

AUSTRALIAN INSTITUTE OF OCCUPATIONAL HYGIENISTS INC

AIOH PERTH



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CROWN PERTH, WESTERN AUSTRALIA
5-9 DECEMBER 2015

33rd ANNUAL CONFERENCE & EXHIBITION

Australian Institute of Occupational Hygienists Inc
Unit 2, 8-12 Butler Way
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**33rd Annual Conference & Exhibition of the
Australian Institute of Occupational Hygienists Inc**

5 – 9 December 2015

**Crown Perth
Perth, Western Australia**

2015 CONFERENCE PROCEEDINGS

Editor

Dr Martyn Cross

www.aioh.org.au

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A NOTE FROM THE 2015 AIOH PRESIDENT



Alan Rogers COH, MAIOH, CIH
2015 AIOH President

A NOTE FROM THE 2015 ORGANISING COMMITTEE CHAIR

Kelly Sutherland

A NOTE FROM THE PAPER PEER REVIEW PANEL

This year a number of authors have elected to have their papers double blind peer reviewed. This system was initially introduced in 2006 for AIOH conferences. Each paper was peer reviewed by two reviewers to meet the requirements of the “2015 HERDC Specifications for Collection of data”. This document is a guide to research institutions in Australia about what count as a research publication and will affect funding of the research establishments and may influence tenure, promotion or admission into research degrees of authors.

The full document is available at:

<https://education.gov.au/higher-education-research-data-collection>

A panel of AIOH members with research qualifications volunteered to assist in the process.

List of Reviewers with qualifications:

- Dr Jacques Oosthuizen - PhD, MMedSci, GDip Ed, BEnv Hlth (COH), MAIOH
- Dr Sue Reed - PhD, MSc(Occ.Hyg), MEngSc BSc, COH, CIH, FAIOH, FSIA, MASA
- Dr Dino Pisaniello - BSc (Hons) MPH PhD FAIOH FSIA FRACI
- Dr Deborah Glass – MA, MSc PhD, Dip Occ Hyg, COH, FAIOH
- Dr Robert Sutherland – B.App.Sc., Grad Cert OHS Management, Grad Dip Occupational Hygiene, Ph.D
- Dr Raelene Young – BSc (Hons) PhD
- Dr Kelly Johnstone – BAppSc(OHS), BHLthSc(Hons), MSc(OHP), PhD
- Dr Marcus Cattani – PhD, MSc
- Dr Jimmy Hu - PhD DipMgt
- Dr Craig Simpson – BAppSc MSc PhD
- Dr Greg O’Donnell - PhD BAppSc MRACI CChem

The AIOH is grateful to the excellent job performed by the members who reviewed the papers. Eventually three (3) papers were considered by the Paper Peer Review Panel to have passed the peer review process.

1. Ismail Ismaniza, *Dermal absorption of organophosphorus insecticides: effects of concentration and temperature on skin penetration of omethoate*
2. Adrian Moscoso, *Application of CAPA earplug fit testing in an underground mine hearing conservation program*
3. Kiran Shankar, *Integrating occupational hygiene monitoring into a regulatory program to improve safe use of an authorised carcinogen: MOCA*

Dr Kelly Johnstone - BAppSc(OHS), BHLthSc(Hons), MSc(OHP), PhD
Chair of Paper Peer Review Panel 2015

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Enquiries should be directed to the AIOH Administration office.

BIOGRAPHICAL NOTES OF THE KEYNOTE & PLENARY SPEAKERS

Dr Vincent Covello



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Dr. Vincent Covello is the founder and Director of the Center for Risk Communication in New York City. He is a nationally and internationally recognized researcher and expert in risk and crisis communications. He has conducted trainings and consulted for several hundred organizations. Dr. Covello's assignments include trainings, workshops, and consultations related to a wide range of emergency and crisis situations throughout the world, including communications about industrial accidents, hazardous waste storage, oil and chemical spills, workplace hazards, organizational change, radiation, air pollution, water pollution, terrorism, natural hazards, radiological accidents, and disease outbreaks such as pandemic influenza and Ebola.

Over the past thirty years, Dr. Covello has held positions in academia and government. Prior to establishing the Center for Risk Communication, he was Associate Professor of Environmental Sciences and Clinical Medicine at Columbia University (1988-1992). Dr. Covello also serves as a senior advisor, consultant, and crisis communication trainer for the World Health Organization, the US Department of Health and Human Services, the US Environmental Protection Agency, the US Department of Agriculture, the US State Department, the US Centers for Disease Control and Prevention, the British government, and other national and international agencies.

Dr. Covello is the Past President of the Society for Risk Analysis, a professional association with over 3000 members. Dr. Covello received his doctorate from Columbia University in 1976 and his bachelors with honors and masters degrees from Cambridge University in England. He has authored or edited more than 25 books and over 100 published scientific articles on risk and crisis communications. One of his recent books, "Effective Media Communication During Public Health Emergencies: A World Health Organization Handbook," is currently being used by agencies and organizations around the world to communicate effectively about the H1N1 (swine flu) outbreak and Ebola.

Dr Jimmy Perkins



Jimmy L. Perkins, PhD is retired Professor of Environmental Health Sciences at the University of Texas School of Public Health. He was a Certified Industrial Hygienist and has worked in the petroleum industry, the US National Institute for Occupational Safety and Health, and with a wide range of industries including foundries, specialty metals products, poultry production, printing, telecommunications, educational facilities, and petrochemicals. He has presented short courses in Kenya, Australia, Columbia, South Africa, and Mexico. He has served as Chairman of the American Board of Industrial Hygiene and of the American Conference of Governmental Industrial Hygienists and was Board liaison to the TLV Chemical Substances Committee. He is currently (2015) resident of the International Occupational Hygiene Society. Publications span a wide range of topics including environmental exposure assessment, dermal exposure risk management, air and water quality, and hazardous waste. His most recent research used modeled air pollution levels, including speciated particulate matter, and effect estimates from dozens of epidemiological studies to examine health risks associated with coal fired power plants.

Dr Michael Donoghue



Michael is the Director of Health and Chief Medical Officer for Alcoa of Australia. He is a member of Alcoa's Global Health Committee, the International Aluminium Institute's Health Committee and the Australian Aluminium Council's Health Panel.

Michael is a medical specialist in occupational and environmental medicine – with Fellowship qualifications from Australia and the United Kingdom. His PhD from Curtin University was on acute heat illness in underground miners. His DMed from the University of Queensland was on occupational and environmental medicine in mining and metallurgy.

Prof Lin Fritshi



Professor Lin Fritshi is a cancer epidemiologist at Curtin University, Perth, with a particular interest in occupational causes of cancer. She has a medical degree from the University of Queensland, a doctorate in epidemiology from the Australian National University and is a Public Health Physician with the Royal Australasian College of Physicians. Lin has led many large case-control and cohort studies investigating occupational exposures and cancer. She is particularly interested in improving the way we assess historical exposure to chemicals at work and has developed a web-based application (OccIDEAS) to assist in this task (www.occideas.org).

Dr Doug Boreham



Dr Douglas Boreham earned a Ph.D. from the University of Ottawa in 1990 and subsequently worked as a research scientist for 10 years at Atomic Energy of Canada Ltd, Chalk River Laboratories and then became a professor at McMaster University from 2000 - 2012. . Dr Boreham is currently a professor at the Northern Ontario School of Medicine and Division Head for the Medical Sciences Division. His research has produced over 80 peer reviewed articles on a variety of topics including: health effects and anti-carcinogenic processes induced by low doses of medical diagnostic radiation (CT and PET), environmental impacts of low levels stressors, Radioprotective dietary supplements, predictive assays to identify radiosensitive cancer patients, and emergency biological dosimetry using cytogenetic assays. He was selected as an expert Canadian delegate for the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) in 2012 and has earned several honours and awards including: McMaster President's Award for Excellence in Instruction, Canadian Nuclear Society - Canadian Nuclear Achievement Award for outstanding Education and Communications, Canadian Radiation Protection Association – Distinguished Achievement Award in Recognition of Outstanding Contributions in the Field of Radiation Protection, and the Radiation Research Society – Mentor of the Year Award for Scholars in Training. Recently the International Dose-Response Society selected Dr Boreham as recipient of the 2015 Outstanding Leadership Award in the field of Dose Response.

Dr Louise Schaper



As the leader of Australia's peak professional organisation for digital health, Dr Louise Schaper is a renowned advocate for the transformation of healthcare through technology and information. Louise is intimately connected to Australia's substantial national health reform efforts, where e-health is acknowledged as a key enabler to achieving high quality, safe, sustainable and patient-centred care. With her passion for innovation and commitment to entrepreneurship within Australia's digital health community, she has achieved a global reputation in the rapidly evolving field of health informatics. In addition to her leadership of HISA, Louise sits on the Advisory Board for the Stanford Medicine X conference, is a National E-Health Transition Authority Clinical Leader, and previously chaired the E-Health International Advisory Group of the World Federation of Occupational Therapists. Louise has a background as an occupational therapist, a PhD on technology acceptance amongst healthcare professionals and is a graduate of Stanford University's Executive Leadership Program.

**Dr Andreas
Mayer**



Andreas Mayer is a Mechanical Engineer. His special expertise is in Nonsteady Flow, Diesel Combustion Supercharging and Emissions. Andreas is an emissions expert who works for the Swiss EPA. He is a consultant for authorities such as: EC, UBA, DEEP, SUVA and AUVA. Andreas is also the organizer of the yearly International Conference on Nanoparticle Measurement in Zurich. He is a global expert from VERT Association. VERT is a Swiss nonprofit organisation which aims to establish and approve the Best Available Technology (BAT) for combustion engine exhaust emission control, for both retrofit and original equipment. VERT believes the high filter quality required in these systems can lead to reduced treatment costs for many serious ailments, including cancer, cardiovascular, allergies, asthma and probably even Parkinson's and Alzheimer's.

**Prof Cas
Badenhorst**



Cas Badenhorst is the Global Lead: Occupational Health and Hygiene at Anglo American plc. He is also appointed as Associated Professor in Occupational Hygiene in the School of Physiology at the North West University, Potchefstroom, South Africa and as Honorary Lecturer in the School of Public Health, University of Witwatersrand, South Africa. Cas is the current President of the Southern Africa Institute of Occupational Hygiene (SAIOH). Cas holds a number of tertiary qualifications in the area of physiology, occupational health and hygiene and mine environmental control. He is a registered Occupational Hygienist and has been working in the field of occupational health and hygiene for more than 20 years. He serves on a number of national and international advisory and technical committees and have also co-authored a number of international published articles. Specific areas of interest include health risk assessment, exposure to chloroplatinates, nickel and diesel engine emissions, engineering control practices and the application of technology in the area of occupational hygiene.

Andrew Chaplyn



Andrew Chaplyn is the Director Mines Safety in the Resources Safety Division of the Department of Mines and Petroleum. Andrew joined the department in 2009 and has been Director Mines Safety since 2012. In 2014 he was also appointed Western Australia's State Mining Engineer, with responsibility for administering the provisions under the Mines Safety and Inspection Act 1994. Andrew has over 30 years professional experience in the mining industry, working in a variety of roles from graduate mining engineer through to senior leadership positions in both private industry and government. Andrew has been a key member of the management team that has delivered the reform and development strategy for Resources Safety since 2010. In his current roles he is responsible for managing the State's mine safety inspectorate, approving key mining submissions, and chairing the Board of Examiners and the Mines Survey Board.

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Ismail Ismaniza, *Dermal absorption of organophosphorus pesticides: effects of concentration and temperature on skin penetration*

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Wolfgang May, *Drug Testing in the Workplace Environment Utilising Oral Fluid Samples*

Andy McCarthy, *Diesel Particulate Filters: Do they work?*

Adrian Moscoso, *Application of CAPA earplug fit testing in an underground mine hearing conservation program*

Brian Murphy, *Flood, Fire and Mould Assessment Processes – The Impact of an Informed Occupational Hygienist*

Karen Niven, *‘Speaking out for Occupational Hygiene’*

Sally North, *How do regulators use workplace exposure standards?*

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Pierina Otness, *Opportunities for Integration of Occupational Hygiene Skills to Assess and Manage Public Health Issues*

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Sue Reed, *Bioaerosols in an Australian Dairy: A Pilot Study*

Chris Russell, *Innovations in pump technology, the impact on sampling quality and how to choose a pump that’s right for your sampling environment*

Kiran Shankar, *Integrating occupational hygiene monitoring into a regulatory program to improve safe use of an authorised carcinogen: MOCA*

Nathan Sumner, *Workplace Drug Test: The Latest*

Peter Teague, *Measureable Improvements from Integrating an Occupational Noise Exposure Reduction Project across Defence*

Michel Vangeel, *Case Study: Controlling exposure to Animal Allergens in Research & Development*

Michel Vangeel, *Controlling exposure to Active, Pharmaceutical Ingredients*

Michel Vangeel, *Case Study: Controlling exposure to isoflurane used in animal surgical procedures in Research & Development*

Wan Sabrina Wan Mohamad, *Benzene Exposure Assessment and Controls: From Upstream Production to Downstream Distribution*

Kevin White, *Impact of poor building design and materials in overseas constructed modular buildings – A case study of an IEQ investigation into the assembly of pre-fabricated buildings in a hot and humid climate*

Steve Wilkinson, *Application of tracer gas flow profiling to improve exposure to diesel particulate matter in underground mines - a pilot study*

Liam Wilson, *Health Status and Safety Incident Risk*

Simon Worland, *Challenges of implementing a Buy Quiet Program in Australia in 2014*

Poster Abstracts

Vasos Alexandrou, *Whole Body Vibration across the mining industry*

Jacqueline Campbell, *How extensive should a building investigation be? Case study of a water damaged property with toxigenic mould in the roof space.*

Jacqueline Campbell, *The risks of reliance on data only - What are your air samples not telling you?*

Deborah Glass, *Firefighter Study*

Sara Jackson, *Respirable Crystalline Silica Exposure in Western Australian Horse Riding Instructors*

Adelle Liebenberg, *Clearing the air: Dirty Jobs*

David Lowry, *Development of a Health Monitoring Program for Drinking Water Quality Management*

Ted Madison, *Assessing worker attitudes about use of hearing protectors and effects of intervention following individual fit testing*

Alison Morgan, *Naturally occurring asbestos: Airborne levels associated with disturbance*

Lindy Nield, *Setting Guidelines to Protect Health and Community Concerns – A Balancing Act!*

Lindy Nield, *If smoking cigarettes potentiates noise-induced hearing loss, should smokers be compensated?*

Sally North, *Lead risk workers over the years*

Sally North, *Dermal lead levels, hygiene factors and blood lead levels in fire assay workers*

Stuart Rietkerk, *Household Chemical Waste Classifications*

Bill Stavropoulos, *Evaluation of a Solvent Free “Dry Sampler” for the Determination of Monomeric and Oligomeric Isocyanates in Workplace Air*

Ruairi Ward, *An assessment of noise exposure for musicians in a marching flute band*

KEYNOTE & PLENARY

RISK AND CRISIS COMMUNICATION

Dr Vincent Covello

Center for Risk Communication, USA

ABSTRACT

This keynote address will describe how findings from the behavioural sciences and neuroscience can help risk and crisis communicators be more effective.

It will explore:

- limitations of the brain for processing high stress/high risk information
- cognitive barriers to informing people about risks
- tools for building trust and credibility
- tools for dialogue and community engagement
- tools for using social media effectively in risk communication
- tools for dealing with angry people
- tools for effective communication with culturally diverse audiences.

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INTEGRATION OF RESEARCH INTO OCCUPATIONAL HYGIENE PRACTICE

Dr Jimmy Perkins, UK

ABSTRACT

In 1996 the first results from long term prospective studies of large populations indicated a link between cardiovascular disease and exposure to ambient, small particulate matter (PM_{2.5}). This was surprising in that CVD was originally examined in that study as a negative control, since to that time no one had postulated that particles could have an effect across the lung, let alone on the CV system. Since then many mechanistic hypotheses have been formulated and supported by observation. Furthermore the CVD link has been repeated in many epidemiological studies around the world. Since CVD accounts for 25-40% of deaths in most developed countries, even a small effect would account for many early deaths. A persistent question is what in the PM_{2.5} that is causing the effects? A perplexing observation is that these effects are occurring at levels much lower than those allowed in workplaces. Only recently have research efforts focused on workers, but there are many issues restricting efforts. Nonetheless occupational health professionals should assume that many factors in the workplace, including exposure to PM, are affecting CVD outcomes.

THE IMPORTANCE OF NATIONAL-LEVEL DATA REGARDING OCCUPATIONAL HAZARDS

Prof Lin Fritshi

Curtin University

ABSTRACT

Work-related diseases are ideal candidates for prevention and there are clear opportunities for policy action which will make a difference. However, in order to prevent occupational disease we need first to understand who is exposed to agents which cause conditions such as cancer, asthma, and hearing loss. We need to know how many workers are exposed to these agents, in what industries the exposures occur, and whether available controls are being used. While we may know this for particular worksites or industries, until recently we did not have any idea of the extent of exposure to such agents on a national level. We have developed a method of estimating and describing hazardous exposures at work on a nationally representative basis. This information can be used to model different scenarios to underpin advice regarding which agents should be banned; which agents can be effectively controlled in the workplace; and where the biggest “bang for the buck” can be obtained.

AUSTRALIA'S NUCLEAR RENAISSANCE AND RADIATION FOR LIFE

Dr Doug Boreham

Northern Ontario School of Medicine, Canada

ABSTRACT

Nuclear technology has had a profound impact on health, environment, energy and the economy. For over 70 years, Canada has embraced nuclear technology and has become a world class leader in nuclear power and medical radiation. Canada and Australia share a substantial portion of the world's supply of uranium. Australia is currently debating the economic and societal prospects of the entire nuclear fuel cycle. Experience and lessons learned from a Canadian perspective will be highlighted and compared to the current Australian landscape. Australia is poised to make significant contributions to reduce climate change, produce clean affordable energy, and develop new methods to detect and treat disease, all using modern nuclear technology.

TECHNOLOGICAL ADVANCES AND DIGITAL DISRUPTION: HEALTHCARE'S TIME HAS COME

Dr Louise Schaper

Health Informatics Society of Australia (HISA)

ABSTRACT

Work-related diseases are ideal candidates for prevention and there are clear opportunities for policy action which will make a difference. However, in order to prevent occupational disease we need first to understand who is exposed to agents which cause conditions such as cancer, asthma, and hearing loss. We need to know how many workers are exposed to these agents, in what industries the exposures occur, and whether available controls are being used. While we may know this for particular worksites or industries, until recently we did not have any idea of the extent of exposure to such agents on a national level. We have developed a method of estimating and describing hazardous exposures at work on a nationally representative basis. This information can be used to model different scenarios to underpin advice regarding which agents should be banned; which agents can be effectively controlled in the workplace; and where the biggest “bang for the buck” can be obtained.

TECHNOLOGICAL ADVANCES AND DIGITAL DISRUPTION: HEALTHCARE'S TIME HAS COME

Dr Andreas Mayer

Technik Thermische Maschinen, Switzerland

ABSTRACT

The toxic medium is the aerosol as inhaled. In this spirit traditional PM_{2.5} epidemiology and PM toxicology are inadequate to explain the effects and establish air quality limit values which can protect the exposed urban population. Monitoring, source apportionment and epidemiology must include particle size, number concentration and substance. Toxicology in animal- or cell culture-exposure using PM-samples where UFP are firmly attached by van der Waals forces to large particle surfaces are misleading by systematic artefacts. Aerosol related epidemiology and toxicology methods shall be presented to illustrate the big differences compared to traditional mass related methodologies.

The technical solution is available since 3 decades and meanwhile proven in over 90 million applications on European roads: exhaust gas filtration by ceramic wall flow traps eliminates UFP by over 99 %. These porous trap substrates can be catalytically coated to also convert volatile toxic substances like PAH very efficiently. Application is demonstrated in large numbers for first-fit, option-fit and retro-fit on Diesel engines in all applications and environments – even for high sulfur fuel. This is not limited to Diesel, application to petrol and gas engines is also proven and recommended. The state of the art shall be presented including retrofit of combined SDPF for PN-and NO_x reduction.

The big step for new on-road engines was Euro 6/VI in 2011/14 with the introduction of the particle number count PN criterion #/kWh – prepared over many years by retrofit projects, new PMP measurement and a new health effect. What, however, happens to the large fleet of in-use engines, which will go on to pollute urban air for another 20 years? What we need is a new approach, which mandates the engine manufacturers to provide “Emission Upgrade Technology” readily available options for all their engine technology in operation. Implementing EUT-policy will be the next step and it will definitely be a win-win for industry and public health.

OCCUPATIONAL HEALTH, HYGIENE, SAFETY AND ENGINEERING: DIFFERENT POINTS ON THE SAME TIMELINE

Prof Cas Badenhorst

Anglo American, South Africa

ABSTRACT

Occupational health and hygiene practitioners share a common vision with safety practitioners - that of zero harm (and a healthy and productive workforce) through the effective management of safety and occupational health risks in the workplace. A safe working environment cannot be safe if it is not healthy. And a healthy working environment cannot be healthy if it is not safe. In the fields of both occupational hygiene and safety the focus is on preventing injury and illness. In the case of safety the impact of an incident is immediate and usually affects an individual or small number of individuals whilst a health risk can potentially affect a large number of individuals, and even whole communities, and is usually a result of exposure to a health hazard or a combination of health hazards over a long period of time. In other words, safety is the 'now' and health and hygiene is the 'future' or, indeed, the effects of the 'past' that need to manage. They are merely different points on the same timeline. They are different impacts that happen at different speeds - but with the same potentially harmful results. If a potential health risk is treated as a safety risk and a control failure, as if there could be an immediate impact or an immediate injury, a lot of the health problems that are only picked up years later will be prevented.

This keynote lecture will address the overall value of occupational hygiene - how it is risk based and generally mirrors the processes used to manage safety, a back to basics approach with the emphasis on keeping it simple where possible and cost effective. The discussion will provide the audience with some understanding that the benefits of sound occupational hygiene programmes and practices in the workplace have value to individuals as well as business beyond the prevention of occupational disease. The audience will further be introduced to the concept of "source based, control effectiveness driven" occupational health risk management and the use of Visible Felt Leadership and "health incidents" as tools available to manage workplace health risks.

HEARING CONSERVATION IN THE PRIMARY ALUMINIUM INDUSTRY

Dr Michael Donoghue

Alcoa of Australia

ABSTRACT

Noise induced hearing loss has been an intractable problem for heavy industry. We report our experience minimising the incidence of age corrected confirmed 10dB hearing shifts (averaged over 2kHz, 3kHz and 4 kHz) amongst employees in the primary aluminium industry in Australia over the period 2006 to 2013. Annual audiometric data were analysed to determine the number of hearing shifts that occurred amongst Alcoa of Australia's employees in two bauxite mines, three alumina refineries and two aluminium smelters. The annual hearing shift rates were calculated as the number of shifts divided by the number of employees tested, multiplied by 100. Hearing conservation initiatives undertaken during the study period are described. An assessment of similar exposure group (SEG) noise exposures was also undertaken to determine the magnitude of noise exposure reductions during the study period. When all of the operations were considered in aggregate (mines, refineries and smelters) the hearing shift rates declined from 5.5% per year in 2006 to 1.3% per year in 2013 ($P < 0.001$). The decline in shift rates was particularly marked for the mines and refineries, which started at higher shift rates than the smelters. Modest reductions in noise exposures occurred during the study period. In summary, we report a substantial decline in hearing shift rates and describe the hearing conservation initiatives undertaken during the study period that have collectively been associated with this decline. We suspect these initiatives could be deployed relatively easily and at modest cost in other industries with noise-exposed employees.

WA HARMONISED LEGISLATION – DEVELOPMENT OF THE NEW LEGISLATION AND THE EXPECTED CHANGES FOR THE INDUSTRY

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ABSTRACT

The Western Australian government has proposed to develop a single legislation, Work Health and Safety (Resources) Act, for the resources industry. It will cover mining, major hazard facilities and petroleum industry. The rest of the industry will be under the Work Health and Safety Act being developed by the Department of Commerce. Both legislations are proposed to be based on WHS model with some changes to accommodate WA industry needs.

The petroleum industry and major hazard facilities, as is the case now, will continue to operate under 'safety case'. The occupational health and safety aspect including occupational hygiene for the major hazard facilities which currently is administered by WorkSafe will be transferred to the 'Resources safety legislation'.

For mining industry, necessary changes will be made to the WHS model legislation to suit the needs of the industry. These will be based on National Mines Safety Framework non-core drafting instructions. The mine operators will have the responsibility of developing safety management system and implement it to achieve desired outcomes. It will require risk based management to either eliminate or so far as is reasonably practicable minimise the risk by implementing suitable controls.

It will help minimise prescriptive regulations although some standards in the area of occupational hygiene will still be prescribed.

To increase the awareness of the industry, the Department has planned information sessions for the industry covering risk-based hygiene management planning. The sessions will focus on ventilation, managing noise and diesel emission management plans, as well as hygiene management and contaminants monitoring procedures.

CONCURRENT

HAVE YOU GOT YOUR HEAD IN THE SAND?

Respirable Crystalline Silica Exposures of Restoration Stonemasons

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ABSTRACT

Restoration stonemasons play a vital role in preserving culturally significant heritage buildings and the majority of culturally significant buildings in Sydney are constructed using Sydney sandstone, with an average silica content of 75%. Stonemasons conducting the close inspection required for precision sandstone grinding restoration works are considered at significant risk of exposure to respirable crystalline silica (RCS).

An occupational hygiene survey was conducted to assess the risk of RCS exposure of restoration stonemasons conducting various tasks. Exposure monitoring for respirable dust (RD) and RCS was undertaken and the task of grinding sandstone determined as the highest exposure risk. 'Spinning' and 'Chopping out' tasks were identified as 'high risk' activities with excessive exposures of 4, 6 and 12 mg/m³, well above the workplace exposure standard (WES) of 0.1 mg/m³.

Short duration task monitoring was conducted to better evaluate worker exposures and job rotation during the highest risk grinding task was not determined as a suitable control to reduce stonemason exposures. A trial was undertaken using on-tool dust collecting shrouds attached to local exhaust ventilation (LEV) system to evaluate the effectiveness and suitability to grinding tasks, with a 99% exposure reduction achieved.

Reducing stonemason exposures below the WES was still not possible for grinding tasks; and numerous control measures were recommended to ensure workers are not exposed to concentrations of RCS likely to cause risk to health. Implementation of a combination of control measures is essential in reducing RCS exposure risk. Controls selected in line with the hierarchy of controls include:- mini enclosures, wet methods of dust suppression, on-tool dust collection shrouds and local exhaust ventilation (LEV); along with appropriate respiratory protection commensurate to exposure and powered air purifying respirators (PAPR) when grinding sandstone.

Stonemasons grinding sandstone are considered at high risk of RCS exposure. They were encouraged to participate in equipment trials and evaluate their effectiveness. The more **informed** the stonemasons became, the more **inspired** they were to reduce their RCS exposure and **integrate** small, effective changes during sandstone restoration activities. Utilising knowledge from industry experts was **invaluable** in ensuring a successful trial, and gaining the confidence of the cohort. Throughout the risk assessment process, the stonemasons **increased** their knowledge and understanding of RCS.

Keywords: silica exposure, respirable, crystalline, stonemasons, grinding, sandstone

1. INTRODUCTION AND BACKGROUND

Silica is an extremely common mineral and tens of millions of workers worldwide are exposed to this substance on a daily basis, with many workers suffering diseases caused by respirable crystalline silica RCS. Known as alpha quartz or crystalline silica, it is found in most types of rock, soil, sand, clay and gravel (AIOH 2009). As a major component in building materials such as stone, tiles, concrete and bricks, it poses a risk to health for many workers in a broad range of occupations and industries conducting crushing, blasting, grinding and cutting activities.

Commonly referred to as '*silica*', a higher risk profile is specifically associated with the inhalation of **respirable** sized crystalline silica particles (generally <10 µm) to the lower regions of the lungs (AS2985-2009), leading to the fibrotic lung disease '*silicosis*'. '*Acute*' and '*accelerated*' forms of silicosis are an increasing concern as rapid death can occur within months and/or several years of exposure (Leung et al 2012), where workers are exposed to RCS concentrations ranging from 1.5 to above 10 mg/m³ (NIOSH 2002). '*Chronic*' silicosis often diagnosed after 10 and 30 years of RCS exposure.

RCS is classified as ‘carcinogenic to humans Group 1’ by the International Agency for Research on Cancer (IARC 1997), as a ‘definite lung carcinogen’ by the USA National Toxicology Program (NTP 2000), and is the second highest occupational carcinogen in Great Britain with exposure to RCS considered to become one of the main causes of occupational cancer in the future (HSE 2014). Whilst the carcinogenic status of RCS is widely recognised around the world, it is currently not listed as a carcinogen on the SafeWork Australia Hazardous Substances Information System (HSIS), even though it was identified in Australia as an occupational carcinogenic agent requiring priority preventative action in 2012 (Fernandez et al 2012).

The majority of culturally significant buildings in Sydney are constructed using Sydney sandstone, with an average silica content of 75%. Therefore Sydney sandstone constitutes a significant health risk for restoration stonemasons preserving heritage sandstone buildings, and occupational hygiene assessment for RCS was conducted.

2. SITE & PROCESS DESCRIPTION

The majority of heritage restoration works undertaken at the site are conducted in-situ on sandstone buildings by stonemasons, with work areas often located on elevated scaffold. Site operators use a variety of manual and power tools such as lump hammers, chisels, angle grinders, jackhammers and saws.

Various activities are conducted at this site including ‘chopping out’ old weathered and degraded stone with grinder and jack hammer, ‘spinning’ with grinders, drilling out and pinning sandstone, patching and re-pointing stone, dry sweeping, dry shovelling waste, manual carrying and disposal of waste into skip bins etc.



Figure 1: Lump hammer & chisel



Figure 2: ‘Spinning’ with angle grinder



Figure 3: ‘Chopping out’ with grinder

Source: K. Alamango 2015

Excessive sandstone dust and debris can often be present on work surfaces. Controls such as wet dust suppression methods are not utilised to reduce the generation of dust, and water sprays aren’t suitable for use with grinders. Respiratory protection is usually the only control used to protect operators from RCS exposure, and may be worn when conducting highly dusty tasks, and not when adjacent to dusty processes.

3. MEASUREMENT STRATEGY

An occupational hygiene study was conducted to assess the risk of RCS exposure of a small cohort of 7 workers replacing weathered sandstone on buildings, with personal exposure monitoring for respirable dust (RD) and RCS undertaken.

SIMPEDS miniature size-selecting cyclones were operated at a flow-rate of 2.2 Litres/min, and calibrated pre and post sampling using a calibrated secondary flowmeter as per AS2985-2009. Personal samples were taken within the operator breathing zone to estimate worker exposure to respirable dust (RD) and RCS during a representative work period of (e.g. 8 hours).

When required, 2 hour and 15 minute short term samples were taken during highly dusty tasks. Samples were taken and analysed in accordance with AS 2985-2009 ‘Workplace Atmospheres - Method for Sampling and Gravimetric Determination of Respirable Dust’ in conjunction with the ‘Direct on filter method’ of the National Health & Medical Research Council (NH&MRC) ‘Methods for Measurement of Quartz in Respirable Airborne Dust by Infrared Spectroscopy and X-Ray Diffractometry’, October 1984.

The samples were analysed by NATA accredited laboratory Pickford & Rhyder Consulting using gravimetric techniques and the airborne concentration of RD was calculated using the total volume of air passed through the filter as per (AS2985-2009). RCS analysis by Fourier Transform Infrared (FTIR) Spectroscopy was chosen as its sensitivity has been determined superior to X-ray Diffraction (XRD) with detection limits of as low as 1 to 3 micrograms reported (Ojima 2003).

Results were compared with the current SafeWork Australia Workplace Exposure Standards (WES) for respirable crystalline silica of 0.1 mg/m³ 8 hour, time weighted average (TWA). To place restraint on exposure excursions significantly higher than the WES, results were also compared with the (NOHSC 2001) permissible variation guidelines, where short term (30 minute) exposures should not exceed 0.3 mg/m³ and single short term (15 min) values should not exceed 0.5 mg/m³.

Safework Australia does not publish a WES for respirable dust; however results were compared with the (AIOH 2014) 'Dusts - Not Otherwise Specified' (DNOS) trigger value of 1 mg/m³ (TWA), where trigger values are considered reasonable benchmarks for control implementation.

4. MEASUREMENT RESULTS

The estimated RD and RCS results, for 18 personal samples as measured over three days at the site are summarised in RCS ascending exposure order as follows:-

OPERATOR & TASK (8 hour samples, unless task samples as indicated below)	Respirable Dust (AIOH DNOS trigger value 1 mg/m³)	Respirable Crystalline Silica WES 0.1 mg/m³
Site Manager, supervising works	0.03	0.010
Site Manager, supervising works	0.04	0.024
Labourer, dry sweeping & water washing	0.40	0.115
Labourer, clean-up & pointing and clean with water gurney	0.31	0.140
Stonemason, water gurney cleaning, colour match/stone patching	0.30	0.179
Stonemason, drilling out pins, prepping stone for patching	0.55	0.323
Stonemason grinding and core drilling	0.51	0.350
Stonemason Patching, hand chiselling, opening up joints with grinder for 12 mins (2 hours)	1.20	0.824
Stonemason Grinder 'spinning' with dust shroud (15 mins)	2.11	1.21
Stonemason, indenting stone dressing with grinder	7.06	4*
Stonemason, spinning with grinder, patching & re-tooling with chisels	6.77	4*
Stonemason, stone preparation grinding, hammer & chisel	1.56	6*
Stonemason Grinder 'chopping out' with dust shroud (15 mins)	8.60	6.45
Stonemason, 'chopping out' using grinder & jackhammer	20.5	12*
Stonemason, demolish stone/'chopping out' using grinder & demolition hammer for 40 mins (2 hours)	19.5	15*
Stonemason, Grinder 'spinning' no dust shroud (15 mins)	170	97*
Stonemason, Grinder 'chopping out' no dust shroud (15 mins)	629	472*
BELOW RCS WES & AIOH RD DNOS trigger value		ABOVE RCS WES & AIOH RD DNOS trigger value

RD: Detection Limit 0.01 mg

RCS: Detection Limit 0.005 mg

*Result calculated using percentage of RCS in stonemason RD samples as quartz amount exceeded FTIR calibration range of 1.0 mg per filter

5. DISCUSSION

RCS results for all stonemasons exceeded the WES of 0.1 mg/m³, with some exposures calculated at 40, 60 and 120 times above WES. These results highlight significant risk for workers. RD results for stonemasons conducting spinning and chopping out tasks ranged from 7 to 20 times above the DNOS trigger value of 1 mg/m³.

Results for short duration (2 hour) samples for spinning and chopping out tasks were 8 and 150 times above the WES, and they well exceeded the permissible variation guideline of 0.3 mg/m³. Based on these results, a common control strategy such as job rotation would not be suitable.

The use of half face negative pressure respirators was the predominant method of RCS control for workers, however many exposures far exceeded the protection factor achievable by the respirators of ‘ten times’ the WES. In addition, the majority of operators had beards and/or significant stubble growth, and would not be adequately protected against RCS exposure (AS/NZS 1712:2009). This type of respiratory protection is considered ineffective for workers with facial hair.

Water, whilst generally not used for dust suppression on this site, is highly desirable as a control method as it not only reduces the generation of airborne dust, but also rapidly ages RCS dust, thereby reducing its toxic effect on lung cells (AIOH 2009). Dust captured at the source is the preferred method of controlling dust as it reduces contamination of the work area and reduces exposures for operators and adjacent workers. Therefore, to assess the effectiveness and suitability as a control method, and to quantify potential RCS reductions, equipment trials were undertaken using on-tool dust collection shrouds and local exhaust ventilation (LEV) systems to capture and control dust.

6. EQUIPMENT TRIALS

Trials were carried out using on-tool dust shrouds and an LEV system provided by Makita Australia. The trials were conducted by on-site stonemasons with and without dust collecting shrouds to assess effectiveness. The stonemasons were initially sceptical speculating that the use of dust shrouds would make tasks more difficult and not provide any benefit. The assistance and knowledge from Makita, an industry expert, was invaluable in ensuring a successful trial. They were able to recommend new and innovative tools incorporating anti-vibration technology and dust collection shrouds for a variety of equipment and stonemason tasks. This strategy proved very successful, ultimately gaining the confidence of site personnel.

Results for short term (15 minute) samples for stonemasons conducting spinning and chopping out tasks without dust shrouds were extreme at 97 and 472 mg/m³, and well exceeded the permissible variation guideline of 0.5 mg/m³. Where worker RCS exposures are greater than 1 mg/m³ in an 8 hour work shift, there is greater risk of **acute silicosis** (HSE 2006), and immediate action should be taken to reduce the generation of dust.



Figure 4: ‘Chopping out’ no dust shroud
 Source K. Alamango 2015



Figure 5: ‘Chopping out’ with dust shroud



Figure 6: ‘Spinning’ with shroud

The trials for spinning and chopping out tasks with dust shrouds were very successful in reducing RCS concentrations by a **notable 99%**. However, even with dust shrouds and LEV, RCS concentrations were still 12 and 64 times above the WES for these tasks. Therefore implementation of combination of engineering controls along with a fully comprehensive respiratory protection program in accordance with AS/NZS 1715 is essential to adequately protect workers.

7. RESPIRATORY PROTECTION

The current respirators do not provide sufficient protection for many site tasks, only providing protection for operators exposed to RCS concentrations of up to 10 times the WES, if worn correctly by clean shaven, fit tested operators. It is noted that most site operators had full beards or several days’ stubble growth meaning this type of respirator would have limited effectiveness due to inadequate facial seal.

Respirators must be suitable for the level of risk associated with individual tasks, with a variety provided to suit all workers, face sizes and shapes, and selected for RCS use from Australian Standard:- ‘AS/NZS 1715:2009:- Selection use and maintenance of respiratory protective devices’ with fit testing, respirator use and training mandatory requirements.

Respirators supplied for use were half face negative pressure respirators with replaceable particulate cartridges, for which most operators had not been fit tested. For this workforce, a powered air purifying respirator (PAPR) with P2 filter (e.g. 3M Versaflo M-406 PAPR belt mounted air units) is suitable where high levels of particulate protection is required (e.g. over 10 times and less than 50 times the WES) i.e. for most spinning tasks, or when operators have facial hair growth such as beard, goatee or stubble.

PAPR's with P3 filters are suitable to protect operators from RCS exposures up to and exceeding 100 times the WES, i.e. during chopping out tasks. Whilst PAPR's are widely recognised as appropriate for abrasive blasting activities, stonemasons conducting grinding activities are often exposed to RCS concentrations far in excess of abrasive blasters (HSE 2012), making PAPR's highly suitable for stonemasons. A clean shaven policy may be considered for operators not required to use PAPR's.

8. LOCAL EXHAUST VENTILATION (LEV) SYSTEMS

LEV systems for use with on-tool dust collection shrouds should be chosen as per the AS/NZS 60335.2.69:2012 'Requirements for wet/dry vacuum cleaners', with systems used for 'mineral dust (containing quartz)' required to be 'at least Class M'. In this document, Class M (Medium hazard) systems are suitable for use with hazardous substances with a WES of $\geq 0.1 \text{ mg/m}^3$ such as the Festool Australia CT361M. However, Class H (high hazard) systems are listed as 'suitable for use with carcinogenic dusts' with a WES of $< 0.1 \text{ mg/m}^3$.

The UK Health and Safety Executive (HSE 2012) recommend the use of a minimum Class M system with silica dusts, to better maintain flow rate for superior capture and control of dust. European and International standards (i.e. EN 60335-2-69 and IEC 60335-2-69), recognise RCS as a carcinogen with Class H systems recommended.

There is much confusion with the Class of LEV system that should be used with RCS, and for any system in use, education and training is necessary. Most Australian industry suppliers recommend Class L (low hazard) systems for use with RCS and not the minimum requirement Class M system. In addition, whilst the RCS WES of 0.1 mg/m^3 is borderline for classification as per AS/NZS 60335.2.69:2012, as it is considered a carcinogenic dust by IARC only a Class H system should be chosen for use to ensure workers are adequately protected.

Simple, relevant and practical information should be created by Government legislators to provide guidance to Australian Small and Medium Enterprises (SME) and industry suppliers, to advise suitable LEV systems for the control of RCS.

9. RECOMMENDATIONS

Implementing a range of suitable control measures is required to reduce worker exposure and the generation of RCS dust in the workplace, including but not limited to:- use of mini enclosures for dust containment, on-tool dust shrouds, minimum Class M LEV systems, regular housekeeping, water for dust suppression, training, provision of clean laundered clothing.

Implementation of a fully comprehensive respirator program including:- fit testing, training and appropriate respiratory protection commensurate to RCS concentrations for different activities, including PAPR's for high risk operators.

Health monitoring including work and medical history, physical examination, chest X-ray and lung function tests along with workplace exposure monitoring are required for all workers exposed to RCS above 0.05 mg/m^3 as recommended by SafeWork Australia and the AIOH.

RCS is currently classified as a hazardous chemical by SafeWork Australia. The reclassification of RCS as an occupational carcinogen in Australia, in line with the IARC classification, is considered important to drive action towards ensuring the protection of workers who may be exposed to RCS.

As a priority, it is recommended a new RCS fact sheet is developed created by Government legislators to provide the latest RCS guidance information to small and medium enterprises (SME), equipment suppliers etc. Guidance material should include the IARC carcinogenic classification of RCS, requirements for worker health and workplace exposure monitoring, appropriate types of respiratory protection for worker tasks and exposure concentrations, and cost effective engineering controls including dust collection shrouds and at least the minimum Class M LEV systems for use with RCS.

The creation of industry networking groups is recommended to share knowledge, where SME occupational health personnel can connect with experts including occupational hygienists and equipment suppliers. Information such as exposure data and

new generation equipment, would greatly assist stonemasons and SME's with the preparation of RCS risk assessments and minimisation of RCS exposures.

10. CONCLUSION

Sampling results indicate restoration stonemasons are exposed to excessive RCS concentrations of up to and at times in excess of 12 mg/m³, even with dust shrouds, and therefore may be susceptible to inflammatory lung responses and respiratory system diseases such as silicosis. There is also greater risk of **acute silicosis** when RCS exposures exceed 1 mg/m³.

Exposure monitoring and grinding trials confirmed it is not possible to reduce stonemason spinning and chopping out exposures to below the WES with dust shrouds, and implementation of a combination of engineering control measures, including PAPR's with P2 and P3 filters for some operators and tasks, is essential in reducing RCS risk.

Whilst initially resistant, this stonemason cohort became more engaged as they trialed new equipment and practices. They observed the great effect of **integrating** small changes such as regular housekeeping and hosing of work surfaces to improve their workplace and reduce potential exposures to RCS. The more **informed** the stonemasons became about RCS, the more **inspired** they were to reduce their RCS exposures.

Utilising knowledge from industry experts was **invaluable** in ensuring a successful trial, and gaining the confidence of site personnel. Throughout the RCS risk assessment process stonemasons **increased** their knowledge and understanding of this hazardous material.

11. LIMITATIONS

Whilst numerous chemical and physical hazards were recognised during the survey, this paper is limited to the assessment of RCS & RD exposures.

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MORTALITY AND CANCER INCIDENCE IN BAUXITE MINERS AND ALUMINA REFINERY WORKERS

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ABSTRACT

The Healthwise Cancer and Mortality Study investigates cancer and mortality outcomes in a cohort of employees of Alcoa Australia in Western Australia. The study involves three alumina refineries and three bauxite mines. The third round of cancer and death registry linkage was undertaken in late 2010 and 2011 and we report the findings for the analysis comparing outcomes in workers who were and were not exposed to bauxite dust, caustic mist and alumina dust.

Methods: For this report, mortality data with cause of death was available until the end of 2007 from the National Death Index (NDI), whilst cancer incidence data was complete until the end of 2009, based on data obtained from the Australian Cancer Database (ACD) and the West Australian Cancer Registry (WACR). Age standardized mortality ratios (SMR), Standardized Incidence Ratios (SIR) and 95% Confidence Intervals (CI), were calculated using the non-exposed workers in the mines and refineries as the reference.

Results: There was an association between inhalable alumina dust and cerebrovascular disease mortality (RR=4.55,95%CI:1.64-12.63) but this may be due to a low mortality in the non-exposed workers compared to the general population (SMR=0.58;CI:0.36-0.95). There was an association of increased mortality from non-malignant respiratory disease and bauxite dust with trend p-value=0.04, but this also may be due to a very low risk in the non-exposed compared to the general population (SMR=0.24;CI:0.09-0.64). There was no association found between any workplace exposures examined and the development of melanoma and thyroid cancer even though these were found to be in excess in previous analyses.

Conclusion: Although we found some associations with mortality from exposure to bauxite dust and inhalable alumina, these findings may be due to an increased healthy worker effect in the unexposed workers at the mines and refineries compared to the general population.

COMMON FARMING TASKS AND THE RESULTING CARCINOGEN EXPOSURES

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ABSTRACT

Farming is a very diverse occupation with a high variation in day to day tasks. Therefore, there are a number of carcinogenic exposures to which farmers are potentially at risk. Pesticide use and the resulting exposure has often been the main focus of studies. However, there are many other tasks that farmers undertake which have the potential to expose workers to a range of carcinogenic agents.

To determine the most common agricultural tasks that result in exposure to carcinogens and investigate the control measures currently used to reduce exposure.

The Australian Work Exposures Study (AWES) was a cross sectional study conducted in 2012 that interviewed 4993 Australian workers about the tasks they carry out in their workplace. 148 respondents worked in farming (113 males and 35 females), ranging in age from 18 to 65 years.

On average, farmers were exposed to six different carcinogens. The highest exposure prevalences occurred among males and those working on combination crop and livestock farms. The most common tasks resulting in exposure were working outdoors, using diesel powered equipment and refuelling petrol powered equipment, with over 80% of farmers undertaking each. These common tasks resulted in high exposure prevalences to solar radiation (98%), diesel engine exhaust (93%) and benzene (80%), respectively. Control measures for which there was information were inconsistently used by farm workers.

The variation in tasks they undertake results in exposures to a wide variety of carcinogens and require similarly diverse control measures.

BOWTIES AND HALF WINDSORS: THE EVOLVING FACE OF MANAGING CRITICAL HEALTH RISK IN MINING

Dr Ross DiCorleto, PhD

ABSTRACT

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.

This paper outlines the evolution of a critical health risk management approach which initially started with a well-known safety methodology, the Bowtie. It outlines how this use of common terminology across disciplines is facilitating a better understanding of key health risks within the workforce and line management. It is also proving to be a powerful tool to demonstrate the effectiveness or otherwise of some PPE programs in use.

In addition, it more closely scrutinises the critical controls associated with their management, assesses the true adequacy and effectiveness of those controls and introduces a line owned and managed assurance process.

Keywords: Health, Risk, SQRA[®], Critical Risk, Critical Control

Introduction

From the days of Agricola's "*De Re Metallica*" it has been recognised that there are numerous health hazards and associated risks inherent to the mining process. Whether these are related to particulate inhalation or physical energy exposures such as heat, noise or radiation, they are well recognised risks.

In an earlier paper (Di Corleto & Firth 2012) the structure for the hazard identification and management for health, safety and environment (HSE) at Rio Tinto was discussed. It has been structured into a three level approach. Each stage indicates a particular level of increasing risk and subsequently more rigorous risk investigation and assessment.

The Initial Approach

The first level is undertaken by the employee in the field as a pre-task hazard assessment, and takes the form of STOP, Take 5 or job hazard analysis (JHA), for example. These risk assessments look at the immediate work environment and tasks and are more consequence based. They have been developed to encourage employee ownership of the immediate work environment risk as they undertake their day to day job. They are however, prone to significant subjectivity and often based on the risk acceptance level of the individual. They are qualitative and the results are not always repeatable, particularly across individuals or groups.

The second level introduces a degree of measurement and some limited consistency by utilizing a risk matrix modelled on that introduced in Australia in AS/NZS 4360 (1995). This allows the combination of consequence and likelihood/probability to determine the level of risk applicable to the scenario in question. Rio Tinto has added a level of quantification to the likelihood criteria by including occupational hygiene monitoring results (see Table 1). This process is usually undertaken by a group of individuals familiar with an exposure scenario and often includes one or more participants with health knowledge and skills. Repeatability is improved but there has been an element of "*this is the health team's risk*" and consequent lack of ownership from the field. It can also result in the expectation that the risk should also be managed by them. This is always a risk if the health and safety professional is perceived to have had too much influence when facilitating the assessment.

Likelihood	Proposed Substance Exposure
A - Almost Certain	Frequent (daily) exposure at > 10 x OEL.
B – Likely	<i>Frequent (daily) exposure at > 2 x OEL.</i>
C – Possible	<i>Frequent (daily) exposure at > OEL.</i>
D – Unlikely	<i>Frequent (daily) exposure at > 50% of OEL. Infrequent exposure at > OEL.</i>
E – Rare	<i>Frequent (daily) exposure at ≤ 50% of OEL. Infrequent exposure at ≤ OEL.</i>

Table 1. Likelihood Table for Health Risk Assessment

In the management of critical health risks, the third level of assessment involves a closer examination of the causes and controls and utilises the Health SQRA[®] process as detailed in Di Corleto & Firth (2012). This process has proven to be successful in assisting businesses to obtain a better understanding of the overall cause and control profile of the critical health risks.

To date the implementation of the program has been effective. Part of the success has been as a result of adapting a process already in place and being utilised by the safety discipline at the sites. This had a number of benefits:

- The same terminology was used so is readily understood,
- No introduction and explanation of new terms and hence less confusion
- Not seen as a new process but an extension of one already in place
- Proven track record
- A visual easily understood representation of the cause-control process (Bowtie)
- General documentation and tools already available (with some minor modifications)

This approach is helping to build a stronger understanding of the key health risks that are material to the business and more importantly an understanding of the effectiveness or otherwise of the controls.

Modifications to the Approach

There have been a number of modifications made to the program since the initial implementation in 2011. Some of the key changes have been in relation to:

Higher emphasis on prevention rather than on mitigation

As the term ‘bowtie’ implies, there are two balanced sides to the risk process in the bowtie approach; prevention on the left hand side leading to the exposure event in the middle flowing on to the mitigation controls on the right hand side. In the health approach the vast majority of the time is spent on identifying the left hand side of the process with a much reduced emphasis on the mitigation controls.

Introduction of exposure limits in the determining of risk level quantification

The original risk quantification step was developed based on dose response curves for a number of hazards, i.e. asbestos - (MacDonald & MacDonald, 1986; Hughes, 1991), respirable crystalline silica (HSE, 2002; HSE, 2003) and arsenic (Enterline *et al*, 1987). The effort involved in the adaptation of these curves to the process was found to be resource and time consuming. Given the numerous potential hazards that were required to be assessed at various sites and in some cases the lack of a valid dose response curve, the process was adapted to use occupational exposure limits. This approach has made the process far more practical and user friendly.

How controls are viewed in relation to the bowtie (i.e. PPE)

Controls are defined as: “An act, object (engineered) or system (combination of act and object) intended to prevent or mitigate an unwanted event” (ICMM, 2014).

In many bowtie approaches, PPE is regarded as a mitigation control. However, in order to get a better understanding of the health risk control taxonomy, PPE was included on the left hand prevention side of the Bowtie. This allowed it to be included (reluctantly) as a critical control and then undergo full adequacy assessment. This proved to be quite an enlightening exercise

for non-health focused participants in the risk assessment. The process emphasised the many parameters required to ensure that the PPE even met minimum requirements.

Current Status

In the earlier development of the level 3 process, PPE was purposely included as part of the risk control calculation. Sites were required to estimate the level of impact of their PPE program on the control of exposure. A table was produced and the “% impact” was determined by comparing the overall impact of the many different aspects of a PPE program, ranging from no program or policy up to a comprehensive best practice program. This would allow the business to claim a benefit from PPE of up to 60 % (or a factor of 0.6) in the overall risk score for a best practice program. This reduced by approximately 10% (or part thereof) for each component of the program missing down to 0% for no program in place. An example of the criteria is presented in Attachment 1.

This also proved to be useful in the Level 2 qualitative risk process. There were now some guidelines available for those undertaking these risk assessments to allocate some level of impact from the PPE that was being used. Previously when these assessments were undertaken, PPE was either over-rated or in some instances not included at all as part of the risk control equation. In risk assessment workshops line employees would often ask, “If it has no impact on the risk then why do we use it?” There is no denying that however small, PPE does reduce the amount of exposure to a particular hazard but its success is determined by the effectiveness of the overall program.

The focus on the prevention side of the bowtie along with the inclusion of the PPE has dramatically altered the profile and it now resembles a “Half Windsor” rather than a bowtie. This very soon became an eye opener. One thing that became very apparent was the heavy reliance on PPE as a control and even to the extent that PPE was also acknowledged as being used as a critical control in many of the risk control profiles.

Whilst still in the early stages, a preliminary review of 13 businesses that had undertaken the level 3 assessments on noise exposure has determined that 80% of critical controls were either PPE or Administrative (Figure 1). In relation to substance exposure there was a similar profile with 85% reliance on PPE and/or administrative controls (Figure 2).

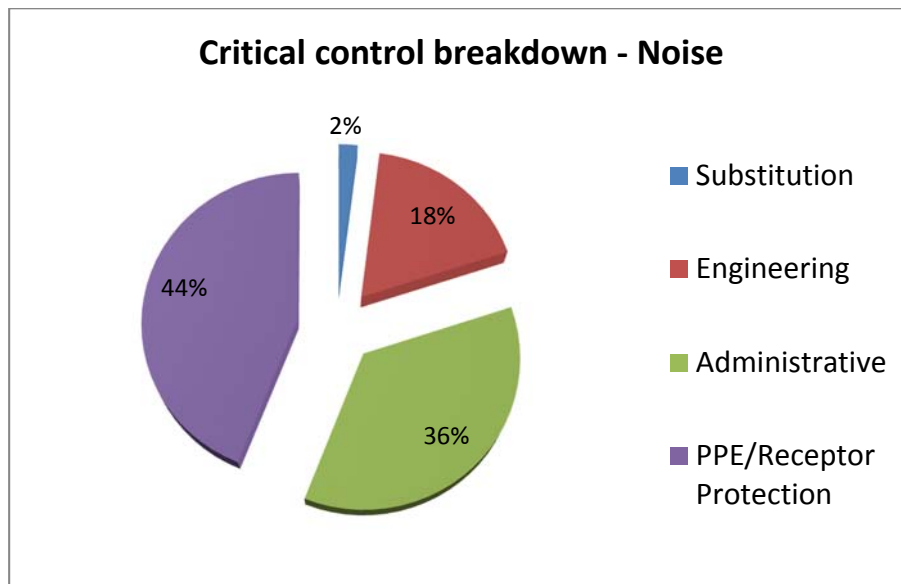


Figure 1: Distribution of control types for noise control.

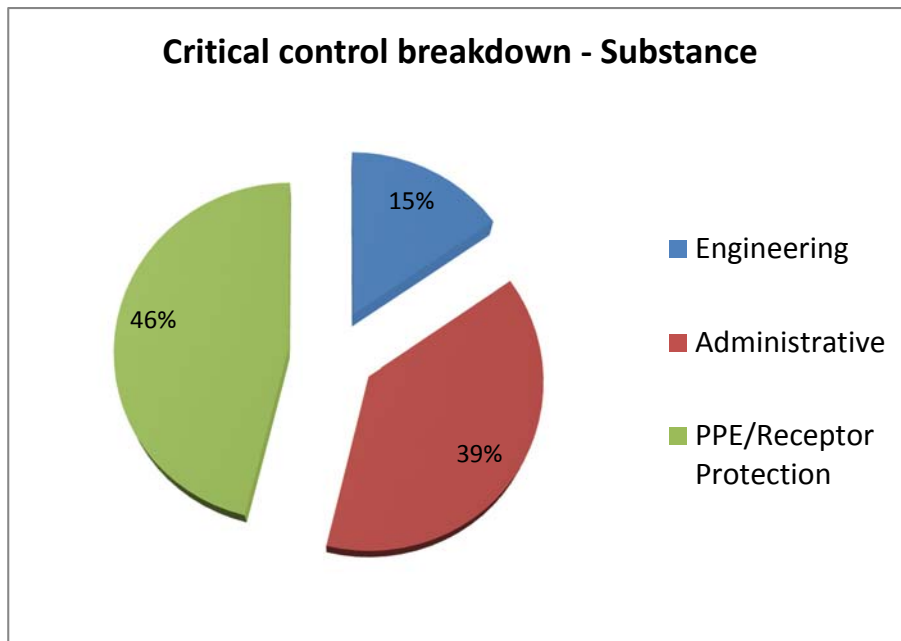


Figure 2: Distribution of control types for substance control.

Once determined as being a critical control they are required to undergo an adequacy assessment. This assessment identifies issues and inadequacies in the critical control and allows businesses to rectify or improve any shortcomings. The next phase of the program requires the identification of key performance indicators of these controls so that a monitoring program may be developed and used to provide assurance that the control is continuing to work as designed. These are referred to as a Critical Control Monitoring Program (CCMP). These measures may be across varying time frequencies and complexity, ranging from an annual full ventilation system balance to the simple daily observation of a red/green coloured magnehelic gauge to determine correct pressure. Metrics are tailored to the group undertaking the measurement and can range from fully documented reports, one page monitoring plans (see Appendix 1) to simple binary ‘yes/no’ checklists which incorporate images and colour (Figure 3).

The implementation of CCMP programs are now being tracked as a leading corporate target across the Group for material health risks in the business.

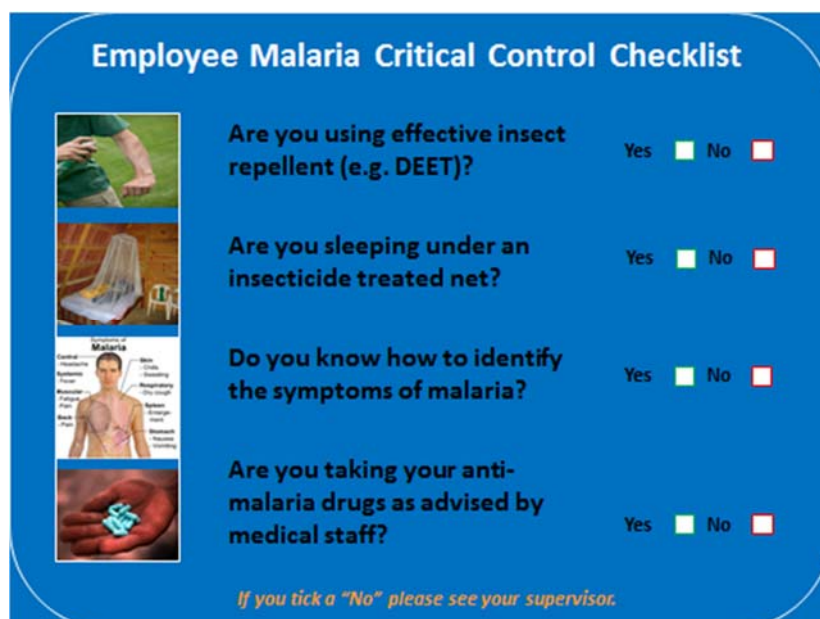


Figure 3: Simple binary checklist for some key Malaria controls for ex-pats.

This risk process is not only identifying the reliance on administrative and PPE controls but it is now pointing out the many shortcomings of this approach and enabling the identification and correction of these gaps.

In the ideal world there would be no need for PPE and all of our controls would be selected from the top of the hierarchy of controls. It is however not an ideal world with unlimited resources to design and implement these controls. At a minimum we are obliged to ensure that those lower end short term controls that are in place and utilised are actually working when implemented and continue to work.

Where to from here?

Allowing PPE to be nominated as a critical control also introduced the requirement of a more comprehensive critical control adequacy assessment. The PPE program was now required to be more closely scrutinized by looking at the design, planning and suitability of the PPE, the implementation program, workforce involvement and the ongoing monitoring and reporting of key performance indicators of the overall program.

This process very quickly picked up areas for improvement and highlighted areas where businesses were lacking. It also began to make businesses more aware of the many aspects and resources required to run an effective PPE program and demonstrate that it is not in fact a quick fix. These programs require an ongoing commitment of human resources and significant financial cost to maintain. This is becoming a powerful tool to demonstrate that PPE is not always the most cost/resource effective approach to management of health exposures. It would be naïve to believe that industry does not rely heavily on PPE and hence it would be remiss of the occupational health professional when it is used, to ensure that systems are in place to confirm it actually functions as designed.

The next phase of the program will be to build on this clearer understanding of the health hazards and the controls across the businesses. We intend to initiate programs to restore the effectiveness of, for example the original ventilation system or acoustic enclosure, or develop the potential engineering controls identified in the initial level three assessments.

Ultimately, the goal is to use the information to educate leadership and develop a control culture that looks first to the top of the hierarchy of controls, not the bottom. It will not happen overnight but at least we now have the tools to help promote them, not only as more effective, but as a good business case.

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
Attachment 1: PPE Impact Table

Personal Protective Equipment Impact Table							
	60 %	50%	40%	30%	20%	10%	0%
Respiratory Protection ¹	As per 50% criteria, plus: Positive pressure powered respirators and/or airline / supplied air respirators available; Formal RPD maintenance program.	As per 40% criteria, plus: Full and half-face negative pressure respirators available.	As per 30% criteria, plus: Quantitative fit testing program; Risk-based spirometry program.	As per 20% criteria, plus: Negative pressure half-face respirator, non-disposable.	As per 10% criteria, plus: Facial hair policy.	Respiratory protection policy; Qualitative fit testing; Negative pressure half-face disposable respirator; Formal RPD training program; RPD audit process, Workplace HSE interaction program.	No respiratory protection policy.
Hearing Protection	As per 50% criteria, plus: Active/radio earmuffs available.	As per 40% criteria, plus: Custom fitted moulded earplugs available.	As per 30% criteria, plus: audiometry program. Quantitative fit testing;	As per 20% criteria, plus: HPD Audit process; Workplace Qualitative fit testing; Annual	As per 10% criteria, plus: Ear muffs and/or disposable earplugs available.	Hearing conservation policy; HPD procedure; Formal HPD training program; Only earplugs available. HSE Interaction program.	No hearing conservation policy.

¹ Note that where biological monitoring is being used it may be utilised to justify a higher level of the PPE impact.

Attachment 2: Worked Example – Critical Control Monitoring Plan For Health Risk

Hazard	Substance	Which of the 19 Rio Tinto hazard types does it align with?
Risk Scenario	Respiratory exposure to fume & dust (Potroom)	What is the title of the equivalent risk scenario(s) in SQRA?
Risk owner	Potroom Manager	Who is the risk scenario owner?
Reference Documents	SEG 1 (Potroom Operators) Flouride & Dust monitoring results. Extraction system design specifications. Preventative maintenance planning schedule and criteria.	The primary documents where information about the critical control exists. For example, the Operating Procedure, Design Standard, Work Instruction, monitoring results, regulatory requirements etc

Control Definition (Steps 1 & 2)				Measures (Step 3)					
Critical Control <small>(What is the title of the critical control?)</small>	Control Hierarchy	Control Objective <small>(What is the objective of the control that prevents or mitigates the major hazard and makes it critical?)</small>	Control Owner <small>(Who is the owner of the specific control?)</small>	Performance criteria <small>(What is the criterion to be achieved to meet its objective?)</small>	Measurement process <small>(What process could be used or established to determine whether the control meets its performance requirements?)</small>	Metric <small>(What measurable outcome would be applied?)</small>	Target <small>(What is the target performance?)</small>	Frequency & Rating <small>(At what frequency would the measurement occur & what is the current rating?)</small>	Responsibility <small>(Who has direct responsibility for the measurement occurring?)</small>
Fume extraction System	Engineering	To ensure that the fume extraction system operates and is maintained to meet design requirements.	Potroom Manager	Scheduled preventative maintenance is carried out on the system monthly	Internal and/or external auditing of PM schedule in the business solution	Percentage of PM completed to schedule.	>95% 70%-95% <70%	Quarterly 	Maintenance Superintendent
				System flow is measured and balanced every six months	Internal and/or external auditing of PM schedule in the business solution.	Percentage of balances completed to schedule.	100% 50% <50%	Six monthly 	Maintenance Superintendent
				System capture velocity is at design specification	Face velocity measurements undertaken every three months for at least six pots per line.	Percentage of measurements within control design criteria	>95% 70%-95% <70%	Quarterly 	Maintenance Superintendent
Overall Rating									 On Watch

One rating is selected for each criterion

The overall rating is based on the weighting of the different criterion but can only be satisfactory if all targets are achieved

ARE YOU ADEQUATELY PROTECTING WORKING MOTHERS? A REVIEW OF KEY REPRODUCTIVE WORKPLACE PHYSICAL HAZARDS ASSOCIATED WITH PREGNANCY

Dr Ellen Di Corleto, MBBS and Dr Ross DiCorleto, PhD

ABSTRACT

Within the changing socio-economic climate and across cultural divides we are seeing more females in the workforce that whether by choice or necessity, remain at work well into the final stages of their pregnancy, often returning to work after only a short period away from the workplace. It is important that the occupational hygienist is aware of the potential increased risks associated with exposure of pregnant employees and their future children to some of these hazards. This paper reviews the literature in relation to three of these key physical exposures and highlights a selection of the more common risks that need to be identified and controlled. The review has found that exposure to these three physical occupational exposures can potentially place women at an increased risk of preterm delivery, spontaneous miscarriage and intrauterine foetal demise, but the threshold level of exposure to trigger these events is not easily ascertained. Other consequences found included intrauterine growth restriction, congenital foetal anomalies and potential for learning difficulties, but these are not confirmed. While heat exposure has many studies providing strong evidence of these adverse effects in relation to women and pregnancy, more research into the effects of noise and whole body vibration on pregnancy is required.

Keywords: Pregnancy, whole body vibration, heat, noise, occupational exposure,

BACKGROUND

It was Bernardino Ramazzini, recognized as the father of occupational medicine that first asked the question, "What is your occupation?" In his book *De Morbis Artificum Diatriba* (Ramazzini, ("Diseases of Workers")) he emphasized the importance of an individual's occupation on their health and wellbeing. What is not as well known is that in relation to women as weavers he also stated "Now an occupation so fatiguing naturally has its drawbacks, especially for women, for if pregnant they easily miscarry and expel the fetus prematurely and in consequence incur many ailments later on"(Ramazzini, 2001).

Many centuries later the asking of that original question has become commonplace amongst occupational health professionals. However, is it a routine question asked by a general practitioner when a female worker is first diagnosed as being pregnant?

There are studies (Zenz 1994, Paul 2004, Sakr et al 2010) that outline the hazards associated with exposures to reproductive toxins, teratogens and mutagens and due to the enormity of the range of potential chemical and physical exposures impacting on pregnancy, the discussion in this paper will be limited to three particular occupational exposures: heat, noise and whole body vibration. These three hazards have been chosen as they are becoming key issues within the mining environment particularly as we see an increase in female heavy mobile equipment operators and the locations of many of the mines in regions of elevated temperature.

Method

This paper presents a narrative review of a number of papers from literature related to physical hazard exposures and potential outcomes associated for pregnant mothers and in the foetus. It will attempt to summarise a number of studies (including a meta-analysis) addressing the key areas of exposure. Literature was searched via a number of recognised scholarly literature search engines including but not limited to PubMed, Medline, CINAHL and UQ Summon.

Discussion

In the opening paragraphs of this paper Ramazzini's question relating to occupation was highlighted for a reason. We have seen by reviewing just three physical workplace hazards that there is indeed significant evidence that the pregnant mother is at increased risk in the workplace. Whilst this may not come as a surprise to many it still begs the question as to how many general practitioners, let alone employers ask the question of the mother's occupation, which should lead to understanding of potential work exposures. The first trimester presents as a key period of susceptibility. This is also often a time of uncertainty for the new mother, whether the pregnancy is unknown or they wish it to remain private until after this period of vulnerability is successfully completed.

1. Heat exposure in pregnancy

A seminal study by Edwards et al (1978) identified the significant teratogenic potential of heat in many mammalian species. The impact of heat (hyperthermia) as a potential teratogen in humans has also been acknowledged for many years. The influence of elevated temperatures on pregnant mothers is increased as the mother must dissipate not only her own excess heat but also the foetal body heat which is usually approximately one degree higher than her own.

Pregnancy also tends to make the mother more susceptible to heat stress. This may be as a result of added fat deposits and the decrease in the ratio of body surface area to body mass. This has a negative impact on the ability of the pregnant mother’s ability to cool via the loss of heat to the external environment. (Tillet 2011)

Epidemiological studies have shown correlation between reduced birth weights and mean annual temperatures in a number of different global regions (Roberts 1968). It can also cause intrauterine growth retardation during later stages of the pregnancy (Bell 1987). Of the more serious adverse effects the main target is the central nervous system (CNS), particularly in the first trimester of the pregnancy. The CNS is most affected because the rapidly multiplying cells are very sensitive to temperature elevations. (Upfold et al 1987).

