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SATURDAY 1st - WEDNESDAY 5th DECEMBER 2012

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AIOH ADELAIDE 2012
MEETING GLOBAL CHALLENGES

30th ANNUAL CONFERENCE & EXHIBITION

MEETING GLOBAL CHALLENGES

2012 CONFERENCE PROCEEDINGS

AIOH

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30th Annual Conference & Exhibition of the Australian Institute of Occupational Hygienists Inc

1st – 5th December 2012

Adelaide Convention Centre
Adelaide, South Australia

2012 CONFERENCE PROCEEDINGS

Editors

Associate Professor Dino Pisaniello
Dr Sharyn Gaskin
Dr John Edwards

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

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A NOTE FROM THE 2012 AIOH CONFERENCE CHAIR
CHARLES STEER

On behalf of the organising committee I am delighted to invite occupational hygiene practitioners, researchers, regulators, new hygienists, and all those striving for a healthier workplace to the 30th Occupational Hygiene Conference in Adelaide, South Australia.

The Conference theme is meeting global challenges in occupational hygiene. It is very clear that Australia influences and is influenced by the science and art of occupational hygiene in many sectors such as mining, defence, government and academia. Key health challenges include old enemies such as dusts, fibres chemicals and noise as well as potential newer concerns such as nanoparticles and allergic effects. Legislative initiatives such as REACH in Europe will affect all of us. Closer to home we are seeing the challenges involved in the harmonisation process of health and safety legislation throughout Australia as well as the Australian Work Health and Safety Strategy.

There will be three broad themes over the three days covered by our outstanding International and Australian keynote and plenary speakers. The keynotes and plenaries will range from the latest research to strategic challenges in occupational hygiene.

Global challenges and perspectives will cover a range of topics including but not limited to nanotechnology, dermal and inhalation exposure and the effect of genetic differences, respiratory health and occupational hygiene issues across a range of countries.

Applied Science including occupational hygiene issues in radiation health, challenges and developments in the military and mining environment as well as specific applied research.

National and international strategies to control health affecting agents including perspectives from Europe, the UK and Australia. Specific technical challenges in exposure assessment and standard setting will also be covered.

We invite you to visit the extensive trade exhibition where you can see the latest products, services and technologies. The exhibition will also be a great place to network.

The Conference will again provide a full and enjoyable social program including speed networking, the welcome function and dinner, the 3M night and of course the AIOH Annual Dinner. We also invite you to enjoy Adelaide and its surroundings while you are here. There is wide range of accessible attractions and activities including renowned wineries in the Hills and surrounding areas, sandy beaches for swimming or sailing, city and bush walks in the nearby Adelaide hills as well as great night life.

I take this opportunity to thank all of the Conference Committee who have not only been hard working and capable but also very creative over the past two years. I also thank the AIOH Council for their support as well as our generous sponsors.

Lastly we thank you as delegates for coming as it is your participation that makes the Conference come alive. We hope that you find the Conference enjoyable and professionally enriching.

Welcome to the 30th Conference and Exhibition of the Australian Institute of Occupational Hygienists.

A NOTE FROM THE 2012 AIOH PRESIDENT DR BARRY CHESSON

Dear AIOH members, friends of the AIOH and all those striving for a healthy workplace,

It is with great pleasure that, on behalf of Council, I welcome you to the Annual AIOH conference, the premier event in the AIOH calendar.

The conference has much to offer in terms of professional development, networking and an outstanding trade exhibition, and I congratulate Charles Steer and his team on putting together such a comprehensive event.

I would like to thank the major sponsors of the Institute for their on-going and unwavering support: Air-Met Scientific, 3M, Drager Safety Pacific, SEA, Active Environmental Solutions, GCG Health Safety Hygiene, Honeywell and Thermo Fisher Scientific.

For those new to the Conference and to the AIOH I extend to you a warm welcome. I am sure you will find attendance at the conference and interaction with Institute members both professionally stimulating and welcoming.

The occupational hygiene profession continues to enjoy substantial growth in Australia and attention, and I congratulate you on being a part of this growth and on your efforts to make workplaces safer and healthier for workers.

Again, welcome! Enjoy the conference and your stay in Adelaide.

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 *"2011 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:

http://www.innovation.gov.au/Research/ResearchBlockGrants/Pages/HigherEducationResearchDataCollection.aspx.

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 Margaret Davidson - PhD, B App Sci (EH) Hons
- Dr Joseph Mate - PhD, MSc, BSc(Hons)
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- Dr Ryan Kift
- Dr Steve Thomson - BSc(Hons), PhD, Grad Dip Occ Hyg
- Dr David Bromwich - PhD(Griffith), MAppSc(Med.Phys., QIT), MSc(Occ.Hyg, Lond.), BSc(Hons. Physics, Adel.), FAIOH, MARPS, CIH, COH, COC(BERBOH)

The AIOH is grateful to the excellent job performed by the members who reviewed the papers. Eventually four (4) papers were considered by the Paper Peer Review Panel to have passed the peer review process.

1. Sue Reed, Sue Cusbert, Melanie Reed and Veronica du Toit *"Dust and noise levels in a teaching podiatry laboratory"*
2. Sue Reed and Jane Whitelaw "*Comparison of OHS course accreditation procedures in Australia"*.
3. Liam Wilson, *"Fatigue: A case study of sleep obtained versus sleep opportunity in mining"*.
4. Kevin Hedges, Sue Reed, Robert Mulley and Fritz Djukic *"What parameters adversely impact lung function of workers exposed to Respirable Crystalline Silica?*
5. Xiaohui Liu, Dino Pisaniello, Barbara Sanderson and He Wang "*Cytotoxicity and Genotoxicity of Ultrafine Iron-ore Dust"*

Jacques Oosthuizen, PhD, MAIOH, COH
Chair of Paper Peer Review Panel 2012

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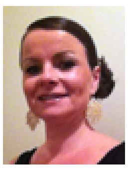

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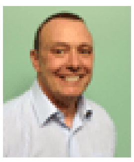

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BIOGRAPHICAL NOTES OF THE KEYNOTE & PLENARY SPEAKERS

Dr Leena Nylander-French

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Dr. Nylander-French has dedicated her scholarship to explore the interface between exposure science, toxicology, genomics, and human health effects. She focuses on understanding the consequences of human exposure to toxic substances in order to establishing the relationship between exposure and mechanisms of toxicity leading to disease. Her research group has pioneered approaches to quantitatively measure both skin and inhalation exposures to toxicants and the related biomarkers. Additionally, her group has developed sophisticated exposure modelling tools using mathematical and statistical principles in an effort to standardize and improve exposure and risk assessment.

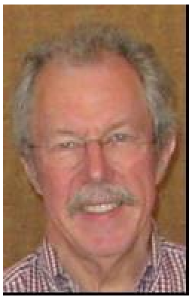
Currently, she is developing exposure assessment methodologies and in vitro reconstructed human skin tissue models to investigate the role of individual genetic and epigenetic alterations to variations observed in biomarker levels after exposure to xenobiotics and to understand the impact and plausibility of these alterations on development of disease in exposed populations. This research requires a new scientific approach to quantitatively measure exposure to toxicants, determine individual differences, including genetic and epigenetic differences, between exposed subjects, and sophisticated exposure-modelling tools in order to determine the role of variability in both exposure levels and an individual response in a population of individuals.

In this presentation, Dr. Nylander-French will focus on the tools her group has developed to investigate the interaction between inhalation and skin exposure to xenobiotics in order to discriminate between the systemic dose that results from these routes of exposure. Quantitation of the individual dermal and inhalation dose and determination of a mechanism of action hinges upon identification of appropriate biomarkers of exposure that can discriminate between acute and chronic exposure, and also on development of quantitative analytical procedures.

In addition, she will discuss methods to investigate the effect of individual genetic variation in the analysis of biomarkers of exposure. Her studies provide the first evidence that a biomarker level can be used as an intermediate quantitative trait when investigating the association between genetic polymorphic markers and exposure-dose relationship. The tools that Dr. Nylander-French's group is developing have the potential to provide biological plausibility to explain the relevance of genetic polymorphisms (SNP and CNV) on biomarker levels, mechanistic insight into the etiology of exposure related disease, and identification of susceptible subpopulations with respect to exposure.

In summary, Dr. Nylander-French will provide evidence that individual genetic differences and the impact of personal and workplace exposure factors on the measured biomarker levels should not be ignored when investigating factors (personal and environmental) that may affect the outcome in exposure assessment and epidemiological studies.

Noel Tresider



Noel Tresider comes from a background of over 16 years as industrial hygiene advisor and product safety specialist for Mobil Oil Australia, and over 40 years in the oil industry. In addition, he has provided industrial hygiene service to Mobil affiliates in New Zealand, Micronesia, Malaysia, and Hong Kong. From 1996, when he formed Petroch Services, he has provided industrial hygiene services to other major oil companies in Australia and Qatar, and also to small business and tertiary institutes. Since 2004, he has been working part-time at the Baker Heart – International Diabetes Institute as their Chemical Project Officer.

He is a Certified Industrial Hygienist - American Board of Industrial Hygiene, a Certified Occupational Hygienist, and Fellow of the Australian Institute of Occupational Hygienists (AIOH), and is a Visiting Fellow of the University of Wollongong.

He was President of AIOH 1998-99, and is currently the President (2011-2012) of the International Occupational Hygiene Association Board (IOHA), Past Chair of the IOHA National Accreditation Recognition Committee and Past Chair of the IOHA Communication Committee.

IOHA is the world peak body for occupational hygiene associations and societies (covering 29 associations, 27 countries, 14 languages). IOHA provides the occupational hygiene profession with an international voice through its recognition as a non-governmental organisation (NGO) by the ILO (International Labour Organisation) and the WHO (World Health Organisation).

Jeroen Douwes

Professor Jeroen Douwes is the Director of the Massey University Centre for Public Health Research (CPHR). He has completed both his MSc and PhD in The Netherlands (Wageningen University) but is based permanently in New Zealand since 1998. Jeroen is recognised internationally for his work on indoor and occupational health. His current research programme focuses on asthma causation, mechanisms and prevention. In particular, it involves studies in children and adults focusing on protective and risk factors associated with the development of allergies and asthma; and the role of non-allergic immune mechanisms in asthma. He is currently the principle investigator of studies on occupational dermatitis; neurotoxic effects of solvent exposures; and occupational intervention studies to reduce exposures to hazardous substances. He is also the Director of a $5.6M Programme Grant on occupational health in New Zealand which focuses on occupational causes of motor neuron disease, congenital malformations, asthma and neuropsychological disorders.

Jeroen has (co)-authored 100+ peer reviewed scientific publications, and is Associate Editor of the International Journal of Epidemiology and Community Health.

Perry Logan

Perry is currently manager for 3M Corporate Industrial Hygiene and leader for 3M's Global EHS Team both providing leadership, technical support and governance to manufacturing operations worldwide. He holds degrees in chemical engineering (BS), industrial hygiene (MS) and environmental health (PhD). His previous professional experience includes environmental, health and safety at large manufacturing facilities, occupational hygiene consulting, hazardous waste operations, and emergency response. Perry regularly delivers professional development courses, workshops and technical presentations on professional judgment, leadership, comprehensive exposure assessment, Bayesian and mathematical exposure modeling, surface and air sampling system technologies for occupational hygiene. Perry is currently an Advising Professor for the University of Minnesota, College of Public Health, actively engaged in supporting graduate student research projects and mentoring. He was the 2006 AIHA Kusnetz Award recipient, past chair of AIHA's Exposure Assessment Strategies Committee (2009) and Gas and Vapor Detection Systems (2002) Committees. He has provided leadership for the AIHA Future Leaders Institute (2011), Professional Conference of Industrial Hygiene (2010-2012) and many science and technical symposiums. Perry is currently President of the AIHA Academy of Industrial Hygiene charged with supporting professional certification and strengthening professional practice globally.

Doug Boreham

Dr Douglas Boreham currently is a Professor in the Department of Medical Physics and Applied Radiation Sciences at McMaster University (2000-Present). Before joining McMaster University, Dr. Boreham spent 14 years as a radiobiology research scientist at Atomic Energy of Canada Limited. He supervises undergraduate, graduate and post-doctoral students and has published over seventy peer reviewed scientific manuscripts. Dr. Boreham has published research on a variety of topics including health effects and anti-carcinogenic processes induced by low doses of medical diagnostic radiation (CT and PET), radioprotective dietary supplements that prevent age related cognitive decline, radiation therapy predictive assays to identify radiosensitive patients, and developed cytogenetic assays to detect DNA damage and for emergency biological dosimetry. Dr. Boreham has won several teaching

awards and was the Canadian Delegate for the United Nations Scientific Committee for the Effects of Atomic Radiation (UNSCEAR). Over the past four years, Dr. Boreham has been employed by Bruce Power, a large nuclear power company, to support scientific oversight of Environmental Assessments for Proposed New Nuclear Reactors and Integration of R&D in Nuclear Operations. As Principal Scientist and Manager of the Integration Department at Bruce Power he has responsibilities for oversight of R&D programs related to university and industrial partnerships.

Martin Jennings

Martin Jennings has more than 30 years' experience as an Occupational Hygienist, in both the private and public sectors.

Prior to joining the Department of Defence in September 2006, he had several years' experience in defence with the (UK) Ministry of Defence.

Martin is a past-President of the AIOH and is a Fellow of the Institute. He is a Certified Occupational Hygienist (COH) and a Certified Industrial Hygienist (CIH) with the American Board of Industrial Hygiene.

He was awarded the AIOH-3M Award in 1988 and the AIOH-Bilsom Award in 1992. He was a contributing author to Principles of Occupational Health & Hygiene (2007).

As an item of trivia, his small claim to fame is that on 6 July 2004, he created the very first entry for 'Occupational Hygiene' in Wikipedia.

Stewart Bell

Mr Bell holds a Bachelor of Applied Science (Chemistry) and has over 30 years experience and expertise in various aspects of mine safety and health, including extensive mine safety work in China and India. He has performed his current role as Deputy Director-General, Safety and Health for the past five years.

Mr Bell, as Commissioner for Mine Safety and Health, is responsible for the management and strategic direction of the coal and metalliferous mines inspectorates, petroleum and gas inspectorate and the explosives inspectorate. He also has strategic overview responsibility for Simtars, the Queensland Government's Safety in Mines Testing and Research Station.

Mr Bell is a Chartered Chemist and a Fellow of the Australian Institute of Occupational Hygienists and has extensive experience in the control of coal mine fires and explosions and the application of occupational hygiene principles to the mining industry.

Mr Bell is the Chair of the Queensland Mines Rescue Service Technical Advisory Committee and the Coal and Metalliferous Safety and Health Advisory Councils. He is also the Queensland representative on the steering committee of the National Mine Safety Framework.

In December 2010, Mr Bell was appointed a Royal Commissioner to the Royal Commission investigating the Pike River Mine disaster which occurred in New Zealand on the 19 November 2010.

Mr Bell received the Public Service Medal in the 2011 Queen's Birthday honours list recognising his services to mine safety and his significant contribution to Queensland having one of the best mine safety records in the world.

Igor Agranovski

Prof Igor Agranovski is a research scientist with 26 years of experience in aerosol science, bioaerosol research and nanotechnology and their applications in design and development of air quality control and monitoring technologies. He was born in former Soviet Union and after graduation from Moscow University of Chemical Engineering in 1986 started his career at State Research Institute for Nitrogen Industry (Moscow) as a Research Fellow. He moved to Australia in 1993 and joined newly established School of Environmental Engineering. Prof Agranovski completed PhD Degree (Moscow University-Griffith University) in 1995 and defended his Doctor of Physical Mathematical Science Degree at State Institute of Physical Chemistry (Moscow) in 2008. In year 2008 he has been promoted to Professor at Griffith University. Prof Agranovski has published more than 170 papers, presented results of his research at 51 conferences and has 5 patents. He has very broad research interests covering air quality, aerosol science, microbiology, nanotechnology, gas separation, high temperature superconductivity and theoretical physics. He has publications in top international peer reviewed journals representing all these areas. He has strong research collaborative links with world leading laboratories and is frequently invited to run projects in USA, France, Japan, Korea, Russia, Israel and other countries.

Bob Rajan

Dr Bob Rajan is the President of the British Occupational Hygiene Society (BOHS) and has been a member of the Society since 1990. He served the Society in various roles since becoming a member. Bob is also a Management Committee member of the Safety Groups UK (SGUK); a JP and a Deputy Chairman of the Lord Chancellor's Advisory Committee on Magistrates.

