp dust. Chronic exposure to hemp dust has the potential to cause permanent and disabling lung dysfunction in a relatively short period of time. Hence, it is shown workers in the Australian hemp industry are at considerable risk of suffering deleterious respiratory health effects from high exposure to hemp dust.

CONCLUSION

Industrial hemp processing is an emergent industry in Australia. With the enactment of new legislation, allowing hemp to be grown and sold as a nutritional supplement, the industry is expected to experience significant growth. High exposures to organic dust in hemp processing has been demonstrated to cause acute and chronic respiratory disease in workers. This study, undertaken in a typical small hemp processing facility, established that workers in this industry are at risk of developing permanent and disabling respiratory disease due to high hemp dust exposure. Presently, there is no Australian OEL for hemp dust nor any specific guidance material for industry leaders to follow. Thus, it is recommended further research is needed, in all hemp based industries, and industry specific guidance material or model code of practice devised and promulgated, in relationship with industry, to provide awareness on hemp dust health effects and to effectively control exposures.

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PREVENTING SILICOSIS: EXPOSURE MONITORING, HEALTH SURVEILLANCE AND HAZARD COMMUNICATION ON RESPIRABLE CRYSTALLINE SILICA AMONG ENGINEERED STONE WORKERS

Mahinda Seneviratne

Introduction Exposure to respirable crystalline silica (RCS) causes the serious lung disease silicosis among many workers globally. There was renewed attention to silicosis when new cases were reported among workers involved in the use of engineered stone in bench top manufacturing.

Methods A regulatory verification program was conducted in the State of New South Wales in Australia to investigate exposure of stone workers to RCS, compliance with health surveillance requirements and to improve communication of the health hazards of RCS to poorly informed workers. Airborne RCS exposures were measured in the workers' breathing zones using cyclone sampling heads for particle size selection. X-ray diffraction (XRD) analysis was performed to assess the silica content of the respirable dust. Compliance with national Work Health and Safety Regulations on health monitoring for RCS exposure, which include annual chest x-rays, were verified at each workplace. Hazard information was developed in consultation with workers and small group education conducted to improve their awareness and knowledge on silica hazards.Result The Australian Workplace Exposure Standard (WES) of 0.1 mg/m3 for RCS was exceeded in many personal air samples. Workers who had worked in the industry for many years had not undergone a complete health monitoring including chest x-ray and spirometry.

Discussion The WES for RCS is being reviewed and lowered to 0.025 mg/m3 in some countries whilst some industries raise concerns on whether they can practicably achieve this limit. The reliance on chest x-rays and spirometry in the early detection of silicosis has also been queried by numerous case studies and by the Australian inquiry into coal worker pneumoconiosis. We report our findings and explore whether technological changes result in high RCS exposures and a re-emergence of silicosis among poorly informed workforces. Developing professional collaboration among different disciplines to prevent this deadly disease will be discussed.

DEVELOPMENT OF A HEARING PROTECTION FIT TESTING PROGRAM

Fouad Rizk

Noise is a significant health hazard to personnel at work. Hearing protection devices (HPD) are routinely used to protect workers from harmful levels of noise exposure. The level of protection each individual will receive from the same HPD will vary depending on a few factors such as size and shape of ear canal, fitting technique and training. Prolonged exposure to noise can lead to progressive hearing loss and deafness. How can the level of protection achieved by a HPD be tested? How can confidence in the Hearing Conservation Program (HCP) be achieved, particularly in the selection and use of HPDs and training in their correct fitting?

In order to address these issues, the Occupational Health team at Esso Australia launched Hearing Protection Fit Testing, a collaborative team initiative that compliments the organisation's HCP. The program provides a mechanism to identify workers at risk for developing noise-induced hearing loss (NIHL), train workers on proper selection and fit of HPDs and motivate workers to obtain the proper fit by providing individual performance metrics.

Since the launch of the program, 513 employees underwent hearing protection fit testing within Australia. A total of 2165 tests were completed. Of all earplug tests, the failure rate was 35%. In contrast, the failure rate for earmuffs was only 2%. Moreover, 74% and 98% of workers passed the test from the first attempt for earplugs and earmuffs, respectively. Hearing protection fit testing can improve an organisation's HCP by identifying at-risk workers and tailoring a fit-for-purpose hearing protection training.

INVESTIGATION OF WHOLE-BODY VIBRATION EXPOSURE LEVELS IN DOZER OPERATORS WORKING AT A SURFACE COAL MINING OPERATION.

Roseanne Baxter

Dozer operation at surface mining operations has traditionally been considered one of the higher risk tasks undertaken in the surface coal mining industry due to exposure to significant levels of whole-body vibration. As per Australian Standard AS2760.1, SafeWork Australia promotes the practice of regular monitoring of whole-body vibration levels and encourages employers to minimise workers' exposure levels to below levels associated with increased risk of health affects. Although not legally binding, these limits are considered benchmarks in industry monitoring reports.

Recent published Australian research has shown a large spread of exposure levels, some of which exceeded recognised limits for likely health effects. A research project has been undertaken to gather whole-body vibration data matched to video and operator survey to investigate which tasks and in what ground conditions are dozer operators at a surface mining operation exposed to the higher levels of whole-body vibration.This provides rationale for prioritisation of allocation of controls targeted at the tasks and/or ground conditions associated with higher whole-body vibration readings.

Discussion regarding the range of data analysis methods currently referred to in research and industry reporting is advocated to improve consistency of reporting and understanding of results.

BLUE LIGHT EXPOSURES OF DENTAL STUDENTS USING DENTAL CURING LAMPS: SCENARIO BASED OBSERVATIONS AND EXPERIMENTAL DATA

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Abstract: Intense blue light exposure is a risk factor for retinal photoreceptor damage. Dental curing is the process by which plastic materials become rigid to form a denture base, filling, impression tray, or other appliance. It is achieved by intense blue light sources, used for the curing of composite resins. Dental students repeatedly use these handheld lamps as part of simulation clinics and must be able to cure resins at various angles within the mouth. Students may undertake curing procedures with both limited supervision and awareness of the blue light hazard. Whilst investigations of curing lamps suggest retinal risks for professional dentists, there have been no studies of student exposures.

Preliminary observations were made in a university dental simulation clinic to understand student procedures in more detail, including the use of lamps and shielding, and to determine time-activity patterns and exposure geometries. Worst case and typical scenarios were simulated in the laboratory and blue light effective radiances (L_B) were measured using a *Specbos* spectroradiometer. Two commercially available blue-light protective glasses were also tested for blue light attenuation.

Blue-light protective glasses were effective in minimizing exposure but were not typically worn. Shielding around the lamp body was of limited effectiveness in practice, as L_B values in the visual field showed wide variability, depending on location of the tooth and angle of the curing lamp. Values often exceeded the radiance limit of 100 W/m^{2}sr. It is recommended that blue-light protective glasses be worn and that training include more information on the nature of the blue light hazard and control measures.

1. INTRODUCTION

Damage to rod and cone photoreceptors in the retina can cause vision impairment. (Algvere, Marshall & Seregard 2006; Wu, Seregard & Algvere 2006). Blue light can destroy the retinal photoreceptors and thus intense blue light exposure is a significant risk factor for retinal photoreceptor damage. (Ham, Mueller & Sliney 1976). Dental curing lamps are intense blue light sources, used for the curing of composite resins and there are three types of dental curing lamps: halogen, plasma and LEDs. Since 1980, potential ocular hazard from the dental curing lamps has been considered from the use of the initial quartz-tungsten-halogen (QTH) curing lamp. From that point on, plasma and LED sources became more affordable and more studies related to their hazards were done in many countries. (Labrie et al. 2011; McCusker et al. 2013; Price et al. 2016). Currently, the use of LEDs is the most common of the three main types of dental curing lamps.

In 2017, there are 22,383 registered dental practitioners in Australia and 89.5% of the total practitioners are in the 25-59 age range. (Australian Health Practitioner Regulation Agency 2017). Thousands of students and staff are also studying and teaching in dental-related schools. Dental students, in particular, use these handheld lamps repeatedly as part of simulation clinics, and they must be able to cure resins at various angles in the mouth. Students thus may be more at risk of eye injury from the use of these lamps than professional dental practitioners because of a lack of safety knowledge/technique due to limited field experience. One US survey study in 2006 showed that only 84 percent of dental schools-responded provided blue light protective glasses to protect students' eyes from exposure to curing lamps during lab procedures. The survey emphasised that all dental schools should provide continuous safety education to students for protection of their eyes (Hill 2006). Unfortunately, however, there are currently no studies (either practitioners or students) about the potential ocular hazards/risks from UV/blue light exposure to dental curing lamps in Australia.

Potential retinal photochemical damage from the dental curing lamp has been described in many experimental studies. The studies measured various types of dental curing lamps, as previously mentioned, at various distances from 10 cm to 1 m (Bruzell Roll, Jacobsen & Hensten-Pettersen 2004; Labrie et al. 2011; Price et al. 2016) and at two different angles (e.g. direct and indirect path of the light from the curing units to the operators' eyes) (Labrie et al. 2011). The maximum permissible exposure times to blue light varied from 6 sec to 100 min depending on angles, distances (Labrie et al. 2011; McCusker et al. 2013). Most papers recommended appropriate protective eyeglasses from exposure to dental curing lamps emitting intense blue wavelengths. Moseley et al., in particular, estimated that the light of a dental curing lamp was reflected by 30 percent at 30 cm distances from the treated tooth to the operator's eyes and estimated maximum permissible exposure durations per day were between 40 and 100 min (Moseley, Strang & MacDonald 1987). The levels of the exposure can differ depending on the angle of light direction, the distance to the light sources, the types of dental curing lamps used, as well as the anthropometric characteristics of the operator (Bruzell Roll, Jacobsen & Hensten-Pettersen 2004). The levels of the potential effective spectral radiances (L_Bs) of a dental curing lamp can depend on various exposure factors, e.g. angles, directions or durations of usage of a dental curing lamp. Generally, the working distance of dental students is very close and thus, the visual field for the students is narrower than the 'normal' visual field and the retinal damage risk can be higher. Potential blue light hazards should be determined in the occupational visual field (OVF) (Piccoli et al. 2004).

This study was aimed (1) to characterise the potential blue light exposure to dental curing lamps through an observational case study, (2) to assess the curing lamp in a dental simulation clinic based on real working scenarios and (3) to compare exposures with International Commission on Non-Ionizing Radiation Protection (ICNIRP) guidelines. This study can also be useful to highlight the practical issues of assessment of blue light hazards in the workplace for hygienists.

2. ASSESSMENT METHODS

Field observational studies

Through relevant literature and internet sources, preliminary research was conducted to understand what a dental curing lamp is and how it is used in the field of the dental care. With this information, the field observational studies were designed in a university dental simulation clinic to conduct simulation measurements with time-activity patterns and exposure geometries.

The dental simulation clinic of the University of Adelaide was visited five times from Oct 2017 to Apr 2018 to conduct observations in the clinic and to do simulations using a dental curing lamp on the mannequin mouth. The observations were conducted without any interruptions to students' procedures and there were no ethical issues during the observations. Worst case and typical scenarios were created from observational data, e.g. time activity patterns and frequency of use of a dental curing lamp during the training courses. The on-site inspections revealed that no other blue-light sources where present in the clinic, other than the dental curing lamp.

Instrumentation

A spectroradiometer, Specbos 1211 UV (JETI Germany, S/N: 2010143), was used to measure the spectral radiance (L_Bs) of a dental curing lamp in the dental simulation clinic.

Characteristics of a dental curing lamp

A LED type of professional dental curing lamp, BA Optima 10 curing light (B.A International LTD, S/N: H12010470B), was used by the students. It is set in the wavelength range from 420 to 480 nm and the curing outputs are from 1000 to 1200mW/cm^2. The peak wavelength measured by Specbos was 455 nm. The Dental School used two types of digital radiometers to regularly calibrate their lamps. (Figure 1)

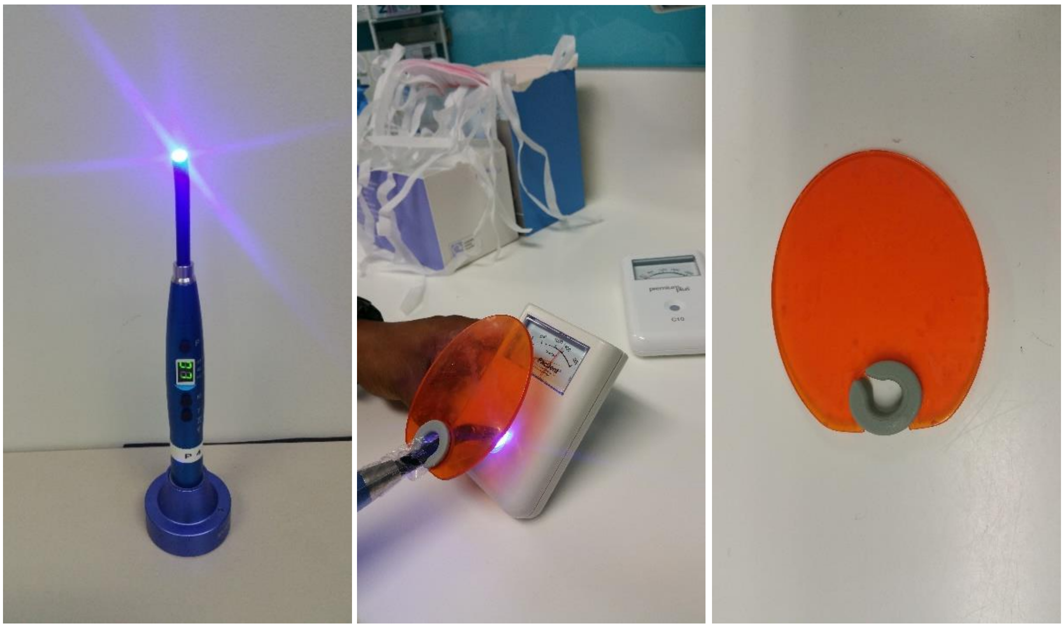

Figure 1. A dental curing lamp, digital radiometers and blue protective shield used in the dental simulation clinic.

The curing lamp emission was evaluated in the lighting laboratory at Thebarton campus of the University of Adelaide as the initial assessment before the simulation experiments in the dental simulation clinic. (Table 1)

Table 1. Emission characteristics of a LED dental curing lamp.

Measuring equipment	Measurement	BA Optima 10 curing light
Spectroradiometer Specbos 1211UV	Luminance [cd/m^2]	5966 – 6272
	CCT [K]	NA
	Blue-weighted radiance L_B [W/m^{2}sr]	104.5 – 114.5

ICNIRP guidelines

In order to calculate the effective spectral radiance (L_B) and the radiance dose (D_B), the equations based on the ICNIRP guidelines were used as follow. (ICNIRP 2013). ICNIRP guidelines provide the exposure limits for the effective radiance and the radiance dose according to the durations of blue light exposure. For viewing durations up to 10,000 sec (2.8 hours), the radiance dose (D_B) should be under 10^6 J/m^{2}sr and the radiance limit is 100 W/m^{2}sr, if the exposure duration is 10,000 sec or more.