Miller et al (2005) assessed the rate of birth defects induced by hot conditions during pregnancy. They found that there appeared to be no threshold for hyperthermic events and that temperature elevation for any duration during pregnancy has the potential for adverse effects. To this point Miller et al (2005) conclude, that there is unlikely to be a specific threshold and state: “any temperature increment for any duration has some effect”. In an earlier study by Miller et al., (2002), where they evaluated peer-reviewed literature, the percent of embryological defects versus a specific thermal dose showed “an essentially linear relationship between thermal dose and percent embryological defects”.

Over the years there have been a number of suggested thresholds for hyperthermia induced bio-effects (see table 1). These include but are not limited to:

- 1.5°C – 2.5°C above normal physiological levels (Edwards 1986)
- 2°C above normal (Kimmel et al (1993)
- No more than 1.5°C above normal physiological levels (Barnett et al 1994)

Early developmental effects (Embryonic)	Mid – late foetal effects
Anencephaly	Pre-term delivery
Spina bifida	Growth retardation
anophthalmia	Abortion
Resorption or abortion	Learning deficits
Heart anomalies	Blindness
Neural tube defects	Cleft lip
Central nervous system	

Table 1. Hyperthermia related bio-effects. (Adapted from Edwards et al 2003)

In 2014, a study by the University of Montreal’s Department of Social and Preventative Medicine found a number of interesting observations. The study assessed data from over 300,000 births in Montreal over the period of 1981 to 2010. It was found that for pregnant women who reached 37 – 38 weeks of the term there was a 17% risk of early term delivery following a three day episode of 32°C or more. This increased to 27% if the episode lasted form 4 – 7 days (Auger et al 2014).

There were limitations associated with this study, that were highlighted,

- miscarriages and caesarean deliveries were not included,
- confounding environmental factors such as smoking and potential use of air conditioning as mitigation controls,
- use of individual-level birth data rather than aggregated daily number of births.

Whilst there appears to be inconsistency in the level of the threshold temperatures (range of 0 to 2.5°C) this is most likely due to the developmental stage at which the exposure occurs and hence the variability of the sensitivity of the

embryo/foetus. It would appear therefore that such values will vary and are tissue and developmental stage specific (Edwards et al 2003). Hence different time-temperature windows and thresholds will significantly impact on the different endpoint consequences (Ziskin et al 2011). Much of the data in this area is based on either general mammalian studies (Edwards et al 1978, Edwards et al 2003, NCRP 2002) or on a retrospective approach (Shiota 1982, Smith et al 1978, Erikson et al 1991) however there is significant evidence that exposure to elevated temperatures of the pregnant mother can be harmful to the developing foetus.

2. *Noise exposure in pregnancy*

One of the biggest concerns with noise exposure is the effect on hearing loss, with noise-induced hearing loss being known as one of the major causes of preventable hearing loss for decades (Seidman and Standring, 2010). In relation to pregnancy, foetal hearing is developed by 24 weeks gestation, with maturation of auditory pathways by 28 weeks. In relation to noise exposures to the foetus, the uterus is an effective sound attenuator. This attenuation of external noise varies from 39 decibels at 500 Hz to 50 decibels at 3000 Hz. (Zenz 1994, p. 832). An important aspect to also bear in mind is that the average sound level inside uterus due to physiological processes is 85 decibels (about the same as a passing diesel truck). This level of exposure is equivalent to most modern occupational exposure limits. It is thought that foetal hearing is through bone conduction rather than through external and middle ear systems, based on studies on ewes (Gerhardt and Abrams, 1996).

There is varying evidence in relation to the impact of noise exposure on the foetus in pregnancy.

Dzhambov et al (2014) found both negative effects and minimal effects in relation to prolonged noise exposure in pregnancy. This was based on performing a meta-analysis involving thorough investigation of 29 shortlisted studies and focusing on key factors identified in earlier studies in relation to impact of noise exposure. These studies spanned a 30-year time period in three different languages. They found no effect on preterm birth, preeclampsia, perinatal death or spontaneous abortion, but noise exposure impacted maternal blood pressure levels, increasing the risk of gestational hypertension. This causes uterine blood flow to the placenta to reduce as a result, thus causing an increased rate of intrauterine growth restriction.

Wu et al (1996) noted, in their study of the impact of noise exposure on the foetus, that there were no adverse effects on birth weight. The study involved monitoring noise exposure via the use of personal dosimeters, with a total of three different timeframes monitored (first, second and third trimesters). Wu et al (1996) also utilised known causes of low infant birth weight in conjunction with the noise exposure findings to make their conclusion. Rocha et al (2007) studied hearing in children exposed to occupational noise versus children who were not exposed, with no increased number of children affected by a hearing impairment after intrauterine exposure to occupational noise.

However there are a number of studies that have indicated adverse effects.

The main adverse effect of occupational noise exposure noted by many studies is a decrease in birth weight, either as small for gestational age, intrauterine growth restriction or low birth weight (Figa-Talamanca, 2006; Hartikainen et al, 1994; American Academy of Paediatrics Committee on Environmental Health, 1997; Nurminen, 1995). Other effects of noise exposure include increased risk of miscarriage (Figa-Talamanca, 2006), unnamed and named congenital abnormalities such as urogenital abnormalities (Figa-Talamanca, 2006; Krueger et al, 2013), preterm birth (Figa-Talamance, 2006; American Academy of Paediatrics Committee on Environmental Health, 1997; Nurminen, 1995), decreased placental lactogen levels (Krueger et al, 2013; Nurminen, 1995) and intrauterine foetal demise (Zhang et al, 1992). Krueger et al (2013) also mentioned the risk of hearing deficits and abnormal childhood social behaviours as a result of occupational noise exposure in pregnancy, but no further evidence in relation to occurrence or significance was noted in the paper.

Another effect of noise exposure to the mother involves the activation of a stress response mechanism, resulting in the activation of the sympathetic-adrenal axis (Prasher, 2009). This in time releases catecholamines, which can increase maternal blood pressure and lower uterine blood flow, affecting placental blood flow and foetal oxygenation (Dzhambov et al, 2014; Krueger et al, 2013). Maternal cortisol is easily passed through the placental barrier, and can therefore affect the foetal hypothalamic-pituitary-adrenal axis, resulting in potential effects on neonatal cognitive development (Davis and Sandman, 2010). The increased cortisol release in relation to the stress response caused by noise exposure may also cause problems with reproduction disturbances and infertility, but the cortisol may not be a primary cause of reproduction issues based on a study by Herod et al (2011).

Whilst there is varying conjecture on the impact of noise during pregnancy the general consensus is that there can be adverse effects on the new born where the mother has been exposed to elevated noise levels. However, the extent of the impact on the new born, as well as the critical time at which the foetus is at greatest impact, is still inconclusive, with many studies contradicting each other, and only a small amount of human research involved. This is a field where ongoing research would be recommended.

3. **Whole body vibration in pregnancy**

In general, there are limited studies into the effects of whole body vibration in relation to pregnant working mothers as has been noted by others (Burgess & Foster, 2012).

A number of studies were undertaken in the 1990's, and in a meta-analysis undertaken by Seidel (1993) vibration was linked to a number of adverse conditions including:

- uterine prolapse
- menstrual irregularity,
- spontaneous abortions, and
- still births

These were mainly associated with transport related occupations such as public transport and crane operators. This was also reflected in a literature review relating to hazards associated with air medical work during pregnancy (Van Dyke, 2009) including the comment "*Vibration exposure can probably contribute to the pathogenesis of disorders of female reproductive organs (decrease in uterine blood flow, menstrual disturbances, and anomalies of position) and disturbances of pregnancy (abortions, stillbirths)*" from a study by Penkov (2007). It is worth noting that the comment begins with "vibration exposure can probably..." which reflects some of the uncertainty still evident in the relationship between whole body vibration and the pregnant mother.

Zenz et al state that vibration exposure in the range of 5-10 Hz can be damaging when it resonates through the human body (Zenz 1994, p. 832). Whilst there is limited epidemiological information relating to whole body vibration there have also been a number of studies involving either modelling of scenarios and animal studies.

Modelling of spinal load as a result of whole body vibration showed that pregnant mothers experienced a higher spinal load than non-pregnant women (Abrams 1993). Qassem and Othman (1997) developed a mechanical model of a 60 kg pregnant woman and subjected the model to a series of vertical and horizontal vibrations to assess the impact on the different body segments. The study revealed that the vibrations effect varied from segment to segment. Horizontal vibrations tend to affect the torso more so than the vertical vibrations which impact more on the thorax region.

In animal studies carried out by Nakamura et al (1996) vibration exposure to pregnant rats showed decreased uterine blood flow, prostaglandin E2 and decreased levels of progesterone there were also increased levels of corticosterone observed. Other such studies (Skilianov et al, 2005, Ohsu et al 1994) have identified potential impacts associated with chronic placental insufficiency.

This is being recognised in many regions and there are now more countries beginning to put in place guidance and regulations specifically in relation to this impact. For example in the Health and Safety Executive document on whole body vibration control, 118 Regulation 5(3)(c) requires the employer to "...take particular account of people who are more sensitive to vibration..... pregnant workers and those who have recently given birth."

Conclusion and Recommendations

There is strong evidence in the literature that exposure to elevated temperatures during pregnancy can result in deleterious consequences for the mother but from the studies reviewed, more specifically for the foetus. Impacts can include:

- CNS defects,
- neural tube defects,
- cardiovascular abnormalities,
- abortion, and
- pre-term delivery.

It is difficult to pinpoint a threshold as the impact of the temperature elevation is very dependent on the stage of the pregnancy and hence those particular mechanisms occurring in the embryonic or foetal development.

There is growing evidence that exposure to excessive levels of whole body vibration can result in serious consequences which can include:

- uterine prolapse,
- menstrual irregularity,
- spontaneous abortions, and
- still births.

There is still some uncertainty but there is growing evidence of the negative impact of whole body vibration on the pregnant mother and her child. There is a need for more information and research in this area in order to better characterise these risks.

There is less conclusive evidence on the consequences for the mother and child associated with exposure to noise, as there are fewer studies that focus on the effects of intrauterine noise exposure in humans. The main adverse effect of occupational noise exposure noted by many retrospective studies is a decrease in birth weight, either as small for gestational age and/or intrauterine growth restriction. Other significant effects such as preterm delivery, intrauterine foetal demise and hearing deficits in offspring have been noted in the literature, but more extensive research is needed to determine if these are true complications as a result of occupational noise exposure.

There is a very real need for the raising of awareness of prospective and expecting mothers. Whether their medical provider or occupational health professional undertakes this, it needs to be done to ensure that they and their employers understand there are potential risks being faced and thus be able to make an informed decision in relation to their work and the possibility of adverse consequences to themselves and their children.

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ISOCYANATES: FROM NAZI BOOTS TO BREAST IMPLANTS WHAT TO MONITOR AND WHY?

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ABSTRACT

(Di) Isocyanates are a family of highly reactive, low molecular weight chemicals, predominantly manufactured for use in the production of Polyurethane. Polyurethane is one of the most versatile polymers in existence; the utility of this polymer ranges from mattresses and bowling balls to thermal insulation, shoe soles and hard wearing protective coatings. In 1998, 7.5 million tonnes^[1] of polyurethanes was produced globally and it is expected to reach 17,946.20 kilo tons next year^[2]. Polyurethanes are produced by reacting the diisocyanates with polyols and other chemicals. The diisocyanates used most predominately in this process are toluene diisocyanate (TDI) and methylene bisphenyl isocyanate (MDI). These (di)isocyanates pose a health risk to anyone who is exposed, both during their production (Bhopal, where up to 8000 may have died after a release of methylisocyanate) and as end users. So how do we monitor these chemicals to ensure a safe working environment?

^[1] *MDI and TDI: Safety, Health and the Environment. A Source Book and Practical Guide*

^[2] Plastemart.com

PERSONAL PROTECTIVE CLOTHING (PPC) TREATED WITH PROBAN® – EXPOSURE TO FORMALDEHYDE THROUGH SKIN AND INHALATION

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ABSTRACT

There are growing concerns about the health effects of formaldehyde exposure due to occupational exposures experienced by workers required to wear PROBAN® treated clothing. PROBAN® is a chemical additive and process that is applied to fabrics to provide flame retardancy. The objective of the assessment was to determine whether workers are potentially exposed to formaldehyde through skin and via inhalation while wearing PROBAN® treated clothing. Brand new and previously worn and washed PPC garments were tested for this research. Personal monitoring was undertaken to determine formaldehyde levels workers could be exposed to while opening packaging and wearing PROBAN® treated clothing. Additionally, laboratory analyses of PROBAN® treated clothing were undertaken according to DIN EN ISO 14184-1 (2011-12) to determine whether formaldehyde content in textiles complies with interim non-regulatory reference limits published by the Australian Competition and Consumer Commission (ACCC).

Keywords

PROBAN®, formaldehyde, formaldehyde health effects, formaldehyde in fabrics

Introduction

This study was undertaken following recognition of concerns regarding potential exposure to formaldehyde through inhalation and direct skin contact while wearing clothing that has been treated with PROBAN®.

PROBAN® is a chemical additive and process that is applied to fabrics made of cellulosic type fibres (such as cotton) to provide flame retardancy. This process is understood to produce formaldehyde as a by-product. During the PROBAN® process an inert cross-linked polymer is formed. This polymer is embedded within the individual fibres of the clothing and is insoluble. Majority of the formaldehyde is “locked” in a cross-linked polymer embedded within the individual fibres and is not available for exposure; however, some formaldehyde may still be present as a “free” compound in brand new PROBAN® treated clothing.

The objectives for this study were to assess whether opening packaging containing PROBAN® treated clothing, donning and wearing PROBAN® treated clothing poses a risk of exposure to formaldehyde at concentrations that may lead to adverse health effects. A secondary objective was to determine if the residual concentration of formaldehyde in PROBAN® treated clothing was below interim, non-regulatory reference limits published by the ACCC (the reference limit).

This study was undertaken in three separate stages:

Stage 1 – Inhalation study

A selection of PROBAN® treated clothing in its original packaging was randomly chosen from a storage facility. This study involved direct read testing of formaldehyde concentrations inside each packaging; followed by personal exposure monitoring for formaldehyde on workers while the clothing was unpacked, donned and worn for a designated period of time.

Stage 2 – Skin exposure

A selection of PROBAN® treated clothing in its original packaging as well as previously worn and washed clothing items were assessed. This study involved the selected items being tested for formaldehyde content and the obtained formaldehyde concentrations being compared to the reference limit.

Stage 3 – Skin exposure – removing excessive formaldehyde

PROBAN® treated clothing identified in previous tests as containing high concentrations of formaldehyde were selected for further study. The objectives were to identify whether residual formaldehyde could be removed or the concentration reduced by washing the items following the manufacturer’s washing instructions, and to identify how many washes are required to reduce formaldehyde concentrations below the reference limit.

Exposure Standards and Consumer Guidelines

Inhalation

A Workplace Exposure Standard (WES) for exposure to formaldehyde through inhalation is set by Safe Work Australia. An 8-hour time weighted average (8-hr TWA) and a 15-minute short term exposure standard (STEL) are both available for formaldehyde (see Table 1). Based on Safe Work Australia information, formaldehyde is classified as a “sensitiser”. Sensitiser means that the particular chemical compound can cause a specific immune response. Exposure to a sensitiser, once sensitisation has occurred may manifest itself as a skin rash or inflammation or as an asthmatic condition, and in some individuals this reaction can be severe.

Table 1 – Formaldehyde Workplace Exposure Standard

Compound	TWA		STEL		Notes
	ppm	mg/m ³	ppm	mg/m ³	
Formaldehyde	1	1.2	2	2.5	Sensitiser

Consumer Guidelines

There are currently regulations for formaldehyde in fabrics in a number of countries. In Australia, the ACCC has provided interim, non-regulatory reference limits for concentrations of formaldehyde in various products based on limits set by the European Union Standards. These are:

- Infant’s clothing – 30 ppm (parts per million)
- Clothing specifically marketed as suitable for people with sensitive skin – 30 ppm
- Garments which contact skin – 100 ppm
- Other garments or fabric – 300 ppm.

Methodology

Sampling for Formaldehyde inside Clothes Packaging

Direct read monitoring was undertaken using colorimetric tubes – specific to formaldehyde (Dräger – Formaldehyde 0.2/a) in conjunction with a hand held sampling pump (Dräger Accuro® Pump). The standard measuring range of this tube is 0.2 – 2.5 ppm (requiring 20 pump strokes) or 0.5 – 5 ppm (requiring 10 pump strokes). A leak test was performed on the pump prior to monitoring.

The principle of this monitoring is to draw the air through the tube. If formaldehyde is present a chemical reaction will cause the contents inside the tube to change colour from white to pink.

All direct read samples were taken from inside new unopened clothes packaging. Each sampled packaging/gear bag was opened just enough to place the sampling tube inside and directly sample the atmosphere inside the packaging.

Personal Monitoring

All clothing items used for direct reading of formaldehyde inside enclosed packaging were subsequently used for personal monitoring. Personal monitoring was undertaken simulating normal situations, meaning picking up a package with a new piece of clothing, opening the packaging, donning the clothes and wearing it for a period of 15 minutes. Personnel were asked to move around and undertake tasks simulating field conditions while wearing the PROBAN® treated clothing. Different clothing combinations were tested to simulate real-life situations.

Personal monitoring was undertaken using UMEX 100 passive samplers for formaldehyde. The sampler contains a treated tape for formaldehyde sampling. The tape incorporates a “blank/correction” section in addition to the sample section.

Analysis is by high-performance liquid chromatography (HPLC) for identification of formaldehyde that may be present in the sample. The sampler collects formaldehyde in the 5 parts per billion (ppb) to 5 parts per million (ppm) range.

Due to the UMEX 100 relatively high sampling rate and sensitive analysis, it can be used for 15-minute sampling in the ppm range. The UMEX 100 validation range is 0.06 to 3.0 ppm. The lower detection limit for 15-minute monitoring is 0.2 ppm.

Personal samples were delivered to a NATA accredited laboratory under a chain of custody (COC) and analysed for formaldehyde concentrations.

Formaldehyde in Textiles

A selection of PROBAN® treated clothing in its original packaging as well as previously worn and washed clothing items were assessed for formaldehyde content in fabrics. The laboratory analysis followed the DIN EN ISO 14184-1 (2011-12) *Textiles – Determination of formaldehyde – Part 1 – Free and Hydrolysed Formaldehyde*. The methodology involves three steps:

1. Cutting out a fabric sample (approximately 10x10cm sample – up to 2g of fabric) of provided uniform items.
2. Placing these samples into 40°C water for formaldehyde hydrolyses using specified reagents, and obtaining a sample of the reaction solution.
3. Mixing the reaction solution with another reagent (DNPH) to obtain a final solution for analysis by HPLC with ultraviolet detection.

The laboratory results are provided in mg/kg (milligrams of formaldehyde per kilogram of textile). The reference limit is provided in parts per million (ppm). Mathematically, mg/kg is equal to ppm and therefore no recalculation was required.

Fabric samples were taken from different parts of the uniform items to ensure representative samples were obtained. Samples were taken from areas expected to be in direct contact with skin when worn. Some uniform items had reflective strips and printed signs; these were not included in samples as they were on the outside of the item and would not be in direct contact with skin. In the case of multiple layers of fabric the inner lining was sampled.

Removing Excess Formaldehyde

The Manufacturer's instructions (*Care and Maintenance of PROBAN® Treated Garments*) state that PROBAN® treatment should last for at least 50 washes at 75°C providing the correct laundering instructions are followed.

In the majority of situations, personnel would be expected to take their uniforms home to be washed. Therefore this assessment aimed to replicate as far as possible normal household washing procedures.

The Manufacturer's washing instructions state that items can be tumble dried. For the purposes of this assessment, tumble drying was not used as not every household has a dryer or may not be using a dryer during the summer months. Therefore, as a representative domestic scenario uniform items were washed using OMO Radiant washing powder (recommended by the Manufacturer) on a 40°C washing cycle and dried in air by hanging on a clothes line.

Once dried, fabric samples were taken from each item, appropriately packaged and delivered under COC to the laboratory for formaldehyde analyses. This process was repeated four times.

Table 2 provides a summary of methods used in this study.

Table 2 - Summary of Sampling Methods Used

Study stage	Sampling performed	Clothing items	Sample time (min)	n	Equipment	Method
Stage 1 – Inhalation study	Air sampling inside clothes packaging	1x pants 1x jacket 4x overall (different types) 2x vest (different types) 5x chainsaw trousers/chaps (different types) 1x neck flap 1x badge 3x gear bag (containing mix of previously worn and washed uniform items)	1.5 – 3 (10 – 20 pump strokes)	18	Dräger – Formaldehyde 0.2/a tube and Dräger Accuro® Pump	Direct read result – colorimetric tubes
	Personal monitoring (opening packaging, donning and wearing PROBAN® treated clothing)	1x overall 1x overall + helmet + neck flap 4x chainsaw trousers/chaps + jacket + helmet + neck flap 1x chainsaw chaps + jacket + pants + helmet + neck flap + vest 1x jacket + pants + helmet + neck flap 2x overall + helmet + neck flap 1x overall + vest + helmet + neck flap 1x overall (from a previously used gear bag)	15	12	UMEX 100 passive samplers for formaldehyde	OSHA 1007 – Formaldehyde – diffusive sampler
Stage 2 – Skin exposure	Formaldehyde in fabrics	1x overall (previously worn and washed) 3x overall (new - different types) 1x jacket (new) 1x pants (new) 1x chainsaw trousers (new)	N/A	7	Laboratory analyses using HPLC with ultraviolet detection	DIN EN ISO 14184-1 (2011-12)
Stage 3 – Skin exposure – removing excess formaldehyde	Formaldehyde in fabrics – washing process	1x jacket 1x pants 1x chainsaw trousers 1x overall All items tested brand new then washed 4x and tested after each subsequent wash	N/A	20	Laboratory analyses using HPLC with ultraviolet detection	DIN EN ISO 14184-1 (2011-12)

Results

Stage 1 – Inhalation study

Table 3 provides a summary of the results obtained from direct read sampling.

Table 3 – Direct Read Results – Inside Packaging

Clothing items	Formaldehyde concentration (ppm)
Pants	< 0.2 *
Jacket	< 0.2
Overall (different types)	< 0.2
	< 0.2
	< 0.2
	< 0.2
Chainsaw chaps (different types)	< 0.2
	< 0.2
Gear bag (containing a mix of previously worn and washed clothes)	< 0.2
	< 0.2
Vest (different types)	< 0.2
	< 0.2
Badge	< 0.2
Neck flap	< 0.2

Chainsaw trousers	> 5
	> 5
	> 5

*0.2 – detection limit for the relevant analytical method

A summary of results of the personal sampling for inhalation exposure are provided in Table 4. Results were all below the detection level for the method and indicated that personnel are unlikely to be exposed to formaldehyde in air at concentrations at or above either the STEL or the WES.

Table 4 – Personal Exposure Monitoring Results – 15 minutes

Clothes combination	Formaldehyde concentration (ppm)
Overall	< 0.2*
Overall + helmet + neck flap	< 0.2
	< 0.2
	< 0.2
Overall + helmet + neck flap + vest	< 0.2
Overall (previously worn and washed)	< 0.2
Chainsaw chaps + jacket + helmet + neck flap	< 0.2
Chainsaw chaps + pants + jacket+ helmet + neck flap + vest	< 0.2
Jacket + pants + helmet + neck flap	< 0.2
Chainsaw trousers + jacket + helmet + neck flap	< 0.2
	< 0.2
	< 0.2

*0.2 – detection limit for the relevant analytical method

Stage 2 – Skin exposure

Results of testing for formaldehyde in clothing showed concentrations ranging from below 10 ppm to 270 ppm – see Table 5. Results shown in red are those which were above the reference limit.

Table 5 – Results for garments expected to be in direct contact with skin

Clothing items	Formaldehyde concentration (ppm)
Gear bag – Overall returned from field, uniform item previously washed	< 10*
Overall	30
Overall (different type)	69
Jacket	120
Pants	270
Chainsaw trousers	240
Overall (different type)	250
Reference Limit – Fabric in direct contact with skin	100

*10 ppm – detection limit for the relevant analytical method

Stage 3 – Skin exposure – removing excessive formaldehyde

Four items, expected to be worn in direct contact with skin, were identified in stage 2 as having formaldehyde concentrations above the reference limit. Four new items were selected and tested in stage 3 and results are shown in Table 6.

Table 6 – Results for garments expected to be in direct contact with skin after washing

Samples tested	Formaldehyde concentration (ppm)			
	Jacket	Pants	Chainsaw trousers	Overall
Upon delivery (new items in original packaging)	730	330	1300	1000
Post 1 st wash	97	197	61	283
Post 2 nd wash	190	180	44	390
Post 3 rd wash	110	190	23	320
Post 4 th wash	120	160	24	275
Reference Limit – Fabric in direct contact with skin	100			

Discussion

Stage 1 – Inhalation study

Results of testing for formaldehyde inside unopened packaging showed that for most items the concentration was below detection limit. Formaldehyde was detected in concentrations exceeding 5ppm inside of enclosed packaging of chainsaw trousers.

Results of personal monitoring during a 15 minute period, including the opening of packaging, donning and wearing of this clothing, were all found to be below the detection limit.

These results indicate that off-gassed formaldehyde within the packaging is readily dispersed and diluted with ambient air once the packaging is opened.

Stage 2 – Skin exposure

A number of PROBAN® treated uniform items provided for the assessment have the potential to be worn in direct contact with skin. These would include overalls, jackets and trousers. Occasionally, long cotton clothes items (thermal undergarments) may be worn underneath. However, the potential for the uniform items to be worn directly in contact with skin is not negligible. This may be particularly influenced by changing seasons. In summer, only singlets or short sleeve T-shirt and undergarments would be worn underneath while long sleeve tops and long underpants may be worn underneath during winter.

The clothing items that may be worn in direct contact with skin and were found to contain formaldehyde in concentrations exceeding the reference limit were:

- Jacket
- Pants
- Chainsaw trousers
- Overall

Other items that have the potential to be worn in direct contact with skin returned results below the reference limit (below 100 ppm).

The Stage 1 – Inhalation study has shown that this free formaldehyde quickly dissipates once the uniforms are removed from their original packaging. It is expected that all the free formaldehyde will be removed during a first wash, as shown by the results of a previously worn and washed uniform (Gear bag – Overall returned from field) that returned formaldehyde results below the detection limit.

The formaldehyde results for the clothing expected to be worn next to the skin are above the reference limit that is intended to protect against skin irritation and contact dermatitis. The formaldehyde concentrations are expected to decrease after the items are washed.

Stage 3 – Skin exposure – removing excess formaldehyde

Chainsaw trousers were identified to have the highest formaldehyde concentration upon delivery (1300 ppm) however this concentration was significantly decreased after the first wash to below the reference limit value of 100 ppm. The concentration remained below 100 ppm following subsequent washes.

The jacket was analysed to contain 730 ppm of formaldehyde upon delivery which also decreased after the first wash below the reference limit. However the concentration of formaldehyde was shown to be above this reference limit following subsequent washes.

The pants and overall were found to contain formaldehyde concentrations above the reference limit upon delivery and following all subsequent washes.

These results indicate there is likely to be a significant reduction in formaldehyde concentrations in the PROBAN® treated clothing after the initial wash. However, no significant change/decrease in formaldehyde concentrations was observed following the second and all subsequent washes for all items. In fact the majority of results showed that formaldehyde concentrations increased following subsequent washes.

These results are consistent with other studies reporting that formaldehyde concentrations may decline initially after washing, but may increase again after multiple washes possibly due to the polymer molecule being broken down by, amongst other things, washing and ironing. The effect of laundering on formaldehyde concentrations also depends on other factors, such as the alkalinity and hardness of the water and whether bleach is used (the use of bleach is not recommended for PROBAN® treated clothing as it may lead to the flame retardancy becoming ineffective).

Conclusion

Stage 1 – Inhalation study

The monitoring results indicate that even though formaldehyde was detected inside of enclosed packaging; personal monitoring results were below the detection limit for formaldehyde and therefore below any WES or STEL limits. Based on the findings of this assessment, opening packaging, donning and wearing the PROBAN® treated clothing does not result in exposure to formaldehyde through inhalation at concentrations that are likely to pose a risk to health, based on current knowledge and WES.

Stage 2 – Skin exposure

The laboratory results indicate that elevated concentrations of formaldehyde were present in some new PROBAN® treated clothing items. By contrast, an Overall that had been previously worn and washed showed formaldehyde concentration below the detection limit.

Based on the findings of this assessment, wearing new PROBAN® treated items directly next to bare skin prior to being washed may pose a risk of skin contact with residual formaldehyde and potentially cause skin irritation, contact dermatitis or other related skin conditions.

Stage 3 – Skin exposure – removing excess formaldehyde

The laboratory results indicate that elevated concentrations of formaldehyde (significantly above the reference limit) were detected in all new PROBAN® treated clothing, however formaldehyde concentrations were shown to be significantly decreased after the first wash.

No significant change/decrease in formaldehyde concentrations was observed following the second and all subsequent washes.

It is expected that majority of the formaldehyde is “locked” in a cross-linked polymer embedded within the individual fibres and is not available for exposure. However, the results suggest that the washing process may have the potential to cause the release of residual formaldehyde from the PROBAN[®] treated fabric. These results are consistent with other formaldehyde studies available.

Based on the findings of this assessment, wearing new PROBAN[®] treated clothing in direct contact with skin prior to being washed may pose a risk to health, potentially causing skin irritation, contact dermatitis or other related skin conditions.

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TLV[®] ADJUSTMENTS FOR SENSITIZATION

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ABSTRACT

The possibilities of having a sensitized worker in the workplace are significant given that 40-45 % of the population can become sensitized. At the same time, TLVs[®] are based on the reaction of “normal healthy workers” to workplace chemicals. Sensitized workers, such as those with allergies or asthma do not fall into the category of “normal healthy workers” and the TLVs may not protect them. If the chemical has a sensitization notation (DSEN or RSEN) it is identified as having the potential to cause sensitization, and the TLV may be based on other effects but may be low enough not to cause sensitization. When the basis for the TLV includes sensitization, the TLV should be low enough to prevent sensitization, but neither will protect workers who are already sensitized. It is the duty of the occupational hygienist to identify potentially hazardous situations and ensure that sensitized or potentially sensitized workers have their exposures maintained as low as reasonably practicable, and not just to meet the minimum requirements of the TLV. This presentation provides some guidance in the identification and protection of susceptible workers.

INTRODUCTION

The TLVs[®] “represent conditions under which it is believed[®] that nearly all workers may be repeatedly exposed day after day without adverse effects.”⁽¹⁾ The TLVs are written as guidelines to be interpreted by occupational hygienists relative to the workplace and the workers within it. Because of individual differences, heredity and environment, some workers will react to a chemical at much lower exposure levels than expected even when these individual differences are taken into consideration. These workers may have become sensitized to the presence of the chemical through previous exposures. As shown in Table 1, these sensitized workers can react to sensitizing materials at much lower levels than will the “normal” worker.

Table 1: Comparison of TLVs for selected sensitizers and the exposure levels that may cause an effect in sensitized workers.

Sensitizing Material	TLV	Reaction Level for Sensitized Workers
TDI and HDI ⁽²⁾	0.005 ppm	<0.00001 ppm
Ethylenediamine ⁽³⁾	10 ppm	0.3 ppm
MDI*	0.005 ppm	0.0014 ppm

*From MSDS

Our main interest here is not with primary irritant dermatitis such as by acids, alkalis, detergents, or solvents where cell damage occurs. Our interest is with allergic contact dermatitis which affects only specifically sensitized individuals where the skin has been sensitized by previous exposure.

Sensitization occurs when a material capable of producing an antigen – antibody complex gets past the body’s defense by injection, inhalation, ingestion, or absorption and produces an allergic – type reaction. For most people allergens are normally harmless substances, such as pollen, food, and house dust mites. In susceptible individuals the allergen provokes an exaggerated immune response to materials that are inhaled, ingested or that come in contact with skin.

This response can explain why a small number of workers can have adverse reactions to workplace environments when all other workers show no reaction. The simple comparison of exposure limits to air samples will lead one to conclude that there is no workplace problem but a worker problem. This can be wrong; the professional must look deeper to find the truth of the situation.

The potential for having a sensitized worker in the workplace is not trivial. About 15 % of the white population in the United States is easily sensitized to many things. Another 25 – 30 % are less easily sensitized, while the majority, 55 – 60 % does not

appear to become sensitized⁽⁴⁾. What this means is that there is a real possibility that any workplace can already employ sensitized or sensitizable workers.

WHAT ARE SENSITIZERS?

Health Canada defines sensitizers or allergens as materials that can cause severe skin and/or respiratory responses in a sensitized worker after exposure to a very small amount of the material. Sensitization develops over time. When a worker is first exposed to a sensitizer, there may be no obvious reaction. However, future exposures can lead to increasingly severe reactions in sensitized workers. Not all exposed workers will react to sensitizing materials. As mentioned above, some workers will never become sensitized.

Allergens are usually large molecules (high-molecular-weight (HMW) substances) such as proteins from plants, bacteria, or animal origin. However, allergens can also be small reactive molecules (low-molecular-weight (LMW) substances) such as isocyanates, acid anhydrides, platinum, nickel, or other metallic salts, persulfates, and reactive dyes, any substance that, after absorption, attach themselves to proteins within the host's body creating a new protein that is foreign to the host. Examples of different sensitizers/allergens are shown in Table 2 with examples of occupations where they can be found.

Table 1: Some occupations that may lead to sensitization, and the related sensitizing agents^(5, 6, 7).

Occupation	Agent
Animal breeding /Handling	Animal dander, urine, bird products, crustaceans, egg protein
Baking	Flour, insects mite debris
Hairdresser	Sodium/ potassium persulfate
Coffee processor	Green coffee beans
Detergent enzyme worker	Proteases
Farm worker	Animal antigens, vegetable dusts, moldy hay, herbicides, insecticides, antibiotics
Food additive worker	Tartrazine
Grain handler	Grain dust, insect debris
Laboratory worker	Animal antigens
Leather worker	Formalin, chromium salts,
Lumber & woodworking	Wood dusts
Milling	Flour, insects, mite debris
Paper product manufacture	Natural glues
Pharmaceutical worker	Penicillin, ampicillin, tetracycline
Plastics industry	Diisocyanates, anhydrides
Platinum refiner	Platinum salts
Plating, welding	Nickel, chromium, platinum
Printer	Vegetable gums
Veterinarian	Animal antigens
Vegetable oil production	Flaxseed, cottonseed, castor bean

The most common occupational reaction to a sensitizer is contact dermatitis, with allergic rhinitis and asthma being less common. Table 3 shows routes of entry, conditions that can affect the reaction, and examples of sensitizers/allergens. Episodes occur after exposure; however, the symptoms may occur several hours after exposure, and they usually disappear during weekends. The symptoms can resemble a cold or mild hay fever and include difficulty in breathing, chest tightness, wheezing and coughing, fever, and general feelings of bodily discomfort.

Table 3: Routes of entry for sensitizers, some of the conditions that affect that reaction, and Examples of sensitizers.

Route of Entry	Conditions	Examples
Skin	Wet skin, local effect	Flour, detergents, vegetables, nickel, chrome, rubber, azo dyes, formaldehyde
Digestive tract	The effect is reduced through the cooking and digestive processes An inflammation of the mucosa allows more of the allergen to pass Affects organs elsewhere in the body	Raw foods
Respiratory tract	Infections increase effect Increased exposure increases effect Affects organs elsewhere in the body	pollens, animal hair, dust, isocyanates, metal salts, plant products, microbial agents, organic dusts
Injection		Insect stings

Once a person has become sensitized to one material, they may also react to other similar materials as shown in Table 4.

Table 4: Examples of cross-sensitivity as reported in material safety data sheets.

Group Showing Cross-Sensitivity	Examples
Isocyanates	TDI, HDI, MDI, PMPPI
Aliphatic polyamines	Ethylenediamine, triethylenetetramine, 2,2'-diaminodiethyl amine
Aromatic diols	Resorcinol, resorcinol monoacetate, hexylresorcinol, hydroquinone, catechol, phenol, pyrogallol, hydroxyhydroquinone, orcinol
Chemical/physical (light)	Chromium salts
Azo dyes	Derivatives of paraphenylenediamine (PPD)
Metal salts	Chromium, nickel, cadmium

THE ROLE OF HEREDITY

Heredity helps determine the likelihood that an individual will develop an allergic reaction to materials in their environment^(5, 7, 8). Heredity does not determine what they will become sensitive to, but rather whether they will become sensitized at all.

About 10-15 % of the population in the United States is easily sensitized to many things. Another 25-30 % are less easily sensitized, while the majority, 55-60% do not appear to become sensitized⁽²⁾. 15-30 % of the European countries are readily sensitized and 9-20 % in Turkey^(4, 9).

A family history of allergies is strongly associated with the easily sensitized group, and decreases with the other two groups. If both parents were allergic, 60-80 % percent of the offspring were allergic; the rate decreases to 30-50 % percent if one

parent was allergic, and 6-10 % percent if neither were allergic^(10, 11). Thus, knowledge of a positive family history of allergies would be useful in determining if sensitization is, or could be a problem in the workplace. Unfortunately, this may be considered confidential medical information and therefore may not be available to the occupational hygienist.

THE ROLE OF THE ENVIRONMENT

Just as heredity determines the probability that a worker will become sensitized, environmental conditions determine to what the worker will become sensitized. These environmental conditions include both the pattern of exposures as well as the chemicals in the workplace.

A non-workplace exposure that seems to predispose workers to allergic sensitization is smoking. Perhaps this is due to the injury to the bronchial epithelium which enhances permeability of the bronchial epithelium⁽⁵⁾.

The worker is normally repeatedly exposed to a sensitizing material before sensitization occurs. In most cases, there is a latent period of weeks or years between first exposure to the occupational allergen and the onset of symptoms. The likelihood of becoming sensitized to a material is dose dependant. Intermittent high-level exposures have been reported as being important in the development of asthma. Workers exposed more frequently to spills or who maintain equipment report more asthma like symptoms. But once the worker is exposed, very low levels of the substance can provoke an asthmatic reaction.

Exposure to most allergens is not a problem unless you have been exposed to it previously and are sensitized to it. As mentioned, it may take months or years of repeated exposure before full-blown allergic symptoms develop.

However, some materials can cause sensitization after a single high exposure and a short latent period (as little as four days). Examples of this include plant toxins as found in poison ivy, poison oak, cashew nut, oils from mango fruit, lacquers from the Japanese lacquer tree and Cedar wood.

ALLERGIC CONTACT DERMATITIS

Although the prevalence of contact dermatitis due to environmental agents is unknown, it is felt to be a major public health concern. In 1975, about 45 percent of occupational diseases were work-related skin conditions, most of which were contact dermatitis. In 2011 the incidence of occupational skin diseases in western industrial countries was estimated at 0.5 – 1.9 cases/1,000/year, but it is assumed that the prevalence of occupational contact dermatitis was underestimated by a factor of 30–50 %⁽¹²⁾.

It should be noted that except from the worker's medical history, there are usually no distinguishing features between occupational and nonoccupational contact dermatitis. A history of allergic episodes occurring after exposure, ending when exposure stops, and recurring on re-exposure, suggests an occupational dermatitis.

There is a minimum interval between first contact and the development of sensitization of between 6 and 25 days; sometimes it does not occur until after months or years of repeated exposures. After sensitization, further contact will usually cause a reaction within 1 to 2 days and sometimes within a few hours.

A delayed allergic reaction is responsible for 20 % of all cases of contact dermatitis. This type of reaction requires active participation of the immune system and very low concentrations of the causative agent. Many allergens are also irritants, but the threshold for irritation is usually much higher than that required for sensitization⁽¹³⁾.

The usual sites for occupationally related contact dermatitis are the back of the hands, the inner wrists, and forearms, but it can occur anywhere on the skin. When the forehead, eyelids, ears, face, or neck is involved, dusts, fumes, or vapors should be suspected. Generalized contact dermatitis comes from a massive exposure such as wearing contaminated clothing or a sensitization from preexisting dermatitis.

Reactions may be exacerbated when the skin has been damaged by chapping, friction, or other trauma so the rate of the absorption of the allergen is increased. These reactions are decreased when there are immunological deficiencies, such as those caused by lymphomas, metastatic diseases, malnutrition, immunosuppressant drugs, or glucocorticosteroids.

Table 5: Common skin allergens ⁽¹³⁾.

Metals Nickel Chrome Cobalt Mercury	Rubber additives Mercaptobenzothiazole Thiurams Carbamates Thioureas	Dyes Paraphenylene diamine Photographic colour developers Disperse textile dyes
Plants Urushiol (<i>Toxicodendron</i>) Sesquiterpene lactones (<i>Compositae</i>) Primin (<i>Primula obconica</i>) Tulipalin A (<i>Tulipa</i> , <i>Alstroemeria</i>)	Plastics Epoxy monomer Acrylic monomer Phenolic resins Amine catalysts	Biocides Formaldehyde Kathon CG Thimerosal

Once a worker has become sensitized to one material such as poison ivy, they can become sensitized to similar materials such as poison oak, and can have a reaction to the first exposure without the latent period.

Sex-related differences to allergic contact dermatitis usually represent differences in occupational or environmental exposures to various allergens rather than actual gender differences. Other genetic factors, however, do play a role; for example, a worker with a light-complexion or redheaded workers are less resistant to skin damage when working with irritant dusts and solvents.

PHOTOALLERGIC CONTACT DERMATITIS

Photosensitivity occurs when there is a chemical substance on the skin surface that can be activated by ultraviolet radiation in the 290 – 400 nm wavelengths. These are frequently chemicals with aromatic rings. If the material cannot absorb UV radiation, a reaction is unlikely.

Phototoxic reactions

Phototoxic reactions are the most common of the photosensitivity reactions. They can be produced in all workers when there is sufficient light and photosensitizer present. There is an immediate burning, stinging, or smarting of the skin shortly after exposure to the sun. The appearance is that of an extreme sunburn. Workers exposed to coal tar products are susceptible to this reaction. Factors affecting phototoxicity include:

- Skin pigmentation
- Skin thickness
- The dose received of the photosensitizing chemical
- The dose of the UV light
- Skin covering (clothing, hair)

Photoallergic reactions

Photoallergic contact dermatitis is slightly different and has a much lower incidence⁽¹⁴⁾. Since the means of action is different than phototoxicity, photoallergic reactions do not occur on the first exposure to an agent.

The light alters the chemical structure of either a normal metabolite or a foreign substance such as a drug which then becomes a true allergen. In photoallergic contact dermatitis, the epidermal changes resemble those of a typical allergic contact dermatitis and are limited to sun-exposed skin where the allergen has been in contact. It becomes evident immediately as a type of skin rash notable for dark red, raised, itchy bumps (hives). It can also appear as a delayed hypersensitivity reaction 24 to 48 hours later.

The following list contains examples of chemicals with phototoxic and photoallergenic properties. It should be noted that ingredients for sunscreens are included in the list. Since sunscreens are a control method, care should be taken in selecting an appropriate sunscreen.

Coal Tar Products	Dyes
Crude coal tar	Acridine
Pitch	Eosin
Creosote	Fluoroscein
	Rhodamine
	Rose bengal
	Methylene blue
Plants	Mustard
Carrots	Parsley
Celery	Parsnip
Bergamot	Rue
Buttercup	Gas plant
Klamath Weed	Angelica
Dill	Goose foot
Figs	Scurfy pea
Lemons	St. John's wort
Limes	
Essential Oils and Fragrances	Rue oil
Angelica root oil	Cedarwood oil
Bergamot oil	Sandalwood oil
Lemon oil	Lavender oil
Lime oil	Musk ambrette
Orange oil (bitter)	6-methyl_coumarin
Drugs	Ibuprofen
P-aminobenzoic acid and esters	Nonsteroidal antiinflammatories
Chlorothiazides	Benzophenones
Diphenhydramine	Nalidixic acid
Enoxacin	Quinine
Estrogens	Tetracyclines
Fenofibrate	Sulfonamides
Phenothiazines	Sulfisoxazole
Griseofulvin	Thoridazine

Antimicrobials	Dapsone
Halogenated salicylanilides	Isoniazid
Bithinal	Mupirocin
Hexachlorophene	Pyrazinamide
Flucytosine	Sulfonamide derivatives
Grisoflavin	Chloroquine
Terconazole	Proguanil
Ceftazidime	Pyrimethamine
Miscellaneous	Cyclamates
Sunscreens (PABA, cinnamates, benzophenones)	Optical whiteners
Saccharin	Epoxy resin

OCCUPATIONAL ASTHMA

The US National Heart, Lung, and Blood Institute defined asthma as ‘... a chronic inflammatory disorder of the airways.... In susceptible individuals, this inflammation causes recurrent episodes of wheezing, breathlessness, chest tightness, and cough, particularly at night and in the early morning. These episodes are usually associated with widespread but variable airflow obstruction that is often reversible either spontaneously or with treatment.’

The symptoms of occupational asthma usually improve during weekends and vacations, and become more severe during the weekday. The symptoms must be accompanied by exposure to a material that can cause asthma.

There are two types of occupational asthma: allergic or non-allergic. Here we are addressing allergic occupational asthma, or sensitizer-induced asthma which includes 65-80 % of asthma cases. Occupational asthma is asthma that is caused by exposures to agents in the workplace. As with other allergic type of reactions, individuals at high risk for developing this disease include those with a family history of asthma, previous sensitization to one or more allergens, exposure to tobacco smoke, and, most importantly, employed at high-risk workplace⁽⁷⁾.

Asthma can develop at any time in life but it has been estimated that about 50–60% of all cases develop in adulthood⁽¹⁵⁾. With adult-onset cases, clear causal relationships can sometimes be established between the disease onset and exposure to agents in the workplace. About 9–15 % of adult-onset asthma cases can be attributed to exposures at work. These can be prevented if exposure to known occupational allergens can be avoided. People with occupational asthma often have to change jobs or careers to relieve their symptoms; hence, work disruption and economic hardship are common consequences of the disease.

Risk factors include tobacco smoking, previous allergic sensitization and a genetic predisposition⁽⁵⁾. However, the level of exposure (dose, duration, etc.) to workplace sensitizers and irritants is most important in the development of occupational asthma.

There is evidence that tobacco smoking aggravates work related asthma. There is also some evidence that tobacco smoking contributes to the risk of developing occupational asthma by increasing the likelihood of sensitization to some causal agents. When combined with smoking, exposure to isocyanates, platinum salts, salmon and snow crab increases the risk of occupational asthma compared to exposure alone. But the relationship between smoking and the risk of developing occupational asthma is unclear when the causal agents are laboratory animals, enzymes, or acid anhydrides.

SENSITIZERS AND SHIFTWORK

Allergic responses increase at night with the greatest decrease in FEV₁ (volume that has been exhaled at the end of the first second of forced expiration) occurring after a late-evening exposure to a potential allergen. There is also a greater potential

for the symptoms to begin several hours after exposure and may continue for many hours or days. This response is called late asthmatic response (LAR). A person could be exposed to a sensitizer during the day, but the maximum effect may not take place until the evening, leaving the impression that there was a non-work related evening exposure⁽¹⁶⁾.

Cutaneous allergy response can also vary significantly depending on the time of day the exposure occurs.

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INVESTIGATING THE PREVALENCE OF EXPOSURE TO OCCUPATIONAL ASTHMAGENS IN AUSTRALIA

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ABSTRACT

Aim: It is estimated that up to 3,000 new cases of asthma each year in Australia may be attributable to workplace exposures. To better understand how many people in Australia are at risk of work-related asthma, the Australian Work Exposures Study-Asthma (AWES-A) aimed to investigate the prevalence of occupational exposure to 277 asthmagens (in 27 broad groups).

Methods: We conducted a cross-sectional telephone survey of 5,020 workers aged 18-64 across Australia. A screening interview determined those who were in jobs with potential exposure to any of the asthmagens. These 2,593 workers were then asked detailed questions about their current job, the main tasks they carried out, and other aspects of their working environment. An online application (OccIDEAS) was used to provide an assessment of the probability (none, possible, probable) of exposure to each of the 27 groups of asthmagens.

Results: Preliminary analysis indicates that 42% of respondent Australian workers were exposed to at least one asthmagen, with the most frequent exposures being to bio-aerosols (21%), latex (21%), arthropods (18%) and industrial cleaning agents (15%). Of those exposed most were males (55%) and aged 35-54 years (58%).

Conclusions: This study provides much-needed information about the prevalence of exposure to asthmagens in Australian workplaces, and will allow us to estimate the future burden of occupational asthma in Australia. These results will also have important implications for prevention, as they will provide an important input to the determination of where best to focus regulatory activities and inform strategies for risk reduction.

CALIBRATION OF RAW EXHAUST DIESEL PARTICULATE MATTER MEASUREMENT INSTRUMENTATION

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ABSTRACT

Three units are currently commonly used within the Australian Coal Mining Industry to measure raw exhaust elemental carbon (EC). These are two laser light scattering (LLS) devices; the AVT530 and MAHA-4M, and the ChekMate which operates using back-pressure measurement technology. Over time a lack of repeatability of results and suspicion of incorrect total suspended particulate to elemental carbon (EC) conversion factors have been raised (Davies 2013, Mason 2014) which has resulted in a lack of confidence within mine maintenance engineers as to the suitability of all raw exhaust measurement instrumentation.

To address this concern a comparison exercise was undertaken involving at least two of each instrument type.

All instruments were compared at five different load levels using a test rig fitted with a Detroit 706 LTE engine and a hydraulic dynamometer. Six measurements on each instrument were taken at each of the five load levels and samples were collected on quartz filters by two independent methods for analysis by NIOSH method 5040. All sampling was undertaken in the presence of key stakeholders including manufacturers, end users & statutory authorities.

A number of outcomes were determined. These included useful results can be obtained from in-service engines using either the MAHA-4M or the ChekMate instruments providing a standard method of collecting the sample prior to control technologies is used, properly maintained sampling devices need to be calibrated appropriately on the same engine load basis that is used in routine sampling or erroneous results are obtained, results should not be reported below the level of uncertainty of the instrument used.

Key words: diesel exhaust, elemental carbon, backpressure, ChekMate, MAHA-4M, AVT 530

Introduction:

In recent years, two laser light scattering devices have been popular within the Australian mining industry for measuring diesel particulate matter (DPM). In 2014, a simple screening tool was introduced to the market, using backpressure, to determine an equivalent elemental carbon (EC) result. Uncertainty within the mining industry due to a lack of repeatability of results, variability between devices and the suspicion of incorrect total suspended particulate to elemental carbon conversion ratios lead to a comparison exercise being undertaken between these three instruments. The standard for comparison of devices was samples collected under the same conditions and analysed using NIOSH 5040 Elemental Carbon.

The exercise was conducted in an open forum under controlled conditions and involved end users in the mining industry, instrument manufacturers and an approved monitoring organisation. Owners of the equipment operated their own devices where possible. Representatives from the Resources and Energy Division of the NSW Department of Industry observed the exercise.

Methods:

DPM Measuring Instrumentation

The instrumentation used in this exercise is in current use within the Australian mining industry. This consisted of two different types of laser light scattering devices (AVT 530 & MAHA - 4M) and the ChekMate which is based on the measurement of backpressure on a filter. The full list of equipment, last calibration date and project identification number is provided in Table 1. The aim was to have at least two of each type of device available.

Table 1 – Instrumentation used in exercise

Instrument Model	Serial Number	Date Last Calibrated	Project Identification
AVT 530	Not Available	1 May 2014	Instrument (1)*
AVT 530	0106/8530128408	6 June 2014	Instrument (2)
AVT 530	71002264	7 January 2015	Instrument (3)
MAHA - 4M	536034-001	1 May 2015	Instrument (4)
MAHA - 4M	537165-004	4 May 2015	Instrument (5)
ChekMate	CM 001	13 May 2015	Instrument (6)
ChekMate	CM 005	13 May 2015	Instrument (7)

*Instrument 1 was excluded at the beginning of the exercise as it was found to have an incorrect sampling time and unknown correction factor loaded into its operating system. This device was on loan from a mine site; the site representative was advised the device was not configured as per the manufacturer’s instructions and could therefore not be included.

Raw Exhaust Source

A diesel test rig fitted with a Detroit Diesel 706 LTE engine coupled to a hydraulic pump provided the raw diesel exhaust for the exercise. This allowed different loads to be placed on the engine and accordingly different EC levels were generated in the raw exhaust.

A number of sampling points are available along the exhaust pathway of the test rig. The exhaust for this exercise was collected as close to the manifold as possible, as far as possible from any bends in the exhaust pathway and before any control technologies. The raw exhaust was directed to an ERP mixing and cooling system which ensured a suitably mixed and cooled (maximum 30°C) sample was delivered to three instruments at the exact same time with no change in load to allow for sampling and/or collection. The ERP mixing and cooling system has previously been proven to be an effective and efficient system (Hines et al 2014 & Mason 2014).

Fuel used in the testing was Shell ultra-low sulphur diesel (ULSD).

Sampling Protocol

Comparison testing was carried out over five (5) different engine loads. The engine was initially set at 1400 revolutions per minute (RPM) which is peak torque for the engine and a known load was added via the hydraulic pump system to induce increasing loads (and resultant increasing EC concentrations) at each level. The carbon dioxide (CO₂) concentration was measured continuously at each load level using an ECOM EN2-F to monitor any changes in engine load. The five load level parameters are listed in Table 2.

Table 2 – Load level parameters

Load Level	Initial RPM	Load (psi)	Resultant RPM	% CO ₂
1	1400	Nil	1400	2.2
2	1400	600	1350	2.9
3	1400	1800	1230	4.9
4	1400	2200	1200	5.6
5	1400	2450	1150	6.4

At each engine load level the probe of each instrument was inserted 20 cm into the ERP mixing unit and a measurement on each instrument was taken. The mixing unit has the capability to securely hold three (3) probes at the same time. The process was repeated until at least six (6) samples on each instrument had been recorded. The process was repeated with the next set of instruments until all instruments had analysed the exhaust for EC at that particular load setting. A detailed list of the sample matrix and numbers of samples is provided in table 3.

The entire process was repeated until all five (5) load levels had been sampled for all available instruments.

Table 3 – Sample collection matrix

Load level	Instrument (2)	Instrument (3)	Instrument (4)	Instrument (5)	Instrument (6)	Instrument (7)	NIOSH 5040 (37mm filters)	NIOSH 5040 (ChekMate)
1	6	6	6	6	6	6	2	12
2	6	6	6	6	6	6	2	12
3	6	6	6	6	6	6	2	12
4	6	6	6	6	6	6	2	12
5	6	6	6	6	6	6	2	12
	30	30	30	30	30	30	10	60

NIOSH 5040 sample collection and analysis

Samples for NIOSH 5040 (NIOSH 1994) EC analysis were collected by two independent methods. Method 1 was to reserve each quartz filter used in the ChekMate instruments and method 2 was to collect samples on 37mm quartz filters at a flow rate of 3.5 L/min for 2 minutes prior and post any testing at each load level so as to provide a 7L, high volume samples for EC analysis. Methods 1 and 2 have been used and validated in research on previous projects (Davies 2013; Hines et al 2014).

All samples collected for NIOSH 5040 analysis were forwarded to Sunset Laboratories Inc. in Portland Oregon USA who are internationally recognised experts in the field of NIOSH 5040 analysis (Volkwein et al 2008).

Six (6) ChekMate filters from each load level were analysed for EC by NIOSH 5040. The filters were randomly selected for either ChekMate 1 or ChekMate 2 for each load level. This provided 30 individual ChekMate filters plus 10 high volume samples for analysis by Sunset Laboratories Inc.

Results:

Summary of Results

The results summary for samples collected on 19 May 2015 is listed in Table 4. In regard to the results listed in Table 4 the following notes should be considered.

- All results (except those from NIOSH method 2) are recorded as the average of six readings plus the 95% UCL & LCL where sufficient data was available.
- All instrument results have been rounded to the nearest 1 mg/m³ EC.
- Results marked (+) did not have a value recorded from the calibration graph for these instruments as the reading was below the range of the calibration for the flowrate being used.
- No samples were collected with instrument 1 as per previously provided reasons.

Subsequent testing of MAHA & ChekMate

Following a review of all the data collected on 19 May 2015 it was realised that the high range calibration for the ChekMate instruments (15 – 60 mg/m³ EC) was developed on a transient load basis (20 second idle - 20 second load – 20 second idle) consistent with testing raw exhaust as per MDG 29 (2008). As the ERP test rig was operating in a steady state mode the use of such a calibration would be incorrect as the ChekMate was sampling over the whole 60 second sampling period. The low range calibration (2 – 15 mg/m³ EC) had been previously conducted on the ERP test rig under steady state conditions and thus applicable to the current application.

Given this oversight, on 29 June 2015 the ChekMate high range calibration was redone using steady state conditions (60 second load) and further limited sampling using Instrument 5 (MAHA – 4M), Instruments 6 & 7 (ChekMate) plus comparative analysis for NIOSH 5040 by the two independent methods was undertaken. The results are listed in Table 5. Instruments 2, 3 (AVT 530) & 4 (MAHA-4M) were not resampled as it was considered no added value would be gained from further sampling as the aim of the further sampling exercise was to demonstrate that an incorrect calibration curve had been inadvertently used for instruments 6 & 7 (CheckMate) during the sampling conducted on the 19th May 2015.

In regard to Table 5 the following notes should be considered;

- a) The results are recorded as an average plus the 95% UCL & LCL where sufficient data was available.
- b) All instrument results have been rounded to the nearest 1 mg/m³ EC.

It should be noted that as far as could be established current laser light scattering devices are calibrated against a steady state source. Calibration of a MAHA – 4M by Mason (2014) identified a difference in the total suspended particulate (TSP) to EC than that recommended by the manufacturer. The work by Mason (2014) was performed on in service engines using a transient load test as per MDG 29 (2008).

Collaboration of calibration

Following on from this testing, and the realisation that the MAHA-4M, provides better results with the variation in calibration factor (Mason 2014), it was determined by PM-Tech (the manufacturer of the MAHA) that the instruments would be better calibrated to NIOSH 5040 using the same test rig that the ChekMate has been calibrated- thus aligning these instruments to NIOSH 5040. This also involved sampling at the gas sampling port closest to the manifold using the ERP Mixing system to cool and mix the exhaust. PM-Tech had their reference instrument calibrated in this way (September 2015), and subsequent comparison of the ChekMate and reference MAHA-4M have shown excellent correlation.

Discussion:

Initial results:

The initial results highlighted a number of differences between the instruments and also identified a difference in calibration technique.

Instrument 1 (AVT 530) was excluded from the sampling exercise on the basis that the stored sampling period was not consistent with MDG 29 (2008) and the fact that the stored calibration factor to account for sample volume and TSP conversion to EC was not that recommended by the manufacturer. A discussion with the instrument owner could not identify where the non-standard factor was derived.

The results of instruments 2 & 3 (AVT 530) while consistent were significantly different to those obtained by NIOSH 5040. Given the origins of these instruments (Perth & Melbourne) the variation in results is suggestive of a systematic calibration error which should be investigated by the manufacturer.

It is clear that instrument 4 (MAHA-4M) had a serious fault which was confirmed onsite by comparison to the manufacturers test “calibration plug” which did not read its recommended value. This instrument had been previously calibrated by the manufacturer on 1 May 2015 and had not been used by the owner during the period 1 – 19 May 2015. The device had been transported from Brisbane (manufacturer’s service centre) to Melbourne (owner) and then to Unanderra (ERP Pty Ltd) so it can only be assumed that damage occurred during transport.

Instrument 5 (MAHA-4M) gave the best comparison to NIOSH 5040 over the full range of load levels while instruments 6 & 7 (ChekMate) gave good comparison at the two lowest load levels and much lower concentrations than the NIOSH 5040 values at load levels 3 – 5. This abnormality was identified as being a result of the calibration for instruments 6 & 7 (ChekMate) being performed using the transient test procedure (maximum 20 seconds under load with a 20 second pre & post load idle period) required in MDG 29 (2008) rather than the full 60 second steady state load used in the testing. This oversight was supported by the fact that the results for load levels 1 & 2 for instruments 6 & 7 (CheckMate), which were consistent with instrument 5 (MAHA-4M), were determined from a steady state calibration as it had been found impossible to find a large number of “in service” vehicles with a range of raw exhaust concentrations between 2 - 15 mg/m³.

Consequently, a steady state load calibration curve was developed for instruments 6 & 7 (ChekMate) at EC levels above 15mg/m³ and further samples collected on 29 June 2015 using instruments 5 (MAHA-4M), 6 & 7 with samples also collected for NIOSH 5040 analysis using both method 1 & method 2.

Subsequent testing of MAHA and ChekMate

The results on 29 June 2015 confirmed that the calibration curve used for the sampling on 19 May 2015 for instruments 6 & 7 (ChekMate) was incorrect due to steady state conditions being used to load the engine rather than transient load conditions employed in MDG 29 (2008). Using a calibration based on steady state conditions the results for instruments 6 & 7 were comparable to those of NIOSH 5040 (figure 4) highlighting how in any measurement exercise the calibration for any instrument must be under the same conditions used in routine analysis.

Following up on this issue a number of tests were run on vehicles which could not be loaded using the torque stall or hydraulic load approach common for many mine vehicles to see if a low range calibration graph for instruments 6 & 7 would need to be developed. The types of vehicles are usually 4WD over-the-road vehicles used in the metaliferrous industry. The alternative load approach nominated in MDG 29 (2008) comprises placing a load on the engine using a series of timed snap loads. The tests involved loading a series of engines using a steady state load and analysing the exhaust for EC using instruments 6 & 7 and then repeating the exercise by loading them using the alternate method (snap test) stipulated in MDG 29 (2008). These two sets of results were compared to see if there were any significant differences.

The results of these tests showed that although the CO₂ concentrations on each load method were different the raw exhaust EC concentration were the same. While it would have been expected that the lower CO₂ concentration produced with the snap test would mean that the EC concentrations would also be lower than the steady state test the fact that the snap test requires the turbocharger to spin up a number of times is likely to have caused the EC to be the same as the steady state test. On this basis it would appear appropriate to use the steady state low range calibration for vehicles such as 4WD over-the-road vehicles used in the metaliferrous industry.

The results from instrument 5 (MAHA-4M) versus NIOSH 5040 on 29 June 2015 were confusing given that this instrument was the closest instrument to the NIOSH 5040 results over the five load levels on 19 May 2015. Discussions with the operator revealed that the instrument had suffered an inflow of water carried over from a scrubber tank when testing a vehicle the previous work day and the instrument had not been recalibrated in the interim.

This situation highlights the need for all sampling from the raw exhaust of diesel engines to be performed using appropriate technology that ensures that any carryover water from control technologies in the exhaust pathway is removed. In the calibration sampling exercise reported herein the raw exhaust was passed through an ERP mixing system which cools and mixes the exhaust and allows any carryover water to drop out of the measured exhaust pathway.

Load versus EC mg/m³

As raw exhaust carbon dioxide is an excellent indicator of load % CO₂ was plotted against the measured concentration of EC for each instrument type and the high volume NIOSH 5040 analysis. The high volume NIOSH 5040 analysis was used as it had a lower underlying analytical uncertainty to that of the ChekMate samples (+/- 5% versus +/- 12%).

The plots of these comparisons for samples collected on 19 May 2015 are provided in figures 1, 2, 2a & 3. Figure 2a has been included as the data from instrument 4 has been removed to better show the comparison of instrument 5 (MAHA) with the NIOSH 5040 results.

Figure 1 shows that instruments 2 & 3 (AVT) give consistently higher results than those of the NIOSH 5040 results. This is suggestive of a calibration factor error especially as instruments 2 & 3 were independently sourced from two different organisations.

Figure 2 clearly demonstrates that the results from instrument 4 (MAHA) are significantly different to those of instrument 5 (MAHA) (and NIOSH 5040). This is indicative of a fault. In figure 2a the data from instrument 4 has been removed to better indicate the comparison of instrument 5 to NIOSH 5040. As can be observed the comparison is good but consistently lower right across the spectrum of results. Interestingly, when the adjustment recommended by Mason (2014) is applied to the data of instrument 5 (calibration factor of 0.67 rather than 0.52 recommended by the manufacturer) a very close approximation to the NIOSH 5040 values can be observed as illustrated in figure 2b.

Figure 3 shows that instruments 6 & 7 (ChekMate) follow a similar pattern to the NIOSH 5040 results but a significantly lower than the NIOSH 5040 results. This variance was identified as being caused by the fact that instruments 6 & 7 had been calibrated on “in service” engines using the normal transient load method specified in MDG 29 (2008) rather than a steady state load as used in the current exercise. Instruments 6 & 7 were recalibrated using a calibration curve prepared under 60 second steady state conditions and further sampling undertaken to confirm this finding.

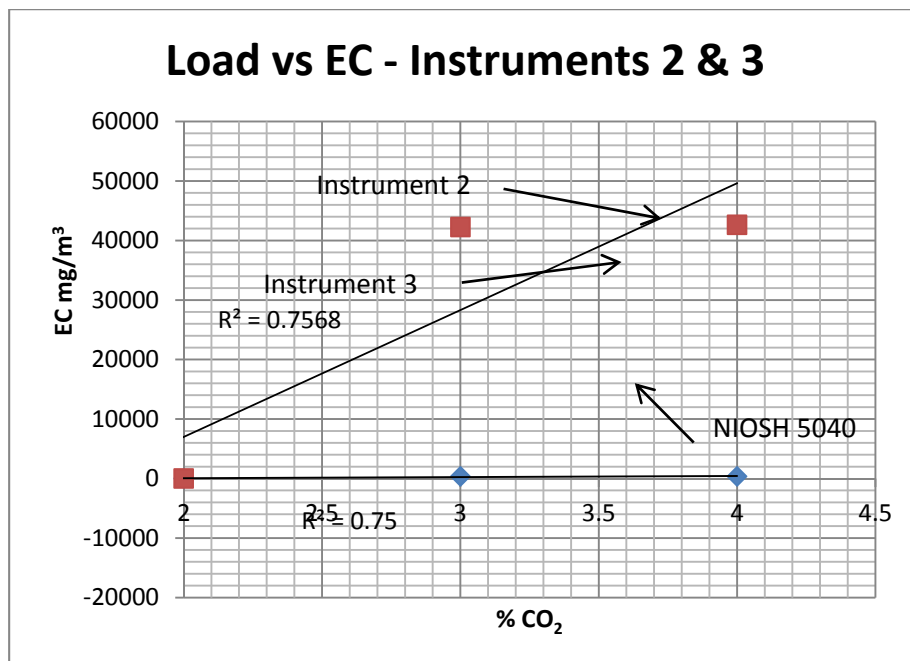


Figure 1 – Plot of engine load vs. EC for instruments 2 & 3 (AVT 530)

The results of sampling performed on 29 June 2015 using this revised calibration for instruments 6 & 7 is shown in figure 4. The result of instrument 5 (MAHA-4M) which was also used in the resampling exercise is shown in figure 5.