Bob is a principal strategist in Occupational Hygiene and Principal Specialist Inspector with the Health and Safety Executive [HSE]. Bob has worked for the HSE since 1991, before which he was Senior Occupational Hygiene Advisor to the Flag Officer Plymouth, in the Royal Navy, and previously held academic and consultancy research posts. He also lectures and carries out external examiners' functions at a number of universities. He is an author of peer-reviewed scientific publications, articles, technical guidance, books and conference papers, and was

awarded an OBE for services to the Department of Works and Pensions and occupational hygiene, in 2007.

Bob was the 2009 winner of BOHS's 'Working for a Healthier Workplace – The Peter Isaac Award', for his leading role in developing innovative approaches to ill-health reduction at work. For the last few years has focused his efforts on strategies and projects which promote and encourage behavioural changes at work, achieving benefits for individuals as well as businesses.

These have included extensive initiatives around preventing work-related dermatitis, and encouraging effective and appropriate use of respiratory protective equipment (RPE) for preventing serious lung diseases and other effects; he was responsible for Safety Groups'(SGUK) 'It's in your hands' campaign, and has been instrumental in the industry-wide 'Fit2Fit' competency scheme for RPE fit testers, the 'Clean Air? – Take Care!' campaign and the web based RPE selector tool. BOHS and Bob are closely involved in a recent initiative to help SMEs. It is known as the "Health Risk at Work.–Do You Know Yours?" (HR@W). This initiative has resulted in a simple, concise information pack to help small businesses manage common health risks and protect their future. At the heart of it is a set of rapid reference cards (RRCs) on common health risks. Bob and his colleagues in BOHS, HSE, the Scottish Centre for Health Working Lives (SCHWL) and SGUK, are pleased that this initiative has won a number awards both nationally as well as internationally.

Bob was awarded the prestigious Distinguished Service Award by the Royal Society for Prevention of Accidents (RoSPA), this year.

His hobbies include gardening, reading, cruise holidays and model railways.

Daniel Drolet

Daniel works at the Institut de recherche Robert-Sauvé en santé et en sécurité du travail (IRSST) in Montréal, Canada. He received a master's degree in analytical chemistry from the University of Québec in Montréal (UQAM) and INRS-Santé. His main research activities deal with the development of laboratory analytical methods and exposure assessment strategies, Adjustment of PELs to unusual work schedules, and the study of the application of toxicological interaction data to risk estimation. He has developed with many collaborators numerous applications for both laboratory and industrial hygiene uses, for the benefit of the industrial hygiene community (MIXIE, Saturisk, ProtecPo, Heat Stress tools…). Daniel is also an active member of the AIHA Exposure Assessment Strategies Committee and has been involved in their "cool new tools" (Multilanguage IHSTAT, IHMOD and IH SkinPerm). He has been selected this year by AIHA to receive the Edward J. Baier Achievement Award in recognition of his significant contribution to industrial hygiene in recent years.

Wayne Creaser

Wayne spent 25 years working in the work health and safety field in government, initially as an occupational hygienist and mines inspector in the Northern Territory. His work then took him to managing the OHS and dangerous goods inspectorate in the Northern Territory and then to a similar role in the ACT, before moving into the national policy arena with the National Occupational Health and Safety Commission (a predecessor agency of Safe Work Australia).

In his time in the two territories, Wayne was involved on a number of national standards projects including plant, dangerous goods and construction (first iteration). He also had significant involvement in the development of consolidated OHS regulations in the NT and the dangerous substances legislation in the ACT.

Wayne has a Bachelor of Applied Science in Chemistry and Graduate Diplomas in OHS and Technology Management.

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KEYNOTE & PLENARY

BIOMARKERS IN EXPOSURE SCIENCE: THE TOTALITY OF THE DOSE

Leena A. Nylander-French, PhD., CIH, Professor
Department of Environmental Sciences and Engineering, Gillings School of Global Public Health, The University of North Carolina at Chapel Hill, North Carolina, USA

KEYWORDS

Biological monitoring, Biomarkers, Exposure assessment, Inhalation, Skin, Risk assessment, Toxicokinetics, Toxicogenetics

ABSTRACT

Workers experience inter-individual variability in inhalation and skin exposure and in biological responses following exposure to chemicals. Quantitation of an individual's dose received through airways and skin and determination of a mechanism of action hinges upon identification of appropriate biomarkers of exposure that can discriminate between the routes of exposure and between acute and chronic exposure. Validation of such biomarkers requires accurate characterization as well as sensitive and specific analytical procedures to measure them in biological media. In addition, appropriate statistical and mathematical models are required to evaluate the importance of intrinsic and extrinsic factors that contribute to intra- and inter-individual variability in exposure. Quantification of differences between biomarker response and sources of variance in response to exposure levels predicts individual differences and, thus, individual susceptibility to toxicity and associated disease. Our ability to quantify exposure and internal dose is critical for the development of exposure and risk assessment models.

INTRODUCTION

Exposure to toxicants and measuring outcome in both occupational and environmental settings is a complex process influenced by the magnitude, duration, and routes of exposure, as well as a variety of personal (intrinsic) and environmental (extrinsic) factors. Inhalation exposure has traditionally been the main focus in occupational exposure assessment and numerous validated sampling and analytical methods exists for quantification of airborne toxins in the work environment. Despite the well-recognized importance of exposure to skin and the risk of developing disease, skin exposure has been poorly investigated. In addition, the current methods for quantification of skin exposure are not standardized and suffer from methodological issues. However, recently published occupational exposure studies have demonstrated that a tape-strip method to quantify skin exposure can be predictive of both the concentration of the toxicant in the skin and the internal dose received through skin (Chao et al., 2006, Flack et al., 2009, Gaines et al., 2010, Kim et al., 2006). Biological monitoring is based upon measurement of a toxicant or its metabolite in a biological media (e.g., blood, urine, saliva). The bioavailability of a toxicant depends upon the exposure concentration, rate of uptake into the systemic circulation, retention or residence time in storage and target tissues, biotransformation through reactive intermediates into stable water-soluble metabolites and/or complexes, and elimination from the body through multiple routes. In an occupational setting, biological monitoring coupled with exposure monitoring can reduce uncertainties in overall exposure, hazard characterization, and risk assessment. Biological monitoring data strengthens exposure and risk assessment through integration of exposure from all sources and routes, thus providing important knowledge on overall exposure and internal dose received (Albertini et al., 2006). However, biomarker measurements alone do not provide adequate information for estimating the health risks. Large uncertainties exist along the exposure-dose continuum based upon individual variations in exposure and response that will influence interpretation of exposure and associated health risk. A concomitant quantification of an individual's exposure and biomarker levels provides more specific information regarding variability and time trends in exposure (Albertini et al., 2006).

BIOMARKERS

The biomarker measured can be the toxicant itself (i.e., parent compound) or its metabolite or biotransformed metabolite, conjugate (e.g., glucunoride), or DNA or protein adduct. Endogenously produced molecules can also be used as exposure markers (e.g., acetyl-cholinesterase enzyme activity). Biomarkers of effect include disease markers, molecular changes, and cellular or tissue changes (e.g., DNA or protein adducts resulting in a mutation or change in protein function). Inter-individual differences in enzymes involved in bioactivation and detoxification of toxicants are recognized as potential biomarkers of susceptibility to toxicity based upon individual differences in associated genotypes and altered physiological function.

The toxicokinetics of an agent specific biomarker in human body and the time between exposure and sample collection plays a critical role in determining the best biological specimen for collection, analysis, and interpretation of exposure data. Selection of the appropriate biological media and sampling must be tailored according to the exposure pattern and physical-chemical properties of the toxicant (Sexton et al., 2004). Media that is commonly used for biological monitoring include blood, urine, saliva, hair, feces, breast milk, and fingernails. Urine is often the preferred media because an ample sample volume and non-invasive sample collection. However, urine may not be an ideal media for many toxicants because of potential confounding indicators, e.g., intermediate metabolites that are common to other toxicants. In addition, inter-individual differences in phase 1 or 2 enzyme metabolism of chemicals due to genetic polymorphisms can complicate the assessment of exposure-dose and dose-response. For example, increased attention has been focused on the role of genetic factors in modifying individual's susceptibility to asthma (Wikman et al., 2002). Workers possessing polymorphisms in *N*-acetylator (NAT) and/or glutathione-S-transferase (GST) genes have variations in NAT and/or GST enzyme activities that are involved in diisocyanate metabolism and, therefore, may have differing types and relative amounts of metabolites formed that could pose them to an increased risk of asthma (Wikman et al., 2002).

In contrast, blood sampling is invasive and provides a relatively small sample, which may limit detectability of biomarkers and the number of assays performed. Compounds that form adducts with blood proteins, such as albumin and hemoglobin, are commonly used as biomarkers of exposure (Sepai et al., 1995, Flack et al., 2011). Albumin or hemoglobin adducts reflect past exposures to toxicants rather than acute or recent exposures due to the half-life of albumin of ≈21 days (Peters, 1975) or the lifespan of a red blood cell of ≈120 days (Landaw, 1991). In addition, biomarkers of effect, which include early biological response as well as clinical effects, can be measured in blood. Thus, blood biomarkers can provide a link between exposure, dose, and health effect. However, knowledge on the magnitude and timing of exposure, and the distribution/elimination kinetics of the toxicant in the body is important in interpreting and utilizing blood biomarker data in exposure assessment.

VALIDATION OF BIOMARKERS

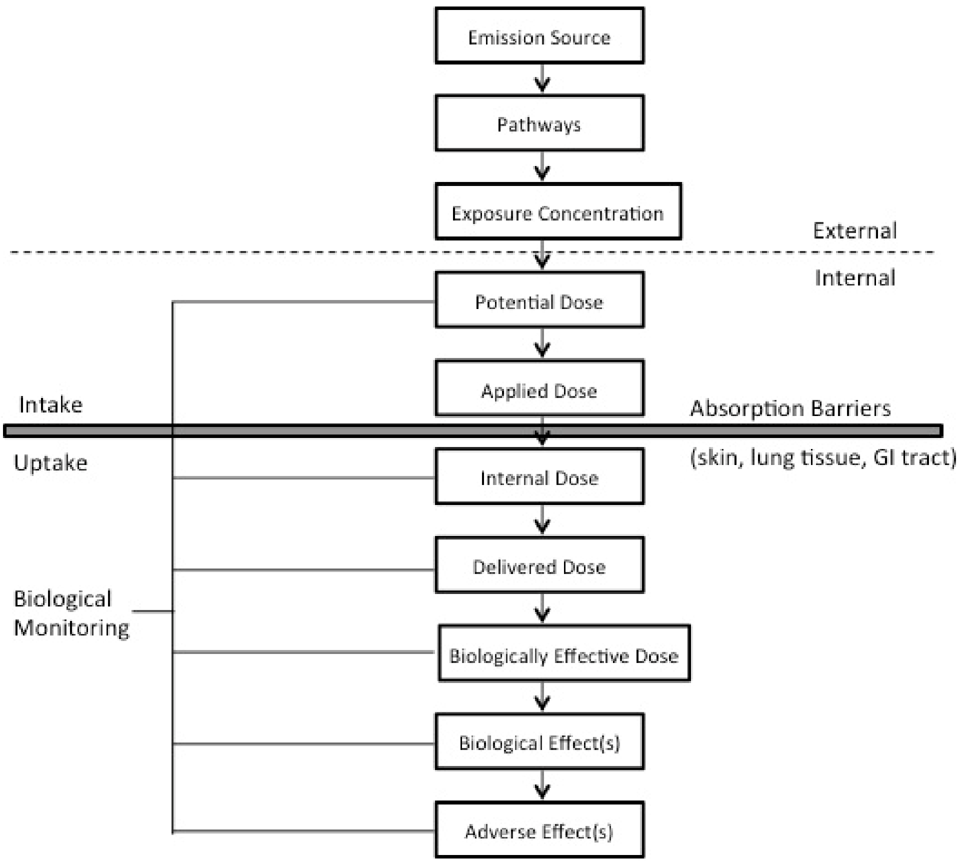
Validation of biomarkers of exposure, effect, or susceptibility occurs at three levels: (1) sample collection and stability, (2) sensitivity and reproducibility of the analytical method used, and (3) sensitivity and specificity of the biological marker itself in relation to the exposure or to a health effect. For biomarkers of exposure, the biological marker must demonstrate that an exposure is occurring or has occurred, and that it can be used to separate individuals on the basis of their level of exposure. Biological monitoring requires analytical methods with high sensitivity, specificity, and reproducibility. Therefore, biological monitoring data must be supported by quality control, analytical standardization, availability of control groups, and other relevant data to limit uncertainty and technical variability (Albertini et al., 2006).

The temporal relevance of the marker, identification of background variability, and determination of potential confounding factors are also important components of biomarker standardization and validation. Temporal relevance is critical because it relates the timing of exposure to the appearance of a measurable biomarker and to the duration of time that the biomarker is measurable following cessation of exposure. Validation of a biomarker requires both controlled human laboratory tests and occupational exposure assessment studies, which demonstrate the applicability of the biomarker to predict the internal dose received by an individual at the measured external exposure concentration.

EXPOSURE-DOSE MODELING

The measure of exposure must accurately reflect the dose or biologically relevant amount of material absorbed into the body. Cumulative exposure is a commonly used exposure metric to express the total amount of toxicant available that has been absorbed. However, cumulative exposure does not necessarily indicate the biologically relevant exposure that can be related to a health effect. Biological monitoring plays an important role in providing data on the relation between exposure and absorbed dose, of which several different types are relevant to exposure estimation (Fig. 1) (Pirkle et al., 1995). The potential (total) dose is the amount of chemical that could be ingested, inhaled, or deposited on the skin. The applied (contact) dose is the portion of the potential dose in direct contact with molecules of the body's absorption barriers, such as the skin, lung tissue, and gastrointestinal tract, and available for absorption. The internal (absorbed) dose, also called "body burden", is the portion of the applied dose that is absorbed into the body through biological membranes (e.g., the lungs, skin, gastrointestinal tract) and is, therefore, available for metabolism, transport, storage, and elimination. The delivered (tissue) dose is the portion of the internal dose that reaches a tissue. The biologically effective (target) dose is that portion of the dose delivered that reaches a tissue site(s) that results in a biological response.

Figure 1: Dose types relevant to biomonitoring within exposure assessment framework (modified from Pirkle et al., 1995).



Physiologically-based pharmacokinetic (PBPK) models are used to predict the portion of the dose that is absorbed, distributed to organs and tissues, metabolized, and eliminated (i.e., ADME processes) for a variety of toxicants and are often used in conjunction with studies on the mode of action (i.e., biochemical interactions that produce their toxic effect). This information is critical for the establishment of the relationship between biological levels and health effects. Information can be used to establish the relationship between the degree of exposure and the biological levels of the exposure indicator, determine allowable levels for xenobiotic exposure [e.g., Biological Exposure Indices (BEI) set by American Conference of Governmental Industrial Hygienists (ACGIH, 2012) or Biological Tolerance Values (BAT) set by Deutsche Forschungsgemeinschaft (DFG, 2012)], to select proper sampling time for biological marker, to identify confounding factors such as inter-individual and intra-individual differences in the body response to exposure. The use of PBPK modeling and knowledge on toxicokinetics of a toxicant can provide critical support for interpretation of biological monitoring data for risk characterization.

Issues related to variability and uncertainties have become important considerations in exposure and risk assessment. In exposure assessment, variability refers to measurable differences in exposure between individuals in a population, which can be assessed through sampling methods and quantitative analyses. Uncertainty is related to a model used to characterize risk, the parameters used to provide values for the model, or both. Our lack of knowledge on variability and uncertainty in exposure and risk assessment has driven us towards probabilistic risk assessment methods, which offer a significant improvement over past practices of using point estimates of risks and benefits since any point estimate represents a gross simplification that ignores important underlying dynamics (Thompson, 2002). The primary advantage of a probabilistic risk assessment is that it can provide a quantitative description of the degree of variability or uncertainty (or both) in risk estimates for both cancer and chronic health effects, and thus ensuring a scientific basis to control occupational hazards.