- $L_B = \sum_{300}^{700} L_\lambda \cdot B(\lambda) \cdot \Delta\lambda$
- $D_B = L_B \cdot t$
- $D^{EL}_B = 10^6$ J/m^{2}sr
- $L^{EL}_B = 100$ W/m^{2}sr

L_B : Effective radiance of blue light (W/m^2·sr)
D_B : Effective blue light radiance dose (J/m^2·sr)
L_λ : Spectral radiance (W/m^2·sr·nm)
$B(\lambda)$: Blue light hazard function
$\Delta\lambda$: wavelength interval (nm)
t : Exposure duration (seconds)
D^{EL}_B : Exposure limit of effective blue light radiance dose (0.25 s ≤ t < 10,000 s)
L^{EL}_B : Exposure limit of effective blue light radiance (t > 10,000 s)

3. RESULTS

Field observational studies

Average time is 3 hours per class in the simulation clinic and all students basically wore clear safety glasses, gloves, masks and lab coats according to the safety requirements of the University. Working distances from the treated false tooth of a mannequin mouth to the student eyes were around 15 to 30cm and depended on locations of teeth or students' personal behaviour and anthropometric measures. Angles from a curing lamp to student eyes also differed depending on the locations of teeth being treated. Dental curing lamps used in the clinic were typically set to be on for 20 sec, ranging from 1 to 40 sec and the distance between a treated tooth and the curing lamp was 1-2 mm. Frequency of use of the curing lamp varied according to the treated tooth and students generally gazed at the tooth an average of 3 times per treatment, for 2 to 3 sec., while using a curing lamp. No students gazed at the tooth under treatment for the whole curing time (set-up 20 sec).

Based on the observational information above, estimated exposure durations for the second year dental students were created to use for the experimental calculations in this research. Table 2 is the potential/possible exposure durations of the students per one 3 hour class in terms of typical and worst case scenario. The estimated exposure duration for a dental student is typically 12 sec and the worst case estimate is 36 sec.

Table 2. Scenarios for second year dental students based on the observations.

	Exposure Frequency/treatment	Exposure duration (s) /viewing	Total Exposure duration (s)/class
Typical case (2 teeth treatment)	2	3	**12**
Worst case (4 teeth treatment)	3	3	**36**

Figure 2 shows the measurement points of the mannequin teeth by targets and angles, and the measurement locations for the curing lamp. The L_Bs were measured at various points within 0.1 radian (6 degrees) alongside the lamp as per ICNIRP guidance (T1 to T4 on Figure 2) and at various angles in the fixed targets (A1 to A6 on Figure 2). The measurement distance was 25 cm and it was determined through the average of working distances of the dental students during the observations. One point for targeting were measured at least 5 times and the average levels of the L_Bs were calculated in the table 3.

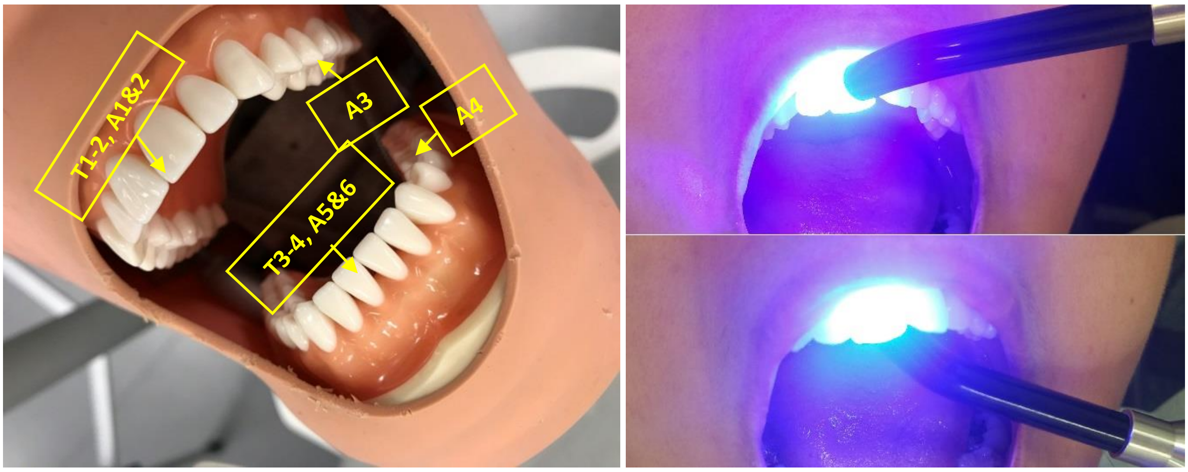

Figure 2. (a) Targets by targets (T1 to T6) and angles (A1 to A6), and (b) directions (top right: indirect, bottom right: direct).

Table 3 presents the outcomes from the simulations with the LED dental curing lamp using the estimated exposure durations. According to Labrie et al.'s study, the potential risk of the direct exposure from the part of light emission of a dental curing lamp to the eyes can be higher than the indirect exposure (Labrie et al. 2011). However, in the simulation experiments in this study, the both levels of the L_Bs varied depending on locations and angles between treated teeth and the dental curing lamp.

Table 3. The effective radiances (L_Bs) and the daily estimated effective radiance doses (D_Bs) for dental students by direction.

Exposure Direction	Target	Range of L_B (W/m²sr)	D_B/class (J/m²sr)	
			Typical case (12s/class)	Worst case (36s/class)
Indirect	T1	36.55 - 196.30	438 - 2355	1316 - 7066
	T3	117.50 - 194.50	1,410 - 2334	4230 -7002
	A2	3.21 - 123.60	38 - 1483	115 – 4449
	A3	0.66 - 175.80	7 - 2109	23 – 6328
	A4	0.65 - 187.30	7 - 2247	23 – 6742
	A6	10.97 - 51.18	131 - 614	394 – 1842
Direct	T2	13.63 - 46.81	163 - 561	490 – 1685
	T4	20.59 - 117.40	247 - 1408	741 – 4226
	A1	2.81 - 137.20	33 - 1646	101 – 4939
	A5	2.16 - 196.40	26 - 2356	78 - 7070

The range of the measured radiances (L_Bs) at 6 degrees were from 0.65 to 196.30 W/m²sr for indirect targeting and from 2.16 to 196.40 W/m²sr for direct targeting respectively. The estimated radiance doses (D_Bs) were 7 to 2356 J/m²sr for the typical case scenario and 23 to 7070 J/m²sr for the worst case scenario. The highest L_B that was able to be measured by the Specbos during initial experimentation with the mannequin mouth was 212 W/m²sr which would mean, for the worst case scenario, the estimated D_B would be 7632 J/m²sr. In terms of L_Bs the results of the direction of the exposure were not much different.

According to the ICNIRP Guidelines, all results of the D_Bs calculated by the estimated exposure durations did not exceed the limit (10^6 J/m²sr) during 8 hours per day even if the levels of some L_B exceeded the radiance limit (100 W/m²sr). Even though, the results of the L_Bs and D_Bs did not exceed the limits, it is still too early to conclude that there is no risk for students' eyes from exposure to the dental curing lamps during the class as it is possible that, depending on viewing technique as well as different environmental and layout conditions, the values of the L_Bs could exceed the limit of 100 W/m²sr.

4. DISCUSSION

Dental curing lamps emit blue light wavelengths ranging from 400 to 450 nm and are used for polymerizing dental resin-based materials. According to the observations in the dental simulation clinic, second year dental students receive their practical training in this clinic for around 160 hours per semester. The working distances were quite close, from 15 to 30 cm, and the average of angles from the teeth being treated to students' eyes was around 45 degrees. However, both distances and angles varied depending on the locations of the treatment. The potential exposure duration of a typical and the worst-case scenario estimated from the observations, were 12 sec and 36 sec during 3-hour classes respectively.

The levels of L_Bs differed depending on targets and angles of the teeth, ranging from 0.65 to 196 W/m²sr (Table 3), with the highest possible L_B being 212 W/m²sr (above this was not measurable by the spectroradiometer). Unfortunately the centre and the edge of a curing lamp were too high (off scale) for measurement by the spectroradiometer. Thus the radiance values assessed potential for overexposure to blue light from a dental curing lamp during dental classes may be higher than those measured in this research.

Unlike Labrie et al.'s study (Labrie et al. 2011)**,** there were no significant differences between direct and indirect exposure to the curing lamp probably because in direct exposure, the teeth blocked light from the curing lamp. Obviously, depending on where/how the students use the lamp, the risks will vary.

Blue-light protective glasses can be effective in minimizing exposure but were not typically worn in the courses. Shielding around the lamp body was of limited effectiveness in practice, as L_B values in the visual field showed wide variability, depending on location of the tooth and angle of the curing lamp. Values often exceeded the radiance limit of 100 W/m^2sr (ICNIRP 2013). Bruzell et al. reported that lack of eye protection could occur through protective glasses or shields with poor quality while using dental curing lamps but there are no current regulations regarding blue light transmittance for the protective equipment. More information on standards for protecting eyes from the blue light exposure is needed. (Bruzell et al. 2007)

5. CONCLUSIONS AND RECOMMENDATIONS

Depending on positions-targeted and angles between the treated teeth, the dental curing lamp and the students' eyes, the ranges of the L_Bs were measured. Although the effective blue light radiance doses (D_Bs) did not exceed the limit of the ICNIRP guidelines within the acceptable exposure duration per day, values of the effective blue light radiances (L_Bs) often exceeded the radiance limit of 100 W/m^2sr, close to the LED unit of a dental curing lamp and if the exposure duration exceeds 10,000 sec. It is also important to note that working conditions in a public hospital or in a private clinic ward/outpatient could be substantially different from those studied here, due to the more limited available space. Furthermore, paramedical and technical staff, not present in a dental simulation clinic but largely present in medical settings, should be considered for risk assessment.

It is recommended that blue-light protective glasses be worn by students and professionals, and that techniques to minimise exposure to this type of light be taught. New types of LED units (e.g. colour, shielding) for the dental curing lamp should be also considered. Since the radiation beam is filtered by the protective shield or safety glasses, it is difficult for the student to verify the exact position on the tooth surface as the blue light is being blocked. Consideration could be given to the use of an alternate colour co-annular light source for teaching purposes, if not for more general use.

Training should include more detailed information on the blue light hazard. Epidemiological studies into the prevalence of eye related damage of dental practitioners and more information regarding exposure time activity patterns in the occupational visual field should be considered in future studies.

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SELECTING THE RIGHT DOUBLE HEARING PROTECTION STANDARD FOR A LARGE LNG OPERATION IN THE MIDDLE EAST

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Introduction

During a comprehensive review of workplace Health Risk Assessments (HRAs) in 2016, the use of 95dB for a mandatory Double Hearing Protection (DHP) standard was highlighted as a potential issue. This standard had been set historically, using a Hearing Protection Device (HPD) de-rating system specified by the United States (US) Occupational Safety and Health Administration (OSHA). Some of the issues identified with setting a DHP standard at 95dB include;

- Signage – cost of identifying locations, printing and erecting signs (i.e. a greater number of zones identified as DHP zones at this noise level)
- Personal Protective Equipment (PPE) – additional costs of providing DHP for nearly all workers
- Compliance – increased requirements for monitoring and enforcing compliance with the DHP standard (i.e. higher numbers of workers required to wear DHP)
- Communication issues due to overprotection (i.e. DHP use in a 95dB zone could result in 'in-ear' noise levels lower than 70dB which can cause difficulties hearing warning signals etc.) (Health and Safety Executive (n.d.).

Further, a review of the US OSHA HPD de-rating system raised concern as to whether this this was; a) correctly implemented and b) the most appropriate de-rating system to use. These issues justified the need for review, and the challenge was to determine an appropriate DHP standard for implementation across a large diverse workplace.

As the second largest Liquefied Natural Gas (LNG) operation in Qatar (the Company), the workplace extends across a geographical area of more than 4000km^2, with nine LNG trains, three helium plants, two offshore platforms and 13 remote wellheads. As such there were many issues to consider, including;

- The need to retain clear communication between operators on the helicopter pads, and the helicopter Pilots on offshore platforms;
- Which HPDs are most suited for use with mandatory hardhats;
- Concurrent use of other personal protective equipment (PPE) such as respirators, breathing apparatus, welding shields etc.;
- Use of handheld radios or mobile phones in some work areas – i.e. the need for clear communication between operators in plant areas, and
- A workforce culture of wearing balaclavas or face scarves to protect against sunburn.

To reach our decision we undertook a review of the various aspects of a hearing conservation program. These included an evaluation of the existing Company noise exposure standard, a review of noise levels in areas of the plant already identified as DHP zones, and analysis of personal noise dosimetry samples collected from our workforce over the preceding years. Once the noise exposure standard was 'agreed' and the noise levels validated, the next phase involved a detailed look at HPD ratings and de-rating systems, and specific recommendations for DHP standards. The final phase included evaluation of, and assurance that, our approved HPDs could adequately reduce the in-ear noise levels to below the agreed exposure standard and consideration of the effect of other PPE on HPD performance. This paper describes the review process and the final outcomes achieved.

Review of Noise Exposure Standards

HPDs are used to control worker exposure to excessive noise, which can be defined as noise above a given 8hr Time Weighted Average (TWA) exposure standard in A weighted decibels (dBA) ($L_{Aeq,8hr}$). Table 1 summarizes the range of noise exposure standards considered.

Table 1 – Global Review of Noise Exposures Standards

Source	$L_{Aeq,12hr}$ (dB)	Adjusted $L_{Aeq,12hr}$ (dB)	Peak Noise L_{CPeak}
Existing *Company* Hearing Conservation Procedure E07-X03-003 - Section 6.1	**85**	**83**	**140**
US OSHA1901.95 - Table G-16	90	Not specified but calculated as 88	140
HSE - Control of Noise at Work Regulations 2005	87	Not specified but calculated as 85	140
CDC - Occupational Noise Exposure – Revised Criteria 1998	85	83	140
US Mines Safety and Health Administration	90	Not specified but calculated as 88	140
IFA (Germany) Article 282 of the Workplace Ordinance 2015	80	Not specified but calculated as 78	135
European Agency for Safety and Health at Work - Directive 2003/10/EC - noise	85	Not specified but calculated as 83	140
QATAR Executive By-law for the Environment Protection Law – Decree Law No 30 - 2002 Article 69*	85	Not specified but calculated as 83	140
Australian Model WHS Regulations	85	Not specified but calculated as 83	140

**This standard is specified for 'Closed places of work' and also includes a maximum 115dB without hearing protection at any one time (Executive By-Law for The Environment Protection Law Issued vide the Decree Law No. 30 for the Year 2002, 2002).*

Whilst aiming for best practice across our industrial hygiene program in general, based on this review we concluded that retaining the existing Company standard (bolded in Table 1) was most appropriate as it achieved compliance with local legislation and was in line with the recommendations of most major Safety & Health Organizations.

Noise Level Validation in DHP zones

A review of noise survey records for the Company was undertaken, including a comprehensive Plant Noise Survey completed in 2009 and various sporadic surveys conducted between 2011 and 2015. Inconsistencies in the records and an absence of good quality data meant that validation surveys were necessary. Given the focus of this assessment was on the use of DHP, the areas re-surveyed in 2017 were restricted to existing DHP zones in both onshore and offshore work environments. Using DHP maps developed in 2011 each area was surveyed using a calibrated Type 1 Quest SE/DL Sound Level Meter, field calibrated daily before and after use using a Quest QC10 acoustic calibrator. Sound levels were measured for 30 seconds to 1 minute at selected points in each work area where plant noise was continuous, and for longer in areas where noise levels were variable due to operational demand (i.e. steam release, plant load or emergency venting). Every effort was made to measure 'normal' and 'worst case scenario' noise levels, and to understand the frequency and expected duration of these emissions. Consultation with operators and contractors helped us to understand the likely activities performed in the DHP zones while plant is operational.