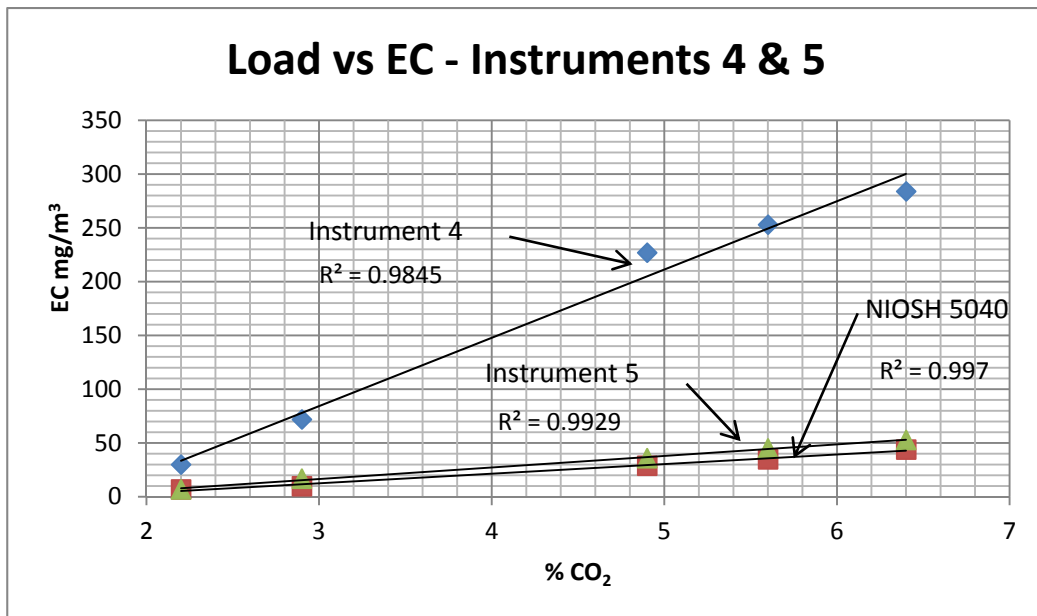


Figure 2– Plot of engine load vs. EC for instruments 4 & 5 (MAHA-4M)

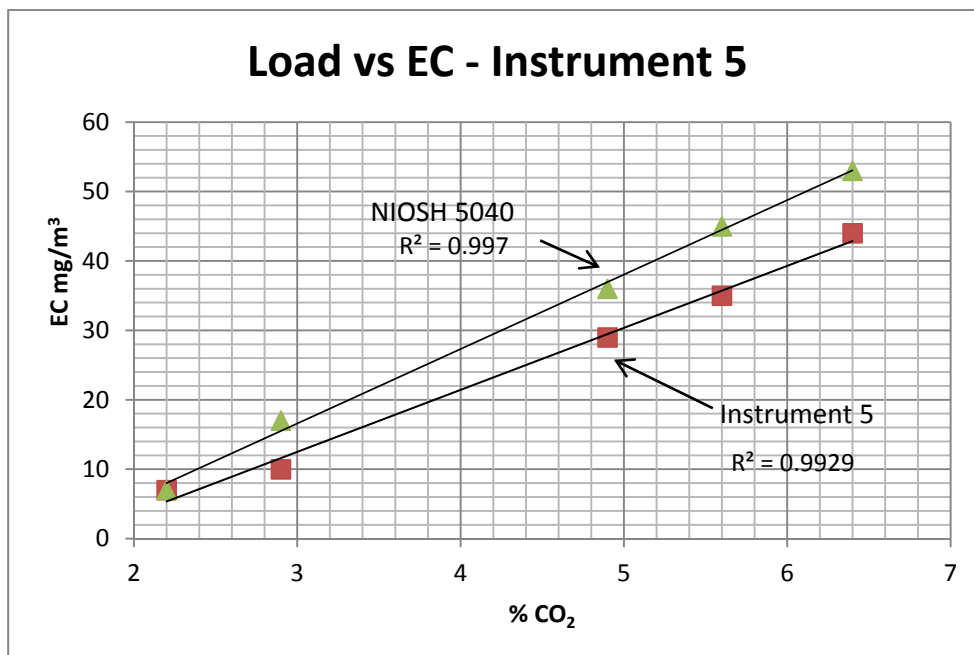


Figure 2a– Plot of engine load vs. EC for instrument 5 (MAHA-4M)

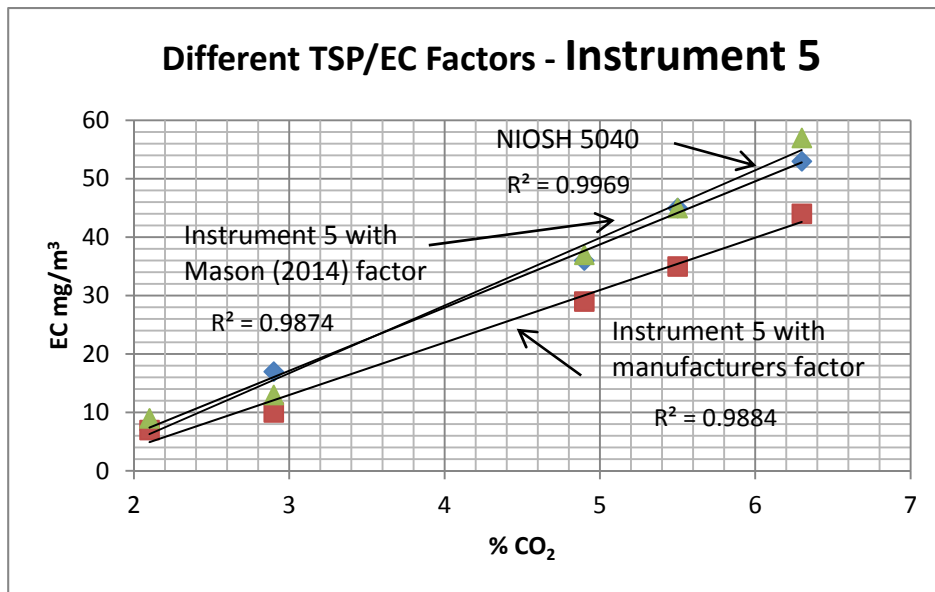


Figure 2b– Plot of engine load vs. EC for instrument 5 (MAHA-4M) using manufacturers & Mason (2014) factors

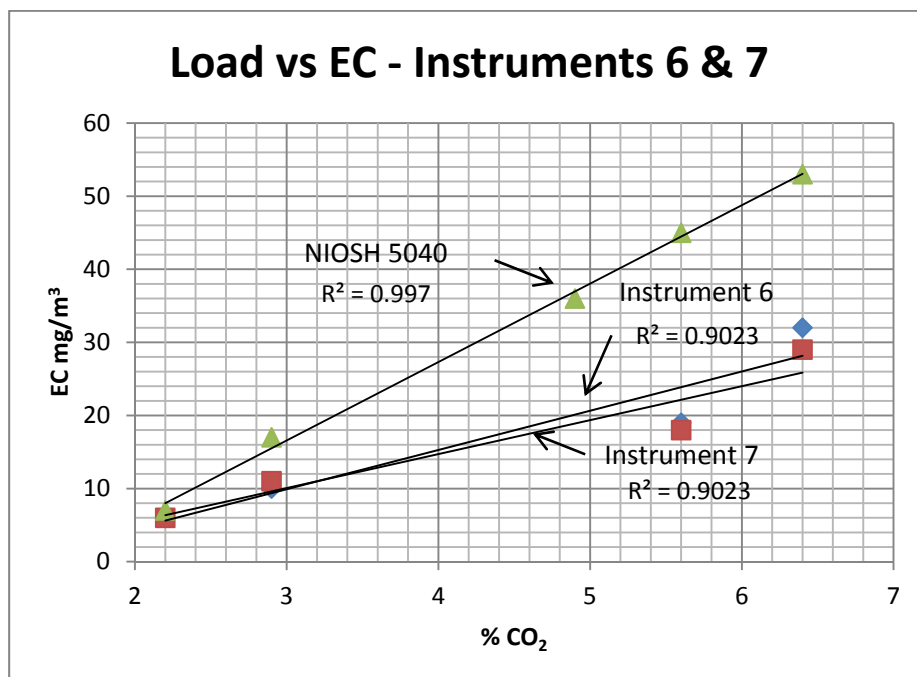


Figure 3 – Plot of engine load vs. EC for instruments 6 & 7(ChekMate) on 19 May 2015

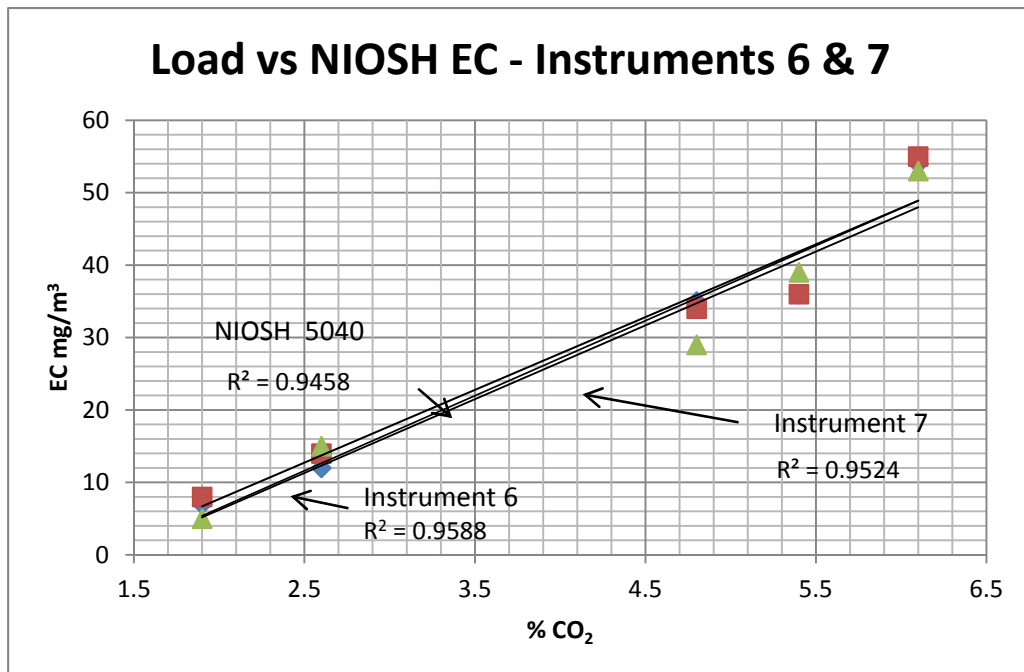


Figure 4– Plot of engine load vs. EC for instruments 6 & 7 (ChekMate) on 29 June 2015

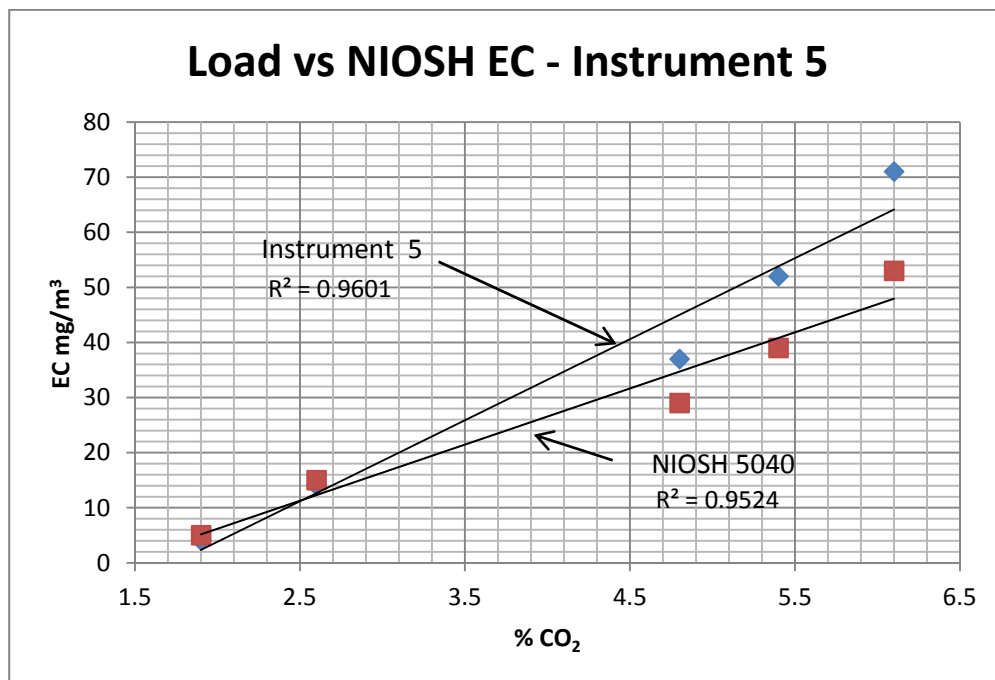


Figure 5– Plot of engine load vs. EC for instrument 5 (MAHA-4M) on 29 June 2015

To be certain that the load conditions between the 19 May 2015 & 29 June 2015 had not significantly changed the results of engine load (% CO₂) versus EC by NIOSH 5040 were plotted as can be observed in figure 6. The change in concentration at the different load levels on the different sampling days was within the analytical uncertainty for the NOISH 5040 analysis thus confirming the test rig load mechanism as repeatable & stable.

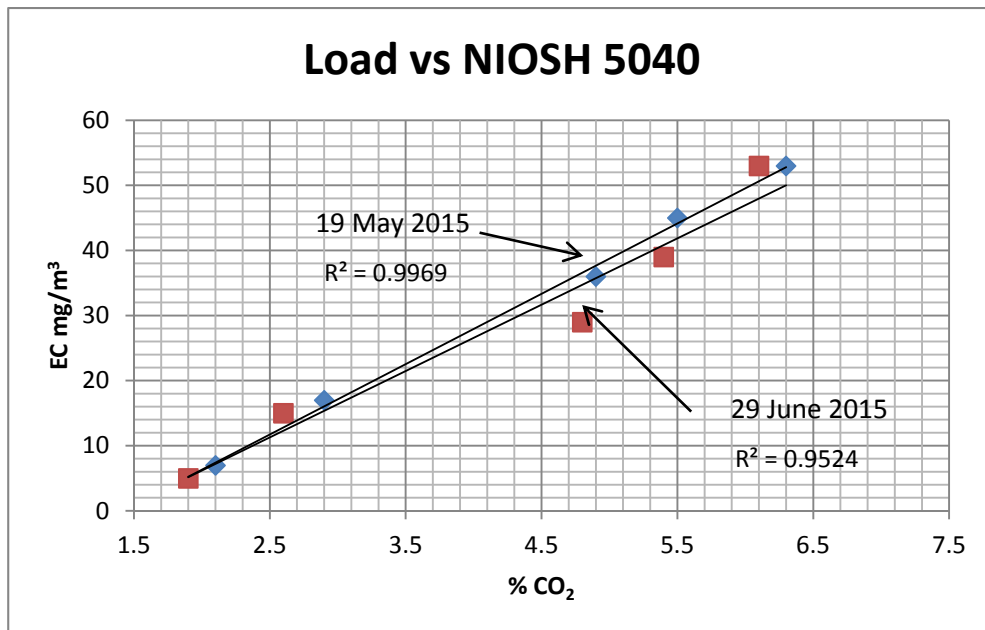


Figure 6 – Comparison of engine load on 19 May & 29 June 2015

Measurement uncertainty

In any analytical analysis the result finally arrived at is subject to a degree of uncertainty. The level of uncertainty is made up of a number of factors including, analytical measurement, sampling method and sampling time to name a few. While the uncertainty of time is quite small the level of uncertainty associated with sample collection can be (and usually is) very large. In this exercise the use of the ERP mixing system would reduce the level of uncertainty associated with sample collection significantly however there would still be an undefined level of uncertainty associated with this action.

In addition the level of underlying analytical uncertainty of the NIOSH 5040 EC analysis as determined by Sunset Laboratories Inc. was +/-12 % for the samples collected using method 1 and +/- 5% for method 2. The difference in the methods was that method 2 used a larger filter deposit area and higher sample volume thus leading to a reduced level of uncertainty.

Given the above, the level of uncertainty of the results recorded in this exercise by any of the three instrument types used could never be better than +/- 5% plus the undefined level of uncertainty of the sampling process. It is highly likely that the undefined level of uncertainty associated with sampling would be at least as high as that of the NIOSH 5040 analytical method giving an overall estimated uncertainty significantly in excess of +/- 5%.

When translated to reporting results the level of uncertainty of all instruments should be understood so that comparisons of results to statutory or other requirements, is made in an appropriate manner. For example, when significant levels of uncertainty are likely to be present in the results the use of defined baseline comparisons which require compliance, at similar levels of uncertainty as that provided by the analytical instruments, is not valid.

Result of Collaboration of Calibration

Figure 7 shows the calibration of both the ChekMate and the PM-Tech (MAHA-4M) against NIOSH 5040 EC. The excellent correlation demonstrates that when an appropriate sampling protocol is used an appropriate calibration it is possible to get good inter instrument correlation.

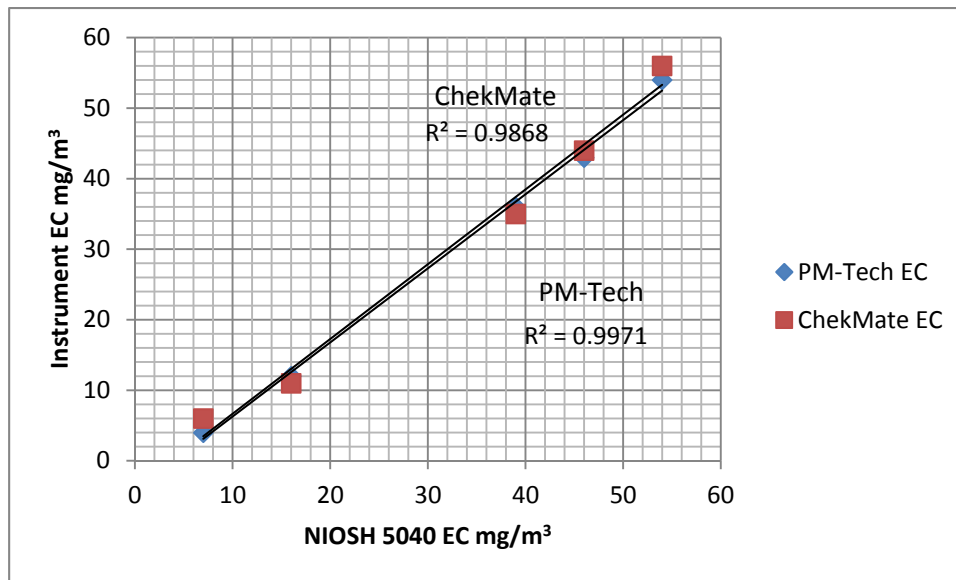


Figure 7 – Comparison of ChekMate and PM-Tech (MAHA-4M)

CONCLUSIONS

From the results of the exercise it is possible to draw a number of conclusions;

- For the accurate analysis of EC in the raw exhaust of engines used in the mining industry it is a fundamental requirement that the calibration of any instrument must be on the same engine load basis as that used in routine sampling especially at the higher EC concentrations.
- It is possible to obtain a good correlation between the concentrations of EC in the raw exhaust of a diesel engine to that measured by NIOSH 5040 if the calibrations mentioned above are used.
- There is good correlation between instrument 5 (MAHA – 4M) and NIOSH 5040 (19 May 2015) and instruments 6 & 7 (ChekMate) and NIOSH 5040 (29 June 2015) if the factor recommended by Mason (2008) is applied to the results of instrument 5.
- The results from instruments 2 & 3 (AVT 540) are highly suggestive of a systematic calibration error which should be investigated by the manufacturer.
- Following the inflow of any water into an instrument, or any other damage, the device should be removed from service for maintenance & recalibration. The issue of water inflow can be managed by using a device that does not allow water to contaminate the exhaust pathway to be sampled. Such devices are commercially available and should become standard practice.
- For useful results to be obtained from engines in service using any of the instruments tested in this exercise (provided they are suitably calibrated) there is a need to have a standard method of presenting the sample to the instrument such that possible interferences are mitigated. Sampling from the exhaust pathway prior to any control technologies provides useful information on the engine condition and for that reason it should be the prime sampling location Hines et al (2014) & Mason (2014). Sampling post control technologies is possible provided a mixing unit such as that used in this exercise is part of the sample collection process. The current practice of inserting a probe in the tailpipe of an engine in any achievable orientation without a mixing unit will undoubtedly lead to incorrect and confusing results.
- The current practice within the Australian mining industry of reporting results to levels of uncertainty well below that possible with the instrument should cease and all stakeholders should be informed that ALL results have a level of uncertainty dependent of the underlying instrument calibration and sampling errors.

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Table 4 – Summary of results for samples collected on 19 May 2015

Load Level	% CO ₂ Average	Instrument 2 EC mg/m ³	Instrument 3 EC mg/m ³	Instrument 4 EC mg/m ³	Instrument 5 EC mg/m ³	Instrument 6 EC mg/m ³	Instrument 7 EC mg/m ³	NIOSH 5040 Method 1 EC mg/m ³	NIOSH 5040 Method 2 EC mg/m ³
1	2.2	13 (12-14)	17 (17-18)	30 (28-32)	7 (5-8)	6 (6-7)	6 (6-7)	6 (6-7)	7
2	2.9	26 (25-27)	28 (29-30)	72 (70-74)	10 (10-11)	10 (9-11)	11 (10-13)	15 (14-15)	17
3	4.9	70 (62-77)	64 (60-66)	227 (204-250)	29 (28-29)	+	+	32 (31-33)	36
4	5.6	77 (72-82)	71 (67-75)	253 (241-266)	35 (33-36)	19(17-21)	18 (17-19)	39 (36-42)	45
5	6.4	86 (79-92)	88 (86-91)	284 (266-302)	44 (42-46)	32 (29-36)	29 (27-30)	49 (48 – 50)	53

*Instrument 2 & 3 (AVT530), Instrument 4 & 5 MAHA – 4M, Instrument 6 & 7 Chekmate

Table 5 – Summary of results for samples collected on 29 June 2015

Load Level	% CO ₂ Average	Instrument 5 EC mg/m ³	Instrument 6 EC mg/m ³	Instrument 7 EC mg/m ³	NIOSH 5040 Method 1 EC mg/m ³	NIOSH 5040 Method 2 EC mg/m ³
1	1.9	4	7	8	5 (4-5)	5
2	2.6	14	12	14	13	15
3	4.8	37 (34-41)	35	34	34 (32-36)	29
4	5.4	52 (49-55)	36 (34-38)	36 (35-38)	38 (36-39)	39
5	6.1	71 (66-77)	54 (48-62)	55 (48-66)	51 (49-54)	53

*Instrument 4 & 5 MAHA – 4M, Instrument 6 & 7 Chekmate

LEARNING OCCUPATIONAL HEALTH BY EXPERIENCING RISKS (LOCHER) A Pilot Project among Motor Vehicle Accident Repair Students at the South Essex College

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ABSTRACT

Industries such as engineering, motor vehicle maintenance, stone/wood working, and welding/fabrication use/create hazardous substances. These are known to contribute to significant numbers of new cases of short-term as well as long latency work-related diseases (LLWRD). Young learners (YLS) entering these industries are potentially at risk of exposure to excessive amounts. The contributing factors include inexperience of risks and their mitigation requirements.

The Learning Occupational Health by Experiencing Risks (LOCHER) project targets YLS, in innovative ways, before they enter workplaces and aims to equip them to recognise the dangers to their health from exposure to hazardous substances and what they could do to prevent. Three pilots (motor vehicle accident repair, wood working and welding) are currently being developed with the help of YLS. This paper describes what has been achieved, so far, with motor vehicle accident repair students.

Key Words

Isocyanates, behavioural safety, motor vehicle repair, incentives, exposure control, respirator, breathing apparatus

Introduction

The UK Health and Safety Executive (HSE) estimate that every year approximately 10,000 new cases of breathing or lung problems are caused or made worse by long latency work-related diseases (LLWRD) (HSE, 2014a). These are caused by excessive exposure to hazardous substances. Many of these new cases can lead to premature deaths and unnecessary suffering. The social and personal costs arising from these new and existing cases can run into billions of pounds (HSE, 2014b). A number of industries, including engineering, motor vehicle maintenance, stone/wood working, and welding/fabrication use/create hazardous substances. Exposure to these is known to contribute to significant numbers of new cases of LLWRD and more immediate health effects (HSE, 2014a). These are priority areas for HSE. Young learners (YLS) entering these industries are potentially at risk of exposure to excessive amounts of hazardous substances and may develop LLWRD. The contributing factors include inexperience of risks and their mitigation requirements as well as the potential for lack of consistent behavioural approaches over many years.

HSE and the UK industry (HSE, 2014c) are continuing to seek and promote effective and innovative ways to reduce the incidence of future work-related cancers, respiratory and skin diseases. Safety Groups UK (SGUK) - using the umbrella theme "Health Risks at work! Do you Know Yours?" - has been in the forefront of developing innovative solutions to help reduce the future burden from work-related exposure to hazardous substances (SGUK, 2014). This time round, their solution-searching exploration, in association with the International Institute of Risk and Safety Management (IIRSM) and HSE, resulted in the LOCHER project. It targets YLS before they enter the world of work and aims to equip them to recognise the dangers to their health from exposure to hazardous substances and what they could do to prevent. Three pilot areas (motor vehicle accident repair, wood working and welding) are currently being developed with the help of YLS. This paper describes what has been achieved, so far, with motor vehicle accident repair students at the South Essex College (SEC), UK.

Developing the LOCHER Project

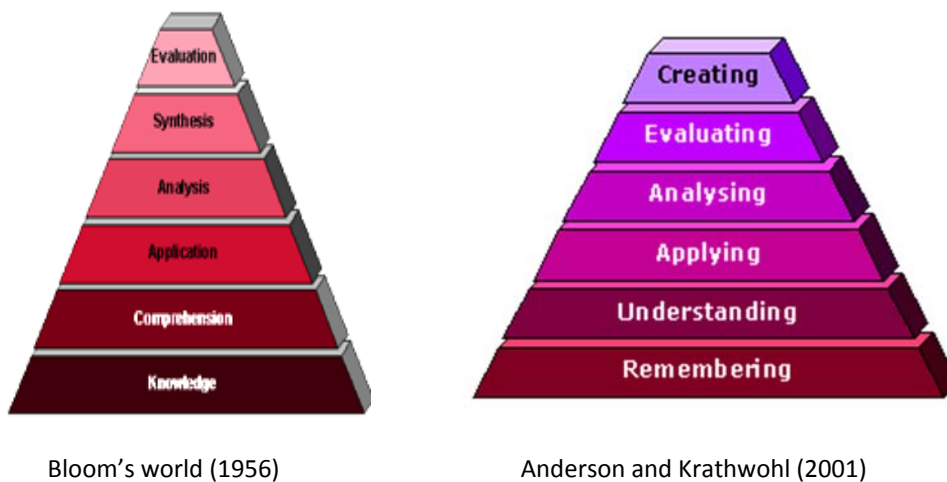
Learning

Learning is an integral part of information, instruction, and training (IIT) as well as competency development required by workplace law such as the Control of Substances Hazardous to Health regulations (COSHH) (HSE, 2013). Competency development is closely interwoven with the ability to make sense of new information. Getting this right among YLS, who are preparing to enter the world of work, is important, this group being the critical cohort (others are those already exposed and suffering from LLWRD and those currently being exposed and may suffer from LLWRD) for improving the statistics on LLWRD.

In order to contribute to an effective IIT, competency development and desirable behaviours, the LOCHER project outputs need to be innovative, inspiring, informing and appealing to YLs. In addition, the outputs should concisely integrate information provided by authoritative and respected sources such as HSE. In aspiring to meet these challenges, the LOCHER team researched much of the key aspects associated with YLs approaches to learning, emotional needs, communication preferences and how to nudge behavioural changes without the big sticks of legislation and enforcement.

Cognition is a term associated with, among other things, one’s ability to process information (knowledge), think about the new information, understand the reasons behind the information, relate to the situation and applying it as well as remembering it for recalling it, when required, at a later date. Analysis, synthesis and evaluation of the information (knowledge) are considered as much more demanding (See Figure 1, for illustration). Therefore, the LOCHER outputs should deal with every aspect of the cognition effectively to maximise positive effects. Having stated briefly about cognition, we move on to memory.

Figure 1: Cognitive domain



Source: <http://www.learningandteaching.info/learning/bloomtax.htm>

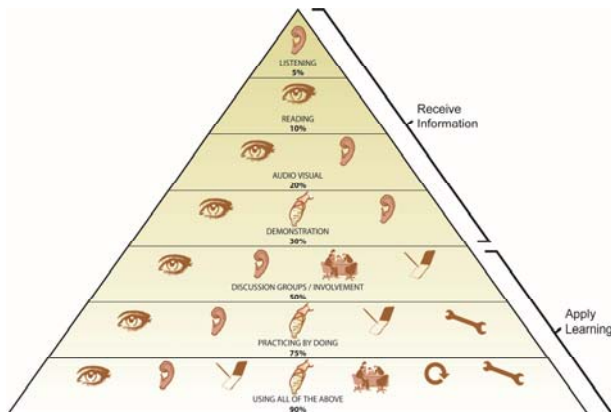
Our short-term memory (STM) stores information using the signals of our five senses and the thinking process. After processing and storing the current information, in due course the STM forgets a vast majority because it is replaced by new information streaming through. However, some of the short term information is passed to the long-term memory (LTM), where it is placed in a structured way. If the information in the LTM isn’t recalled regularly to STM and preferably used in some way, it will be forgotten in due course. There are exceptions to this rule, for example, information or an event which has a greater emotional significance or attachment to the person (Petty, 2004).

A typical relationship between learning methods, sensory routes and recall rates, is summarised in words below and pictorially in Figure 2. (Sithamparanadarajah, 2008).

“People will remember –
 A little of what they hear;
 Some of what they read;
 Much of what they practice, and
 Almost all of what they understand fully, practice and experience.”

Figure 2 shows that the percentage of material learners can recall after experiencing different learning approaches. It shows that the best recall rates require learners to actively apply the learning rather than passively receiving it from chalk and talk such as electronic presentations of law, hazards, risks and exposure control measures.

Figure 2: Learning and Recall



YLS learning preferences

Having explored about cognition, memory and recall, the team then explored YLs’ learning preferences. YLs learn new things in a variety of ways. Research at a secondary school showed that students’ top preferences in teaching methods were group discussion, simulation, role-play, experiments, developing ideas and artwork. Less effective methods included lectures and theoretical approaches (Petty, 2004). There are many other research publications in this area, examples include Ralevic, 2004, Fardon, 2013, and Loughborough University, 2010. A fellow occupational hygienist and a judge at Canberra schools YLs competitions asked his daughter, aged 14, and son, aged 16, about their learning preferences (Morris, 2014). Their responses are summarised in Table 2.

Table 2: YLs response to Learning and Remembering, an example

14 Year old girl	16 Year old boy
Doing things when there is a social interaction, e.g. having fun with friends	When I have freedom to choose how it’s done
Safety precautions, e.g. particularly when students got into trouble for not doing the right thing	Fun experiments, e.g. like the Thermite reaction
When things went wrong, e.g. dropping eggs on the floor, breaking skins of eggs	Experiments where there is a competitive element
When something similar has happened on a TV show, e.g. looking at fat on brown paper and something similar on the Simpsons	When it’s been done on TV, e.g. on shows such as Mythbusters or Catalyst
Vivid colours	Working in groups
Actions, e.g. Explosions and over-boiling test tubes	Doing dissections – because there was lot of hype about it in the class, they all wanted to do it and there was a bit of excitement about it
Approach to Learning	
A visual learner Theory → Practice → Further Theory	A practice based learner Practice → Theory → Practice

HSE conducted research on how best to communicate health and safety messages to YLs in vocational education and training (HSE, 2010). The main findings of the research are summarised in Table 3.

Table 3: Communicating H&S Messages to YLs in Vocational Training

Views
H&S information was seen as important to their profession
Vocation entailed a certain amount of risk, but has to be managed effectively
Information provided lacked clarity about long latency disease and is given in complex and technical ways
Preferences
Tailor information to the profession concerned
Visually engaging material over dense written text
Concise, well laid out information in sections with headings and photographs
Non-technical language, which is easy to absorb
Multiple unrelated messages are disliked

Behavioural Insights

Influencing behaviour is central to health and safety practice. But, ‘talking about behaviour change is a sure fire way of making sure it doesn’t happen’ (Norton, 2009; UK Cabinet Office, undated). Therefore, we need to understand behavioural insights for changing behaviours and then use the information without talking about behaviour change. To achieve this, three areas require careful examination. These are: Who the behaviour change requirement affects; What type of behaviour is intended; and How the change will be accomplished. In order to incorporate the elements of behavioural insights, we studied and adapted the MINDSPACE mnemonics developed for the UK Cabinet Office by the Institute for Government (Undated). It was developed to help bring about significant changes in public behaviour through government policies at relatively low cost. Therefore, it has significant resonance to the LOCHER project. The elements of the MINDSPACE are shown in Table 4 and ‘the 6Es frame work for applying the MINDSPACE’ is reproduced in Figure 4.

Table 4: MINDSPACE and Its Elements

Messenger	we are heavily influenced by who communicates information
Incentives	our responses to incentives are shaped by predictable mental shortcuts such as strongly avoiding losses
Norms	we are strongly influenced by what others do
Defaults	we ‘go with the flow’ of pre-set options
Saliency	our attention is drawn to what is novel and seems relevant to us
Priming	our acts are often influenced by sub-conscious cues
Affect	our emotional associations can powerfully shape our actions
Commitments	we seek to be consistent with our public promises, and reciprocate acts
Ego	we act in ways that make us feel better about ourselves

Figure 4: The 6Es Framework for Applying the MINDSPACE



Notes for Figure 4: legislation goes beyond encourage. Law stipulates what must be done.

The LOCHER project and the Motor Vehicle Body Repair Students

The information in preceding paragraphs show that traditional occupational hygiene approaches (such as chalk and talk, leafy guidance, using exposure measurement results, talking about toxicology and respiratory physiology) in teaching and awareness raising for tackling occupational disease require significant rethinking. Therefore, the challenge for the LOCHER project team is to incorporate a variety of relevant cognitive, communication, behavioural insights and marketing principles as well as other aids for recalling information in innovative and inspiring ways. These are clearly needed to maximise learning and to persuade YLs to act in the desired manner when they come across risks. It means the LOCHER project is based on the following principles:

- YLs should prepare the behavioural modification and risk mitigation messages for their peers. It should encourage other YLs to learn and construct their own ways for learning and reinforcement
- The LOCHER information should enable the learning of risk control messages by experiencing risks and their controls
- Information should build on learners' existing knowledge as well as new knowledge and understanding of concepts
- Experiments and experiencing of the simulated risks should not place the YLs in harm's way

The Pilot Project

The pilot project is being conducted at the South Essex College with the cooperation of the key staff members and some of the YLs learning motor vehicle accident repair.

In order to help invigorate innovation among YLs, the LOCHER team constructed simplified draft resources which contained:

- Basic information on "working with two-pack isocyanate paints", including what you can do to prevent exposure to isocyanates
- An incomplete example of a potential poster to cover hazard, risks and exposure control
- Examples of experiments to experience simulated risks – (i) Spray clearance time in a booth (based on HSE video); (ii) Do not flip the air fed visor until the clearance time has passed; (iii) Removing gloves without contaminating the hands

- Reference to supporting HSE web resources

YLS were given a free-hand and requested to come up with their own ideas and design the communication materials for promoting the information to colleges providing motor vehicle maintenance courses in the UK. YLS did not receive further guidance or training from the LOCHER team.

Results and Discussion

Posters

Nine YLS participated under the immediate guidance of one of us (CL) – the course tutor. Based on the guidance and information available to YLS, they produced 8 draft posters, sometimes by partnering. Seven posters were considered to be on cue. The other one was a Powerpoint slide. Four of the posters are reproduced in the Appendix. To produce the posters, the participating YLS, (who did not have any expertise in occupational hygiene, behavioural science, sociology, marketing or communication) adopted modern technology, their imagination, experience of learning new information, and the ways in which they prefer to communicate/receive information. Their approaches and outputs mimicked many of the research findings reported in previous paragraphs.

The posters produced were not similar to posters or leaflets normally produced by regulators and H&S specialists. The contents were highly visual with minimum amount of words. In addition, the language was direct, humorous at times, assertive and emotionally engaging. These are likely to leave a long lasting impression on YLS.

The approaches taken by the YLS involved a number of elements of the ‘6Es’ in the frame work for applying the MINDSPACE (see Figure 4). We consider that significant aspects of the MINDSPACE requirements were incorporated in these posters and examples are listed in Table 5.

Table 5: A comparison of the poster content with MINDSPACE

Messenger	It has been shown that demographic/behavioural similarity and the feeling between the messenger (YLS at SEC) and receivers (other YLS) improve effectiveness of intervention. In addition, SEC can be considered as an authoritative messenger
Incentives	The information is provided in bite sizes and mainly in visual form. It explains the potential loss that might happen in an assertive, humorous and emotionally engaging way. The timing is right as the learners are preparing to enter the world of work. An early evaluation shows that the posters are designed for impact
Norms	The required behavioural norms are proposed by the peers for the peers, very effectively. Power of networking will be employed by LOCHER
Defaults	As the three key control messages (wear air-fed respirator, do not lift visor before clearance time, spray in booth) are provided by the peers. We expect other YLS to “go with the flow”
Saliency	The relevant information is provided concisely, in novel and persuasive ways
Priming	The emotion catching words/images and other visual methods and simplicity of presentation expected to deliver desired outcomes
Affect	The act of experiencing through the posters can be a powerful decision maker. Similarly, experiencing risk experiments will do the same
Commitment	The LOCHER approach is not seeking multiples of disconnected behaviour changes. It concentrates on one area and the actions required are easy to do. Once learnt, it can become a habit and acted by the subconscious mind quite easily
Ego	The messages provide a desire for comparing self-behaviour with peers. The desired behaviour can be helped by the presence of early adopters and these are students at colleges

Work Remaining

The following work is ongoing.

(i) Evaluating the posters among the SEC student population. (ii) Construction of a virtual handout. (iii) Experiments to simulate experiencing risks. (iv) Seeking the support of industry leaders in motor vehicle making and maintenance. (v) Marketing the products with the help of YLs and others using various mediums. (vi) Construction of a website for depositing LOcHER information. (vii) The LOcHER project team is working with other colleges on welding and wood working.

Conclusions

Based on the early outputs from the first pilot, we consider that the approaches taken to communicate exposure control messages to YLs would deliver significant success and outcomes. We assert this because the outputs are meeting research findings on learning, behaviour change and communication.

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Appendix – Examples of posters

WORKING WITH TWO-PACK ISOCYANATE PAINTS

Isocyanates are used as hardening agents

Isocyanates are TOXIC substances

To cure a painted surface highly misted to breathe as well as wear and tear

The risk of developing occupational e.g. asthma occurs because paint spraying produces a lot of invisible airborne mist!

Isocyanates and solvents can cause short term effects (e.g. eye irritation, dry skin) and the long term health effects (asthma, dermatitis)

Lung sensitisation

THE EARLY SIGNS OF ASTHMA

- Chest tightness, often outside working hours
- Persistent cough
- Recurring blocked or runny nose
- Recurring sore or watering eyes
- Wheezing
- Breathlessness
- Flu-like shivers

AIR FED MASK SHOULD BE WORN WHEN SPRAYING

Safety Groups UK
PROMOTING HEALTH & SAFETY WELLBEING

Charlotte Hunt: 12 March 2015

It is what you can't see that will cause you harm!

Just because you can't see the fine spray it doesn't mean it's not there in the booth!

Are your lungs important to you?

Remember your air fed mask protects you. Living with occupational asthma is not fun!

Safety Groups UK
PROMOTING HEALTH & SAFETY WELLBEING

Adam Gentry 18: 29/04/2015

ASTHMA

Caused by...

- Smoking
- Soldering fume
- Welding fume
- Spray painting
- Wood dust

Is it worth it?
Use the right controls!

Safety Groups UK
PROMOTING HEALTH & SAFETY WELLBEING

Dirazic Sheridan 29/4/15

DISEASE EXPOSED TO 2PACK PAINT

If exposed to two-pack paint spray, you can easily get Asthma. The side effects include persistent coughing, a runny nose and tightness of the chest.

- Spraying produces a lot of invisible mist. Never spray outside of the spray booth.
- Make sure you know the clearance time of your spray booth.
- Sprayers should not lift the visors of their masks immediately after spraying.
- Wait for the clearance time to pass.

Normal bronchiole Asthmatic bronchiole

Use Your' Noggin - Use Your Mask...

Safety Groups UK
PROMOTING HEALTH & SAFETY WELLBEING

Lucas Colyer 6: March 2015

DERMAL ABSORPTION OF ORGANOPHOSPHORUS INSECTICIDES: EFFECTS OF CONCENTRATION AND TEMPERATURE ON SKIN PENETRATION OF OMETHOATE

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ABSTRACT

Exposure to organophosphorus compounds (OP) is not limited to agricultural workers, but can involve emergency responders, workers involved in manufacturing, transport, storage and disposal of OPs. While gloves are used for hand protection, concentrated and diluted OPs can be spilled or splashed onto exposed skin. These incidents could occur outdoors at relatively high ambient temperatures. Information regarding the effects of concentration and temperature on skin penetration is limited, so we investigated the effects of these factors using omethoate, an OP insecticide widely used in Australia, replicating plausible working scenarios. Human abdominal skin samples were exposed to full (814 g/L) and application strengths (0.6 g/L) omethoate, in an *in vitro* model according to OECD protocols, at 23 (± 2)°C and 37°C for up to 8 hours. Analysis was via High Performance Liquid Chromatography (HPLC-UV). Omethoate penetrated at varying degrees for all exposure conditions. At 23 (± 2)°C, omethoate penetrated at 15 mins (application strength) and 6 mins (full strength), with increased maximum flux rate from 0.2 (± 0.13) $\mu\text{g}/\text{cm}^2/\text{min}$ to 4.9 (± 1.7) $\mu\text{g}/\text{cm}^2/\text{min}$. Similarly, at 37°C, breakthrough times were shortened to 8 min (application strength) and 4 mins (full strength) respectively, with higher maximum fluxes and greater cumulative penetrations. When the temperature was elevated to 37°C, penetration of application strength omethoate doubled, from 0.03 (± 0.004) mg to 0.05 (± 0.08) mg, whereas full strength omethoate increased by 70-fold from 0.8 (± 0.1) mg to 56 (± 10.3) mg over the 8-hour exposure period. The findings indicate that concentration of omethoate and temperature can enhance penetration through the skin. However other factors may also contribute to the enhanced penetration.

Keywords: dermal exposure; skin penetration; organophosphorus pesticides; omethoate; static Franz diffusion cell

1. INTRODUCTION

Organophosphorus insecticides (OPs) are extensively used in many industries, and exposure to these substances may occur through skin contact, which is more prominent than the respiratory route. Dermal contact with OPs potentially occurs during manufacturing, formulation, transport, storage, harvesting, cleaning of OP containers for disposal, as well as to users (agricultural workers) and ambulance workers attending to OP poisoning and accident cases. Estimates of skin penetration may become a critical part of risk assessment when personal protective equipment is not worn to prevent skin contact, or when the skin is exposed to the OPs trapped on the inside of the gloves over long periods of time. Exposure may also happen by splashes and spills during mixing and loading of concentrated OPs, as well as from wind drift when spraying and re-entry into sprayed fields that repeatedly expose the workers to low concentration (diluted) products (Tielemans, Louwse & de Cock 1999; Wolfe, Armstrong & Durham 1966). Residue on spraying equipment, PPE or treated surfaces after pesticide application may also contribute to dermal exposure of OPs to the workers. Whether in concentrated formulations or in diluted form, OPs can be absorbed through the skin very well (Kamanyire & Karalliedde 2004; Riviere 2006). While many variables may affect skin penetration of OPs, the complexity of skin makes dermal studies more complicated.

Although in real life scenarios, tasks with high and low concentrations of OPs may be performed in warmer conditions, literature describing the effects of these variables on skin penetration is limited and needs further exploration (Chang, Brownie & Riviere 1994; Chang & Riviere 1991; Clarys et al. 1998; Moore et al. 2014; Patel, ten Berge & Cronin 2002; Thongsinthusak, Ross & Dong 1999). Therefore, this study was conducted to investigate the effects of omethoate concentration and elevated ambient temperature on skin penetration for a better understanding of OP penetration through the skin.

2. METHODOLOGY

Experimental design

Omethoate, a commonly used OP in Australia, is classified as Chemicals of Security Concern in Australia by the Council of Australian Government (COAG) and is prohibited by the European Union (Commonwealth of Australia 2013; Immig 2010). This study was designed based on a practical model with exposure time for up to 8 hours and two realistic exposure temperatures (normal room temperature (23±2°C) and elevated temperature (37°C)) to observe the extent of omethoate penetration through the skin. Four to seven replicates of the skin testing were conducted on the epidermal skin samples using commercially formulated omethoate at two concentrations; full strength (814 g/L) and application strength (0.6 g/L) to mimic exposure to the concentrated formulations during spillage and splashes, as well as exposure to the recommended diluted mixture for spraying. This study applied infinite dose regime by putting 200 µl of the test chemical into the donor chamber to allow for a maximum rate of penetration of the test substance (per unit area of skin) (EHC235 2006) and in order to mimic an occupational exposure situation, this study was conducted for up to 8 hours

Chemicals

Commercially formulated omethoate was used in this study; Folimat® (Ospray Pty Ltd, Queensland, Australia) containing 814 g/L omethoate and 400 g/L propylene glycol methyl ether acetate (PGMEA) as the carrier solvent. The concentrated omethoate is hereafter referred as 'full strength'. Application strength omethoate (0.6 g/L) was prepared by diluting the full strength with pure MilliQ water. Analytical grade compounds (Fluka-36181 for omethoate) from Sigma-Aldrich was used for preparing standard solutions.

Skin membranes

Abdominal skin samples were obtained following reductive abdominal surgery from two female, Caucasian donors aged 35 and 58 with no obvious signs of skin damage, scarring or tattooing. The full thickness skin slab was thoroughly washed with water, and the subcutaneous tissue and fat removed without damaging the skin. The epidermal layer was removed from full thickness skin by submerging it into water at 60°C for 60 seconds (Davies, Ward & Heylings 2004; OECD 2004). Samples were stored at -20°C and allowed to thaw at room temperature before use. In order to ensure that the skin was still intact prior to the skin testing, skin barrier integrity was assessed by electrical resistance (ER) measurement using Tinsley LCR Databridge 6401 (Tinsley Prism Instruments) set in modes of Resistance (R), Parallel Equivalent (PAR), and 100 Hz. Skin samples with a capacitance lower than 10 kΩ were considered to have abnormally high permeability, therefore replaced (Lawrence 1997).

Static Franz diffusion cells set-up

The prepared epidermal sample (with *stratum corneum* side up) was mounted between the donor chamber and the receptor chamber of the static Franz diffusion cells. A rubber ring was placed on top of the skin sample to ensure proper seal and the chambers were clamped together. The donor chamber was filled with 200 µl of the test chemical and covered with a marble to avoid evaporation loss. Receptor fluid (pure MilliQ water) was kept in contact with the skin under surface and continuously stirred with a Teflon-coated magnetic stirring bar at 350 rpm on a Variomag Multipoint Electronic Mat (Quantum Scientific). At appropriate time intervals, 200 µl of receptor fluid was withdrawn out through the side-arm (sampling port) using a syringe to analyse if there was any penetration of OPs to the recipient chamber, and replaced with same amount of fresh receptor fluid throughout the experimental period.

Apparatus

Samples were analysed by High Performance Liquid Chromatography (HPLC) with Shimadzu SPD-20A Prominence UV/Vis detector, connected to a GBC LC 1120 HPLC Pump and a PE Nelson 900 Series Interface. A volume of 20 µl sample was directly injected into an Alltech Alltima (C18, 5 micron, length 150 mm, I.D 4.6 mm) separation column. Omethoate was eluted with a mobile phase consisting of aqueous methanol 30:70 v/v (flowrate 0.5 ml/min, UV wavelength 220 nm). Quantification of OPs was based on the integrated peak area of the OPs related to a standard curve.

Calibration graph

A calibration graph for determination of OPs was obtained by diluting the stock solution with pure MilliQ water to 10 working standards. Their concentrations ranged from 0.01 – 1,000 µg/ml. To obtain a linear calibration curve, peak areas were plotted

as a function of the concentration and the curve was used to determine the concentrations in the experimental samples. Good linear fits were obtained daily for accuracy, with reasonable correlation coefficient closest to 1. The Limit of Detection (LOD) (3:1 signal to noise ratio) for both OPs were found to be 0.01 µg/ml.

Descriptors of penetration

The ability of OPs to penetrate through the skin into the receptor fluid was described as breakthrough time (BT), average maximum flux and cumulative penetration. BT (mins) is based on the time that shows evidence of OP penetration in the receptor fluid. Flux (µg/cm²/min) refers to the penetration rate of which the amount of OPs (µg) crossing the skin area (cm²) in a set time (min). Cumulative penetration (mg) is the total amount of OPs recovered in the receptor fluid at the end of the 8-hour test duration. Calculation of these descriptors was based upon measurement of OPs in the receptor chamber during the experimental period.

RESULTS

Comparison of OP penetration through the skin under variable conditions.

At the end of the 8-hour experiments, omethoate demonstrated different results for different exposure conditions in terms of breakthrough times, average maximum fluxes and average cumulative penetration, as summarised in Table 1.

Table 1: Summary of skin testing outcomes of omethoate under various temperatures and concentrations

	Room temperature (23±2°C)		37°C	
	Application strength (0.6 g/L)	Full Strength (814 g/L)	Application strength (0.6 g/L)	Full Strength (814 g/L)
Breakthrough time, BT (mins)	15	6	8	4
Average maximum flux (µg/cm ² /min)	0.2 (±0.13)	4.9 (±1.7)	0.5 (±0.3)	537 (±169.9)
Average cumulative penetration (mg)	0.03 (±0.004)	0.8 (±0.1)	0.05 (±0.08)	56 (±10.3)

Notes:

Cumulative penetrations presented are for the amount calculated at the end of the 8-hour test period

Average values are for replicates, n=4 to 7

BT denotes breakthrough time observed when OP penetration was observed in the receptor fluid, based on 0.01 mg/mL limit of detection. The first reading was taken at 0.5 min, followed by 1, 2, 4, 6, 8, 10, 15, 30 mins and hourly for up to 8 hours.

Higher concentration of omethoate decreased the breakthrough times and resulted in higher average maximum fluxes and greater cumulative penetrations which are statistically significant (p <0.001). At room temperature, application strength omethoate showed evidence of breakthrough at 15 minutes and shortened to 6 minutes for full strength omethoate (with average maximum fluxes of 0.2 (±0.13) and 4.9 (±1.7) µg/cm²/min respectively) (Table 1). At 37°C, increase in concentration from application strength to full strength resulted in increased average maximum fluxes by approximately 1,000-fold (from 0.5 (±0.3) to 537 (±169.9) µg/cm²/min). Average cumulative penetrations also increased from 0.05 (±0.08) to 56 (±10.3), with shorter breakthrough times. In other words, full strength omethoate has the tendency to penetrate the skin faster and in a greater amount over time for both temperature conditions.

Results presented in Table 1 show that increase in temperature from 23 (±2) °C to 37°C resulted in shorter BTs, greater average maximum fluxes and average cumulative penetrations. The difference is found to be statistically significant for application strength as well as full strength (p <0.001). Application strength omethoate took 15 minutes to penetrate the

skin, and the breakthrough was shortened to 8 mins when the temperature was elevated to 37°C. Additionally, approximately 2-fold increase in average maximum fluxes and average cumulative penetration (from 0.03 (±0.004) to 0.05 (±0.008) mg) at the end of the 8-hour test period were observed with the temperature increase (Figure 1).

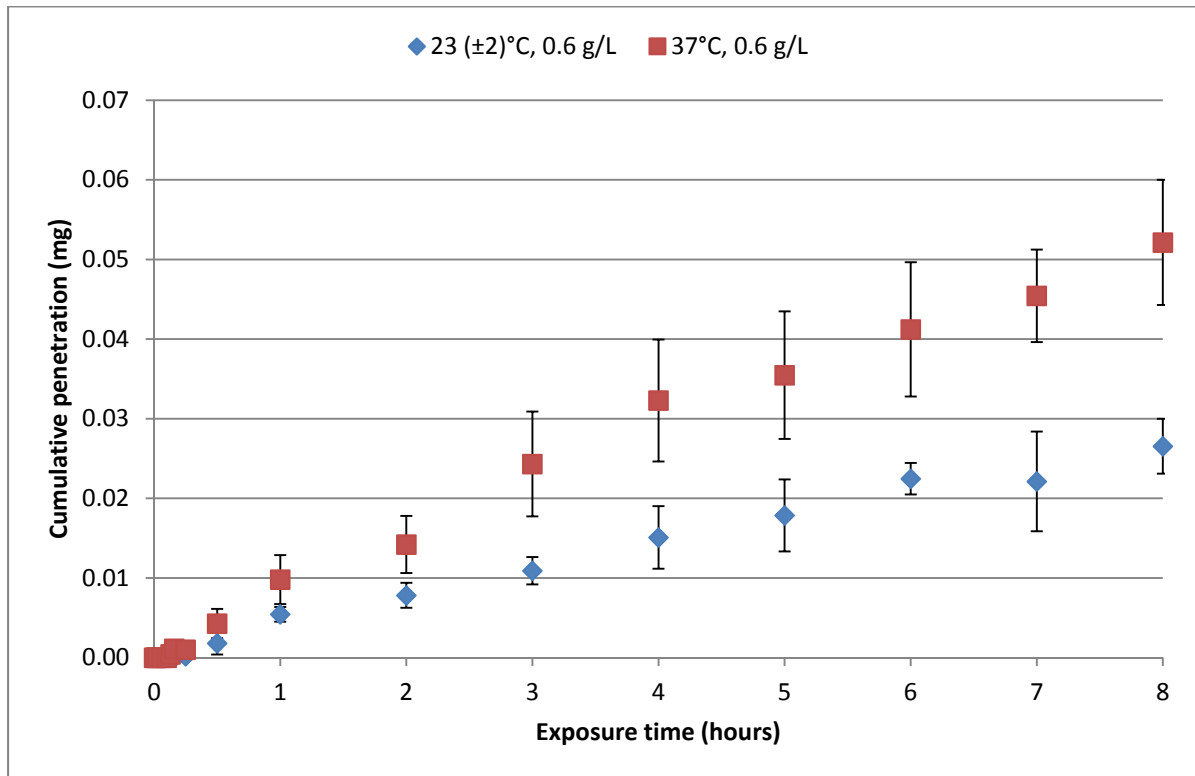


Figure 1: Penetration of application strength formulated OPs through the skin at ambient temperature (25°C) and elevated temperature (37°C).

Similarly, shorter BTs (from 6 minutes to 4 minutes) were recorded for full strength omethoate when the temperature was elevated (Figure 2). Average maximum fluxes were more than 100-times higher than at room temperature for full strength omethoate, indicating enhanced penetration of omethoate in warmer conditions, in which the average cumulative penetration multiplied by 70-fold (from 0.8 (±0.1) to 56 (±10.3) mg).

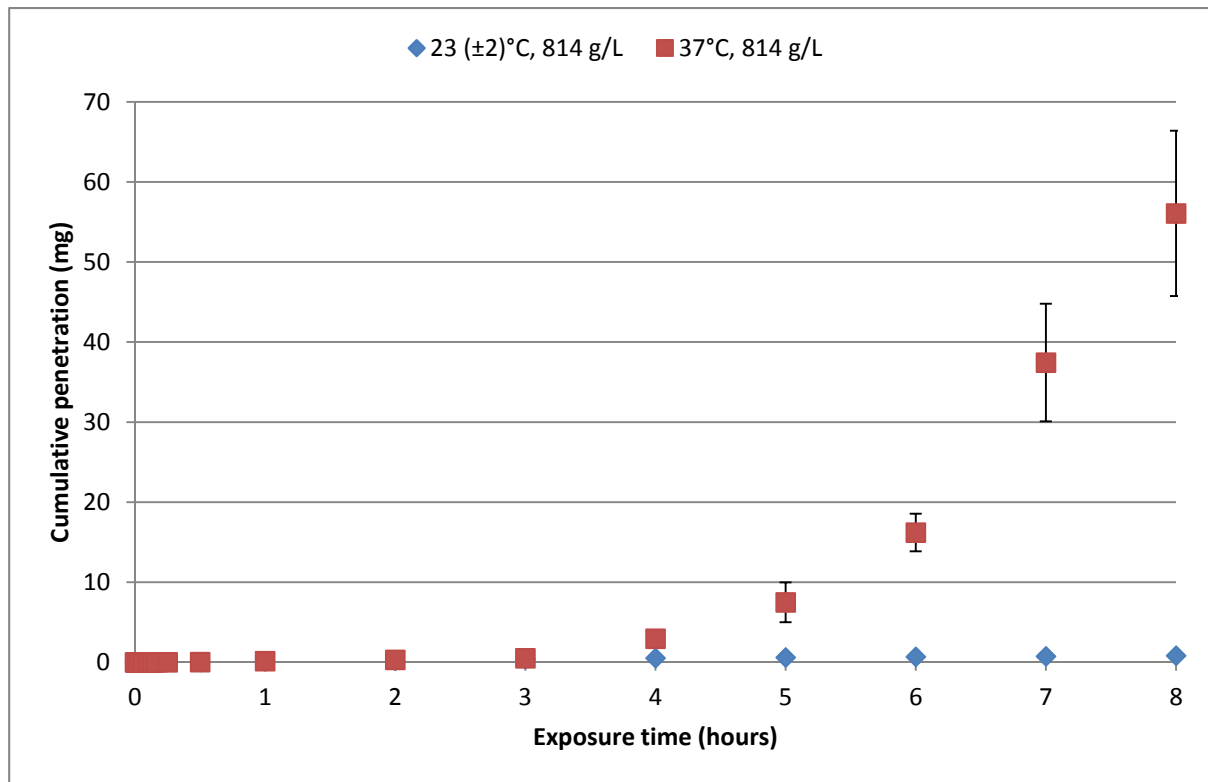


Figure 2: Penetration of full strength formulated OPs through the skin at ambient temperature (25°C) and elevated temperature (37°C).

DISCUSSION

Effects of omethoate concentration and elevated temperature on skin penetration

This study shows the skin penetration of omethoate may differ when in full strength (during mixing and loading) or application strength (during spraying), in normal room temperature (23 (±2)°C) or a warmer condition (37°C), especially when gloves are not worn.

High concentration (full strength) omethoate recorded shorter breakthrough times, higher average maximum flux and greater cumulative penetrations compared to omethoate in application strength throughout the 8-hour experiments. This finding is similar to a previous study by Thongsinthusak, Ross and Dong (1999) where dichlorvos demonstrated increased absorption with increased dose, although the remaining 15 pesticides showed an inversely proportional relationship.

The findings of this study showed short BT (15 mins for exposure to 0.6 g/L or 9.1 nmol/cm² applied concentration at 23 (±2)°C), while the work by Sartorelli et al. (1998) demonstrated a lag time of 0.98 (±0.56) hour for 61.6 nmol/cm² of applied omethoate. The difference could owe to the different types of skin used, where Sartorelli and colleagues used full thickness monkey skin, while this study used *stratum corneum* of the human skin. The penetration ability of human skin and other laboratory animals were discussed by previous researchers (Bronaugh, Stewart & Congdon 1982; Dugard & Walker 1983). The lower amount of omethoate penetration compared to findings in this study could also be explained by the use of commercial omethoate, which was formulated with a glycol ether, a carrier solvent that may have high skin penetration capacity, hence assisting in penetration of omethoate (Nielsen, GD et al. 2000; Venier et al. 2004).

Besides the concentration of omethoate tested, this study showed that elevated temperature resulted in increased average maximum fluxes and cumulative penetrations with shorter BTs at the end of the 8-hour exposure. These findings are similar to the work by Craig, Cummings and Sim (1977) where greater absorption and penetration of VX, an anticholinesterase inhibitor was reported at an elevated temperature. Temperature may also affect relative humidity, occlusion and skin hydration, local blood flow, lipid transition in *stratum corneum* and consequently enhance skin uptake (Auclair et al. 1991; Boman & Maibach 2000; Chang & Riviere 1991; Gay et al. 1994; Schafer et al. 2002; Vanakoski et al. 1996; Wiechers 1989).

Therefore, there is a likelihood of accelerated omethoate penetration through the skin where it may occur in warmer conditions e.g. farmers mixing and spraying omethoate on hot days.

In addition, skin penetration may also be influenced by other factors, including the physicochemical properties of the chemicals e.g. octanol-water partition coefficient (log Kow), solubility, molecular size of the pesticides and biological factors of the skin e.g. skin thickness, anatomical site and metabolism (Feldman & Maibach 1967; Holmgaard & Nielsen 2009; McDougal & Boeniger 2002; Nielsen, JB 2004; Semple 2004).

Extrapolation of the penetrated amount of omethoate

Because dermal exposure does not have occupational exposure limits (OELs), acceptable daily intake (ADI) may be used as a benchmark for the intake level of a chemical that can be ingested daily over an entire lifetime without appreciable risk to health. According to Department of Health Australia (2015), ADI for omethoate is 0.0004 mg/kg bw, therefore by extrapolation to a 70-kg human, the limit is 0.028 mg of total omethoate. The potentially exposed surface areas are 800 cm² (hands) and 1,200 cm² (forearms) which totals up to 2,000 cm² if the recommended elbow-length gloves (hands and forearms) are not worn by OP handlers (WHO 1986). Estimated OP penetration and toxicity relevant to occupational exposure are calculated in the following scenarios, and summarised in Table 2.

Table 2 Calculated penetration of OPs for exposure scenario to omethoate in various conditions

Exposure scenario					Ratio of amount penetrated/ ADI (for a 70-kg man)
Concentration (g/L)	Exposure temperature (°C)	Duration of exposure	Part(s) exposed	Cumulative penetration (mg)	
0.6 (application strength)	23 ±2 (room temperature)	30 mins	Hands and forearms (2,000 cm ²)	0.002	212
814 (full strength)	23 ±2 (room temperature)	6 mins	Hands (800 cm ²)	0.001	50
814 (full strength)	37 (elevated temperature)	4 mins	Hands (800 cm ²)	0.001	48

Source: Department of Health Australia (2015)

Note: Cumulative penetration is for the exposure at the respective duration

In an example of a scenario, assuming that a farmer immerses his bare hands and arms in application strength omethoate for 30 minutes at room temperature, the cumulative penetration is 0.002 mg. Extrapolation to a 70 kg worker in support of the above findings, the total load is 5.9 mg (more than 200-fold greater), which indicates an unacceptable dermal risk.

In a more realistic situation, the farmer might experience splashes of the full strength omethoate onto his ungloved hands while mixing and loading the OP at room temperature. If the hands are not immediately washed, it is estimated that 1.4 mg (from 0.001 (±0.00004) mg cumulative penetration) may penetrate into the body after 6 minutes in contact with the omethoate that is 50-times greater than the set ADI. Similar cumulative penetration is demonstrated if it occurs in a warm condition (37°C), but with a shorter breakthrough time (4 minutes). If this exposure is repeated over time, it may be absorbed into the body and result in various acute (including salivation, lacrymation, urination, diarrhoea, gastric upsets, respiratory paralysis) and subacute symptoms (such as delayed neuropathies) of OP toxicity (Balali-Mood & Abdollahi 2014).

CONCLUSIONS AND RECOMMENDATIONS

This study demonstrated that high concentration of omethoate and elevated temperature had definite effects on skin penetration, with higher average maximum fluxes and higher cumulative penetrations. Breakthrough times of the omethoate were also affected, with shorter BTs recorded at high concentrations and higher temperatures. Penetration of full strength omethoate through the skin was rather alarming. Therefore, considerations should be given on the correct selection of gloves for hand protection and good hygiene practice should be adopted (e.g. thorough handwashing, frequent change of gloves) especially when handling full strength OPs, under warm conditions.

For future studies, skin penetration of other OPs of different physicochemical properties should be conducted to better understand the potential risks. In addition, the influence of concentration and varying exposure temperature on skin penetration should also be explored, especially the situation closest to real life scenarios. While customarily in vitro studies on OPs have looked at pure OP chemicals (active ingredients), there is a need to explore commercial formulated products, which contains carrier solvents that may affect skin penetration (Baynes et al. 2002; Baynes & Riviere 1998). Other aspects that may affect penetration and are worth exploring include penetration of OPs through damaged, abraded or irritated skin (Bronaugh & Stewart 1985; Grandjean 1990; Ilyin et al. 1975; Levang, Zhao & Singh 1999) as well as the effects of occlusion on skin penetration (Idson 1971; Wester & Maibach 1983; Wurster & Kramer 1961).

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HEALTH PERFORMANCE MANAGEMENT AND KPIS

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ABSTRACT

Safety performance using the KPI's, LTIFR and TRIFR, have been incorporated into business plans and personal performance contracts for over 20 years in the major corporate companies. More recently, environmental performance, reporting on CO2 emissions and losses such as spillages, has become well developed as part of the licence to operate for major companies. However, the identification of health performance KPIs and health programs have struggled to achieve the same business profile as safety and environment. This paper provides guidance for OHS professionals on the selection of health performance KPIs. Examples of Health KPIs currently being used as well as the future generation of leading KPIs based on critical control management are described along with many key references.

1. Introduction

Health and Safety (OHS) performance is routinely reported by many companies not just by the major international companies. It has become part of the suite of reporting KPIs and frequently linked to personal performance contracts. Although they are referred to as health and safety, they refer predominately to accidents and safety events rather than occupational health and the incidence of material issues such as disease and cancers. The predominant health issue reported in safety KPIs will be musculoskeletal injuries. However these are only reported when strong evidence determined that they were a work related incident.

Occupational health is more difficult area to develop leading indicators for many reasons:

- Lag time between exposure and symptoms
- Problems with identification of the illness or disease
- Occupational health itself often takes a lower profile than accidents due to the immediate attention that accidents attract and
- Understanding of occupational health issues by management & workers in some industries can be poor.

Changes in expectations of the OHS reporting culture and greater awareness of health hazards and risks, provides a climate and opportunity to improve the standing of health reporting. This paper will provide guidance for OHS professionals at promoting and improving reporting Health KPIs.

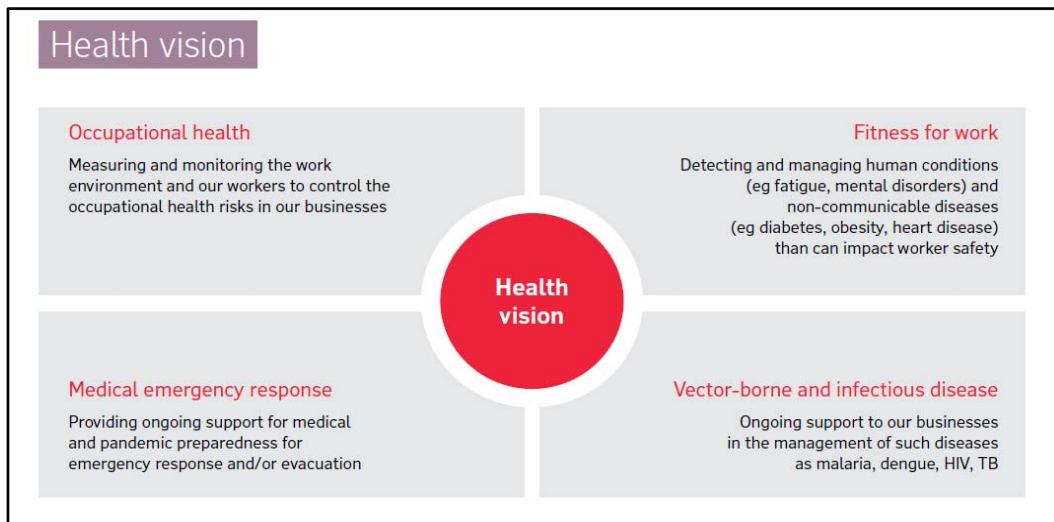
The real value of reporting performance KPIs is that it allows managers to set targets and monitor performance. The quality of the exercise is that management and workers identify issues, have the discussion about effective strategies and improvements to prevent harm to the worker's health.

2. Sustainable Development Reports

Detailed information about company in-house health performance KPIs is difficult to access. However published information about health activities can be found in the annual Sustainable Development Reports. A review of ten companies in the global oil & gas, mining, chemical and pharmaceutical sectors demonstrated that health programs were being implemented. However the information was frequently more of a narrative about programs, case studies or initiatives rather than performance KPIs. Programs reported were predominantly:

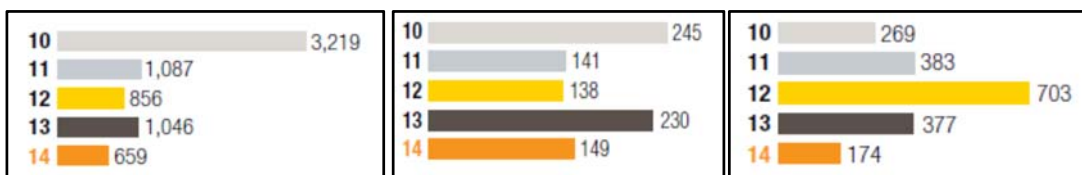
- Fitness for Work (Fatigue, Drug & Alcohol programs & Testing)
- Wellness programs
- Community health programs

A good example can be seen in the RioTinto, *2014 Sustainability Report*, (Reference 1), which provides the focus for their Health Vision, and then a series of stories about their programs across the businesses.



Source – RioTinto, 2014 Sustainability Report (Reference 1),

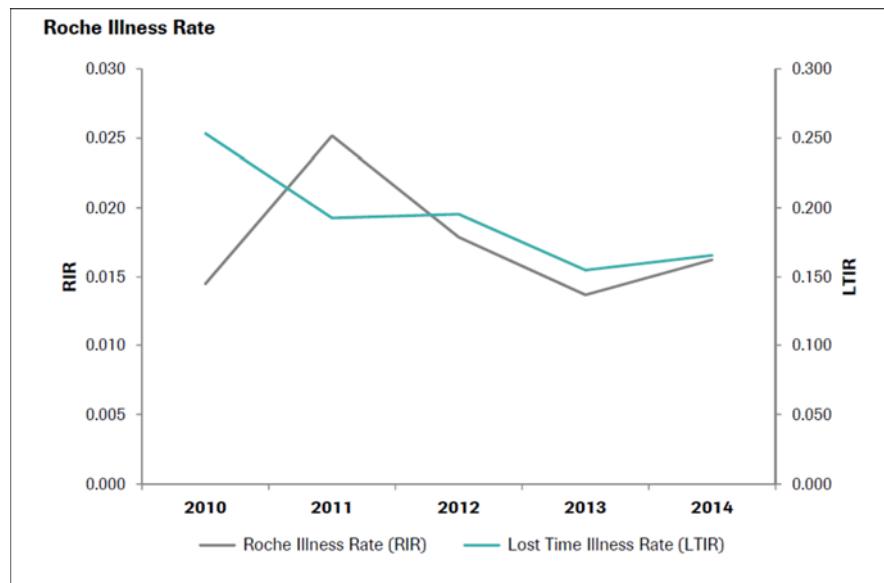
The health performance KPI which was frequently reported for companies working in tropical areas was incidence of malaria. This is because it is considered as being a high risk issue which could cause fatalities and it is relatively easy to collect numbers. Bar charts such as those below from the AngloGold Ashanti, *2014 Sustainability Report*, (Reference 2), provided management and workers with a summary of the incidents and consequently, progress and success of controls such as fogging, wire screens on accommodation blocks and bed nets.