GENE-ENVIRONMENT INTERACTION

New advances in systems biology, genetics, and technologies derived from genomics research have created exciting possibilities for application in human health risk assessment for occupational and environmental exposures. With this information, inter-individual differences in exposure and how chemicals interact with ad individual's genetically unique biological systems to cause toxicity and exposure-related disease can be determined. Inter-individual differences in how various toxicants are metabolized or in DNA repair capacity and efficiency based on gene polymorphism, whose source may include single nucleotide polymorphisms (SNPs) or copy number variations (CNVs), may influence susceptibility to disease (i.e., gene-environment interaction). Polymorphisms in genes regulating enzymatic metabolism may result in higher levels of active metabolites, which, in turn, can lead to increased reactions with DNA and macromolecules and susceptibility for disease. Various occupational studies have linked genotype polymorphisms on levels of chemicals and/or their metabolites in biological samples (Jiang et al., 2012, Kang-Sickel et al., 2011, Migliore et al., 2006), early biological indicators of genotoxicity (e.g., chromosomal damage and micronucleated binucleated cells) (Leng et al., 2004, Migliore et al., 2006, Wang et al., 2009), and disease risk from occupational chemical exposure (Leinweber, 1991, Christiani et al., 2008). For example, we performed a candidate gene and genome-wide association analyses to investigate individual differences in SNPs as genetic markers associated with naphthyl-keratin adduct levels measured in the skin of fuel-cell maintenance workers exposed to naphthalene (Jiang et al., 2012). The relative contribution of these SNPs, as well as personal and workplace factors, on naphthyl-keratin adduct levels was determined using a multivariate linear regression model. Thus, advances in genotyping strategies (e.g., DNA microarrays), exposure assessment studies utilizing biological monitoring, and computational methods to identify candidate significant polymorphisms (e.g., using candidate gene and genome-wide association analyses) can improve predictive models linking exposure and disease (Jiang et al., 2012).

Epigenetic marks that regulate gene expression, such as DNA methylation or histone modification, may be affected by cumulative exposure to chemicals. For example, DNA methylation was inversely associated with lead exposure, which may have important implications for the mechanisms of action of lead on health outcomes (Wright et al., 2010). As the use of genome-wide association studies to identify genetic and epigenetic polymorphisms associated with intermediate phenotypes and disease becomes more frequent, there is increasing interest in evaluating individual genome interaction with environmental factors. In the analysis of gene-environment effect modification, statistical power becomes an even greater issue as studies typically require large sample sizes to detect effect modification (Hwang et al., 1994). Even small errors in the exposure assessment can result in an increased sample size requirement for the detection of effect modification (Burstyn et al., 2009). Thus, high quality exposure data are needed to improve the ability to detect genetic and epigenetic effect modifications related to disease development.

The consequence of potential individual genetic variation affecting ADME from exposure to multiple sites of contact is largely unknown. Furthermore, individual differences in DNA damage and repair, adduction (DNA and protein), variable expression of detoxification enzymes on metabolites (biomarkers), and physiologically processing maintaining homeostasis may affect the detection and use of exposure biomarkers based upon individual genetic variations. Determination of genes responsive to xenobiotic exposure (detoxification as well as innate and/or acquired immunity) will provide focus for translational research on disease prediction and the development of preventive or intervention strategies and medicines for environmentally related disease. Furthermore, demonstration and recognition of individual differences in detoxification and gene-expression patterns in response to xenobiotic exposure, and their contribution to toxicity and risk, will thus impact both prevention policy and translation studies crucial to the protection of health and treatment of disease of the exposed individuals and making valid associations between exposure and disease.

FUTURE NEEDS AND CONCLUSIONS

Biological monitoring data can provide important information on exposure and absorption of a variety of occupational and environmental chemicals. Therefore, biological monitoring data can be used to identify high priority exposures, evaluate the effectiveness of intervention and prevention strategies, recognize time trends in exposure, establish reference ranges of tissue concentrations, and provide integrated dose measurements (Pirkle et al., 1995). Moreover, biological monitoring can also be used to investigate the inter- and intra-individual variability in response to exposure and, thereby, identify genetic variants as codeterminants of internal exposure, and susceptible individuals/groups for further evaluation of health risks. Biomarker data can be included in a variety of computational models to evaluate exposure at the individual or population level and be used to predict the incidence or outcome of disease (Sobus et al., 2011, Toniolo et al., 1997). In terms of risk management, biological monitoring has the potential to be a valuable tool for prevention and to guide engineering controls as well as eliminating or reducing exposure. For these reasons, biological monitoring is quickly becoming the "gold standard" of environmental exposure assessment (Sexton et al., 2004). However, given the increasing sensitivity of analytical methods, detection of a chemical in a biological sample should not be confused with or equated to increased risk. Critical knowledge gaps still exist, which add to the uncertainty of the interpretation of biological monitoring data.

Scientific understanding and identification of best practices in the application of biological monitoring data is required in several areas. We need to strengthen our understanding of the predictive relationships/linkages between measures of exposure and dose affecting the individual within the context of the exposed population. This would allow us to develop an interpretation strategy and specific criteria for filling data gaps in the source-disease framework. Biomarker validation and analytical precision of biomarker measurements (e.g., inter-laboratory comparison) is required for establishing their application in exposure and risk assessment. In addition, characterization of baselines for biomarker levels, and applying statistical methods to assess temporal departures from baseline can aid in identifying subpopulations at increased risk of exposure, understanding factors affecting exposure, and health effects. Rapid advances in systems biology and genomics can be overshadowed by several challenges, including inconsistencies in study design and sampling strategies, lack of quantitative or qualitative correlations of exposure, dose or adverse health effects, and the lack of bioinformatics and analytical tools to manage the volume of research findings (Henry, 2003). Study designs must be improved to better assess intra- and inter-individual variability related to measures of exposure, dose, metabolism, and health effects, which would influence the chance of observing predictive relationships between these variables. Lastly, new technologies in the area of genomics and systems biology can be applied to develop potential biomarkers, which can be used as screening tools to identify candidates for biological monitoring (Albertini et al., 2006). Development of a multidisciplinary approach including cross-sectional and longitudinal exposure assessment with biological monitoring, epidemiology, toxicology, and genomics will be important in shaping the future direction of risk assessment and risk management strategies to protect worker health.

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GLOBAL IH CHALLENGES AND HOW THEY RELATE TO AUSTRALIA

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ABSTRACT

In the short term the global IH challenges are:

1. Insufficient occupational hygiene skills. The opportunities to address this are by the growth of Occupational Hygiene Training Association http://www.OHlearning.com

   The OH skills issues are:

   - A shortage of competent Occupational/Industrial hygiene practitioners in many developing/industrialising countries/regions, including South America, Africa, Asia, southern and eastern Europe;
   - Restricted availability of suitable training programs in these same areas, particularly in respect of practical training;
   - Transferability of competency standards at all levels of industrial hygiene practice.

   Australia (AIOH) is a key participant in OHTA and this role will expand.

2. How to contribute to the broader global health agenda. There are opportunities to participate with WHO work plans 2012-2017, and the programs of others.
   - What can the occupational hygiene profession contribute to this agenda? – Training and expertise in Silica and Asbestos, Tool-Box approach, Control Banding, Occupational Hygiene content to existing ILO programs.

   Australia can participate in the WHO Regional activities and contribute to ILO-ICOH programs such as WIND and WISE.

3. How to develop IH networks in the Asian Region

   Australia and New Zealand are traditional 'western' nations in a changing Asian world. We can share our knowledge, assist and mentor others.

OCCUPATIONAL HEALTH AND HYGIENE RESEARCH IN NEW ZEALAND: PROGRESS AND PROSPECTS

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ABSTRACT

Each year in New Zealand we have an estimated 17,000-20,000 new cases of work-related disease. Most of these are potentially preventable. Occupational asthma and dermatitis are among the most common work-related disorders in industrialised countries including New Zealand. This keynote address will present a recent study on occupational asthma in the sawmill industry. In particular, it will show evidence that wood dust exposures well below the current exposure standards in Australia and New Zealand are associated with an elevated risk of asthma and lung function decline. A recent prospective study in New Zealand provides further evidence of a continuous decline in lung function in these workers. An intervention study to reduce dust levels in this industry is currently being developed and will be presented separately. Wood dust exposure is also a major concern in joinery and furniture workers and data will be presented of a study using video exposure monitoring to identify peak personal exposures and the first results of an intervention study aimed to reduce these exposures. Although occupational exposures are generally associated with adverse health effects, a recent study in New Zealand has shown that farm exposures may protect farmers against asthma despite the increased risk of other respiratory diseases (COPD, farmers lung etc). This is at odds with studies in Europe where farmers tend to have greater risk. The potential reasons (including exposures to dust and microbes) will be discussed. Occupational dermatitis is a very common disorder, but research into this area is rather limited in New Zealand (and Australia). This keynote address will discuss results of a large study on occupational dermatitis in cleaners including measurements of trans-epidermal water loss.

CRITICAL ASPECTS OF PROFESSIONAL JUDGMENT AND LEADERSHIP IN OCCUPATIONAL HYGIENE

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ABSTRACT

Occupational hygienists utilize a wide range of skills that are considered a mixture of science and art to anticipate, recognize, evaluate and control health hazards. These diverse skills include many technical aspects related to chemistry, physics and engineering as well as more social aspects to understand human behavior in order to inspire important individual and organizational changes. Specific technical skills enable occupational hygienists to make decisions with limited information and data by using the well known but not well understood concept of "professional judgment". A variety of "leadership" skills are also needed to both understand human behavior and inspire change across the complexity of social and demographical combinations seen in workplaces and communities so that people are properly protected. Sound "professional judgment" and "leadership" are critical for protecting workers, communities and strengthening the occupational hygiene profession today and well into the future. With a review of important studies and facilitated audience interaction, we will explore critical aspects and important intersections of leadership and professional judgment for individuals and the global network of occupational hygienists.

OCCUPATIONAL AND MEDICAL RADIATION EXPOSURE AND MODIFICATION OF RISK BY DIET AND EXERCISE

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ABSTRACT

Ionizing radiation is naturally occurring or manmade and is ubiquitous with life. Manmade exposures are typically from two sources: 1) occupational exposure in the workplace, or 2) through medical procedures to identify and treat illness. The levels of exposures from low dose occupational (nuclear energy worker, commercial aircrew) and low dose medical diagnostic tests will be compared to higher doses like those used to treat cancer or after radiation accidents. Risk estimation from exposure to high levels of radiation has been largely based on atomic bomb survivor studies and uses a controversial linear non-threshold (LNT) model. However, there are many studies that show that radiation risk is not proportional to radiation dose. The overall goal will be to present the current state of knowledge related to low dose exposures and show that radiation risk assessment is complicated and depends fundamentally on biology and not just the actual dose. Research on the modification of risk will be discussed and recent results showing that exercise and diet can modify radiation risk will be presented.

EFFECTING CHANGE WITHIN A LARGE ORGANISATION - OCCUPATIONAL HYGIENE IN DEFENCE

Martin Jennings
Defence Centre for Occupational Health

ABSTRACT

The Department of Defence is one of the largest and most complex organisations in Australia. This complexity includes differences in culture, structure and function.

Defence works with regional states and Australia's allies to manage potential global security threats. Consequently, Defence employees can be deployed in some of the world's most difficult environments, facing extreme hazards. Alternatively, they may be based in garrisons, working in challenging industrial environments. Case studies will be given to illustrate some of the issues facing Defence personnel. The paper also discusses how global initiatives, such as training present opportunities for hygienists from allied countries to work more closely.

This paper describes how Defence has being working to develop its occupational hygiene capability, the leadership skills required to provide this capability and how it has addressed major occupational health related issues at an organisational level.

Despite its size and significant level of resourcing, ($28,429 million in financial year 2011-12), Defence continues experience difficulties in managing its work health and safety problems. It could be argued that in part this is due to the inherently dangerous nature of much of the work and the risk-taking culture that is required to undertake these activities.

The case studies illustrate a catastrophic failure and a success. The first has been well documented in the public arena and the consequences are still playing out, even years after the event. The success has not featured in the public eye, but it has a number of remarkable features to commend it to occupational hygienists.

INTRODUCTION

This paper will not address issues such as operating on deployments, as this will be discussed later by Colonel Mark Ireland. In another paper, Dr Peter Teague will be discussing the Defence approach to their most costly and ubiquitous issue - noise management, so this will not be discussed here either.

Case Study 1: The F-111 Deseal/Reseal Disaster

The F-111 was Australia's primary air strike weapon over the latter part of the last century and into the early part of this century. One special, even unique capability of the F-111 is its long range capability, enabling the aircraft to operate over very long distances without refuelling. To do this, the F-111 maximises the storage of fuel in a way not adopted with any other aircraft in the RAAF. Unlike many other aircraft, the F-111 has no fuel bladder. In a sense it is a 'flying fuel tank' with armaments attached and a cockpit for the crew.

One consequence of the unique fuel storage system on the F-111 is a requirement for repair work in an environment not replicated on any other RAAF aircraft. Australia's 24 F-111 aircraft required significant fuel tank repair and maintenance work from the moment of delivery in 1973. The discovery of the deteriorating fuel tank sealant, meant that the RAAF was required to rectify major fuel leak issues on the aircraft from the outset. This repair work in cramped, hot and humid conditions, was carried out for some decades by F-111 fuel tank maintenance workers – primarily in the formal deseal/reseal programs but also through ad hoc maintenance.

By 2000, the health of more than 400 people had been ruined and the Air Force finally realised it had a serious problem on its hands (Hopkins, 2005). Workers reported symptoms of skin irritation, gastrointestinal problems, loss of libido, rapid mood swings, headaches, dizziness, haemorrhoids, skin cancers and memory loss (RAAF, 2000). They continue to be monitored for ongoing long term consequences.

In 2000 the Chief of Air Force commissioned a Board of Inquiry (BOI) to examine the deseal/reseal program in relation to health, chemical exposure and work practices. The BOI researched over 1.5 million documents, covering a period of 27 years and took statements from over 650 individuals. The BOI produced 53 recommendations, all of which were accepted by the Air Force.

In a somewhat unusual move, the RAAF appointed an external person to the Board, Dr Andrew Hopkins an Associate Professor sociologist from Australian National University (ANU). Hopkins had previously written about other disasters, such as the Moura mine disaster and the explosion at the Esso Longford plant. Hopkins brought a fresh insight to the investigation and determined that the root cause of the disaster was an organisational failure by the RAAF. The prevailing culture was one in which the safety of the ground crews was very much secondary to that of aircrew, and where platforms (aircraft) were put before people.

Hopkins (2005) pinpointed major cultural deficiencies in RAAF as an organisation. However, with the benefit of hindsight, he could probably have gone further in his analysis and made recommendations as to how these organisational failures could be applied to the whole of Defence. The diagram in Figure 1 shows the analysis by the Board of Inquiry into the organisational factors that contributed to the situation.

Over the ensuing years a number of health and toxicology studies were undertaken. Key studies are listed below. These are all detailed on the Department of Veteran's Affairs website (http://f111.dva.gov.au/history.htm):

- Study of Health Outcomes in Aircraft Maintenance Personnel (SHOAMP)
- SR51 Chemical Hazard Assessment Laboratory, University of Sydney (CHALUS) Study
- Mitochondria in fuel & solvent exposed RAAF personnel (Bowling)
- Psychological effects on spouses (Coxon)
- Danek report
- Study of Mortality & Cancer incidence (4th study in 2011)

One of the responses to the analysis of the Defence organisation and culture, was to develop the concept of the exposure reduction plan, which will be discussed later.