The validation process showed that noise levels in the existing DHP zones was commonly below 90dB, with only a few areas above 95dB. In fact the surveys indicated that an 80% reduction in the number of DHP zones was warranted with the existing DHP standard of 95dB. Further reductions would be possible if the DHP standard was increased to 100dB – as demonstrated in Figures 1 and 2 which show a reduction from eight DHP zones to just one in one particular LNG train.

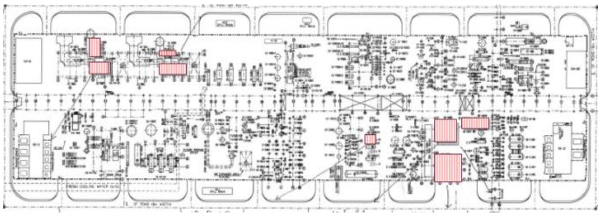

Figure 1 – LNG Train DHP Zones 2011 – 95dB

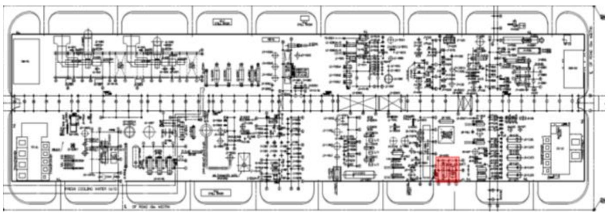

Figure 2 – LNG Train DHP Zones 2017 – 100dB

Analysis of Personal Noise Dosimetry Data

To further understand the noise exposures in our plant we undertook an analysis of more than 500 personal noise dosimetry samples collected between 2007 and 2013. A review of historical data showed that there were almost no personal noise samples collected between 2014 and 2016, and that static samples were predominantly task related, therefore no personal noise dosimetry samples were included in our analysis for these years. Also, samples collected during 2017 were not included as there were insufficient numbers available at the time of finalizing this work.

Sample data were allocated to Similar Exposure Groups (SEGs), checked for acceptability, rejected if there were any inaccuracies (i.e. pre and post calibration differences; absence of TWA result etc.) and then analysed using the American Industrial Hygiene Association (AIHA) statistical analysis tool - IHSTAT. Sample data were first converted to pascal$^{2/hr}$, analysed against the adjusted occupational exposure limit (OEL) of 83dB (for 12hr shift workers), and then reverted to dB. Analytical outcomes were predominantly used to determine the noise risk profile for each SEG and provide insight into areas requiring further investigation however, to understand the likelihood of a worker requiring DHP during 'normal' operations we looked at the % of samples above the existing DHP standard of 95dB and an alternative DHP standard of 100dB. Table 2 provides a summary of results relevant to the scope of this paper.

Table 2 – Review of Personal Noise Dosimetry against the DHP

SEG	Year	n	%>OEL 83dB	%>OEL 95dB	%>OEL 100dB
Utilities	2007	31	48.38	9.67	0
	2013	41	65.85	2.44	0
Operators - Trains 1 & 2	2007	26	53.84	15.38	11.53
Operators - Trains 3/4/5	2007	62	79.03	17.74	4.8
	2013	7	57.14	0	0
Operators - Trains 6 & 7	2010	24	70.8	8.3	0
	2013	33	60.6	6.06	3.03
Operators - AKG	2007	25	88	20	0
	2010	13	53.84	7.69	0
	2013	30	33.3	3.33	0
Operators - Offshore	2010	16	68.75	0	0
	2013	11	72.72	9.09	0
ALL Operators	*ALL*	*319*	*63.94*	*9.71*	*2.19*
Offsites	2010	12	8.3	0	0
	2013	16	18.75	0	0
EMS	2011	30	3.3	0	0
Maintenance	2007	24	95.83	12.5	0

401 samples were accepted for analysis from Operations, Offsites (jetties and other non-plant areas), Emergency Management Services (EMS) and Maintenance personnel. Operations personnel were separated into those working Offshore, in Utilities and in various LNG Trains. Our analysis showed that EMS and Offsite workers were the least likely to require DHP, with no sample exceeding the existing DHP standard of 95dB.

Our maintenance workers had the highest exposures with 12.5% of samples exceeding the existing DHP standard of 95dB, however none exceeded the alternative DHP standard of 100dB.
Of the remaining 319 Operator samples only 9.71% exceeded the existing DHP standard while 2.19% exceeded the alternative standard of 100dB.

In summary the key findings of this analysis were as follows;

- Maintenance personnel had the highest risk of noise exposure above the OEL, however our HRA process determined this was predominantly task related, as maintenance activities are almost always undertaken when plant is shut down and/or equipment is isolated. It was determined that noise generated by specific tasks would require ongoing management through Safe Work Practices but that these exposures would have no impact on the setting of a DHP standard, or any consequent 're-setting' of DHP zones across the plant.
- Offsite and EMS workers would be highly unlikely to require DHP during normal activities.
- Operators would require DHP on some occasions depending on the location of work (i.e. if supervising activities near to DHP zones while plant is operating), irrespective of whether the DHP standard remained at 95dB or was increased to 100dB.
- Whilst mandatory use of hearing protection in the plant would provide protection against most exposures above the OEL, sustained education and training regarding the need for DHP would be required for all Operator SEGs.

HPD Rating Systems

HPDs, usually earmuffs, earplugs and similar devices, are used commonly as the last line of defence to protect people against the effects of excessive noise such as Noise Induced Hearing Loss (NIHL). HPDs must meet certain test standards and are provided with a rating that indicates the level of protection they can provide. There are three common rating systems used around the world, shown in Table 3, which indicate the level of attenuation achieved by that particular HPD under 'test' conditions.

The HPD rating is determined through specified procedures of which there are two basic methodologies[i], the microphone in real ear (MIRE) method and the real-ear attenuation at threshold (REAT) method. The MIRE method involves placing a miniature microphone in the ear canal behind the HPD and then determining the difference between the sound level outside and behind the HPD. The REAT method is basically an audiogram conducted without HPD and then with the HPD, followed by an assessment of the difference in the hearing thresholds. The method used is determined by the governing legislation in the country of use and once the rating is set, it can be used by safety practitioners, industrial hygienists, audiologists and other specialists to determine if a particular HPD is suitable for a given environment. However, there is a wealth of evidence that demonstrates that the rating assigned to a HPD is not at all similar to the level of attenuation actually achieved by a person in real-world conditions.

Table 3 – Ratings commonly used for HPDs (Bacou-Dalloz 2002)

<table>
<tr><th colspan="2">Rating</th><th>Additional Information Provided</th><th>Country of Origin</th></tr>
<tr><td>NRR</td><td>Noise Reduction Rating</td><td>The chart showing mean attenuation values and standard deviations at each of the seven test frequencies (from 125 Hz through 8000 Hz) is also part of the labelling required by the US EPA.</td><td>United States</td></tr>
<tr><td>SNR</td><td>Single Number Rating</td><td>Package labelling also includes information regarding the attenuation provided against;
H – high frequency noise environments
M – mid frequency noise environments
L – low frequency noise environments</td><td>European Union</td></tr>
<tr><td>SLC80</td><td>Sound Level Conversion</td><td>A Class Rating (1 through 5) is also assigned at 5dB intervals (Safe Work Australia, 2015)
<table>
<tr><th>Class</th><th>SLC$_{80}$ range</th><th>$L_{Aeq,8h}$ dB(A)</th></tr>
<tr><td>1</td><td>10 to 13</td><td>Less than 90</td></tr>
<tr><td>2</td><td>14 to 17</td><td>90 to less than 95</td></tr>
<tr><td>3</td><td>18 to 21</td><td>95 to less than 100</td></tr>
<tr><td>4</td><td>22 to 25</td><td>100 to less than 105</td></tr>
<tr><td>5</td><td>26 or greater</td><td>105 to less than 110</td></tr>
</table></td><td>Australia/New Zealand</td></tr>
</table>

Laboratory versus Real-World Attenuation

In 1993 Elliot H. Berger, Senior Scientist in Auditory Research, published the 20th E.A.R.Log$_{20}$ technical monograph 'The Naked Truth about NRRs' (Aearo Company 2000). Berger referenced work conducted by hearing conservationists in the 1970s, using the REAT method on workers in real workplaces to measure the 'actual' attenuation afforded by different types of HPDs. According to Berger, by 1992 there were at least 20 available studies providing measurements of real world attenuation spanning more than 80 industries across seven countries. This is noteworthy as the outcome of these studies showed indisputably that the HPD rating determined in laboratory conditions (whether the MIRE or REAT method is used) is far higher than what is actually achieved in real world, or in-field, conditions – see Figure 3.

Figure 1 - Comparison of NRRs published in North America (labeled values based upon laboratory tests), to real-world "field" attenuation results derived from 20 separate studies.

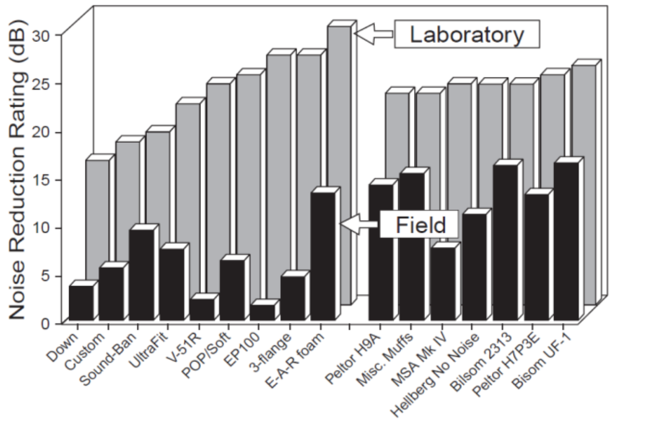

Figure 3 – Taken from Aearo Company 2000.

There have been several other studies espousing similar findings, including the UK Health and Safety Executive's 'Real World Use and Performance of Hearing Protection' (2009) (Health and Safety Executive 2009) which tested the attenuation loss of various HPDs with and without a range of other PPE such as safety glasses, helmets, balaclavas, face shields etc. The general conclusion was that the attenuation achieved in real world conditions was on average 5.5dB less than the manufacturer's SNR values. The study also showed that the use of other PPE can further reduce the achievable attenuation (Commonwealth of Australia 2004).

HPD De-Rating Systems

To tackle this concerning aspect of HPD performance, some countries introduced HPD De-rating systems. These De-Rating systems are intended to account for the loss of attenuation achieved in real-world situations, caused by one or more factors, including;

1. The rating (NRR, SNR or SLC_{80}) doesn't take into account the misuse and improper fit of the HPD, particularly if people are not trained to use and fit HPDs properly.
2. Laboratory ratings are generated under the best conditions, without any physical human movement and without any noise other than the test source. These conditions do not represent real-world conditions in almost every environment where HPDs might be used.
3. The ratings are based on 'new' products and there is no allowance for wear, such as headband stretching on earmuffs, which has been shown to reduce the in-ear attenuation by up to 8.5dB (Aearo Company 2000).

Accordingly, just as there are differences in how the original HPD rating is achieved depending on the country of origin and the test method used, there are also differences in the de-rating system, as summarized in Table 4 below.

Table 4 – De-rating Systems used by some major Health and Safety Associations

Standard	Earplugs	Earmuffs	Double Hearing Protection
US OSHA Technical Manual (1983)	TWA (dBA) – NRR - 7 x 50%		TWA (dBA) – NRR – 7 + 5 x 50%
US OSHA Technical Manual Section III Chapter 5 (2013)*	TWA (dBA) – NRR - 7		TWA (dBA) – NRR – 7 + 5
CCOHS CSA Standard Z94.2-14	L_{eq} – NRR (0.5) -3	L_{eq} – NRR (0.7) -3	L_{eq} – NRR (0.7) -3
UK Health & Safety Executive – Managing Noise Risks	Reduce 4dB from the NRR / SNR / SLC80		
South Africa	No de-rating		
Australia	No de-rating		

*The US OSHA de-rating system originally required the deduction of 7dB from the declared NRR, and then a further 50% reduction safety factor. Sustained argument about this 50% safety factor (across the US and globally) resulted in an amendment in 2013, stating '***However,*** *when assessing **the adequacy of the hearing protection for hearing conservation (HC) purposes**, CSHOs should **only** subtract 7dB from the NRR' (United States Department of Labor n.d.).*

Recommendations for a DHP Standard

At the time of this study Qatar did not have its own Health and Safety authority, therefore we had the liberty of referring to any other standard if the recommendation was a good fit for the business. Our review looked at whether or not any country actually specified the noise level at which DHP should be worn, and while several countries make recommendations, most simply state that the in-ear noise attenuation must be sufficient to reduce exposures to below the exposure level – refer Table 5.

Table 5 – Global Review of Recommendations for DHP

Standard	Suggested DHP Standard for TWA Noise	Suggested DHP Standard for Peak Noise
NIOSH – CDC 1998	100dB	
UK Health & Safety Executive – The Control of Noise at Work Regulations (2005)	110dB	150dB
US Mines Safety and Health Administration	105dB	
US OSHA 1901.95	Depends on HPD – must reduce in-ear noise to at least the OEL (85dB for all except US OSHA, which is 90dB)	
IFA (Germany) Article 282 of the Workplace Ordinance 2015		
Australian/New Zealand Standard 1269:2005 (Parts 0 — 4), Occupational Noise Management.		
EU Directive 2003/10/EC		

Taking all of this into account we chose to continue using NRR rated HPDs and apply the 2013 US OSHA De-rating system shown in Table 4. Further, we determined that the DHP standard should be selected based on both the performance capability of our approved HPDs and a detailed understanding of plant noise levels and personnel noise exposures, rather than choosing any 'recommended' standard.

Evaluation of Company approved HPDs

Consequently we evaluated four different types of earmuffs and two types of earplugs already approved for use by the Company. HPDs were assessed and calculated for their respective De-rated NRRs using the following calculation:

HPD NRR – 7 = De-rated NRR

Results are summarized in Table 6. We then looked at the 'maximum' noise level for which the approved HPDs could provide protection in 'real-world' conditions, given our eight and 12 hour OELs (85 and 83dB respectively). Results of this assessment are shown in Table 7.

Table 6. *De-rated NRRs of Company approved HPDs*

Hearing Protection Device	Brand	Model	NRR dB	De-rated NRR
EARMUFF,HEAD BAND,LIGHT,HB-25,ELVEX	ELVEX	HB-25	25	18
EARPLUG,DISPOSABLE,CORDED,SNR37DB	3M	1110	29	22
EARMUFF,HELMET MOUNTED,27DB,H10P3E,3M	3M	H10P3E	27	20
EARMUFF,CLIP-ON,WITH BRACKETS	3M	H10P3E	27	20
EARPLUG,DISPOSABLE,UNCORDED,NRR29DB	3M	311-1001	29	22
EARMUFF,HEAD SET,W/COMMUNICATION HELMET	ELVEX	COM-690-CAP	25	18

Table 7. Maximum protection level offered by Company approved HPDs

Brand	Model	NRR dB	De-rated NRR	Max Protection level (dB) OEL + De-rated NRR	
				12hr OEL 83dB	8hr OEL 85dB
ELVEX Earmuff	HB-25	25	18	101	103
ELVEX Earmuff	COM-690-CAP	25	18	101	103
3M Earmuff	H10P3E	27	20	103	105
3M Earplug	311-1001	29	22	105	107
3M Earplug	1110	29	22	105	107

From these calculations we concluded that the Company does not *require* DHP until the noise level is at least 101dB. From Table 7 the maximum noise level for which protection could be achieved was 105dB for 12hr shift workers, and 107dB for 8hr shift workers (using 3M earplugs models 311-1001 and 1110).