Source: AngloGold Ashanti, 2014 Sustainability Report (Reference 2)

The Roche pharmaceutical company reported on their website, their LTIR, Loss Time Illness Rate, http://www.roche.com/sustainability/for_employees/safety_health_wellbeing.htm

They reported “The lost time illness rate (LTIR) which defines the number of illnesses per 200,000 working hours, also increased in 2014 from 0.155 to 0.166. The types of illnesses reported have remained unchanged over recent years. Locomotor disorders continue to be the most common. Most of these are back problems and especially inflammation of the upper limbs caused by repetitive movements (e.g. using computer workstations). Illnesses attributable to the use of chemicals are limited to allergies and there were no reported cases of poisoning.”



Source: Roche, 2014 Sustainability Report, (Reference 3)

In recent years, BHP Billiton has been a leader in health performance reporting by including Health in their performance reporting and using occupational exposures as their main KPI. This sits alongside Safety and Environment KPIs in the HSE performance table.

● Not achieved ● Achieved ○ On track			
Target	FY2015 Performance		
	Result	Commentary	Target date
Health			
In addition to the use of personal protective equipment, which safeguards our workforce, we will reduce potential occupational exposure ⁽²⁾ to carcinogens and airborne contaminants by 10%.	○	A 40% reduction in potential exposures compared with our FY2012 baseline.	30 June 2017

Source: BHP Billiton, 2015 Sustainability Report, (Reference 4)

3. Health Performance Indicators, Lead and Lag Performance KPI

Traditional OHS performance KPIs are lag indicators such as LTIFR. Health lag KPIs are best applied to acute effects but problematic when looking at hazards which have long latency periods such as cancers and diseases. Typical lag Health KPIs which have been reported have been for tropical diseases such as malaria, and in the case of the mining sector biological monitoring of metals for exposed work groups for example blood lead levels and urinary arsenic levels. **All these are post the exposure and the damage has been done to the worker’s health.**

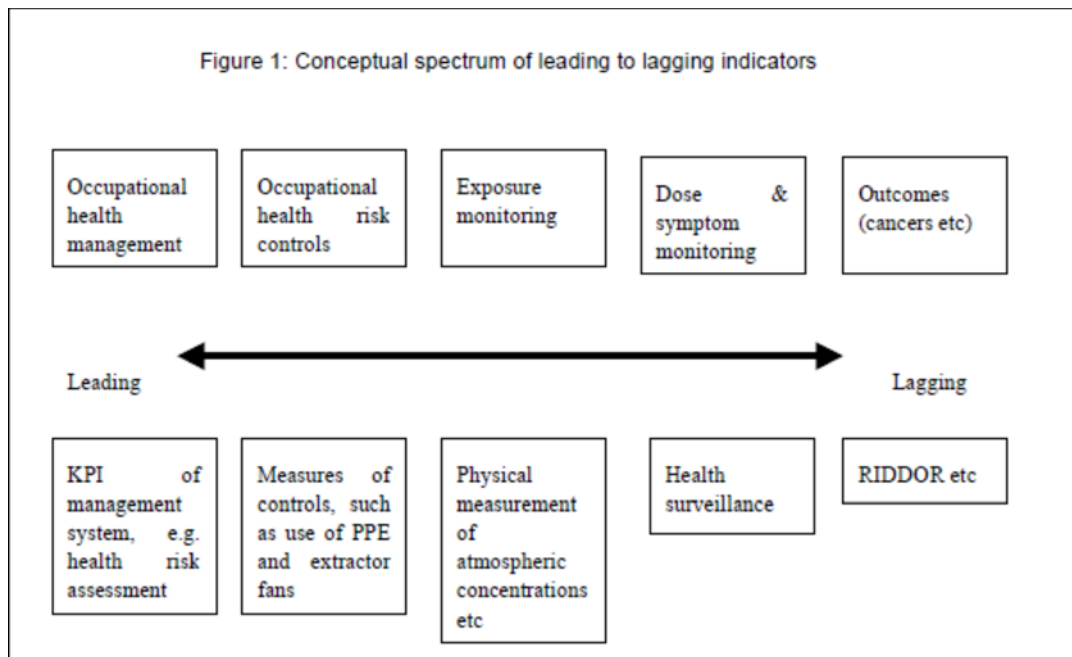
Performance KPIs acceptable to managers need to be:

- Simple to identify, collect, measure, understand and use
- Cost-efficient in use of equipment, personnel and additional technology
- Provide immediate and consistent indications of the level of performance within an identified normal and abnormal range
- Relevant to the operation and understood by line management
- Provide a clear indication of a means to improve performance and
- Align with other strategic measures and the culture of the organisation.

Publications frequently used for definitions for OHS KPIs can be found in the following references:

- OSHA Injury and Illness Recordkeeping and Reporting Requirements, (Reference 5)
- ICMM, International Council on Mining & Metals, (2014) - Health and Safety Performance Indicators, (Reference 6)
- Australian Standard on Workplace Injury Recording, AS 1885.1.

The UK HSE publication, *“Leading Indicators for Assessing Reduction in Risk of Long Latency Diseases,(2009), (Reference 7),* demonstrates the relationship between lead and lag indicators for health in the Figure 1 Conceptual Spectrum of Leading to Lagging Indicators, shown below.



(RIDDOR – UK, Reporting of Injuries, Diseases and Dangerous Occurrences Regulations)

Source: Reference UK HSE, Reference 7.

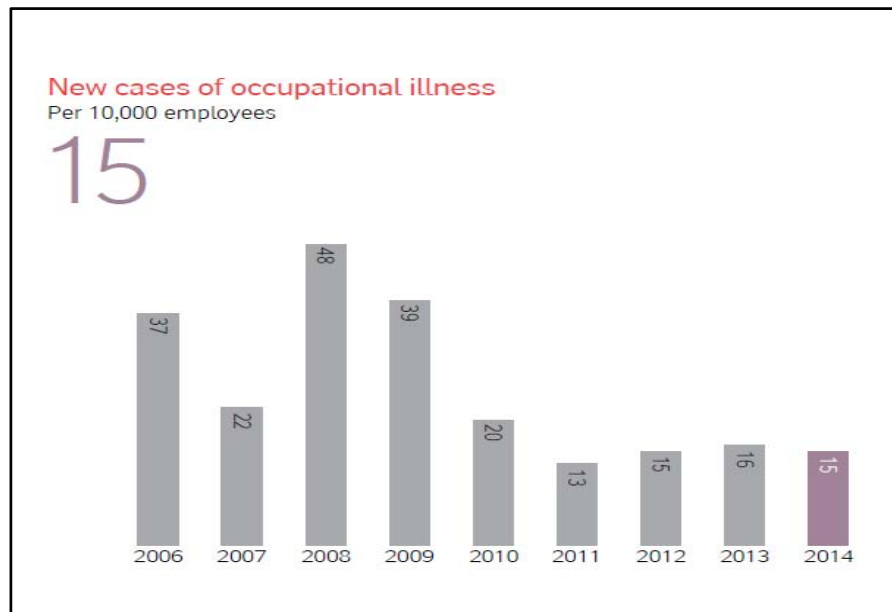
The focus on health performance KPIs should be on exposure monitoring and health risk control. These are hard wired issues which management can directly influence during their daily operations and hence are strong candidates for health KPIs.

The soft issues such as occupational health management systems, audits etc are weak KPIs for managers as they do not directly manage these outcomes and rely on inputs from a variety of people. Consequently there is no direct ownership except by the senior manager at the site.

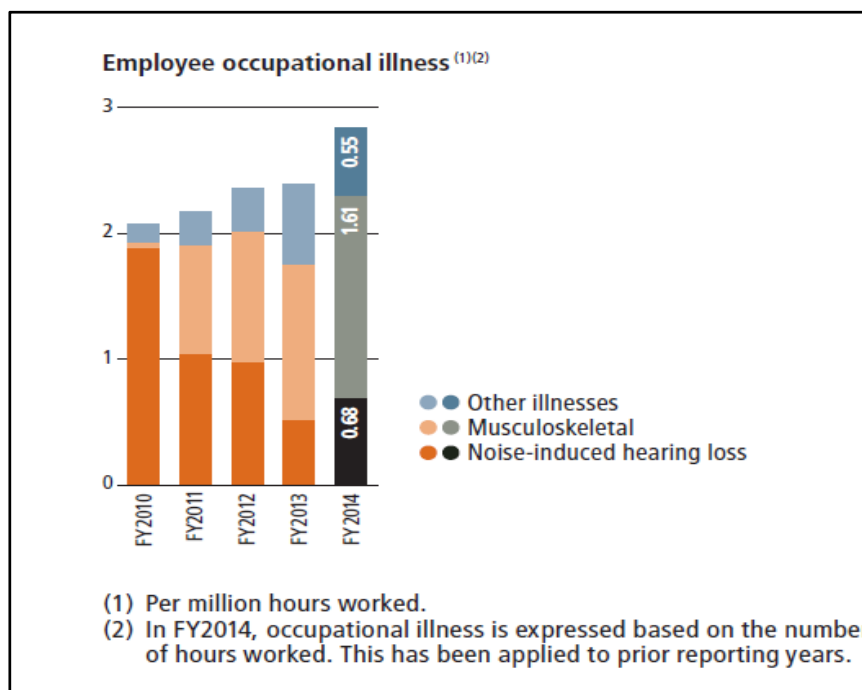
Health issues which have been used for performance KPIs include the following:

- Exceedance of OES for Carcinogens
- Reduction of Hearing Loss
- Reduction in Musculoskeletal Injuries

Mining companies have taken the lead in including Health KPIs in their reporting processes. Good examples of lag Health KPIs can be found in the sustainability reports for RioTinto Ltd and BHP Billiton Ltd. In the case of BHP Billiton Ltd, health performance KPIs have included noise, carcinogenic substances such as silica, radon, diesel particulate matter, nickel and sulphuric acid and other airborne contaminants as coal mine dust and musculoskeletal stressors.



Source: RioTinto, 2014 Sustainability Report, (Reference 1)



Source: BHP Billiton, 2015 Sustainability Report, (Reference 4)

Lead KPIs are better to monitor because the closer a company gets to “zero harm”, as measured using lagging indicators, the more difficult it is to ensure health and safety through tracking lagging performance. In addition for infrequent events such as health issues, it can be difficult to make any generalized causal inference from too few data points. Therefore focus should be on more frequently measurable leading indicators. Leading indicators should be implemented as business-critical tools, fully integrated with relevant management systems and not as “yet another health and safety initiative”, the effectiveness of which has been shown to be decreasing through initiative weariness or overload

4. Critical Controls – Health Risk Controls

After establishing an appropriate parameter for Health Performance KPI an appropriate critical controls KPIs should be developed. An excellent reference is the ICM, International Council on Mining & Metals, (2015) *Health and Safety Critical Control Management, Good Practice Guide (Reference 8)*. The document provides guidance on how to identify and manage

critical controls that can either prevent a serious incident occurring in the first place or minimize the consequences if a serious incident were to occur. The overall process about the identification of the outcome which is to be prevented through to the critical controls such as engineering, maintenance etc, as well as owners is detailed below in Table 1. The principles in Tables, 1, 2 and 3, can apply to a wide variety of workplaces.

Table 1 – Critical Control Management Steps and Target Outcomes

	STEP	TARGET OUTCOMES
Planning Stage	1	A plan that describes the scope of the project, including what needs to be done, by whom and the timescales.
	2	Identify Unwanted Material Event (MUEs) that need to be managed.
	3	Identify controls for MUEs, both existing and possible new controls. Prepare a bowtie diagram.
	4	Identify critical controls for the MUE.
	5	Define the critical controls objectives, performance requirements and how performance is verified in practice.
	6	A list of owners for each MUE, critical control and verification activity. A verification and reporting plan is required to verify and report on the health of each control.
Implementation	7	Define MUE verification and reporting plans, and an implementation strategy based on site specific requirements.
	8	Implement verification activities and report on the process. Define and report on the status of each critical control.
	9	Critical control and MUE owners are aware of critical control performance. If critical controls are underperforming or following an incident, investigate and take action to improve performance or remove critical status from control.

TABLE 2 - Critical Control Management Process

CRITICAL CONTROL MANAGEMENT

STEP 5: Define Performance and Reporting

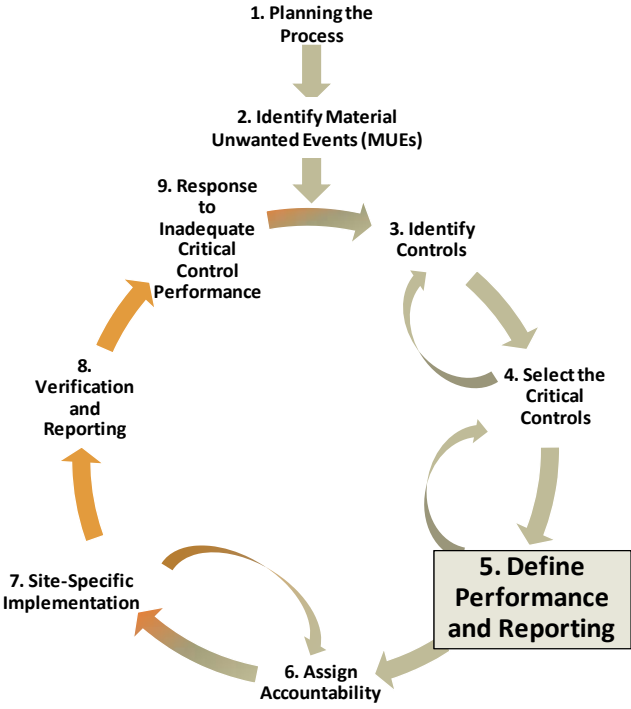
<p>Target outcome</p> <p>Define the critical controls’ objectives, performance requirements and how performance is verified in practice.</p> <hr style="border-top: 1px dotted #000;"/>  <p>Key actions</p> <ul style="list-style-type: none"> • Define objectives and performance requirements for each critical control. • Identify current activities that affect the critical control’s performance. • Describe activities to verify performance and reporting requirements. • Identify what would trigger immediate action to stop or change the operation and/or impose the performance of the critical control. 	<p>Step 5 involves examining the objectives, performance requirements (including current performance) and reporting mechanisms for a critical control. The following questions should be considered when defining each of these points:</p> <ul style="list-style-type: none"> • What are the specific objectives of each critical control? • What performance is required of the critical control? (This is sometimes referred to as a performance standard.) • What activities support or enable the critical control to perform as required and specified? • What checking is needed to verify that the critical control is meeting its required performance? How frequent is the verification needed? What type of verification is needed? • What would initiate immediate action to shut down or change an operation or improve the performance of a critical control? <p>Control information summary</p> <ul style="list-style-type: none"> • For each critical control the following information is needed: • The name of the critical control • What are the specific objectives of the critical control? • What performance is needed from the critical control? • What activities support the performance of the control to the standard? • What verification activities are needed to ensure the critical control is meeting its required performance? <p>An example of a critical control system for a specific MUE is provided in Table 3.</p>
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TABLE 3 - Critical Control Management – Example using Diesel Particulate Matter

CRITICAL CONTROL MANAGEMENT

STEP 5: Define Performance and Reporting *continued*

Table 3: Health example (a critical control system)

1 What is the name of the critical control for diesel particulate overexposure (MUE)?		
Enclosed cab on mining equipment		
2 What are its specific objectives related to the MUE?		
To restrict the access of diesel particulates into the operators' environment to levels well below the occupational exposure limit		
3 What are the critical control performance requirements to meet the objectives?	4 What are the activities within the management systems that support having the critical control able to do what is required?	5 What can be sampled from the set of activities for verification, providing a clear image of the critical control status?
Positive pressure cabin environment maintained to level that prevents ingress of diesel particulates Pressure differentiator indicator that alarms when pressure drops below critical level	Scheduled maintenance and calibration of indicator according to manufacturer's requirements	Review maintenance and calibration records Review alarm log and corrective action taken
Air intake filter operating at greater than 99% efficiency	Pre-shift filter housing inspection for damage Filter inspection at planned maintenance every 500 hours Filter change-out every 1,000 hours	Review documented pre-start inspections Review 500-hour inspection records Review 1,000-hour change-out records
6 What is the target performance for critical control?		
100 per cent of inspection and tests either satisfactory or repair is done before truck is put back into operation		
7 What is the critical control performance trigger for shutdown, critical control review or investigation?		
5 per cent of inspections and tests indicate cab ventilation issues that cannot be resolved or are not resolved before truck returned to service		

5. Conclusion

Prevention of harm to health is the core driver of management approaches to workplace OHS.

Traditional LTIFR, which have been used for over 20 years, do not impact or prevent material health risks, such as cancer and diseases. It is time to change and find new approaches to protect worker's health.

The use of a strategic Health KPI along with appropriate lead KPIs based on control measures will reduce exposures. Managers and workers need to focus on measuring performance of controls as part of their daily operations and make a difference to workplace conditions.

In addition, periodic occupational exposures monitoring will confirm that exposures are maintained below the legislated occupational exposure standards and meet compliance.

The focus of occupational hygiene will truly move from Recognition, Evaluation TO CONTROL, to protect worker's health.

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Recommended Reading:

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DRUG TESTING IN THE WORKPLACE ENVIRONMENT UTILIZING ORAL FLUID SAMPLES

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Draeger Safety Pacific

ABSTRACT

Australia is one of the leading countries worldwide with systematic drug testing in the workplace environment besides road side testing by police forces. A first standard was released already back in 2006 to secure a safe and accurate testing of oral fluid samples. Meanwhile it's getting more and more important besides the measurement of gases and vapours for industrial hygienists to test workers especially in certain industries like mining and oil & gas industry that they appear at work unimpaired, i.e. without immediate influence of drugs and alcohol in order to underscore safety in the workplace for the employees but also to secure assets which usually represent quite significant values for mining companies. Also, oral fluid testing would allow for a clear differentiation between being impaired and having consumed certain illicit drugs a couple of days or even weeks earlier.

Introduction

The traditional human media used to be urine which is, however, a bit intrusive for the person being tested besides cumbersome facilities like toilets which need to be provided to get a urine sample. Needless to say that also witnesses must be present to make sure that a specific urine sample really comes from a specific person, which makes it even more embarrassing. An alternative to human beings as witnesses could also be installed cameras in the toilets, however, this does not mean that it is less intrusive. There have been some reservations versus oral fluid testing mainly because of a different accuracy. Urine testing is still perceived to be quick and accurate enough for these kind of tests being conducted. On the other hand modern oral fluid tests which comply with AS 4760-2006 have shown that both sensitivity and accuracy are well within the expected and accepted range, the same products are also used by different police forces in the country for road side testing. A 3rd party testing by the well recognized Victorian Institute of Forensic Medicine in Melbourne has proven the claimed specifications to comply with the Australian Standard.

Another problem in detecting drugs in urine is that there is some metabolism which takes place in the human body and thus alters the original drug having been consumed, some original drugs like THC (cannabis) cannot be detected in the original form in urine, only the oxidized product. Drugs will stay in the urine longer than in saliva so that the analytical window will be a bit wider and could also detect drugs which have been consumed significantly earlier and would not be relevant for the person being impaired from the perspective of workplace safety. There is a clear differentiation between an impaired person in the workplace area and a person who has taken drugs some days or even weeks ago. The most critical point in time is the presence of drugs in the brain of a person, as a drug or a mixture (cocktail) of drugs will have certain effects on the transmission of information in the brain and also an impact of the speed of reaction as well as a reduction of the viewing angle in particular which underlines not only a risk for the person but also for the assets like quite expensive machines in the mining or oil & gas industry.

Urine or oral fluid (saliva) samples ?

There are quite a number of advantages utilizing oral fluid samples from a human being for testing of drugs being present, one is the significantly more comfortable and absolutely non-intrusive sample taking besides there is no need to walk a person to a toilet to get a urine sample in the presence of a witness, which is of course time consuming, although urine tests are still perceived of being quick, which is definitely not the case if we fairly take all necessary steps into consideration.

Already last year the Australian Manufacturing Workers Union has put major mining companies on notice to discontinue urine tests for the detection of drugs and also alcohol in the body system of workers, drug testing based on oral fluid can be done in the same clean environment of the e.g. health department of a company together with detection of alcohol as both groups of substances can lead to a worker being impaired and thus unsafe for going to work.

How to get a reliable oral fluid sample ?

Getting an oral fluid sample is quite simple and straight forward, there is usually a porous sampling area on a holder which goes into the mouth of the person to be tested. The sampling device can be moved in the mouth in order to get a

representative sample in a reasonable period of time which is usually one minute or even less. The response time towards consumed drugs is very rapid when oral fluid is utilized, about 5 to 10 minutes after drug consumption the illicit drugs can be detected and drugs can be detected about a day after consumption in oral fluid.



Fig. 1: sample-taking of oral fluid

The location of this sample taking procedure is quite flexible, it can be done in the vehicle which is representing the work place of a person, it can be done – as already mentioned – in the health department and almost anywhere else e.g. directly at the entrance gate before entering a company. Who is tested and how often a person and which people are tested is up to the drug- and alcohol policy of a company. In most cases tests are done on a random basis once per worker and year.

Direct evaluation or electronic reading ?

There are two testing principles available on the market, one method which would need the human eye to detect the presence or non-presence of a line which is formed when a drug isn't present or a line which is not formed at a predetermined location on the testing device when a drug is present. Under all circumstances there will be a so-called control-line which must be visible or detectable in order to confirm that a testing device is working properly, within the predetermined life time, and thus the result is acceptable.



Fig. 2: drug-testing device with visual evaluation

All drug-testing devices available in the market are based on immunoassays utilizing biochemical antibodies to detect the drugs being sensitive and specific. Utilizing immunoassays requests certain conditions for storage and total shelf life of a test. This is also the reason why this control line must be visible after a test has been done at a person. Tests are available for the most commonly used drugs, like amphetamines, methamphetamines, cannabis (THC), heroin, marijuana, etc.

All results which are obtained based on visual evaluation of humans are done under a certain subjectiveness, especially in our case, as not all lines may appear strong and clearly visible which can be the reason of some discussion based on some severe consequences for the worker based on a positive drug test result. Although we have to say that nobody is fined based on such a so-called screening test. As soon as a test shows a positive result a second oral fluid sample is taken from a person with no direct reading on site but with a subsequent laboratory analysis using mass spectrometry in combination with liquid chromatography. The key-advantage of these screening tests for drugs is cost-saving as a laboratory analysis is significantly

more expensive than a screening test. A second advantage is time, the laboratory like the Chemical Test Centre in Perth is usually not waiting for a specific sample to be analysed, a result with a screening test is immediately available, a negative result means there is no consequence for the worker and this person is not kept in stand-by until the laboratory result is back, no replacement colleague is required for the time being, so again, cost-saving.

In order to avoid any discussion on the presence or non-presence of lines in a drug testing there is another method available which is based on opto-electronic evaluations of the test results in a reader or analyser. The sample taking for oral fluid samples is very similar to the first one mentioned, the main difference is that the testing cassette is placed into an electronic reader after the sample taking. Here we do also have a certain flexibility in getting the result, it's not necessary to insert the test immediately after sample taking into the machine, a waiting period of 20 to 30 minutes is acceptable, however, under the prerequisite that the test is protected from contamination during this waiting period.



Fig. 3: drug testing device with an electronic analyser consisting of the sampling cassette and the reader

The sample-taking with the testing cassette is very similar to the one mentioned earlier for the device with visual evaluation, in this case the cassette itself works as a handle and only the part with the porous material goes into the mouth of the worker, again for an average time period of roughly one minute. After sample-taking is completed the whole cassette goes into the reader following by an activating cartridge to activate the enzymes and antibodies prior to the analytical procedure. After the cassette is totally inserted and the cartridge added we can close the front door and the analyser would do the work for us, the result will be displayed at the very end of the analysis as a qualitative result, meaning the presence or non-presence of a drug will be shown. All measurement results can be stored in the data logger of the analyser, transferred to a computer or directly printed on site with signatures of the donor of the saliva sample and the testing person being added. For even more convenience a small key-board can be connected to the analyser for keying in the personal data of the person to be tested as well as the testing officer to provide a comprehensive measurement report. From the print-out one sample can be taken by the worker, the other part stays with the testing institute.

Also the testing system with the analyser is regarded a screening method with the key advantage of avoiding discussions about a line being present or not present, it is not necessary to monitor any timing and finally the results can be displayed, stored, printed, and transferred to a computer for documentation or statistical evaluations of the situation. If any of the drugs is present a subsequent saliva or oral fluid sample is taken and send to a laboratory for final analysis. Nobody will be fined based on the result of any of the screening methods, only the result from the laboratory will be the relevant for that potential step. Again, it's a cost- and time saving advantage to use the screening method prior to the direct laboratory analysis.

Sensitivity and accuracy of the screening methods

Both screening methods have been developed to comply with the sensitivity from the Australian standard for oral fluid testing

ON-SITE INITIAL TEST TARGET CONCENTRATIONS



Class of drug	Target concentration ng/mL
Opiates	50
Amphetamine-type stimulants	50
Δ^9 -tetrahydrocannabinol (THC)	25
Cocaine and metabolites	50

NOTE: These targets represent the undiluted oral fluid concentration.

Fig. 4: Reference is made to the Australian Standard AS 4760-2006 regarding sensitivity levels for oral fluid testing

The standard describes a certain and accepted quality level of the products to be applied in the field for drug testing, the sensitivity is usually given as a so-called cut-off concentration in ng per mL of saliva, below this cut-off concentration a result would be given as negative, no drug is present in a relevant concentration, if the test result is above the cut-off concentration the test is regarded as positive, i.e. at least one drug concentration is larger than the cut-off. Those cut-off limits have been defined by experts based on the observations that below the cut-off concentration the person can be regarded as unimpaired, in other words the drug if present would have no impact on the behaviour or speed of reaction in the workplace environment. If the drug concentration is exceeding the cut-off concentration than the tested person is regarded as impaired, meaning that the drug has an impact on behaviour and speed of reaction in the work place environment.

Summary

Drug testing has been implemented many years back in Australia in the mining industry in order to avoid a risk for the worker being impaired by drugs in his system at the workplace environment, especially as these are workplaces with a fairly high risk in underground mining in general and expensive assets can also be protected at the same time. The original method of the choice were urine tests, however, they come along with quite a number of disadvantages, they are intrusive for the worker to be tested, toilets are required at the testing location as well as witnesses to make sure that a certain urine sample comes from a particular person. These days more and more companies are changing over to utilize oral fluid or saliva samples from a person to be tested for drugs as it is non-intrusive, more comfortable to be carried out anywhere in the field as well as accuracy or sensitivity does comply with the Australian Standard AS 4760-2006.

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DIESEL PARTICULATE FILTERS: DO THEY WORK?

A study on the efficacy of Diesel Particulate Filters in reducing personal exposure to Diesel Particulate Matter on underground Diamond Drillers

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ABSTRACT

This project was undertaken to assess the effectiveness of diesel particulate filters (DPF) when fitted to selected underground heavy vehicles on the exposure of underground diamond drillers and drillers off-siders to diesel particulate matter (DPM) during normal working situations.

Historical data demonstrated that the similar exposure group (SEG) at the greatest risk of exposure to DPM is the underground diamond drillers and drillers off-siders. Data analysed for this project included data collected one (1) year prior to the installation of the DPF and one (1) year post-installation of DPF.

Pre filter installation, the UCL_{1,95%} of the workgroup was 235% of the occupational exposure limit (OEL), which demonstrates non-conformance to the OEL. There was a significant exposure risk in the workgroup with 85% of all samples collected pre filter installation above the OEL.

Post filter installation, the UCL_{1,95%} for these data were reduced to 84% of the OEL, which demonstrates conformance to the OEL. 25% of the post filter readings remained above the OEL, which shows further work is needed, however, a significant shift in exposures has been achieved.

Results of the study have demonstrated a positive relationship between the installation of DPF and a reduction in DPM exposure on the workgroup. Both workgroup exposures and recorded OEL exceedances have reduced as a result of DPF installation.

KEY WORDS: Diesel Particulate Matter, Diesel Particulate Filters, Occupational Exposure

INTRODUCTION

The monitoring for this project was undertaken in an underground gold mine located in the Goldfields of Western Australia. Diesel particulate filters (DPF) have been installed in an attempt to decrease exhaust emissions of underground vehicles. Haul trucks and boggers were specifically selected for DPF fitment as they spend most of their time underground and are in almost constant 24 hour operation. It was assumed that a decrease in emissions will lead to a decrease in DPM exposures to underground miners and ancillary workers.

Diesel powered mining equipment is essential to the ongoing success of the mining industry. Diesel vehicles are used in underground mining for safety reasons. Diesel fuel burns at a lower temperature than petrol and therefore there is a decreased potential for ignition. Adverse health effects following prolonged and chronic exposure to DPM is widely known, with the International Agency for Research into Cancer (IARC) classifying DPM as a Group 1 Carcinogen in 2012 (WHO, 2012). Acute effects of exposure can include irritation of the nose and eyes, lung function changes, respiratory changes, headache, fatigue and nausea (Sydbom, 2001).

The purpose of this project was to assess the extent of exposure of diamond drillers and drillers off-siders to DPM following the installation of DPF on all haul trucks and boggers underground. DPF retro-fitted to these vehicles reduce diesel emissions, with some manufacturers claiming up to a 99% reduction in DPM emissions (www.mammoth.com.au). Diamond drillers work a 14 days on 7 days off, 12 hours per day roster, alternating between day and night shift. There are 36 drillers and off-siders employed at the mine working over 3 crews. This workgroup was selected as the study group, because, typically, they operate at lower points of the mine, in secondary and tertiary ventilation areas. The quality of air in these locations is affected by the number of vehicles working above them, the volume and quality of exhaust emissions, the positioning of the secondary and tertiary ventilation fans and the location of raised air drives.

The workgroup in focus is well versed in the potential impact of exposure to DPM poses to their ongoing health, both acutely and chronically. Education 'toolbox' sessions are held regularly to discuss how the workgroup has performed according to

the measurements of DPM taken over a specified period (usually quarterly). The use of personal protective equipment (PPE) was made available for the workgroup. However, it is not a regularly used control measure due to comfort, wearing a respirator for upwards of 10 hours a day is not feasible for most people. Despite the proven exposure risk mitigation, PPE is also the least effective method of control according to the hierarchy of control for risk management (SafeWork Australia, 2009).

The primary control for minimizing exposure to DPM underground is the ventilation system, which dilutes contaminants in the atmosphere to acceptable levels. At the mine in the study, this has proven historically ineffective in reducing exposures to safe and tolerable levels, although air quality has greatly improved. DPF were selected to implement another engineering control to further reduce DPM exposures.

Diamond drillers are generally the first personnel to permanently work in new areas of the mine. Other workgroups enter and work in these areas for short term projects such as running services, engineering, survey or geology. The role of diamond drillers is to drill exploration and ore body characterisation holes for assessment and mapping. Diamond drillers use hydraulic electric high speed rotational drills for this process and are generally static in their workplace location for up to 10 hours per shift.

DIESEL PARTICULATE MATTER

Emissions

As a result of the combustion process, diesel engines emit exhaust gases, including a wide range of organic vapours, volatile organic compounds and a small amount of metallic compounds. Organic vapours and volatile organic compounds absorb onto agglomerated carbon molecules, collectively these agglomerated particulates are referred to as DPM (DMP, 2014). DPM emissions pose both acute and chronic risks to health, ranging from mild effects, such as headaches, irritation and nausea, to chronic respiratory disease and cancer. There is also a risk of asphyxiation from exposure to Carbon Monoxide (CO) which is present in exhaust emissions (DMP, 2014).

The correlation between DPM exposure and adverse health effects has long been known. In 2012, the International Agency for Research on Cancer (IARC) amended their classification of Diesel Particulate (exhaust emissions) from a Group 2A (probable carcinogen) to a Group 1 (carcinogenic to humans). The working committee concluded that there is 'sufficient evidence' that diesel exhaust is a cause of lung cancer. There was also a positive association observed between exposure and bladder cancer (WHO, 2012).

At the mine site, DPM is treated as a chronic contaminant, although there are documented and known acute effects. Chronic contaminants can have a cumulative effect on personnel if exposed to unsafe levels over long periods. The latency period between exposure to chronic contaminants and onset of disease can be many years.

Occupational Exposure Limits and Shift Adjustment

There is currently no national Australian Occupational Exposure Limit (OEL) for DPM. However, personnel in the workgroup are known at the study site to be exposed to levels of DPM which exceed the adopted Occupational Exposure Limit of 0.1 mg/m³. This standard has been recommended by the AIOH (2013) and adopted by the DMP (2014).

As personnel at the mine work extended work shifts, the eight hour exposure standard for sub-micron elemental Carbon is adjusted for the 12 hour shifts worked according to contaminant type, shift length and swing length.

The shift adjustment is calculated using OSHA (Paustenbach, 1994) methodology (adjustment category 4). This method reduces the exposure standard to 0.063 mg/m³. This is calculated by dividing the hours worked in a 'normal' work week (40) by the hours worked by the workgroup (63). This methodology takes into account hours worked per week according to the length of each person's swing.

$$\text{Reduction Factor} = \frac{40}{\text{Weekly Exposure Hours}}$$

The OEL for DPM has been selected to both minimise the acute effects of exposure to DPM (eye and respiratory irritation), while maintaining an adequate protection factor for the chronic effects (lung cancer) (AIOH, 2013), the shift adjustment

method selected maintains a safety factor for the extended shifts worked while ensuring conformance to the OEL can be achieved.

As this OEL has been set at an already conservative level (minimizing the acute effects for most people), adjustment using the Brief and Scala (1975) technique would reduce the OEL to levels which may not be achievable in underground mining, and may be considered over conservative. The Quebec model (Drolet, 2008) does not provide an adjustment factor for DPM, and was therefore eliminated from the options. The Pharmacokinetic model (Hickey and Reist, 1977) was also eliminated as an adjustment option as there is no data available on biological half-life of DPM.

METHODOLOGY

Monitoring

Data were collected from the breathing zone of Diamond Drillers and Offsiders using an SKC 'Airchek' XR5000 Air sampling pump. All pumps used were within the approved calibration period. Each pump was fitted with a length of 'Tygon' scientific tubing and a SKC 225-68 DPM cyclone. In the cyclone, a SKC 225-317 37mm DPM cassette with a precision jeweled impactor to ensure the correct size fraction is collected during sampling. The air pumps were calibrated to 2.0 Litres per Minute using a SKC Bios Defender 510 primary standard calibrator. NIOSH Method 5040 (NIOSH, 2003) was used by a NATA accredited laboratory for analyses. This method is recommended both in Australia (AIOH, 2004 and 2013) and internationally (Kimbal et.al. 2012).

Quantitative data

Data collected pre-filter installation (14 samples) were used to identify the atmospheric baseline of underground mine prior to the introduction of DPF. A further 20 samples were collected post-filter installation to demonstrate what (if any) difference the installation of DPF made to workgroup exposure. These data ensured an adequate data set for statistical comparison.

Improvements/changes in ventilation have not been taken into account for this study, the study is specifically aiming at the installation of DPF. Ventilation is constantly changing to ensure minimum standards are met across the mine.

Qualitative data

Post monitoring discussions were held following the collection of DPM samples to ascertain qualitative data around air quality, any other 'differences' from day to day operations and any issues identified throughout the shift. This information was recorded on a field sheet and filed.

Although there is no established correlation between DPM concentration and carbon monoxide (CO) concentration (Davies, 2012), these contaminants are both present in the exhaust emissions. DPM is presented through complete combustion, whereas CO is a product of incomplete combustion. One can reasonably assume that if there is elevated CO in the atmosphere, then DPM will also be present. Diamond drillers have a gas detector at each drill rig which monitors the CO levels throughout the shift. These results form a part of the post monitoring discussion.

Analyses of Data

As previously discussed, these personnel work greater than 8 hour shifts; therefore OEL needs to be adjusted to suit their extended shifts. All data points are then converted into a percentage of the OEL. This technique gives more meaning to the data when presented to management and the workforce. From experience, personnel find a percentage figure more meaningful than a concentration figure.

Data were put through the statistics generator IHSTAT, which is made available through the American Industrial Hygiene Association (AIHA, 2015). Statistical calculations were also conducted using Microsoft Excel.

Statistics

Analysis of the collected data was undertaken to provide a simplified overview of the information collected. In occupational hygiene monitoring, there are specific parameters which are calculated and reported to provide an accurate and statistically valid explanation of results. This provides the end user with a mathematical explanation of exposure risk.

W-Test for distribution

The Shapiro and Wilk test determines what distribution the data set fits. This demonstrates goodness of fit. The distribution will determine whether the data set has been drawn from a normal or lognormal distribution. The distribution of the data (normal, lognormal, both or neither) determine whether parametric or non-parametric statistical calculations are to be made (Rumsey, 2003).

Arithmetic mean

The arithmetic mean is the most accurate determination of long term health risk (Grantham and Firth, 2014). The collected data shows a normal distribution, therefore the arithmetic mean is used (Rumsey, 2003).

Geometric Standard Deviation (GSD)

This demonstrates how similar the data is, or how far it deviates from the mean. A GSD of < 2.5 is desirable. A data set with a GSD of greater than 3.5 demonstrates variability within the data set and the potential for absence of controls (Grantham and Firth, 2014).

Upper Confidence Limit (UCL_{1,95%})

The UCL_{1,95%} demonstrates with 95% confidence that if a very large number of samples were taken, the true mean would be less than this figure (Grantham and Firth, 2014). This is an acceptable comparison to determine workgroup conformance to the OEL. This figure is compared with the OEL to determine conformance. If the OEL is less than the UCL_{1,95%}, then the SEG can be deemed conformant, whereas, if the UCL_{1,95%} is greater than the OEL, a review of controls should be conducted to ensure that the exposure risk is managed and the SEG is deemed non conformant to the OEL. This demonstrates with 95% confidence that the true mean will fall below the OEL. This is acceptable to determine workgroup conformance to the OEL.

95th percentile

This figure demonstrates with 95% certainty that 5% or fewer samples (if many samples are taken) will exceed the OEL (Grantham and Firth, 2014). This figure demonstrates best practice and shows that only 1 in 20 samples taken on the workgroup will exceed the OEL.

T-Test

A t-test is conducted to determine if data sets are statistically different from each other. The study was based on this test to demonstrate that there was a statistically significant reduction in the exposure profile of the workgroup. For this t-test, alpha was set at 0.05, a result of less than this will demonstrate with 95% confidence that the data sets differ from each other. For the analysis, a 2 tailed 2 sample t-test assuming unequal variance was used with α set at 0.05 (to provide a 95% confidence interval). This test provides statistical evidence that there is a difference between the pre and post DPF installation data sets.

RESULTS

Table 1: Summary of Monitoring Results and Before and After DPF Installed

Parameter	Pre-filter	Post-filter
Number of Samples (n)	14	20
Sample Distribution	Normal	Normal
Mean (% OEL)	191	73
GSD	2.1	1.6
LCL _{1,95%} (% OEL)	148	62
UCL _{1,95%} (% OEL)	235	84
95 th percentile (% OEL)	343	119
% > OEL	86	25

Pre-filter

Table 1 shows that the DPM exposures before the filter was installed were distributed normally; and that the data collected fitted within a single SEG as it had a GSD of 2.1. Prior to the fitting of the filters 85% of all samples collected were above the OEL. The UCL_{1,95%} for this data set was 235% of the OEL, which demonstrates non-conformance to the OEL on an annual basis. Both the LCL_{1,95%} and the UCL_{1,95%} was above the percentage OEL, which was a clear demonstration that there was a significant exposure risk in the workgroup.

Post-filter

The monitoring data collected post the filter installation (Table 1) also shows that the potential exposures are normally distributed with a smaller GSD of 1.6. The results show that there is a significant reduction in exposures, but as 25% of the post-filter readings remained above the OEL, further research is needed on how to reduce the exposures further. The UCL_{1,95%} for this data set was reduced to 84% of the OEL, which demonstrates conformance to the OEL on an annual basis. The UCL_{1,95%} was below the percentage OEL, which was a clear indication that the exposure risk has been reduced and the exposure profile of the SEG is statistically acceptable.

Comparison

The aim of this study was to demonstrate with 95% confidence that a statistically significant reduction in DPM exposure had been achieved by the installation of DPF. The t-test returned a result of 0.0003 ($\alpha < 0.05$). This test confirms with 95% confidence that the installation of DPF has demonstrated a statistically significant change in the DPM exposure profile on the workgroup. Figure 1 shows a comparison of all the exposure data collected, Figure 2 shows a comparison based on the grouping of the data pre and post filter installation.

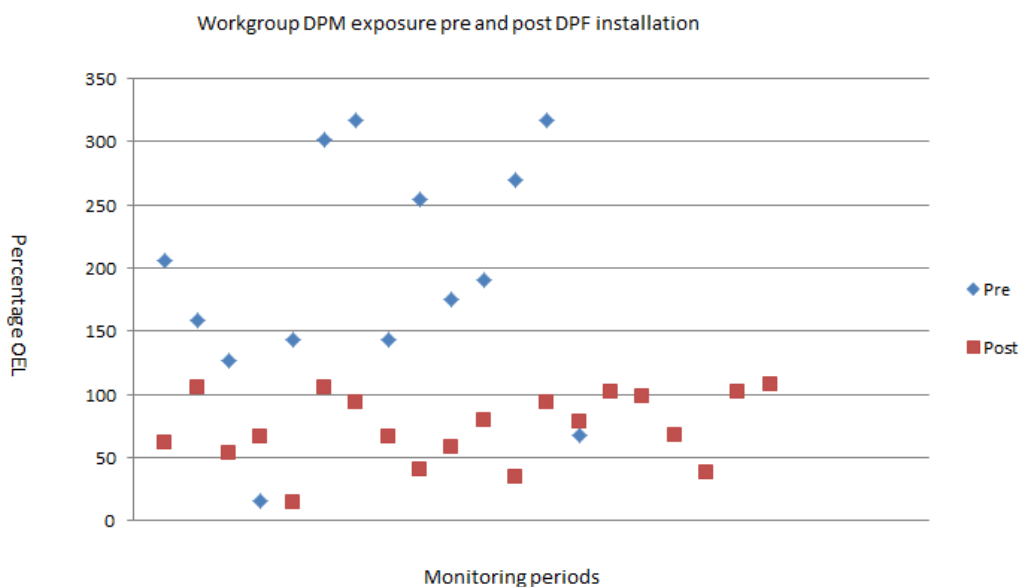


Figure 1: Exposure Data Pre and Post DPF Installation

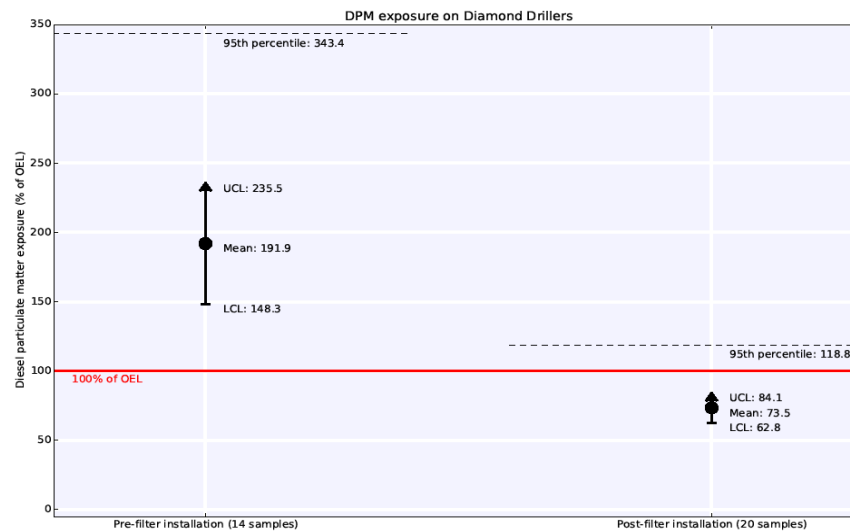


Figure 2: Comparison of the Summary Exposure Data Pre and Post Filter Installation

As previously discussed, 25% of the post-filter installation samples exceeded the OEL and further reductions are needed to reduce all exposures to below the acceptable OEL.

CONCLUSION AND RECOMMENDATIONS

This study has shown that there is a benefit in the installation of DPF not only from an emissions viewpoint but also a reduction in personal exposure to DPM. This benefit justifies the significant investment, in both time and financial, by the mining company.

The use of DPF alone is not sufficient to eliminate all exposures to DPM underground; however, they do contribute a significant amount to the reduction of exposures. Ongoing education of the workforce on the hazards and risks associated with DPM exposure needs to continue to ensure that all underground personnel are aware of their responsibilities and how they can contribute to further exposure reduction.

Further investigations need to be undertaken into all underground unfiltered vehicle emissions (including LV) to identify which vehicles are the major contributors to the underground DPM exposure, so they can be identified for maintenance to specifically reduce DPM emissions. If a DPF cannot be fitted to a vehicle consideration should be given to the fitting of an air purifier to provide some reduction in exposures to airborne DPM.

The mine should continue to demonstrate improvements in air quality with the fitting and maintenance of the DPF in conjunction with an ongoing review of the ventilation system, regular DPM emission monitoring and occupational exposure assessment to DPM.

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APPLICATION OF CAPA EARPLUG FIT TESTING IN AN UNDERGROUND MINE HEARING CONSERVATION PROGRAM

Adrian A Moscoso

ABSTRACT

Hearing protection plays a significant role in the prevention of hearing loss amongst miners. This study evaluated the application of CAPA, a field Real-Ear Attenuation at Threshold (REAT) device, to ensure that workers have the most appropriate type of earplug according to their noise exposure.

With 135 field-REAT tests of six commercial earplugs, the results were that real world attenuation was lower and significantly different against their labelled values on most hearing frequencies.

CAPA also offers a briefer version of REAT, called the flash test, which aims to reduce the testing time. Subjects completed both conventional and flash tests for a type of earplug. Findings demonstrated that the flash test is more suitable after a conventional REAT baseline is completed.

Finally, a survey determined that fit testing improved employee's confidence and compliance with the hearing conservation program. Factor analysis showed that earplug fit testing could also positively affect the work climate.

Key words: earplug; hearing protection; factor analysis; field REAT; fit testing

Introduction

In an underground mine there are ranges of noise levels across multiple areas and tasks. The use of hearing protection devices (HPDs) plays a significant role in the prevention of noise induced hearing loss. The selection of HPDs is currently based on a class rating, which has the potential of providing poor or excessive hearing attenuation to an individual. Furthermore, hearing protectors display attenuation data based on laboratory tests, which are not representative of the actual group using HPD (Berger et al., 2008). In Australia, earplug manufacturers are required to test the earplug by the REAT method as per AS/NZS 1270:2002 Acoustics – Hearing protectors (Standards Australia, 2002). The test is performed on a minimum of 20 subjects that meet an specific criteria of age, gender and training, which does not match the demographics of the current mine workforce, which is strongly male dominated with some earplug experience and training (ABS, 2015).

A new hearing conservation program addresses this problem. The inclusion of earplug fit testing to each individual into the program aims to match the actual noise exposure to the field, real world, HPD attenuation.

Currently, there are three major types of field test methods available: REAT (real-ear attenuation at threshold), Loudness balance, and MIRE (microphone-in-real-ear). Others have extensively discussed the advantages and disadvantages of each test method (Berger et al., 2008, Brueck, 2009, Michael, 1999, Neitzel et al., 2006, Toivonen, 2002, Trompette and Kusy, 2013, Tufts et al., 2013).

The underground mine required an HPD fit-testing equipment that could test any type of earplug and that not demanded lengthy sessions per worker. The device "CAPA", developed by HearingProTech, offers a circumaural field-REAT method that can complete a "conventional" test, a type of test that covers the 7 classic audiometric frequencies (Trompette and Kusy, 2013) in only 7 minutes; which is much quicker than estimated speed of other field-REAT variants as discussed by Berger et al. (2008). Furthermore, CAPA also provides the ability of producing a shorter version of the test named "flash test", which covers only a reduced number of random frequencies in each ear, lasting only 3 minutes per person. As reported by the manufacturer, for 85% of test subjects, one frequency is enough to determine the compliance of the HPD. For the remaining 15%, a second measurement or even third measurement on other additional frequencies can be necessary for their compliance test algorithm to work.

The mine also uses the software "Medgate" to manage the industrial hygiene and medical records. Medgate's Hygiene Module records and analyses all personal noise monitoring results for similar exposure groups (SEGs). The Medgate's Medical Module can schedule tests for employee's earplug fitting through an activity named "Earplug fit test".

SEGs with high levels of noise exposure are flagged to have earplug fit tests periodically. CAPA’s conventional test results are imported into Medgate, where completion of the activity is flagged. Prior to this study, no CAPA flash tests were entered into Medgate, as the validity of the flash in field conditions had not been studied.

The goals of this study include:

1. To assess the suitability of the site’s available earplugs, by comparing the actual and real world attenuation against the labelled (laboratory) values.
2. To determine whether the Flash test is a suitable HPD compliance test for the mine, by comparing its results against the ones obtained by the conventional test.
3. To determine if fit testing has improved employee’s confidence and compliance with the hearing conservation program

Methods

Participants

112 subjects participated in the study (101 males and 11 females; mean age of 35.8 years (SD = 10.2) and average of 10.8 (SD = 8.6) years of working in mining or heavy construction. The study sample consisted of belt repairers, mechanical fitters, diesel mechanics, electricians, boilermakers, processing plant operators, underground mobile equipment operators, underground mine services operators, and logistic operators. Participants were informed that this study is part of the employer's existing responsibility to provide a safe workplace and to ensure the right protective equipment is provided to the employees.

Each participant received a voluntary questionnaire, name not required, that assessed the perceptions of earplug utilisation, work climate and the benefits of earplug fit testing. Ninety-four participants completed the questionnaire.

Noise exposure

From July 2013 until June 2015, the mine completed personal noise exposure recordings across site. Approved noise officers, using the approved WA-DMP method (Resources Safety, 2005), completed the sampling. The statistical results (Table 1) were computed automatically by Medgate, and calculations were verified by downloading the raw data and then manually entering it into AIHA IHSTAT+ tool (Mulhausen, 2013). The reported values were selected according to AIHA (Bullock et al., 2006). To obtain the range of protection, the reported value was subtracted by 82 dB and 70dB as per Berger (2003) discussion about the effects of HPD on auditory perception. CAPA, in the other hand, subtracts by 75 dB and 70 dB.

Table 2: Calculated required level of protection for similar exposure group based on noise exposure statistical analysis between 01/07/2013 and 30/06/2015

Similar exposure group / positions	# of samples	UCL _{1,95%} of mean as %OEL (dBA)	Geometric SD (as %OEL)	Range of protection: (dBA)
ADM03 Processing plant operators	13	507 (92.0)	2.51	17 to 22
ADM04 Surface metal and repair trades	18	688 (93.3)	3.43	18.3 to 23.3
ADM05 Underground mobile equipment maintainers	7	668* (93.2)*	5.29* Range: 2107	18.2 to 23.2
ADM06 Secondary breaking and blasting	9	4690 (101.7)	1.90	26.7 to 31.7
ADM07 Underground mobile operators (boggers, drills)	22	974 (94.9)	2.10	19.9 to 24.9

ADM08				
Service Crew (ventilation, resin injection, pumps, strata consolidation, cable bolters)	21	2070 (98.1)	3.03	23.1 to 28.1
ADM12				
Logistic operators (forklifts, flatbeds)	9	196 (87.9)	2.59	12.9 to 17.9

* ADM05 results were reported by descriptive statistics due to high level of variability of the samples.

Hearing protectors

The available earplugs were 3M E-A-R Classic (SLC₈₀ 23dB), 3M E-A-Rsoft FX (SLC₈₀ 26dB), Howard Leight 303L (SLC₈₀ 22dB), Howard Leight Xtreme (SLC₈₀ 26dB), Howard Leight Laser Lite (SLC₈₀ 25dB), and Moldex Pura-Fit 6800 (SLC₈₀ 27dB).

Experimental procedures

The tests took place in a quiet room as per CAPA's fit testing procedure. For the initial test, employees were first given the opportunity to test their preferred earplug. CAPA provides a fitting white noise that allows the participant to check if the earplug is blocking as much noise as possible. While the participant was inserting the earplug, its technique was observed; and if required, it was corrected before proceeding with the fitting tests, in order to diminish poor attenuation from the earplug (Toivonen, 2002, Tufts et al., 2013).

The employee completed both conventional and flash tests for the selected earplug. Between tests, the employee removed the earplugs, and then re-inserted another set of earplugs of the same model, to prevent re-inserting ear wax.

In the case of poor or excessive attenuation from the preferred earplug, the employee completed additional flash tests on alternative earplugs until obtaining compliance on one of them. Then, the employee completed subsequent conventional test on the compliant earplug to obtain the attenuation values' full range.

Survey

Participants completed a multiple-choice questionnaire regarding their perception about earplugs, work climate, and the fit testing programme. The questionnaire comprised 11 statements with 5-point Likert-type scales. The questionnaire items were adapted from similar studies in other industries (Brady and Hong, 2006, Edelson et al., 2009, Gates and Jones, 2007). Three items measured earplug utilisation, four measured work climate, and four measured the usefulness of the earplug fit testing programme.

The questionnaire was in English and scored Flesch–Kincaid eight-grade reading level, and a Flesch readability ease of 57.8% by MS Excel (version 14.0.7145.5000 32-bit)

Data analysis

For the study goal #1, assessing the suitability of available earplugs, the steps taken were:

First, comparing the earplug labelled values against its field attenuation results, the former values were set as benchmark (hypothesised mean) for each octave band. Then, the field attenuation results were compared to the benchmark values through a series of one-sample T tests, on each octave band frequency, for both ears per earplug.

Second, the field attenuation results' mean and standard deviation for each octave band were used to calculate a real-world SCL₈₀.

For the study goal #2, determining whether the Flash test is a suitable HPD compliance test, the results of both of conventional and flash test on the same subject and earplug were compared.

The null-hypothesis is that the success rates for conventional tests are equal to flash tests. The alternative hypothesis is that the success rates for conventional tests are not equal to flash tests. The Cochran Q Test was applied on the data obtained for subjects who completed both tests.

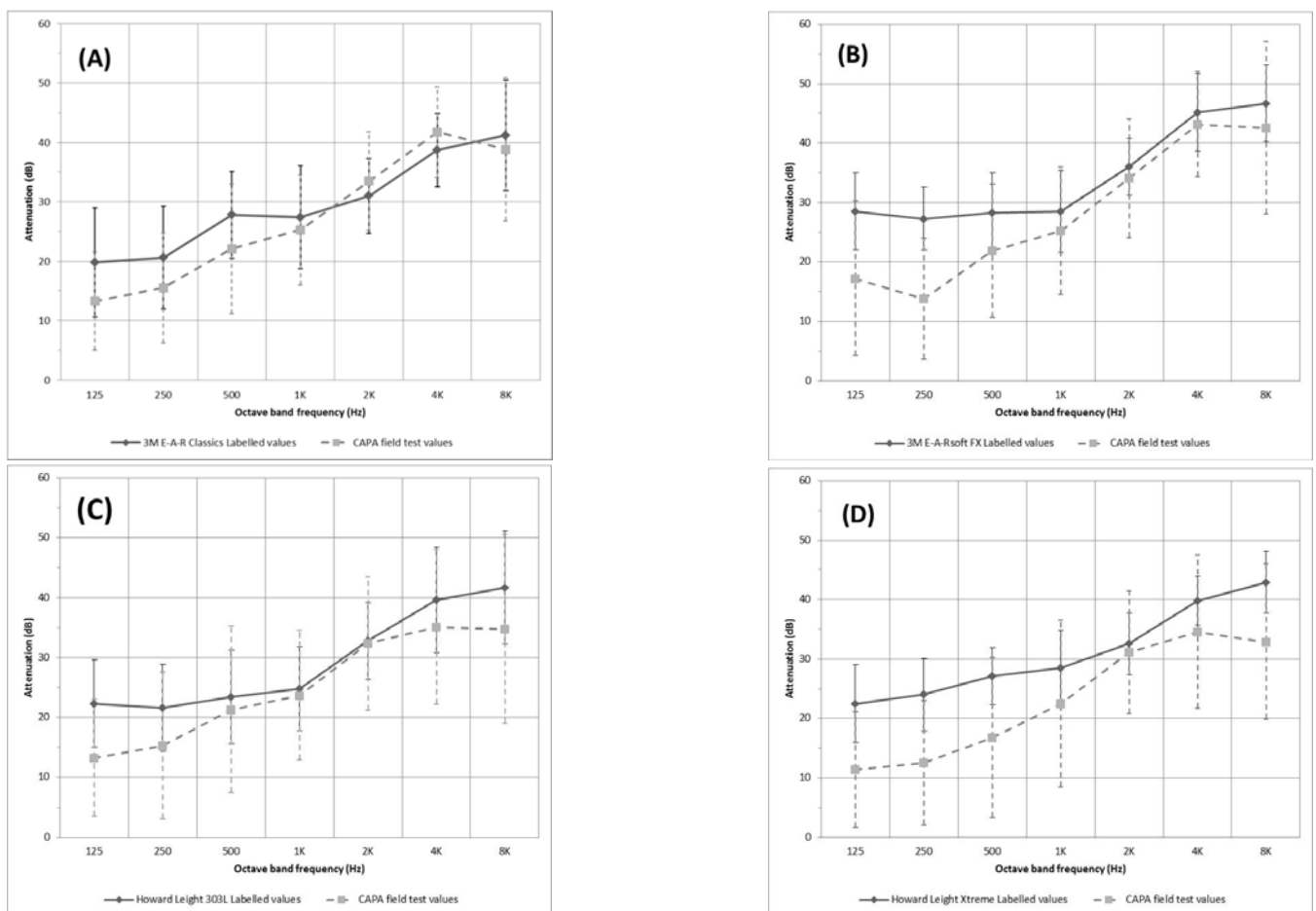
For the study goal #3, determining if earplug fit testing improved employee’s perceptions about the new hearing conservation program, the questionnaire was tailored to identify if earplug fit testing was an improvement on its on merit, or if it was more of a manifestation of the perceptions about hearing protection or work climate (latent variables).

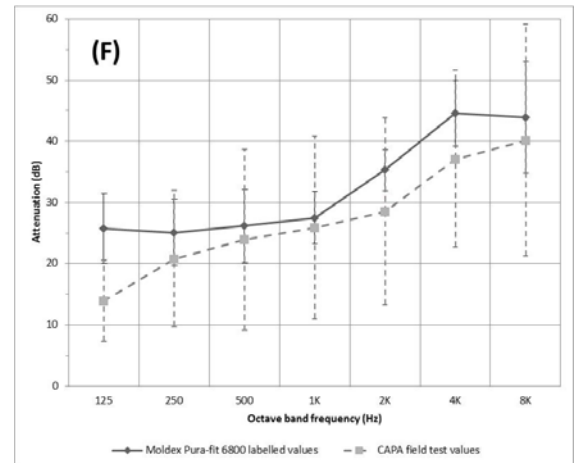
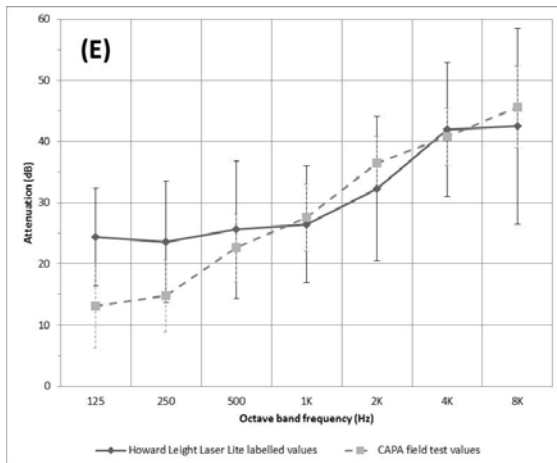
The overall reliability of the original questionnaire computed a Conbrach’s alpha of 0.57. Then, after applying an Exploratory Factor Analysis (EFA), it was determined that by removing items C, D and I from the questionnaire (Kaiser-Meyer-Olkin value of 0.544, 0.492 and 0.514 respectively) the overall reliability score raised (Conbrach’s alpha of 0.66). A ‘Scree Plot’ aided to identify the number of factors to extract, ensuring that the extraction retained the majority information and the variance.

The factor matrix, rotated by the Varimax method, maximised the item loadings towards their underlying latent variables or factors. This process aided for interpretation of between-item relationships.

RESULTS

Figure 1 shows graphical comparisons for earplug labelled values and obtained CAPA attenuation results for six types of earplugs. All the CAPA results show lower values for low frequencies, and higher variability (displayed as standard deviation). A series of T-test results comparing the differences between these tests appear in Table 2. These results confirm the patterns of the graphs, showing that there are significant differences ($p < 0.05$ to $p < 0.001$) between labelled and field values for lower frequencies. These findings are consistent with the studies of others (Berger et al., 2007, Brueck, 2009, Trompette and Kusy, 2013).





Furthermore, four out of six earplugs show that CAPA values are lower than the labelled values in the rest of frequencies as well. CAPA results on 3M E-A-R Classics and Howard Leight Laser Light showed higher values than the labelled values at higher frequencies. 3M E-A-R Classics show significant differences in all frequencies but at 8000Hz. Howard Leight 303L and Xtreme, were the other two earplugs showing significant differences at 4000Hz and 8000Hz against the labelled values. This can be due to a larger number of successful fit tests performed in these three earplugs at higher frequencies, but could also be explained by the proximity of the average values and associated length of standard deviation and the selected statistical test. The alternative statistical tests are the Z-test or Two-sample T tests, but since the number of samples, or demographic population used by the manufacturers is unknown; these were not suitable.

Table 3: One-sample T test for each selected earplug per octave band frequency with the labelled value as hypothesised mean, two tails (alpha 0.05). Degrees of freedom in parentheses

Earplug model	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	8000 Hz
3M E-A-R Classic	-7.7828 (96)***	-5.3039 (93)***	-5.1068 (95)***	-2.2362 (96)*	2.9532 (97)***	3.6417 (85)***	-1.7318 (76)
3M E-A-Rsoft FX	-4.5888 (27)***	-7.0236 (27)***	-2.9743 (26)*	-1.6450 (27)	-1.0362 (27)	-1.1472 (24)	-1.3923 (23)
Howard Leight 303L	-6.5218 (48)***	-3.6213 (47)***	-1.0708 (49)	-0.7342 (49)	-0.2901 (47)	-2.2791 (41)*	-2.7822 (40)*
Howard Leight Xtreme	-7.1363 (39)***	-6.8884 (39)***	-4.7943 (39)***	-2.7232 (40)*	-0.9190 (39)	-2.4267 (36)*	-4.4850 (34)***
Howard Leight Laser Lite	-5.6382 (15)***	-3.5507 (15)**	-1.0591 (15)	0.4463 (15)	1.4239 (15)	-0.3909 (13)	0.7333 (13)
Moldex Pura-Fit 6800	-6.7621 (13)***	-1.4567 (13)	-0.5555 (12)	-0.4102 (13)	-1.6651 (13)	-1.6432 (9)	-0.6512 (10)

* significant at $p < 0.05$; ** significant at $p < 0.005$; *** significant at $p < 0.001$

Table 3 shows real-world SCL_{80} values obtained from CAPA conventional tests. SCL_{80} were obtained by calculating each octave band frequency attenuation, rather than using CAPA's average PSNA. The reason is that PSNA are individual values for each person; while SCL_{80} requires information from the whole sample tested. However, field SCL_{80} values appear to agree with average PSNAs subtracted by a SD.

ADM03 and ADM12 SEGs have optimum protection by most of the earplugs tested. ADM04, ADM05, ADM07, and ADM08 have a compliant protection with most of the earplugs tested. No earplugs provided compliant protection for ADM06.

Table 4: Suitability of tested earplugs per SEG, based on calculated Field SCL₈₀, within ideal range of protection and minimum protection

Earplugs	Labelled SCL ₈₀	Average PSNA in dB (SD)	Calculated Field SCL ₈₀ (% of Label)	SEGs in ideal range (70-75dB in ear) based on Field SCL ₈₀	SEGs protected (under 82dBA in ear) based on Field SCL ₈₀
3M E-A-R Classic	23	24.6 (9.2)	18 (78)	ADM03, ADM12	ADM04, ADM05, ADM07, ADM08
3M E-A-Rsoft FX	26	20.8 (9.0)	17 (65)	ADM03, ADM12	ADM04, ADM05, ADM07, ADM08
Howard Leight 303L	22	22.3 (11.1)	14 (64)	ADM12	ADM03, ADM04, ADM05, ADM07
Howard Leight Xtreme	26	22.4 (11.0)	11 (42)	-	ADM12, ADM04, ADM05, ADM08
Howard Leight Laser Lite	25	26.5 (8.7)	18 (72)	ADM03, ADM12	ADM03, ADM05, ADM07, ADM08
Moldex Pura-Fit 6800	27	26.4 (11.7)	14 (52)	ADM12	ADM04, ADM05, ADM07

Table 4 shows Cochran Q tests applied horizontally that compare both conventional tests and flash tests for each ear; and Cochran Q tests applied vertically that compare both ears for each test. A Cochran Q test for the four combinations (left ear and conventional, left ear and flash, right ear and conventional, right ear and flash) yielded a value of 0.1169. None of the Q-tests yielded significance, therefore, it appears there is no difference between a conventional and flash test.

Table 5: Success rate (n=70) from conventional and flash test within subject with the same type earplug type (alpha 0.05). Q-stat between earplugs from top to bottom, and between tests from left to right. Q-stat obtained for all four types of tests is 0.1169 (df 3, p > 0.05).

Ear	Conventional Test	Flash Test Left	Q-stat (df)
Left	88.73%	88.73%	0.000 (df 1, p > 0.05)
Right	88.73%	90.14%	0.077 (df 1, p > 0.05)
Q-stat	0.000 (df 1, p > 0.05)	0.077 (df 1, p > 0.05)	

Furthermore, the left ear success rates of both conventional and flash tests are equal. The proportions between conventional and flash test of the right ear are very close to each other, with a 1.41% higher success rate for flash test. However, in 11 cases out of 75, the flash test resulted in a pass while the conventional test resulted in a failure. Furthermore, eight cases out of the 75, the flash test resulted in a fail while the conventional test resulted in a pass.

The survey intended to measure the perceptions of Earplug Fit Testing as inclusion in the new hearing conservation program. Responses for each item were scored from one to five, from the most negative response to the most positive score, while three is the neutral score. Items B, C and E were reverse scored. The questionnaire template was uploaded to Medgate to minimise data entry errors and scoring errors.

Figure 2 shows the spread of the responses of the questionnaire. The percentages of respondents who agree with the items are shown to the right of the zero line; the percentages who disagree are shown to the left.