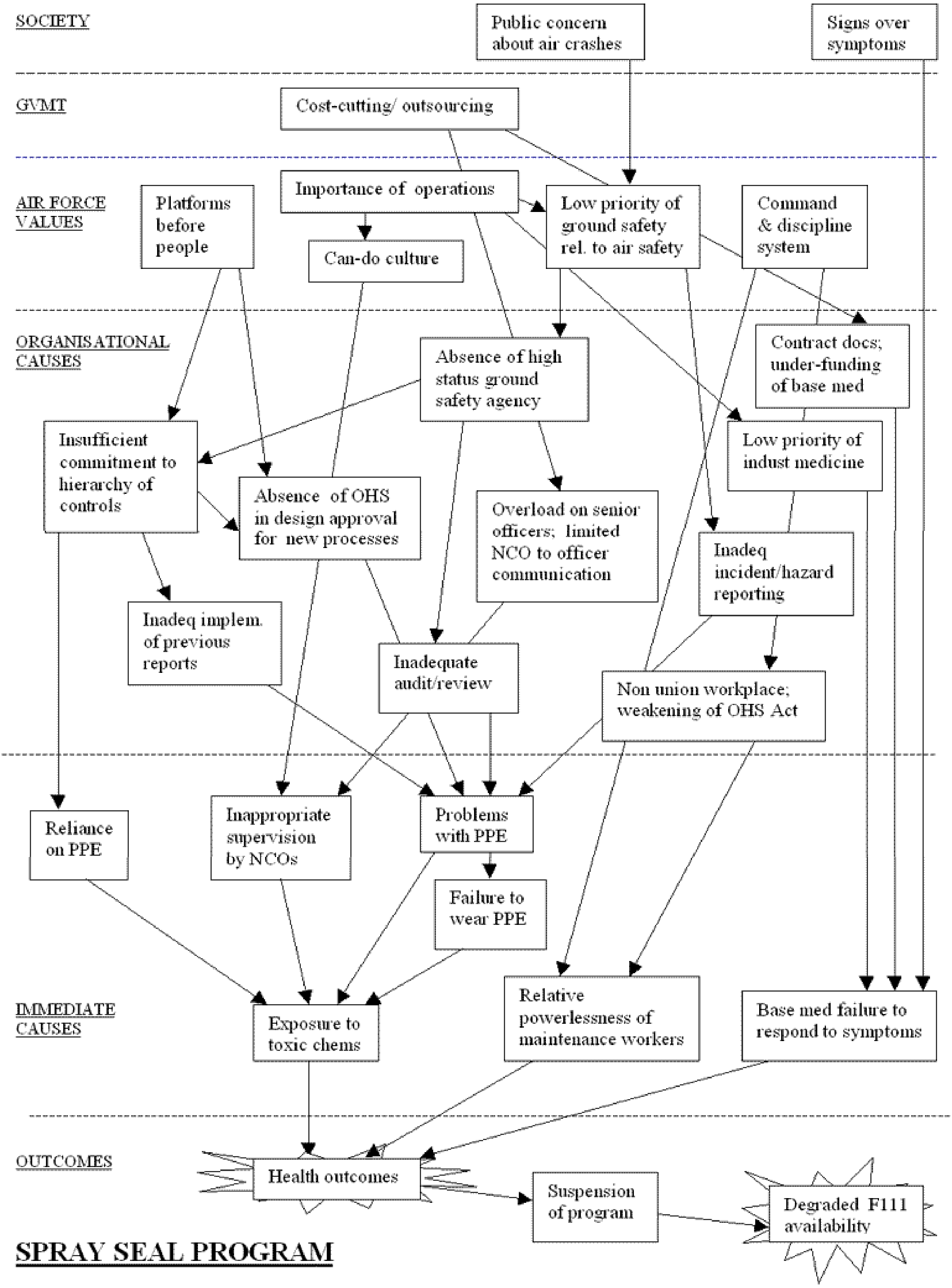

Figure 1 Causal Factors identified by Board of Inquiry into health damage to F-111 workers (RAAF, 2001)

Case Study 2: Lead Management in Indoor Firing Ranges

The second case study involves users of an indoor firing range complex. These personnel are predominantly members of Special Forces and concern about exposure was included in a study into Special Air Services (SAS) veteran's health (DVA, 2002). This chart is an updated version of one presented by Redfern (2010) as a poster at the AIOH Conference in Tasmania.. Users of indoor ranges are exposed to significant quantities of lead. In fact, the new WHS regulations now include in the definitions of a lead process, one that exposes a person to lead dust or lead fumes arising from firing weapons at an indoor firing range (Safe Work Australia, 20110).

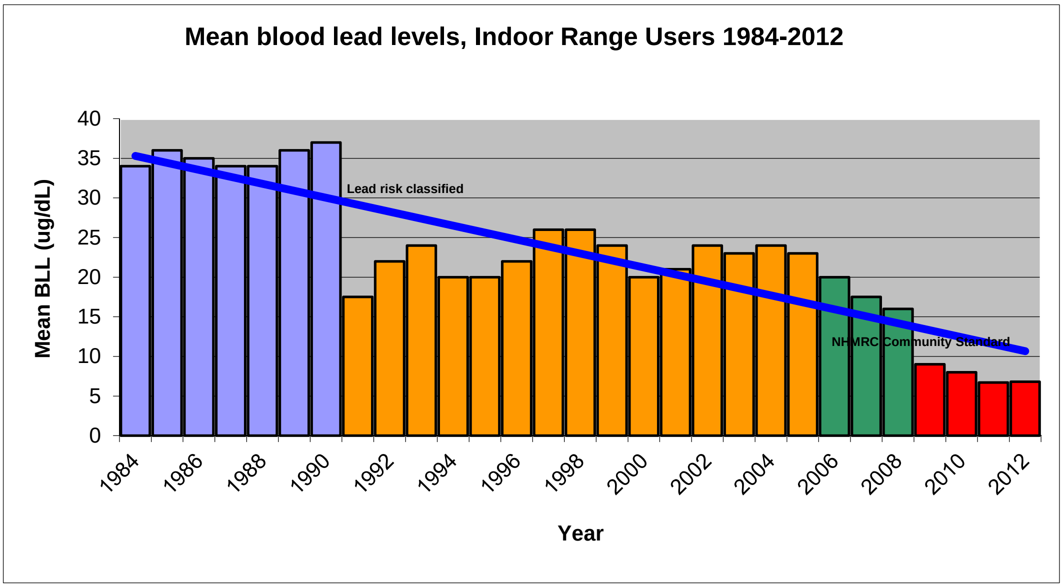

Figure 2: Blood lead levels in users of indoor firing ranges (after Redfern et. al. 2010)

As shown in Figure 1, the average blood lead levels of the users of the indoor firing range were around 36 µg/dL, between 1984 and 1989. This value remained essentially constant during this time. In 1989, a new Range was constructed, with greatly improved ventilation, and equally important, it was clean, i.e. lead free. This produced a 50% step-change in the level of exposure, of some 18 µg/dL. Unfortunately, nothing further was done in the following years to improve this situation. By 2004, the situation had deteriorated to the point that the average blood lead level of the users was now around 24 µg/dL.

An occupational hygiene survey at this time indicated that the lead was present mainly as a surface contaminant, and that airborne concentrations continued to be well controlled by the ventilation. As reported at the time, (Jennings 2004), surface contamination had not been considered as a possible source of exposure and so the evidence from these findings indicated that tackling this source of exposure presented a more promising approach.

This resulted in two significant initiatives. The first entailed training users to recognise the need for improved personal hygiene and paying closer attention to habits such as not washing before eating or smoking; nail-biting and other hand-mouth behaviours. The mess room in the indoor range complex used for making coffee and snacks was closed and relocated. Contaminated clothing was to be laundered on the premises and was not to be taken home. Specialised cleaning products (DeLead®) were sourced as soaps, hair shampoos and as laundry detergent. This immediately resulted in a small but measurable reduction of 23 ug/dL to 20 ug/dL. Over the next two years, this dropped further to around 17 ug/dL.

At the same time, an Architect was appointed to advise on providing practical recommendations based on sound architectural detailing for a range of measures that will either limit the volumes of lead dust settling on various surfaces throughout the Administrative Areas of the Complex, or assist in making surfaces more readily cleanable, by either improving access to those surfaces, or improving the cleanability of them.

When this work was completed, a dedicated contract cleaner was engaged and given a very detailed schedule of activities, indicating how the premises were to be cleaned, how often, even to the extent of specifying as to how waste water or dust from the vacuum cleaner was to be disposed of. Defence also retained the right to follow up on the cleaning and take surface wipe samples, as a quality assurance measure.

As a consequence, the advanced cleaning regime produced another step-change improvement from 17 to 9 ug/dL, and then to 8 ug/dL in 2010. Since then, there have been further improvements, so that the average blood lead level of the users in 2012 is 6.8 ug/dL and well within the 10 ug/dL limit set by NHMRC for the general community. In the near future, it is envisaged that the introduction of lead free training rounds (ammunition) will reduce the blood lead levels even further.

There are a number of noteworthy aspects of this case-study:

- It tracks a highly homogeneous SEG over a period of 28 years;
- The success is demonstrated from reducing levels from being 'Lead risk' workers, to levels comparable to the general community;
- The impacts of interventions are clearly defined and are quantifiable;
- The evidence based approach to determining an appropriate control method, and of reviewing the effectiveness of the interventions;
- The concept of continuous improvement is built into the plan;
- The application of the hierarchy of controls, without use of PPE;
- The role of the "educated client" in their use of the occupational hygiene data.

DIFFICULTIES IN DEFENCE AS AN ORGANISATION

In previous papers presented to this conference, (Jennings 1993, 1999) I argued the importance of understanding how organisations work if a hygienist was to achieve enduring improvements in worker health. In Defence, a number of factors were identified that mitigated against this:

- The Posting Cycle – Defence personnel are routinely rotated into new locations and positions every 2- 3 years. Consequently, it is difficult to establish any corporate memory.
- Increased operational tempo has resulted in reduced focus on WHS;
- Inter service cultural differences – this leads to a silo effect, whereby each organisation tends to do is own thing.
- Local vs national – a lack of coordination between different sites means that there is little or no visibility of work being done at different locations.
- Lack of ownership of issues
- Multiplicity of stakeholders to be consulted

- Complex and bureaucratic business model.

LESSONS LEARNED

Consideration of the two case studies was instrumental in developing a strategy to tackle some of the issues. A project was developed to develop the occupational medicine and occupational hygiene (OMOH) capability over a period of three years at a cost of $10 million.

Baseline surveys - The initial action in this project was a series of baseline surveys of a representative number of bases conducted across all Defence Groups & Services. In the case of Navy, this was a survey of each class of vessel. This action was a direct response to the failure in the case of the F-111 to identify hazardous agents, especially those which are not obvious, or the people affected. The outcomes of the baseline surveys were:

- A comprehensive list of hazardous agents,
- Personnel exposed to those agents, classified into similar exposure groups (SEGs);
- A proposed monitoring regime to quantify the levels of exposure;
- Equipment requirement;
- Resource requirements, including costings of contractors, etc.

Provision of Assistance to Groups & Services – A number of highly qualified and experienced occupational hygienists were engaged to respond to requests for assistance. The immediate benefit of this was to raise awareness of occupational hygiene and how hygienists can be employed in resolving problems. Later, each of the Services was allocated an embedded hygienist, to help them build on the outcomes of the baseline surveys and to develop a more proactive approach. This program was so successful that it became difficult to meet the demand for services.

Exposure Reduction Plans (ERPs) - The success of the lead management program in the indoor ranges indicated that it should be possible to apply a similar technique to reducing the level of exposure to other hazards. At the same time, the concept of the ERP was developed to overcome some of the cultural and organisational difficulties identified earlier. This was to be achieved through engaging subject matter experts (SMEs) to conduct gap analyses between extant practice and the ideal state. The baseline surveys identified a number of common hazards, and ERPs were developed for:

- Fuels
- Noise
- Asbestos
- Hand Arm Vibration

Education and Training – In 2007, Defence purchased the AIOH Basic Principles Course material to present to Army safety auditors, in response to a request to raise their awareness of occupational hygiene. This proved so successful that the course was modified to reflect the Defence environment and was renamed 'Monitoring of Health Hazards', and it was mapped against National Educational and Vocational Unit of Competency *BSBOHS406C - Use equipment to conduct workplace monitoring* (TGA). The course has now been presented on 14 occasions to over 140 participants and forms part of the Army Preventive Medicine Technician's promotion course.

Provision of Equipment – To enable the trainees from the MOHH course to provide a useful service as occupational hygiene technicians, they will be equipped with a basic kit of monitoring equipment. A total of 36 kits were purchased, and these include:

- 5 x Casella P314210 intrinsically safe pumps and calibration equipment
- 5 x Casella CEL-350 Intrinsically safe Personal Sound Exposure meters and calibrator and software
- Bruel & Kjaer 2250L sound level meter, microphones, calibrator, tripod and software
- Svantek SV 106 Human Vibration meters with hand/arm and full body sensors, calibrators and software
- TSI IAQ – Calc 7545 system Indoor Air Quality monitors
- MultiRAE Lite Multi-gas PID with calibration gases and software
- TSI 8530 DustTrak II Particulate Monitor with calibration kit and software
- Kitagawa Colorimetric Gas Detection system
- Extech Heavy duty Light meter
- TSI 9535 Anemometer

Governance System – A policy has now been drafted, as a Manual which outlines the technical regulatory framework for occupational hygiene in Defence. This covers the roles and responsibilities of those working in occupational hygiene; their qualifications; reporting structure, etc. As an adjunct to this, there is a number of supporting procedures which address sampling methodologies and strategies, use of standards, and usage of the above equipment.

FOR THE FUTURE

The OMOH project finished at the end of FY 2011-12. It was then anticipated that this would transition to business as usual with the Groups & Services at a mature enough state to manage their own occupational hygiene. This is happening, albeit at varying degrees and there is still a significant amount of work required to help bed this down.

At the corporate, i.e. whole of Defence level, there are a number of activities afoot:

Technical network - There is now a cadre or corps of trained personnel, who need to be sustained. Use of a software program such as Sharepoint will facilitate knowledge sharing and information flow. At the same time, the development of L2 and L3 hygienists will be pursued.

Record keeping – it is a major concern that there is no single, robust system for data storage or interrogation. It is hoped that the implementation of a WHS Management Information System (WHSMIS) in late 2013 will rectify this.

Training development – the recent development of the international training framework (OHLearning.com) is being monitored with great interest. Their training levels align with those of Defence and the Basic Principles of Occupational Hygiene course is essentially identical to the MOHH course described earlier. There has been some preliminary discussions between Australia, Canada, New Zealand, UK and USA around common training as a means of promoting interoperability.

Maturing the Occupational Hygiene function - Figure 2 shows the summary page for Element 7 (Occupational Health) of the Defence Maturity Model for the WHS Management System. Currently, Defence is operating predominantly at the reactive level, with some hazards, such as noise possibly achieving the managed level. The challenge for Defence is obviously to grow the level of maturity.

Figure 3: The Defence WHS Maturity Model

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PIKE RIVER ROYAL COMMISSION – WHAT DOES IT MEAN FOR AUSTRALIAN MINING?

Stewart Bell, PSM
Deputy Director-General
Commissioner for Mine Safety and Health

ABSTRACT

The Pike River Royal Commission released its report in late 2012 and this presentation will cover the learnings from the report and why such a disaster was able to occur in a modern underground coal mine.

The presentation looks at underground coal mining issues relating to ventilation, gas monitoring, methane drainage, electrical installations, training and emergency response.

RECENT ADVANCES IN THE ASSESSMENT OF BIOAEROSOLS

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KEYWORDS

Bioaerosol detection, personal bioaerosol sampler, multiplex real-time PCR

ABSTRACT

Bioaerosols in occupational and residential environments are generally complex mixtures that may include microorganisms (viable and dead) as well as their fragments and toxins. They are known to cause various health effects, including infections, hypersensitivity, toxic reactions, irritations, and inflammatory responses. The growing concern for human exposure to bioaerosols has created demand for advanced, more reliable and more efficient monitoring methods for rapid detecting, identifying and enumerating airborne biological particles. An individual exposure could mainly be accurately evaluated by personal bioaerosol samplers, as these devices track the effects of human time-activity patterns. Due to these facts, the development of bioaerosol sampling equipment over recent years has been primarily focussed on personal devices, which could be located directly on an individual during equipment usage. Some historical aspects along with cutting edge procedures recently developed for bioaerosol monitoring will be discussed.

INTRODUCTION

A number of infectious disease outbreaks over recent years have raised various scientific and public health issues related to the transmission, monitoring and control of infectious microbiological agents. The threat of bioterrorism (Anthrax letters) has gained additional public attentions to these issues. The above factors, as well as a generally growing concern about human exposure to bioaerosols, have created a considerable demand for advanced, reliable and efficient monitoring methods for detecting, identifying and enumerating airborne biological particles to control exposure, to evaluate controls, or to identify potentially hazardous conditions (Lacey and Dutkiewicz, 1994; Comtois and Isard, 1999). The requirements for an ideal bioaerosol sampler have been described by Macher (1997). Among others, maintaining high biological efficiency is considered to be one of the main requirements for an efficient performance of the bioaerosol samplers.

Individual exposure to bioaerosols can best be evaluated by the use of personal aerosol monitors, as these samplers track the effects of human time-activity patterns. In regards to the personal sampling, the ideal bioaerosol monitor would be compact, would allow specific identification of particles and would maintain high physical and biological efficiencies (Crook, 1995) over prolonged periods. Currently, most of the commercially available sampling devices for viable bacteria and fungi utilize either filtration, impaction onto agar or impingement into liquid. The advantages and disadvantages of these methods have been extensively discussed in the literature (Nevalainen et al. 1993). Collection of bioaerosols by direct impaction into a nutrient allows one to achieve a high rate of microorganism recovery. However, some species may not turn into a culture, as different microorganisms require different types of agar. Also, for unknown concentrations of bacteria in the air, the impactor may become overloaded which reduces the accuracy of the subsequent colony count or makes counting impossible (Nevalainen et al. 1993). In addition, these methods are entirely unsuitable for viruses.

The filtration methods have traditionally been used primarily for total microbial enumeration through microscopic analysis (Cox and Wathes 1995). The viability of biological species collected by such methods is usually very low due to desiccating effects.