The application of different standards for different HPDs however, is neither practicable nor realistically achievable in a large workplace, consequently we determined that a DHP standard of 100dB would be most suitable for the business. This standard would in effect, provide two layers of added protection - the 7dB NRR De-rating for HPDs in general, and a further 1-5 dB depending on the HPD selected for 12hr shift workers.

Using this standard we then assessed the maximum level of protection possible for workers wearing DHP in accordance with the selected 2013 US-OSHA methodology. This methodology requires adding an additional 5dB to the HPD with the highest NRR after De-rating. An example of this calculation is as follows;

(HPD with the highest NRR – 7) + 5 = protected dB with DHP

From Table 6, the Company's approved *earplugs* have an NRR of 29 and therefore have the highest NRR of the available HPDs. We assessed the maximum possible level of protection using these earplugs with any of the approved earmuffs, and considered whether additional control measures such as time restrictions would be required while working in our plant area under 'normal' conditions. Although it would be extremely unlikely that an Operator would spend more than a few minutes in any DHP zone during a shift, the HPD performance capability was assessed based on a full shift exposure against a selection of high noise measurements from our 2017 DHP zone validation surveys. Results showed that over a full 12hr shift DHP would provide adequate protection in almost all locations, with only one location requiring further controls. In fact, this assessment showed that in most locations, adequate protection could be afforded with just single hearing protection (3M earplugs – De-rated NRR 22dB). Table 8 shows a summary of this assessment.

Table 8. Maximum protection level wearing DHP in specified plant areas.

Noise Source Description	Measured Noise Level (dB)	HPD	Manufacturer NRR (dB)	De-rated NRR (dB)	DHP NRR Earplug with muff	In-ear Received Noise Level (dB)	
						Single Hearing Protection	DHP (Highest De-rated NRR + 5dB)
Plant Area – general*	94.9	3M Earplug Model 1110	29	22	27	72.9	DHP Not Required
IBH control valve at AKG	116					94	89***
LNG Train compressors	105.5					83.5	78.5
DHP Zones – general**	103.7					81.7	DHP Not Required

**The Maximum recorded noise level in non-DHP zones*
***Maximum recorded noise level in DHP zones from >70 measurements.*
****Additional controls required – i.e. Time Restrictions*

Given the following considerations, this assessment raised the question of whether 'signed' DHP zones were even necessary;

- Only two high noise areas actually required the use of DHP

- Maintenance staff conduct work when the plant is either completely shut down or the working area is isolated. So for maintenance personnel DHP would not be required to manage exposure to 'plant noise'
- Operators do not spend more than a few minutes in any DHP zone during the course of their normal activities.

Using the NIOSH daily noise dose calculation, which is a factor of the noise level and the exposure time (see Table 9), Operators could technically spend up to one hour in the nosiest location (IBH Control valve at AKG) before DHP would be required, a practice which was considered highly unlikely.

Table 9. Time to reach maximum allowable Daily Noise Dose of 100%

Noise level (dBA)	Time to reach 100% without HPD
83	12 hours
85	8 hours
88	4 hours
91	2 hours
94	***1 hour***
97	30 minutes
100	15 minutes

The Impact of other PPE on HPD performance

Before a final decision was made, the effect of 'other' PPE on the HPD performance was also considered. A study conducted by the Health and Safety Executive (HSE) in 2009 (RR720 Research Report) clearly shows that the in-ear noise attenuation provided by HPDs (earmuffs) with an NRR of 25, for workers who wear various items of head coverings with PPE, is in the range of 13.5 – 22.5dB. The afforded in-ear noise attenuation for workers wearing head coverings in particular was only 13.5 dB. This aspect of the HSE study was of particular importance because of the many contract workers at the Company who wore head coverings such as balaclavas and head scarves.

The HSE study also reviewed the insertion loss related to the fitting of earplugs and showed that poor fitting of earplugs results in significantly less noise-attenuation than that stated by the manufacturer. The EAR Classic earplug tested by the HSE has a manufacturer's NRR of 29dB (same as the Company's foam earplugs), yet the in-ear attenuation achieved with poor-fitting ranged from 4 – 9dB. Poor fitting of earplugs included folding or squashing the earplugs, rather than rolling them according to instructions, and inadequate depth of insertion.
The HSE study indicated that the in-ear noise attenuation of poorly fitted earplugs was much lower than that calculated using the 2013 US OSHA method.

Table 10 demonstrates the afforded level of protection for two of the HPDs assessed in Table 6 with the HSE study indicated in-ear noise attenuation.

Table 10. In-ear protected dB using HSE study findings

Noise Source Description	Noise Level (dB)	HPD	Manufacturer NRR (dB)	HSE Study indicated in-ear noise attenuation (dB)	In-ear Received Noise Level	
					Single Hearing Protection	Double Hearing Protection (Highest NRR + 5dB)
Plant Area – general*	94.9	3M Earmuff Model H10P3E	27	13.5 (with head covering)	81.4	DHP Not required
IBH control valve at AKG1	116				102.5	97.5
LNG Train Compressors	105.5				92	87
DHP Zones – general**	103.7				90.2	85.2
Proposed 100dB DHP Standard	99.9				86.4	81.4

Noise Source Description	Noise Level (dB)	HPD	Manufacturer NRR (dB)	HSE Study indicated in-ear noise attenuation (dB)	In-ear Received Noise Level	
					Single Hearing Protection	Double Hearing Protection (Highest NRR + 5dB)
Plant Area – general*	94.9	3M Earplug Model 1110	29	4***	90.9	Not assessed as Earmuffs have highest in-ear noise attenuation
Plant Area – general*	94.9			9****	85.9	

**The Maximum recorded noise level in non-DHP zones*
***Maximum recorded noise level in DHP zones from >70 measurements.*
****Lower end of range of noise attenuation achieved from poor fit of ear plugs*
***** Upper end of range of noise attenuation achieved from poor fit of ear plugs*

In contrast to the initial assessment, results from Table 10 indicate that single hearing protection may in fact *NOT* be adequate for Company workers who use head coverings, in fact this assessment showed that in several areas DHP would be required *as well as additional controls*. Further, these results raised questions as to whether earplugs are suitable for use as single hearing protection, or whether earmuffs should be provided as the only approved HPDs for general use, with earplugs only available when DHP is needed.

Outcomes and Implementation

Using all of the information gathered to this point, our decisions were as follows;

- Maintain the current occupational exposure standards of 83dB (12hr shifts), 85dB (8hr shifts) and 140dB peak noise
- Utilise the 2013 US OHSA De-rating system for assessing HPDs
- Maintain use of currently approved HPDS, and
- Increase the DHP standard from 95dB to 100dB

To implement these changes we needed to;

- Undertake a change management risk assessment to identify and consider the potential consequences of increasing the DHP standard
- Develop a presentation for management and gain approval for the change
- Update all DHP Zone maps and provide new maps and signage to all Assets
- Develop and deliver communication packs to all Assets
- Support Production and Maintenance to update all relevant Safe Work Method Statements to reflect the new standard
- Support the Training Department to update the Company induction and other relevant training packages, and

In achieving this change, Management approval was obtained in November 2017 and new DHP Zone maps were completed in January 2018. Communication of the change was rolled out to all Assets in April and May 2018, for implementation by end of 2018 (e.g. removal of old DHP signs, installation of new signs, roll-down communication to all workgroups). Future work is panned to;

- Improve workforce education to limit the use of head coverings when wearing HPDs, and
- Consider mandatory use of earmuffs as single HPDs with earplugs only available for DHP zones and identified high noise tasks.

Conclusion

This paper has summarised the many stages of a small project looking to change the DHP standard for a large LNG operation in Qatar. The exercise demonstrated the many and varied standards available globally, the significance of understanding how to properly use those standards, the need to revalidate data where information is missing or dated, and the value of considering 'other' impacts on HPD performance than just noise.

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H2O VS LEV: WHICH IS BEST FOR REDUCING RCS IN ROCK CUTTING?

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With tunnel construction in Australia is at an all-time high there is an influx of new industry participants, which brings a substantial deficit in awareness of health risks related to tunnelling and the necessary skills and experience in managing these risks. Additionally accelerated construction programs and the requirement to build very large tunnels mean that more work activities are being undertaken concurrently. Subsequently there is potential for exposing more workers to RCS than previously before (Cole, 2017). Over time research and development into ventilation systems and dry dust collectors has led to a substantial improvement in underground dust management (Kanaoka, et al., 2000; Li, et al., 2017; Nie, et al., 2017; Torano, et al., 2011). However works behind the primary tunnel excavation to excavate service trenches generate high levels of dust, but typically rely on water sprays for dust suppression. These water sprays have low efficiency against respirable dust, consume large volumes of water, and are easily damaged, which due to production constraints may result in failure to repair and maintain (Li, et al., 2017).

To improve dust management during rock sawing, a shroud was designed and constructed to fit to a 3m diameter rock saw attachment, which connects to a dry type dust filtering system to capture dust as it is generated at the source. A comparative trial between conventional water suppression and the LEV system was undertaken during rock sawing activities associated with tunnel construction. Worker exposure to RCS and respirable dust was evaluated in accordance with Australian Standard AS 2985 with gravimetric analysis for respirable dust and quartz determination by infrared spectroscopy. Samples were collected from workers breathing zones to evaluate RCS exposure. Static area samples were collected to control for variability associated with personal exposure monitoring. Direct reading aerosol monitoring was conducted concurrently using a calibrated TSI 8532 Dusttrak II aerosol monitor. This supplementary method was employed to control for variation by standardising sample location and duration. To control for other confounding variables, measurements were taken of production rates and environmental conditions including tunnel ventilation air velocity and direction relative to the cut, LEV flow rate and water flow rate. Other variables such as operator experience, excavator cabin hygiene and down times were also accounted for. The RCS and respirable dust concentrations from the two methods were compared using a paired T- test. It was found that using LEV significantly reduced exposure to RCS and respirable dust when compared to using water suppression. This project has wide application across tunnelling, civil infrastructure and building operations and demonstrates a well-designed higher order control such as LEV can significantly reduce operator exposures to RCS and improve health outcomes.

DO PAPRS ADEQUATELY FILTER DPM?

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Respiratory protection is a widely used control measure in many industries to protect workers from exposure to diesel emissions. Recent research by the same authors (Coal Services Health & Safety Trust 2015-16 Project 20634 & WorkCover Applied Research grant 2015/005356) evaluated penetration of DPM through eight commonly used negative pressure respirator filters at the flow rate designated some respirators after a rea short wear time.

Powered air purifying respirators (PAPRs) are also used extensively in workplaces to protect workers against DPM and may be used increasingly due to changing standards on recommendations on work rates outlined in ISO/TS 16976-4:2012.

Without data on the filtration efficiency of PAPRs against DPM, there is uncertainty around whether these devices are fit for purpose and wearers are adequately protected.

Further research was conducted (Coal Services Health & Safety Trust 2016 -18 Project 20641) to determine whether PAPRs certified and used in Australian workplaces, effectively filter out Diesel Particulate Matter.

The methodology included:

1. challenging three PAPR filters commonly used in mining workplaces with DPM and measuring the % Elemental Carbon and the ultrafine particles that penetrated the filters, and
2. challenging the same three PAPR filters using current Sodium Chloride and Paraffin standard certified methods and challenge aerosols

This research raises concerns regarding the adequacy of the respiratory protection commonly provided against DPM.

REDUCING MUSCULOSKELETAL INJURY IN MANUAL CONSTRUCTION TASKS: OBJECTIVE MEASUREMENT AND WORK REDESIGN

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2, 3, School of Health Sciences, RMIT University
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5, Risk and Injury Management Services.

Abstract:
Musculoskeletal disorders (MSDs) are the most common work-related conditions in Australia and are associated with hazardous manual tasks and poorly designed work. International research identifies construction as a particularly high risk industry for work-related MSD. Construction work involves a variety of ergonomic hazards, for example heavy lifting, repetitive movements, awkward postures, vibration and forceful exertions.

The research aimed to:
1. Improve knowledge relating to the risk factors and potential for MSD in five targeted tasks.
2. Provide an evidence-base relating to the opportunities to reduce the risk of MSD in the tasks.
3. Measure and objectively assess the benefits of redesigning aspects of the selected tasks.
4. Use wearable sensors to enable the capture and analysis of objective data to understand the risk factors, as well as identify and evaluate work redesign strategies for the prevention of MSD.

Twelve healthy male adult volunteers (age: 32.1 ± 11 yrs.; mass: 92 ± 21.2 kg; height: 177.8 ± 9.2 cm) participated in this study. Five tasks selected for analysis were: steel fixing, shotcreting, cable-pulling, shovelling and jackhammering. An applied experimental design was combined with objective measurement of body movement patterns (i.e. joint motion and posture) and muscle activity using wearable sensors. This paper presents data relating to three of these tasks: steel fixing, cable-pulling and shovelling.

The research results reveal that, in some cases, ergonomic risk factors in the construction tasks analysed may be reduced by relatively simple, low cost measures. This research highlights benefits associated with using technology-enabled measurement tools to objectively measure human movement. The resulting data can be used to: (i) understand risk factors for work-related MSD; (ii) evaluate the potential impacts of ergonomic interventions; and (iii) provide evidence to guide the development of future ergonomic interventions to reduce MSD risk in the construction industry.

1. WORK-RELATED MUSCULOSKELETAL DISORDERS IN CONSTRUCTION

Musculoskeletal disorders generally occur when physical workload exceeds the physical capacity of the human body and can take place as a result of a single event or of repeated exposures. Risk factors commonly associated with work-related MSDs include repetition, force required, awkward posture, vibration, and contact stress [1].

Musculoskeletal disorders (MSDs) are the most common work-related conditions in Australia. In 2014-15, 43,555 serious workers' compensation claims were lodged for body stressing in Australia. Of these, 10 per cent were lodged by labourers [2]. The *Australian Work Health and Safety Strategy 2012-2022* targets a reduction of at least 30 per cent, to be achieved by 2022, in the incidence rate of claims for musculoskeletal disorders resulting in one or more weeks off work. The *Strategy* also identifies construction as a Priority Industry [3].

International research identifies construction as a particularly high risk industry for work-related MSDs [4;5]. Construction work involves a variety of ergonomic hazards, for example, heavy lifting, repetitive movements, awkward postures, vibration and forceful exertions. Body stressing is the most frequently cited cause of injury in the Australian construction industry, accounting for 37 per cent of occurrences [2]. Back injuries account for 20 per cent of serious workers' compensation claims made by construction workers [2].

Construction workers suffering MSDs are less likely to return to work and more likely to retire with a disability than workers in other occupations [6;7].MSDs are also costly to employing organisations, resulting in sickness absence, turnover costs, impacts on morale, lost productivity and diminished quality of work [8].

Given the unprecedented program of major transport infrastructure construction work currently underway in Victoria and New South wales, understanding and addressing the causes of work-related MSDs associated with manual rail construction work tasks was identified as a priority. The tasks investigated in the research were identified in consultation with supply chain participants, contractors and subcontractors on the basis that they present a high risk of work-related MSD in rail construction work.

2. RESEARCH METHODS

Existing knowledge on the dose-response relationship between physical risk factors in the workplace and MSDs is mostly based on self-reported data, or data obtained from biomechanical laboratory studies in which an experiment involving static postures is conducted in a controlled environment. However, there is a significant advantage to conducting experiments in real working conditions – that is, on construction sites when dynamic lifting is being performed. Undertaking technical measurements of physical work exposures during the working day may provide more realistic information than that obtained thus far. The development of small wearable sensors has enabled measurement of physical load during an entire working day [9].