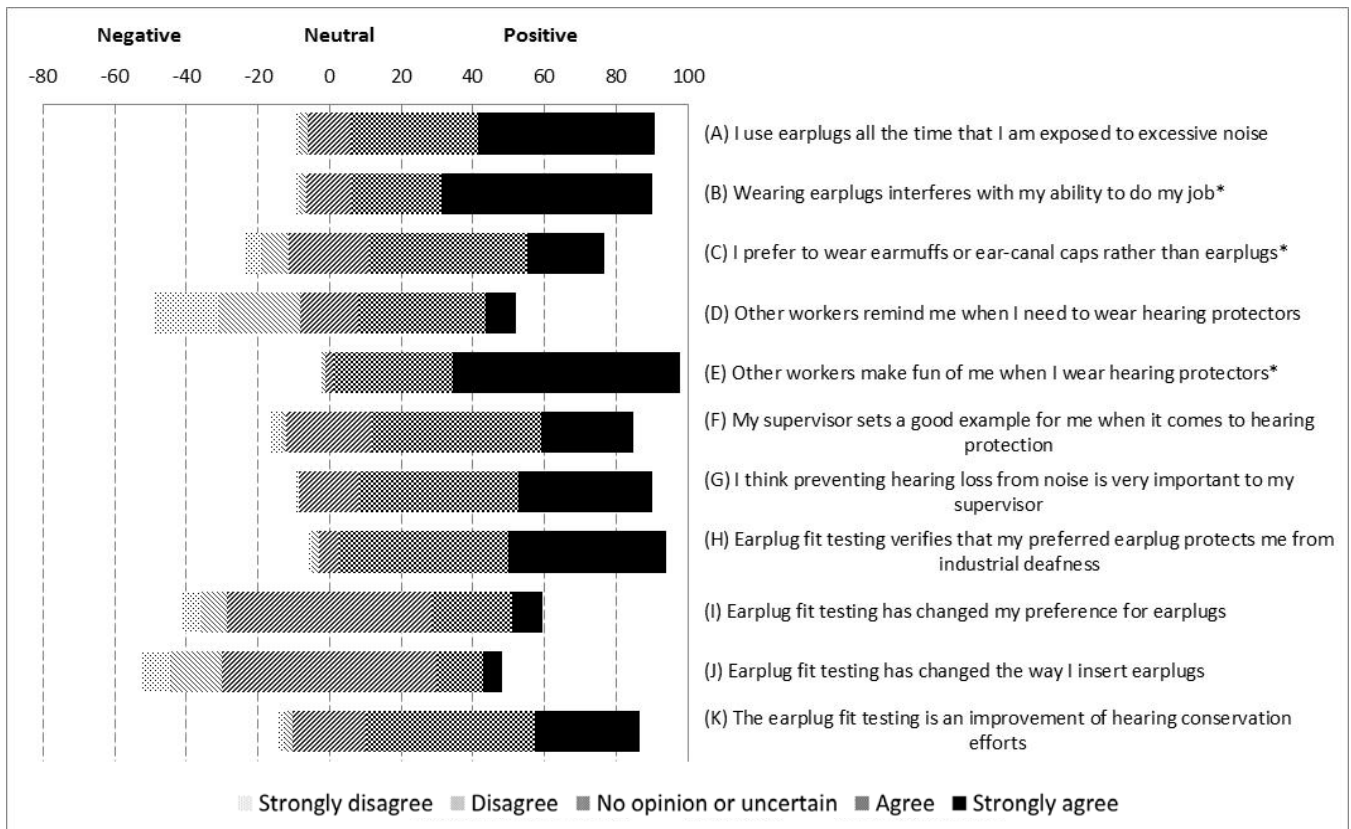


Figure 1: Spread of questionnaire responses by percentage of respondents (n=94) in relation to the extent of agreement or disagreement with the questionnaire items. *Items reverse scored

While the majority of items spread towards are in the positive side; items D, I and J spread towards the neutral response (median of three in all of them). Items H and K have a median of four.

Following with the EFA, post item deletion, a principal component analysis was undertaken. The screen plot shows that three factors explained the majority of the variance (Fig. 3). The first three factors extracted have an eigenvalue greater than one (Brown et al., 2011).

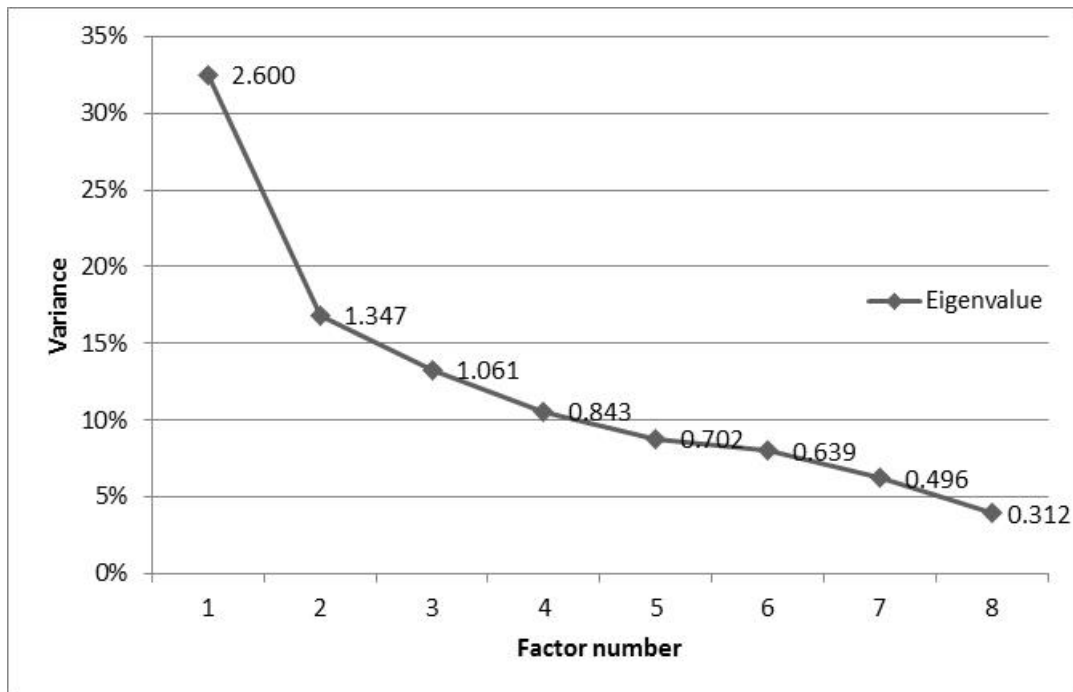


Figure 2: Scree plot that shows the variance accounted for successive factors, or latent variable of the questionnaire items.

Table 5 shows the item loading in each of those factors, after a Varimax rotation. Item G has the strongest loading score towards factor 1, seconded by F and H. Item B has the strongest loading towards factor 2, seconded by items A and E. Item J has the strongest loading towards factor 3, seconded by item K. Both items E and H have some loading towards Factor 3.

This 3-factor solution explains up to 62.6% of the variance within the questionnaire. Item correlations computed as in only those three factors existed appear in Table 6. The remaining 37.4% of the variance within the questionnaire, named residuals, are in Table 7. The residuals explain errors of underestimating (positive sign) or overestimating (negative sign) the correlations from making the assumption of three factors only.

Table 6: Rotated Factor Analysis Summary Table for Earplug Questionnaire

Item	Loadings			Communalities			Total
	Factor 1	Factor 2	Factor 3	Factor 1	Factor 2	Factor 3	
A	0.217	0.707	-0.222	0.047	0.499	0.049	0.596
B	-0.089	0.806	0.062	0.008	0.650	0.004	0.662
E	0.234	0.495	0.341	0.055	0.245	0.116	0.416
F	0.796	0.140	-0.049	0.634	0.020	0.002	0.656
G	0.881	-0.011	0.122	0.776	0.000	0.015	0.791
H	0.661	0.176	0.328	0.436	0.031	0.108	0.575
J	-0.019	-0.035	0.871	0.000	0.001	0.759	0.761
K	0.433	0.024	0.603	0.187	0.001	0.364	0.552
Variance accounted for				2.144	1.446	1.418	5.009
Percent of total variance				26.8%	18.1%	17.7%	62.6%

Table 7: Reproduced correlation matrix

	A	B	E	F	G	H	J	K
A	0.596							
B	0.537	0.662						
E	0.325	0.399	0.416					
F	0.283	0.040	0.239	0.656				
G	0.157	-0.080	0.243	0.694	0.791			
H	0.195	0.104	0.354	0.534	0.620	0.575		
J	-0.222	0.027	0.275	-0.063	0.090	0.267	0.761	
K	-0.023	0.019	0.319	0.318	0.454	0.488	0.517	0.552

Table 8: Error matrix

	A	B	E	F	G	H	J	K
A	0.404							
B	-0.235	0.338						
E	-0.152	-0.226	0.584					
F	-0.089	0.050	0.026	0.344				
G	-0.026	0.106	-0.066	-0.095	0.209			
H	-0.044	-0.013	-0.021	-0.179	-0.098	0.425		
J	0.112	-0.017	-0.114	0.146	0.034	-0.094	0.239	
K	0.119	0.021	-0.172	-0.118	-0.029	-0.093	-0.182	0.448

High correlations amongst G, F, and H combinations show that these three items fit into one group. Items A, B and E fit into another, while items J and K into a third one. E, F, and K have some positive correlations, but around half of the covariance between them could be overestimated.

DISCUSSION

All the obtained SCL_{80} values with CAPA show that the tested earplugs perform below the labelled values (ranging from 38% to 78%), with significant differences in the majority of the frequencies. Consequently, relying on earplugs labelled values to protect workers from NIHL may not be appropriate.

Berger (2003) stated that under no circumstances should labelled NRRs (USA's attenuation rating) be used as if for making predictions of groups of wearers. Furthermore, he discussed USA OSHA approach of derating the labelled values by 50% to reflect real world attenuation.

While statistically the CAPA flash test appears to be an acceptable proxy of the "full" conventional test, there have been some mismatches. The flash test might have chosen a frequency where the participant suffers from hearing loss, or another physiological characteristic that interferes with the test. In the case of failure, this could lead to test another earplug, but in the case of a pass, there could be a false sense of confidence, exposing the participant to NIHL.

In regards to the questionnaire, the majority of responses for item H "Earplug fit testing verifies protection" and K "Earplug fit testing is an improvement", were positive. 91.4% of respondents agreeing with item H and 76.3% of respondents agreeing with item K.

Furthermore, the factor solution has provided more insights regarding earplug fit testing items with other questionnaire items.

To facilitate the interpretation, factors were named to the items that strongly exemplify the factor (DeVellis, 2012). For the cluster A-B-E, A and B have the strongest loading scores on factor two, therefore, this factor was dubbed "earplug utilisation". Items F, G, and H fit into one group for factor one, dubbed "work climate". Finally, items J and K fit into a group for factor three, dubbed "fit testing benefits".

Item H has significant loading towards "work climate" factor and significant reproduced correlations with items F and G, and small residuals. Furthermore, there are some other correlations of some significance between "work climate" and "fit testing benefits" items [$\text{corr}(F,K) = 0.318$ and $\text{corr}(G,K)=0.454$]

These correlations indicate that an encouraging work climate has a positive perception of the earplug fit testing program, or that the earplug fit testing program could lead to a perceived positive perception of the work climate.

Limitations

Line management (team leader and coordinators) were included in the study, however, no upper management were. While the earplug-testing program is currently in progress, the data in this study was accurate up to the date of submission.

The survey only included a reduced number of items related to work climate, however, they were selected as the best predictors in earplug utilisation as per studies of Brady and Hong (2006) and Edelson et al. (2009). Moreover, information of participant's age and years in the industry were captured, but were not utilised in the analysis, as it were not considered as important variables as per Edelson et al. (2009).

The survey original length showed low reliability, but was later increased by eliminating some items. This suggests that with higher samples, these items can be re-included and even provide more insights, including a potential confirmatory factor analysis.

For both fit testing and survey results, these findings cannot be generalised to other workplaces.

Conclusions

This study has revealed the benefits of earplug fit testing, and the utility of CAPA as a tool.

First, it suggests the need for reviewing HPD selection process. After identifying SEG's noise exposure profile, the earplug's field attenuation data should be used. If not feasible neither because the SEG's noise exposure profile nor the real-world performance of a specific earplug is clear, a precautionary 50% de-rating approach should apply.

Second, it suggests that the mine should test any new earplug with CAPA before introducing it to the workforce.

Third, earplug fit testing is well received by the workforce, and potentially affect the perceived work climate positively.

Finally, while the CAPA flash test is comparable to the conventional test and saves significant time, there were some "false" pass errors. Therefore, it is suggested that a conventional test should be established as a baseline for an earplug for an individual before using the flash test as subsequent periodical tests.

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APPENDIX

Survey Questionnaire:

A	I use earplugs all the time that I am exposed to excessive noise	Almost never	Occasionally	Sometimes	Frequently	Almost always
B	Wearing earplugs interferes with my ability to do my job *	Almost never	Occasionally	Sometimes	Frequently	Almost always
C	I prefer to wear earmuffs or ear-canal caps (semi-insert) rather than earplugs *	Strongly disagree	Disagree	No opinion or uncertain	Agree	Strongly agree
D	Other workers remind me when I need to wear hearing protectors	Strongly disagree	Disagree	No opinion or uncertain	Agree	Strongly agree
E	Other workers make fun of me when I wear hearing protectors *	Strongly disagree	Disagree	No opinion or uncertain	Agree	Strongly agree
F	My supervisor sets a good example for me when it comes to hearing protection	Strongly disagree	Disagree	No opinion or uncertain	Agree	Strongly agree
G	I think preventing hearing loss from noise is very important to my supervisor	Strongly disagree	Disagree	No opinion or uncertain	Agree	Strongly agree
H	Earplug fit testing verifies that my preferred earplug protects me from industrial deafness (noise-induced hearing loss)	Strongly disagree	Disagree	No opinion or uncertain	Agree	Strongly agree
I	Earplug fit testing has changed my preference for earplugs	Strongly disagree	Disagree	Stay the same	Agree	Strongly agree
J	Earplug fit testing has changed the way I insert earplugs	Strongly disagree	Disagree	Stay the same	Agree	Strongly agree
K	The earplug fit testing is an improvement of hearing conservation efforts	Strongly disagree	Disagree	No opinion or uncertain	Agree	Strongly agree

(*) Reversed questions for scoring.

FLOOD, FIRE AND MOULD ASSESSMENT PROCESSES – THE IMPACT OF AN INFORMED OCCUPATIONAL HYGIENIST

Brian Murphy

ABSTRACT

Following a major event and subsequent impact to a building and its occupants whether flood, fire or discovery of extensive mould growth, the initial steps taken by the project team are fundamental to protecting occupant health and mitigating loss.

The critical role that can be played by an informed occupational hygienist in *anticipation*, recognition, evaluation and control of physical, chemical and biological hazards during these events is often not known, understood or valued by the project team. As a consequence, this often results in general lack of consensus, clarity and independence in the roles and advice provided by different stakeholders. To overcome this issue, process flow charts were developed to assist property owners, managers, occupants and insurers on a single cohesive approach to follow. The processes outline a logical approach to building assessment methodologies after a major event specifically the key roles and responsibilities played by different parties' including competent, independent occupational hygienists in pre and post remediation activities. The peer reviewed processes have had a significant and positive impact on the flood, fire and mould assessment and remediation industry. These have been adopted by various property managers, building owners, insurers and loss adjusters with a positive outcome of a consistent robust approach. The processes emphasize the value and key role played by independent occupational hygienists in these situations to provide valuable advice and assist stakeholders to make informed decisions to protect health and mitigate loss.

SPEAKING OUT FOR OCCUPATIONAL HYGIENE – INTERNATIONAL AND UK PERSPECTIVES

Dr Karen Niven

Shell International and President of IOHA

ABSTRACT

This paper explores occupational hygiene from an international/global perspective. It provides an overview and history of OH from the perspective of a country (UK) and internationally (IOHA). The main challenges for the OH-skillpool will be explored as well as reflections on expected changes for the coming 5 years. This presents an opportunity to share learnings from other societies/countries: to explore opportunities for more joint working, what is energizing, what works well, what is successful and positive and how to strengthen initiatives with the intention of instilling a feeling of 'can do', a future full of possibilities.

According to the World Health Organization (WHO), almost 2/3 of the world's 3 billion workers are employed in unhealthy and unsafe working conditions. The International Labour Organization (ILO), the United Nations tripartite agency responsible for drawing up and overseeing international labour standards, reports nearly 2 million deaths each year from occupational disease. In addition, 160 million of the world's workers get sick every year due to non-fatal occupational diseases. There are 270 million fatal and non-fatal work related accidents yearly and of those there are over 2 million who die from work-related accidents or diseases.

Clearly there is a need for action. The overall objective of this paper is to explore the potential for occupational hygiene to make a significant contribution to a world vision where workers do not get sick because of their work. The purpose is to identify future possibilities for the profession to contribute to achieving healthy workplaces for the healthy high performing people who work there. This is done by exploring where occupational hygiene has come from and where it is now with its current challenges and opportunities.

What is the current approach?

The current approach is explored through three lenses: that of a national association (the British Occupational Hygiene Society (BOHS)); an international Non Governmental Organisation (NGO) association (the International Occupational Hygiene Association (IOHA)); and a charity (Workplace Health without Borders (WHwB)).

BOHS is the UK's Chartered Society for Worker Health Protection (<http://www.bohs.org/>). It is a learned and professional society, established for over 60 years, and provides internationally recognised qualifications, scientific conferences, membership services and the world leading research journal 'The Annals of Occupational Hygiene'. BOHS has over 1600 members in 50 countries. As a national association, the BOHS, like many national associations develops a strategy to articulate outcome-based purpose statements from both demand and supply perspective for key themes. For 2016 – 2020 these are:

- Raising awareness of occupational hygiene
- Expanding occupational hygiene education
- Increasing visibility and influence of the Society
- Improving standards and recognition of competence
- Ensure a sustainable future for the Society in country and internationally

IOHA is a NGO, recognized by the ILO and WHO (<http://www.ioha.net/>). It is an association of occupational hygiene organisations from across the world and represents the global community of occupational hygienists. Since its creation in 1987, IOHA has grown to 29 member organisations, representing over 20,000 occupational hygienists worldwide. The IOHA aims to improve, promote and develop the practice of occupational hygiene throughout the world so as to improve and protect worker health and well being.

Since 2000, the IOHA has operated a National Accreditation Recognition (NAR) programme to promote global respect for and recognition of professional certification programmes which meet or exceed the IOHA Model Certification Programme. It also provides technical support and advice in collaboration with WHO and ILO (e.g. a position statement on Control Banding and an international code of ethics). Endorsing and promoting international occupational hygiene qualifications framework has been a major activity for IOHA via the Occupational Hygiene Training Association (OHTA) (<http://www.ohlearning.com/organisations-people/ioha.aspx>).

Like BOHS, IOHA also has developed a strategy for 2016 – 2020, which has the following goals:

- Promoting occupational hygiene
- Improving occupational hygiene capabilities and practice
- Creating effective networking and knowledge management
- Ensuring robust governance

Clearly there are strong similarities between the two and it seems reasonable to conclude that these goals are broadly representative of where hygiene is heading in the next few years.

IOHA have developed a set of five principles to underpin their goals:

Principle 1: Strong network...

Protecting worker health is a task that requires that individuals are part of a worldwide network that, if constructed and used effectively, allows the whole network to be greater than the sum of individuals. IOHA has a unique opportunity to be a prime mover in developing this network. This involves Global outreach to the worldwide worker community; new and innovative solutions; better public awareness and stimulation of new initiatives by member associations.

Principle 2: Visible...

From a Global perspective, IOHA can be the world's clearinghouse for OH Knowledge. There is a need to assure that the vast occupational health (OH) knowledge is available to the entire world, not just the countries or organizations from which it originates. To achieve this IOHA aims to provide venues and formats for information exchange worldwide. Current ways of achieving this are via its newsletter; website and tri-annual scientific conference.

Principle 3: Resourceful...

Education is seen by IOHA as the most important factor in promoting occupational hygiene, as well as improving the number and calibre of practitioners of occupational hygiene internationally. IOHA values human capital and recognises that it must leverage its limited resources so as to maximize its output. This means development of guidelines; training standards and further development of the Occupational Hygiene Training Association (OHTA) system.

Principle 4: Tactfully Tactical...

IOHA is an international organization and therefore must accomplish its objectives through diplomacy, sensitivity, understanding and judiciousness to understand cultural and societal norms. Having limited resources, IOHA must use effective tactics that leverage our members and individuals. .

Principle 5: Influential...

IOHA aspires to be influential; to be so means creating visible results through a strong network that optimally utilizes resources and respects the cultures and social norms of its members.

WHwB is a not-for-profit organisation with charitable status (<http://www.whwb.org/>). It was formed in 2011 by a group of international occupational hygienists, to address occupational health and safety issues around the world in the knowledge that most of the world's workers do not have access to occupational hygiene expertise. They lack the resources, knowledge

and technology to identify and control workplace exposure to disease-causing agents like chemicals, microbes, noise and radiation.

WHwB engages volunteers to provide workers with technical assistance, training and skills development to help them to develop the capacity and local infrastructure to manage and improve health conditions in their workplaces. They also focus on providing assistance to Non-Governmental Organizations (NGOs) who serve communities and workplaces in developing countries to integrate occupational health into their operations around the globe.

Conclusions & Key Messages

Clearly there is a “pull” for occupational hygiene: particularly in the developing world. There is also significant activity already underway to address this pull. There is also a need for Occupational hygienists to “push”: to make the step change in mindset and behaviours that will catalyse progress towards the goal of healthy high performing people and businesses.

There are 4 key challenges facing hygiene as it moves into an increasingly volatile world.

The first is about getting occupational health and hygiene back on Governments policy agenda. In the late 1980’s and 1990’s health and safety legislation became more prominent. In the European Union and in the UK especially, this backfired somewhat after the millennium as the concept of realistic risk seemed to have been replaced by a desire to remove all risk. For example, in the UK there is now a term ‘elf and safety’. This is a disparaging way of referring to Health and Safety legislation. Most of us would agree that people working in mines or on construction sites, for example, shouldn’t be at risk of illness or death because their employers refuse to spend money on basic safety measures. But minimizing risk can be taken too far, and the UK press regularly features articles about schools banning children from throwing paper planes (in case someone gets injured) or a local council deciding that its famous palm trees represent a danger to visitors. In other words, there are benign and ‘extreme’ versions of Health and Safety. This led to the backlash from government in January 2012 when the UK Prime Minister David Cameron famously noted his New Year’s resolution was to “kill off the health and safety culture for good”. He gave his reasons that Health and safety legislation has become an “albatross around the neck of British businesses”, costing them billions of pounds a year and leaving entrepreneurs in fear of speculative claims. He added: “I want 2012 to go down in history as the year we get a lot of this pointless time-wasting out of the British economy and British life once and for all.”

Secondly, occupational hygiene needs to become more outward facing, championing legitimate concerns over workplace hazards but learning to express these concerns in terms that are understood by businesses and the general public –building credibility and trust in the art of risk communication. Occupational Health has always been at a disadvantage from a public perception when compared to more currently tangible safety risks. This is because safety risks can be seen as here and now. Health risks are likely only to occur in the future (latency) and are also dose dependent, both concepts notoriously difficult to address with conviction. There is a well-developed community specialising in risk communication (e.g. Professor Sir David Spiegelhalter’s work in understanding uncertainty, which was a highly popular keynote at the IOHA conference in London in April 2015 (<http://understandinguncertainty.org/>)), which occupational hygiene could do well to begin dialogue.

Thirdly, occupational hygiene has an opportunity to evolve from a generally narrow focus on process and regulatory compliance to a wider appreciation of business relevance. A regulatory risk assessment report can be thought of as only one product in the offering range of an occupational hygienist. Increasingly though, there is a need for hygiene to show real business added value, and not just by the avoidance of prosecution. Impact on the business bottom line is an undeveloped “Unique Selling Point” (USP), that the hygienist needs to think about. So, focusing on outcome as well as output.

What’s the difference between outputs and outcomes? In her Harvard Business Review article (<https://hbr.org/2012/11/its-not-just-semantics-managing-outcomes>) Deborah Mills-Scofield reflects that the difference between outputs and outcomes is fundamental and profound. In the non-profit world, outputs are programs, training, and workshops; outcomes are knowledge transferred and behaviors changed. In the for-profit world, the distinctions are things we produce and the outcomes are the difference our contribution makes. She cites an example of a highway construction company’s outputs being project design and the number of highway miles built and repaired. Outcomes are the difference made by the outputs: better traffic flow, shorter travel times, and fewer accidents. Key to this begins with truly understanding your customers’ needs—their challenges, issues, constraints, priorities—.

Finally, there exist further significant skill gaps in hygiene. Noel Tresider, a past President of the AIOH and IOHA has estimated that there is a worldwide demand for nearly 50,000 certified professional occupational hygienists against a backdrop of less than 8,000 currently.

Additionally, globally there are increasing difficulties in recruiting occupational hygienists to more senior roles as leaders. For example, courses based on syllabi such as W501 supported by the last update of the AIHA IH strategy manual, is a good foundation for developing the right technical skills. However, occupational hygienists also need skills in making use of professional judgement, development of fit-for-purpose assessment strategies (involving both use of professional judgment, indicative sampling and detailed assessments), data quality (including the whole assessment chain).

The final gap can be termed as “effective leadership attributes”. The author’s observation is that many occupational hygienists’ systemically confuse leadership with management. An important distinction is that management is a skill that can be taught (so using the left (logical) brain which is a natural fit for the taught modular mindset underpinning most IH training programs), whereas leadership is about qualities that can be encouraged and developed (such as self-awareness and making contact with the right (limbic and intuitive) brain to inspire others). So the inclusion of the qualities of passion and creativity are essential to emerging curricula for occupational hygiene.

HOW DO REGULATORS USE WORKPLACE EXPOSURE STANDARDS?

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**This paper represents the views of the authors and not necessarily the views of their employers*

ABSTRACT

This paper aims to inform delegates about the various ways work health and safety regulators in Australia apply workplace exposure standards (WES) to evaluate and control exposures to airborne hazardous substances. Work health and safety legislation in each Australian jurisdiction references WES, as published by Safe Work Australia. WES are also included in Safe Work Australia's Operational Plan for work on "improving effectiveness". Hygienists from three diverse regulatory regimes provide examples of how they apply WES to make decisions on compliance and exposures in workplaces. These examples include findings from regulators' hygiene monitoring programs, the use of consultants' reports, and the application of WES in proactive, reactive, advisory and awareness activities.

Key words: workplace exposure standards, occupational exposure limits, work health and safety regulation, regulator, air monitoring

Background

WES have been defined as "the airborne concentration of a particular substance or mixture that must not be exceeded. The exposure standard may be of three forms: 8 hour time weighted average (TWA); peak limitation and short term exposure limit." (Safe Work Australia 2012a). Safe Work Australia (2011a) also states that exposure standards do not delineate between safe and unsafe exposure, as individual differences may mean a small proportion of people could experience health effects at exposures less than the exposure standard. This is particularly true for substances which are sensitizers, and in the case of pre-existing medical conditions.

In Australia, WES are generally adopted into work health and safety legislation (such as the *Model Work Health and Safety Regulations 2011* which have been adopted in most jurisdictions (Safe Work Australia 2011b) and the *Western Australian Occupational Safety and Health Regulations 1996*). The use of WES in Australia is currently under review, with the aim of providing "a responsive and effective regulatory framework that improves the health of workers, reflects best practice and is able to respond and adapt to changes in scientific and technical knowledge" (Safe Work Australia 2012b).

Australian WES, established by Safe Work Australia (and its predecessors), were influenced by the Threshold Limit Values (TLVs[®]) set by the American Conference of Governmental Industrial Hygienists (ACGIH) (Golec & Grantham 2013, p. 54). Documentation as to how each WES has been set is available from the Safe Work Australia Hazardous Substances Information System website (Safe Work Australia n.d. (b)). There have been few updates of Australian WES in recent years, with the exceptions of formaldehyde and synthetic mineral fibres in 2012 (Safe Work Australia n.d. (b)).

Some substances may be considered overdue for a WES review. For example, hexavalent chromium has an Australian exposure standard of 50 µg/m³ and a US (NIOSH) recommended exposure limit (REL) of 0.2 µg/m³, and manganese has an Australian exposure standard of 1 mg/ m³, a UK (HSE) WEL of 0.5 mg/ m³ and an ACGIH TWA (respirable) of 0.02 mg/m³ (Safe Work Australia n.d. (b); CDC 2013; HSE 2013 and ACGIH 2015). Indeed, NIOSH indicates that exposure to hexavalent chromium at a level approximately that of the Australian exposure standard would cause an additional 70 to 280 cancer deaths per thousand exposed workers (CDC 2013, p. 78). A recent assessment of lung function among quarry workers suggests the exposure standard for crystalline silica also requires review (Hedges et al. 2013).

Some substances that are used extensively across Australian workplaces and mines do not have a WES assigned by Safe Work Australia. An example of this is 1-bromopropane (1BP), a solvent used for degreasing, dry cleaning and spray adhesives. The ACGIH have assigned 1BP a TLV of 0.1 ppm on the basis of central nervous system, peripheral nervous system, reproductive and haematological effects (ACGIH 2015). In 2013 the US National Toxicology Program (NTP) considered classifying 1BP "reasonably anticipated to be a human carcinogen" (National Toxicology Program 2013). A process for periodic review and consideration of WES will assist industry and regulators to identify the most appropriate WES, potentially preventing illness and disease.

Where WES are adopted into legislation, the feasibility of achieving the relevant level is usually a consideration in addition to health effects, and some frameworks include WES set for reasons of practicability as well as health reasons (Stouten, Ott, & Bouwman 2008). WES in Australia are not fully health based, as indicated by Safe Work Australia's statement that "there are a number of instances where other considerations, such as, economic, social or technological implications, or sampling and analytical limitations, have also been taken into account" (Safe Work Australia 1995).

WES are included in Safe Work Australia's Operational Plan (Safe Work Australia, n.d. (a)) for work on "improving effectiveness", and this work may explore models other than direct referencing of WES in legislation.

Regulators' use of Workplace Exposure Standards

WorkSafe division of the WA Department of Commerce

WorkSafe (WA) conducts both proactive and reactive work. In the occupational hygiene area, proactive work may include air monitoring and make reference to workplace exposure standards. WorkSafe (WA) has a small occupational hygiene laboratory and a team of five scientific officers in the occupational hygiene and noise control area.

Inhalable dust, respirable dust and respirable crystalline silica in assay laboratories

In 2011-2013 WorkSafe (WA) assessed exposure to inhalable and respirable dust and respirable crystalline silica in assay laboratories. Personal air monitoring was conducted at nine assay laboratories in Western Australia to characterise worker exposure, with reference to the control measures used in each workplace. Seventy-eight personal samples were collected. Mean exposures were 0.16 mg/m³ for respirable crystalline silica (RCS), 2.0 mg/m³ for respirable dust, and 13.8 mg/m³ for inhalable dust. Around half (52%) of the results for RCS exceeded the WES of 0.1 mg/m³. For respirable dust, 10% of results exceeded the reference value of 5 mg/m³ and 44% exceeded the recommended trigger value (Cherrie et al. 2013) of 1 mg/m³. Inhalable dust exceeded the recommended trigger value (Cherrie et al. 2013) of 5 mg/m³ for 75% of samples.

A number of practical control measures were identified. This study found there is a need for assay laboratories to improve their dust management to reduce the risk of respiratory health effects such as silicosis and chronic obstructive pulmonary disease. Where results exceeded the workplace exposure standard, enforcement action (improvement notices) was taken to improve controls. Guidance was provided to industry on suitable controls to manage dust exposure.

Isocyanates in vehicle repair workshops

During 2008-2010 WorkSafe (WA) completed an inspection campaign in the vehicle spray painting industry, with a focus on the management of hazardous substances such as 2-pack paints containing isocyanates. This campaign involved air monitoring for isocyanates and urine testing for isocyanate metabolites, and found that the urine testing was a more sensitive exposure measure than air testing (Hu et al. 2014). A variety of hazardous substances related breaches were identified during this work, particularly in relation to selection and use of personal protective equipment, the provision of quality air for air supplied respirators, information and training and provision of health surveillance. This work did not identify any breaches of the isocyanate exposure standard. Health surveillance reports in this industry have increased 600% since this campaign.

Air quality in nail salons

WorkSafe has been conducting proactive visits to nail salons over the last four years with a focus on the safe use of hazardous substances. Air monitoring has been conducted in a small number of workplaces and results to date have identified the presence of methyl methacrylate (MMA) rather than ethyl methacrylate. Whilst the inhalation exposure results to date have been a small percentage (< 5%) of the methyl methacrylate exposure standard, the presence of MMA poses additional hazards to staff in terms of sensitisation and irritation and raises questions about the accuracy of information products such as safety data sheets. WorkSafe's approach in this industry has been largely educational, with the production of guidance material in English and Vietnamese, however around 50 improvement notices have also been issued.

Lead in assay laboratories WorkSafe conducted a small amount of air monitoring for lead in assay laboratories several years ago, which found levels of up to twice the exposure standard. These results were addressed with improvement notices. This year further air monitoring has been conducted in such workplaces, as well as dermal sampling of lead workers' hands to investigate the significance of hand-mouth transfer to the workers' total lead exposure, as indicated by their blood lead level.

This work is considered particularly relevant in view of proposals to consider reductions in the permissible blood lead levels for lead workers, and the lead exposure standard (Safe Work Australia 2014).

Provision of information and guidance Where air monitoring is done as part of a proactive campaign, information is provided to industry by direct communication and, in broad terms, on the WorkSafe website and serves to guide industry and the inspectorate as to the most effective controls to achieve compliance.

Reactive work

During WorkSafe's reactive work, direct reading indicators such as colourimetric tubes, a Dusttrak meter, or a photoionisation detector may be used. These techniques can help inspectors form opinions about the adequacy of controls whilst on site, particularly useful where the issue is in relation to short duration tasks such as some construction activities.

WorkCover NSW

WorkCover's Hazardous Chemical Services (HCS) Team has four specialist inspectors engaged in occupational hygiene and toxicology activities to prevent illness and disease from exposure to workplace chemicals. They undertake intervention, verification and advisory and awareness raising programs as well as providing technical assistance to the general inspectorate to address occupational hygiene issues.

Occupational hygiene assessments and the application of WES are regularly used by the inspectors as a powerful tool to improve exposure control, particularly in small to medium sized enterprises (SME) in NSW. Results from a carcinogen verification program and a case study of airborne dust control in a glass recycling facility are provided to illustrate this.

Verification program on safe use of an authorized carcinogen: MOCA

Personal air monitoring and surface swab sampling were incorporated into a regulatory program to assess worker exposures to a restricted carcinogen under WorkCover's high risk verification program in 2014. All users of the **aromatic amine 4,4' methylene bis(2-chloroaniline), commonly known as MOCA, in the polyurethane manufacturing industry in NSW were visited to review and improve exposure control measures in these SMEs.**

Air monitoring showed no worker was at risk of inhalation exposure to MOCA as all results were well below the Australian WES of 0.22 mg/m³ TWA (8 hr). However, surface contamination with MOCA was evident in all workplaces (in 86% of all samples collected) with levels up to 1104 ng/sample detected (Shankar et al. 2015, unpublished).

In the absence of any established exposure limits or guidance levels for surface contamination with MOCA in workplaces, compliance with airborne WES was useful in directing attention towards controls to prevent dermal exposures in each workplace.

Case Study: Airborne dust control at a glass recycling facility

Following a complaint of exposure to fine dust at a glass recycling facility, a WorkCover inspector issued an Improvement Notice to the PCBU to undertake hygiene monitoring of workers to assess any crystalline silica exposure. The HCS team reviewed the hygiene consultant's dust exposure assessment report for the SME and noted that all the personal exposures for two similar exposed groups (SEG) were below the Australian WES of 0.1 mg/m³ TWA for crystalline silica. However, it was noted that many exposures were above the 10% action level with one at 80% of WES.

Through good hazard communication and advice on the application of WES to exposure control, the inspector influenced the PCBU to implement better control measures by purchasing a wet cutting machine that would eliminate dust-generating dry work in the facility altogether.

The above two are recent examples of how WorkCover has applied WES in its high risk regulatory verification programs as well as in routine compliance, advisory and assistance work by the general inspectorate.

WorkCover NSW has undertaken extensive workplace hygiene monitoring over the years and reviewed numerous third party hygiene reports on a range of hazardous airborne workplace contaminants. In all these situations, the Australian WES that is called up under the relevant WHS regulations of the time would be applied to assess potential health risks, particularly from those that cause long-latency chronic illness and disease. This approach has enabled WorkCover Inspectors to confidently verify regulatory compliance and where necessary, educate SME operators in particular, on WES so they can take appropriate

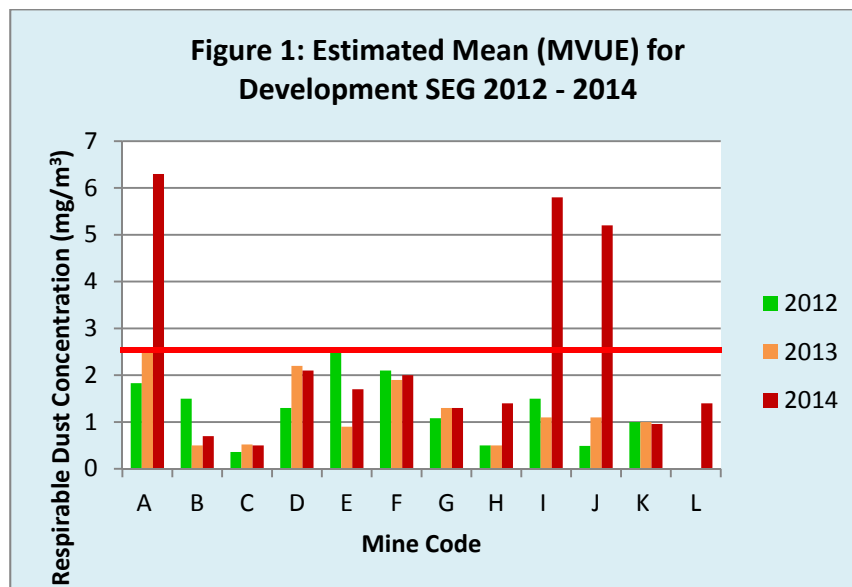
measures to reduce exposures. Professionals who provide occupational hygiene services to industry should also inform and educate their SME clients on the application of WES, explain the hierarchy of controls and build their capability to implement practical control measures in their businesses.

Department of Natural Resources and Mines - Queensland Mine Safety and Health

Queensland Mines Safety and Health have recently expanded the skill base of the mines inspectorate by appointing a number of field based occupational hygiene roles (specialist Inspectors). These inspectors routinely use the WES for industry benchmarking programmes, compliance assessment and for proactive research and development. The considered application of the WES is fundamental to these activities and helped drive change and ultimately improve the health of mine workers. Examples are provided below.

Industry Benchmarking

The Chief Inspector of Coal mines routinely requests exposure data from underground coal mining operations to understand the state of control in the industry with respect to respirable coal dust and diesel particulate matter (DPM). This data is processed and analysed by the inspector of occupational hygiene and reported against the regulated WES for respirable coal dust and in the case of DPM, the adopted guideline limit value. These results are used by the Mines Inspectorate to make evidence based decisions about risk, exposure control and compliance. This then forms the basis for prioritising inspections and allocating resources for field activities. Figure 1 illustrates estimated mean exposures for development coal mine workers for all underground operations during the period 2012 – 14. A similar exercise was conducted for DPM in 2009 and again in 2013. While this process was able to identify sites that warranted regulatory intervention, it was also useful in identifying sites that had adopted best practice such as an emission based maintenance program. The information gathered and the exposures reported were presented in a de-identified format to industry to allow benchmarking of their level of control and share of best practice.

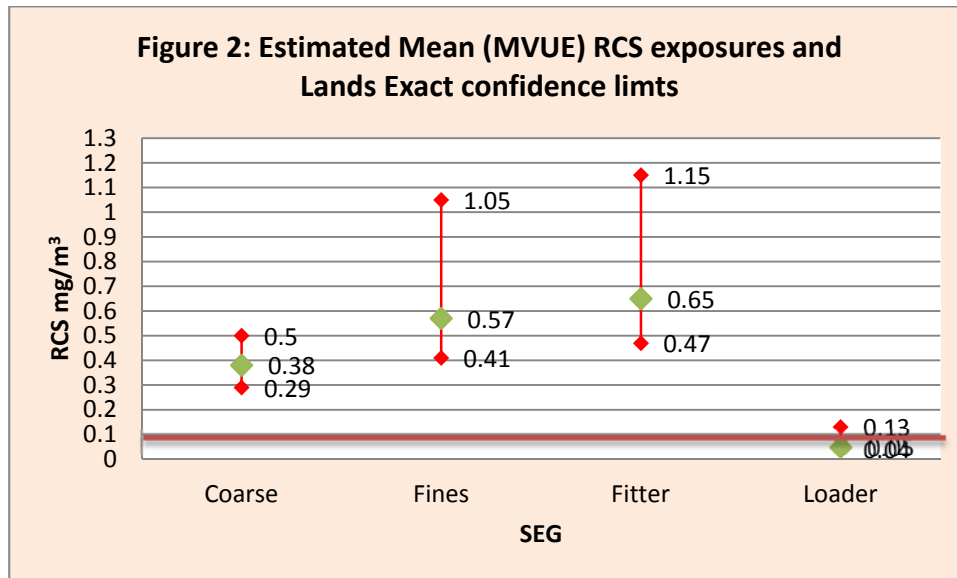


Compliance

Under Queensland mining legislation the functions of an inspector include “to monitor safety and health performance at mines” (Queensland Government 1999). In order to monitor performance effectively it is essential that the regulator has in place standards for what are considered to be acceptable limits of exposure. The Queensland mining legislation has promulgated regulatory limits for certain hazardous substances. These are based on the WES published by Safe Work Australia and include respirable coal dust and respirable crystalline silica.

The Queensland mines inspectorate will only make decisions on compliance when considering representative exposure data for a similar exposure group, applying statistical analysis to this data set and making comparison against the shift adjusted regulatory limits. This process forms the basis for compliance action in the form of a “Directive” issued to “reduce risk”. Directives will only be closed when representative monitoring verifies the effectiveness of implemented controls. In the case

of small mines and quarries, specialist inspectors may conduct personal monitoring for compliance purposes. Figure 2 illustrates calculated respirable crystalline silica levels at a sand processing mine and the basic statistical parameters used for assessing control and initiating compliance action.



Research and development

During the period 2008 -12 the Queensland Mines Inspectorate participated in a joint research project with the University of Western Sydney to review personal respirable crystalline silica exposures across a number of quarries (Hedges et al. 2013). Personal monitoring was undertaken on 26 workers from standardised SEGs at 5 quarries. Results indicated that workers at four of the five quarries exceeded the WES for RCS. This study considered the relationship between loss of lung function and measured RCS exposure and challenged the level of protection afforded by the current exposure standard.

In addition the study assessed the effectiveness of standard cabin air conditioning systems to prevent operator exposure to respirable dust. Personal monitoring demonstrated significant ingress into the cabin with exposures exceeding the WES. A pre-cleaner, filter, pressuring unit (PFP) was installed and monitoring demonstrated significant reduction in personal exposures. This information has since been used by the inspectorate to promote best practice and improve operator cabin designs across the industry.

Conclusions and recommendations

WES have long been a valuable tool for occupational hygiene assessments, providing a guide to understanding whether control measures are adequate and risks managed. They are equally a useful tool for WHS and OSH regulators. However, there is at present no system within Australia for the regular review and updating of WES. This has the potential to provide employers, workers and inspectors with a false sense of security, in cases where the WES may not have been set with reference to the latest health data. A system of updating WES should be addressed as a priority, as the government has a responsibility to ensure WES in use are current and health based.

The future of Occupational Exposure Limits (OELs) or WES was raised by a number of experienced overseas occupational hygienists through the international professional body IOHA as far back as 2009 (IOHA 2009). While recognising that OELs are critical to risk assessment and measuring compliance, they identified a number of challenges to the global community including the resources and expertise needed to establish OELs and asking whether OELs are a true threshold of toxic effects.

If resources to update and maintain Australian WES are not available, it may be more prudent to reference the WES of selected organisations, where WES are set on a health basis and regularly reviewed, rather than mandate out of date WES. If this approach were to be used, it would not be feasible to reference the WES in regulation (due to the need for regulatory impact assessments on each change), and the WES would be considered a guide. Regulators would, however, be able to consider worker exposure to a hazardous chemical, the guidance WES and the current controls, and enforcement action could be taken where controls are inadequate.

Current and health based WES are a useful part of the WHS and OSH regulatory framework, whether in regulation or in supporting guidance material. As the above examples illustrate, occupational hygiene assessments with reference to WES have the potential to lead to improved workplace controls and lower health risks. It is important that Australia have a responsive, transparent and health based system for setting and updating WES.

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Implementation of a comprehensive Asbestos Management Plan – The Caltex Experience

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ABSTRACT

The new National Model Work Health & Safety Regulations (National Regs) outline the key requirements that industry must comply with to manage the risk of asbestos and asbestos-containing materials (ACM) in an effective and sustainable manner. The associated Model Codes of Practice provide guidance to industry on how this can be achieved.

With a diverse portfolio of structural assets, Caltex faced a significant challenge to effectively document and manage the risks associated with ACM located across 890 sites nationally.

Caltex has implemented a comprehensive documented Asbestos Management Plan, which details a consistent process for the safe management of ACM across all assets within the business such that the incidence of asbestos-related diseases, such as mesothelioma, asbestosis and lung cancer, are minimised.

This paper will outline the challenges faced by Caltex in meeting the key requirements detailed within the National Regs as well as the management system parameters required to ensure the consistent management and effective governance of ACM.

To address these challenges and meet the management system parameters required, Caltex implemented the customizable Lupin Systems HazMat online software application tool to effectively manage ACM across the business.

Using the removal of ACM during the decontamination and decommissioning of an oil refinery as an example, the practical effectiveness of the Lupin Systems HazMat online application as a historical repository for key compliance documentation will also be highlighted.

Key Words: Asbestos

Introduction

Chapter 8 of the National Model Work Health & Safety Regulations¹ outline the key requirements that industry must comply with to manage the risk of asbestos and asbestos containing materials (ACM) in an effective and sustainable manner. The associated Model Code of Practice; How to Manage and Control Asbestos in the Workplace² provides guidance to industry on how this can be achieved.

Identification

Key to effectively managing the risks associated with asbestos is the identification of all ACM at the workplace and recording this in a site asbestos register.

For a company such as Caltex, this basic requirement posed a significant challenge. Caltex has a diverse portfolio of structural assets throughout Australia that includes a refinery, 13 terminals, 81 depots and 705 owned or leased service stations.

Responsibility for managing asbestos across these retail sites has another layer of complexity in that not all are Caltex owned or operated. Of these 705 retail sites, only 86 are Caltex operated and of the 629 franchisee service stations, a significant proportion of these sites are leased by Caltex through a third party.

Caltex needed to have a comprehensive and accessible database repository for all site asbestos registers.

To comply with this requirement Caltex had to initially determine what site asbestos registers were currently in existence and the date they had last been reviewed. For those sites where a register could not be obtained, the age of structures on site were verified to determine the likelihood of ACM being present. This initial review identified that not all service station and depot sites had a current site asbestos register.

With this information Caltex was able to take a risk-based approach to meeting compliance. That is, developing registers for those sites that did not have an asbestos register and reviewing those registers that were out of date (greater than five years since last review).

In the first phase, asbestos surveys were conducted for all sites that were either Caltex owned or operated and were built prior to 1990. The second phase of surveys was conducted on franchisee sites that were built prior to 1990.

Given that many of these franchisee sites were on sites leased by Caltex from small businesses, such as husband and wife investors, Caltex chose to take on the responsibility of ensuring that an asbestos register was developed.

The third phase of surveys were conducted on franchisee sites built after 1990 but prior to the regulatory “cut-off” of 31 December 2003.

Asbestos management – Comparing apples with apples

Caltex implemented the customisable Lupin Systems HazMat online software application tool to allow all site registers to be made available to both internal and external key stakeholders (employees and contractors) and to effectively manage ACM across the business. This system can be accessed by all Caltex employees through the Caltex intranet portal, while key contractor stakeholders can access the system by logging in through the internet.

This system provides Caltex with consistency of information across all sites. Due to geographical spread of site locations, Caltex is required to engage more than one external service provider to undertake asbestos audits and re-surveys across Australia. When undertaking these activities it is critical that the same information is collected by all service providers and that the condition of ACM is assessed in a consistent manner.

This system ensures that this happens by allowing Caltex to develop an asbestos audit template and risk assessment matrix that all service providers must utilise when developing an asbestos register. This template contains key data required for the effective management of an ACM such as location, description, application, amount present, confirmatory analysis information, material condition, risk rating and, where necessary, remedial actions required.

Critical to the effective and timely management of ACM is its risk ranking. Caltex utilises a risk assessment matrix to allow service providers to allocate the ACM a “Priority” (P) rating of between 1 and 4.

- P1** Restrict access and isolate material immediately. Plan for removal as soon as practicable (less than one month). The identified material presents an immediate occupational/environmental risk in its present condition.
- P2** Limit access as an interim measure and identify for planned removal (less than three months). The identified material presents a potential occupational/environmental risk in its present condition.
- P3** Identify for removal where maintenance or refurbishment may cause disturbance of the material. Treat material (make safe, seal) to prevent potential fibre release as an interim measure.
- P4** Leave in situ. The identified material presents a low occupational / environmental risk in its present condition unless acted upon.

External contractors are required to undertake asbestos surveys in a consistent manner following a documented Caltex procedure. This procedure details the exact scope of works to be conducted and the methodology followed. Critical aspects such as thoroughness of inspection, identification and reporting of inaccessible areas, labelling, collection of samples, sample analysis, risk assessment and limitations of inspection are all clearly defined.

This procedure also details the process to be followed if ACM identified during the survey presents an immediate health risk or requires an urgent asbestos removal works notification.

Caltex requires contractors to enter survey findings directly into the Lupin HazMat System following a documented procedure. This ensures that all key information is consistently entered allowing comparable risk ranking of ACM deposits across the entire Caltex asset portfolio.

Confirmation analysis – A risk-based approach

Confirming the presence of asbestos for all assumed ACM deposits across the entire Caltex asset portfolio presents a number of practical challenges. As such, confirmatory sample analysis is undertaken using a risk-based approach. If the condition of a material assumed to contain asbestos potentially places anyone at possible risk of exposure to friable asbestos (anything rated P1, P2 or P3) then a sample is taken. A deposit that is in good condition and poses no risk of exposure is rated P4 and

is recorded in the system as ‘assumed’ to contain asbestos. If at a later date the condition of the deposit deteriorates due to weather, wear and tear or an accident, then a sample will immediately be taken for confirmatory analysis. In this instance confirmation is necessary to determine the appropriate actions to be taken.

Keeping the Caltex Asbestos Management Plan up to date – asbestos removal

For the Caltex Asbestos Management Plan to continue to be effective it must include processes to capture any changes to existing site registers as well as identify any new site locations entering the Caltex portfolio.

Existing site asbestos registers must be updated whenever the condition of an ACM deposit changes or ACM is removed. For Caltex, such scenarios can include physical impact due to vehicle movements and facility maintenance activities, while entire ACM deposits can be impacted or removed during facility upgrades. As part of the Caltex annual asset improvement plan, Project Services undertake site refurbishments and knock down rebuilds (KDRs). Caltex also undertakes site divestment projects.

To help capture these changes and ensure that key asbestos removal documentation is obtained, Caltex has developed an Asbestos Removal Notification Form. This form must be completed by the manager of the project, facility or remediation at the completion of any asbestos removal works and sent to the Caltex HazMat administrator.

This Asbestos Removal Notification Form is not only used to record the details of all asbestos removed, but also serves as a checklist to ensure that all key asbestos removal documentation is obtained and uploaded onto a site’s asbestos register. Such documents include the contractor’s Asbestos Removal Control Plan, licensing and employee training records, air monitoring results, clearance reports and asbestos disposal receipt records. Using this completed form the Caltex HazMat administrator updates the site register to reflect any changes that have occurred, as well as upload these key compliance documents.

The online system allows ‘owners’ of sites to be updated whenever there is a change to the site’s asbestos register. The Lupin Systems HazMat online software application allows ‘watchers’ to be notified by email whenever a change has occurred.

Caltex has a documented process in place to ensure that, for newly acquired assets (service stations and depots), an asbestos register is obtained from the previous owner. Or, where a register is not available, a process is used to confirm the age of all structures and, where necessary, a site asbestos survey is conducted.

Where there has been no documented change to a sites asbestos register, a review is conducted by a competent person every five years. This review is conducted by either an internal HSE specialist or by an external service provider. Caltex HSE specialists have been trained to undertake site (service station and depot) register reviews. During such reviews HSE specialists reconcile the presence of each deposit at site, along with the condition of the ACM with the current asbestos register. Changes in the condition of any assumed ACM would prompt for a sample to be taken for confirmatory analysis. Result of this analysis would dictate what action would be required to manage the deposit. This review process also ensures that all asbestos removal works undertaken follow due process by highlighting any changes to ACM on site that have not been reflected in the current site asbestos register.

Access to the HazMat Management System

Key to the effectiveness of the Caltex online asbestos management system is the ability of stakeholders to easily and quickly search and access a specific asbestos register. Stakeholders must not only be able to easily access the specific asbestos register required, but be able to easily identify a specific deposit and whether the deposit contains ACM.

The Caltex online asbestos management system has a comprehensive search function that allows stakeholders to search or view registers via a range of Caltex specific search criteria. Criteria includes site ID number, regional location, asset type, site address and site name.

Sites are not only risk-ranked, but also colour-coded. Sites that do not have any ACM present on site are colour-coded “green”. Sites containing ACM are risk rated by the highest ranked ACM deposit present at that location and are colour-coded as follows;

P1 – Red

P2 – Orange

P3 – Yellow

P4 – Blue

Identification of a specific ACM deposit can easily be confirmed by the deposit photo which clearly identifies the ACM and its location. A photo is required for all deposits to aid in verifying the location and condition of the ACM.

In almost all instances stakeholders wish to know the current status of ACM present. To simplify the information available, employees accessing the system through the Caltex intranet and contractors accessing the system remotely, only have access to the current asbestos register.

To ensure that stakeholders can download this information easily, Caltex has developed a number of PDF reports which sit within each site entry.

Caltex has developed template reports for sites new to industry (NTI), knock down rebuilds (KDR), site divestment, initial asbestos audits and asbestos register reviews. The current status of each site will determine which PDF report is available to stakeholders. These documents can be easily printed out.

Caltex has a requirement that all depot and service stations have a printed copy of the site asbestos register present in the site contractor sign in book.

Stakeholders who may be required to access historical information relating to specific sites have individual log on details and expanded Lupin Systems HazMat functional permissions.

Asbestos Management – governance & regulatory compliance

Ensuring that all ACM is risk-assessed using the same criteria is essential in utilising the online system as an effective governance tool. All sites in the system are listed in order of risk from P1 down to P4. This allows a powerful governance verification tool to identify deposits that pose a possible exposure risk to Caltex employees, contractors or franchisee operators.

In the first instance, external service providers undertaking the asbestos surveys are required to communicate any high risk items and associated management controls to their site contact. In the case of a service station they are required to communicate the issue with the store manager prior to leaving site, who in turn would then enter a maintenance request in the Caltex internal facilities maintenance system.

For P1 and P2 items the service provider is also required to contact the Caltex HazMat Management System Administrator, who in turn will communicate the item and associated actions to be taken to senior management.

Secondly, high risk items are tracked at a senior management level to ensure that they are managed in a timely and effective manner. Quarterly governance reporting flags the number of P1 and P2 rated deposits to senior management. These are discussed and assurance obtained that these high risk deposits are dealt with in a timely manner and that all actions associated with such deposits have been closed out.

The Lupin System HazMat application provides simple template reports which allows risk owners across the business to quickly identify high ranked risks and overdue audits. These reports also allow for planning annual budgets by identifying what register reviews are required in the next twelve months. These reports also aid in identifying personnel resources (both internal and external) that may be required to ensure all required asbestos register reviews are conducted.

Capturing asbestos removal work – refinery decommissioning & demolition

Due to the delayed onset of disease associated with exposure to asbestos, it is critical that Caltex is able to provide retrospective assurance that appropriate and effective controls were implemented throughout the entire life cycle of the ACM. To achieve this Caltex must capture and record all changes to an ACM throughout its entire lifecycle.

This is very important during the decommissioning and decontamination (D&D) of a refinery where a significant number of personnel may potentially be exposed to friable asbestos in the absence of an asbestos management system and associated controls.

In 2014 Caltex commenced a project to decommission, decontaminate and demolish the Kurnell refinery. A major component of the decommissioning process was the safe removal and disposal of ACM.

The vast majority of this ACM was present along pipeways and the site power plant in the form of potentially friable asbestos containing lagging used to insulate pipe and ductwork. Other lower risk ACM present included bonded cement sheeting used for wall linings and exterior roofing, refractory and gasket material.

Prior to decommissioning, an asbestos removal control plan was developed and submitted to Caltex for approval by the contractor undertaking the asbestos removal work. The asbestos control plan detailed the specific controls implemented by the removalist to ensure that all asbestos and ACM was safely and effectively removed. This plan, as a minimum, covered the items detailed in Appendix A of the Code of Practice: How to Safely Remove Asbestos³.

Key compliance documents associated with the removal of ACM were obtained in a timely manner from stakeholders involved to provide regulatory assurance that ACM was safely removed and that controls implemented during the removal process were effective. The following key compliance documents were uploaded onto the Caltex online HazMat management system;

- Asbestos removal control plan & SWMS's
- WorkCover NSW asbestos removal notification licences,
- Removalist licencing and employee training documentation
- Air monitoring reports
- Site clearance reports, and
- Disposal Receipts.

An asbestos removal auditing tool was also developed that allowed Caltex to undertake random audits of asbestos removal works to ensure that the asbestos removalist and clearance inspector was adhering to the requirements detailed within the asbestos management plan. This auditing tool provided Caltex with further assurance that appropriate controls and procedures documented in the contractor's Asbestos Control Plan were undertaken / complied with.

References

- 1 National Model Work Health & Safety Regulations (2014), Australian Government
- 2 Safe Work Australia (2011) How to Manage and Control Asbestos in the Workplace, Code of Practice, Australian Government
- 3 Safe Work Australia (2011) How to Safely Remove Asbestos, Code of Practice, Australian Government

OPPORTUNITIES FOR INTEGRATION OF OCCUPATIONAL HYGIENE SKILLS TO ASSESS AND MANAGE PUBLIC HEALTH ISSUES

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ABSTRACT

Occupational hygienists are the experts at exposure assessment and monitoring airborne contaminants. Their training and experience demands a high level of knowledge of the potential and limitations of the equipment and the sampling and analytical techniques they employ to monitor workplace exposures. Currently in Western Australia, occupational monitoring is being applied in a number of para-occupational settings during investigation, remediation and validation of contaminated sites. This work is often undertaken by environmental technicians who are unfamiliar with the equipment, standard methods and application of the results which frequently produces spurious or meaningless information, often at significant cost to the client. Similar opportunities exist for the occupational hygienist to assist with performing the health risk assessment and producing integrated management plans to protect the health of workers and the neighbouring public into perpetuity. Specific contaminated site scenarios will be introduced with the aim of inspiring consultant hygienists to integrate their skills into environmental and public health management. For example, with increased demands for housing in the metropolitan area, there is an increased motivation for urban infill developments on historical landfill and petrol station sites where there is potential for vapour intrusion from contaminated soil, groundwater and/or ground-gases.

Key words: contaminated sites; exposure assessment; health risk assessment; para-occupational asbestos monitoring; health risk assessment; site management plans

Introduction

Identification, recognition, assessment, prevention and control of environmental agents that can adversely affect health is the focus of both occupational and environmental health

The main differences between the occupational and environmental settings relates to the population and exposure profile. For most practising occupational hygienists, the workplace is a limited population, usually set in industrial or mining workplaces where there may be a number of toxic environmental agents. Exposure duration is limited to the time spent in the workplace with opportunities for recovery away from the contaminants. The workforce population is predominantly adult population from 16 to 65 years old who have been medically assessed as fit to work in these physically demanding environments. As a result the "Healthy Worker Effect" is often described in epidemiological studies, where the workforce population is found to have lower relative risk of common health indicators than the general adult population.

While there is some consideration of sensitive populations in the occupational environment, eg. pregnant employees with potential exposure to teratogens, pre-existing conditions, the environmental setting includes all of the most sensitive population groups, including infants and children, people with pre-existing medical conditions (eg. asthma) and older people. Toxicity and exposure scenarios need to apply to all those potentially exposed. Exposure scenarios for children need to consider physical factors such as higher metabolic and breathing rates, an immature immune system and behavioural factors such as a greater tendency for uptake through soil ingestion.

Exposure to environmental contaminants can be for extended periods without a break and exposure is involuntary. Exposure can occur from a wide range of sources and situations from contaminants present in air, water, soil and food and exposure from all sources needs to be considered in public health risk assessment.

These factors, along with problems associated with ongoing monitoring and control the environment and limited risk knowledge available for exposure at lower concentrations, increases the complexities associated with public health risk assessment.

One common factor is the need for adequate exposure assessment. The exposure assessment component of health risk assessment is often misunderstood and poorly executed in both occupational and environmental health settings.

Occupational hygienists are able to provide expert knowledge in this area in occupational health and there are opportunities for transferring their skills and knowledge into public health risk assessment.

Public Health Risk Assessment

The National Environmental Health Strategy (1999) adopts a risk based approach that recognises that all situations carry some degree of risk and that analysis of these risks can contribute to decisions aimed at minimising harm to individuals and communities. Health risk assessment provides us with a systematic approach for characterising the nature and magnitude of the risks associated with environmental health hazards (enHealth, 2004).

The nature and the quality of the decisions in risk management, and the confidence we have in them depends on the quality of the information provided by the health risk assessment. A health risk assessment that provides the best and most objective scientific information available about health risks will enable the best possible discussions and decisions to follow. If the risk management process is based on flawed information, then subsequent decisions will be flawed (DoH, 2006).

Most activities or projects undergo government approval processes. The nature of this approval will often dictate the need for and the level of health risk assessment required. Some situations may have specific guidelines, such as the Department of Environment's (DER) Contaminated Sites Guidelines (DER, 2014).

Large complex projects or projects on potentially contaminated sites (on green or brown sites) where multiple agents and a variety of exposure types exist, require more detailed health risk assessments. They will usually require approval at state government level and may involve a number of different agencies that assess proposals and make recommendations to decision making authorities. These decision-making authorities consider the recommendations and make the final decision on whether the project can proceed and under what circumstances. Health risk assessment carried out for these types of projects will generally be detailed and situation-specific.

In Western Australia, decision making authorities such as the DER, Department of Planning, Department of Transport, consult with DOH with regard to reviewing public health risks associated with developments and proposals. This role is intended to be formalised with revisions to the Public Health Act 1911. Part 6 of the proposed Public Health Bill 2014 is concerned with public health assessments. Provision is provided for the Chief Health Officer to require public health assessment of any assessable proposals² and to give advice or make recommendations to the decision-making authority as to any public health risks from implementing that proposal.

Much of the health risk assessment work that is done is concerned with contaminated sites. Contaminated sites in Western Australia are regulated by DER in accordance with the *Contaminated Sites Act 2003* and *Regulations 2006*. Every site classification is reviewed by DOH whether it is through formal referral or review at final sign off. Currently, all contaminated sites that relate to asbestos contamination or that are accompanied by health risk assessments are referred to DOH for review.

Other relevant public health risk areas include:

- Assessment, remediation and validation following illegal drug lab contamination.
- Air quality monitoring from commercial and industrial emission sources.
- Para-occupational asbestos monitoring during asbestos removal work.

Each project undergoing a health risk assessment will involve a range of stakeholders. These typically include those proposing the project (the proponent); members of the community or workers potentially affected by the project; government representatives from all levels of government; other experts and consultants; environmental planners and other health officials.

Given the depth and breadth of knowledge required for an extensive health risk assessment, it is usually not realistic for any one professional to effectively address all aspects of all issues. The range of medical and health experts that provide

² Assessable proposal means a proposal that the regulations provide is an assessable proposal. A proposal is a project, plan, program, policy, operation, undertaking or development

information, advice or expertise reflect the complex nature of some health risk assessments. For complex assessments, agreement between stakeholders on what experts will be used for specific aspects of the health risk assessment is needed.

A good health risk assessment aims to provide the best and most objective scientific information about the risks of a specific situation and follows four main steps, as shown in Figure 1. This framework is used in most health risk assessment models around the world and provides a uniform approach to assessing and quantifying risks from environmental health hazards.

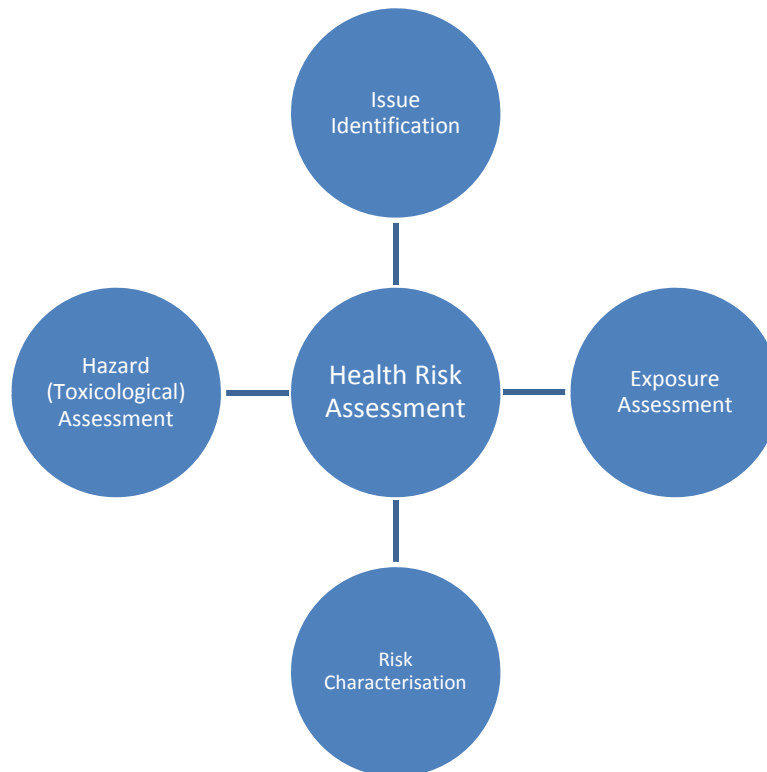


Figure 3: Risk Assessment Steps

The health risk assessment process is usually situation specific and care should be taken at each step to use information and models that are most relevant to the situation. Any information used, including toxicological data, routes of exposure, exposure assessment and health or population data, should reflect the situation as closely as possible.

Exposure Assessment

Public health exposure assessments consider what exposures are likely to be experienced under the current or, in the case of project proposals, the anticipated conditions. In many cases the public health assessment is theoretical and prospective rather than based on actual on-site measurements.

Exposure assessment is a critical component of the health risk assessment process. Exposure assessment is what puts the whole risk assessment into a meaningful context. Reports about substance toxicity as part of the hazard assessment, if used out of context, can cause unnecessary alarm and public health concern.

The possibility of multiple exposures is an important consideration in environmental health risk assessment as “typical” exposures from air, soil, water, soil and food sources, from occupational sources and even from lifestyle factors such as diet and smoking need to be considered in judging acceptable levels of risk.

Exposure assessment is the one component that is highly variable for each project or proposal. The information about the contaminants involved and their behaviour through various exposure pathways is generally well reported and understood. The circumstances relating to the exposure assessment need to be site specific and well described within the health risk assessment.

In particular, good exposure assessment is aided by good quality monitoring data. Occupational hygienists are the experts at exposure assessment and monitoring airborne contaminants. Their training and experience demands a high level of

knowledge of the potential and limitations of the equipment and the sampling and analytical techniques they employ to monitor workplace exposures.

Sometimes an occupational hygienist is consulted for air quality sampling, particularly for para-occupational asbestos sampling during asbestos removal and contaminated sites remediation work. However, more often, environmental technicians are used who may be unfamiliar with the equipment, standard methods and application of the results which frequently produces unreliable and erroneous data that cannot be used, adding significant costs to a project by either requiring re-assessment or adoption of highly protective management options to address the poorly characterised risks.

While an exposure assessment may initially involve higher initial costs to do properly, it has the potential for extensive savings by being able to focus decision making on the elimination and management of the most significant health risks, rather than unnecessary and overly precautionary risk management options.

Scientific Exposure Models

For proposed projects, scientific modelling of measured contaminants in soil and water are often used to predict inhalation exposure concentrations. These are a necessary, yet imperfect exposure assessment tool.

Models will use environmental samples that have the potential to give the most direct measure of exposure levels. Proposed projects usually rely on experience from similar projects in existence and the use of transport and fate models that forecast what happens to a substance after it is released into the environment. The data used for these models, the choice of model and the uncertainties and limitations associated with each, should be clearly understood and stated in the health risk assessment report.

Data Quality in Exposure Assessment: Garbage in - Garbage Out

The quality of the information used in the exposure assessment process needs to be clearly stated. This will include disclosure of the source of the information, details of the studies from which data was used and quality assurance systems for collection and analysis of data and samples.

As different sources of data are considered more reliable and to carry more weight than others, it is important to use the most current, relevant and accepted data supported by the jurisdiction reviewing the work.

Gaps in available knowledge may also occur in health risk assessment and the effect of these gaps on the quality or certainty of the data needs to be addressed. Professionals make judgements calls constantly, but declaration of and justification of assumptions and omissions must be clearly explained with the final report. This is discussed in more detail below.

Let's talk about assumptions and uncertainty

Every exposure assessment will include assumptions. These assumptions may be part of the models used in the assessment or may be made when there are gaps in the available knowledge. Health risk assessment reports submitted for review to DOH often don't adequately declare assumptions made during the exposure assessment. It is important to clearly state any assumptions made and the justification for using them. This allows transparency in the process, which is vital.

Transparency involves clearly detailing each step of the process, so those reviewing the assessment understand the arguments for support of the conclusions made. A health risk assessment that does not provide sufficient information upon which its conclusions are based, cannot be defended and will generally lead to more questions than answers.