Impingement into liquid provides significant benefits, as it can be used for serial dilutions and subsequent analysis of viable and non-viable organisms using various techniques, including colony enumeration, plaque assays, endotoxin determination, immunologic, genetic and viral analyses. The main disadvantage of most currently available impingers is that achieving a sufficient physical collection efficiency requires a very high sampling velocity (up to subsonic range) which usually results in violent bubbling of the collection fluid and corresponding microbial stress. Due to high-speed impingement and violent bubbling, conventional impingers, such as the AGI-30 (Ace Glass Inc., Vineland, NJ) may loose a considerable amount of the collection fluid within the first hour or two of sampling (Lin et al. 1997). Some airborne microorganisms collected into the liquid may be reaerosolized and escape from the collection medium. These effects decrease the physical collection efficiency of impingers. The viability of sensitive microorganisms collected by conventional impingers is also affected by the sampling time (Lin et al. 2000). These problems have been addressed in the Swirling Aerosol Collector (Willeke et al. 1998), which is commercially available as the BioSampler (SKC Inc., Eighty Four, PA). The BioSampler utilizes a viscous, non-evaporative collection fluid for long-term sampling providing relatively high physical sampling efficiency with d_{50} = 0.3 µm and operates at the air flowrate of 12.5 L/min. A pressure drop at operational air flow rate reaches 50 kPa which requires substantially sized pumping equipment.

The majority of conventional bioaerosol monitoring devices are not adaptable for personal monitoring. Most have a relatively high pressure drop (2,000-50,000 Pa) and operate at high sampling flow rates (10-50 L/min), thus requiring stationary pumping equipment. Many of these samplers have considerable size and weight that also restrict their use as personal samplers. Due to the limitations of stationary bioaerosol samplers, it is historically common practice to assess personal exposure to bioaerosols using small filter cassettes originally designed for monitoring non-biological aerosols. However, the desiccation effect, caused by large volumes of air passing through the filter during the sampling of bioaerosols, may dramatically diminish the viability of microorganisms, especially of the sensitive ones (Wang et al., 2001). Several attempts have been made to adopt existing aerosol samplers for bioaerosol sampling; for example, a standard IOM gravimetric dust sampler (SKC, Inc., Eighty Four, PA) has been modified for personal monitoring of airborne microorganisms, but has not been proven to maintain microbial viability during eight-hour sampling, which is usually required for occupational exposure assessment (Kenny et al., 1998). To decrease the influence of desiccation on the viability of collected microorganisms, such personal samplers should be operated only for very short sampling times. However, the data from single, short-term sampling may be orders of magnitude higher or lower than the average long-term exposure and are unlikely to represent human exposure accurately. Some sources may release bioaerosols as "concentration bursts" that may not be detected by short-time sampling, while such episodic releases may produce significant health effects.

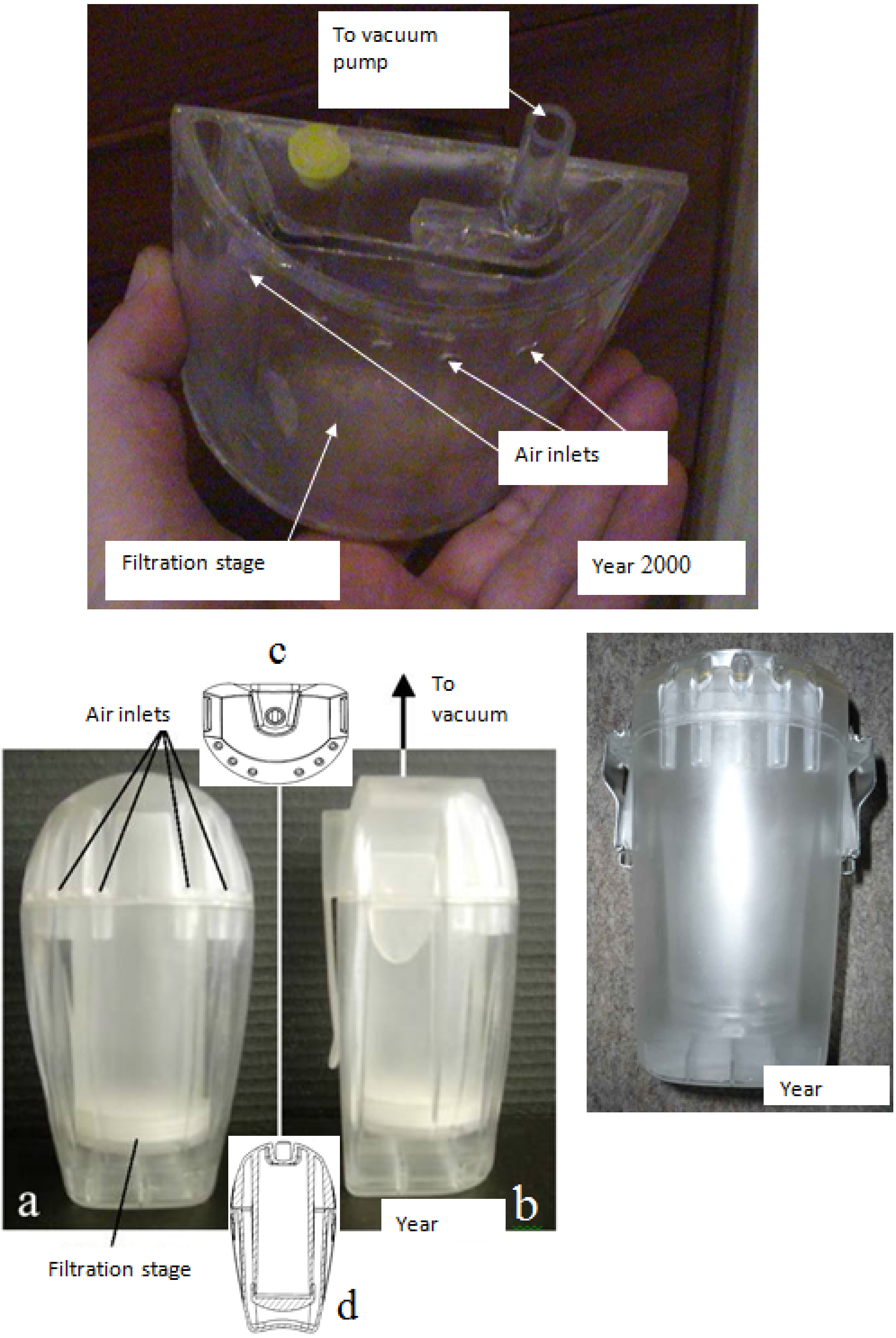
BIOAEROSOL SAMPLER

To address these issues, we designed a personal sampler for collection of bioaerosols. The operational principle of this sampler is based on a method, which was earlier developed for removal solid and liquid particles from gas carriers for engineering control purposes (Agranovski et al., 1999; Agranovski et al., 2001). In this method, a porous medium is submerged in a liquid layer and a polluted gas, such as air contaminated with particles, is blown through it. The gas carrier is split into a multitude of very small bubbles. The particulates are scavenged by these bubbles, and, thus, effectively removed. A range of filters with various physical characteristics along with a number of collecting liquids were used to optimize the process. It was found that various physical characteristics ought to be considered to meet particular process requirements. They include fiber size and wettability, filter packing density and thickness, irrigating liquid viscosity and surface activity and many others. Based on the results of this research, the first prototype of the technology was built and tested under controlled laboratory conditions on monitoring of viable airborne bacteria and fungi in year 2000.

In comparison to other bioaerosol sampling techniques, initial performance evaluation experiments on bacteria and fungi demonstrated a very high physical collection efficiency of ≥97% for particles ≥0.3 μm in aerodynamic diameter during 8 hours of continuous operation. The pressure drop across the sampler at operational air flowrate was below 1,700 Pa, much lower than that of most conventional bioaerosol samplers and the collection fluid losses due to evaporation and aerosolization did not exceed 18% in 8 hours (this number could be adjusted for real world conditions depending on local climate). Laboratory and field evaluation of the viability of sampled microorganisms also demonstrated an outstanding recovery rate of stress-sensitive (especially selected to represent the worst case scenario outcome) gram-negative Pseudomonas fluorescens bacteria at the level of 61%. This number is significantly higher compared to those achieved using available techniques, even when these techniques are utilized for sampling of only one to two hours in duration (Agranovski et al., 2002a; 2002b).

Due to its soft operational regime and lack of desiccation from the surface of captured microorganisms, the new technique had a potential for monitoring viruses in the ambient air. Our investigations have demonstrated that the recovery rate of the stress sensitive influenza virus was approximately 20%, whilst the recovery rate of the robust vaccinia virus was around 90%. In addition, the personal sampler was successfully used for monitoring of a number of other common environmental viruses, including Mumps, Measles, various strains of Influenza and SARS in our following investigations (Agranovski et al., 2004a; 2004b; 2005a; 2005b; 2005c).

Figure 1. Personal bioaerosol sampler (top photograph – first prototype made in the year 2000; bottom photograph – final prototype made in the year 2005). On the bottom photograph: front (a) and side (b) views are presented along with the diagrams of the top (c) and vertical cut (d) of the sampler. Current shape (right photograph) year 2010



RECENT DEVELOPMENTS

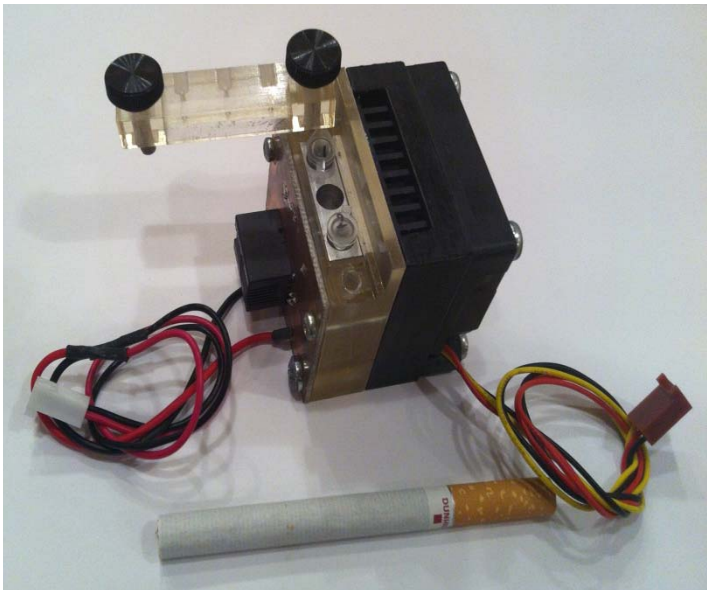


Figure 2. *Mini PCR device*

As the representative sampling of viable airborne microorganisms, even viruses, into liquid became feasible, the next important step of the technique development process was the investigation into the potential for minimising the length of time lapsed in the process of, at least, qualitative determination of particular microorganisms in the air. This step is especially important for potential users from biosecurity, animal farms, epidemiologists and defence forces. Using the conventional PCR was found suitable for the rapid analysis of collected microorganisms in this application. Monitoring of Mumps and Measles viruses in a hospital was successful and both viruses were reliably detected and enumerated (Agranovski et al., 2006; 2007; 2008).

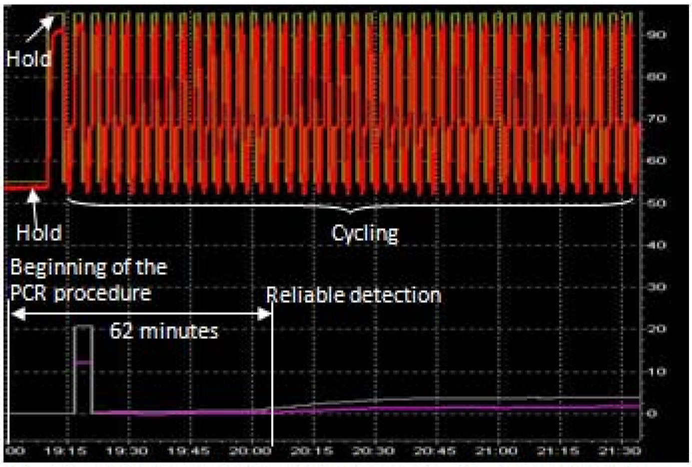


Figure 3. *Amplification of Had5 and Flu viruses by mini-PCR machine*

In addition, the real-time, quantitative PCR devices that are currently available could minimise this time even further (Pyankov et al., 2007; Usachev and Agranovski 2012). However, due to the substantial size and weight of standard PCR equipment, combining the sampler with such devices would have significant limitations on mobility. Some miniaturisation was required in order to develop a mobile and user-friendly technique to address these limitations. Based on this demand, we developed a quantitative mini PCR device and validated its suitability for the rapid detection and enumeration of bioaerosols collected by the sampler. At this stage, a fully operational prototype of the device has been developed and verified under controlled laboratory conditions (Fig. 2). This technology is suitable for reliable detection of microorganisms of interest within 1-2 hours, which in comparison to all other currently available techniques is significantly faster (Fig. 3).

However, there are some bottlenecks related to application of the PCR technique. Firstly, the PCR is not continuous process, and it requires triggering upon some corresponding event, i.e. appearance of unexpected airborne materials in the air. Using of, for example, a particle counter as a trigger, makes the device much less economically feasible for wider community. Secondly, further decrease of detection time is physically not feasible, as the PCR device has to undergo through thermal cycling with no results obtained prior a particular cycle, when the difference between the fluorescence signals acquired for the sample and control reaches statistically significant value. In many applications, this issue is crucial, as detection time is the main characteristic of the bioaerosol monitor in the areas of biosecurity, defence, human and animal health, and many others. As the result, due to abovementioned operational restrictions of the PCR technique, further investigations are required to develop a bioaerosol monitor which truly operates in real time.

CURRENT DEVELOPMENTS

Optical affinity biosensors based on surface plasmon resonance (SPR) present one of the most advanced label-free optical sensing technologies. The ability to monitor the interaction between a molecule immobilized on the surface of the sensor and the interacting molecular partner in a solution have made SPR sensors a very powerful tool for the detection of bio threat agents in different sources. The SPR technique allows for the utilisation of the multiplex approach for the detection of multiple analytes from within a sample in real-time mode. The SPR sensors that are based on the principle of measurement can be classified as: (1) SPR sensors with wavelength modulation (angle of incidence is fixed and the coupling wavelength serves as a sensor output), (2) SPR sensors with angular modulation (coupling wavelength is fixed and the coupling angle of incidence serves as a sensor output), (3) SPR sensors with intensity modulation (both the angle of incidence and the wavelength of incidence light are fixed at nearly resonant values and the light intensity serves as a sensor output).

SPR affinity biosensors that are used for the detection of bio agents are devices that consist of three main subsystems: the sensor hardware (optical reader), a biorecognition element, and a sample preparation and delivery system. In the SPR sensor, biorecognition elements are immobilized on a thin metal film (gold is common for the application). A variety of molecules, such as antibodies and their fragments, engineered affibodies, antigens, peptides, oligonucleotides, molecular imprinted polymers and small organic ligands could be used. A SPR sensor possessing a silver layer demonstrates far greater sensitivity than that with only a gold layer. Despite this, gold is the preferred option for use as it is far more resilient than silver against oxidation when exposed to air or water. Recently, a new structure of resonant metal films based on bimetallic layers (with gold as the outer layer) was suggested that combine properties of both metal sensitivity and chemical stability. A careful selection of specific biorecognition elements and the chosen immobilization method are the most crucial factors in optimising SPR performance characteristics such as specificity and sensitivity. The main factors considered in the selection of the biorecognition element include high affinity to a target analyte, stability of biological activity, specificity, and availability of functional groups for their direct immobilization on a solid surface. There are various approaches for the immobilization of the biorecognition element on the SPR sensor surface. These include procedures based on physical adsorption via hydrophobic and electrostatic interactions, strong covalent binding, or attachment of tagged proteins by a site-specific non-covalent interaction between the tag and a capture molecule. The attachment to the surface can be mediated by high-affinity molecular linkers in multilayer systems such as streptavidin-biotin interaction, proteins A or G with immunoglobulins, or DNA hybridization.

The combination of the above personal sampler and SPR device will allow for the development of a real-time bioaerosol monitor unlike anything that is currently in existence. It will create a major breakthrough in the field of bioaerosol monitoring, which is crucial in many areas, especially in the area of public health as it will provide an ability to localise pandemics which are caused by airborne pathogenic viruses. Figure 4 shows a schematic diagram of the proposed technique. Personal sampler charged by fifty millilitres of collecting liquid will be operated by a portable sampling pump capable to provide up to 5 L/min air flowrate. The discussed above operational principle enables to collect bioaerosols from the ambient air with the efficiency above 95%. Liquid from the sampler will be continuously circulating through the SPR's optical chamber by miniature peristaltic pump capable to provide controlled liquid flowrate starting from 1.6 ml/min. In a case of appearance of microorganisms of interest in the air, they will be collected by the sampler and pumped with a liquid stream to the PSR module. The kinetics of interaction with the paired biological material immobilised on the detector's surface will be traced by the SPR device and immediately reported to the user.