Further, measurement through wearable sensors allows quantitative risk assessment to be undertaken while minimising the level of subjectivity that acts upon that assessment – a previously noted flaw of expert observation. In the research, a whole body system of miniature wearable sensors was used to measure biomechanical risk factors inherent in the five manual rail construction work tasks. These sensors measured key joint angular motion (e.g. back motion) and muscle activity (using electromyography) while workers performed these tasks. Body movement patterns (joint motion and posture) were collected with a three-dimensional (3D) portable motion analysis system (Xsens Pty Ltd, MVN BIOMECH Enschede, Netherlands). The Xsens sensor placement is described in Table 1. Further details of the measurement, extraction of data and calculation of joint angles is provided in the full research report that is available from rmit.edu.au/musculoskeletalriskreductionresearch.

Participants were recruited from worksites forming part of the Major Transport Infrastructure Program (Victoria). For three tasks (steelfixing, cable-pulling and shovelling) data were collected using a conventional way of performing the task, as well as a modified method. The data collected using conventional and modified methods were then compared to ascertain whether there were any significant changes in biomechanical risk factors. This paper presents a summary the analysis of these three tasks.

Table 1: Xsens sensor placement

Segment	Location	Placement	Method of attachment
Trunk/ head	Head	1-2cm above eyebrows, on the midline	Double-sided tape on skin
	Shoulders	On the upper border of the scapula , midway between the spine and shoulder joint	Double-sided tape on skin
	Sternum	On the level of Manubrium (T3-4)	Double-sided tape on skin
	Pelvis	On top of the sacrum in the midline	Velcro on lower side of sensor, adhering to the pelvic band
Upper limb	Upper arms	On the middle of the upper arm, on the lateral side of each arm	Velcro on lower side of sensor, adhering to upper arm band
	Forearms	Just above each wrist	Velcro on lower side of sensor, adhering to forearm band
	Hands	Centre of the dorsum of each hand	Double-sided tape on skin
Lower limb	Upper legs	Midline of the upper leg on the lateral side of each leg	Velcro on lower side of sensor, adhering to upper leg band
	Lower legs	On the head of tibia on the medial side of each lower leg	Velcro on lower side of sensor, adhering to lower leg band
	Feet	Where the metatarsal bones meet phalangeal bones of each foot	Double-sided tape on skin or sock

3. RESULTS

Study participants were 12 healthy male adult volunteers (age: 32.1 ± 11 yrs.; mass: 92 ± 21.2 kg; height: 177.8 ± 9.2 cm) (Table 2).

3.1 Steel fixing results

Steel fixing involves positioning steel rods and fixing them together using wire ties in preparation for concreting work. The steel fixing task involves heavy manual materials handling, work in awkward postures and higher levels of energy expenditure compared to other construction tasks [10; 11; 12] and has been identified as a high risk activity for musculoskeletal injury, particularly to the back and upper extremities [11].

When using a conventional pincer/cutter tool, tying steel reinforcement bars together the participant demonstrated repeated use of the left (non-dominant) hand to supply the tie wire, while the right hand repeatedly clamped, twisted and cut the wire to complete a tie. This tying/cutting cycle takes approximately two seconds and is a repetitive action. It is estimated that steel fixers make 400–600 ties using this method per workday [13].

Table 2. Data collection dates, sites, participants and work tasks assessed.

Assessment Date	Site	Participant ID	Task	Age (yrs)	Height (cm)	Mass (kgs)
8 June 17	1	1	Testing	55	170	80
29 June 17	2	2	Shovelling	55	165	82
29 June 17	2	3	Steel fixing	29	178	85
3 Aug 17	4	5	Steel fixing	18	182	68
18 Aug 17	4	6*	Steel fixing	28	173	73
25 Aug 17	6	8**	Cable pulling	34	162	74
6 Oct 17	8	8**	Cable pulling – trestle test	34	162	74
6 Oct 17	4	6*	Steel fixing – tool tests	28	173	73
21 Oct 17	9	11	Shovelling – supplementary handle test	25	82	180
21 Oct 17	9	12	Shovelling – supplementary handle test	60	72	173

* Indicates repetition of the task with tool modification (same participant).

** Indicates repetition of the task with tool modification (same participant).

In addition to assessing the use of a conventional pincer/cutter tool, two alternative tools available for steel fixing were also assessed. These were a hand-held power tying tool and a long-handled stapler tool. Figure 1 shows these three tools in use when fixing steel at ground level.

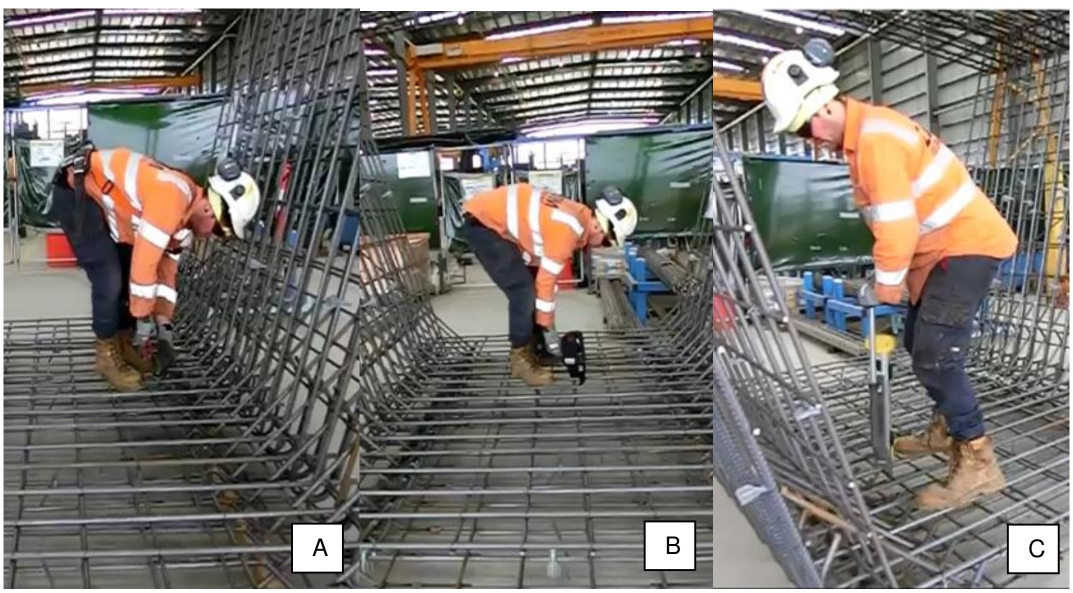
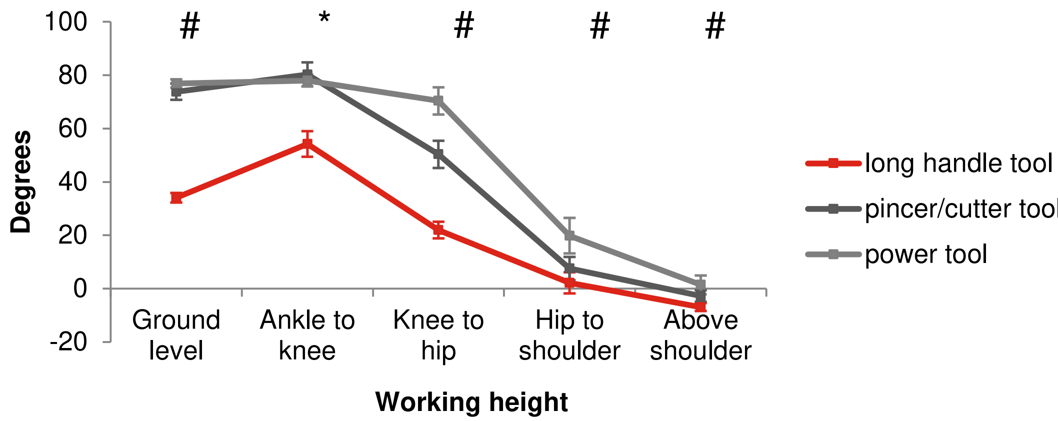


Figure 1. Use of the pincer/cutter (A), power tying tool (B) and long handled stapler tool (C) at ground level

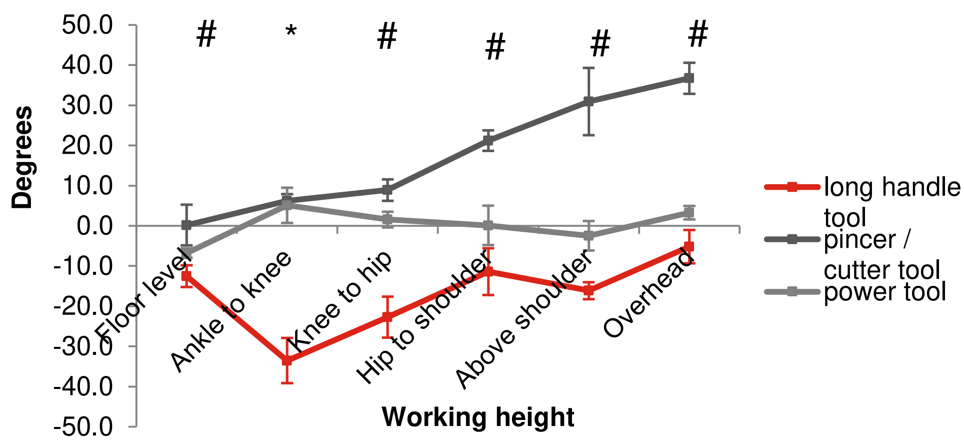


*Long-handled stapler tool significantly different to manual and power tying tool (p < 0.05).
All three tools significantly different to each other (p < 0.05).

Figure 2. Mean trunk inclination at different working heights by tool

At all working heights, the long-handled stapler tool had significantly lower mean trunk forward flexion than the manual pincer/cutter tool and the power tying tool (Figure 2). At all working heights, except ankle-to-knee, the power-tying tool produced significantly higher mean trunk forward flexion than the manual tool.

The power tying tool exhibited the lowest ($p < 0.05$) peak rotation; that is pronation or supination. The pincer/cutter tool exhibited the greatest pronation whereas the long-handled stapler tool exhibited the greatest supination (Figure 3).



*Long-handled stapler tool significantly different to the pincer/cutter and power tying tools.
#All three tools significantly different to each other.

Figure 3. Peak right wrist rotation at different working height by tool (pronation is positive and supination is negative)

The two alternative tools assessed (a power tying tool and a long-handled stapler tool) demonstrated some features that could, in part, overcome the limitations of the conventional pincer/cutter tool. However, neither of the tools was found to overcome all limitations. The results also show that MSD risks vary significantly depending on the height at which work is to be conducted. The size, dimensions and shape of the steel frame structure to be constructed should be considered when selecting the best tools for fixing steel.

3.2 Cable pulling results

Cable pulling involves feeding and pulling cables through an underground conduit system to the required length and location. Pulling cables can involve repetitive bending to grasp the cable at ground level and pulling the cable upwards. High force is involved in pulling the cable through the conduits. This force increases with the length and diameter of the cable. A simple trestle was manufactured to guide the cable at hip height (Figure 4).

Figure 4. Cable pulling without(A and B) and with (C) the trestle

Mean trunk inclination for the usual method of cable pulling, when standing in a fixed position was high (42.9 ± 21.3 degrees). Introducing the trestle led to a reduction in the mean trunk inclination of approximately 50 per cent (mean 21.3 ± 0.03 degrees) (Figure 5).

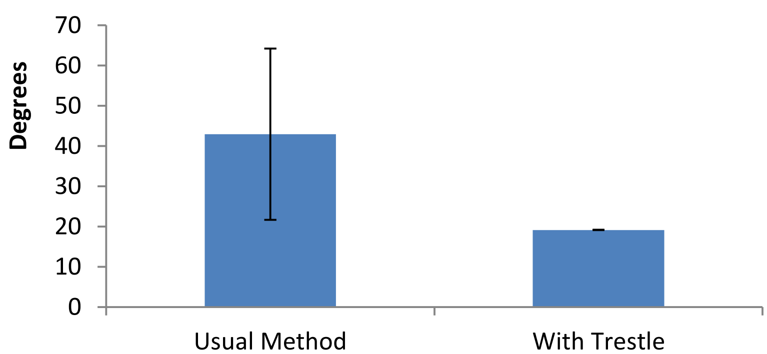


Figure 5. Trunk inclination (Mean ± SD) values for the usual and trestle methods of cable pulling

For the usual method of cable pulling, when the participant was standing in a fixed position, 56.0% of task time was spent with a trunk inclination greater than 40 degrees (Figure 6). Using the trestle, the participant's forward inclination did not extend beyond 40 degrees at any time at either of the two cable pulling locations on this site.

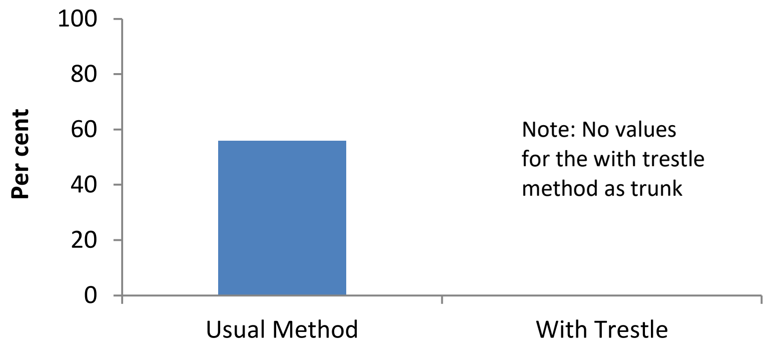


Figure 6. Per cent of time spent above 40 degrees trunk inclination when cable pulling

WorkSafe Victoria's Manual Handling Code of Practice identifies working with a trunk inclination greater than 20 degrees combined with undertaking a task for more than two hours over a whole shift, or continually for more than thirty minutes at a time, as a risk factor for musculoskeletal injury. The analysis showed that the conventional method of cable pulling places the trunk and lumbar regions of the back in greater forward flexion increasing the risk of injury, and the use of a trestle device to elevate the cable (when mechanised pulling methods cannot be used) can substantially reduce this risk. Notwithstanding the benefits associated with the trestle, the design and use of mechanical cable pulling devices should be prioritised to eliminate or substantially reduce manual cable pulling, particularly in situations in which cable pulling over longer distances is required.

3.3 Shovelling results

Most large scale moving of materials in construction is performed using mechanised methods. The use of shovels is restricted to infrequent and smaller scale tasks of scraping, clearing surfaces of debris, and levelling small areas. However, shovelling is reported to present a high risk for work-related MSD in the construction industry [14].

In the assessment of the shovelling task, the potential for a supplementary handle design (Figure 7) to reduce back and upper limb movements for the operator was assessed.

Figure 7. Supplementary handle design for shovel

Participants were asked to use a conventional shovel, and one fitted with the supplementary handle to:

- dig and toss material to the side,
- dig and toss material into a wheelbarrow, and
- scrape and toss material to the side.

The use of the handle significantly reduced the percentage of time that the trunk was spent in a forward bent position greater than 40 degrees (Figure 8).