Each report needs to provide a clear indication of limitations, errors and uncertainties. Uncertainty may arise because of incomplete information, the errors and uncertainty inherent in areas such as data collection, sampling and measurement and uncertainty in the models used in the process. As those reviewing the data are likely to have experience in performing exposure assessments, including sample collection, suspicions will be automatically raised if perfect data is presented.

Uncertainty needs to be clearly addressed at each step of the process. An overall assessment of uncertainties can be useful for planning future studies or monitoring that will fill in gaps in the current knowledge and sensitivity and potentially reduce levels of uncertainty.

It is recognised that health risk assessment is not an exact science. However, adherence to the above principles for assumptions and uncertainties provides a process in which the potential health risks of any project are assessed in an open

and objective manner. Such an approach is crucial to the establishment of a process that is trusted by the community, the government and proponents alike (DOH, 2006).

Issues arising from exposure assessments

There are a number of common issues noted during reviews of public health exposure assessments, including:

- Availability of technicians experienced in air quality monitoring including personal air sampling and asbestos sampling.
- Air monitoring strategies that do not consider exposures assessment needs, ie. how the exposures will occur.
- Limited utilisation of indoor air quality assessments for vapour intrusion assessment, reliance on modelling even when buildings are already present on a site (understanding the use of diffusion badges in indoor environments, when to sample, indoor air ventilation assessments, and comparison with outdoor air).
- Sampling and analytical errors, eg. errors noted include incorrect or no pre and post sampling calibration, not using open cowl in asbestos sampling, incorrectly positioned monitors, programmed time on air sampling pumps, selecting incorrect flow rates, concentration calculation errors, selection of appropriate sampling method for personal sampling or for the contaminants of concern.
- Selection of data and models relevant to the situation.
- Incomplete Preliminary Site Investigations. Risk assessment is not an isolated activity. Input is needed from those knowledgeable about site conditions, site history, prospective use and exposures.
- Not using site specific information in exposure assessment models.
- Overreliance on modelling rather than on good qualitative risk assessment.
- Interpretation of guidelines.
- Interpretation of lab results.
- Inappropriate statistical review of data.
- Slavish application of models and guidelines.

Case Studies

Most common contaminated sites reviewed by DOH are contaminated with asbestos containing materials; petroleum and volatile hydrocarbons in soils and groundwater with potential for vapour intrusion into buildings; and ground gases produced from historical landfills (methane (CH₄), carbon dioxide (CO₂), volatile organic compounds (VOCs), and hydrogen sulphide (H₂S)).

Landfill Gas

A community recreational facility, including a building with offices and public areas, was being developed over an old uncontrolled landfill site. This landfill was not considered to be a putrescible landfill site. However, uncontrolled landfill often translates to unknown fill material with potential for landfill gas intrusion into proposed buildings and structures.

In this case, a preliminary site investigation suggested that the site was used for general refuse, domestic rubbish but the consultant and auditor both dismissed these information sources as historical anecdotal evidence. Organic matter was considered, however there was no consideration of non-methane organic compounds (NMOC) from paint tins, oil drums and general domestic rubbish.

Capping used over the landfill included asbestos fragment contamination. It is not uncommon to find asbestos fragment contamination in used in “clean” capping.

Landfill gas was assessed against CIRIA C665 (Wilson et al, 2007) guidelines. High CO₂ levels recorded with low flowrates inferred a low risk. However as full risk characterisation was not completed of other potential gases; several precautionary controls were considered by the proponent and management options were described in a Construction Gas Management Plan (Plan). There were non-compliances with the Plan. For example, there was no final inspection, verification or validation of building design, and no engineering certification of gas protection measures for the building as required by the management plan. Indoor air samples to assess gas levels against trigger levels and testing of the effectiveness of venting systems and vapour membrane were not completed.

A number of results were reported from vent testing even though instruments failed calibration (final calibration outside of acceptable readings) or leak tests failed. Given the small number of sampling events (four sampling events in two years instead of the recommended quarterly testing over two years) and potential for high variability in ground-gas concentrations, these samples should have been rejected and sampling repeated for greater accuracy. Other occupational health and safety reports from the gas sampling of excavations and trenches, during construction of the building, did not provide information on the instrumentation used or sampling and calibration method.

Fortunately the landfill gas risks from this site were very low. However, these types of errors are not uncommon at sites where the risks are more significant. The consultant should have conformed to their own plan and ensured that all equipment was operational and available (eg. calibration gases and regulators) before sampling events, particularly as they were relying on hired equipment.

In conclusion the tasks outlined in their own management plan were not adequately completed. There is little interpretation of the results as the sampling events do not directly relate to exposures of building occupiers. The consultant has had to complete further work to demonstrate that their management criteria have been met, including:

- Design and actual room air changes in buildings.
- Assessment of indoor air quality against trigger levels in their plan.
- Comparison of CO₂ levels from inside the passive ventilation system, inside the building and outdoor air under worst case conditions.
- Indoor air sampling parameters:

This time they engaged a Certified Occupational Hygienist to complete the work. The final report is expected to include a risk assessment using the above results and engineering certification/approval of the building gas protection measures.

Issues from other landfill gas investigations include:

- Sufficient sampling to cover a number of seasonal and atmospheric conditions.
- Inadequate preliminary site investigations to understand the type and quantity of uncontrolled fill and consideration of other landfill gases (than CH₄ or CO₂) such as H₂S and NMOC (BTEX, 1,1,dichloroethane, hexane, dichloroethylene, vinyl chloride etc.).
- Consideration of lateral movement of gases once any construction or barrier is placed over a landfill site (including capping layers).

Asbestos

A metropolitan commercial site was reported as contaminated following the findings of asbestos cement fragments in soil left from the demolition and removal of buildings containing asbestos cement. This is a common enough situation, which can be readily prevented through appropriate application of current regulations and controls, including utilising the final clearance inspection and certificate requirement for all asbestos removal jobs. The soil contamination problem was exacerbated by site works which spread the asbestos fragments across the entire site.

In addition, the site was targeted for illegal dumping of asbestos containing waste, also a common occurrence for construction and demolition sites. Contaminated stockpiles were removed from the site. Investigations for asbestos in soil need to comply with the *Guidelines for the Assessment, Remediation and Management of Asbestos-Contaminated Sites in Western Australia* (DoH, 2009). In particular, a known quantity of soil should be examined for sampling test pits to ensure that comparison with health investigation levels can be made if any asbestos containing material is found. For this site, test pit samples were not completed in accordance with the guidelines. Remediation and validation involved site walkover and emu pick up of asbestos cement material. Officers from DoH visited the site following remediation and validation. There had been some significant rainfall since the completion of the works. A cursory walkover resulted in seven fragments found at the soil surface across the site. In addition a small stockpile of waste was present that contained several more, larger fragments.

Issues with the site included the initial spread of fragments across the site, resulting in fragments that were hidden just below the surface and exposed after rainfall. Sampling was not compliant with guidelines and there was a lack of information regarding the fate of the stockpiles and their appropriate removal and disposal. Disposal receipts for disposal of all asbestos containing material needs to be provided in accordance with DOH guidelines (DOH, 2009). Disposal receipts should provide sufficient detail regarding the source, quantity and type of waste being disposed.

Based on the information provided in the report, the site walkover, and the proposed commercial use of the site which would result in the surface being completely covered by building and hardstand, DoH concluded that any remaining contamination did not present a significant risk to health and the site could be developed for its proposed commercial use, following confirmation of removal of the small waste stockpile.

Conclusions

There is a (underutilised) role for occupational hygienists to be involved in public health risk assessment.

Occupational hygienists have the necessary knowledge and skills to complete high quality exposure assessments, including the selection and application of appropriate methods for sampling and analysis of environmental contaminants, in particular for asbestos and gas and vapour sampling.

Occupational health and safety professionals can assist in the development of integrated site management plans that incorporate management of future potential occupational and environmental health issues.

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COMPARATIVE STUDY ON ACCURACY OF AIRBORNE AND BLOOD INDIUM CONCENTRATION IN A ITO (INDIUM-TIN OXIDE) MANUFACTURING INDUSTRY

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ABSTRACT

Indium-tin oxide (ITO) is widely used in liquid crystal displays and other display devices. Recently, it has been found that indium exposure poses a serious adverse effect to workers in the ITO-manufacturing processes. Because of possible exposure to highly purified, nano-sized indium particles, it is suspected that adverse health effects possibly arises at very low concentration far below than the current occupational exposure limit (OEL; 100 µg/m³ as In, total dust). It has been proposed 10 µg/m³ as In for respirable dusts both in Japan and Korea. It is generally recommended to measure airborne concentration down to 1/10 of the OEL. For the new proposed OEL, it should be measured ideally down to 1 µg/m³ which is believed in the range of detection limit of current sampling and analysis method.

This study was conducted to evaluate accuracy of the sampling and analysis of airborne indium concentrations in a ITO-manufacturing process. Two respirable samples were taken simultaneously for each worker. Two samples were sent separately to two labs, in Korea and Japan respectively for the analysis. The airborne concentration levels were ranged in 0.32-5.11 µg/m³. The differences between results of two labs were from 4% to 252%. Main reason of the big differences was estimated due to the sampling locations of left or right side. Relatively small differences were found in the area samples (2.7~66%) even in the low concentration range of 0.24-1.05 µg/m³.

It is concluded that it is reasonably possible to measure down to 1 µg/m³ which 1/10 of newly proposed OEL for indium in respirable dust.

PILOTING THE COLLECTION OF “LEADING INDICATORS” OF EXPOSURE CONTROL PERFORMANCE FOR LONG LATENCY DISEASE

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SUMMARY

Whilst many regulators worldwide have initiatives to reduce long latency diseases caused by hazardous substances, currently there are no effective leading indicator measures to determine whether these initiatives can have long term beneficial effects. If the current practices continue, such as monitoring the final outcome of initiatives i.e. the deaths and disease that eventually materialise, we will always be 30-40 years behind in our assessment of progress. Hence, there is a need to develop more intermediate outcome measures as leading indicators, such as data on adequate exposure control for these substances, where we know there are strong links to disease.

With this mind, we have developed benchmarks and a pro-forma for ‘standardising’ the data collection approach so that the process is more structured and formalised and the information is captured with a high degree of uniformity and reliability. These have been field tested. This paper presents the findings of the pilot.

Key words: leading indicators, chemicals, asthma, isocyanates, wood dust, benchmarking

Introduction

Past occupational exposure to hazardous chemicals and process-generated substances is estimated to cause at least 13,000 deaths each year (approximately 5,000 each due to Asbestos-related conditions, with non-asbestos related cancers and chronic obstructive pulmonary disease accounting for the other 8000) (HSE, 2014a). While many such exposures are likely to have been reduced, the extent of the future health impact arising from recent and current workplace conditions is not clear. Shorter latency health conditions such as work-related asthma continue to be a significant issue in several sectors such as those working with isocyanates and flour.

Whilst HSE has initiatives to reduce long latency disease (HSE, 2014b), there are no effective early leading indicator measures to determine whether these initiatives are having an effect. If HSE continues to rely heavily on monitoring the health outcomes, i.e. the deaths and cases of disease that eventually materialise, it will always be 30-40 years behind in the assessment of the effectiveness of interventions. It is also known that ill-health tends to be under-reported and even physician-led reporting schemes (SWORD and THOR) do not give relevant leading indicator information. Hence, there is a need to find more intermediate outcome measures, such as adequate exposure control for substances hazardous to health, where there are strong links to disease.

Other driving forces further highlighted the need for action in this area. The recent Triennial Review of HSE by Martin Temple (2014) urges HSE to improve its performance measurement and a new performance framework is being developed, with a proposal for inclusion of “leading indicators for long latency disease”. Furthermore, the HSE Board and external stakeholders are expecting HSE to “Develop more sophisticated measures for the impact of HSE’s work in Occupational Disease” (HSE, 2014c).

What information do we need to collect?

It is not reasonably practicable or economically viable to establish large-scale national surveys to collect precise exposure measurement data and its associated exposure control information on individual substances. Therefore, there is a need for “proxy” indicators, focussing on the highest priority exposures which are estimated to cause the most harm. These proxy indicators need to be sufficiently “macro” to enable HSE and others to make judgements about the totality of exposure to a particular substance without the need for specific exposure measurements. Their purpose would be to enable judgements to be made about standards of exposure control for a particular substance which in turn can be used to monitor the likely ‘direction of travel’ over time of harder measures – such as actual exposures – which are challenging and expensive to obtain in a way that can be used to assess progress in reducing future long latency disease risks. The direction of travel

information should be as representative of the overall exposed population as possible, because if HSE only assesses a particular group (e.g. poor performers), it would lead to a biased view and it would not help HSE to say with confidence whether overall things are improving, or not.

It is considered that proxy measures of exposure control information could be a useful intermediate outcome measure (Brooke, et al., 2006; Bullock and Ignacio, 2006; Christopher, et al., 2007). In this case, gathering structured observational data (essentially qualitative) and its analysis to show influence on exposure levels. The information collection would focus on issues such as:

- are the appropriate control measures in place? (enclosure, engineering design, safe working distance, personal protective equipment etc.)
- are the controls being used correctly? (including observations on human factors issues)
- are the controls being maintained correctly? (management systems in place etc.)

Together, these can form a ‘basket of indicators’. Using these, HSE will be able to demonstrate the extent of exposure control, explain the underlying shortcomings, if any, and the direction of travel over a chosen period (e.g. a comparison for a five year period). Therefore the “basket of indicators” can amount to a “leading indicator” on health outcomes. The most efficient way for HSE to collect information about workplaces is to coincide its data collection with existing day-to-day planned inspection initiatives/activities.

In 2014/15, the topics selected were wood dust and isocyanates in motor vehicle body repair (MVR), and HSE occupational hygienists developed a format for collecting the ‘basket of indicators’ with easy to use guidance for inspectors on how to use it. The approach describes what effective and ineffective exposure control looks like and how to benchmark what is seen in the workplace. Although some topics are well characterised in terms of guidance to inspectors, our aim was for this user guidance to include pictorial versions of major control failures and what is required to comply.

It was considered that the approach described would enhance the quality of information collected and, importantly, contribute to better assessments of a dutyholder’s ability to manage occupational health risks, enabling more graduated judgements on the level of compliance.

Methodology

The first phase of the pilot involved:

- Developing an exposure control ratings form to capture information in an unambiguous and consistent style that can be codified to aid future analysis
- Developing benchmark forms to sit alongside the ratings forms to make data acquisition more objective and less susceptible to any selective perception of the observer, which may distort data
- Developing a feedback questionnaire to test the usability and acceptability of the proposed approach

The pilot exercise involved 49 wood working premises and 37 MVR premises. In all, 35 inspectors took part in the pilot.

Initial findings

Wood working and exposure control to wood dust

The analysis of the pilot survey data showed that, although 65% of premises had appropriate local exhaust ventilation (LEV) in place. We can only be confident that effective control was achieved at 25% of these premises. This is because in 12% of these premises, LEV was not being used correctly and in 63% of the premises, dutyholders were not adequately checking or maintaining their LEV to ensure correct performance, which is essential to deliver adequate exposure control.

For wood sanding tasks, HSE recommends that respirators should be used in addition to LEV for achieving adequate exposure control. Although 66% of the dutyholders provided RPE, only 3% of these dutyholders carried out facepiece fit testing for tight fitting respirators and none made sure correct use and maintenance of the respirators.

MVR and exposure control to isocyanates

It was found that 97% of the premises used an appropriate spray booth or room. We can be confident that effective control was achieved at 46% of these premises because they had satisfied all the parameters on exposure control indicators. However, 38% of premises need to improve how they use their booth and 46% of premises need to improve on checking or maintaining their booth.

Inspectors' view of the pilot

More than 90% of the participants found that the explanatory guidance provided was clear and they felt that the descriptors for the ratings conveyed the exposure classifications clearly.

Discussion

The analysis of the pilot surveys showed that:

- The approach produced new insights on exposure control and more than 80 forms were returned
- Unambiguous data was obtained and was easy to codify for analysis
- Inspectors found the benchmarks particularly helpful and found the rating system quick to use.
- Inspectors commented that the addition of pictures to the benchmark would help
- The data showed what occupiers are getting right and what needs to be done to improve control
- The exercise identified where the approach needs to be refined, for example extra guidance on how to classify not applicable category

Consistency of rating between inspectors could not be assessed due to a lack of opportunity to joint visit with an occupational hygienist, but is being investigated in a separate exercise. A full report will be produced in due course.

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BIOAEROSOLS IN AN AUSTRALIAN DAIRY: A PILOT STUDY

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ABSTRACT

Exposure of workers to bioaerosols in the dairy industry has been shown to cause a number of adverse respiratory effects including hypersensitivity pneumonitis, chronic obstructive pulmonary disease (COPD) and chronic bronchitis (Reynolds et al 2013). However, little has been published on bioaerosol exposures of dairy workers in the Australia and South East Asia region, other than basic exposure assessments of a small number of Australian dairies (Reed, 2003; Reed et al, 2006).

In this pilot study of a large Australian dairy, inhalable dust samples were collected using IOM sampling heads according to AS3640:2009. The average dust concentrations varied from 0.69 mg/m³ to 3.13 mg/m³ in the milking parlour and maternity barn respectively. Whereas, the endotoxin concentrations ranged from 6.4 EU/m³ in the maternity barn, to 61.7 EU/m³ in the milking parlour.

The inhalable dust concentrations measured at the large dairy are higher than similar studies undertaken in smaller Australian dairies. Further sampling is required to ascertain if similar results are obtained in other large dairies.

Key Words: Bioaerosols; dust, endotoxin, dairy exposures

Introduction

Modern farming practices involve intensive production by way of large scale dairy farms with high stock density. Biological aerosols from the animals, their feedlots and waste products may become highly concentrated within an enclosed area called “livestock confinement buildings”. Dairy farming activities have been intensified in Australia over the last few decades with an increase in the capacity of farms. While there has been a decrease of approximately 7% in the number of farms, there has been a 3.5% increase in the number of cows over the last 3 years. As a result, workers are at an increased risk of exposure to potentially hazardous situations, which commonly include dusts, bioaerosols, noise, heat and chemicals *e.g.* pesticides and solvents.

The size of the work force on most Australian farms is relatively small. For example, approximately 94% of Australian farms employ 6 or fewer employees (Lower, Fragar and Temperley, 2011). As such, the potential health impacts of excessive exposure to inhalable dust and its microbial content are not well identified, particularly through compensation statistics (Safe Work Australia, 2015). Consequently, there is potentially a high prevalence of hidden occupational dust related respiratory diseases in the Australian farming workforce.

In general, exposure to aerosols of organic origin (bioaerosols) among dairy workers has been shown to cause adverse respiratory effects including hypersensitivity pneumonitis, chronic obstructive pulmonary disease (COPD) and chronic bronchitis (Reynolds et al 2013). However, little has been published regarding levels and composition of bioaerosol exposures of dairy workers in the Australia and South East Asia region, other than simple exposure assessments of a small number of Australian dairies (Reed, 2003; Reed et al, 2006). Analysis of NSW workers compensation data indicates that respiratory diseases accounted for around 0.5% of claims between 1992 and 2001, while zoonotic, other infectious and parasitic disease made up 0.6% of claims during this period (Franklin, Thomas and Fragar, 2005). A high prevalence of childhood asthma related to exposure to fungi of the genus *Alternaria* has been reported for regional Australia (University of Sydney, 2004, Peat et al. 1995), with daily and annual *Alternaria* spore concentrations recorded in Wagga Wagga between 1997 and 1999 noted as being some of the highest worldwide at the time of publication (Mitakakis, Clift and McGee, 2001). This suggests that *Alternaria* sp. could be a potential bioaerosol of significance in the occurrence of occupational asthma in Australian farm workers. In addition to their pro-inflammatory effects, bioaerosols may also expose workers to infectious microorganisms such as *Coxiella burnetii* (Q Fever), *Burkholderia pseudomallei* (melioidosis), *Leptospira hardjobovis* and *L. Pomona* (leptospirosis) and *Aspergillus fumigatus* (Aspergillosis) (Davidson and Thornton, 2013; Driscoll, 2005).

The sampling and analysis of bioaerosols in Australia has been both problematic and expensive, making it difficult to undertake exposure assessments in remote regions. To characterize worker exposures to bioaerosols, standard sampling and analytical methods need to be established, including storage and transportation of samples prior to analysis. Additionally, microbial markers and indicators (endotoxins, 3-hydroxy fatty acids, muramic acid, and ergosterol), which have been described as effective metrics in monitoring the farming environment, should be considered (Poole et al 2010).

The aim of this pilot study was to gain an understanding of dust and bioaerosol constituents in a large Australian dairy by determining the typical exposures to inhalable dust, endotoxins and 3-hydroxy fatty acids (3-OHFA) and muramic acid.

Methodology

A large Australian dairy located in NSW with more than 2000 milking cows was recruited for this pilot study. Static monitors were located in three areas of the dairy, specifically the milking parlour, free shed and nursery. Each area was sampled between 5.5 and 8.0 hours on three separate days in November 2013.

The Inhalable dust samples were collected on 25mm PVC filters with 5µm pore size (SKC Inc., Eighty Four, PA) in pyrogen free IOM sampling heads (SKC Inc., Eighty Four, PA) according to AS3640:2009. IOM samplers fitted with pyrogen free IOM cartridges were connected to SKC Airlite (SKC Inc., Eighty Four, PA) personal sampling pumps and the flow rate calibrated to 2 L/min using a DryCal calibrator (BIOS, Butler, NJ).

The filters were equilibrated for 24 hours in a balance room before gravimetric analysis on a Mettler-Toledo MX5 balance (Mettler-Toledo, Columbus, OH). All handling of the filters was undertaken using pyrogen free tweezers. The IOM cartridges and tweezers were heat-treated, while wrapped in foil, at 180°C for 4 hours. The IOM cartridges and tweezers were retreated between use.

Each sampling device was positioned in the centre of each sampling location and placed at approximately 1.5 metres above floor level. Each location had 3 replicates collected on randomly selected days. Controls included field and laboratory blanks, 3 per session.

Following weighing, all samples were transferred to separate 50 mL centrifuge tubes and placed in a transportation box containing desiccant and shipped to the Colorado State University (CSU) Environmental and Radiological Health Sciences Laboratory for endotoxin analysis. At CSU, all samples were prepared and analysed using a Standard Operating Procedure (SOP) developed by the laboratory. The endotoxins were extracted in 5mL pyrogen free water containing 0.05% Tween-20 and agitated for 1 hour at room temperature (22°C) and 100 rpms. Filter extracts were analysed using the Recombinant Factor C (rFC) assay (Lonza), as described by Saito et al. (2009). The 3-OHFA and muramic acid sample analysis was undertaken using a GC-MSMS method described in Poole et al. (2010) and Reynolds et al. (2012).

Results

The analysis of the sampling results presented in Table 1 indicated that inhalable dust concentrations across the entire farm were normally distributed, while bioaerosol concentrations were log normally distributed as were each of the independent areas sampled. The data was statistically analysed using IHSTAT (AIHA, 2015). Exposure data that was found to be lognormally distributed is indicated with an *, data that is neither normally or log normally distributed is indicated with #.

Biologically active endotoxins were determined from the Recombinant Factor C (rFC) assay and the total endotoxin is assessed by measuring the 3-OHFA by GC-MSMS method.

**Table 1: Summary of the Inhalable Dust and Bioaerosol Concentrations Measured in Different Sections of Dairy Farm
Analysed by IHSTAT**

Location of Sampler	Statistical Parameter	Inhalable Dust (mg/m ³)	Biologically Active Endotoxin (EU/m ³)	Total Endotoxin (3-OHFA) (ng/m ³)	Muramic Acid (ng/m ³)
Free Stall	Mean (AM)	1.20	23.87	254.30	61.53
	Geometric Mean (GM)	1.14	20.86	252.00	27.19
	Geometric Standard Deviation (GSD)	1.47	1.91	1.18	4.91
	95% Percentile	2.15	48.23	324.92	202.36
Maternity	Mean (AM)	3.13	6.41	222.31	85.54
	Geometric Mean (GM)	2.51	6.14	192.47	21.46
	Geometric Standard Deviation (GSD)	2.50	1.45	1.96	8.22
	95% Percentile	6.38	9.86	452.31	685.54*
Milking Parlour	Mean (AM)	0.69	61.74	268.93	90.54
	Geometric Mean (GM)	0.66	59.77	255.91	45.45
	Geometric Standard Deviation (GSD)	1.49	1.38	1.57	6.24
	95% Percentile	1.09	91.04	461.26	220.87
Whole Farm Combined	Mean (AM)	1.67	30.67	245.96	79.20
	Geometric Mean (GM)	1.23	19.71	228.66	29.82
	Geometric Standard Deviation (GSD)	2.21	2.91	1.54	5.16
	95% Percentile	4.53*	75.28	397.49	228.91 [#]

Note: * Exposure data is lognormally distributed

[#] Exposure data is neither normally or log normally distributed.

Discussion

The results of the static inhalable dust monitoring at the large dairy (pilot study) ranged from 0.42 to 4.58 mg/m³. These results are similar to a larger study undertaken in the United States (US) where concentrations varied between 0.02 and 6.82 mg/m³ across the entire dairy (Davidson et al, *in press*). However, the geometric mean (1.23 mg/m³) in the Australian study was twice the US concentration of 0.67 mg/m³. The statistical analysis estimates that less than 0.5% of workers will be exposed to dust concentrations above the Australian Exposure standard (WES) of 10 mg/m³ (Safe Work Australia, 2015). Although, if the trigger concentration for inhalable dust (NOC), as recommended by the AIOH (2014) were applied, then 3.8% of worker exposures would exceed the 5 mg/m³ limit and therefore be considered at potential risk for occupational illness.

The maternity shed had the highest exposure to inhalable dust (3.13 mg/m³), followed by the free stalls (1.20 mg/m³). This is attributed to the woodchip flooring (Figures 1 & 2), which was selected to suppress growth of bacteria that cause mastitis in the cows, as well as reduce hoof damage. The higher dust levels in the maternity shed may be associated with the excessive movement of the cows and calves during and after birth. The low dust concentrations and the higher endotoxins concentration in the milking parlour may be due to the frequent water spraying used to flush away cow manure and other contaminants in this area.



Figure 1: Maternity Shed



Figure 2: Free Shed

The endotoxin concentrations measured using the rFC Assay were low, ranging from 4 to 73 EU/m³, with the highest exposures occurring in the milking parlour (269 EU/m³). In comparison, the US study had higher exposures which varied from the limit of detection (LoD) to 4430 EU/m³, with a geometric mean endotoxin concentration of around 1000 EU/m³ in the milking parlour (Davidson et al. *in press*). Additional monitoring is required in other Australian dairies to determine if the endotoxin concentrations measured are typical. This dairy has gone to significant effort to improve the health and wellbeing of the cows. Modifications have involved changing the bedding to wood chips and using water sprays to keep the cows cool, which has resulted in a lower incidence of mastitis and other bacterial infections. The endotoxin concentrations measured at the dairy, were below the health-based exposure guideline of 90 EU/m³ recommended by *Health Council of the Netherlands (2010)*. Although none of the measured endotoxin exposures exceeded this level, based on the spread of the results it is predicted that around 7% of workers could be over exposed, and therefore further control methods to reduce exposure need to be investigated. It should also be noted that before any conclusive decisions can be made that further monitoring is required especially of individual workers and on other dairies and wells as during other seasons.

The concentration of Gram-negative bacteria endotoxin and 3-OHFA, as well as muramic acid from Gram-positive bacteria were all highest in the milking parlour. This may be as a result of the large amount of water present in the parlour which would promote microbial growth. The concentrations for endotoxin, muramic acid and 3-OHFA in the maternity shed and the free stall were lower and varied across the days on monitoring, which would be expected due to the open dry environment of these quarters.

Previous studies in Australia have not reported measuring either muramic acid or 3-OHFA. In this Australian study, muramic acid ranged from 6 to 244 ng/m³, which is similar to the US study where exposures varied between the LoD and 250 ng/m³. The 3-OHFA exposures ranged from 97 to 373 ng/m³, and like endotoxin, significantly lower than the US study. Neither, muramic acid or 3-OHFA have exposure guidelines published anywhere in the world, but they have been associated with inflammation, especially even chain OHFAs and muramic acid (Poole et al, 2010). As both the measures for endotoxin (rFC Assay) and 3-OHFA, are lower than similar studies in the US (Davidson et al. *in press*; Reynolds et al. 2012; Garcia et al. 2013), it is proposed that the concentration of gram negative bacteria will be lower in the Australian dairies.

Conclusion

The results of this pilot study show that the current exposures to inhalable dust and bioaerosols are within acceptable levels when measured as area (static) samples in the dairy, however, area samples are typically much lower than personal exposures. Before any final conclusions can be made on exposures in dairies personal sampling of the farm workers is required over multiple seasons and in various areas of Australia. The maternity shed had the highest exposures to dust which could be the result of the wood chip dust and the moving of the calves during and after birth.

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INNOVATIONS IN PUMP TECHNOLOGY, THE IMPACT ON SAMPLING QUALITY AND HOW TO CHOOSE A PUMP THAT'S RIGHT FOR YOUR SAMPLING ENVIRONMENT

Andrea Bowen and Aamir Qureshi

Casella

ABSTRACT

Gravimetric data and analysis from sampled filters and sorbent tubes remain the preferred method of calculating exposure levels for very many hazardous substances. The personal sampling pump therefore remains an essential tool for the Occupational Hygienist.

This paper examines the recent innovations in pump technology. Innovations including pulsation damping, flow control, battery technology, pressure inlet sensing and ergonomic design, with Casella incorporating the unique features of motion sensing and Bluetooth® connectivity to their newest pump. These innovations provide greater confidence to the user throughout the sampling process; in better sample integrity and ultimately in the final report. It also investigates the delicate balancing act in pump design in order to fully meet recognised performance standards and in order to offer the Occupational Hygienist best performance for their particular requirements.

ISO13137 is the recognised performance standard for personal sampling pumps. We show how those specifications for flow control, pulsation, battery life, size and weight, intrinsic safety and factors such as stability to varying temperature, humidity and barometric pressure directly impact the quality of the sample. For example, a recent NIOSH ⁽¹⁾ report suggests that many pumps cannot meet the current pulsation criteria of $\pm 10\%$ and that those pumps tested showed significant changes in sampling efficiencies over $\pm 25\%$ pulsation.

The conditions under which the personal sampling pump needs to operate vary: differing media and environmental factors may affect the quality of the final result. Understanding the design specifications of a sampling pump enables the Occupational Hygienist to make an informed choice of device.

Introduction

According to International Labour Organisation figures ⁽²⁾, it is estimated that there are about 2 million deaths annually caused by work related disease, 386,000 annually from exposure to airborne particulates and 152,000 deaths from carcinogens. The annual global number of cases of non-fatal, work-related disease is estimated to be 160 million. The estimated direct and indirect costs are US\$2.8 trillion which equates to around 4% of global GDP. These figures indicate that this is a problem that is not going away. Occupational Hygienists must continue their work and Manufacturers aim to design products to aid them incorporating new technologies to make better product.

Casella first started producing personal sampling pumps in the 1960s and the pumps today do the same job as they did then; draw a known volume of air through sampling media. Gravimetric data and analysis from sampled filters and sorbent tubes remains the preferred method of calculating exposure for hazardous substances. Until real time personal dust measurement can gain equivalency with these methods in a usable format, it will remain so.

Technology has moved on with focus on miniaturisation and connectivity and it seems like sampling pump design has remained static. Despite the perception that "it's just a pump", innovation in pump design has also moved on apace. The recent standard ISO 13137:2013⁽³⁾ demands certain performance levels and that drives manufacturers to improve their designs.

The mission is to improve battery life and back pressure capability against producing more lightweight, quieter pumps whilst simultaneously ensuring flow control and minimised pulsation; including a great user interface, motion sensors, connectivity and data download. It's quite a balancing act and overlaying all that is intrinsic safety so that they can be used in the most hazardous environments. Include the customers' desire for a cost-effective solution and it is quite a challenge.

A pump must work efficiently. If the pump fails, the sampling opportunity is lost which may be a day's work but during a plant shutdown the opportunity may not arise again for some months. It's definitely a serious issue.

This paper outlines the factors that manufacturers take into account which customers need to know when comparing manufacturers' specifications. The customer needs to consider what type of sampling they mostly do and which pump in the market best meets their requirements, e.g. are you using membrane filters, are you running the pump for a long period of time, do you need intrinsic safety etc.

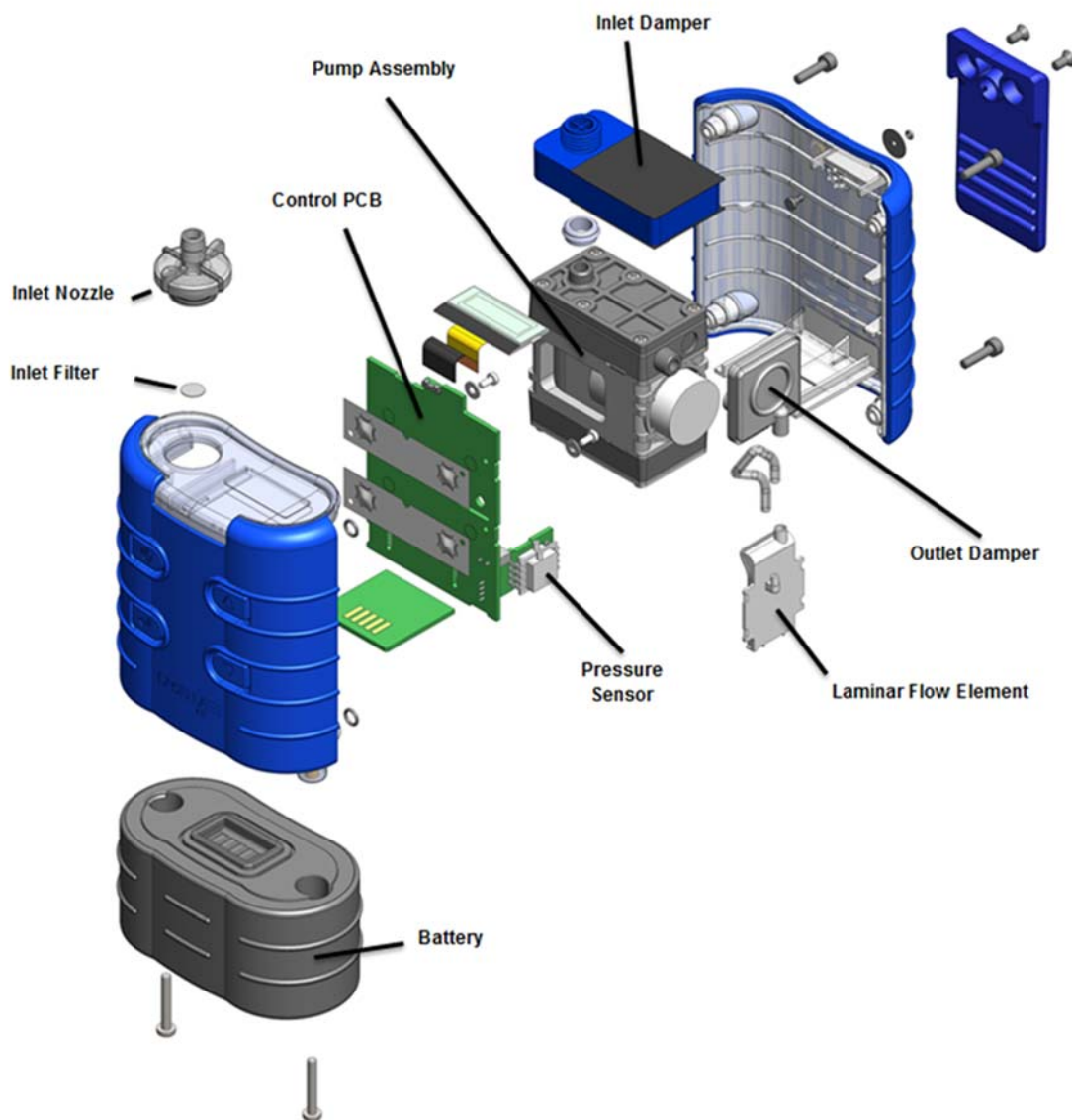


Figure 1⁽⁴⁾ TUFF® pump showing the component parts

Figure 1 shows the component parts of a TUFF® pump. Different manufacturers have different configurations and orientations but most have the same components.

Batteries

The batteries drive the motor for the entire monitoring period so have to be powerful enough to cope with increasing back pressure. Adding a bigger battery pack has an impact on the size and weight of the pump and the desire is to keep it as small as possible for wearer compliance.

Modern sampling pumps have used Nickel Cadmium (NiCd) and Nickel Metal Hydride (NiMH) batteries with the latest designs of pumps incorporating Lithium Ion (Li-Ion) technology. Figure 2 shows a comparison chart of the battery types.

Parameter	NiCd	NiMH	Li-Ion
Relative Capacity	1	1.4	3
Charge/Discharge Cycle Life	500+ cycles	300+ cycles	300+ cycles
Memory Effect	Noticeable effect. Can be eliminated by periodic conditioning	Little effect	No memory effect
Conditioning	Recommended periodically to eliminate memory	Recommended when new and after long storage periods	Not necessary
Operating Temperature	-22 to +140°F (-30 to +60°C)	-4 to +122°F (-20 to +50°C)	+14 to +122°F (-10 to +50°C)
Charging Temperature	+32 to 113°F (0 to +45°C)	+32 to +113°F (0 to +45°C)	+32 to +104°F (0 to +40°C)
Storage Temperature (>90 days)	+32 to +86°F (0 to +30°C)	+32 to +86°F (0 to +30°C)	+32 to +86°F (0 to +30°C)
High-Temperature Susceptibility	Some permanent loss of capacity above 140°F (60°C)	Greater permanent loss of capacity above 140°F (60°C)	Greater permanent loss of capacity above 140°F (>60°C)
Self-Discharge	20% loss of charge/month at 77°F (25°C)	30% loss of charge/month at 77°F (25°C)	Self-discharge is much lower than Nickel chemistries. 3% loss of charge/month at 77°F (25°C).
Recycling	Required by law in the U.S.	Not Required, but recommended	Not Required

Figure 2.⁵

Rechargeable batteries have a finite life span and typically lose the ability to hold charge after several hundred cycles. NiCd batteries do perform the best with this consideration and they are also cheaper and operate effectively over a wider temperature range. However recycling is mandatory at their end of life due to their environmental impact and they do have a ‘memory effect’.

The ‘Memory Effect’ occurs when the pump is used, for example, for one short term sample per day and then re-charged. The battery becomes conditioned to only discharge to that level and the full capacity of the battery is not accessible. The battery never fully discharges. So the batteries will fail when faced with a full shift. It is recommended to fully discharge and recharge the batteries every 3-4 months.

NiMH batteries are better in this respect although there is still a recorded ‘Memory Effect’. They have become the norm for pump manufacturers as they perform better than NiCad, storage capacity wise, and they are more environmentally friendly. They are also more thermally stable than Li-Ion batteries so there are not so many challenges in their use in intrinsically safe pumps.

The Li-Ion battery in the latest pump designs has the highest energy density meaning you need fewer cells to achieve the same performance. That results in a smaller, lightweight pump. There is no ‘Memory Effect’ meaning that you don’t have to cycle your batteries and the Li-Ion cells have low self-discharge, around 3% per month, so if the pump is only used periodically, it will retain charge.

There are considerations around Li-Ion batteries, however. The number of cycles of the batteries is less; around 300 discharge/charge cycles and the operating temperature range is slightly narrower. There are also negative perceptions of explosion and fire risk from their usage in laptops and mobile devices. As a manufacturer of sampling pumps, where a major specification is to be intrinsically safe, this adds another challenge to the development project: How to incorporate this technology into the pump whilst gaining I.S. Approval. Fortunately, there is precedence:

Alexander Technologies Develops first MSHA Approved Li Ion Battery⁽⁶⁾

“The company developed the Lithium Ion solution over an 18 month period of extensive research, design and testing. ‘Mining applications present unique challenges’ said James Pflueger, regulatory Manager, Alexander Technologies’ ‘While Li-ion offers many benefits, its chemistry is such that it requires a unique solutions to be utilized in potentially gaseous or high particulate environments such as mining. Our experienced team of engineers developed a proprietary method to meet both MSHA and cell manufacturers’ safety requirements, maximising the benefits of Li ion battery power. We are delighted to receive the first MSHA approval” (Press release published Dec 2012)

Pulsation

ISO13137:2013,⁽³⁾ the standard for personal sampling pump manufacture states that “the pulsation shall not exceed 10% of the flow rate” but what is pulsation and why is it so important?

With every cycle of the pump, air is drawn in and expelled simultaneously and this process of reciprocation causes an uneven flow through the sampling train. Pulsation is the measure of the difference in air flow between cycles shown by this calculation, Figure 3:

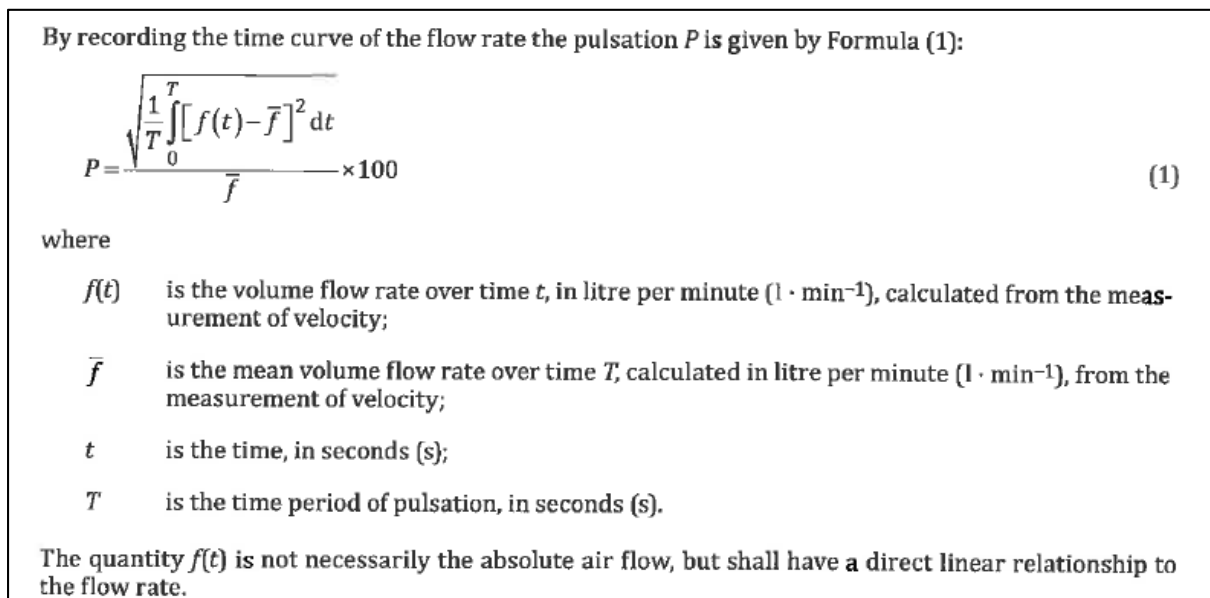


Figure 3⁽³⁾

A large pulsation value means that the size cut performance of the cyclones used can be affected because their performance is flow rate dependent. In addition, less sample is collected using pumps that generate significant pulsation⁽⁷⁾. As a result, many manufacturers have included pulsation dampeners into their designs to regulate the flow. These are diaphragms which stretch to provide an extra reservoir of air to draw upon to smooth the flow. Figure 4 shows an example of an inlet dampener.

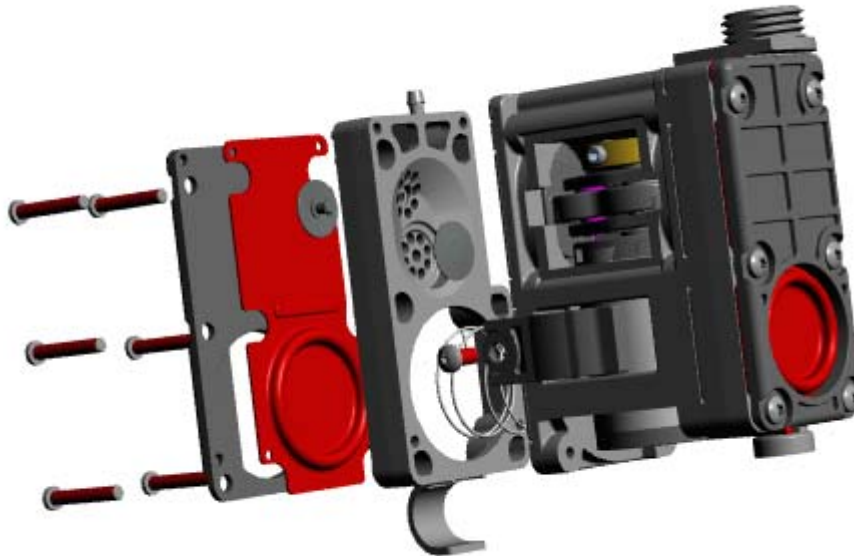


Figure 4. A Pulsation Dampener

To show performance variability, Figure 5 shows a chart with the respirable convention curve, particle size vs. sampling efficiency using a 25mm Dorr Oliver Cyclone⁽¹⁾ with a reference cyclone. Also plotted on the chart are the performances using a pump which does conform; the Casella Apex (pulsation $\pm 5\%$) and a pump which does not; the Basic5 (pulsation $\pm 70\%$)*. As you can see there is significant deviation from the standard curve which would have a very real impact on final exposure calculations.

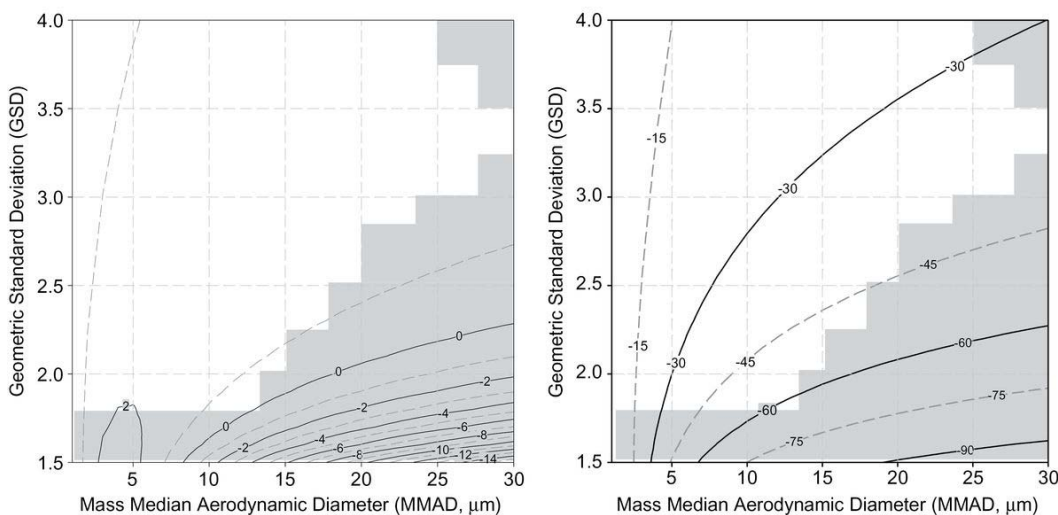
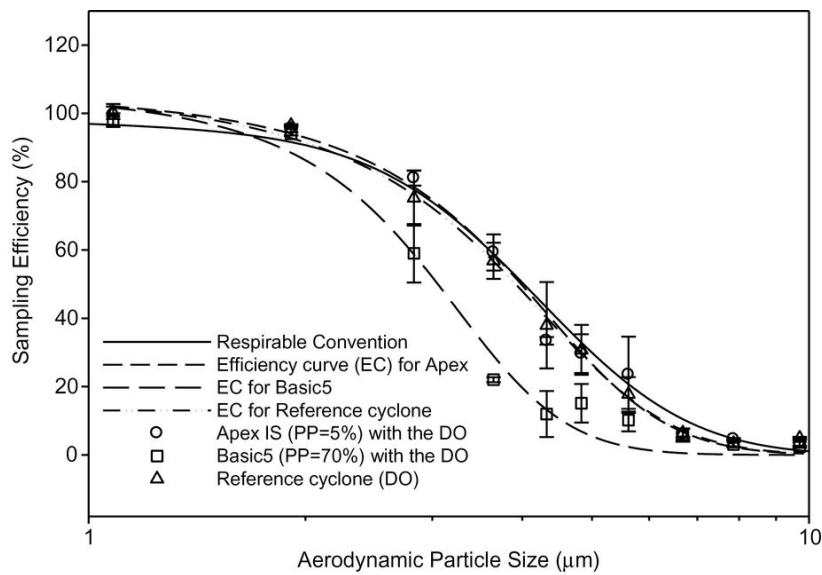


Figure 5.

**It should be noted, that the methods in these experiments involved a ‘real world’ sampling train and those methods recommended by the standard⁽³⁾ use a resistor instead of a sampler⁽⁹⁾. ‘Real World Sampling gives consistently higher values. The researchers showed that their methodology producing a 25% result is equivalent to an 11% result by the standard method*

Back Pressure

Back pressure is the resistance to air flow caused by factors like air density, friction of the motor and resistance by the tubing. The filter used in the sample train is the biggest factor, however. The smaller the diameter and the pore size of your filter and the greater the flow rate, the greater the back pressure and the harder the motor needs to work. As the media becomes loaded during sampling, a greater back pressure is exerted. The pump needs to be powerful enough to overcome the resistance.

Back pressure is generally measured in inches or centimetres of water. Below is a table (Figure 6) of approximate back pressures exerted by different unloaded MCE filter at different flow rates.

Flow Rate ml/min	37mm MCE/0.8µm	25mm MCE/0.8µm	25mm MCE/0.45µm
1000	5cm	15cm	36cm
2000	10cm	31cm	71cm
2500	13cm	38cm	89cm
3000	15cm	46cm	102cm
4000	23cm	64cm	127cm
5000	28cm	79cm	160cm

Figure 6

If the majority of your sampling involves a high amount of particulate or if your media has a small pore filter (e.g. 25mm 0.45µm MCE) then your pump should be capable of overcoming a large back pressure.

The pump needs to be efficient to be able to cope with high back pressure levels as this makes it work harder and drains the battery. Efficiency is achieved by improving the drive control circuitry meaning that energy losses are minimised. In our latest pump, we estimate a 40% power saving through improved circuitry and this extra power is harnessed to save battery life. That means a battery with a 2600mAh capacity would have the same performance as a more traditional 4400mAh, heavier battery.

Flow Control

Constant Flow Control

Pumps have a control system in the circuitry to maintain the flow rate which, according to ISO 13137⁽³⁾, must be within ±5% of the initial flow rate set. So if there is a change in back pressure, i.e. due to filter loading, the motor works harder to maintain the flow rate.

A constant flow means;

- You are confident in the total volume of air drawn through the pump and in your exposure calculations.
- Maintaining cyclone performance: The flow rate affects the cut point and the sampling efficiency of a cyclone.

Figure 7 is a graph showing a comparison of flow control of our new Apex2® vs. the old Tuff® with increasing back pressure at a 2l/min flow rate. Innovation in the pump stack, pressure sensor and control algorithm lead to better flow control.

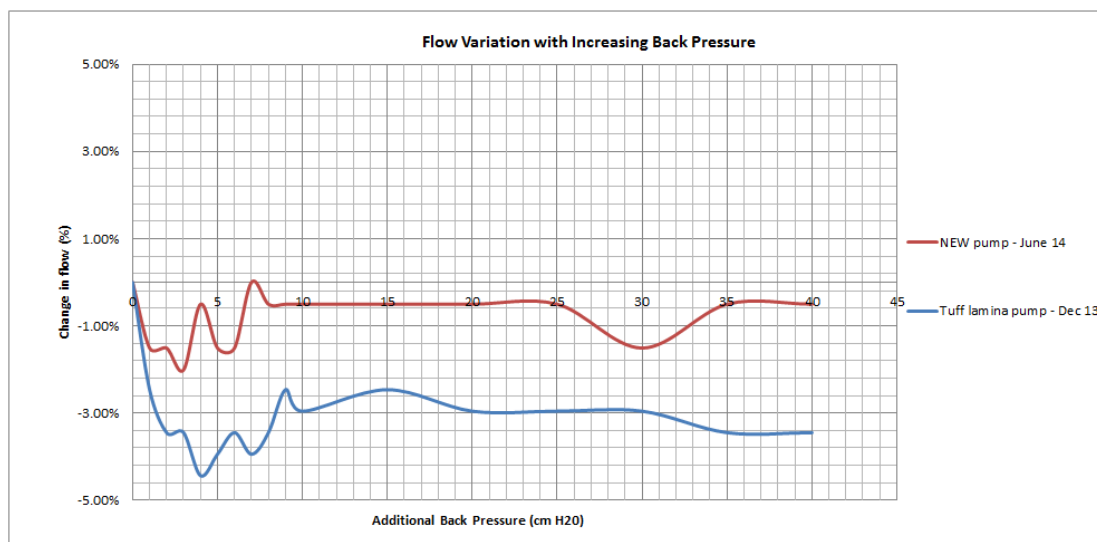


Figure 7

Environmental factors also have an effect on the flow control. They need to work effectively for a wide range of applications and environments, e.g. down a mine in South Africa or on a construction site in Qatar where ambient pressures, temperatures and humidity are extreme. The designer of the pump needs to take into consideration these factors.

A recent report by the INRS in France⁽⁹⁾ showed that not all pumps available in the market were able to cope. They carried out a number of tests for temperature, humidity and flow compensation during pressure drop with very mixed results, certainly for lower flow rates <1l/min and for prolonged periods at high temperature.

Constant Pressure Control

Constant Pressure Control is another method of flow control, primarily used for low flow applications where multiple sampling is taking place. Up to 4 separate samplers (usually sorbent tubes) can be attached via a manifold. This method controls the flow rate by holding a constant pressure level in the tubing between the samplers and the pump. This means that if one of the samplers became blocked or shut off completely, the pressure within the tubing is maintained and the flow rate in the other samplers remains constant. If this were a constant flow control system, the pump would sense the drop in total flow from one of the samplers and the motor would speed to up compensate.

For many pumps, this ‘constant pressure controller’ is a separate piece of equipment which you would purchase as part of a ‘low flow adaptor kit’. If you are doing lots of low flow measurements, it is worth investing in a pump which has a Constant Pressure Mode built in.

Size, Weight, Wearability and Motion Sensing

The goal is to create a pump with great performance but the biggest challenge is to create something that is acceptable to the wearer. In many industries, the culture of monitoring is still in its infancy and for those industries where monitoring regimes are standard practice there is still little desire to wear a pump. A recent ‘ignite’ session at the 2014 BOHS conference, ‘I’m Not Wearing That’ highlighted exactly this⁽¹⁰⁾. Customers have also told us that sometimes wearers remove the pumps and return them at the end of the shift resulting in no meaningful sample. The addition of a motion sensor is invaluable to the design ensuring the pump has been worn and the sample is valid.

Manufacturers are under pressure to design pumps with greater wearer acceptance. The size of the pump is driven predominantly by the battery size and motor but trying to package that as something unobtrusive is challenging. The Simpeds respirable dust sampler from 1968 was a hefty 2.5Kg and 25cm high and would be worn by a miner throughout their shift. Our latest pumps are less than half the size and a fifth of the weight so progress has been made.

Much thought is given to the casing and design. We try to make it as small as possible but who and where on the body will it be worn: A large man, a small woman, on the belt, on the chest? The case needs to be sturdy but is additional protection required, e.g. a rubber boot? Does the pump need to be decontaminated? If so, the casing needs to be smooth and how waterproof does it need to be? Some of the latest designs are IP65 rated.

Connectivity and Data Download

The whole point of a monitoring programme is to gather exposure data so reporting of that data is key.

Many manufacturers provide bespoke software to download the data into. These vary from very complex data analysis programs to simple utilities transferring direct to Excel. Some companies don’t allow or support bespoke packages on their system. Users have to download onto their own device then integrate into approved reporting packages. Or the software is only used intermittently resulting in a learning curve each time and frustration. And data from the pump is only half the data necessary and lab results and notes are added manually.

In the wider world, the use of smartphones and mobile devices are commonplace and it is unsurprising that this trend filters down into monitoring equipment. The use of Bluetooth® low energy technology means that it can be included in pumps without draining the battery as Bluetooth®BR/EDR (classic Bluetooth®) was prone to do. This means that the user can monitor and control the pump from their mobile device without having to disturb the worker and email the data alongside photos and notes direct from site.

Intrinsic Safety

Manufacturers wishing to promote their pumps into potentially explosive environments, e.g., oil and gas, must design a pump which is intrinsically safe meaning that it must not be a source of ignition. They must be compliant with International Standards and undergo stringent testing by a nationally recognised testing laboratory. For the Mining Industry, the standards and testing involved are more stringent.

The definition of the IS circuit [in a pump] from the standard IEC79-11 is:

“A circuit in which any spark or thermal effect produced in the condition specified in this International Standard, which include normal operation and specified fault conditions, is not capable of causing ignition in a given explosive gas atmosphere.”

Murphy Pickard from Hach Co⁽¹⁾ comments in his article:

“Thus, a circuit must contain safety components that prevent spark or heat energy of a sufficient level to cause an explosions under fault conditions. It is the responsibility of the circuit designer to incorporate these protective components into the design while still maintaining proper circuit operation. This is seldom an easy task”

The International Standards are unclear about the design necessary and manufacturers must provide ‘appropriate’ protection. This protection will have an impact on performance, e.g. the power to the motor is limited. And there is an impact on the size, e.g. batteries are generally encapsulated making them larger.

The accreditation process can only begin with a production model, so new pumps are launched as non-IS versions. The process takes months to complete and for the manufacturer they cannot access the wider market, impacting their sales. Most importantly, Intrinsic Safety must be considered at the very start of any product development to ease this process to maximise the sales of the new product.

Discussion

For many users, the perception is that a sampling pump is “just a pump” but given the importance of the monitoring operations, the variations in applications and conditions, it is paramount that it is reliable.

Innovations have taken place to work towards exactly this. The pump designer’s job is not an easy one; to maximise the performance, to have long battery life and balancing that against pulsation and flow control, to make it acceptable to the wearer and over-arching all of that; to be Intrinsically Safe. And to provide it at a cost that the market is willing to bear.

When purchasing a new pump it is important to examine the specifications and compare against your applications. If you are using a cyclone then pulsation value is key. For media with small pore sizes then back pressure capability is important. Not all pumps are created equal and there may be compromises in the design.

What about future innovation? There is much talk of lowering the exposure limits for hazardous substances and this means quantifying increasingly lower levels which in fact becomes close to the limits of detection for a laboratory. An obvious answer may be to collect more sample by having a higher flow rate; perhaps 10l/min but then designing a pump that would do this means more power so bigger batteries and a bigger motor perhaps, resulting in a bigger, bulkier pump that no-one’s going to want to wear with more pulsation issues and therefore poor sample integrity. So it’s definitely a challenge. What about innovation outside of monitoring devices? We have seen a step already in including connectivity into the pumps in the form of Bluetooth® low energy inclusion. But there are devices that we use in our everyday lives that we take for granted and a challenge would be for the manufacturer to include this technology into their monitoring devices. It’s an exciting time.

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INTEGRATING OCCUPATIONAL HYGIENE MONITORING INTO A REGULATORY PROGRAM TO IMPROVE SAFE USE OF AN AUTHORISED CARCINOGEN: MOCA

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ABSTRACT

MOCA, an industrial chemical classified as a Group 1 carcinogen by the IARC is regulated through a process of authorisation under WHS legislation. This study reports on a regulatory program that integrated occupational hygiene and biological monitoring to verify the safe use of MOCA in nine workplaces in NSW, Australia. While workers' exposure through inhalation was minimal, evidence of MOCA found in urine suggested that the main contributing factor to exposure was skin absorption due to poor housekeeping and inadequate personal protection. Recommendations were made on practical improvements to control exposure and were communicated to the workplace to improve workers' awareness of the hazards of MOCA.

KEY WORDS: Carcinogens; MOCA; authorisation; hygiene; monitoring; biological monitoring.

INTRODUCTION

Occupational exposure to carcinogens may account for around 5,000 cases of cancer (6.5% of new cases) diagnosed in Australia every year (Fritschi and Driscoll, 2006). It has been suggested that cancer from exposure to chemical carcinogens at work has been highly under-compensated (Cancer Council WA, 2015).

The aromatic amine 4,4'-methylene bis(2-chloroaniline), commonly known as MOCA, is primarily used as a curing agent for polyurethane polymers. MOCA is a pelleted, yellow flaked solid that binds other molecules to form relatively stable complex polymer structures. These tough abrasion-resistant polymers are used to manufacture castable urethane rubber products such as industrial tyres, rollers, shock-absorption pads and conveyer belts.

The International Agency for Research on Cancer (IARC) has classified MOCA as a Group 1 carcinogen, which means exposure to this substance can cause cancer in humans (IARC, 2010). Under the *Work Health and Safety Regulation 2011* (WHS Regulation) MOCA is listed as a restricted carcinogen in its *Schedule 10* and the regulatory requirements of *Chapter 7 Hazardous Chemicals* apply to its use. Use of MOCA at workplaces in NSW must be authorised by the regulator SafeWork NSW.

Workers that handle MOCA or work in the MOCA area at manufacturing sites are at risk of occupational exposure and at increased risk of adverse health effects. The acute health effects of MOCA to exposed workers include irritation and burn to the skin and eyes, nausea, gastrointestinal and renal effects (Osorio *et al*, 1990). While animal studies showed many years ago that MOCA is a carcinogen that can cause bladder cancer following chronic exposure (Kaderlik *et al*, 1993), increased risk of bladder cancer in workers exposed to MOCA has been reported in a few studies (Ward *et al*, 1990, Liu, 2005)

The Safe Work Australia national phone survey of about 5,500 workers in Australia found that 67% of workers interviewed in the manufacturing sector had probably been exposed to at least one carcinogen in the workplace (Darcey *et al*, 2015). It found that control measures were on the whole not well used in this sector and highlighted that there was a scarcity of workplace data on exposure to carcinogens and their control in Australia. Hence, they recommended more quantitative measurements of workplace carcinogen exposures and more detailed information on the use of control measures in order to be able to develop more effective policies to protect workers' health.

This study reports on an occupational hygiene survey that was integrated into a SafeWork NSW verification program on compliance with the NSW legislation on carcinogens. All nine workplaces in NSW that have been authorized to store and use MOCA were verified for regulatory compliance and the exposure to MOCA was measured in each workplace. The hygiene survey was used to establish the effectiveness of the control measures to reduce the workers' exposure to MOCA.

Process description

The study assessed a polyurethane manufacturing process that was usually conducted in a separate area of a small business premises. It usually involved mechanically dispensing of MOCA from a hopper located within a local exhaust ventilation system into a melting pot placed underneath. MOCA was then melted on a gas stove located within a large fume hood. Small amounts of molten MOCA were then added into a mixture containing a pre-polymer of 2, 4-Toluene Diisocyanate that was usually carried out inside a large fume hood. The mixture was then poured into metal moulds and cured in an oven for several minutes. The moulds were then allowed to cool, and then removed from the oven and trimmed for finishing and packaging on a nearby table. The MOCA workers wore P2 disposable masks and typically used cotton gloves inside long rubber gloves during the MOCA handling tasks.

METHODS

The occupational hygiene survey was conducted as part of a SafeWork NSW *High Risks Verification Program* on the use of authorized carcinogens. The survey involved:

- The collection of workplace process information
- Worker and supervisor interviews
- Identification of workers most likely to be exposed to MOCA
- Evaluation of the exposure control measures, including local exhaust systems and personal protective equipment
- Evaluation of administrative control measures such as rosters and job rotation
- Evaluation of worker knowledge of potential health effects
- Evaluation of employer health monitoring program
- Performing a quantitative assessment of the exposure to MOCA.

Inhalation exposure was assessed by air monitoring and possible skin exposure was assessed by detecting surface contamination. Biological monitoring was used to assess all routes of exposure. Seven manufacturing sites and two suppliers were visited by a specialist inspector and an occupational hygienist from the *Hazardous Chemical Services Team*.

Air Monitoring

Personal and static air monitoring was carried out as per the US Occupational Safety & Health Administration (*OSHA*) *Method 71*. Calibrated Gillian personal air sampling pumps were used to collect the breathing zone air of the MOCA workers.

Surface Contamination Monitoring

Alcohol swabs were taken from surfaces in different locations in the workplace using 70% iso-propyl alcohol Liv-Wipe[®] swabs (55 x 65 mm) obtained from Livingstone International Pty Ltd. The workers were categorised into five similar exposure groups (SEG) and samples were taken from each group. Samples were transported and analysed for MOCA contamination at SafeWork NSW - TestSafe Australia, Chemical Analysis Branch laboratory in Thornleigh, Sydney.

Biological Monitoring

Biological monitoring of workers exposed to MOCA was carried out at seven workplaces. Post shift urine samples were collected from those working with MOCA as well as from workers whose duties did not involve handling MOCA. The workers were informed of the purpose for collecting urines samples and consent was obtained from each worker who submitted their urine samples for anonymous publication. The workers urine was analysed for total MOCA which comprised of the free MOCA and the *N*-glucuronide conjugates of MOCA. All urine samples were analysed for the amount of creatinine and the test results were normalised against this amount to account for worker hydration. Hence, the final test results were expressed as micromole MOCA per mole of creatinine ($\mu\text{mol/mol cr}$).

Australian Exposure Standards

Airborne MOCA

The Australian Workplace Exposure Standard (WES) expressed as a time weighted average (TWA) for an 8-hour shift for MOCA is 220 µg/m³ or 0.02 ppm in air (Safe Work Australia, 2013).

MOCA in urine

The WHS Regulations does not mandate a Biological Exposure Standard. However, the SafeWork NSW Biological Occupational Exposure Limit (BOEL) Committee has recommended a BOEL of 15 µmol/mol creatinine for urinary MOCA. This limit was adopted from the UK Health & Safety Laboratory.

Data Analysis

The data analysis was performed using the statistical program IHSTAT V 1.01 Dec 2007, AIHA. All calculations were verified using Microsoft Excel 2010 V 14.07015.1000. The ANOVA calculations and all graphs were generated in Microsoft Excel 2010 V 14.07015.1000.

RESULTS

The occupational hygiene survey was conducted at seven polyurethane manufacturing workplaces authorised to use MOCA in NSW. Most of these workplaces were small to medium sized enterprises. Two non-manufacturing MOCA supplier sites were also investigated using surface contamination sampling.

All sampling locations at each site were categorised into one of five similar exposure groups (SEG) based on the tasks performed in relation to MOCA at those locations. The full description of the SEGs can be seen in Table 1.

Table 1. Description of Tasks for Similar Exposure Groups (SEG) at MOCA user workplaces

SEG	Activity	Task descriptions or sampling locations
SEG 1	MOCA Use	Weighing MOCA pellets; melting MOCA; dispensing molten MOCA; Mixing molten MOCA with pre-polymer;
SEG 2	Production	Casting into moulds; Curing in ovens; Trimming and Finishing
SEG 3	Non-Production	Administration; Lunch and staff facilities
SEG 4	Storage	MOCA drum storage
SEG 5	Other	PPE, Waste bins; Polyurethane product; Vacuum cleaners

Most of the factories visited were less than 2,000 sq metres in area and usually consisted of high roofs and large door entrances. The polyurethane manufacturing areas comprised of open floor areas inside the building with local exhaust ventilation. All factories had a MOCA controlled access area marked with yellow lines and signs that were visible from the entrance of the building.

During inspection it was noted that empty MOCA containers were being used as waste bins on some sites. All sites had a vacuum cleaner with a HEPA filter that was used to clean up spills. Workers wore long sleeved thick cotton material shirts and trousers. These clothes were washed daily. Employees at most sites working in the MOCA areas wore impervious leather gloves and class A P2 half facemasks for respiratory protection. Some workplaces manually handled MOCA on a daily basis. Other chemicals that were used at most sites included diisocyanates and methylated spirits.

A total of 24 personal air monitoring samples were taken from workers handling MOCA in SEG 1 at six of the seven manufacturing sites. The test results for each worker are shown in Table 2.

Table 2. Personal air monitoring of MOCA in SEG 1 from six workplaces in NSW

Worker	Site 1 ($\mu\text{g}/\text{m}^3$)	Site 2 ($\mu\text{g}/\text{m}^3$)	Site 3 ($\mu\text{g}/\text{m}^3$)	Site 4 ($\mu\text{g}/\text{m}^3$)	Site 5 ($\mu\text{g}/\text{m}^3$)	Site 6 ($\mu\text{g}/\text{m}^3$)
A	0.03	0.23	< 0.04	0.22	0.30	< 0.03
B	0.13	-	0.04	< 0.04	0.09	0.14
C	0.17	-	0.22	-	-	0.06
D	-	-	0.07	-	-	-
Static sample	0.06	0.03	0.17	< 0.03	< 0.05	< 0.04
Static sample 2	0.15	-	-	< 0.03	< 0.05	-

A dash indicates no sample taken at that site.