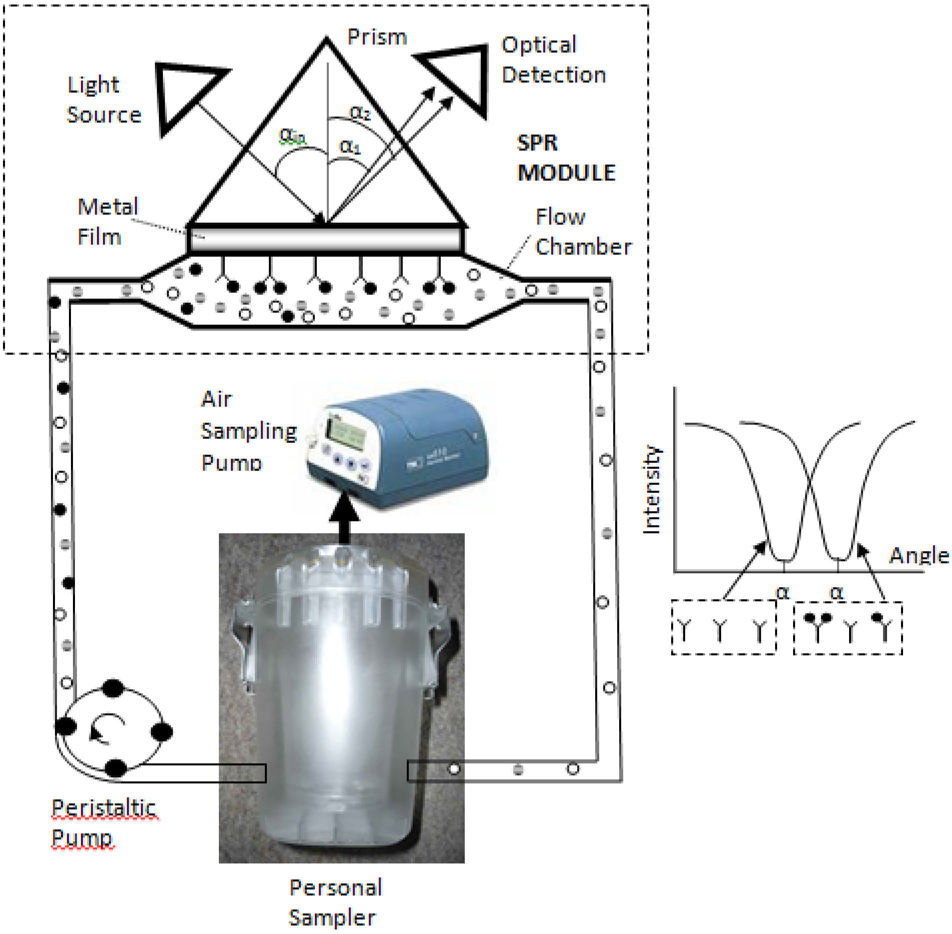


Figure 4. *Schematic diagram of the proposed combined technology*

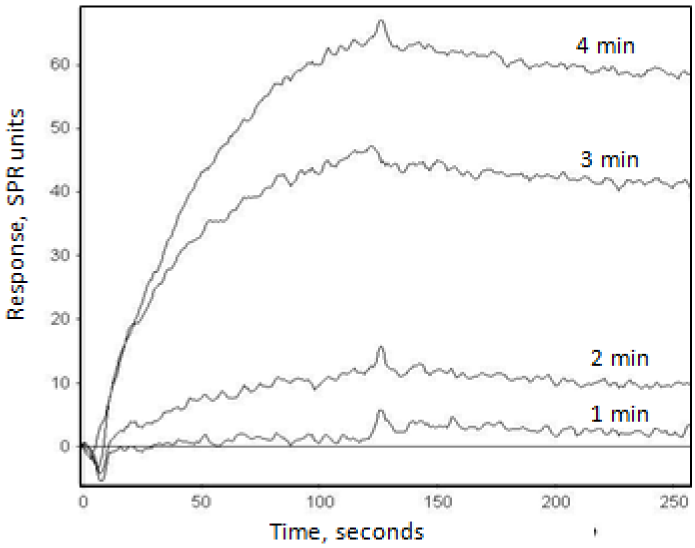


Figure 5. *SPR signal gain for airborne MS2 phage collection*

At this stage, we have built a prototype of the SPR technology and used it in combination with the personal sampler for detection of airborne MS2 bacteriophage. MS2 phage was aerosolized in an aerosol chamber from suspension by a Collison nebulizer according to a procedure described in Agranovski et al. (2005c). The personal sampler was used to sample bioaerosol for four minutes. Aliquots of collection liquid were taken every minute and passed through the SPR cell. The results of the experiment are shown in Figure 5. As is seen, even after one minute, the signal was measurable and the presence of microorganism in the collecting liquid was detected within 120 seconds (the best currently available bioaerosol monitors could identify bioaerosol in the air within few hours). The signal was correspondingly stronger for more concentrated aliquots collected 2, 3 and 4 minutes after commencing of the experiment. This graph looks very promising for further development of the proposed technology, which would become first in the world real time bioaerosol monitor.

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CURRENT AND DEVELOPING PHILOSOPHIES IN OCCUPATIONAL EXPOSURE RISK MANAGEMENT TO CHEMICALS

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ABSTRACT

Chemical usage has grown rapidly since the early 1900s. Approximately 8 million chemical-based products and nearly 100,000 chemical substances are commercially available. Manufactured chemical products have been integrated into nearly all industrial, agricultural and extraction processes, building materials, transportation and commercial and domestic goods. Relatively few chemicals are thought to pose significant risks to the health of workers. Research undertaken in the western world, over many years has shown that extent of occupational exposure to harmful substances and the resulting numbers of occupational ill-health and fatalities have been coming down for the last 30 years or so. However, the extent of ill-health and fatalities in the western world remain unacceptably high because of exposure to a relatively small number of potent chemicals. In addition, there is significant potential for a greater burden in developing countries from exposure to a vast array of corrosive, toxic and very toxic chemicals.

Occupational hygienists have played a significant role in bringing down the number of people affected by exposure to chemical substances. They have spent a significant amount of their resources on exposure assessment, monitoring and raising risk awareness through traditional teaching methods. The physical control approaches utilised can be categorised into three main areas. These are:

- Control at source;
- Control along the exposure pathway; and
- Control at workers

Traditionally, occupational hygienists have concentrated on controls along the pathway and at workers. They tend to recommended local exhaust ventilation (control along the path way) and Personal Protective Equipment (PPE) as the main measure for achieving exposure control. Not many hygienists have actually become involved in designing controls at source, ventilation systems or PPE.

Currently, strong and unstoppable technological, scientific, social and business trends are dramatically influencing the way the profession delivers its services for chemical exposure control. The profession must attempt to respond effectively and positively to maintain its credibility, power and influence and most importantly for bringing down exposures to highly toxic substances.

This presentation will first discuss current practices for chemical exposure control and then move on to explore what we need to learn and do for the delivery of chemical exposure risk management services in the 21st Century.

A POTPOURRI OF COMPUTER TOOLS TO HELP OCCUPATIONAL HYGIENISTS IN THEIR JOB

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ABSTRACT

Occupational hygienists must deal with a wide spectrum of issues requiring knowledge in various disciplines such as chemistry, engineering, toxicology, ergonomics, etc. For many years, we have worked with different specialists in order to build user-friendly computer tools supporting OHS staff in their day-to-day duty. Based on Microsoft Excel® or JavaScript programs, these tools can be used directly on the WEB or downloaded on any computer. This presentation will be a rapid-fire succession of *real-time-demonstration* of selected tools built over the years.

- To support Québec regulation, the IRSST has published a Guide for the adjustment of OELs for unusual work schedules and implemented a computer tool allowing its uniform application. A modified-OSHA model has been selected as the adjustment principle to ensure an equivalent degree of protection to workers with a conventional schedule of (8 h/d and 5d/w), and to workers with unusual work schedules.
- As ACGIH®, Québec and Australian regulations state a quite similar concept that when two or more substances are present and have similar effects on the same organs of the human body, their effects should be considered additive, unless it is established otherwise. MIXIE is a user-friendly WEB-based tool allowing the identification of possible additive and interaction effects of mixture. When the exposure concentrations are entered, the tool calculates the sum of the fractions of the OELs.
- In 2007, ACGIH® changed its TLV® documentation on Heat stress and strain: revised decision-making process, concept of Action Limit (AL), clothing adjustment factors, metabolic rate for each category of work at the screening level and, a more specific procedure for the work/rest regimen (WRR) as administrative controls. A computer tool performs an iterative calculation to propose the WRR when the conditions at work exceed the TLV® or AL curves.
- IHMOD is an EASC-AIHA “cool modeling tool” containing more than 10 chemical exposure models (Well-mixed box, Eddy turbulent diffusion, Plume or two-zone models …) with an easy-of-use interface that allows entering and editing variables in each model. It is thus possible for the user to visualize the relationship between these variables and the temporal or spatial chemical exposure. To assess overall uncertainty, it is also possible to run a Monte-Carlo simulation procedure with IHMOD. The result is then presented as a probability distribution, which allows a better representation of reality.
- IH SkinPerm simulates the "chemical fate" for three skin absorption scenarios: instantaneous deposition, prolonged contact with time and vapour absorption through skin. The algorithm, developed from QSARs studies, takes into account many parameters. The objective of its development is to provide a better understanding of the process of absorption through the skin and allow a fair assessment by occupational hygienist to ensure better protection for workers.

These decision-making tools can help occupational hygienists doing better risk assessment but will never replace their professional judgement on a particular situation. Finally, the aim of this presentation is not only to share these tools with the audience but (and why not!) to get some ideas and needs for future tool development.

AUSTRALIAN WORK HEALTH AND SAFETY STRATEGY – WHERE DO OCCUPATIONAL HYGIENISTS FIT IN?

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ABSTRACT

The *Australian Work Health and Safety Strategy 2012-2022* (Australian Strategy) represents a real commitment by governments, industry and unions to work collaboratively to drive work health and safety improvement in Australia.

The Australian Strategy builds on the work of the existing *National OHS Strategy 2002-2012* and was developed following an extensive 18 month consultation process. With the ultimate vision of '*Healthy, safe and productive working lives*' it sets realistic targets and has seven national action areas which will collectively improve work health and safety now and in the future. Through the perseverance of all levels of governments, industry, unions, business, workers and community groups working together over the next decade the outcomes of these action areas will be achieved.

This session will introduce the Australian Strategy; outline the four outcomes and seven action areas; and discuss the role of occupational hygienists in achieving the Australian Strategy's 2022 outcome of 'reduced exposure to hazards and risks using improved hazard controls and supported by an improved work health and safety infrastructure'.

CONCURRENT

OCCUPATIONAL HYGIENE INTERVENTION IN THE WOOD PROCESSING SECTOR - A NEW ZEALAND GOVERNMENT PROJECT ON REDUCING EXPOSURE TO NOISE AND WOOD DUST.

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Dr John Wallaart, Programme Manager Accident Compensation Corporation
Dr Ian Laird, Massey University Centre for Ergonomics, Occupational Safety and Health
Dr Jeroen Douwes, Massey University Centre for Public Health Research
Dr John Pearse, Acoustics Research Group, Canterbury University.

KEYWORDS

Wood dust; noise; intervention effectiveness research; hazardous substances; exposure prevention.

ABSTRACT

The New Zealand Ministry of Business, Innovation and Employment is trialling an intervention project focussed on reducing exposure to noise and wood dust in the wood processing sector. The intervention focuses on reducing exposure primarily through engineering control, and improved exposure management. The project will facilitate and fund academics, acoustic engineers, occupational hygienists, ventilation engineers and other specialists to work with companies participating in the project. The model is similar to the US OSHA free consultation program for small businesses, and it is envisaged that, if successful in New Zealand, the model could be expanded to a wide variety of workplaces and exposures.

INTRODUCTION

Evidence from recent New Zealand research shows exposure to noise and wood dust in the wood processing sector is causing harm.

Wood processing and sawmilling have some of the highest noise exposures of any sectors (Laird, 2011) and this is reflected in high rates of noise-induced hearing loss compensation claims. Multiple factors lead to poor management of noise exposure in New Zealand. These include: a lack of incentive for industry to reduce exposure; the predominant noise control strategy being minimisation, specifically, the use of hearing protection, with little attention given to elimination, isolation and engineering control; poor effectiveness of hearing protection; lack of monitoring to assess exposure and effectively manage risk; lack of consideration in workplace design and machinery selection to effectively reduce noise exposure; capability constraints limiting the input of technical expertise in providing best practice solutions (Laird et al, 2011).

Research shows an increased prevalence of asthma in New Zealand sawmill workers, and elevated exposure to dust is associated with a significant decline in lung function, of both an obstructive and a restrictive nature (Douwes et al, 2001, 2006, McLean et al, 2012). There is also potentially, a cancer risk as wood dust has been classified by IARC as a Group 1 carcinogen (IARC Monographs, 1995). It is expected that the same factors leading to poor noise management are applicable to wood dust and other exposures. In addition, there appears to be a general lack of knowledge amongst industry about health effects from wood dust exposure e.g. cancers ('t Mannetje, 2012).

To address noise-induced hearing loss and respiratory illness in the wood processing sector, the New Zealand Ministry of Business, Innovation and Employment is trialling an intervention project focussed on reducing exposure to noise and wood dust. The intervention is based on a prevention effectiveness concept (Kristensen, 2005) with the intention that, by reducing exposure, there will be a subsequent reduction in associated adverse health outcomes.

The project will focus on employers reducing harmful exposure in both the short and long term.

INTERVENTION DESIGN

The intervention focuses on three key areas, as proposed by LaMontagne et al (2005). The three focus areas are: the physical environment; organisational environment; and the worker interface. The hypothesis is that intervention in each of the three areas will result in a reduction in exposure to wood dust and noise.

Focus on the physical environment will address changes that can be made to the machinery, work processes or work areas to reduce emissions and levels of noise and wood dust.

Focus on the organisational environment is aimed at raising the level of management via improving exposure and health management systems, and improving knowledge, perceptions, attitudes and behaviours towards occupational health.

The worker interface focuses on what the worker can do to manage their exposure. Again, the aim is to improve knowledge, perceptions, attitudes and behaviours towards occupational health and effective PPE use. The focus also includes assessment of the attenuation of ear plugs, respirator fit, provision of training on the use of hearing protection, respiratory protection, use of exposure controls in the workplace, and hazard awareness training.

The strategy will be tested with a pilot project focussing on up to 10 businesses in the wood processing sector. The businesses will be those willing to participate, who will receive the advice and training for free, and will in an agreed timeframe implement control measures where it is considered they are needed. It is expected that engineering controls will vary in cost and ease of implementation, and as such a realistic timeframe for implementation will be agreed between the business and the Ministry. This model is similar to the US Occupational Health and Safety Administration (OSHA) 'Free On-site Consultation Program' for small businesses. In the program, OSHA facilitates consultants from state agencies or universities to work with employers to identify workplace hazards, provide advice on compliance with standards, and assist in establishing injury and illness prevention programs. In exchange the employer is required to correct serious job safety and health hazards.

COLLABORATING PARTNERS

The Ministry is collaborating with various experts to implement the intervention. These include:

- Massey University Centre for Ergonomics, Occupational Safety and Health, for intervention design and evaluation of attitudes, perceptions and behaviours
- Canterbury University Acoustics Research Group, for noise assessment, identification of sources and engineering controls
- Massey University Centre for Public Health Research, for wood dust exposure assessment and peak exposure identification

- Egmont Air Limited, for assessment of and advice on extraction ventilation systems
- 3M Occupational Health and Environmental Safety Division, for respiratory fit testing and ear plug attenuation evaluation, and training in the selection, use and care of protective equipment.

In addition, there will be collaboration with the onsite engineers and health and safety representatives in identifying exposure and designing and implementing engineering controls. Research from the UK Health and Safety Executive (2009) supports the benefits of including on site engineers in developing control solutions.

INTERVENTION EVALUATION

In their 2005 paper, LaMontagne et al reported "a particular shortage of intervention studies targeting occupational disease and associated exposures" and suggested that such intervention studies be given a high research priority. For such studies, it is also essential that exposure prevention interventions are rigorously tested for effectiveness to ascertain whether the intervention has had the desired effect (Kristensen, 2005).