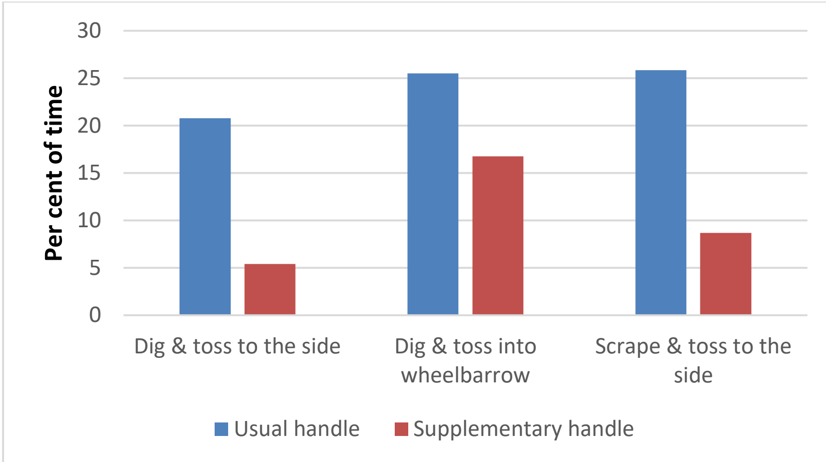


Figure 8. Per cent of time spent above 40 degrees trunk inclination when shovelling

The supplementary handle also significantly reduced the rotation of the left (lower) wrist (as indicated by the values closer to zero in Figure 9). The WorkSafe Victoria Code of Practice for Manual Handling identifies excessive bending of the wrist when undertaking a task for more than two hours over a whole shift, or continually for more than thirty minutes at a time, as a risk factor for musculoskeletal injury.

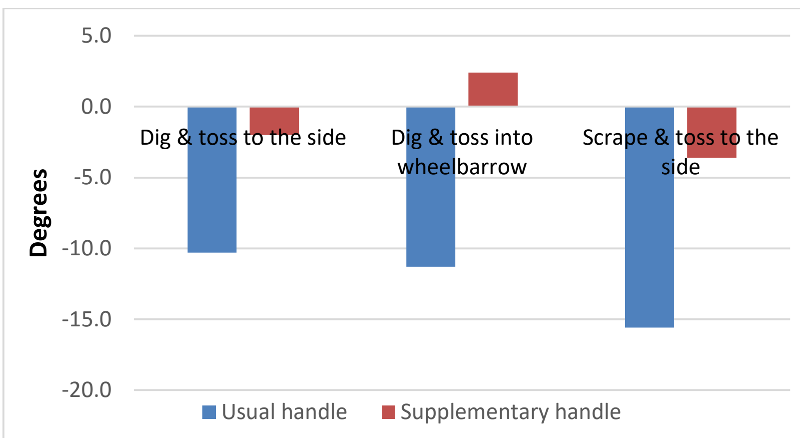


Figure 9: Mean rotation of the left wrist when shovelling

Movement of the left shoulder was also significantly lower when the supplementary handle was in use (Figure 10). In particular, the sideways movement of the shoulder away from the body (abduction) was significantly reduced when using the supplementary handle, reducing the potential for shoulder injury.

These results suggest that the redesign of a traditional tool, in this case a shovel handle, has the potential to reduce MSD risk factors in shovelling.

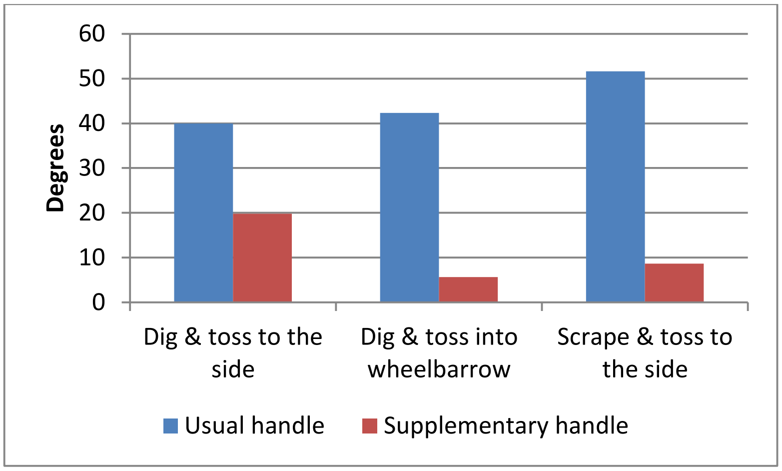


Figure 10: Mean abduction of the left shoulder when shovelling

4. CONCLUSIONS

The results highlight the need to evaluate tools and equipment for their ergonomic and functional performance, and use information in such assessments to inform the ergonomic design and improvement of tools and equipment that are currently available or that could potentially reduce ergonomic risk factors in construction tasks.

Previous research also calls for an analysis of the effect of characteristics of the work area, in particular work height, on the ergonomic risk factors inherent in a task [15].The analysis of steel fixing risk factors involved classifying work according to the level at which it takes place. This classification by work according to height enabled the potential to reduce ergonomic risk through tool replacement to be assessed at each work height. This type of analysis could potentially inform development of standardised solutions or design features for tools that address risk factors for work at different heights.

Historically, MSD risk factors have been evaluated using self-report or observational methods. Some of these methods have been carefully designed to capture a wide range of relevant factors. For example, the Posture, Activity, Tools, and Handling (PATH) method has been previously used to analyse ergonomic hazards experienced by steel fixers [15].

The current study demonstrated the feasibility and potential benefits of direct measurement of biomechanical risk factors for work-related MDS in construction work. Technological developments, and the availability of lightweight and portable whole body systems of wearable sensors, now allow measurement (rather than estimation) of human movement in an objective and reliable way, without disrupting construction work too greatly [16]. This creates the opportunity to more precisely and objectively quantify ergonomic risk factors, and to evaluate risk reduction opportunities and outcomes.

In particular, this measurement provides a reliable and valid way to:

- identify risk factors inherent in manual construction activities,
- identify opportunities for the elimination or reduction of risk exposures for work-related MSD,
- compare and evaluate the risk inherent in different ways of working, and
- inform the development and improvement of ergonomic tools and equipment for the construction industry.

5. ACKNOWLEDGEMENT

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THE EVOLVING FACE OF MANAGING CRITICAL HEALTH RISK IN INDUSTRY

Ross Di Corleto

Understanding the consequence and likelihood associated with health hazards and monitoring the exposures, has always been an area in which the occupational health professional's effort has been directed. Whilst this is an important aspect of risk management it can be lacking in its final delivery of practical and effective controls. Within the mining sector there has been a recent shift to place more focus on the controls in place to prevent or mitigate these risks. Critical risk management has become well established in the safety management process as the acute nature of risks lends themselves well to this approach. However few industries have ventured down the path of adopting this methodology for the management of critical health risks. This presentation will provide an example of the adaptation of this model for three fatal health risks and demonstrates the feasibility and benefits of such an approach across a global resources company.

FATIGUE MANAGEMENT AT SHELL ASSETS

Andrew Bennett Shell Australia

Fatigue risk management is a rapidly evolving discipline within occupational health and safety. The purpose of this paper is to describe the fatigue risk management process used in Shell assets in Australia. It will start by summarising the drivers for a proactive approach to managing fatigue in workplaces and describe Shell's organisational-level fatigue risk management commitment and framework. It will then discuss the components of Shell's fatigue risk management plan, outlining the fatigue reduction and fatigue proofing strategies in use at Shell sites. A key aim of this paper is to show that fatigue risk management is not dissimilar to the management of other occupational health hazards, with occupational hygienists able to play a key part in the process.

Shell's Organisational commitment to managing fatigue

Shell recognizes fatigue as a workplace hazard which if not managed correctly can negatively impact safety and health. Fatigue has been associated with some of the oil and gas industry's most notable workplace catastrophes, including the 1989 Exon Valdese grounding and the 2006 BP Texas City Refinery explosion (Hopkins 2008). Long term exposure to fatigue can also have notable health impacts, including diabetes, hypertension, adverse reproductive outcomes, obesity and cardiovascular disease (Lerman et al 2012). In 2007, shift work that involves circadian disruption was classified by the International Agency for Research on Cancer as probably carcinogenic to humans (IARC 2007). Inadequately managed fatigue can also impact on worker productivity (Lerman et al 2012).

As a result, in 2011, Shell included requirements on fatigue management in its Health Safety Security Environment and Social Performance Global Control Framework which applies to all Shell businesses worldwide. The requirements are as follows:

1. Identify and record workers in scope (see below);
2. Establish and maintain a Fatigue Risk Management Plan for Positions identified by requirement;
3. Provide Fatigue risk management awareness training for supervisors who are in roles that apply the Fatigue Risk Management Plan;
4. Include consideration of the potential contribution of the risk of Fatigue when investigating significant and high potential incidents, as applicable; and,
5. Make workers in scope aware of the risks of Fatigue associated with lack of time off for sleep.

Workers in scope are defined as at a minimum:

- Those in HSSE Critical Positions, *and*
- a planned shift length excluding overtime and handovers *greater than* 12 hours within a 24-hour period; or
- overtime resulting in working hours exceeding 12 hours more than once per month; or
- overtime or Call-outs resulting in more than 16 working hours in one calendar day; or
- shift work or Call-outs at any time between 22:00 and 06:00, including shifts that start during or extend into this period; or
- day-to-day changes to shift start times that are a change of more than three hours
- Workers working more than 5 days in a row or doing 12-hour shifts (local requirement)

The key features of Shell's fatigue risk management approach are that it is risk based rather than prescriptive, it equips and empowers individuals to manage their fatigue risks and it uses a learning approach. The next section of this paper will explore these features in more detail.

Shell's fatigue risk management plan components

Shell's fatigue risk management plan is modelled on the "defences-in-depth" approach described by Dawson et al (2011). This multi-layered approach can be divided into two main groupings – fatigue reduction and fatigue proofing – along with a focus on learning from incidents and its workforce (refer Figure One). Fatigue reduction aims to provide adequate sleep opportunity and enable workers to obtain sufficient sleep. Central to ensuring adequate sleep opportunity is the use of roster and shift fatigue modelling. In Shell, this is accomplished using the fatigue audit interdyne (FAID) tool, described by Roach et al (2004). It identifies the peak fatigue levels and the times these occur as well as compliance of rosters with a designated target fatigue scores. The output of the modelling is used by businesses to make informed decisions about rostering and adopt good roster design principles. Other fatigue reduction elements of Shell's fatigue risk management plan include measures to minimise travel related fatigue, approval processes for extended work and shift swaps and the application of accommodation and worker welfare standards.

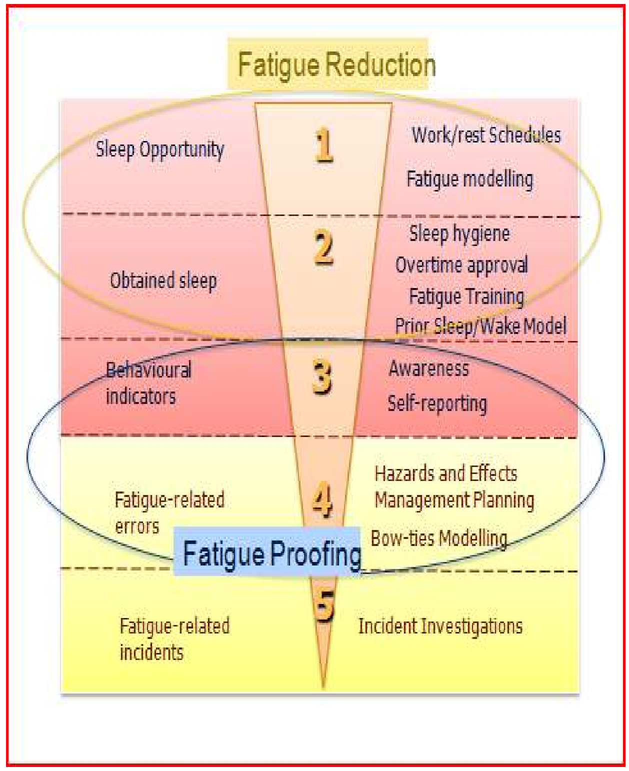

Figure 1 Shell's fatigue risk management plan components

Fatigue proofing focuses on preventing, identifying and managing the behavioural symptoms of fatigue and fatigue related errors. Fatigue proofing relies on an educated and motivated workforce and supervisors, since only frontline workers can detect such behaviours. All Shell workers in scope of the fatigue risk management plan are required to complete two fatigue training modules, while supervisors of such workers must complete a third module as well. This training helps workers become aware of good sleep strategies (part of fatigue reduction) but also helps them recognise fatigue symptoms and understand short term fatigue controls. As a result, they are able to use individual fatigue risk assessment tools to identify when they are fatigued and manage the fatigue to ensure work can be done safely in the short term. An example of an individual risk assessment tool used at Shell sites is shown in Table One.

Table One: Example of individual fatigue risk assessment tool used at Shell sites

Assessment Tools		**Fatigue Risk Level**	**Possible Actions / Controls**
How do you feel?	Prior Sleep Wake Calculator Score		
Fully alert or OK	0	Low	• No specific controls are likely to be necessary
A little or moderately tired	2-6	Moderate	• Adequate hydration & food • Tea or coffee drink • Rest Breaks (increase number and/or duration) • Adjust room lighting and/or temperature • Task rotation
Extremely tired	8-10	High	• Declaration of fatigue risk to team • Task reallocation or rotation • Increased team cross checking • Buddy system • Safety Critical tasks to be suitably monitored and/or supervised • Use of checklists for safety critical work
Completely exhausted	≥ 12	Very High	• No Safety Critical Work • Worker declared Unfit for Work • Safe Return Home Policy implemented

The final element of Shell's fatigue risk management plan is learning from incidents and from our workforce. Shell has recognised that there have been fatigue related incidents within Shell and in response has developed fatigue incident investigation questionnaires to assist investigators in determining whether fatigue played a contributing role in an incident. In addition, Shell's fatigue risk management plan has benefited from proactive suggestions and ideas suggested by Shell's workforce, who share the same goal of desiring that fatigue risks are safely managed. Workers bring ideas from their experiences at other organisations and are typically well-placed to determine what solutions will be successful in a given work environment.

Conclusions

Fatigue can be managed using the same principles as any other occupational health hazard as part of a safety management system. Shell, like many other organisations, has adopted a multi-layer fatigue risk management approach that is split into fatigue reduction and fatigue proofing components, as well as learning from incidents and its workforce. Shell's approach is risk based, equips frontline individuals and supervisors to manage fatigue and is constantly learning and improving.

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A PROGRAM APPROACH TO MANAGING OCCUPATIONAL HEALTH AND HYGIENE ON AUSTRALIA'S LARGEST PUBLIC TRANSPORT PROJECT, THE SYDNEY METRO

Kate Cole MAIOH COH & Holly Fletcher, MAIOH COH

Abstract: Sydney Metro is Australia's largest public transport construction project and has served a unique and substantial *"once in a career"* opportunity to leave a legacy for future generations by setting the benchmark for best practice occupational health performance through the development and implementation of the construction industry's first *Occupational Health, Hygiene & Wellness Performance Standard.*

The Standard, which sets out minimum performance criteria, is the first to be implemented by an Australian government organisation and is paving the way for government clients to drive improved occupational health performance and reduce the occurrence of occupational illness and fatality in the Australian construction industry.

The Standard, now embedded in Sydney Metro tender evaluations and conditions of all contracts is facilitating improved performance by ensuring occupational health risk management becomes the cultural *"norm"* and ultimately is the step change required to rectify less than adequate performance observed historically in the Australian construction industry.

The documented Standard, to look at appears to be just *"words on a page"*. However the successful implementation of such along the construction supply chain has been complex and exceptionally challenging and has required strategic vision, a comprehensive strategy and more importantly collaboration, extensive consultation and effort with industry, the NSW Regulator, our stakeholders and our contract partners.