Workplace Exposure Standard: $220 \mu\text{g}/\text{m}^3$ (Safe Work Australia, 2013)

The air monitoring results show very low levels of airborne MOCA. Of the 24 air samples taken 8 (30%) gave levels below the Limit of Quantitation (LOQ) and are shown in the table as less than values. These values that were less than the LOQ were included in the statistical analysis as a value half the LOQ. The data gave a geometric mean of $0.06 \mu\text{g}/\text{m}^3$ and a geometric standard deviation (GSD) of 2.70 and a 95% percentile of the lognormal distribution of $0.29 \mu\text{g}/\text{m}^3$. This is approximately three orders of magnitude below the Safe Work Australia TWA of $220 \mu\text{g}/\text{m}^3$.

A total of 178 surface contamination samples were collected from the nine authorized MOCA manufacturing sites. Statistical analysis using ANOVA was performed on the distributions of results between the five SEGs and showed SEG 1 significantly different from the other SEGs ($p < 0.001$). SEG 1 showed the highest contamination with a geometric mean of $74 \text{ ng}/\text{cm}^2$ and a geometric standard deviation of 17 and a 95% percentile of the lognormal distribution of $7,751 \text{ ng}/\text{cm}^2$. This illustrates the wide range of contamination levels on the surfaces in the workplaces. SEG 4 of the MOCA storage locations had a geometric mean of $34 \text{ ng}/\text{cm}^2$ and a geometric standard deviation of 11.01 and a 95% percentile of the lognormal distribution of $1,760 \text{ ng}/\text{cm}^2$. The results for all SEGs are displayed in Figure 1.

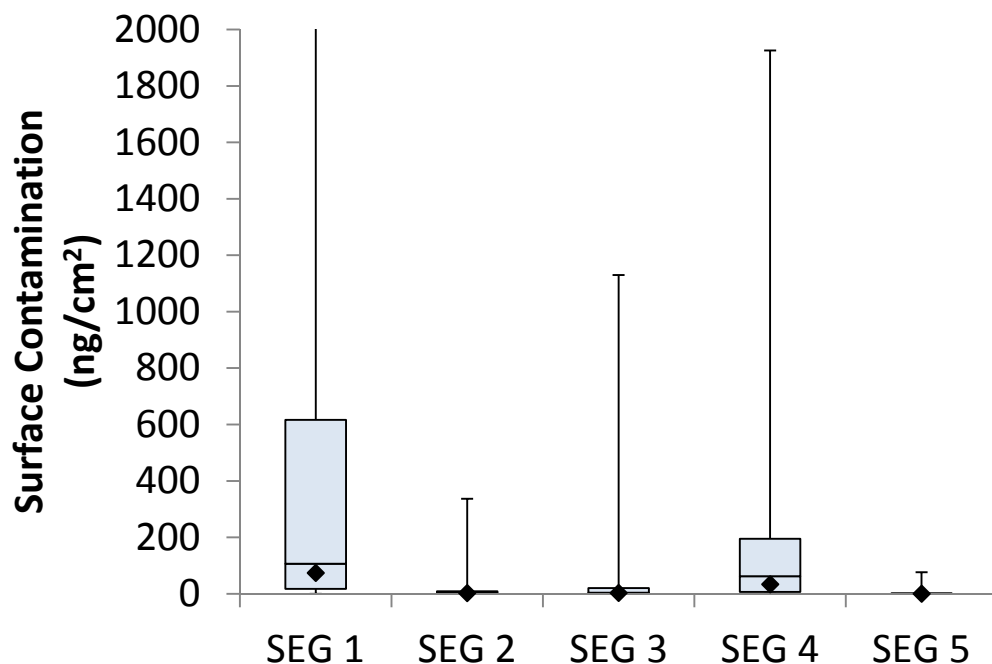


Figure 1. Surface contamination of the similarly exposed work groups for all MOCA user workplaces investigated. Box shows first to third quartile of the distribution and the whiskers show the maximum and minimum values. The maximum value whisker of SEG 1 is not plotted and had a value of $11,040 \text{ ng}/\text{cm}^2$. The median value is indicated by a line across the distribution and the mean value is indicated by a diamond point.

Biological monitoring was performed by collecting post-shift urine samples at seven of the workplaces from 24 workers who may be at significant risk of exposure to MOCA. The distribution of results gave a geometric mean of 0.89 $\mu\text{mol/mol cr}$ with a geometric standard deviation of 11.9 and a 95% percentile of the lognormal distribution of 52 $\mu\text{mol/mol cr}$. The statistical analysis showed that 13% of the distribution could possibly be over the BOEL of 15 $\mu\text{mol/mol cr}$. The test results are presented in Figure 2.

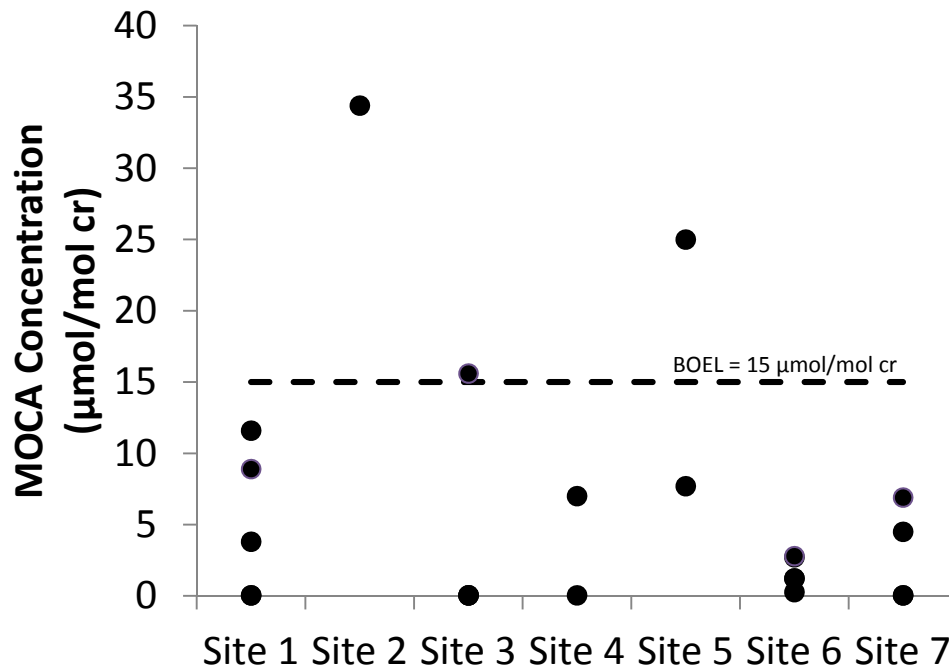


Figure 2. Biological monitoring of MOCA in post-shift urine of workers ($n = 24$) at seven of nine workplaces in NSW. The Biological Occupational Exposure Limit (BOEL) is shown as a dashed line (---) at a MOCA concentration of 15 $\mu\text{mol/mol cr}$.

DISCUSSION

All personal air monitoring samples were well below the Australian TWA of 220 $\mu\text{g}/\text{m}^3$ for airborne MOCA. No test result was within 10% of the WES, indicating that MOCA workers are not at risk of exposure to airborne MOCA through inhalation. This is not a surprising due to the chemical properties of low volatility and high melting point of MOCA.

Surface contamination with MOCA was evident in all workplaces, with high levels found at locations within two exposure group categories. The highest contamination was found at the SEG 1 locations where MOCA was directly handled. MOCA levels as high as 11,040 ng/cm^2 were detected. Surface contamination sampling is an easy convenient tool for workplace assessments but requires sufficient samples to be taken to address the variability of the test results to be able to properly interpret the potential exposure (Kromhout and Vermeulen, 2001).

The tasks at SEG 1 locations in the different workplaces involved filling of hoppers with MOCA pellets, transferring MOCA pellets into the melting pots, dispensing molten MOCA manually into mixing vessels and mixing MOCA with pre-polymer on an open bench. Most contamination was detected on melting area surfaces, mixing benches and on MOCA weighing scales. It appears unsafe work practices causing spills during weighing or melting of MOCA and inadequate cleaning of the surfaces would have largely contributed to this contamination.

Samples from the MOCA storage area (SEG4) also had high contamination evident mostly on the lid or rim of the MOCA drums, as well as the door handles of cabinets where the drums were stored.

Surface contamination samples taken at the MOCA suppliers' work sites during the verification program showed significant contamination on the lids and rims of MOCA drums that were stored for delivery to its customers. This could largely explain the contamination found on MOCA drums within the SEG 4 category of the storage areas.

Some surface contamination samples taken in the non-MOCA use areas (SEG 2, 3 and 5) showed detectable amounts of MOCA. This indicated that contamination from MOCA use areas may have been transferred due to poor personal hygiene, possibly in combination with inadequate housekeeping, practices.

Biological monitoring results showed that three out of 24 workers (12.5%) had MOCA in urine levels exceeding the SafeWork NSW BOEL of 15 $\mu\text{mol/mol cr}$. Twenty one of the workers were below the MOCA BOEL with twelve workers (50%) being below 10% of the BOEL. More than half of those tested (63%) had detectable amounts of MOCA in their urine.

It is noted that some workers had higher urinary MOCA results than their co-workers at the same workplace, despite doing similar work activities under common exposure controls. This suggests that individual hygiene and work practices may be different, hence resulting in higher exposures than their colleagues. In such instances, improving the overall engineering controls at these workplaces would not necessarily reduce personal dermal exposure. Training on how to correctly remove and dispose of contaminated gloves and clothing, along with adequate supervision could potentially reduce exposures for those workers with higher urinary MOCA results.

The BOEL is an exposure guidance value to assess good work practices and it provides an indication of the effectiveness of control measures in place to prevent exposure. Presence of MOCA in the worker's urine is an indication that the worker is exposed to MOCA. However, exceeding the BOEL does not necessarily represent any immediate health effect from this exposure. However, when working with a Category 1 carcinogenic material such as MOCA, controls should be in place to minimise exposure to the lowest possible level practicable.

Since there was no evidence of unsafe airborne exposure to MOCA at any of the workplaces, these results indicate that a number of workers are exposed to MOCA through surface contamination which was evident at all workplaces. This suggests that dermal exposure to MOCA is the most important route of exposure. Since MOCA is a known carcinogen with potential for long-latency illness such as bladder cancer, control measures need to be further improved to prevent long-term health effects to workers.

During the verification program it was noted that all workers who handled MOCA wore overalls, half face mask respirators and various types of gloves to prevent skin exposure. It appears that the high contamination on some surfaces may be transferred to workers through either incorrect choice or use of gloves and/or generally poor hygiene practices.

This study confirms the conclusions of a similar survey conducted in the UK (Cocker *et al*, 2009), that concluded that skin absorption is the most likely route of exposure to MOCA at polyurethane manufacturing sites.

SafeWork NSW specialist inspectors provided an individual hygiene monitoring report with recommendations to each workplace and followed up with verbal advice & assistance on practical measures that can be taken by the employer. Recommended measures included to:

- 1) Conduct MOCA melting and mixing tasks always under a fume hood extraction and to improve natural ventilation in MOCA work areas
- 2) Keep MOCA work surfaces clean and spill-free with safe work practices, good housekeeping and regularly decontaminating surfaces to prevent skin exposures
- 3) Consider job rotation to minimise workers' long term exposure
- 4) Improve workers' awareness of MOCA hazards, its potential health effects and exposure limits for MOCA
- 5) Review types of gloves used and replace them if necessary and promote good personal hygiene practice after using PPE and when removing and storing/disposing protective clothing
- 6) Prohibit the use of empty MOCA drums as waste bins and the storage and consumption of beverages in the areas where MOCA work is carried out

CONCLUSIONS

This hygiene survey was conducted as part of a regulatory program to verify safe use of an authorised carcinogen in a small manufacturing industry sector. The results demonstrated the importance of surface contamination sampling and biological monitoring as useful tools to determine workers' possible exposure to hazardous chemicals.

Risks to workers from airborne MOCA were not evident in the personal air samples, with inhalation levels well below the WES. Control measures to prevent airborne exposures appear to be effective at each workplace. However, biological monitoring indicated personal exposure to MOCA with some workers exceeding the SafeWork NSW recommended BOEL.

Surface contamination monitoring results suggested workers' exposure is likely to have occurred through contact with skin. Although there are no guidance limits on unsafe levels, the surface contamination detected in MOCA work areas and in some storage locations should be addressed. From observation of tasks and other verification information gathered during the workplace visits, improving work practices and surface decontamination would have a significant effect on reducing exposure to MOCA.

It is suggested that training, particularly on how to correctly remove and dispose of contaminated gloves and clothing, would improve individual work practices and reduce workers' exposure to MOCA. Employers must select suitable gloves for MOCA work and provide adequate supervision to reduce exposures for those workers with higher urinary MOCA results.

In addition to the requirement of the authorisation needed to use MOCA, it is also listed in *Schedule 14* of the *WHS Regulation* as a hazardous chemical requiring health monitoring. Exposure prevention in small to medium sized enterprise workplaces in NSW can be enhanced by regular biological monitoring of workers at risk of significant exposure. Regulators and hygienists can assist by improving hazard communication of the long-term health risks of MOCA and promoting safe work practices.

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WORKPLACE DRUG TESTING: THE LATEST

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ABSTRACT

Providing a safe workplace for staff is the most important priority for any employer today. Whether this is safeguarding employees against workplace hazards or guaranteeing that employees are not under the influence of drugs. Ensuring that staff are appropriately fit for work not only reduces the risk to an employer and other employees but it also ensures that business production and performance is maximised. The workplace drug testing space has seen many issues arise over the past five years, such as the emergence of synthetic drugs, the abuse of pharmaceutical drugs and the introduction of alternative testing measures to urine drug testing such as oral fluid drug testing. Many of these issues have attempted to be addressed through a variety of strategies. Many of these strategies, which haven't worked, have commonly been the result of misinformation or a lack of understanding. This presentation discusses the major issues currently facing workplace drug testing and proposes a variety of solutions that are both measurable and enhance the employers fit for work policy.

MEASURABLE IMPROVEMENTS FROM INTEGRATING AN OCCUPATIONAL NOISE EXPOSURE REDUCTION PROJECT ACROSS DEFENCE

Peter Teague¹ and Martin Jennings²

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ABSTRACT

A 5 year Noise Reduction Project for occupational/workplace noise has been developed and implemented across Defence. This project has been designed to address the widespread noise hazards in Defence and the previous deficiencies associated with noise management.

The project's main goals were initially to improve compliance with WHS legislation and then to deliver measurable reduction of noise exposure and hearing loss risk throughout whole of Defence. A coordinated and systematic approach with a range of stakeholders included undertaking best-practice noise surveys and assessments at a representative sample of ADF Bases, which provided an evidence-based dataset to inform effective noise control actions.

Concise Noise Management Plans were developed with prioritised and practical noise control measures, and these were specifically tailored for each Unit at each representative Base. A number of common gaps were identified across different Bases and ADF Services and Groups. This provided an opportunity to streamline actions for improvement and thereby provide efficiency gains within Bases and across Defence.

A number of other noise management tools, such as handy checklists, guides and awareness reminders, were developed to support project implementation and integration. A number of Key Performance Indicators (KPIs) were developed to measure the previous and current level of noise management compliance and maturity at ADF facilities. These KPIs have been used longitudinally over some years now to provide robust indicators of measurable improvements in noise management practices across Defence.

1. Introduction

The Defence Centre for Occupational Health and Safety (DCOHS) identified that occupational noise is a significant hazard and that noise management across Defence needs improvement. As a result, the Department of Defence has established an ambitious project in the area of occupational hygiene to reduce occupational noise exposure in all workplaces across Defence.

Vipac Engineers & Scientists Ltd (VIPAC) has worked closely with the DCOHS since 2009 to develop an Exposure Reduction Plan (ERP) for occupational noise for the Department of Defence (DoD) and the Australian Defence Force (ADF) [1, 2, 3].

The main aims of the project were to understand the extent and impacts of occupational noise across Defence and how to develop and implement an improved noise management system. Recently the project has commenced implementation and integration in Defence and a range of tools have been used to quantify the progress and improvements in noise management.

2. Background

Previous reports [1, 2, 3] and papers [4, 5, 6] have described the development, design and progress of the project. This paper provides a recent update on the project progress.

In the initial phase of the project, a Defence-wide review and evaluation of noise management practices identified a range of deficiencies and recommendations for improvement and action [1, 4]. The evidence-based approach, including extensive stakeholder consultation and the analysis of large quantities of data, highlighted the areas of focus and where the most significant benefits could be realised.

The levels of noise encountered in Defence exceed those experienced in most other work environments, and Defence operations can involve extended periods in close proximity to major noise sources with some of the highest noise levels of any workplace. The damage can be inferred from evidence of hearing loss in personnel (ideally from relevant data including audiometric tests, anecdotal information and DVA compensation claims).

Initial project outcomes included Exposure Reduction Plans [2] developed for each of the stakeholder Services and Groups, with prioritised higher-level strategies and initiatives to improve noise management. The next phase of the Noise Project involved best-practice noise surveys and assessments at a representative sample of ADF Bases, from which effective noise control actions were developed in the form of tailored Noise Management Plans (NMP) [3, 5].

In the most recent project phase, a number of noise management tools and Key Performance Indicators (KPI) were developed to support project implementation and integration throughout Defence and allow for measurement of progress and improvement.

3. WHS Legislation

The harmonised Commonwealth Work Health and Safety (WHS) Legislation, the WHS Act 2011 and WHS Regulations 2011 [8] apply, under which the following main aspects apply for noise.

Noise surveys and associated measurements must be done in accordance with the methodology in the WHS Regulations 56-57, the Approved WHS Code of Practice – Managing Noise and Preventing Hearing Loss at Work and AS/NZS 1269.1 (or an equivalent or higher standard method). Noise measurement surveys should be done by a competent person in accordance with AS/NZS 1269.1 and the WHS Code of Practice.

Audiometric testing must be provided for workers who are frequently required to use personal protective equipment (PPE) as a control measure, such as hearing protection, within 3 months of the worker commencing work, and in any event, at least every 2 years (Regulation 58).

For plant, such as machinery and platforms (i.e. 'materiel'), supplied or imported by Defence, the relevant parts of Defence (DMO) that are responsible for plant procurement and supply must take all reasonable steps to obtain and provide information about the noise emission values for the applicable operating conditions of the plant, and provide that information to any person to whom the plant is supplied (Regulation 59).

4. Defence Policies and Procedures

Defence's top-level workplace safety document is the Defence Work Health and Safety (WHS) Manual [7, 9]. The WHS Manual contains the WHS policies and procedures that apply to all Defence workers and aligns with the requirements of the new WHS legislation [8].

The Defence Noise Policy and Procedures state that noise hazard risks must be identified, assessed, managed, reviewed and communicated. Noise hazards are defined as sources, areas or activities in the workplace that generate, or contribute to, excessive or hazardous noise exposure that can lead to exceeding the workplace exposure standard for noise and can lead to hearing loss. It is important that Defence has a focus on reducing the extent and impact of the major noise sources/hazards and high noise exposure groups, activities and areas.

5. Project Progress and Outcomes

The current status of Defence occupational noise management was reviewed by performing:

- 1) a detailed evaluation of the current standards, practices and levels of compliance, and
- 2) identification of limitations and deficiencies in the system through a gap analysis.

This first project phase involved extensive consultation with a wide range of Defence stakeholders in Canberra and Defence establishments around Australia. Previous AIOH Conference papers in 2011 and 2012 described the process and findings from the initial project work [4, 5]. This paper provides an overview of the results and outcomes from the project to date: specifically the project implementation and integration throughout Defence and the tools that have been used to measure the progress and improvements in noise management.

Overall, even though some parts of Services and Groups are well resourced, it was found that there is limited coordination and cooperation across Defence and therefore substantial inefficiencies as a result. In addition, there are major constraints due to entrenched practices.

Given the variability throughout Defence in the amount and quality of data (and frequency of data collection), a pilot program of best-practice systematic noise surveys and assessments was instigated at a representative sample of ADF Bases.

5.1 Noise surveys and assessment

A new best-practice Statement of Work (SOW) for carrying out noise surveys and assessments was recently developed by the project team for adoption throughout Defence.

Table 1 provides an overview of the noise identification and evaluation process.

Table 1 – Overview of the noise identification and evaluation process

Step	Action
1	<i>Review available information</i> – collate and review relevant workplace data and previous reports.
2	<i>Routine or baseline survey</i> – basic or preliminary assessment, e.g. walk-through inspection.
3	<i>Detailed or targeted survey</i> – noise measurement survey, analysis and risk assessment.
4	<i>Outputs from survey</i> – noise survey report and noise controls (noise management plan).
5	<i>Stakeholder involvement and action</i> – coordination, review, signoff and implement control action plan.
6	<i>Ongoing review</i> – regular follow-up, checks, review and improvement.

Utilizing the new SOW process, comprehensive noise surveys were performed at a total of 8 DoD/ADF facilities including a field survey of Army combat exercise activities [3].

Noise measurements of all Base Units, areas, tasks and noise sources were performed, including sufficient personal noise dosimetry samples (over representative work shift periods), the presence of high levels of peak/impulse noise and noise frequency spectra (i.e. octave or third octave bands) of major noise sources.

The measurement results from these noise surveys were assessed against the regulatory Exposure Standard for Noise; namely, $L_{Aeq,8h}$ 85 dB(A) and L_{Cpeak} 140 dB(C).

The noise assessments also noted concomitant exposure to ototoxic substances (such as fuels, solvents, heavy metals etc.) and/or vibration (particularly hand-arm vibration) present in combination with any noise. Note that a lower noise exposure standard (such as 80 dB(A) instead of 85 dB(A) L_{Aeq}) should be applied in such cases. For workers, such as aircraft refuellers, who are regularly exposed to the combination of high levels of noise (e.g. such as 100 dB(A) or more) and ototoxic substances, a lower noise exposure standard was considered.

Noise dosimetry over typical shift periods for different trades in the ADF showed variations in noise exposure depending on task type and duration. For example, the cumulative noise exposure rises significantly during relatively brief and intense tasks (such as riveting, drilling, grinding, cutting, hammering, rattle/needle guns, surface finishing etc.) and can remain quite high, and in fact well above the exposure standard, until the end of the shift period.

The existing Hearing Protection Areas (HPAs), their colour-coded designation and signage, and the HPA zones required from the analysis, were also evaluated. The assessment also reviewed the currently provided Hearing Protection Devices (HPDs), the specified and actual in-ear attenuation levels and observations about the use and fitting of HPDs.

Noise sources (and SEGs) were ranked and prioritised for treatment based on a risk assessment, using the collected data and a matrix of likelihood and consequence/severity.

5.2 Noise exposure extent

Overall, most of the ADF facilities surveyed did not demonstrate full legislative compliance in all areas nor did they fully meet Defence’s own requirements [3, 6]. A Similar Exposure Group (SEG) risk assessment showed that a wide range of trades/SEGs display moderate, high and very high risk ratings, with some specific groups registering extreme risk ratings; this was used to identify the most at-risk groups to prioritise controls.

The trades or SEGs that experience some of the highest exposure levels include fitters, vehicle mechanics, maintainers, welders, metalsmiths, structural repair technicians, aircrew, aircraft/avionics technicians, aircraft refuellers, air terminal/hangar operators, ordnance operators, artillery/combat troops. Notably, many of these trades are also exposed to a range of ototoxic substances (e.g. solvents and fuels) and hand-arm vibration.

A wide range in noise levels and noise exposures were measured at the various facilities [3, 6]. The 8-hour equivalent $L_{Aeq,8h}$ noise exposure levels were often over 85 dB(A), and many areas (such as workshops, maintenance sections, hangars, flightlines etc.) showed exposure levels over 90 and 100 dB(A). In some cases, L_{Aeq} noise levels reached between 110 and 120 dB(A) during some tasks (such as vehicle maintenance tasks, hand tools, sand blasting etc.).

Very high to extreme impulse noise levels are experienced within the Department of Defence. The L_{Cpeak} levels often exceed the exposure standard of 140 dB(C) during specific activities, such as maintenance tasks (impacts during hand tool use), and reach up to 180 dB(C) during weapons firing (e.g. large calibre artillery).

A resultant exposure risk profile for a particular facility was determined from the SEG noise risk assessment. An example of a risk profile from a major ADF facility is shown in Figure 1.

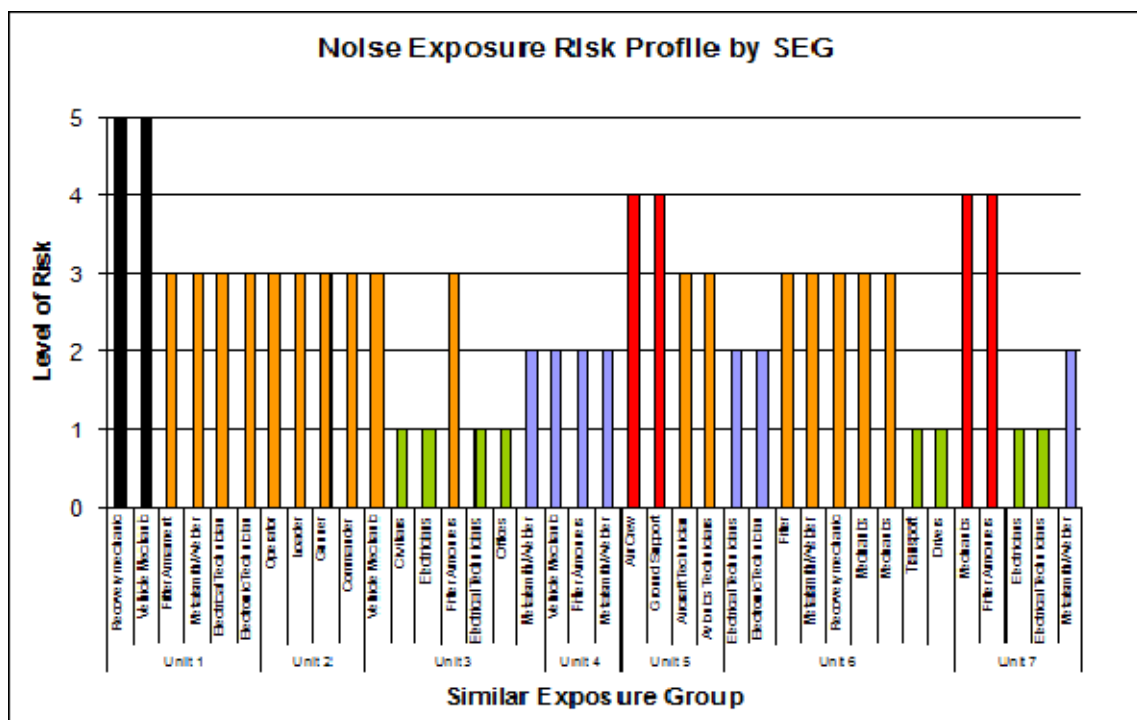


Figure 1: Example exposure risk profile for the range of SEGs at a major ADF facility.

5.3 Adjustments for extended work shifts

For work over extended work shifts (e.g. greater than 8 hours per day; which can occur in Defence), a lower exposure standard was applied.

In such cases, the equivalent noise level over an X-hour shift (i.e. $L_{Aeq,Xh}$) was converted and normalized to an 8-hour equivalent $L_{Aeq,8h}$. Then an adjustment (from +1 to +3 dB) was added to the normalized $L_{Aeq,8h}$ depending on the value of X (in accordance with the WHS Code of Practice and AS/NZS 1269.1).

It is important to note that hearing risk increases for a shorter hearing recovery time (between successive work shifts) and in cases when reasonably high noise levels occur during the recovery time (e.g. greater than 75 dB(A)).

Thus for extended work *weeks* greater than 5 days (e.g. for Navy crew that can be at sea continuously for weeks at a time), a lower exposure standard was applied. In such cases, the equivalent noise level over an X day week (i.e. $L_{Aeq,Xday}$) was converted and normalized to a 5 day week, $L_{Aeq,5day}$ (in accordance with the WHS Code of Practice and AS/NZS 1269.1).

Other noise exposure standards or adjustments were applied for special or complex situations, such as exposure to *high intensity impulse noise* (for example, in situations such as weapons use or explosive ordnance activities). Other relevant standards (such as US Military Standard MIL-STD-1474E [10]) provide guidance on the different exposure metrics for such cases, such as the $L_{Aeq,100ms}$ metric (equal energy model) and Auditory Risk Units (ARU) calculated from the Auditory Hazard Assessment Algorithm for Humans (AHAH) mathematical model.

5.4 Measurement through key performance indicators

A number of Key Performance Indicators (KPIs) were developed to measure the previous and current level of noise management compliance and maturity at ADF facilities. A KPI Measurement & Status Template (and Guide) was developed for application across Defence.

The KPIs have been carefully designed and revised to ensure coverage over the relevant aspects of noise management and processes. The KPIs are a mix of (mainly) lead and lag indicators, and comprise both quantitative and qualitative metrics. Note that lag indicators can be flawed and unreliable, and tend to be a measure of post-event failures, i.e. injury, illness or disease, whereas lead indicators tend to focus more on preventive measures.

The KPIs provide a quantifiable and comparable measure of the current status and progress made (e.g. NMP actions) relating to noise management. Hence, the KPIs provide an effective improvement measure for comparison between Groups/Services (and between Bases within a Service) and longitudinally over time.

KPI scores were determined for 10 distinct KPI areas for each ADF Facility covering the:

- a) WHS management system in place at the ADF Facility, and the
- b) Recent noise survey assessment results and review of controls in place.

The total KPI score provides a realistic measure of the compliance level of noise management at the facility and a measure of the completeness of the recent noise survey and assessment, and then used over time to compare against previous scores. It enables commanders and managers to see how they perform when compared to other facilities, how they perform over time, critical areas needing improvement and how they can improve their performance.

These KPIs have been used longitudinally over 4 years now and show measurable improvements in noise management practices across Defence (see Figure 2). However, further improvements are still required to comply with the WHS Act and WHS Regulations 2011, particularly in the areas of coordination and communication (including hand-over/take-over), audiometric testing, control actions and review, and awareness and training.

Figure 2 shows a schematic comparison chart of the KPI results for a subset of ADF facilities.

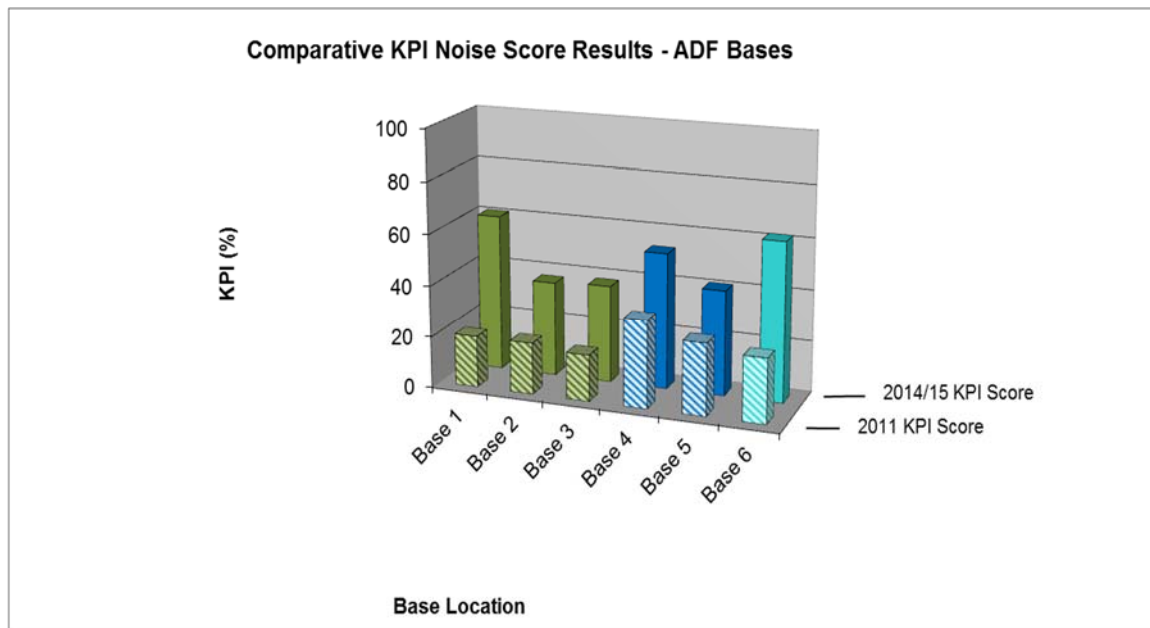


Figure 2: Comparison of Noise Survey Results and KPI Score between Services and Bases.

5.5 Noise control measures

The assessment of the noise survey results inform the noise control actions required. Such actions included engineering controls where practicable and were provided for each ADF facility in the form of detailed Noise Management Plans (NMP) for each unit or section.

Noise control measures were prioritised based on the hierarchy of control, the action type and the level and urgency required. The noise control measures were specific and practical, and considered any functionality or performance constraints that may apply.

Specific engineering or substitution noise controls were recommended where appropriate and practicable (such as installing quiet equipment, acoustic screens/barriers/baffles, silencers and low noise fittings) and a range of administrative control measures were also provided.

Defence must identify new alternate quieter noise sources (i.e. “buy quiet”) and processes, where available and practicable, which could minimise worker exposure. It is recommended that Defence have a *design aim of 75 dB(A)* for all plant and equipment (to be measured at 1 metre or nearest distance to worker/operator), where possible. If the design aim is not reasonably achievable, then Defence should design to ‘so far as is reasonably practicable’.

It is important that noise controls are implemented during the procurement phase and may include redesign or engineering noise controls implemented by the original equipment manufacturer (OEM).

Actions included improved provision and use/fitting/training for hearing protection for all ADF facility personnel. Defence should involve workers in the selection process and offer a reasonable choice of hearing protector types. In addition, HPA signage needs to be improved throughout most facilities and ensure that HPA areas are sign-posted and that HPA boundaries are clearly defined.

Regular audiometric testing, for 6-monthly to annual intervals, has been recommended for a range of the more exposed SEGs. In addition, results of the audiograms must be reviewed by the relevant manager and any changes to hearing thresholds should be noted and recorded with follow-up action.

Risk assessments and control measures must be reviewed periodically, and revised where needed, at regular periods (e.g. when existing control measures are no longer effective or when there are significant changes to noise sources and workplace conditions).

5.6 Noise management tools

A number of specialised tools were developed to support project implementation, assist in integration across Defence and improve the noise management process [3, 6].

- 1) A standardised Statement of Work (SOW) was developed to provide consistent scope requirements for carrying out noise survey assessments (and aligns with the new WHS legislation), and help ensure a consistent best-practice approach across Defence.
- 2) A new innovative tool was developed for application to the primary noise sources in Defence – a Noise Safety Data Sheet (NSDS) provides a snapshot of the noise properties of the source and highlights the noise safety requirements associated with its operation and use (e.g. maximum exposure times and minimum safe distances).
- 3) A clear Noise Management Plan (NMP) template has been developed for application to individual units at a Base. Each NMP action is given an action type based on the priority level and urgency or whether it requires minor or major effort and resources. The NMP is monitored by the relevant managers, along with audit against agreed KPIs.
- 4) A template for a noise-specific Risk or Hazard Register was generated for use by each Unit and Base based on a template developed including a list of NSDSs. In addition, noise-specific Standard Operating Procedures (SOPs) were developed for Units.
- 5) A range of checklists have been developed including a Noise Inspection Checklist, a Noise Workplace Audit Checklist, a Noise Hand-over/Take-over Checklist (for personnel postings), a KPI Measurement & Status Template and a Questionnaire Template for providing feedback responses about current noise management status.
- 6) A number of helpful guides have been developed including a Statement of Work (SOW) Guide, a Guide on Noise KPI Measurement, a Guide on Ototoxic Substances, a Guide on Extended Work Shifts and a Guide on Hearing Protection Area (HPA) Zones.

These tools, checklists and guides have now been made available and accessible on the WHSB intranet website within the Defence network and have started to be effectively used by Groups and Services to integrate and streamline their noise management processes.

5.7 Training and capability development

An online e-learning course on Workplace Noise and Hearing Loss awareness was developed and released at the commencement of Hearing Awareness week 2015. This provides a cost effective, consistent form of training ensuring Defence meets its legislative obligations to all noise exposed staff, regardless of their location and it also provides an up-to-date record of all trained personnel. Noise exposed personnel are also trained in correct fitting and usage of hearing protective devices, as it has been shown that training in correct use of ear plugs can increase the effectiveness of their attenuation by up to 25 dB(A).

For several years, the University of New South Wales has delivered a 1 week training course to Defence Occupational Noise Officers (DONOs). As of 2015, all trained DONOs will be awarded a nationally accredited unit of competency, *DEFOH004B Develop Noise Management Plans*; they are also recognised as competent persons as defined in AS1269.1. Their role is to conduct the general or follow up noise surveys. All DONOs have access to B&K 2250 sound level meters and noise dosimeters, and are encouraged to attend ongoing training by equipment providers.

6. Conclusions

An ambitious and forward-looking project has been established to reduce occupational noise exposure in all workplaces across Defence. The formulation of specifically tailored noise management plans and innovative noise management tools have been integrated across Defence to improve noise control practices and reduce noise exposure.

To measure progress and improvement, specific KPIs were developed to provide a quantifiable and comparable measure of the current status and progress relating to noise management. These KPIs have been used longitudinally over 4 years now and show measurable improvements in noise management practices across Defence. In addition, they highlight areas for further improvements still required to comply with the WHS Act and Regulations.

Commitment and continued improvement (building on the improvements realised to date) will provide ongoing corrective and preventative measures that reduce the extent and impact of workplace noise in Defence, reduce the level of noise-induced hearing loss and claims, provide substantial cost savings over time and improve Defence's capability and reputation.

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CASE STUDY: CONTROLLING EXPOSURE TO ANIMAL ALLERGENS IN RESEARCH & DEVELOPMENT

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ABSTRACT

In the past, controls related to the prevention of exposure to Animal Allergens in R&D were driven by an internal company guideline. Controls were only based on qualitative risk assessments. The problem was these control measures were not supported with Quantitative Risk Assessments.

As a resolution a baseline sampling plan was developed to evaluate the exposure of identified high and moderate risk activities. External laboratories, able to analyze Mouse and Rat Urine Proteins, were evaluated and a selection was made. A company Occupational Exposure Limit was developed. In 2011 the baseline sampling plan was finalized. All the results were statistically analyzed, evaluated and documented in a standard form. As a result of this sampling plan we now have a better understanding of exposure levels of various activities using different containment controls. Additional containment controls are implemented, Personal Protective Equipment has been reviewed and the internal guideline was adjusted based on the outcome. Proven solutions are documented in Containment Solution Guides. These lessons learned are shared with other R&D facilities within the company and with other pharmaceutical companies.

CONTROLLING EXPOSURE TO ACTIVE, PHARMACEUTICAL INGREDIENTS

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ABSTRACT

Active Pharmaceutical Ingredients are developed to have a specific impact on target organs in the body. Therefore, these products have very specific hazardous properties and require a separate approach for the Occupational Hygienist when implementing the basic principles of Occupational Hygiene.

In this presentation this unique approach applied within the Pharmaceutical Business will be presented. Starting from the development of toxicological information of the compounds, the basic risk identification and the Qualitative and Quantitative Risk Assessment including statistical analysis.

Several solutions and challenges will be shared how to control the exposure to these compounds by respecting the hierarchy of controls covering Research & Development, Chemical and Pharmaceutical Production.

CASE STUDY: CONTROLLING EXPOSURE TO ISOFLURANE USED IN ANIMAL SURGICAL PROCEDURES IN RESEARCH & DEVELOPMENT

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ABSTRACT

At three pharmaceutical locations of J&J, there were reports of acute adverse health effects associated with isoflurane in a total of 8 employees. The symptoms reported to Occupational Health were headaches, drowsiness and dizziness, loss of concentration and numbness of the hands. These effects occurred when the anesthetic agent was used in animal surgical procedures in Research & Development facilities. Symptoms were most often associated with exposures in the 10-23 ppm range. Due to these reports, the internal OEL of isoflurane of J&J was reduced from 20 to 2 ppm. Therefore a new baseline sampling plan was developed to evaluate the exposure level during all identified activities at the different work stations in R&D at the Janssen Site in Beerse, Belgium. All the results were statistically analyzed, evaluated and documented in a standard form. Step by step, solutions were developed, tested and implemented to reduce the exposure level to isoflurane below the new internal OEL. Additional containment controls are implemented, Personal Protective Equipment has been reviewed and additional good work practices identified.

These lessons learned are included in an updated internal procedure and shared with other R&D facilities within J&J and other pharmaceutical companies.

BENZENE EXPOSURE ASSESSMENT AND CONTROLS: FROM UPSTREAM PRODUCTION TO DOWNSTREAM DISTRIBUTION

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ABSTRACT

The petroleum industry operations, as a result of select tasks may be a source of occupational exposure to Total Hydrocarbons which mainly come from Crude Oil. Benzene, a natural constituent in crude oil and wide variety of many other derived products in manufactured chemicals, tops the list of concerns. Some activities in the exploration, production, manufacturing and distribution of crude oil and natural gas and its manufactured products may have potential exposure to benzene vapour. Exposure may occur in performing routine tasks and also during maintenance or turnaround. A process and operations review were performed to identify tasks where exposure to benzene could occur and subsequently assessed as part of the health risk assessment activities. Effectiveness of controls and assurance of ALARP status of these tasks were assessed and reviewed simultaneously. This presentation will explore selected tasks where exposure could be significant, the controls applied that would be effective and the challenges in managing benzene emission exposure in derived products from upstream production to downstream manufacturing and bulk product distributions.

BACKGROUND AND INTRODUCTION

The oil and gas industry main activity is in the energy provision via exploration, extracting, refinement, transporting and marketing of oil and gas related products. The industry's business approach is most commonly divided into upstream and downstream operations as some midstream activities may be considered as part of either upstream or downstream operations. The upstream operations mainly involved with the search, recovery and production of oil and gas, namely exploration and production (E&P) sector where the energy reserves were search by drilling and once discovery occurred, the recovery of oil and gas process begins. Main products from upstream would be crude oil and natural gas. The downstream operations deal with manufacturing or refining the materials to finished products and then distributing and marketing the products to customers and consumers. Finished products include liquefied petroleum gas (LPG), gasoline or petrol, jet fuel, kerosene, diesel oil, lubricants, and many more petrochemicals derivatives.

The production effort would involve tasks which will require direct handling of equipment and materials. While most of the activities are performed in closed conditions, there are activities that require personal handling and may introduce risk to the chemical hazards presence.

THE PROCESSES

Once a reservoir has been successfully connected to the integrated production system, the production process begins. Figure 1 below provides simple description of the overall process and distribution chain.

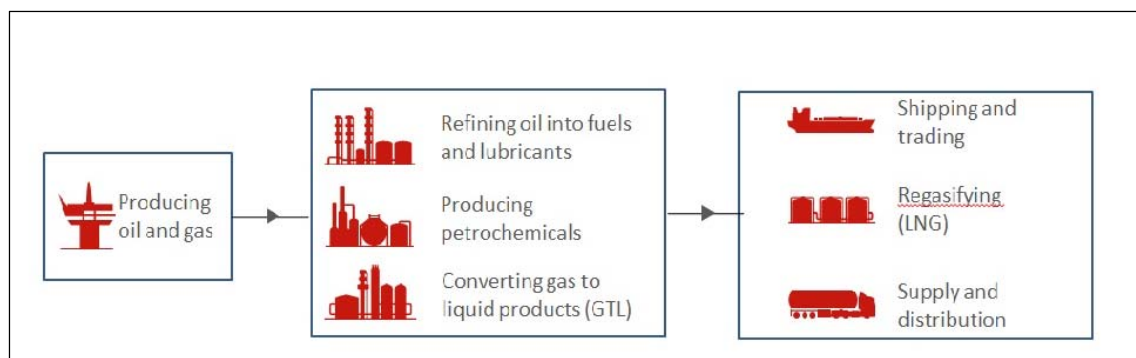


Figure 4: Brief Oil & Gas Production Process Flow

Oil and gas extracted from a field went through separation systems at the production stage before it is then transferred to terminals for storage prior to export via pipeline or marine services for manufacturing process. Manufacturing facilities will then further process the natural resources into finished products. The manufacturing facilities are refinery, chemical processing plant or gas to liquid (GTL) plant. Products from here are then stored at supply and distribution terminals prior distribution to end customer.

Where possible and practical, closed operations are adopted in all processes at all production sectors. However, there are also operations or tasks where direct handlings of product or equipment are unavoidable. This is when exposures to release of hydrocarbons become a concern. At upstream section, tasks of main concerns are pipeline pigging and vessel cleaning. The downstream section has several tasks with potential release and exposure. Specific for this paper, we will be looking at process sampling and tanker loading tasks for downstream section.

THE ASSESSMENT

Crude oil is one of the main products from upstream operations. The composition differs from the regions where it is produced but in general it is a mixture of paraffins-naphthenes-aromatics (Petrowiki, 2015). Out of the paraffins-naphthene-aromatics mixture in crude oil, the aromatics components are of priority interest. The aromatics is not a major constituent, however, in terms of hazard ratings of the chemicals, they would have higher priorities in assessment and controls. At the downstream operations, the crude oil is refined via fractional distillation process to lighter end-products. Gasoline is one of the products produced from the distillation and mixing process. Benzene, toluene, ethyl-benzene & xylene (BTEX) made up the major component of interest for health risk assessment for both crude oil and gasoline. Benzene topped the priority for assessment and controls. Benzene is a naturally occurring compound in crude oil and natural gas and remains as impurities in a very small percentage in the product from the fractional distillation process (Williams et al, 2008). A study done by Verma et al (1992) on hydrocarbon exposures at petroleum bulk terminal indicates exposure to Benzene may have higher potential to exceed the TLV-STEL limits compared to other Total Hydrocarbon components. Thus, this paper will look specifically on benzene exposure at rather than the bigger spectrum of hydrocarbon mixtures.

Exposure to fugitive benzene emission while performing the assigned tasks was assessed using Health Risk Assessment (HRA) methodology. The hazard rating was assigned based on the severity of health effects and consequences. A scenario on how the exposure occurs was reviewed where exposure rating was determined, followed by detailed review on the effectiveness of existing controls. In order to ensure that the exposure is controlled as low as reasonably practicable (ALARP), an ALARP analysis is then conducted and recommendations for gap closure is provided as remedial action.

Pipeline pigging has been identified as one of the tasks with high exposure rating for benzene in the upstream process. During pigging operation, a device known as “pig” is launched into the pipeline via a “pig launcher” for various maintenance operations (Petrowiki, 2015). The pipeline was isolated and depressurized. The residual hydrocarbon vapour inside is released to flare and thus reduce the hydrocarbon emission when the pig launcher door is opened. At the receiving end, water was used to flush the pyrophoric materials inside the receiver once the door the opened. The launcher and receiver are located in open air with good air movement for natural ventilation. These activities are rated with high exposure rating in HRA based on personal exposure monitoring results. This indicates that the process control is not an effective method to reduce personal exposure to Benzene during the operation. Thus, respiratory protection is a mandatory requirement when launching and retrieving the pig device. Further ALARP assessment indicates that there is additional engineering or process control that can be implemented to reduce the exposure level. Nitrogen purging can be introduced into the pipeline prior to opening the door. However, this solution is not business practicable to be implemented at existing platform where as it requires huge investment in redesigning the process pipeline to bring nitrogen into the system. New production area is now designed with pipeline to enable nitrogen purge.

There is not much difference in operational steps in performing vessel cleaning between upstream and downstream process. Post material draining, vessel or tank was isolated via “blinding process”. In some work area, this is called “spading” or “flange break” where the vessel containment is broken to allow maintenance work to be done inside the vessel. Once containment was broken, forced-ventilation is installed to channel the hydrocarbons inside the vessel to identified location. Once the atmospheric condition is safe, cleaning process began. Generally, cleaning is initially done via closed system where chemical or water, depending on the vessel’s content, is circulated inside the vessel and then drained out to the sump pit/interceptor or holding tank for waste management process. Initially, the sludge inside the vessel is flushed out using high pressure water

jet machine and then drained out into the interceptor. The remaining sludge inside the vessel that cannot be removed is then scooped out manually. Manual vessel isolation where there is release of vapour and liquid and manual sludge removal process are tasks with potential high exposure rating to benzene. Forced ventilation is one of the controls that could help in reducing the exposure level; however, it requires long duration for it to be effective which may not be practical for production purposes. When this condition occurs, respiratory protection program is implemented to mitigate the exposure concerns.

Product sampling is the most common process in any sector of the oil & gas industry. It is an important process as it is also a part of product quality assurance. This is where a small portion of the product or intermediate is taken from the process stream for various reasons. The process of taking liquid samples from process stream in any of the sectors is quite similar. The liquid from the process line is initially flushed out for a few minutes and then a sample bottle is placed at the opening point of the process line to collect a set amount of the liquid sample. The sample collection is a simple process and most of the time, completed in a short duration. The release of the hydrocarbon vapours to the operator from flushing activities is controlled via closure of the sampling pot and distance draining. During sample collection, direct exposure occurred via inhalation and skin. The operator would have to get closed to the valve to fill up the sampling bottle. This is where peak exposure could occur as residual vapour from flushing may still linger when the sampling pot door is opened. Skin contact may occur if the operator was not careful when aligning the bottle's opening to the valve head. In-situ direct-reading measurement indicates that there is potential for high exposure in the short duration when sample is taken. However, when a task duration personal sampling is done, the average exposure over the short term would normally stay below the allowable short term exposure limit for benzene. The inhalation exposure has been minimized administratively via process control. Skin protection is provided with the use of nitrile gloves. Exposure monitoring and in-situ measurement data indicated that the routine sampling work is effectively controlled at ALARP.

Another task of interest in downstream sector of oil & gas business is product loading from a tanker at liquid bulk terminal or better known as depot. A tanker driver would collect gasoline at a depot and discharge them at intended location; retail station is one of them. Once documentation verification and product volumes determined, the tanker driver would initiate the loading process. There are two types of loading available, top and bottom loading. A tanker is normally equipped to do product loading from either the top of the truck or bottom the truck, depending on depot's system. A detailed risk assessment indicates that benzene exposure rating from top loading operation is higher than bottom loading. This conclusion is also supported by the study on 'Hydrocarbon Exposures at Petroleum Bulk Terminals and Agencies' by Verma et al (1992). Bottom loading process is a closed system. It is equipped with vapour displacement or vapour recovery to channel the vapour to a distant location from the gantry where product is loaded. Product loading using this methodology is assessed at ALARP when the system works as it is intended for. On the other hand, when the product is loaded from the tanker's top manhole, a total closed system could not be achieved. Vapour would be released from the manhole during loading. Depending on the wind condition, it may persist within the gantry area. Truck driver would need to alight onto the tanker top to open up the manhole and manoeuvre the loading arms into the manholes prior to loading. A system was put in place to allow loading of product to be done at a distance away from the manhole where the truck driver would operate a dead-man valve on the island's platform in the gantry. However, the effectiveness of this control depends on environmental conditions thus making the exposure level fluctuating from compliance to non-compliance level.

CONCLUSION

The selected tasks explored are tasks where closed operations are not possible, either due to pre-existing conditions or nature of the process itself. For most cases, where applicable, a system to minimize the release and exposure to the workers are adopted, however, not all of them would be effective in ensuring sustained compliance to benzene OEL. Thus, to ensure that ALARP condition is achieved, the last hierarchy of control is applied.

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IMPACT OF POOR BUILDING DESIGN AND MATERIALS IN OVERSEAS AND OFF-SITE CONSTRUCTED MODULAR BUILDINGS – A CASE STUDY OF AN IEQ INVESTIGATION INTO THE ASSEMBLY OF PRE-FABRICATED BUILDINGS IN A HOT AND HUMID CLIMATE

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ABSTRACT

Building design, construction methodology and the choice of internal materials can have a significant impact on the final outcome of a habitable building. The rise in popularity of overseas built / pre-fabricated modular buildings is evidenced by the increasing volume of orders placed by mining companies and government departments, to be assembled and complexed on-site as accommodation units or on-site offices across Australia.

This paper provides commentary and observations from three Indoor Environment Quality (IEQ) investigations of modular buildings that have been built off-site and then transported to site for assembly in hot and humid locations. Two cases relate to structures manufactured overseas and shipped into Australia and one case relates to structures manufactured in Perth, Western Australia. The case studies discuss water damage as a result of potential ingress during construction and transport, dew point condensation, interstitial condensation and resultant mould growth issues.

All three case studies identify flaws in design, construction and selection of construction materials which led to extensive mould growth and large blowouts in cost and timelines. Some identified issues were common to all three cases studies whereas some issues related specifically to off-shore construction.

Introduction

Construction of accommodation units in regional centres, such as the Pilbara, Western Australia, can be challenging due to limited local building and manufacturing services and supply chain issues (Campbell *et al.*, 2012). These challenges have led to an increase in sourcing pre-manufactured building components which are then transported and complexed on-site with a reduced need for local construction services. Cost pressures have seen sourcing of modular components constructed in Perth and also from overseas locations such as China.

Construction of accommodation components and units at off-site locations can result in a significant reduction in project completion times and costs. However, construction of structures destined for distant locations can sometimes fail to adequately address design issues such as climatic conditions at the destination and transport issues such as potential water ingress during transport (White *et al.*, 2015). Failure to address these damp or water damaged building materials could then lead to a higher risk of mould growth followed by further downstream health problems experienced by occupants and eventually the deterioration of the building (Cheong, 2013).

Case Study #1 describes 409 modular accommodation units (dongas) that were constructed off-shore and shipped en-masse to a humid coastal location (~20.3° S). Units were stacked to form an accommodation village. Each unit contained four furnished single bedrooms with ensuites. Elevated internal moisture content within approximately 40% of the units resulted in mould growth within the composite wall panels and on the interior cladding and / or furniture.

Eighty eight of the most severely water damaged units were transported to Perth for remediation, a further 68 units were examined and remediated at the site. Potential causes for the elevated moisture content are discussed.

Case Study #2 describes 1,232 modular accommodation units that were constructed off-shore and shipped en-masse to a humid coastal location (~20.8° S). Each unit contained two single bedrooms with ensuites. The clustered units were complexed to expand an existing village. Design issues resulted in cycling of hot humid air through vertical shafts and voids contributing to accumulation of moisture in magnesium oxide (MgO) boards, dew point condensation on cool surfaces, interstitial condensation in wall and ceiling panels and mould growth.

Case Study #3 describes 768 accommodation modules that were constructed in Perth and transported by road to a humid coastal location (~20.6° S). The units were complexed to form a permanent apartment complex. Design issues and lack of vapour and thermal barriers in vertical service ducts spanning all three floors led to dew point condensation on cool surfaces and interstitial condensation in the walls adjacent to apartment living space, resulting in mould growth.

Methods

Building investigations were conducted by IEQ professionals encompassing visual inspections, measurement of internal parameters and air and surface sampling (Neumeister-Kemp *et al.*, 2013; Campbell *et al.*, 2010). For the sake of brevity, mould sampling method and results are not discussed. The purpose of the investigation was to pin point any design defects, incorrect material choice and construction issues that may have occurred before the buildings were / had been complexed and released for occupancy.

The moisture profile of buildings were developed using a moisture meter (GE Protimeter MMS) with measurements reflected in percentage wood moisture equivalent (%WME) based on standard scale A. The same instrument was used to measure IAQ parameters: temperature; relative humidity (RH); and dew point (DP).

Results

In all three case studies, mould growth was directly related to excessive indoor RH resulting from either moisture ingress or construction issues (Case Study #1) or dew point and interstitial condensation (Case Study #2 & #3). Table 1 provides a summary of the construction details for each cases study.

Table 1. Summary of construction details

Case study	Construction and transport	Envelope materials	Floor materials	Services	Floors
#1	China build, shipped via ocean vessel to local port.	Metal sheet exterior, internal steel framework, foiled foam vapour / thermal barrier, SMF insulation, two layers of fire rated gypsum wall and ceiling board, plastic joints.	Linoleum over laminated ply base.	Sealed floor and wall openings. Base open to ambient air.	Two
#2	China build, shipped via ocean vessel to local port.	Metal sheet exterior, internal steel framework, foiled foam vapour / thermal barrier, SMF insulation, gypsum wall board and MgO ceiling board. Voids between modules, sub-floor and roof.	Linoleum over laminated ply base.	Services via open vertical shafts. Open to ambient air at ground level, 1 st floor, sub-floor space and roof.	Two
#3	Perth build, transport via road.	Metal framed modules clad in cement fibre sheeting and bonded alum facia. SMF insulation gypsum wall and ceiling board.	Linoleum over laminated ply base.	Services via open vertical shafts running between floors. Open to ambient air at base.	Three

Remediation was required in Case studies #1 and #3 with remediation and retrofitting of structures in Case Study #2. The costs and time delays associated with remediation / retrofitting were significant. In addition, it is likely there will be a requirement for ongoing mitigation in Case Study #3 for the life of the building to ensure occupant health. Table 2 provides a summary of known costs associated with remediation and proposed retrofitting for each case study. Additional to the costs identified in Table 2 are a wide range of construction and maintenance cost which have not been included in the summary.

Table 2. Summary of known remediation / retro-fitting costs

Case study	Accommodation details	Remediation costs	Proposed retro-fit costs	Cost per unit*
#1	624 single rooms and ensuites.	~\$700,000 to remediate, excludes labour to remove contaminated wall boards and make good, excludes cost to replace contaminated furniture.	N/A	\$1,120 per room.
#2	2,464 single rooms and ensuites.	Unknown	~\$1.1 million to fabricate and install 1,440 panels across floor and roof shafts, excludes any remediation and replacement of damaged ceiling sheets due to gross accumulation of moisture.	\$450 per room.
#3	384 queen sized apartments with ensuites.	~\$300,000 to remediate service ducts throughout the complex. Due to the nature of the construction, design fix unlikely and therefore ongoing mitigation program likely to be required.	Un-costed. Likely to be high due to the highly invasive and disruptive nature of the work.	\$780 per apartment. Ongoing monthly mitigation costs.

Note * Cost per unit is based solely on quantified costs; quantum of additional costs is unknown.

Case Study #1 - Ingress during construction and transport

The vessel transporting the units in Case Study #1 was exposed to severe weather, mid-voyage. Anecdotal evidence suggests the upper and outer parts of the vessels' load sustained ingress through the inadequate roof / wall joint flashings. Ingress through door and window penetrations may have also occurred. Ingress and subsequent retention of moisture within the insulation and cladding led to high RH over several months. High RH and warm, still air are ideal conditions for the growth of mould. Resultant mould growth to wall and ceiling cladding, built in furniture and contents was extensive.

Ingress was initially thought to be the primary source of moisture. However, close examination of 156 of the 409 units suggested there may have been another source of moisture contributing to high RH within the units during shipment. A review of the construction facility in China identified that the workshops where the cladding material (gypsum) was stored, cut and assembled was effectively open to ambient air. Also, during the study period ambient, absolute humidity was sufficiently high to see moisture levels rise in the cladding material from its relatively dry state of 8-9% WME to ~16% WME. Rises in moisture content of cladding material in the facility appeared to correlate with the storage and use of cladding material within the production facility. Cladding in the warehouse (n=28) had a mean, median and max of 13.3%, 13.4% and 15.0% WME; cladding in the workshop (n=38) had a mean, median and max of 13.7% 13.8% and 15.8% WME respectively.

Case Study #2 - Condensation and moisture accumulation

Each cluster consisted of prefabricated modules stacked side by side and on top of each other to form a multi-storey mosaic of inter-connected accommodation under a pitched gable roof. Each module had an opening (shaft) running vertically from the sub-floor to the roof. Each shaft allowed hot humid air to travel from ground level into the voids between each module, the inter-floor space and the gable roof.

Unlike Case Study #1 the modular units did not appear to suffer from ingress during transport, rather, moisture issues were related to the circulation of hot humid air into the internal void spaces and contacting cool internal surfaces resulting in surface dew point condensation, interstitial condensation and moisture accumulation within the internal structure. Surface dew point condensation occurred from the contact of hot humid air on surfaces, such as internal steelwork and cladding, then cooled via weak thermal barriers from internal room cooling. Similarly, interstitial condensation resulted in condensation of moisture within semi-porous cladding (in contact with warm moist air) when the temperature of the material

fell below the dew point of the air mass adjacent to it. Moisture accumulation occurred via absorption and Interstitial condensation in unsealed MgO cladding.

In this case the open shafts effectively bypassed vapour barriers and thermal breaks built into the external walls of the modules allowing extensive moisture and, as a result, mould damage to the internal fabric of the buildings.

Case Study #3 - Condensation

While similar to Case Studies #1 and #2, in this case the prefabricated modules were not fully enclosed; rather the large component parts were joined on site and stacked to form a block of adjoining accommodation. Each pair of apartments (back to back) shared a vertical riser / service duct which spanned all three floors. The duct walls were constructed from gyprock without a backing vapour barrier or thermal break / barrier to minimise heat transfer. As such, surface dew point condensation occurred on the internal surface of the duct. The unsealed nature of the duct cladding also contributed to localised interstitial condensation. Moisture and mould damage to the service duct surface was extensive, concentrated on the service duct capping plate at the third floor, where warm, moist air rose but was unable to exhaust.

Discussion

All three case studies describe conditions that led to extensive growth of common environmental mould within the buildings. The consequences were significant in terms of project delays and costs. The costs described in Table 2 are indicative only.

In Case Study #1 the full cost includes: additional project supervision, return transport and crange of 88 units from the Pilbara to Perth, specialist remediation of the mould affected structure, trades for electrical, plastering, carpentry and painting works and replacement of furniture. The design of the dongas was similar to those found on mainland Australia and the Pilbara, however little allowance was made for potential extreme weather on the voyage; not a rare occurrence and ingress of moisture though inadequately sealed external joints. Such weather events are rarer on mainland Australia and typically, when such events occur, the time between ingress and rectification is short. When ingress, as described, occurs during importation the long transport and storage cycle is conducive to mould growth and damage. The same onshore / offshore paradigm also exists for the construction process. Typically dongas manufactured for the Pilbara are constructed in Perth where RH and absolute humidity tends to be low and the subsequent absorption of moisture into building materials is low. The same cannot be assumed at offshore facilities such as the ones utilised in China. In tandem ingress and internal cladding that has elevated moisture content is likely to result in mould damage during the time between construction and site installation.

In Case Study #2 the design appears to have been well thought out and efficient had it not been for the open shafts allowing hot humid air to circulate through the internal structure. Failure to adequately address potential dew point and interstitial condensation through appropriate climate sensitive design has been an issue in the Pilbara with many “builds” experiencing extensive mould damage and high remediation and mitigation costs (Campbell *et al.*, 2012). An additional issue encountered in this case was the use of MgO board. Magnesium Oxide board is reported to have anti-fungal properties due to its high salt content which acts as an inhibitor of mould (Sawai and Yoshikawa, 2004), has greater tensile strength and is structurally superior to gypsum (Manalo, 2013). Magnesium Oxide board is known to be hygroscopic (International Building Code - IBC) and anecdotal reports suggest Chinese product can be prone to absorption issues. This is particularly an issue if the board receives surface dew point condensation during the construction stage when it is unsealed. Visual examination of some ceiling panels showed strong distortion across the horizontal plain due to assumed moisture absorption. The International Building Code (IBC), Section 2502 states that MgO board must not be used when exposed to weather i.e. moisture must not reach the MgO boards; paints/renders don't prevent this.

A retro-fit to the design was required to seal egress of warm humid air into the internal voids. This was proposed by fitting 672 panels across the subfloor ducts and 616 panels across the upper level duct. The proposed works required workers to crawl under each building and fix / seal a panel over each duct opening and remove ceiling tiles in the upper floor to access the upper ducts (below the gable roof) and fix / seal a panel over each duct opening.

Design flaws in Case Study #3 are primarily limited to the service duct: a relatively small, yet critical with respect to air transfer component of the build. However, inconsistent application of vapour and thermal barriers has resulted in a significant cost to the build, i.e. had the internal cladding had a vapour and thermal barrier and the warm air on the top level been able to

vent to ambient air, condensation would have been unlikely. Remediation was in the form of mould removal and cleaning of all surfaces within the duct, painting of all board with a dense sealant with anti-fungal properties and treatment with hydrogen peroxide vapour (HPV) (White *et al.*, 2012; Neumeister-Kemp *et al.*, 2010). The design flaw resulted in the builder returning a net loss on the build. Due to the nature of the build, retrofitting is not possible without demolition which is considered too costly. Ongoing monthly mitigation with HPV has ensured mould growth is minimal.

The focus on building design often fails to examine performance and interactions with temperature, humidity, rain and the interior climate (Lstiburek, 2002). These climatic factors are environmental loads with principal limiting conditions “*such as rot, decay, mold and corrosion.*” and can be used in applying moisture engineering to building envelopes (Lstiburek, 2002). Building design should integrate the concept of moisture balance. When moisture accumulation exceeds the building materials’ capacity to store moisture (without degrading performance of the product) moisture problems will occur. Lstiburek (2002) compares in the USA an “average” timber framed home’s capacity to store water without issue to an “average” steel frame home. The timber framed and clad home has a buffer of around 170-190 litres of water which can be easily accommodated via hygric redistribution. Conversely, a steel framed home clad in gypsum board has a hygric capacity of less than 20 litres. Constructing highly insulated steel framed, gypsum clad buildings is a significant moisture engineering challenge as it present two risky characteristics: low hygric buffer capacity and slow drying times. So even small amounts of moisture will cause problems (Lstiburek, 2002).

Conclusions

Elevated moisture content in gypsum or MgO boarding at critical construction stages including raw materials storage, building assembly, the export, installation and complexing of the buildings can be prevented with diligent monitoring and appropriate moisture protection of the building material at all stages of the installation. A modular building dampness and microbial prevention program starting from input in the design stage, through material choice, material installation, shipping and on-site complexing, will prevent additional expenditure at commissioning. ‘Out-of-plan’ costs associated with the removal of microbial contamination and water damaged materials, and associated commissioning schedule delays, will be avoided.

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APPLICATION OF TRACER GAS FLOW PROFILING TO IMPROVE SECONDARY VENTILATION PRACTICE – A PILOT STUDY

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ABSTRACT

The mine ventilation system plays an important role in mitigating human exposure to diesel particulate emissions (DPM), exhaust gases and heat in underground mines. The mine's secondary ventilation systems are critical for diluting contaminants when working at the face of a heading.

To improve these systems it is important to understand and visualise the localised air flow profiles. We have considered an approach that includes both tracer gas measurement–modelling to analyse this complex flow behaviour in a heading. The use of tracer gas enables reliable measurements of flow behaviour and differentiation between the contributions of various contaminant sources including DPM.

A pilot study was conducted to demonstrate how tracer gas can be used to directly measure the effectiveness of ventilation dilution in a heading during shotcrete activity. This activity is considered to be one of the more challenging areas for diesel exhaust exposure management. Exposure sources include the diesel engine of the spraying equipment (Spraymech) and concrete agitator truck (Agi) that supplies the shotcrete. During operation both the Spraymech and Agi operators are located outside the equipment's air-conditioned cabins and both are exposed to diesel exhaust.

In the pilot study tracer gas was injected directly into the Spraymech exhaust stream. This allowed thorough mixing, ensuring the tracer gas was able to track exhaust gases and particulates released to the heading. The release was repeated at three different headings with varying degrees of secondary ventilation controls.

The study showed that small changes to the secondary ventilation system can significantly impact the contaminant concentration. It also demonstrated that tracer gas can be used to isolate different contaminant sources. The intent is to use this technique in a more comprehensive study to develop best practice guidelines for secondary ventilation installations. This paper presents the technique used and the preliminary results from the pilot study.

INTRODUCTION

Underground mine workers are exposed to a variety of toxic materials including gases and airborne particulates from strata, blasting and diesel equipment.

In June 2012, the World Health Organisation (WHO) classified diesel engine particulate matter, a diesel exhaust compound, as carcinogenic (Class 1) to humans (Wikipedia, 2015); based on evidence that exposure is associated with an increased risk for lung cancer (WHO, 2012). This puts diesel particulate matter (DPM) in the same category as silica dust and asbestos. The classification by the WHO has significant implications for the mining industry, particularly where diesel engines are used in underground confined spaces.

The mine ventilation system plays a key role in controlling the impact and human exposure levels of diesel emissions. Ventilation helps to improve air quality by diluting dust and toxic emissions from underground engines. It reduces worker exposure to harmful contaminants in the air such as diesel particulate matter. In coalmines the ventilation system also controls the levels of gases such as methane for the prevention of mine explosions and fires. Diesel emissions in underground mines need to be controlled by a combination of lowering the gas and particulate emissions from the engines and providing adequate ventilation to dilute contaminants to concentrations below health guideline levels. Based on the exhaust DPM levels for Tier 1 to Tier 3 engines, it can be demonstrated from first principles that the current practice of supply 0.05 m³/s per rated kW of diesel engine is not necessarily sufficient to dilute DPM levels to below the current guideline of 0.1 mg/m³ if no DPM filters are fitted. It is inevitable that additional controls such as filters and fleet management will need to be implemented to manage DPM; however, it is important that the ventilation system, a primary

control, is optimised to maximise dilution of exhaust gases. In order to achieve this it is important to understand the localised flow profiles on a micro scale to identify areas of improvement.