Given the need for good intervention evaluation, this project includes a number of quantitative and qualitative measures taken both before intervention and following intervention. These include: noise mapping (Leq and frequencies); personal noise exposure measurements; video exposure monitoring to identify and quantify peak wood dust exposures; personal Time Weighted Average wood dust exposure measurements; ventilation effectiveness measures e.g. capture and transport velocity, static and velocity pressure measurements; visual assessment of local exhaust ventilation systems; attenuation of ear plugs; fit testing of respiratory protection; assessment of compliance with the New Zealand Approved Code of Practice for Management of Noise.

DISCUSSION

For this project, finding a balance between good intervention design, valid measurement of exposure reduction, and the need for delivering an outcome in a relatively short time frame is a challenge. However, it is hoped that this model of facilitating experts to work with industry to manage exposure, is successful, and can be expanded and adapted to a wide variety of workplaces with a variety of exposures. It is also hoped that, from the project, the Ministry can develop tools to enable health and safety inspectors to engage directly with companies about options for effective engineering control.

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AN IH 1944 LEGACY IMPACTS UPON A PACIFIC PEOPLE

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ABSTRACT

The underwater environment of Chuuk Lagoon in the south western part of the Pacific Ocean Caroline Islands, Micronesia, one of the largest lagoons in the world, and as a 1944 wartime legacy is the resting place of more than 60 huge WWII vessels, most over 120 metres in length that contain significant quantities of unexploded ordinance, munitions, fuel, oil, and chemical supplies that remain within the vessels. Many vessels are at depths that are technically difficult to access and assess. The superstructure of the vessels have significantly deteriorated with time to the point of exposing some of the stores and cargoes to the ocean and to facilitate and accelerate the release of many materials including those with significant exposure risk and toxicity. The vessels are regularly visited by local and international visitor groups as the fleet represents one of the most unique representations of historical significance of the era in one location. A significant emerging issue is occurring and becoming apparent in the gradual release of chemicals and biologically active materials from the vessels in to the marine and coastal environment as well as having the potential to affect visitors and in particular local people who regularly visit the sites. Personnel visits to the vessels can be frequent for more accessible vessels and can require exposure to significant depths and time for selected less accessible vessel sites. The local underwater dive occupations form part of the island's main industry. A preliminary occupational hygiene review of selected vessels visited is undertaken on behalf of the local resident Chuuk peoples and visitors in order to provide an indication of the potential occupational hygiene exposures that are occurring and ways to manage personal occupational exposure. Some of the commonly accessible vessels and the more technically difficult due to depth and condition are reviewed. Further follow up visits and reviews are planned as part of the program.

INTRODUCTION

Globally in the oceans and the seven seas over 9000 military, auxiliary, and merchant marine vessels were sunk between September 1939 and September 1945 which remains the largest comparable loss of shipping over such a short time period (Petersen 2007). The Asia Pacific region has over 3800 WWII vessels including 330 tankers and oilers amounting to over 13 million tons in the Pacific (Monfils 2005). The international community is realising and recognising the global and local problem of sunken wrecks and potential pollution risks with the International Marine Organisation (IMO) encouraging regional centres and secretariats to assess the situation regarding WWII wrecks that may give rise to oil pollution (IMOC 2004). The significant vessel and building destruction that occurred in and around Truk Lagoon commencing 1944 had significant strategic consequences for Australia and its Allied military forces in the Pacific at the time assisting the regional military campaigns particularly in the New Guinea region directly to the north.

CHUUK GEOGRAPHIC PERSPECTIVE

Chuuk is one of the four states in the Federated States of Micronesia (FSM), the other three being, Yap, Pohnpei and Kosrae. It is located mid-ocean approximately 7 degrees north of the equator and on a line of longitude 151 degrees approximating the eastern coast of Australia (about 2100 km to Cape York) with New Guinea the nearest major landmass about 1500 km to the south. The FSM, consists of many small islands having a total land mass of 701 sq. kilometres in a current economic exclusion zone of 3 million square kilometres is also referred to as the Caroline Islands, and together with the other regional island groups, the Marshalls and the Marianas, with all groups referred to collectively as Micronesia.

Chuuk consists of 19 elevated islands located inside a lagoon called Truk Lagoon, 10 atolls and 225 coralline islands, of which many are located outside the lagoon. The elevated islands are composed of volcanic rock and are the peaks of a mountainous land mass, their total mass above water being approximately 91 sq. kilometres. The lagoon is about 64 kilometres in diameter and has been formed by a barrier reef enclosing an area of 2,125 sq. kilometres of relatively deep and protected water.

1940 ERA HISTORY

Japan controlled Micronesia from 1914 and established major bases there. Headquartered at Truk Lagoon as a fleet base in November 1939, the Fourth Fleet also established naval base forces in the Carolines, Marianas, and Marshalls and the Combined Imperial Japanese Navy Fleet (IJN) were based there from July 1942 to February 1944. At Truk, seaplane bases were developed on Dublon and Moen islands; land plane fields were constructed on Moen, Eten, and Param; and naval facilities were established on Dublon and other islands to replenish the fleet at anchor. No major docking or dry docking facilities were constructed. Truk Lagoon was regarded by the USA during World War II as the strongest naval base in the Pacific with the exception of Pearl Harbor. Over 44,000 Japanese lived and worked in Truk Lagoon, with the local 9,000 Chuukese population until the end of the war in September 1945 (Jeffery 2003) (Takizawa 2000).

The IJN and Truk was used as a base against Allied forces in New Guinea and the Solomon Islands and as part of a strategic plan to isolate and control Australia throughout 1942 and early 1943 by means of a master plan coded Operation FS(Fiji-Samoa New Caledonia) and (with the Japanese army finally supporting the plan with IJN on 10 January 1942) commencing with the Battle of the Coral Sea (7-8May 1942) (Frei 1991). Darwin the northernmost city on the Australian mainland was initially bombed on 19 February 1942 the first of many Japanese naval aviation attacks with the loss of nine ships and 251 people. There was ongoing bombing of the Australian northern and north-eastern coasts with a total of 63 raids on Darwin and a total of almost 100 raids on the region (Morison 2001) (Jenkins 1992).

By the middle of March the Japanese were approaching the doorstep of Australia. Darwin, the only port on the northwest coast, had already been severely bombed. Townsville had also been subjected to air raids. The forces available in Australia were inadequate to meet the Japanese threat. Air and naval strength were particularly weak, and these deficiencies had proved disastrous to the Allied cause elsewhere in the Pacific (MGS1994). In March 1942, in response to strategic analysis the Japanese military adopted a strategy of isolating Australia from the United States by capturing Port Moresby in New Guinea, the Solomon Islands, Fiji, Samoa and New Caledonia (Frei 1991). It was at New Guinea that the Japanese advance was blunted. Over the course of three years, 350,000 Japanese troops were pinned down in New Guinea and they suffered 220,000 casualties (Frei 2004). The Battle for Australia Day was formally observed on the first Wednesday of September commencing 2008.

The Japanese Army at Truk was at its fullest strength in January 1944 and established numerous coastal defence and anti-aircraft guns, pillboxes, bunkers, and caves. An 18 month period of aerial bombardment began in February 1944. Beginning with Operation Hailstone, the base was bombed on February 17 and 18, 1944; again on April 30 and May 1, 1944; then with USA B-24 and B-29 bombers, some on a daily basis over many months, then less frequent until the war's end. Further attacks were launched by a British Aircraft

Carrier group in June 1945. A total of 6,878 tons of bombs were dropped on Truk Lagoon, and in one month alone, June 1944, the total was 1,813 tons.

Over 50 ships (mainly merchant vessels) over 200,000 tons, were sunk in the lagoon and about the same number outside of the lagoon; about 400 aircraft were destroyed; and all five airstrips/seaplane bases rendered inoperable. However, the Japanese Combined Navy Fleet diverted most of its warships out of Truk Lagoon just prior to and in anticipation of the February 1944 attack. Over 4,000 Japanese Navy and Army personnel were killed and wounded and over 120 Chuukese, 30 American, and 2 British were killed and/or wounded during the war (Hezel 1989).

At the conclusion of World War II, the Japanese departed Micronesia and the United States was designated as trustee by the United Nations. The administration of Micronesia, called the Trust Territory of the Pacific Islands, was assigned to the United States Navy until 1951 when the U.S. Department of the Interior took over. Over the next 35 years, an agreement on the independence of what became known as the Federated States of Micronesia was negotiated through a system of "Compacts of Free Association" between the United States and the Federated States. Other regions of Micronesia developed separate arrangements with the United States.

TRUK LAGOON SHIPWRECKS AND AIRCRAFT

The 51 ships sunk in Truk Lagoon include a group of 8 warships, comprised of 4 submarine chasers (130-420 tons), one submarine of 1,785 tons, 2 destroyers (each approximately 1,500 tons), one 935-ton patrol boat, and some smaller landing craft; 39 armed transport ships and tankers ranging in size from a few hundred tons to the 11,614-ton submarine tender Heian Maru (the largest ship in the lagoon); the 8,614-ton armed transport Kiyosumi Maru (which is representative of the 39 transport ships sunk); and 3 tugs. This summary does not include the many smaller craft reported sunk (Jeffery 2003).

Many of the ships were anchored and unloading their cargo of oil, tanks, sea mines, vehicles, aircraft, and other military machinery, foodstuffs, alcohol, and medicines. The ships included the Fujikawa Maru, a 6,938-ton armed transport that still contains "zero" aircraft in its holds; the Shinkoku Maru, a 10,020-ton oil tanker that assisted the Japanese fleet that struck Pearl Harbor; and the 10,437-ton armed transport, Aikoku Maru, that sank after a huge explosion and killed over 730 soldiers and crew. Destroyers and other ships attempting to flee the bombing sank near the passages through the encircling reef.

The remains of nine Japanese and one American World War II aircraft have been found in Truk Lagoon. During the bombing campaign, nearly 450 planes were lost, including 416 Japanese aircraft (the majority of which were destroyed on the ground before take-off), 26 United States naval aircraft (including helldivers, hellcats, kingfishers, avengers, and a Douglas SBD-5 Dauntless), several British planes (a British carrier was attacked in June 1945), and 5 or 6 U.S. Air Force B-24s. Japanese aircraft found inside the lagoon include zero fighters, dive bombers, reconnaissance aircraft, a larger two-engine bomber, and a four-engine flying boat.

CORROSION RISKS

The sea is a sacrificial and corrosive chemical environment for metal objects and wooden structures. The rates of shipwreck deterioration depends upon type of construction, length of immersion, extent of burial, chemical, physical and biological factors. Salt-water corrosion along with shifting sea-bottom sediments, marine bacteria and organisms, destructive storms and currents will reduce a sunken shipwreck back to its original basic chemical elements. Eventually a shipwreck will deteriorate over time under the sea to the extent where it may release some or all of its oil cargo, fuels, lubricants or hazardous chemicals (Monfils 2005). Sunken shipwrecks in shallow waters which are exposed to warm tropical water temperatures will usually deteriorate at a greater rate than cold deep water wrecks. This is primarily due to a number of environmental factors which include shallow oxygenated waters in lagoonal or near shore environments, microbial attack, the impact of storms, unstable bottom sediments and strong local hydrodynamic forces acting on the wreck (Macleod 2002) (Macleod 2007). Merchant vessels lost at sea due to storms, grounding or collision accidents, or military vessels that have been sunk during wartime are expected to have also suffered extensive structural damage, fires and explosion of ammunition prior to sinking. Often during the war, explosions continued even after the vessel sank because depth charges or munitions would explode due to increased water pressure and the shifting and crushing of cargoes.

Overseas visitors and researchers have been diving the shipwrecks and aircraft for over 40 years and the wrecks show signs of deterioration. Although some salvage was carried out on the shipwrecks a few years after the war, and the effects of storms and people have been evident, the shipwrecks are essentially intact and still contain much of their cargo. Their environment has helped maintain the integrity of the ships; many are in 30-60 metres of water and protected by the reef from the effects of currents, winds, and ocean swells (Jeffery 2004).

Made of iron, steel, or aluminium and located in a marine environment, the shipwrecks and aircrafts current state of integrity was studied as part of a Historic Preservation Fund-supported project as the first corrosion survey of the sites in 2002.Of particular interest is the contribution from the iron rich superstructures of the vessels acting as a stimulus to marine growth and diversity counterbalanced with the progressive corrosion and loss of structural integrity of the vessels (MacLeod 2011). The corrosion surveys are important predictors of the rate of corrosion, and for structural integrity of the sites. From the initial survey, a provisional estimate of perforation times, many of the wrecks in Chuuk Lagoon were estimated to retain their existing integrity for perhaps the next ten to fifteen years before portions begin to undergo significant collapse. This finding has major implications for the management of the sites and for the safety of divers undertaking penetration dives (MacLeod 2003). It also has major implications for any fuel and oil in the bunkers of the ships, which if released in an uncontrolled manner could result in major environmental consequences.

The shipwrecks also contain munitions with demonstrated remaining viability, indicated by a local hazardous undercover practice for which some of the munitions materials are used to make bombs for explosive percussion fishing. Handling of the munitions and chemical contents also provides exposure by skin absorption and potentially of inadvertent ingestion dependent upon the hygiene practices used. The subsequent explosions damage nearby flora and fauna and the shipwrecks themselves.

SITE MANAGEMENT

While the United States contributes considerable support to help finance government operations, the Chuukese people have limited economic resources and historic preservation would be assigned a low priority. Effective management of the sites will be difficult in the current economic and social climate in Chuuk. In comparative economic terms a country with a viable economy and a prosperous society would find the effective management of over 50 large shipwrecks and numerous aircraft a burden (Jeffery 2004).

Due to their unique historical significance and relatively intact representation, state of preservation, due in part to restricted accessibility, and tropical location the lagoon and its contents are of interest to a range of knowledgeable groups interested in site preservation and to witness and study the sequence of events and history that are represented in the marine waters. The attraction of the site has led to what is the most significant industry for the local economy.

Given the importance of the underwater sites, it is unusual that there have been no major academic or theoretical studies of the World War II underwater cultural heritage in Truk Lagoon, and only two previous management investigations (Hezel 1989). The shipwrecks are also significantly associated with death and destruction of Japanese ships and the death of Japanese sailors and soldiers (Macleod 2008).

The shipwrecks and aircraft located in Truk Lagoon are protected under Chuukese, Federated States, and United States law. The United States has designated the "Japanese Fleet" or "Chuuk (Truk) Lagoon Monument" a National Historic Landmark and listed it in the National Register of Historic Places and they are the only historic sites in Micronesia. Under Chuukese and Federated States designations, it is illegal to interfere with these sites, punishable by fine or imprisonment. Federated States legal protection covers all artifacts on land and underwater that are older than 30 years. Primarily designed to manage diving on the shipwrecks, Chuuk law protects only Japanese war material below high water, and does not address American war material (Jeffery 2004), (DS 2004).

For military historians, the area is important for its role in charting the future of naval warfare. In the History of United States Naval Operations in World War II, Samuel Morison stated that "The [United States] strike on Truk demonstrated a virtual revolution in naval warfare; the aircraft carrier emerged as the capital ship of the future, with unlimited potentialities (Morison1975). Admiral King the Commander in Chief US Navy considered the danger to Australia from Japan to be so grave in 1942 that he was willing to risk his career and all six of his precious fleet carriers to save Australia from Japanese attack. He lost three of those carriers (Lexington, Hornet, and Wasp) in the direct defence of Australia in 1942 at Coral Sea and Guadalcanal. Yorktown was heavily damaged by a Japanese bomb at Coral Sea, but survived to fight at the Battle of Midway where the tide finally turned against Japan. Saratoga was torpedoed at Guadalcanal, but saved and repaired to fight again. Admiral King was not motivated by any special affection for Australia but a practical appreciation of the strategic importance of Australia, the New Guinea mainland, and the British Solomons to the United States as bases from which the Americans could launch counter-offensives against Japan. The Japanese were equally aware of the strategic importance of Australia, the New Guinea mainland, and the British Solomons to the Americans, and were determined to place them beyond American reach.

To Japanese and American war veterans, Truk Lagoon is a reminder of World War II, the human and material losses, and the Allies' victory. To the Chuukese and Japanese, the lagoon is associated with the deaths and hard-ships suffered during the 18-month blockade and bombardment, a time that included considerable suffering and the overwhelming alienation of the Chuukese from their land and resources (Hezel 1989).