This paper provides an overview of the *"whole of program"* approach to the improved management of health risks along our construction supply chain, and focuses on systematically improving competency, health risk assessment, verification of health risk control, collaboration and continuous improvement.

1. CONTEXT

Fundamentally, construction is one of Australia's poorest performing industries in terms of work health and safety, evidenced by multiple and often repetitive statistics, particularly with regard to the prevalence of occupational disease. For the 2012-2013 financial year, the estimated total economic cost associated with work-related disease and injury was $61.8 billion, representing 4.1% of GDP for the same reporting period (1). Unsurprisingly, the construction industry ranked as the third highest contributor to such economic burden, equating to costs of $5.84 billion, of which occupational disease contributed $2.98 billion, or 51%.

In more personable and less economic terms, statistics released by Safe Work Australia demonstrate that each year on average, 250 workers will die from an injury sustained at work, while over 2000 workers will die from an occupational disease (2). Whilst occupational health and safety policies and systems are inherently focused on safety, as such should, all too often there is a failure to adequately focus on work-related health hazards. Such failures are frequently linked to the specific challenges associated with managing occupational health risks, particularly as such hazards can be invisible, silent and insidious in the long latency of their ill effects, with health problems only emerging many years later.

Such statistics and realised shortfalls prompted Safe Work Australia to review the performance of work, health and safety among all Australian industries. The review identified the construction industry's inherent hazardous nature results in one of the highest incidence rates and highest number of workers' compensation claims when compared to all other industries. As such, in 2012 Safe Work Australia (3) nominated construction as a priority industry for improved performance, with a particular focus on preventing high prevalence occupational diseases.

2. THE NEED FOR AN OCCUPATIONAL HEALTH STRATEGY

Sydney Metro activities significantly depend on contracting companies, of various sizes, to conduct a wide variety of works, the majority of which are carried out in and around high-risk work environments. Historically, approaches for managing contractor occupational health performance has focused effort and resources on monitoring and controlling occupational health activities after contracts are awarded, and while such has contributed to minor improvements in contractor performance, such approaches typically result in significant effort being focused towards reacting to incidences and non-conformances. These reasons prompted Sydney Metro to take a proactive approach to better manage occupational health risks.

Construction activities in Sydney commonly produce silica dust as Hawkesbury sandstone bedrock contains very high concentrations of quartz. Breathing in silica dust can cause incurable diseases such as silicosis and lung cancer (4). Given Sydney Metro's contractors are excavating over 7.6 million tonnes of sandstone underground, construction workers may be exposed to silica dust at quantities that could result in occupational lung disease if not adequately controlled. Expectedly, silica dust exposure is one of Sydney Metro's highest health risks. Because of this, an occupational health strategy was prioritised and implemented to address this issue.

The scope of the strategy to control occupational health risk is unlike any method ever deployed by the NSW Government. Each contract, and indeed each work package along Sydney Metro, brings with it, its own set of unique health hazards. Therefore, a one-size-fits-all prescriptive approach would not be suitable across the entire Sydney Metro program, and required the adoption of a strategic approach to develop the solution. In 2016 we launched our Health and Safety Strategic Plan which included a specific occupational health initiative to ensure effort applied to health risk management was equivalent to that of safety.

As part of our strategy, Sydney Metro first looked inwards to find areas of excellence and successful initiatives across Sydney Metro Northwest—the first stage of Sydney Metro. Our Principal Contractor (PC) engaged to execute the Tunnel and Station Civils (TSC) Contract had implemented a risk-based occupational hygiene program that systematically enabled the prioritisation and allocation of control measures and associated resources to manage the highest health risks, thereby facilitating business leaders to focus their efforts on controlling health risk where it was most needed (5).

The focus then turned to look outwards, to review best practice and health and safety performance on an international scale. This was achieved through active participation in international communities of practice and further supported by information obtained from a Churchill Fellowship on this specific issue (6).

3. OCCUPATIONAL HEALTH, HYGIENE & WELLBEING STANDARD

The collation of local and international best practice was applied to the development of the construction industry's first Occupational Health, Hygiene & Wellbeing (OHHW) Standard which is applied to systematically identify and control health risks through standardised methods of health risk assessment, control verification and ongoing review. The Standard establishes clear systems of work and minimum performance requirements that afford Sydney Metro governance and understanding of occupational health risks across all Project programs.

The Standard is embedded in Sydney Metro tender evaluations with relevant elements included in the *Sydney Metro Principal Contractor Health and Safety Standard* (7) which form the conditions of all contracts and subsequently has become the benchmark for occupational health performance for all PCs delivering the Sydney Metro project.

Such contractual conditions are issued at time of tender so performance expectations are clear to prospective PCs from the outset. Once "on-site", Sydney Metro conduct audits to evaluate the contractor's performance against contract conditions to ensure they fulfil their commitment to improved performance.

3.1 Competency Requirements

Given the complex nature of the construction industry and the traditional heavy reliance on the use of personal protective equipment (8), it was important that PCs were equipped with competent persons at an early stage of the project, to effectively and proactively manage risks to health.

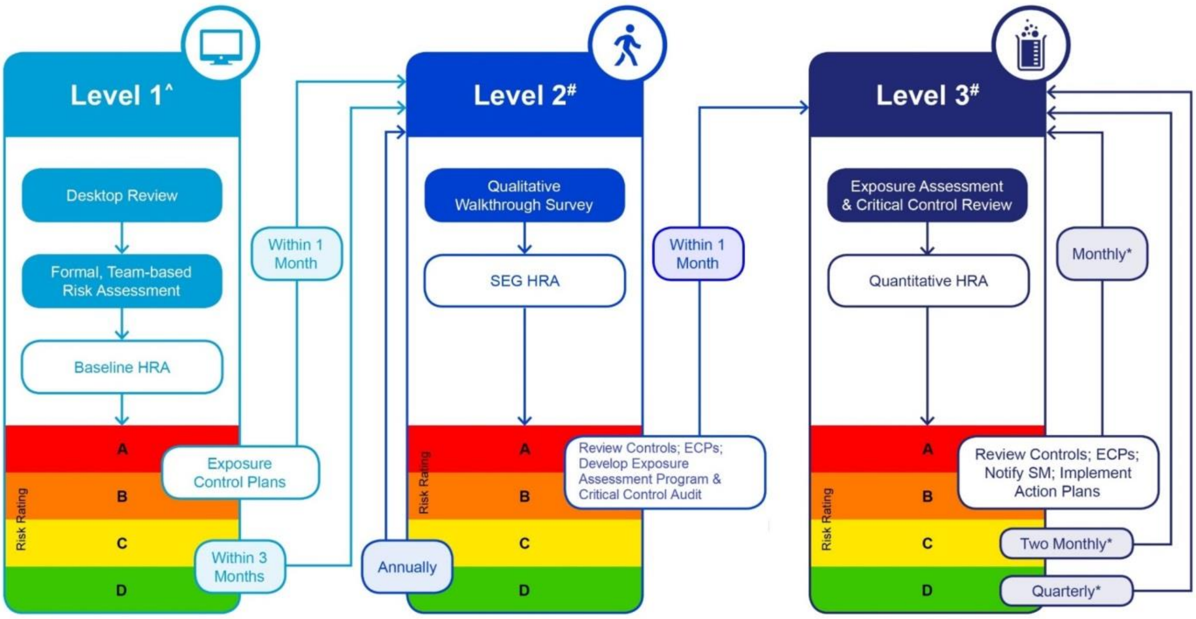
A key element of the OHHW Standard is the requirement for each PC to engage their own Certified Occupational Hygienist (COH)®. The COH provides governance of the PC's OHHW program including ensuring that health risk assessment, control, review and reporting activities are performed in accordance with legislative requirements and the requirements of the OHHW Standard. Additional competency requirements exist for occupational hygienists and health and safety professionals also, thereby reducing the risk of PCs being provided advice and recommendations that may not be fit for purpose.

3.2 Health Risk Assessment

Another key element of the OHHW Standard is the process for Health Risk Assessment (HRA), which is a way of gathering information that describes the magnitude of potential consequences of a harmful event and the likelihood that these consequences will occur. It was essential that "health" became a routine part of "safety" in Sydney Metro's business as usual practices. As such, our Safety Risk Management Standard evolved into a Health and Safety Risk Management Standard that included the consideration of occupational health risks for the first time at both the program and project level. This resulted in health risks being considered alongside safety when performing risk assessment activities.

Three assessment levels are used to direct and prioritise ongoing risk assessment and subsequent risk controls towards the areas that form the highest risk to health over the life of the project. The three-level process aims to provide both a consistent and systematic approach to health risk assessment. The levels are displayed pictorially in Figure 1 and include:

- Level 1 – Baseline Qualitative Health Risk Assessment;
- Level 2 – Qualitative Walkthrough Assessment; and
- Level 3 – Quantitative Health Risk Assessment.



^All Activities performed (or sub-contracted) per Contract Package.
#Per Similar Exposed Group (SEG).
*Review Frequency dependant on assessed risk without regard for PPE.
HRA: Health Risk Assessment.
ECP: Exposure Control Plan.

Figure 1. Sydney Metro Health Risk Assessment Model.

Each level of HRA occurs at a different stage in the project. The first level is frequently qualitative in nature, however later assessments become quantitative with the aim of reducing the uncertainty of the risk assessment. Level 1 is performed prior to starting work, Level 2 is performed soon after work activities commence, and Level 3 occurs within a month of those activities commencing that present a significant risk to health. In the case where works have already commenced, then Level 1 occurs as soon as practicable after the health hazard has been identified. In all three levels, HRA is performed under the governance of the PC's nominated COH in consultation with competent persons who have ownership and an understanding of the risks assessed.

When the Level 1 HRA is completed, the main deliverables include a Baseline Qualitative Health Risk Assessment Report and an Exposure Control Plan (ECP), or series of ECPs. The aim is to prioritise high risks and then put plans in place to document how those high risks will be adequately controlled so far as is reasonably practicable, prior to works commencing.

Level 2 HRA involves a walkthrough survey, which is essentially an inspection of the work activities and the work area to check that the Level 1 HRA adequately captured the activities performed; that the control measures documented in the ECPs are in place and fit for purpose; and to make improvements to the Level 1 HRA where necessary. The key deliverables include a Qualitative Walkthrough Assessment Report, Revised ECPs as appropriate, a Critical Control Audit Tool, and an Exposure Assessment Program where health risks are assessed to be significant, in accordance with the Sydney Metro Health and Safety Risk Matrix.

Level 3 HRA is targeted towards those work groups who are assessed to be at significant risk to health. It involves undertaking exposure assessment in accordance with a documented exposure assessment strategy to quantify the level of exposure to work groups. It also involves completing the Critical Control Audit Tool developed as part of the Level 2 HRA. The key deliverables include a completed Critical Control Audit, Occupational Exposure Assessment Report(s) encompassing the HRA certified by COH.

In essence, the HRA process includes a continuous review cycle, whereby significant health risks are assessed more frequently and improvements are made as part of an adaptive management approach over time. The HRA process does not mandate that Contractors reduce exposures to a point that is no longer reasonably practicable or achievable, but rather provides a structured approach of risk assessment and review. As over one-third of Australia's exposure standards are out of date and therefore unlikely to sufficiently protect worker health (9), it is important that a balance is achieved between the risk of developing an illness/disease, and the associated costs with reducing that exposure.

3.3 Health Risk Control

When managing health risks, the legal requirement is to eliminate the hazard itself, or if not possible, to minimise the risk so far as is reasonably practicable. When doing so, the risk must be minimised by working through the hierarchy of control so that measures that offer the highest level of protection and reliability are given priority and considered before those that rely on human behaviour and supervision to be effective (10). However, in practical terms in the construction industry, it has been reported that over one half of workers who were exposed to airborne hazards for example, were provided both PPE and administrative controls (8), both being low on the control hierarchy.

To address this, the OHHW Standard requires that control measures to reduce the risk from health hazards be reviewed, selected, and documented in order of the control hierarchy prior to commencing work activities. Exposure Control Plans, or "ECP's" are documented by the COH who works to proactively select suitable control measures with the PC at a stage in the project which affords appropriate time to do so.

An ECP is required where a significant risk to health is identified. In such cases, additional documentation is required to identify the necessary medical assessment and health monitoring activities that need to be performed for such work groups. Where personal protective equipment such as hearing and/or respiratory are planned to be used, the PC is required to document the requirements of the relevant Australian Standards (11) (12).

Recognising that the absence of some control measures presents a greater risk of exposure, Sydney Metro's health risk control approaches include an element on *Critical Control Management*. The aim is to improve managerial control over unwanted events by focusing on the critical controls. Such unwanted events include the potential exposure of groups of workers to carcinogenic or other agents at harmful levels over a protracted period. It is based on:

- having clarity on those controls that really matter;
- defining the performance monitoring requirements of those critical controls, and what the critical control has to do to prevent the event occurring;
- deciding what needs to be checked or verified to ensure the critical control is working;
- assigning accountability for implementing the critical control; and
- reporting on the performance of the critical controls.

An audit tool is created by the COH that includes the nominated critical controls. The purpose of the audit tool is to focus on fewer specific control measures that are crucial to prevent or minimise exposure and for them to be monitored more regularly, and routinely, as part of Level 3 Health Risk Assessment activities.

3.4 Health Risk Review

Sydney Metro's occupational hygienists undertake independent audits of health risk assessment and control activities to validate performance across the Sydney Metro program, with audits prioritised based on the assessed risk to health. Additional review activities are performed through trend analysis of exposure assessment results, provided as part of Level 3 HRA activities, in addition to reviewing OHHW incidents which are required to be reported by the PC against set criteria.

4. COLLABORATION PARTNERSHIPS

Engagement and collaboration between Clients, Contractors, Regulatory Authorities, Research Institutions and Industry associations is a best-practice model that has been observed to result in improved health performance (6). Collaboration is one of Sydney Metro's core values, and as such presents an opportunity to be a key stakeholder to drive this style of working.

4.1 Regulatory Authorities

Recognising the importance of regulatory focus and attention on this issue, Sydney Metro entered into a Collaboration Agreement with SafeWork NSW to formalise our relationship in early 2017. That Agreement highlighted both party's commitment to health and safety and our willingness to lead in order to achieve a lasting legacy in health and safety. Working with the Regulator demonstrates our commitment to our looking beyond the mere boundaries of our own project, but rather our aim to leave a lasting legacy to positively affect all workers in the construction industry.

Following an initial scoping workshop, Sydney Metro commenced a collaborative project with SafeWork NSW addressing the occupational health hazard of Respirable Crystalline Silica (RCS). In this capacity, Sydney Metro supported SafeWork NSW with their Hazardous Chemicals and Materials Exposures Baseline Reduction Strategy (13), in which RCS forms one of the top two chemicals of focus.

Understanding that the level of awareness surrounding the issue of RCS would benefit from improvement, Sydney Metro supported the Safe Work Australia in developing their *Silica Series* as part of their Virtual Seminar Series (14). The *Silica Series* featured presentations from Sydney Metro and our delivery partners. It aimed to raise awareness of silica dust as a key risk to health in construction; explain the work of SafeWork NSW in addressing this issue; outline the important role that clients have in delivering positive health and safety outcomes; provide information on international best practice in illness and disease prevention; highlight the work performed by leading contractors on silica dust control; and provide information on how industry is working collaboratively to proactively address silica dust exposure.