In underground mines ventilation is achieved via a complex system of flowpaths. As the mine geometry becomes more complex so does the task of maintaining adequate ventilation and ensuring that air quality in the far reaches of tunnels is maintained. To maintain worker health and safety a full understanding of the mine ventilation system is required. Whilst the macro scale of mine ventilation systems can be readily modelled using commercial network simulation software packages, it is on the micro scale where it becomes difficult to ascertain if sufficient fresh air is being supplied and if toxic materials from the workings and underground diesel engines are being adequately diluted.

It is imperative that the mine ventilation system provides air at sufficient volume, velocity and quality to the place where workers are present. Computation fluid dynamics (CFD) modelling software helps to understand complex airflows, but validation data is necessary to calibrate and verify ventilation systems.

APPLICATION OF TRACER GAS IN UNDERGROUND MINES

The use of tracer gas is not new in underground mines and sulfur hexafluoride (SF₆) in particular has been used in numerous tracer gas studies. In 1987 a trial was undertaken on a prototype *in situ* and real-time analyser for tracer gas studies (Stokes, Kennedy and Hardcastle, 1987). Since those early studies the technology and its applicability in mine ventilation has matured. Today real-time monitors, although costly, is readily available and the modern instruments are highly sophisticated. The advent of CFD techniques that allows for the discrete modelling of localised airstream (air patterns) offers real opportunities when combined with tracer gas technologies. CFD modelling is heavily dependent on input parameters and results can at times be uncertain. Tracer gas offers an accurate measurement technique to verify, validate and calibrate these models, which can then be used for extrapolation and what-if analysis.

Tracer gas techniques allows for an accurate measurement of complex flow behaviour that cannot always be measured by conventional devices such as vane anemometers or Kestrels. For example very low flow rates, dead zones and flow layering is difficult to assess with these conventional instruments. The technology has been widely applied in the mining industry. CANMET's Mining Research Laboratories, for example, has used the technology for:

- the accurate measure of multiple airstreams in underground surveys
- the interpretation of contaminants generated by loaders in stopes and their removal by ventilation
- *in situ* measurement of fan delivery
- testing of auxiliary ventilation systems for leakage
- determining residence and clearance times
- testing the integrity of escape routes
- predicting dust levels inside a processing plant (Hardcastle, Grenier and Butler, n/d).

One of the more interesting applications described by Hardcastle is the use of tracer gas to study the feasibility of controlled recirculation (Hardcastle, Kolada and Stokes, 1982). Australian mines use controlled recirculation extensively in the hard rock mining industry, where a number of blind ends are ventilated in a daisy chain arrangement. Ventilation engineers are concerned on how this practice impacts on the overall air quality when considering diesel fumes, heat and particulates.

Tracer gas has in the past been employed in the mining industry to measure the effects of diesel exhaust on the underground mine environment (Hardcastle, Grenier and Gangal, 2000). The use of tracer gas is considered a valid technology to establish the relations between diesel exhaust rates, number of sources, ventilation rates and practice and contaminant levels. Hardcastle reports successfully using tracer gas to prove that high levels of nitrogen dioxide were measured in the mines and showed that the average travel time of the contaminant through the mines exhaust system was in excess of 24 hours. This level of complexity in terms of gas or particle flow paths through the mine cannot be determined by simple measurement techniques. Hardcastle's situation is not dissimilar to what occurs in blind headings where dead zones may naturally develop, particularly if secondary ventilation is not operating at optimal levels. In these dead zones the

air fails to scour the heading and this can often lead to lower air exchange rates, resulting in the ‘build- up’ of contaminant concentrations.

Tracer gases offer the following advantages in terms of their application to study the phenomena described:

- are safe with no toxic effects
- can be detected at very low concentrations, ie low airflows
- can be measured
- the effective air exchange rates in development headings can be directly determined from tracer gas technologies
- can be used as a surrogate for pollutants such as diesel exhaust
- allows different sources of pollutants to be distinguished from each other.

Complex airflows can be determined by the use of tracer gas technology. The tracer gas is introduced at a very low concentration into the environment to be tested. In this way the gas does not perturb the system but becomes part of it. Measurement of the gas enables flow rates, exchange rates, travel times and flow paths to be determined. Tracer gas can mimic the flow of both gases and small particles such as DPM.

This paper describes how tracer gas was used in a pilot study to demonstrate its application for diesel particulate management.

Choosing the ideal tracer gas

The ideal tracer gas should be chemically and thermally stable, safe, non-toxic, non-corrosive readily attainable and easily transportable, inexpensive, odourless and not naturally occurring in the environment. In addition, it should be easily detected at very low levels and should maintain its stability in the container holding the air sample during transport to a laboratory for analysis.

Sulfur hexafluoride (SF₆) meets these requirements. It can be obtained as a liquid under pressure in cylinders, is a gas under ambient conditions, is inert, non-toxic and can readily be detected at the parts per billion (ppb) level using data logging instruments and at the parts per trillion (ppt) level when analysed in the laboratory. At these concentrations the gas does not disturb the system to be investigated.

A number of occupational health and safety (OHS) assessments for the use of SF₆ in underground systems have been undertaken (Hardcastle, Grenier and Gangal, 200). These usually determine the maximum dose and rate that workers could be exposed to and relate these figures back to published health guideline levels. In most cases the levels are several orders of magnitude lower than the guidelines even if a catastrophic cylinder failure occurred and the entire contents were dumped into the mine.

There are many examples of tracer gases being used to assess the degree of recirculation of intake and return air including monitoring air losses from the intake airway. There has also been significant work done on evaluating the effectiveness of seals and stoppings.

In the aftermath of a mine emergency, including earthquakes and explosions, the state of ventilation controls is often unknown. Tracer gas surveys can be used to rapidly assess changes to the airflows.

Tracer gas techniques have been pioneered in various industries where it is necessary to characterise airflows.

DEMONSTRATION PROJECT IN A WESTERN AUSTRALIAN UNDERGROUND MINE

BBE and Chemcentre recently conducted a pilot study to demonstrate how tracer gas can be used to directly measure the effectiveness of ventilation dilution. One of the more challenging areas for diesel exhaust exposure management is during shotcrete activity. Exposure sources include the diesel engine of the spraying equipment (Spraymech) and concrete agitator truck (Agi) that supplies the shotcrete during application. Another potential issue is the exposure from particulates generated from the actual spraying activity. During operation both the Spraymech and Agi operator is located outside the

cabins and both are exposed to contaminants. The pilot study focused on exposure from the Spraymech exhaust agitator truck. The pilot study was self-funded by BBE and Chemcentre to demonstrate the use of the tracer gas.

OBJECTIVE

The objective of the study was to:

- determine how the tracer gas approach can be implemented practically as part of an emissions study
- demonstrate the use of the tracer gas technology
- obtain preliminary baseline results of exposure.

The approach can then be applied on a broader scale to include more detail analysis, benchmarking of improvements and other mining activities. The ultimate objective is to use the information from the study to make improvements to secondary ventilation systems and work practices that will reduce the risk of exposure.

APPROACH

The pilot study focused on the exhaust from the Spraymech unit during the application of shotcrete. Tracer gas, from a pressurised cylinder, was released via Teflon tubing directly into the exhaust stream at the exhaust pipe at a flow rate of 10 L/min (Figure 1).

This allowed thorough mixing with the exhaust gas, which then allowed the tracer gas to behave in a similar manner to the exhaust gases and particulates in the heading. The release was successfully repeated for two different headings with varying degrees of secondary ventilation controls, which was characterised as ‘very good’ and ‘excellent’ based on a visual inspection of the fan and bag condition; however when measuring the actual heading airflow it was found that one heading did not have sufficient ventilation in the face to meet statutory requirements (Heading 1). Heading 2 on the other hand had sufficient airflow in terms of the typical statutory requirements.

Tracer gas concentrations were measured using a MIRAN SapphIRe Infrared Analyser (Figure 2). The MIRAN SapphIRe is a Fourier Transform Infrared analyser, which is battery powered and capable of logging data in real time. The analyser was set to monitor the wavelength characteristic of sulfur hexafluoride (10.708 μm) with a detection limit of 10 ppb. The analyser draws in air with a built-in pump into the long path gas cell and was programmed to log the concentration data every 30 seconds. Stored data can be downloaded to a computer for further analysis using a variety of software tools. The instrument is specific for sulfur hexafluoride and not subject to interference from components of atmosphere including water vapour or hydrocarbons from mining operations.

The analyser was located at the Spraymech operator’s position for the first heading and at the Agi operator position, plus the opposite side of the truck, for the second heading. All data was logged in the MIRAN internal memory.

A summary of the ventilation conditions in each of the headings measured is given in Table 1.

RESULTS

The data sets for the initial headings measured were sporadic, possibly due to some practical issues with the sampling and release methods. The experience from the first measurements was used to improve sampling and release techniques. Once some of the practical issues were resolved in these first headings a better data set was produced for Heading 1 and Heading 2. The results from Heading 2 gave the best data set and are shown in Figure 3. Heading 1 also gave sufficient data for interpretation (Figure 4). The other headings measured however did not give reliable data and are not presented in this summary. It should be noted that the results from Heading 2 represent ‘excellent’ secondary ventilation that meet the regulatory requirement of 0.05 m^3/s per kW.

The data shows a rapid increase in heading concentrations as the activity starts and tracer gas concentrations quickly reach a steady state of between 4 ppm and 6 ppm of tracer gas. Once the activity stops there is a clear and quick decay of gas concentration. Based on the slope of this decay curve the air exchange rate was calculated to be 26 air changes per hour (ACH). It is interesting to note that the exposure on either side is slightly different. This could be attributed to better airflow on the one side of the machine because of the bag installation relative to the equipment. This anomaly was not studied in

detail for the pilot study however should be considered in future studies as this would provide invaluable information that can lead to improved work practice. The actual location of the Agi operator was to the left, the lower exposure side.

Using a typical DPM value for a Tier 1 diesel engine the predicted DPM exposure can be calculated. The likely concentration is shown on the secondary axis and range between 0.9 mg/m³ and 1.4 mg/m³ from the Spraymech exhaust only. The average calculated exposure at the actual Agi operator location from the Spraymech was 0.7 mg/m³. It is noted that a real-time DPI instrument could be used to measure particulate levels; however, this technique cannot differentiate between the different sources or other particulates released by the Spraymech – the tracer gas technique allows an accurate estimate of specific Spraymech DPM source. Assuming that this activity occurs four to six times per shift for half an hour the Agi operator would be exposed to DPM levels between 0.18 mg/m³ and 0.26 mg/m³ on an eight-hour time weighted average basis from the Spraymech only.

The data for Heading 1 (Figure 4) where the secondary ventilation was clearly less effective showed much higher steady-state concentrations and longer clearance times as would be expected.

Ideally, in future studies the tracer gas release rate should be calibrated against the known exhaust value in a controlled environment such as the surface workshop before underground studies are undertaken.

HOW IS TRACER GAS APPLIED IN OTHER INDUSTRIES?

Hazardous materials/chemical, biological and radiological situations

Tracer gases have been used by ChemCentre in the Hazmat/ CBR (hazardous materials/chemical, biological and radiological) areas in order to understand the airflow of toxic gases either accidentally or deliberately released into an environment.

In the case where it is proposed to shelter in place from a toxic gas cloud it is vital to know the exchange between indoor and outdoor air (expressed as air changes per hour, ACH), as it is this parameter that determines the safe sheltering time. We have also applied the technology to passenger terminals to determine the safest emergency exit route or to confirm that designated safe havens or shelters will remain free of toxic materials for a sufficient period of time. In underground railway systems located in major cities worldwide tracer gases have been used to determine the speed of dispersion and understand the mechanism of transport of toxic gases (such as nerve agents) and bio-aerosols (such as weaponised anthrax) in case of terrorist attack. There are even examples of their use in multilevel hospitals to understand if viral particles can be transmitted vertically from patient to patient. These underground systems consist of shafts and tunnels and have a direct parallel with underground mines.

Some examples of the use of tracer gases for this purpose are given below.

Shelter-in-place or evacuate

When a toxic agent (chemical, bio-aerosol or radioactive dust) is released either accidentally or deliberately, one decision that is required to be made by emergency incident controllers is to instruct the general public to either evacuate the area or to shelter in place. The outdoor concentration of the toxic agent can be estimated by modelling given a known release term, wind direction, air stability and other meteorological parameters. The final parameter needed is the infiltration rate or air exchange rate between indoor and outdoor air in domestic dwellings. Until recently in Australia, emergency agencies relied upon US figures of 0.3 air changes per hour (ACH). Air exchange rates can be measured by the method of tracer gas dilution (ASTM E741–00 (reapproved 2006): Standard testing method for determining air change in a single zone by means of a tracer gas dilution). Using this methodology, we conducted a survey of 76 homes in all states of Australia and showed that in general Australian homes are more leaky than their US counterparts (Chemical Stockpile Emergency Preparedness Program [CSEPP], 2001). The recommended figure for Australia is 0.9–1.2 ACH. Figure 5 shows the effect of different air exchange rates on safe shelter times. In this example it is possible to shelter indefinitely if the air exchange is 0.3 per hour but with a higher air exchange of one per hour the safe sheltering time is exceeded after 30 minutes. The measured air exchange rates provided input to the ALOHA model in order to calculate safe sheltering times.

Predicting toxic agent levels in underground railway systems

ChemCentre has carried out a number of tracer gas and particulate releases in subway systems in Australia (Zang *et al*, 2010) and the US in order to study the possible impact of smoke and accidental or deliberate chemical release on commuters underground, as well as the public in the city streets adjacent to ventilation shafts.

The important things to know in these situations are:

- what the underground transport mechanisms are (ie diffusion, wind transport, railcar transport)
- how quickly the toxic agent moves within the subway
- where the agent goes (ie are there areas where shelter from the agent may be found?)
- whether the prescribed exit routes are safe or if that is where the gas is going to travel
- what concentration levels are reached in various parts of the tunnel system.

In addition, there was a need to be able to validate or otherwise understand whether the current computer models were accurately describing the situation.

In one case (Figure 6) the model predicted a Gaussian rise and fall of concentration as the pulse of gas passed through a particular location in the subway. The reality was quite different with the experimental gas data showing a double peak.

The difference can be explained by the fact that the model did not take into account the arrival and departures of trains, which significantly disturbed the air flow. This was CFD modelling, which is regarded as the gold standard. A model is only as good as the parameters built into it.

We have found examples of where railcars were able to uptake gas from an underground platform (Figure 7) and release the gas to unsuspecting commuters at a remote above ground station or even carry it over an aboveground bridge and the release the gas into another tunnel system. In the figure each pass is on a different railcar but the same MIRAN FTIR instrument is carried from one car to another at the railway line terminus ready for the return journey.

CONCLUSIONS

Tracer gas was used successfully in a demonstration project to characterise exhaust gas distribution during shotcrete application. The impact of the exhaust gas from the Spraymech at both the operator position and Agi operator location was measured. The data showed a significant difference between exposure for good and bad ventilation practice. Higher steady-state concentrations and slower decay of the steady- state concentrations were observed for headings with lower airflows. The data also showed some difference between operator location and how ventilation bag orientation can influence the mixing. The pilot study showed how tracer gas could be used as a tool for exhaust gas characterisation and ventilation improvement on a micro-environment scale.

The next step will be to repeat the studies for different ventilation layouts (ie force duct length, distance to face, force versus exhaust, duct orientation) and different operator locations to determine best practice standards. An important aspect of this assessment is to determine and understand the added contribution of the Agi as well as the spray nozzle as potential source of particulate. The impact of proposed improvement to engineering controls, for example diverting the exhaust pipe flow or extending the exhaust position to be closer to the auxiliary ventilation, could be assessed using this technique.

It is also noted that tracer gas is used extensively in different industries to resolve different ventilation and airflow-related issues. Tracer gas can be used in a similar way to address a large range of issues in underground mines.

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FIGURES



FIG 1 – Tracer gas released into Spraymech exhaust

HEALTH STATUS AND SAFETY INCIDENT RISK

Liam Wilson

ABSTRACT

The relationship of worker health and the outcome related to safety incident risk in mining is unknown. There have been a number studies and literature reviews relating to the impact of individual health factors (for example obesity and injuries) and workplace factors (for example fatigue and injuries) and the impact these have on safety incident risk and workers compensation costs, however nothing specific to a range of health metrics in mining. The purpose of this analysis was to use existing worker health and incident data to determine if there is a relationship between health metrics (weight, body mass index (BMI), blood pressure, blood sugar, waist measurement, cholesterol, smoking, audiometry) of employees and safety outcomes (injuries ranging from first aid through to lost time). The hypothesis was that health status influences safety incidents. The analysis of two de-identified mining operations grouped health and safety incident data, one open cut and one underground was conducted. Analysis was conducted to test the hypothesis and if so, the strength between health status and safety incident risk. The key findings were:

There is a difference in the relationships at the open cut and underground mine,

1. Individuals working in open cut mining with;
 - o a higher average BMI
 - o a wide range of systolic blood pressure readings, and;
 - o those with a lower diastolic BP;

have a higher likelihood of having an incident (95% confidence level)

2. Individuals in underground with a wide range in pulse readings over time (11.7 variance vs. 7.9 variance) have a higher likelihood of having an incident (99% confidence level);
3. Individuals in underground with a BMI trending upwards (incident: +0.8 to BMI vs. no incident: -0.4 to BMI) are more likely to be at risk of an incident (90% confidence level);
4. Certain similar exposure groups (SEG's) were more likely to have incidents. (e.g. maintenance workers in open cut).

The findings of the analysis provide information for further investigation into health factors, specifically weight/BMI, blood pressure and pulse rate. The relationships identified have been deemed statistically significant but do not necessarily represent a causal relationship. The findings will be used to focus and intervene on specific health factors (for example weight/BMI, blood pressure, pulse rate) as opposed to broad brush assessment to determine if improvement in these areas improve health status and in turn reduce safety incidents.

Keywords

Health status, Safety incident risk, First Aid, Lost Time Injury, BMI, Blood pressure, Systolic, Diastolic, SEG, Open Cut, Underground.

Introduction

The relationship of worker health status and the outcome on safety incident risk in mining is unknown. There have been a number studies and literature reviews relating to the impact of individual health factors (for example obesity and injuries) and workplace factors (for example fatigue and injuries) and the impact these have on safety incident risk and workers compensation costs. To date there has been nothing specific to a range of health metrics and specific to mining.^(8, 9, 10) The hypothesis for this analysis was that health status influences safety incidents. The analysis used site monitored health assessment data and safety incident data to determine if there was a correlation between health status and safety incident

risk, and if there was, what was the strength and specific health parameters which had a relationship with safety incident risk.

De-identified, coded health metric data was taken from two mining operations, one open cut and one underground mine for a five (5) year period from 2009-2014. Safety incident data ranging from first aid injury (FAI) through to lost time injury (LTI) was taken from the same period and correlated to determine if there is a relationship and if so, the strength of the relationship between health status and safety incident risk.

Definitions

Blood Pressure Diastolic: the measure of pressure in the arteries between heartbeats (when the heart muscle is resting between beats and refilling with blood).

Blood Pressure Systolic: the measure of pressure in the arteries when the heart beats (when the heart muscle contracts).

Body Mass Index (BMI): is a person's weight in kilograms divided by the square of height in meters. It is an inexpensive and easy-to-perform method of screening for weight category, for example underweight, normal or healthy weight, overweight, and obesity.

Open Cut (OC): a surface mining technique of extracting rock or minerals from the earth by their removal from an open pit.

Safety Incident: all incidents ranging from a first aid to lost time injury.

Similar Exposure Group (SEG): SEGs are groups of workers who have the same general exposure to risk, for example: the similarity and frequency of the tasks they perform, the materials and processes with which they work, the similarity of the way they perform those tasks.

Underground (UG): a technique of extracting rocks or minerals from the earth by their removal through tunnelling into the earth.

Method

De-identified, coded health metric³ data was taken from two mining operations, one open cut and one underground mine for a five (5) year period from 2009-2014. Safety incident data ranging from first aid injury (FAI) through to lost time injury (LTI) was taken from the same period for the analysis.

Methodology

A consultant Deloitte™ was engaged and used analytical techniques to identify correlation based relationships between different attributes in the data (the Analysis). The techniques used for the analysis of the data included correlation, multiple regression (Generalised Linear Models) and statistical hypothesis tests.

Microsoft SQL was used for data preparation. R statistical analysis software was used for statistical analysis. Tableau software was used for the visualisation of results.

The relationships identified by the analysis were assessed based on the strength of the relationship and only those identified as significant (at a 90% confidence level⁴ or higher) have been included.

The analysis was conducted using data from a total of:

³ Health metric data refers to individual employee health based measurements recorded as part of health assessments.

⁴ A 90% confidence level was used to identify potential relationships between health metrics and incident rates. As causal relationships are not being identified, it is appropriate to use a more relaxed confidence level (as opposed to a more typical 95% confidence level).

- 868 workers;
- 2585 Health assessment records associated with these workers;
- 805 Injury incident records⁵.

Health metrics used in the Analysis⁶ were:

- Weight;
- Body Mass Index (BMI);
- Blood pressure;
- Waist measure;
- Cholesterol;
- Gender;
- Smoking;
- Audiometry;
- Lung Function

The analysis focused on identifying any relationships² between each health metric and injury incidents at the site.

The final component of the analysis was related to SEG's and incident likelihood. Individuals were placed into their SEG and an analysis was conducted to determine if there were SEG's which had a higher occurrence of incidents than others.

Outlier values in the data were identified and assessed, and where unable to be validated, were excluded from the analysis. Strong relationships (coefficient of correlation (r) >0.5) were identified to determine if they had the potential to create a bias on the analysis.

Analysis was performed on all health assessment data whether the worker had had an incident or not. Only injury based incidents which could be associated with worker health assessment were included in the analysis.

Limitations

The relationships have been deemed statistically significant² but do not necessarily represent a causal relationship. Metrics were excluded from the analysis where there were insufficient health assessment data (e.g. blood sugar and cholesterol). It was assumed that all employees in the data were employed for the 5 year review period.

Results

The results of the Analysis are summarised for open cut and underground below.

Table 1: Summary of Study Statistics

Metric	Open Cut	Underground
# Employees	420	448
Injured proportion	30%	42%
Average age	41.2	40.4

⁵ Injury incident records include records of first aid injury through to Lost time injury

⁶ Due to low completeness percentages, blood sugar, waist and cholesterol was excluded from the analysis

Gender Split	7% (F) 93% (M)	5% (F) 95% (M)
Weight (kg)	91.2	89.4
Lung function (FEV1/FVC ratio)	83.9%	79.6%

Open Cut

- There were 1047 health assessments for 420 workers.
- 77% of the open cut workers that had an incident were matched to a health assessment.
- 161 employees accounted for 304 injury based incidents.
- 37 workers did not have a health assessment,
- 124 employees (of the 420) were matched to 208 injury based incidents. Analysis was conducted on this data set.

Summary of results is presented in Table 2:

Table 2: Open Cut Analysis summary

Metric	Correlation with likelihood of a safety incident	Statistically significant?	Confidence level
Age	Older employees are more likely to have an incident – highly correlated with BMI	No	-
Gender	No correlation found.	No	-
SEG Group	Maintenance workers at greatest risk of incident, Support staff at lowest risk.	Yes	95%
Smoker	Some qualitative evidence to suggest that smokers were more likely to be at risk of an incident	No	-
Pulse	Some qualitative evidence to suggest employees with a pulse trending upwards are more likely to be at risk of an incident	No	-
Blood Pressure	a. Employees with a large range in their systolic BP were more likely to be at risk of an incident b. Employees with a lower diastolic BP were more likely to be at risk of an incident	a. Yes b. Yes	a. 95% b. 95%
Waist	<i>Not included due to limited number of employees with recorded measurements</i>	N/A	N/A
Weight	<i>Not included due to strong correlation with BMI</i>	N/A	N/A

BMI	Employees with a higher average BMI were more likely to have had an incident	Yes	95%
Cholesterol	<i>Not included due to limited number of employees with recorded measurements</i>	N/A	N/A
Blood sugar	<i>Not included due to limited number of employees with recorded measurements</i>	N/A	N/A
Lung function	No correlation found.	No	-
Eyesight	No correlation found.	No	-

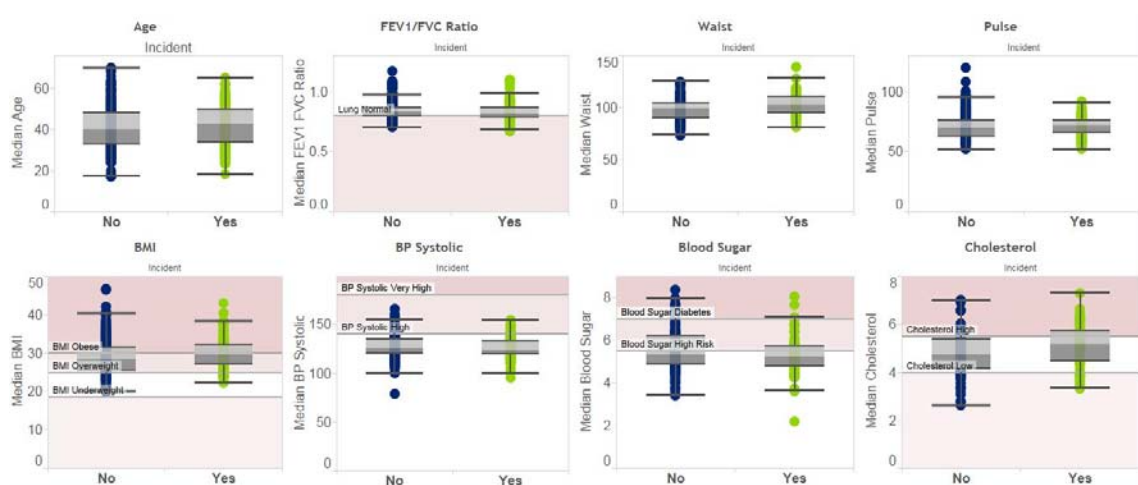


Figure 1: Box plots for open cut health metrics

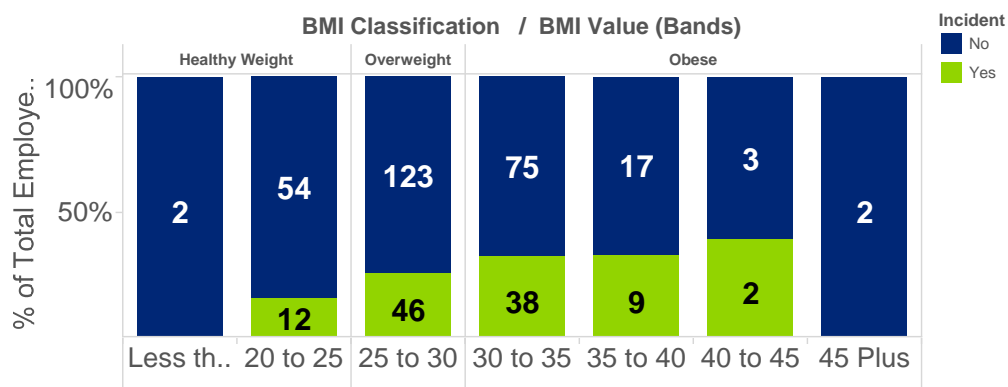


Figure 2: % employee incident versus BMI (green = incident, blue = no incident)

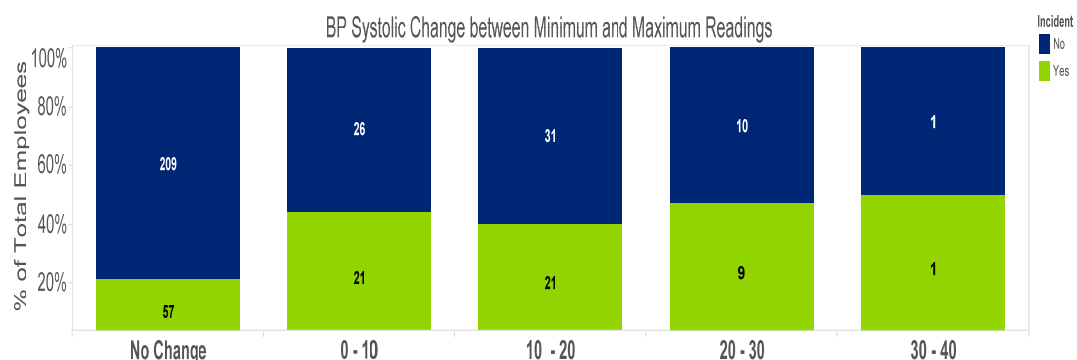


Figure 3: % of Groups having an incident – Variable BP Systolic (green = incident, blue = no incident)

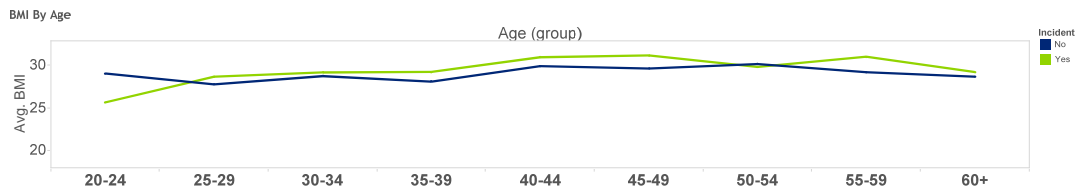


Figure 4: BMI and incident status by Age (green = incident, blue = no incident)

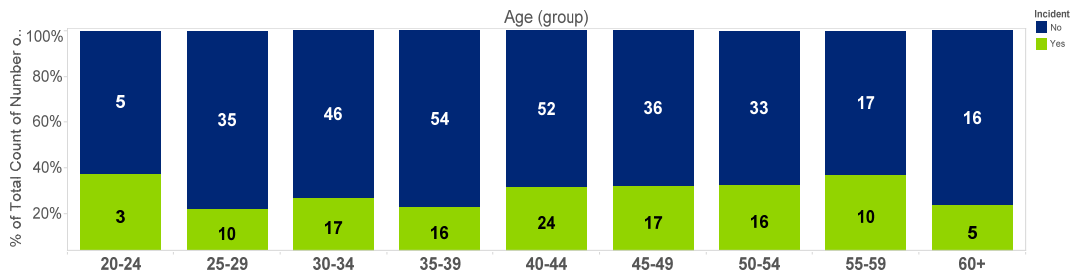


Figure 5: % of Age group having an Incident (green = incident, blue = no incident)

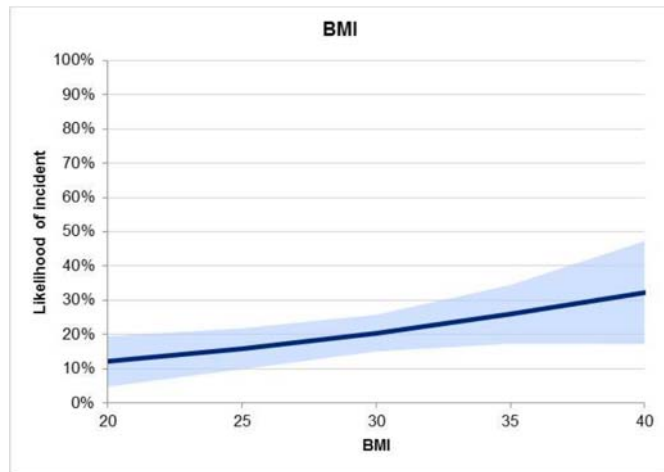


Figure 6: Likelihood of an incident vs. BMI

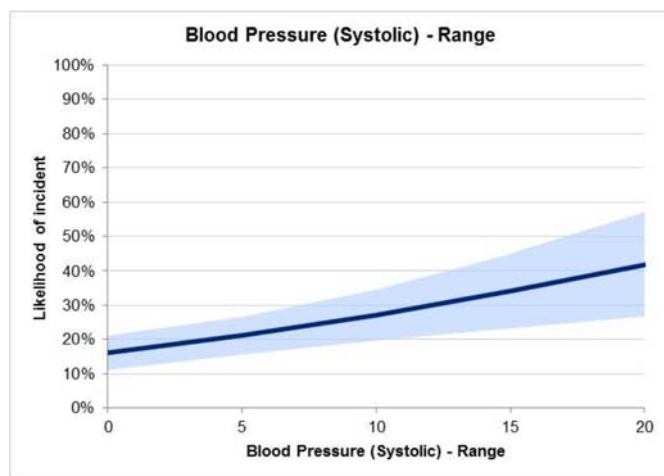


Figure 7: Likelihood of an incident vs. Blood pressure (Systolic) range

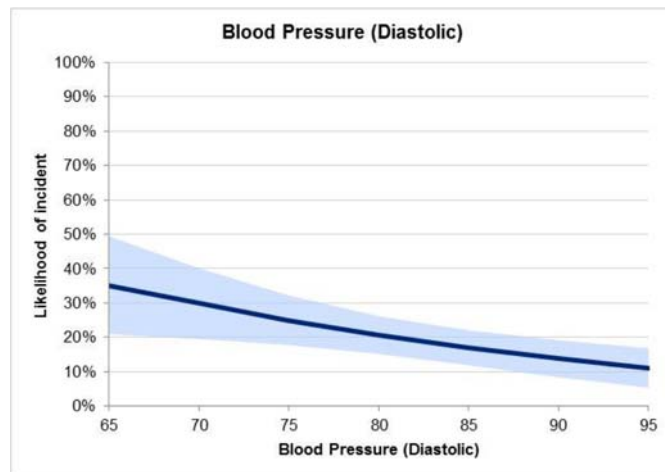


Figure 8: Likelihood of an incident vs. Blood pressure (Diastolic)

Underground Mine

- There were 1538 health assessments for 488 workers.
- 75% of the open cut workers that had an incident were matched to a health assessment.
- 190 employees accounted for 353 injury based incidents.
- 63 workers did not have a health assessment,
- 190 employees (of the 448) were matched to 353 injury based incidents. Analysis was conducted on this data set.

Summary of results is presented in Table 3:

Table 3: Underground Analysis summary

Metric	Correlation with likelihood of a safety incident	Statistically significant?	Confidence level
Age	No correlation found.	No	-
Gender	No correlation found.	No	-
Smoker	No correlation found.	No	-
Pulse	Employees with a large range in their pulse were more likely to be at risk of an incident	Yes	99%
Blood Pressure	No correlation found.	No	-
Waist	Not included due to limited number of employees with recorded measurements	N/A	N/A
Weight	Not included due to strong correlation with BMI	N/A	N/A
BMI	Employees with a BMI trending upwards are more likely to be at risk of an incident	Yes	90%

Cholesterol	<i>Not included due to limited number of employees with recorded measurements</i>	N/A	N/A
Blood sugar	<i>Not included due to limited number of employees with recorded measurements</i>	N/A	N/A
Lung function	No correlation found.	No	-
Eyesight	No correlation found.	No	-

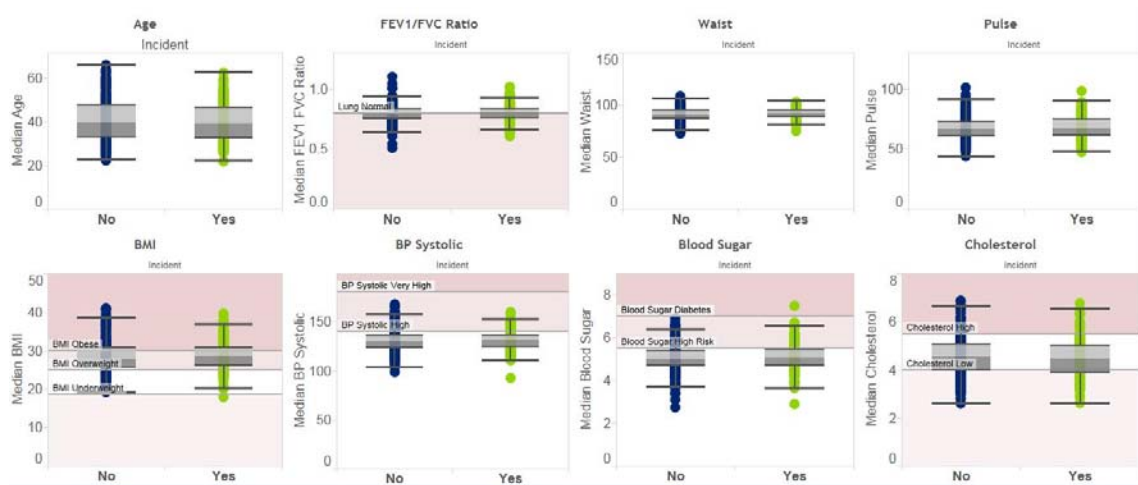


Figure 9: Box plots for underground health metrics

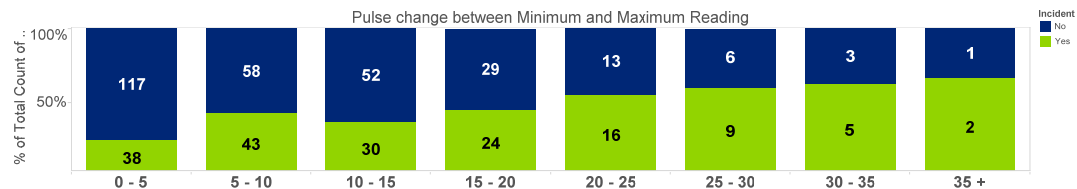


Figure 10: Pulse change between Minimum and Maximum reading (green = incident, blue = no incident)

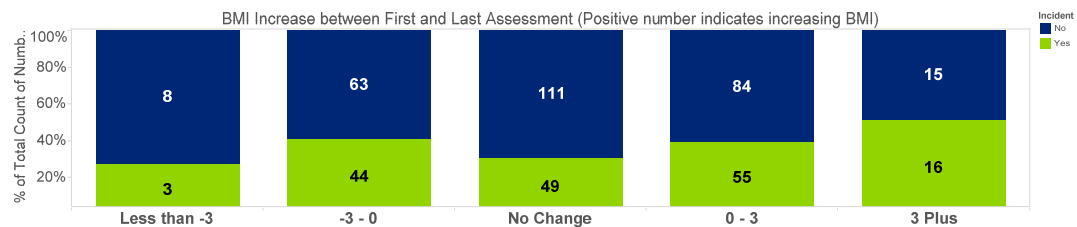


Figure 11: BMI increase between first and last assessment. Positive number indicates increasing BMI (green = incident, blue = no incident)

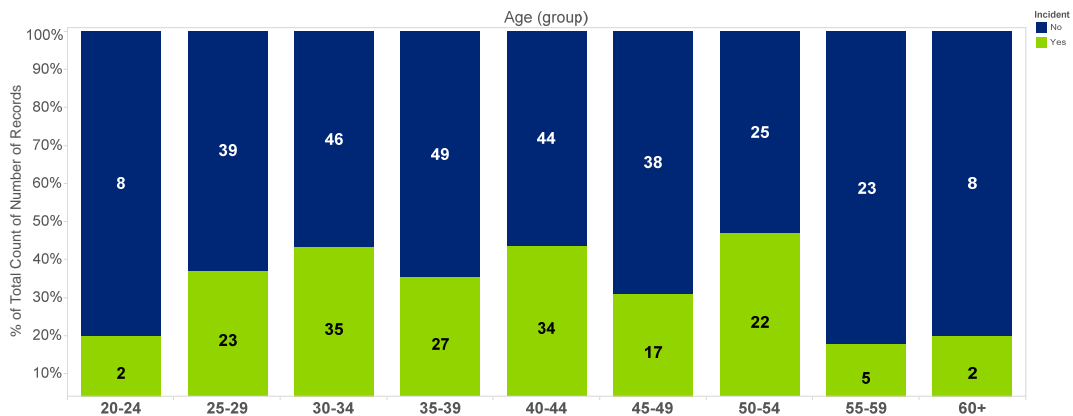


Figure 12: % of Age Groups having an incident

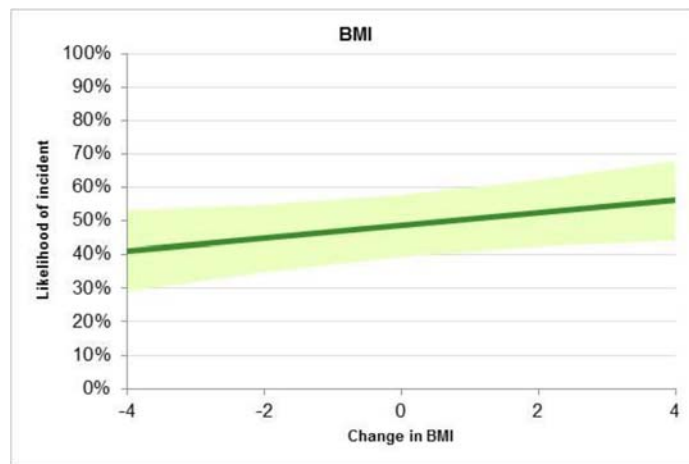


Figure 13: Likelihood of an incident vs. Change in BMI

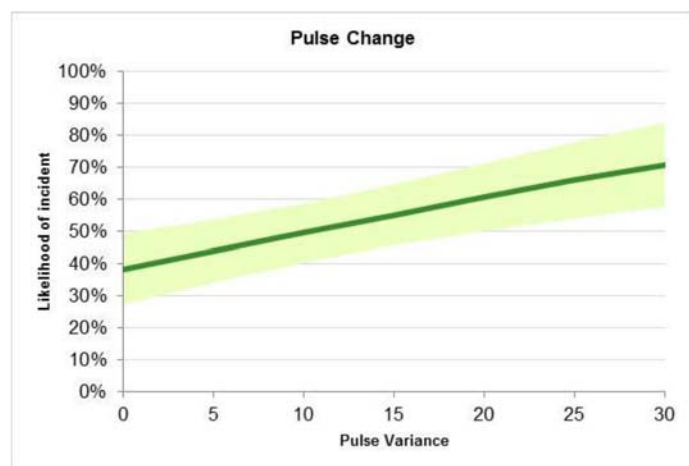


Figure 14: Likelihood of an incident vs. Pulse Variance (mmHg)

Key Findings

. The key findings for open cut and underground are outlined below.

Open Cut Mine

- Employees that have a higher average BMI were found to have a higher likelihood of having an incident than those with a lower BMI (95% confidence level);
- Employees with larger variance in their systolic BP readings across the 5 years of analysis were found to be more likely to have an incident than those that had lower variance (95% confidence level);

- Employees having a low average diastolic BP diastolic also increased in risk (95% confidence level);

Underground Mine

- Employees that have a greater variation in pulse rate (i.e. have a larger range on their pulse readings over time) are more likely to have had an incident [11.7 variance vs 7.9 variance] (99% confidence level);
- Employees who's BMI increased across the 5 years of analysis were more likely to have had an incident [incident = +0.8 to BMI over 5 years, no incident = -0.4 to BMI over 5 years] (90% confidence level).

General Findings/Observations

The general findings for the open cut and underground are outlined below.

Open Cut Mine

- Older age groups (40+) are having proportionately more incidents than younger age groups
- The maintenance worker SEG was two times more likely than production workers to have an incident;
- There was no correlation between gender, eye sight, lung function and the likelihood of an incident.

Underground Mine

- There was no correlation between age, gender, smoker, blood pressure, eye sight, lung function and the likelihood of an incident.

Discussion

The study found that there is a correlation between some health metrics and safety incidents, being:

- BMI,
- blood pressure, and
- pulse rate.

Although not the primary function of the analysis, the study also found that the correlation was different from open cut to underground. Open Cut analysis identified correlation with incidents where there was a higher average BMI, variance with systolic BP and lower diastolic BP, whereas, underground identified correlation with incidents where there was a greater variation in their pulse and with an increase in their BMI over the 5 years.

For open cut, the analysis found that the average BMI was 29. Based on the BMI and incident data, an average BMI of 29 correlated to a 20% increase in the likelihood of a safety incident. The likelihood of a safety incident occurring decreases by 8% when the employee is in the normal BMI range (BMI 21-25) compared to the overweight range of >25. Alternatively as the BMI increases, so too does the risk of a safety incident. A BMI of 20 correlated to a likelihood of an incident of 11%, a BMI of 40 correlated to a likelihood of an incident of 32%.

Employees whose systolic blood pressure varied over the measurement period (five years), had an increased in safety incident risk. Based on the data, no change in the systolic blood pressure over the measurement period showed a 16% likelihood of an incident. A change in the systolic blood pressure over the measurement period of 20 mmHg showed a 41% likelihood of an incident. Diastolic blood pressure showed a correlation with likelihood of an incident. The lower the diastolic blood pressure, the higher the likelihood of an incident. Guidelines for a healthy diastolic blood pressure is <80 mmHg (6). A diastolic blood pressure of 65 mmHg showed a 35% likelihood of an incident. A diastolic blood pressure of 80 mmHg showed a 20% likelihood of an incident. A diastolic blood pressure of 95 mmHg (hypertension/high blood pressure) showed a 10% likelihood of an incident. The analysis shows that an increase in the diastolic blood pressure (mmHg) results in a decreased likelihood of a safety incident. This analysis and correlation requires further investigation due to cardiovascular disease risk and other health impacts of higher than recommended diastolic blood pressure levels.

There was no correlation found between gender, eye sight, lung function and the likelihood of an incident.

For underground, The analysis showed that a high pulse variance results in a higher likelihood of an incident. Based on the data, no change in pulse over the measurement period had a 39% likelihood of an incident. A pulse variance of 30 over the measurement period had a 70% likelihood of an incident. Further investigation is required into the causation of variance of the employees over the measurement period.

The analysis showed that there was little difference in the mean BMI of those who had had an incident and those who hadn't (28.9 vs. 28.5). However, the analysis showed that a change in the BMI over the measurement period influenced the likelihood of an incident. The data showed that an incident occurred where there was an increase in the BMI of +0.8 over the measurement period. No incident occurred where there was a decrease of 0.4 to BMI over the measurement period.

The data was insufficient for the analysis to determine if there is a correlation between blood sugar and cholesterol and the likelihood of incident.

Conclusion

The analysis has shown a correlation between some health metrics and increased safety incident risk. It showed that there was a correlation between some health metrics (BMI, blood pressure) and no correlation for others (gender, eye sight, lung function). There may be potential correlation for blood sugar and cholesterol; however there was insufficient health assessment data to determine if a correlation exists.

The analysis provides an insight into where some relationships occur between health metrics and safety incident risk. It provides information and direction for further areas of investigation and analysis to be conducted and where causation needs to be determined. The study provides some specific areas where if health in those metrics were improved, for example BMI, and measured along with incidents, it could be determined if the safety incident risk decreases.

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CHALLENGES OF IMPLEMENTING A BUY QUIET PROGRAM IN AUSTRALIA IN 2014

Simon Worland

ABSTRACT

Noise Induced Hearing Loss (NIHL) caused by excessive exposure to noise is a major health issue in Australian industry. It is generally accepted that most retrofit noise controls are difficult to maintain and do not deliver business value in terms of exposure reduction per unit cost. Buy Quiet programs relate to procurement of plant and equipment that does the same job but emits lower noise and are considered a feasible way to reduce noise exposure to workers without leading to overly onerous business costs. There is a perception that Buy Quiet programs are sufficiently supported by legislation and that the employers have all that they need to influence the purchase of equipment that emits lower noise. However my experience in Australia suggests that this is not the case. This study describes how obtaining reputable and comparable noise data from suppliers of noisy mining equipment in order to compare apples with apples during Buy Quiet evaluations was not able to be achieved. The study highlights that one reason Buy Quiet programs continue to be ineffective is a lack of knowledge among suppliers of what “noise data” means.

POSTER ABSTRACTS

WHOLE BODY VIBRATION ACROSS THE MINING INDUSTRY

Vasos Alexandrou

Vipac Engineers and Scientists Ltd

The poster presentation will provide a statistical analysis of Whole Body Vibration results measured across the mining industry, as measured by me, during my time at Vipac Engineers.

It will provide a comparison of vibration levels, ratings and results according to different vehicle types and conditions.

The aim being to depict the varying nature of Whole Body Vibration across the mining industry.

HOW EXTENSIVE SHOULD A BUILDING INVESTIGATION BE? CASE STUDY OF A WATER DAMAGED PROPERTY WITH TOXIGENIC MOULD IN THE ROOF SPACE

Jacqueline Campbell¹, Kevin White² and Cedric Cheong³

¹Indoor Air Quality Solutions, ²Greencap, ³Endeavour College of Natural Health

INTRODUCTION: The development of symptoms in individuals exposed to airborne fungi depends on the nature of the fungal material (allergenic, toxic, or infectious), the amount of exposure, and the susceptibility of exposed individuals. For the majority of healthy individuals, a musty or damp odour may be noticed but typical fungal exposure does not cause any obvious reactions or health effects. However, for susceptible individuals, like those with impaired or immature immunological or respiratory systems, even short-term, low level exposure to fungi could lead to or exacerbate medical health conditions. This paper describes the investigation and remediation actions of a damp and water damaged property rented by a family of immunocompromised individuals.

METHODS: An investigation of the property for water and mould damage was conducted involving a series of visual inspections, measurements and field sampling. Moisture testing was conducted with penetrating and non-penetrating moisture meters to determine the moisture profile and extent of water damage. Air and surface mould samples were obtained using culturable and non-culturable techniques.

RESULTS: Since occupying the property the occupants reported a number of additional health concerns including nose bleeds, vomiting, and diarrhoea, fluid-affected cough, extended periods of fatigue / lethargy, ear infections, high blood pressure and an increase in asthma symptoms requiring additional medication. Viable air testing from indoor areas showed indoor mould levels were below the outdoor concentration and of similar composition to the outdoor reference sample at the time of testing. Visible water damage was noted on the ceilings of a bedroom however there was no visible mould growth within the interior of the property. An inspection of the roof space revealed previous damage to the roof, mould growth on layers of discarded wet gyprock and leftover building debris in the roof space. Surface testing confirmed the presence of a number of toxigenic moulds including *Chaetomium sp.*, *Stachybotrys sp.*, and *Stemphyllum sp.*

CONCLUSIONS: Symptoms reported in published case studies related to exposure to toxigenic moulds (mycotoxins) by susceptible individuals include many of the health effects being reported by the individuals in the dwelling. A thorough investigation by a skilled and experienced practitioner was critical in identifying hidden mould that was negatively impacting the health of occupants.

THE RISKS OF RELIANCE ON DATA ONLY - WHAT ARE YOUR AIR SAMPLES NOT TELLING YOU?

Jacqueline Campbell¹, Kevin White² and Cedric Cheong³

¹Indoor Air Quality Solutions, ²Greencap, ³Endeavour College of Natural Health

INTRODUCTION: A substance can only cause health effects if it comes in to contact with the human body through one or more of the four recognised pathways - inhalation, ingestion, absorption and / or injection. Of these four exposure routes inhalation of a substance is the most common way for a pollutant to enter the human body. To effectively manage a respiratory risk the nature of the hazard must be understood and the most common way of quantifying airborne hazards is to sample the air within the work area and check that contamination levels are below occupational health guidelines and

standards. Based on this data decisions are made regarding the health and safety of team members working in the environment.

METHODS: Airborne sampling data was collected across three common occupational hygiene scenarios: clearance testing following a friable asbestos removal job, bioaerosol sampling during a water damage investigation and TVOC sampling during a 'health complaint' investigation. Each data set was independently reviewed by a second appropriately experience team member who did not attended the on-site inspection and had no context for the data; their interpretation and recommendations were noted. This same data was then reviewed 'in context' by the responsible investigator taking in to account the visual inspection, the history of the indoor environment and, where appropriate, the experience of the building occupants.

RESULTS: In all three data scenarios there were differences in the recommendations made by each of the reviewers.

CONCLUSIONS: While high integrity data is an important component to the quantification of airborne hazards this data must be challenged and revalidated if it is not congruent with the findings of a visual inspection completed by an appropriately experienced person, the pattern of historic data or the experience of the building occupants. Hazard management decisions based on data alone should be treated with the utmost caution.

FISKVILLE FIREFIGHTER'S HEALTH STUDY

DC Glass, S Pircher, A Del Monaco and MR Sim

Monash Centre for Occupational and Environmental Health Department of Epidemiology and Preventive

Aim

To investigate mortality and cancer incidence of firefighters who worked, were trained or volunteered at the Country Fire Authority (CFA) Fiskville firefighter training facility between 1971 and 1999.

Methods

CFA supplied human resources (HR) records which were supplemented by self-reported records for a retrospective cohort. Firefighters were allocated to Low (n=252), Medium (n=256) or High (n=95) groups by CFA based on presumed extent of exposure to hazardous materials. Individuals contributed person-years from when they started at Fiskville. The cohort was linked to the National Death Index, the Victorian Cancer Registry and the Australian Cancer Database. Standardised Mortality Ratios and Standardised cancer Incidence Ratios (SIR) were calculated.

Results

Firefighters in the High group had a significantly raised incidence of overall cancers SIR=1.85 (95%CI 1.20-2.73) relative to the Victorian population. Testicular cancer SIR=11.9 (1.44 - 42.90) and melanoma SIR=4.59 (1.68 - 9.99) were also significantly increased in this group.

Brain cancer was significantly increased for the Medium group SIR=5.74 (1.56 - 14.70) and this was more strongly associated with paid than volunteer firefighters in this group.

Mortality was low in the Fiskville cohort. There may be under-ascertainment of the Low and Medium group volunteers probably because of missing HR records.

Conclusions

Despite the small numbers, the High group has a clearly increased risk of cancer. Possible ascertainment problems mean that the findings for the Medium and Low groups are likely to underestimate the risk and should be treated with caution. Future linkages will give more robust estimates of cancer and mortality.

RESPIRABLE CRYSTALLINE SILICA EXPOSURE IN WESTERN AUSTRALIAN HORSE RIDING INSTRUCTORS

Sarah Jackson

This study investigated the respirable crystalline silica (RCS) exposure of horse riding instructors teaching pupils on sand arenas. The assessment involved personal monitoring of 19 horse riding instructors (20 samples) in Perth, Western Australia for RCS during March and April 2014 and compared the results of exposure from workers in irrigated and non-irrigated arenas. Analysis of samples for RCS (FTIR) was performed and the results analysed using IHSTAT. Instructors completed a brief questionnaire to enable calculation of their time spent teaching and to document any respiratory health effects experienced.

The results demonstrate that horse riding instructors working in non-irrigated, sand arenas during summer are likely to be exposed to RCS levels well above the occupational exposure standard (OES) (MVUE at 183% of OES, UCL1,95% at 883% of OES). In comparison, instructors in irrigated sand arenas are unlikely to be exposed above the OES (MVUE at 12% of OES, UCL1,95% at 21% of OES).

The self-reported incidence of respiratory health effects (coughing, wheezing, dry throat, sneezing or shortness of breath) whilst teaching was found to be significantly higher for instructors with measured RCS exposure results >50% of the OES (71% reported incidence), than for those with measured exposure results <50% of the OES (37.5% reported incidence).

Respirable crystalline silica exposure was found to be a critical risk likely to cause health effects for horse riding instructors working in non-irrigated, sand arenas in summer. Irrigation of arenas prior to teaching was found to effectively control the hazard.

CLEANING THE AIR:DIRTY JOBS

A Liebenberg and I Richardson

The University of Newcastle

This investigation was initiated as a result of an alleged health incident resulting from exposure to styrene during sewage relining works. This investigation was conducted to determine the exposure potential and concentration of styrene that workers are exposed to during the Cured In Place Pipe (CIPP) method. A CIPP trial project was established in order to obtain representative data for the purposes of assessing potential emission of styrene and other Volatile Organic Compounds (VOCs).

Static and personal samples were sampled in accordance with the Australian Standard AS 2986.2 (2003) Workplace air quality, sampling and analysis of volatile organic compounds by solvent desorption / gas chromatography, Part 2: Diffusive sampling.

The site observations and findings of the CIPP emissions assessment indicate that there is the potential for styrene to accumulate within the sewer system downstream of CIPP works. In particular, the low level of dilution and ventilation in the enclosed downstream sewer system may result in the accumulation of styrene levels to significant concentrations.

Dependent on the location of such activities, this could potentially result in exposure for other workers in the proximity of the works, particularly if working in or near the sewer system immediately downstream. The low odor threshold of styrene raises the potential of future complaints regarding odor or perceived exposure to airborne contaminants. Simple dispersion modeling indicates that there is the potential for odor impacts to extend a significant distance from the site depending on the site conditions during the works.

DEVELOPMENT OF A HEALTH MONITORING PROGRAM FOR DRINKING WATER QUALITY MANAGEMENT

Heath Bennett and David Lowry

Rio Tinto

The Pilbara Utilities Division is responsible for supplying water, electricity, hydrocarbons and radio communications to Rio Tinto Iron Ore operational sites and towns within North-Western Australia. The large portfolio of responsibility to provide these services and the varied associated risks that are inherent through the provision and consumption of these services

has driven the division to explore risk mitigation through embedded programs to track risk controls. The primary aim is to ensure that “critical controls” key to the prevention and/or mitigation of health risk exposure are identified, are functioning as designed and are understood by all. In an effort to achieve this, a Health Monitoring Program (HMP) has been developed with an emphasis on Drinking Water Quality Management. The primary aim of which is to ensure that no customer or personnel member develops an illness caused through consumption of contaminated drinking water. The development and validation of the HMP for this particular aspect will ensure the appropriate controls are implemented to the required standard and monitored to ensure their effectiveness. It is anticipated that it will also increase the awareness of the risk associated with the provision of drinking water within the risk owners and the Pilbara Utilities Division employees. This paper will outline the five key critical control points that were developed to address this need, and will discuss the rationale behind the decision to include these controls.

ASSESSING WORKER ATTITUDES ABOUT USE OF HEARING PROTECTORS AND EFFECTS OF INTERVENTION FOLLOWING INDIVIDUAL FIT TESTING

Ted Madison

3M USA

Attendees will learn about a study that assessed attitudes toward the use of hearing protection devices (HPDs) and the effect of an educational intervention on fit-testing results by comparing personal attenuation ratings (PAR₅₀) before and after the intervention. Employees (n = 327) from a large metal container manufacturer at four geographic locations were tested with a field attenuation estimation system (FAES) to identify workers (n = 91) requiring intervention. PAR₅₀ values significantly increased from baseline to post-intervention (p < .001, 15.1 to 26.9) and at the 6-month follow-up (p < .001, 95% confidence interval = -11.2, -6.3). Perceived self-efficacy scores for using HPDs significantly declined from baseline to post-intervention (p = .006, 95% confidence interval = 0.3, 1.9), but were not significantly related to PAR₅₀. Therefore, a FAES can assist occupational health professionals to identify workers at high risk (low PAR₅₀), teach proper fit and use of HPDs, and improve hearing protector selection.

NATURALLY OCCURRING ASBESTOS: AIRBORNE LEVEL ASSOCIATED WITH DISTURBANCE

Dr Alison J. Morgan, Mr Craig Lamberton

NSW Environment Protection Authority

Aim: To review the current literature on Naturally Occurring Asbestos (NOA) and collate data on asbestos levels in air during disturbance to NOA areas. To encourage the provision of unpublished data, where it exists, to take additional samples in areas of high potential NOA and to expand the information base to support sound decision making.

Data Assessment: The term Naturally Occurring Asbestos (NOA) is used by public health professionals to describe asbestos that is not commercially mined or used but may be disturbed by human activity. It can be found *in situ* within specific rock types at varying levels. A data search of the current literature for air asbestos levels in and around the vicinities of NOA areas and additional air monitoring was undertaken in Port Macquarie, Woodsreef and Tumut.

Conclusion: This review of the literature and collation of additional air monitoring samples indicates that there are some activities that create dust and may have the potential for asbestos fibres to be inhaled, thereby increasing the risk of developing asbestos related diseases. Additional research in regards to NOA to ascertain potential exposure scenarios would be valuable. Whilst there has been a prolonged campaign in Australia to control asbestos exposures in industry and mining activities and in managing the legacies of asbestos containing materials, there may be some aspects of the communities' interaction with NOA in non-traditional areas such as road building and maintenance; agriculture and recreational activities that may benefit from improved data and prudent control measures to reduce potential exposures.

SETTING GUIDELINES TO PROTECT HEALTH AND COMMUNITY CONCERNS – A BALANCING ACT!

Lindy Nield, Pierina Otness & Dr Martin Matisons

Western Australian Department of Health

Health risk assessment is fundamental in setting public health guidelines to protect the most sensitive people living our communities. Scientific knowledge from the fields of chemistry, epidemiology and toxicology forms the basis of all decisions made by government public health authorities employing a precautionary approach as a rule. However, there have been several cases within Western Australia over the past ten years where consideration of community concerns has influenced the magnitude of the safety factor that was adopted. Issues may be unique to the agent of concern (asbestos, lead and nickel) or idiosyncratic of the local geography (historically settled on heavily mineralised soils) or managed in consultation with the local community itself (prior experience with environmental contamination). This paper presents three highly publicised case-studies and discusses what needs to be balanced when setting appropriate health guidelines to protect public health and manage risk perceptions of community inhabitants.

Key words: Health Guidelines; Public Health; Asbestos; Nickel; Lead

IF SMOKING CIGARETTES POTENTIATES NOISE-INDUCED HEARING LOSS, SHOULD SMOKERS BE COMPENSATED?

Lindy Nield, Dr Le Jian, Dr Yun Zhao & Dr Janis Jansz

School of Public Health, Curtin University

Smoking is a serious public health issue that is a major cause of lung and other cancers and cardiovascular disease. Many mining employees in Western Australia consider smoking at work is their personal choice and right, and this has often been supported by their employers. This paper will explore existing scientific literature regarding the potential for cigarette smoking to increase hearing loss in noise-exposed and not exposed employees. A current investigation of the hypothesis that there is dose-response relationship between pack-years and adult onset hearing loss among Western Australian mining employees, who participated in the Mine Health Surveillance Program between 1996 and 2013, will also be described.

The relationship between smoking and hearing loss has had some concentration over the past ten years with several investigations concluding a positive correlation between smoking cigarettes and hearing loss exists. However, while exposure to side-stream smoke is an occupational health issue, the argument of personal choice has prevented mining employers from prohibiting smoking at work. Yet through integration of this public health message into the occupational health forum, one may question whether there is sufficient incentive to ban cigarettes on mines, or preferentially employ non-smokers, if there is evidence that smoking contributes to, or potentiates, compensable hearing loss.

Key words: Smoking; Cigarettes; Noise Induced Hearing Loss; Compensation; integrating public and occupational health

LEAD RISK WORKERS OVER THE YEARS – TRENDS IN REPORTED BLOOD LEAD LEVELS

Sally North

WorkSafe WA

Background

WorkSafe (WA) requires blood lead levels (BLL) for lead risk workers be reported to the agency. This allows regulatory intervention in the case of high levels. As a result, WorkSafe has data on BLL over some decades. At a national level, there is a current discussion about the adequacy of the BLL at which workers must be removed from lead risk work, and whether a reduction in this level will be practicable for businesses.

Aim

This poster aims to illustrate the trends of BLL among WA lead risk workers over the last 20 years.

Data analysis

WorkSafe data will be analysed to illustrate changes in mean BLL over the last 20 years. The distribution of BLL within the last 12 months will also be examined.

Limitations of the dataset will be noted.

Conclusions and recommendations

Conclusions in relation to the trends over time and on the current reported BLL, and the feasibility of regulatory change to BLL removal levels, will be provided.

This poster should serve to *inform* delegates about current exposures, and also provide *inspiration* by way of improvements that can be observed over time.

DERMAL LEAD LEVELS, HYGIENE FACTORS AND BLOOD LEAD LEVELS IN FIRE ASSAY WORKERS

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Background

Fire assay workers have significant lead exposure, which is associated with a range of adverse health outcomes. Lead on the hands may contribute to exposure via ingestion (from hand to mouth transfer) and skin absorption.

In Australia, consideration is being given to reducing workplace exposure standards for airborne lead, and reducing the blood lead levels (BLL) at which workers must be removed from lead risk work (Safe Work Australia, 2014). Employers will face increased challenges in maintaining worker lead exposure below the required level to avoid the business costs of removing a lead worker from lead work.

Aim

This project was aimed at improving understanding of the potential impacts of dermal lead exposure in contributing to BLL of fire assay workers. This includes determining whether there is a correlation between dermal lead on the hands of fire assay workers, and their most recent BLL.

This work is consistent with the “inform” theme, focussing on hazard identification, evaluation and control.

Methods

A minimum of 5 assay labs were visited and lead workers were invited to participate in the study. The workers were asked to complete a questionnaire on hygiene and other exposure risk parameters, and were asked to self-administer a dermal wipe over both hands mid shift, and again at the end of the shift after washing or showering in accordance with normal procedures. Approximately 90 dermal samples were collected and participants asked for consent to access their existing blood lead data.

Controls at the workplaces were reviewed.

Analysis was provided by ChemCentre in accordance with NIOSH method 9100.

Results

The correlation data between dermal lead and BLL, and between hygiene parameters and BLL, will be presented. The contribution of workplace control factors will be observed qualitatively.

Conclusions and recommendations

Conclusions and recommendations relating to the results achieved, especially in relation to improving control of exposures, will be included.

References

Safe Work Australia. (2014). *Review of hazards and health effects of inorganic lead – implications for WHS regulatory policy*. Retrieved from <http://www.safeworkaustralia.gov.au/sites/SWA/about/Publications/Documents/871/Review-hazards-health-effects-inorganic-lead-report.pdf>

CLASSIFICATION OF HOUSEHOLD HAZARDOUS WASTE

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ChemCentre

The Western Australian Local Government Association has established the Household Hazardous Waste program to assist with the safe collection, storage and disposal of potentially hazardous household products. These products contain chemicals or substances that could be harmful, flammable, toxic, reactive or corrosive. The correct disposal of these can only occur once these products have been classified according to their dangerous goods code. ChemCentre carries out on-site chemical classification, using a combination of classical wet chemical tests and state of the art portable instruments. Portable instrumentation used, include Photoionisation Detectors for identification of volatile organic compounds, flame photometric detection for sulphur and phosphorous compounds, particularly pesticides, Fourier Transform Infrared and Raman spectroscopy for classification of unknown liquids and solids. Once completed, the classification allows for the safe disposal of these products by an authorised contractor.

EVALUATION OF A SOLVENT FREE “DRY SAMPLER” FOR THE DETERMINATION OF MONOMERIC AND OLIGOMERIC ISOCYANATES IN WORKPLACE AIR

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SGS Leeder Consulting

Isocyanates are highly reactive, low-molecular weight chemicals classified as monomers or polyisocyanates. Oligomers are a special class of low molecular weight polyisocyanates with 10 or less diisocyanate monomers.

These chemicals are commonly used in a range of applications and isocyanate exposure is associated with a range of negative health outcomes.

Isocyanate sampling can be difficult as the species of interest can be in the form of vapours or aerosols with various particle sizes. In addition, the compounds of interest may be reactive and unstable and the analytical standards can be difficult to source.

Air sampling using traditional “wet” methods can be challenging and recent literature suggests that wet samplers may underestimate isocyanate exposure as they do not discern vapours from aerosols.

The “ASSET EZ4-NCO” dry sampler is an excellent alternative to these methods and offers a number of benefits including, ease of sampling, high sensitivity and measurement of vapour phase and particulate isocyanate monomers and oligomers.

Previous validation work done by SGS Leeder Consulting focused on isocyanate monomers. Recent work has included oligomers which also need to be considered during air sampling exposure assessment.

There have been a number of recent studies comparing traditional methods of sampling with the new dry sampler method and a summary of the comparisons will be presented.

The presentation will include a description of the laboratory and field work undertaken to confirm that the “dry sampler” is an accurate, reliable and cost effective option for measuring airborne isocyanate monomers and oligomers.

AN ASSESSMENT OF NOISE EXPOSURE FOR MUSICIANS IN A MARCHING FLUTE BAND

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OHMS Hygiene

Marching flute bands are a source of enjoyment and entertainment for musicians and audiences at a variety of community events. Exposure to excessive noise from marching bands, through noise emissions from a musicians own instrument or nearby instruments have the potential to cause permanent hearing loss. The purpose of this study is to examine the risk for noise-induced hearing loss (NIHL) for marching flute band members and to provide advice with respect to a hearing conservation program for a marching band.

The survey was carried out by taking personal noise dosimetry measurements and by octave band frequency spectrum analyses at various locations of interest. Measurements for flute and percussion instruments were analysed with respect to

their contribution to overall sound energy levels and octave band frequency signature. Room reverberation time and sound absorption coefficients in the areas used for rehearsals were also considered.

The results of the survey, possible controls to high noise levels are outlined and their practicality are assessed. Recommendations for a hearing conservation programme in this unique setting are also described with the understanding that these musicians are exposed in a non-occupational setting and cost is keenly observed within this type of community organisation. The recommendations outlined are likely to be applicable to other types of marching bands, for example, marching pipe bands, marching brass bands or marching accordion bands.