4.2 Industry

The formation of industry groups through which major projects collaborate and share information, provides a consultative forum for driving best practice approaches, as they take into account the needs of all stakeholders through consultation and a participatory approach, ultimately resulting in useful tools and guides that positively impact the industry (6).

Understanding the importance of working with industry, Sydney Metro were a key stakeholder in the formation of the construction industries' first *Silica in Tunnelling* workshop, hosted by the Australasian Tunnelling Society (15). That workshop was the springboard to our industries first *Air Quality Working Group*, which consists of stakeholders from each Contractor and Client organisation for every tunnel construction project in NSW, alongside SafeWork NSW.

Collaboration with industry stakeholders is essential to both raise awareness of this important issue, but also to enable effective strategies to be developed that will ultimately be practical and a positive step forward. The *Air Quality Working Group* have been actively meeting bi-monthly and working together to improve health outcomes for tunnel workers specifically related to silica dust. To date the *Air Quality Working Group* have been successful at actively addressing the issue of silica dust exposure at an industry level.

4.3 Delivery Partners

4.3.1 Templates and Tools

It was recognised early in the planning process during the development of the OHHW Standard that for some of our delivery partners, it would be the first time that they would have been required to engage with occupational hygienists and proactively address health risks such as silica dust exposure early in the project lifecycle.

To provide assistance in a collaborative way, Sydney Metro worked to provide a series of tools and templates in a generic form that our delivery partners could use which demonstrated the level of detail required for Sydney Metro to assess conformance against our OHHW Standard. Examples included provision of templates for an OHHW Management Plan, Health Risk Assessment, Exposure Control Plan, Critical Control Audit Tool, and a Respiratory Protection Programme. These were supported by guidance documentation on Health Risk Assessment, Health Risk Control, and OHHW Incident Reporting. This enabled PCs ready access to a framework, templates, and tools to be able to manage the health of their own workforce, if such a framework did not already exist.

4.3.2 Video Exposure Monitoring

The use of video exposure monitoring through the use of EVADE software developed by the National Institute for Occupational Safety and Health (NIOSH) (16) has been observed to create significant behavioural change through collaboration with the workforce using this technology. The system, known as "Helmet-CAM" has led to engineering controls and behavioural interventions being implemented to reduce occupational exposures (17).

Using the Helmet-CAM technology produced by NIOSH, Sydney Metro worked with our delivery partners to establish the MetroCAM system. It comprises a small, helmet-mounted video camera and personal data-logging dust monitor, worn by the worker for a small period of their shift. At the end of the monitoring period the video and exposure data are merged using the NIOSH developed software package EVADE. The synchronised output is viewed onsite, allowing for the identification and assessment of key work processes and tasks contributing to the worker's exposure, with the main focus on any instances of high exposure. The information is then provided to site teams to toolbox the results and discuss future solutions with the workforce through a collaborative approach.

4.4 Research Institutions

Collaboration and engagement with research partners has been identified as an area requiring improvement in the Australian construction industry (6). Recognising the value of collaboration with established and respected research institutions, Sydney Metro engaged RMIT University to research the barriers that exist to effectively apply the hierarchy of controls to reduce health risks (18). Little research has been performed to understand these barriers historically, yet such knowledge is crucial if Client organisations are to assist in overcoming such obstacles.

To date the research has suggested that the likelihood of selecting higher-order controls increases when health and safety is considered early in the construction project life cycle and when construction process knowledge is made available in that early stage, The original OHHW Standard required health risks to be assessed prior to project commencement, however as part of the annual review of the OHHW Standard, the requirement to undertake an assessment of health risks was brought forward to an earlier stage of project development, that being feasibility and design.

The research also revealed inherent biases in the way that people perceive risk, such that safety risks tend to be perceived as being more severe than health risks, that are perceived to be less certain and/or to have a delayed effect. The tendency to underestimate health risks by comparison to safety risks was identified as a barrier to the implementation of higher order control measures for occupational health risks, even though the long term consequences of exposures to occupational health risks are known to be serious and significant (18). The OHHW Standard includes a standardised occupational health consequence criteria, which aligned risk matrix consequence rating descriptors (e.g.: "Insignificant", "Minor", "Moderate", "Major" etc.) to chemical, physical and biological occupational health hazards. Standardising the consequence of certain occupational health hazards, assists in removing bias on the risk assessor's perceived health outcome, and moves towards a standardised approach.

Embedding research partners early in the project life-cycle has enabled Sydney Metro to capture further learnings and adapt to them in a systematic way, to ultimately push further towards best practice during the delivery of our project.

5. OUTCOMES

Traditionally, the focus in the construction industry has been towards safety due to the immediate impact of injuries or fatalities, rather than a focus on issues such as ill health, which may take years to manifest. Sydney Metro have worked to proactively balance this focus through the creation of a new OHHW Standard, which contained specific contractual requirements pertaining to health in addition to a robust assurance and audit framework.

The OHHW Standard has been in place since early 2017. Since that time, each major PC on the Sydney Metro project has engaged the services of a Certified Occupational Hygienist (COH)® who works to assess the risk to health of their workforce, works with the PC to develop suitable methods to control the risk; and then reviews the effectiveness of those methods using a risk-based approach. For some of our delivery partners this is the first time they have engaged such a specialist and have proactively addressed health risks such as silica dust exposure early in the project lifecycle. To date, six COHs work across the various contract packages supporting our delivery partners, which are further supported by numerous other professional occupational hygienists. Recognising the value that such professions provide, one of our delivery partners has embedded their COH into their business operations (19).

Sydney Metro has provided contractors with a framework, templates, and tools to be able to manage the health of their own workforce, with some of our delivery partners embedding these new tools into their wider business. The OHHW Standard has instilled a structured risk-based approach to managing health risks, which has encouraged our delivery partners to address such risks prior to construction and to reduce their reliance on lower-order control measures such as personal protective equipment. Where respiratory protection is utilised, further rigour around its effectiveness has been provided through requiring a respiratory protection programme including requirements for respirator fit testing requirements and a clean shaven policy.

Consultation efforts with industry, regulatory authorities, research institutions, and our contract partners, have provided us with opportunities to identify elements which would likely generate the most success. It also has allowed for the transfer of industry knowledge that may not have been gained otherwise. This information is captured and feeds into our regular review process of our OHHW Standard.

6. CONCLUSION

Sydney Metro recognises the important issue of preventing work related illnesses and diseases for the thousands of workers who will contribute to the successful delivery of our world-class infrastructure. Sydney Metro is the first Australian government organisation to implement a standard which is intended to reduce occupational disease in Australian construction industry workers. The standard is embedded in Sydney Metro tenders, is a condition of all contracts, and has become the benchmark for occupational health performance for all contractors delivering the Sydney Metro program of works. By supporting occupational health from the most senior level, Sydney Metro is driving change by setting new standards in occupational health performance and is paving the way for government clients to drive better health and safety outcomes in the Australian construction industry.

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MENTALLY HEALTHY WORKPLACES - THE ROLE OF OCCUPATIONAL HYGIENISTS AND OCCUPATIONAL PHYSICIANS

Robert McCartney

Psychosocial and human factors related to work are often overlooked as workplaces tend to focus on the physical risks of a job. However, in Queensland psychological and psychiatric injury claims related to work are the most expensive with an average finalised lost time claim cost of $52,782 and 34 weeks off work (in 2014-15). Because of this, Government and regulatory bodies are encouraging industry to focus on developing mentally healthy workplaces.To improve the psychosocial aspects of a workplace it is essential to first evaluate the work environment to identify hazards and establish a starting point to track future improvements. This is where Occupational Hygienists and Occupational Medicine can combine their knowledge of work and health to lead this process. From here, they can then design and implement appropriate control strategies to prevent ill health caused by the work environment and provide periodic testing to evaluate the effectiveness of the intervention/s by tracking improvements and monitor problem areas, and identify potentially new areas of concern early.By investigating and identifying the level of risk in the workplace, employers can better understand the areas of the business that have poorer mental health and how that poorer mental health is related to work characteristics.Good workplace design and organisation promotes active health and wellbeing and there are many performance benefits that derive from this such as productivity, efficiency and the ability to retain talented staff.

EVALUATING NOISE EXPOSURES AND IMPACTS IN THE DOG GROOMING INDUSTRY

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As with any industry, physical occupational hazards such as noise exposure are a potential threat to the hearing of dog groomers. For instance, Noise Induced Hearing Loss (NIHL) is an important issue, which affects many employees across varies industries and organisations. Frequent exposure to even moderately high levels of noise without suitable protective measures may cause permanent hearing loss. Furthermore, excessive noise can cause temporary loss of hearing, interfere with speech, and disrupt concentration, sleep and relaxation.

This project involved having participants (dog groomers) having their personal noise exposures monitored over their entire work shift by wearing noise dosimeters. Additionally, a task-based analysis on activities associated with dog-grooming (e.g. using electric clippers), was undertaken by using a Type 1 Sound Level Meter (SLM). Participants also had their daily tasks, tools and location documented, as well as filling out a brief survey with questions on their experience, and perception of noise exposure. Observations were made in relation to workplace controls to manage noise exposure, if any. Six workplaces (dog grooming salons) were assessed in this study, with fourteen employees being involved, Results to date for both the quantitative (both personal and static monitoring) aspect of the project has indicated that there were results that exceeded the occupational exposure standard. The qualitative assessment also indicated that the perception of noise from staff may not be truly representative of the actual risks encountered in a general shift. As such, this assessment indicated that further controls a needed to be implemented to reduce the exposures to as low as reasonably practicable; as will be shown in later monitoring results.

THE FRENCH ARDUOUS WORK REGULATIONS: AN UPDATE

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In 2016, France introduced the *Arduous Work Regulations* after a long implementation period. The aim of these regulations was to address the differences in life expectancy that is observed between highly skilled workers, independent professionals and workers in jobs that have exposure to risk factors that could lead to adverse health effects. These controversial regulations require significant resources by industry to maintain records of OHS information for the workforce. The regulations were implemented not only in industry across France, but French multi-national companies were also required to implement the regulations for French workers working abroad.

In 2016 we reported on the details of the new regulations, the documentation and records required, the monitoring, hygiene and reporting requirements.The hazards that are included in the regulations are manual handling, arduous posture, vibration, noise, chemical agents, heat stress, hyperbaric and shift work. Exposure was assessed by risk assessment using homogenous exposure groups (HEGs). However, with the election of the Macron La Republique En Marche centrist government in May 2017, significant changes were legislated to the regulations. This has been the case for many labour law changes by the Macron government. In this poster we outline the changes and potential effects on the requirements imposed on industry.

THAT STINKS! ODOUR PERCEPTION, TRACKING AND SOURCE IDENTIFICATION IN AN INDOOR ENVIRONMENT

Claire Bird

Building, facility and staff managers frequently face significant workplace concerns and complaints around odour and lack of wellness in buildings, leading to reduced occupancy, absenteeism and risk to all parties.

Odour investigation presents several challenges including:
The subjective nature of and individual's perception of odour.
Difficulty linking odour complaints to environmental monitoring data.
Deciding on an odour threshold based on inconsistent published odour thresholds for individual compounds.
The impact of agonistic and antagonistic action of individual compounds on odour thresholds.
Difficulty linking symptoms to those associated with physiological versus psychological stress.
Difficulty setting data quality objectives and quantifying uncertainty when relying on standardised odour assessment methods with odour panels, real-time equipment and chemical data.

As such, the Indoor Air Quality Association Australia will present some methods that Hygienists can engage to help resolve odour and health complaint incidents and to start to establish a standardised approach to odour assessments.

By modelling situations based on real-world case studies, the paper will explore common odour sources. It will suggest some methods for identification and source tracking of odour in a commercial office building. The FIDOL model is used for assessing odour from outdoor sources, comprising
Frequency, Intensity, Duration, (Odour) characteristic, and Location of the odour. The paper appraises FIDOL as part of the approach to management of indoor odour and risk perception, and examines how supplementary techniques for assessing source apportionment in the office environment can be employed by Hygienists faced with workplace complaints that are otherwise hard to resolve.

SCIENTIFIC POSTER: LEVERAGING TECHNOLOGY TO CONTROL GAMMA RADIATION EXPOSURE IN URANIUM MINING

Meagan Egerton

As with many industries, the uranium industry has a focus on leveraging available technology to better manage exposure to naturally occurring radioactive materials in a cost effective and innovative way. In the underground environment workers are exposed to gamma radiation from the surrounding ore body with the exposure being managed by reducing the time in the area, increasing distance from the source and shielding by attenuating the radiation with a sufficient application of shotcrete commensurate with the level of activity measured.

Current sampling methodology includes taking regular samples at set measurement points across approximately 600km of underground workings in accordance with the Radiation Management Plan.

This case study will provide an overview of a project which aimed to map underground trends of radiation activity using transportable measuring instruments in conjunction with location services installed on the current underground fleet. This poster will highlight the ways in which technology can be leveraged to prioritize areas for additional control using current resources and will focus on the challenges and difficulties encountered in implementation of an effective solution.

AN ANALYSIS OF THE EFFECTIVENESS OF AUDIOMETRIC TESTING LEGISLATION ON THE INCIDENCE OF NOISE INDUCED HEARING LOSS IN VICTORIA FROM 1978 UNTIL 2017.

Maria Nguyen

Background

Between 1978 and 2017, occupational noise legislation in Victoria, Australia has been updated on three occasions: in 1978, 1992, and 2004. However in spite of enforced noise legislation, occupational noise-induced hearing loss (NIHL) is still considered one of the most significant occupational diseases in Australia.

Objectives

This study was undertaken to determine if enforcing audiometric testing requirements and stricter noise legislation will decrease the incidence of noise-induced hearing loss, thus suggesting that noise legislation is effective at protecting workers from occupational noise induced hearing loss.

Methodology

Statistical analysis was conducted of historical audiometric testing data collected from 1978 – 2017 and obtained by competent audiometrists in Victoria and archived by the health and safety consultancy. The study examined trends between the incidence of noise-induced hearing loss cases (referrals) across three time periods: 1978-1991, 1992-2003, and 2004-2017

Results

199,462 audiometric tests were analysed between 1980 and 2017, inclusive. Of these tests, 4.65% (9,284 tests) were determined as exhibiting a significant change of greater than 15dB at 3000Hz, 4000Hz or 6000Hz (a referral). Audiometric tests conducted during 1980 until 1991 held the largest ratio between subjects that exhibited a significant change in hearing compared with total audiometric tests (5.24%). The proportion of referrals compared to total audiometric tests fell to 3.80% during 1992-2003, and rose back to 4.99% in the following time year period 2004-2017

Conclusion

Based on the data within this study, there appears to be no relationship between the incidence of noise induced hearing loss cases across the three study periods: 1978 – 1992, 1992 – 2004, and 2004 – 2017. The results of this study have found that improvements are still needed in terms of occupational noise induced hearing loss, especially considering that the incidence of occupational hearing loss (as a ratio between subjects exhibiting a significant change in hearing compared to total tests) has increased in the 2004 – 2017 time period, compared to the previous year grouping, 1992 – 2004.

Recommendations

Future studies should consider re-categorising the audiometric test data to include defined industries in order to draw trends and provide insight into where interventions are most required. Consideration should be made to conducting ongoing sequel studies to compare the number of referrals to worker's compensation data to investigate whether the workers who exhibited a significant change in hearing went on to process a claim. A stricter exclusion criterion such as removing subjects who have only completed one hearing test, and removing the subject after the first 'referral' should be applied. Finally, further studies should focus on assessing specific occupational noise interventions to determine which is the most impactful.

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