VESSEL RISKS

Water Depth Access

The vessels are located in depths ranging from 30 - 60 +metres. The depth range from 30 -40 metres is regarded as requiring at minimum advanced recreational training and experience, with 40 - 60 metres requiring technical and advanced training and experience in decompression and mixed gas diving. In addition training in wreck penetration and anti silting techniques at these depths is essential. Despite the increased probability of injury at these depths the incidence of reported decompression related injuries and trauma is low and reflects effective prior training and skills used when visiting the vessels and the guiding skills and experience of the local operators.

Munitions

Large stocks of munitions predominantly from USA and Japan were shipped to various parts of the Pacific to support ongoing military operations. Many of these items when used did not detonate and remain across the surface of the islands or atolls, buried in the soil or sand, or submerged in surrounding lagoons. In addition to the ordnance used in numerous sea engagements between naval warships, high explosive bombs and artillery rounds were fired or dropped in large quantities onto small areas of land occupied by enemy forces. At the conclusion of WWII, a large amount of ordnance remained in the islands posing a significant threat to local communities. After more than six decades, the presence of WWII ordnance risk remains for a number of Pacific Island countries such as the Federated States of Micronesia, Kiribati, Nauru, Palau, Papua New Guinea, Republic of the Marshall Islands, Solomon Islands, Tuvalu, and Vanuatu (Francis 2011). WWII ordnance found in the Pacific Islands can be defined as either unexploded (UXO) or abandoned (AXO). Unexploded ordnance is defined as explosive ordnance that has been primed, fused, armed or otherwise prepared for use in armed conflict but has failed to explode. Abandoned explosive ordnance is defined as explosive ordnance unused during an armed conflict and subsequently abandoned or left behind. UXO and AXO are defined collectively as Explosive Remnants of War (ERW). While figures regarding levels of WWII UXO can only be estimated, it is concluded to be substantial given that items continue to be recovered on a regular basis throughout the region and that for unexploded ordnance alone, the failure rates have been estimated as high as 30% (Chirgwin 2009). UXO has the potential to cause significant impacts on local (land based) communities through (1) safety issues resulting in possible loss of life or injuries as evidenced in PNG and Solomon Islands; (2) environmental impacts resulting from the leaching of harmful chemicals contained in the UXO, or from the links of UXO to hazardous explosive percussion fishing which damages reefs and lagoon ecological systems.

The majority of vessels sunk in Chuuk Lagoon contained not only fuel oil and human life with many containing large quantities of live ammunition, shells, mines, depth charges and other explosives. Many vessels in Chuuk lagoon consequently hold stored munitions that have been subject to sea water corrosion for an extended period and subjected to variable physical and chemical deterioration commencing with the initial wartime tactical destruction of sections of the vessel leading to its sinking and with the ordnance still potentially retaining variable explosive capability. It is concluded that ammunition and explosive storage can never be 100% safe in terms of the "absence of risk", and the best that can be achieved is "tolerable risk" (RMDS 2006).

A comparison with land based clearance in the Marianas indicates that the ordnance will remain live for a very long time which compares with UK WWII underwater ordnance experience and conclusions (UOS 2002) (U O R 2011). A series of corrosion studies of vessels and aircraft in Chuuk Lagoon indicate the extent of deterioration and provides guidance on conservation management of the vessels however further risk based work should be extended to the munitions (MacLeod 2005) ,(MacLeod 2006a), (MacLeod 2006b), (MacLeod 2011).

Munitions Chemical Content

While local officials strongly believe that leaking UXO are contaminating the environment, there is a sparsity of scientific research or data available to provide a clear understanding of the risk. Chemicals in UXO and ammunition include (1) heavy metals such as lead, zinc, copper; (2) explosives such as TNT; and (3) components from propellants such as dinitroluene and dibutylphtalate (Francis 2011).

A review of Japanese munitions used during the second world war indicate that heavy metal compounds were used as priming agents including mercury, antimony and lead compounds. The reaction of the priming agents with the alloy ordnance casings over time can produce more sensitive and unstable compounds (Patnaik 2002).The heavy metal priming agent was contained in the primer caps and initiators and the total mass present was significantly less in comparison with the sub booster and main charges contained in the ordnance. The main charges used at the time were stable during manufacture and storage and were stable enough to be cast and inserted in to the ordnance including TNT, RDX, which did not readily react with metals, but Trintroanisol which was also used for selected ordnance was comparatively less stable to gradually react with water and convert to less stable picric acid (Richter-Torres 1995).Picric acid was used to a lesser extent for specific strategic purposes but reacted with ordnance casings to produce unstable metal picrate compounds of similar hazard to the priming agents.

Hazardous Materials Dangerous Goods

In addition to munitions the vessels transported fuel oil for ships and refined products including avgas and kerosene. Other industrial products were also shipped as part of the supply chain for the local military and industrial workshops .The construction of the vessels involved fireproofing the engine rooms and bulkheads and each of the main engine rooms, decking, and pipe systems inspected demonstrated lagging with asbestiform materials including woven asbestiform fabric around pipes. From the inspections the most commonly visited vessels had asbestiform materials present. It is likely that the remaining vessels when more closely inspected will have asbestiform materials present.

The munitions charge contents are considered to be hazardous wastes with exposure risk from skin contact and inhalation if exposed. Exposure of the munitions to air will increase the risk particularly for picrate and sensitive heavy metal compounds used as priming agents. Leaching of energetic compounds primarily from the main charges from these UXOs may occur through mechanical stress, corrosion, or low-order remedial detonations, potentially constituting a major source of contamination of marine sediments by metal compounds. Further research on extended exposure of RDX to marine water could assist with natural attenuation but would not affect HMX (Darrach et al., 1998) (Monteil-Rivera 2008).

Oil and Fuel

The location of oilers and oil tankers, both military and merchant is of prime concern. These vessels pose a higher risk due to the potentially large quantities of oil carried on board at the time of sinking. The oil tankers pose a real and ever-increasing risk to the marine environment and human well-being from marine pollution leakage. Liquid product tankers during WWII were carrying a variety of products including various crude oils, heavy fuel oil and/or refined fuel products. Heavy fuel oil is considered as the most environmentally significant oil spill threat because of its persistence even after weathering at sea and very slow biodegradation rates. Submarines also contain significant quantities of hazardous chemicals such as lead, acids and mercury which also pose an environmental threat (Monfils 2005)

Of the 52 shipwrecks located in Chuuk Lagoon, three are oil tankers (Hoyo Maru, Shinkoku Maru and Fujisan Maru) and combined that have the potential to hold up to 32,000 tons of oil (approximately 32,000,000 litres or 7,620,000 gallons). It is unknown if they were full or empty when they were sunk in 1944 and with the loss of most Chuuk Japanese records correlation of quantity cannot be readily ascertained (Jeffery2008). An assessment to determine the amount of oil aboard each vessel, quantification of the risk of oil losses, and the impact upon the surrounding environment will require specialist resources in order to provide guidance to the Chuuk Department of Marine Resources in conjunction with Secretariat of the Pacific Regional Environment Programme (SPREP). It is considered that damage to the vessels has led to variable losses over an extended period. The three oil tankers are expected to have reduced quantities of cargo oil. The other ships are about 50% coal powered and have reduced risk of oil to leak. Of the remaining ships, it is very unlikely that much oil was in their bunkers due to the poor state of the Japanese war effort by 1944. Marine biologist Sylvia Earle, observed at least one oil leak from the Hoyo Maru when she first visited Chuuk in 1975 advocates a cautious approach rather than contributing to the problem (Woodward 2008).A comparison between the 1975 underwater photographs with Sylvia Earle and earlier 1969 footage by Jacques Cousteau provides a significant contrast in the change in appearance of the observed vessel surfaces due to corrosion (Earle 1976) (Cousteau 1969).

The identified ships with oil leaks include Hoyo Maru and Rio de Janeiro Maru, Kiyosumi Maru Nippo Maru Hanakawa Maru and San Fransico Maru.

CONTROL INITIATIVES

UXO Clearance Initiatives

Historically there have been a number of UXO clearance activities undertaken in the region by Forum members and international military personnel. Although details are limited, various sources refer to a number of clearance activities undertaken by military personnel from Australia, New Zealand, the United States of America, and the United Kingdom. These activities include missions to Kiribati (1943, 2008),Tuvalu (1980), the Republic of the Marshall Islands (several missions from 1945 to 1969),Solomon Islands, and Papua New Guinea (2009). In comparison selected clearance of Darwin harbour in Australia was conducted in 1997 upon 7 WWII vessels (Adams 1999)

In recent years however, UXO clearance activities in the region have largely been the responsibility of the affected country. With no regional mechanisms or frameworks through which to source assistance, Forum Island Countries have had to either develop UXO clearing capabilities or seek bilateral assistance from countries with sufficient technical expertise and resources. In some Forum Island Countries, NGOs have undertaken large scale UXO clearance projects funded by various donors. (Francis 2011).

In 2003 Landmine Action published A Global Survey on the Explosive Remnants of War which attempted to take a snapshot of global, regional and national levels of ERW and their socio-economic impacts during 2001/ 2002. In reviewing activities in the region, the publication noted that there did not appear to be any systematic demining or awareness programmes being undertaken in the region(Francis 2011).

The main difficulties reported by the national UXO authorities in the study countries involve (1) limited resources; (2) limited technical capacity; (3) lack of reliable information and clarity on extent of UXO issues and resulting impacts on community; (4) lack of awareness at national and international levels; and (5) limited national coordination to implement comprehensive UXO clearance activities according to IMAS.

UXO Site Assessment

Detection methods to assess the underwater release of the munitions charge indicate that apparently intact samples can show trace explosives up to parts per billion concentration levels by chemical methods(Darrach et al., 1998). For the intact rounds, positive results were found at only two of the four cardinal points, indicating a directionality to the source. Intact munitions appeared to be releasing their contents as a slow leak, very likely through pinholes in the eroded casing, or through the screw threads linking the fuse assembly to the main charge. Broken WWII munitions in Halifax harbour Canada, in comparison had their contents dissolved, and showed no evidence for TNT.

Chemical examination of the sea-bottom sediments would provide further information about a UXO site to yield positive results in addition to optical, magnetometer, and sonar instruments that are presently being deployed for UXO detection and classification as part of the ordnance disposal strategy (Darrach et al., 1998).

VESSELS REVIEWED/CONCLUSIONS

A combined series of approximately 80 dives were conducted upon a cross section of 18 of the most popular vessels amongst the group including those that were located deeper and required technical diving. Armed transports, transports, destroyers and submarine tenders had a variety of cargoes including munitions, fuel, and oil dependent upon the original vessel manifest. In order to appreciate the detail for the classes of vessel and the content significantly more research of the current documentation available prepared by the existing general researchers will be necessary.

A general overview of the site was obtained however documentation of the detailed occupational hygiene risks will take further work in 2013- 2014 to prepare a more detailed profile.

Assistance in traditional chemical and physical analysis of the cargo types would be useful and good resolution photographic imaging of the industrial aspects and observable risks at depth and where natural lighting is reduced or obscured by the depth and/ or the vessel orientation is to be conducted, collated, and analysed. The described risks relating to munitions and fuel remain a priority to manage. Additional risks due to asbestiform minerals and their management at depth also needs to be reviewed and placed in context for the activities and potential exposures that could occur. Currently there will be ongoing visits by a general population that will involve variable exposure to the risks. Researchers conducting extended programs may be assessed during the length of stay for their program. The most frequent visitors are the local guides, some who have been involved in the local industry for a considerable portion of their adult life. An assessment of their activities and indication of potential and cumulative exposure will provide a useful guide in managing occupational hygiene risk for the sites.

A methodology to develop awareness within the local population and visitors to recognise and manage the hazards encountered is a priority to be developed. A useful training pathway is being conducted through OHTA and collaboration with a not-for-profit organisation Workplace Health Without Borders (WHWB)..

Preliminary discussions with the (WHWB) founders to improve workplace health in regions of the world lacking adequate occupational hygiene services has been positive and productive. The objective being to develop local skills in a core group of participants as currently there are no professionals resident in the region hence input from local hygiene professionals with technical assistance, training and skills development to enable locals to manage and improve health conditions in local workplaces is essential.

The author has become an Australasian WHWB liaison for the Pacific region with a focus upon Truk. A major focus is to develop a practical risk rank approach to each vessel based upon the identified risk of munitions and cargoes that can be modelled and updated for the vessels in the lagoon and which in turn can be applied to the remaining vessels that have been located and are yet to be located in the Pacific. This approach will assist the local guides to alert researchers to take appropriate action. The documentation and local knowledge gained can be more effectively applied when ordnance personnel have the opportunity to visit the remote sites to undertake remedial actions as required.

An occupational hygiene program to assess chemical exposure using analytical techniques that can be used in remote locations is to be developed. Planning for biological exposure assessment will be dependent upon the robustness of the analytical methods used.

LEGACY

This paper is dedicated to those parents, grandparents, and relatives who were present and involved in the massive upheaval of WWII ,the defence of Australia in the Pacific that may be a distant memory for many, but for some that are still with us it still brings back daily vivid memories and experiences encountered while at war in the Pacific. It is the efforts and actions that were taken in 1939 1945 to which we are indebted. This preliminary occupational hygiene overview of a remote but strategic Pacific wartime location especially for Australia highlights the occupational hygiene consequences of actions taken in 1944 that still impact upon a native people in many islands in the Pacific who remained neutral but for which an unwanted legacy still remains.

There are two legacies that can be highlighted. The first is the IH consequence on a native people of wartime activity in a remote but strategic Pacific wartime location that was especially important for the defence of Australia. The second legacy is the social consequence to the native people and the Australian soldiers involved in the defence of Australia while at war in the Pacific. In particular to Stanley Breed who enlisted in 1942 for a total of 1362 days active service and survived campaigns in Buna, Madang and New Britain ending 840 days overseas service at age 21 and who is still alive today as well as many other soldiers in part due to the actions taken in a remote but strategic part of the Pacific.

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A CONTEMPORARY EXPOSURE ASSESSMENT STRATEGY FOR A MULTI-NATIONAL MINING COMPANY

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ABSTRACT

Between 2011 and 2012, the existing exposure assessment strategies were harmonised. Opportunities were identified to incorporate leading practices into the overall approach.

An international guideline has been developed to increase the level of assurance that health hazard exposures are being effectively controlled.

The guideline provides a system that includes the following elements:

- Health Risk Assessment (qualitative).
- Screening of health risks and expedient control.
- Exposure monitoring.
- Collation of data
- Statistical analysis.
- Assessment on acceptability of exposures.
- Reporting to senior management.
- Controlling exposures following the hierarchy of control.
- Health / medical surveillance.
- Scorecard reporting at an operational and Central Business Unit (CBU) level.
- Reassessment monitoring.
- Trending performance.

The system outlined in this guideline has been modelled on the recently published joint BOHS and Dutch guideline (2011)[1], AIHA strategy (2006)[2], and the *French Journal Officiel de la Republique Francaise Texte 35, Sur 156, Annexe 1, General Rules and Procedures for the Compliance with Occupational Exposure Limit Values*[3]. The system is integrated with the corporate risk management framework so that health risks are more easily understood and managed at a site level.

The guideline provides a process which assists business units around the world comply with Sustainable Development Standard 9 for health and occupational hygiene. The guideline is flexible and has been developed with input from occupational health and safety practitioners and operations from six international business units.

INTRODUCTION

Across industry generally, the management of occupational health hazards do not receive the same attention as the more obvious safety hazards.

Occupational exposure limits are poorly understood and there are inconsistencies when determining compliance.

A common practice, throughout industry and by some regulatory bodies, is to compare average exposures with occupational exposure limits (OEL). Comparing average exposure with an OEL means that where an average exposure is marginally below the OEL, many workers may in fact still exceed an OEL.

Conventional occupational hygiene monitoring programs do not address health risks in a "timely fashion" because of the attention for comprehensive exposure monitoring allowing enough samples for statistical analysis. Although adequate sample sizes are important, controlling the risk at the earliest opportunity is more important.

A qualitative health risk assessment, control banding and screening assessment will expedite the need for control and protect the worker without delay.

To provide a system on how to effectively communicate, manage and report health risks *"Occupational hygiene exposure assessment, reporting and performance measures"* guidance has been developed. The guideline is designed to ensure that minimum international expectations for exposure assessments are consistent, and aligned across all operations.

The guideline provides direction for the collation and analysis of data, remedial action, exposure management including follow-up, and reporting results from occupational hygiene monitoring using a risk based approach.

As part of the reporting process, a scorecard template has been provided for use at both operational and central business unit levels, to provide a measure of performance and show the level of risk reduction for the main health hazards identified.

This scorecard has been designed and a process has been described which requires analysis of occupational hygiene monitoring data, as information is collected, and once a baseline exposure assessment is completed.

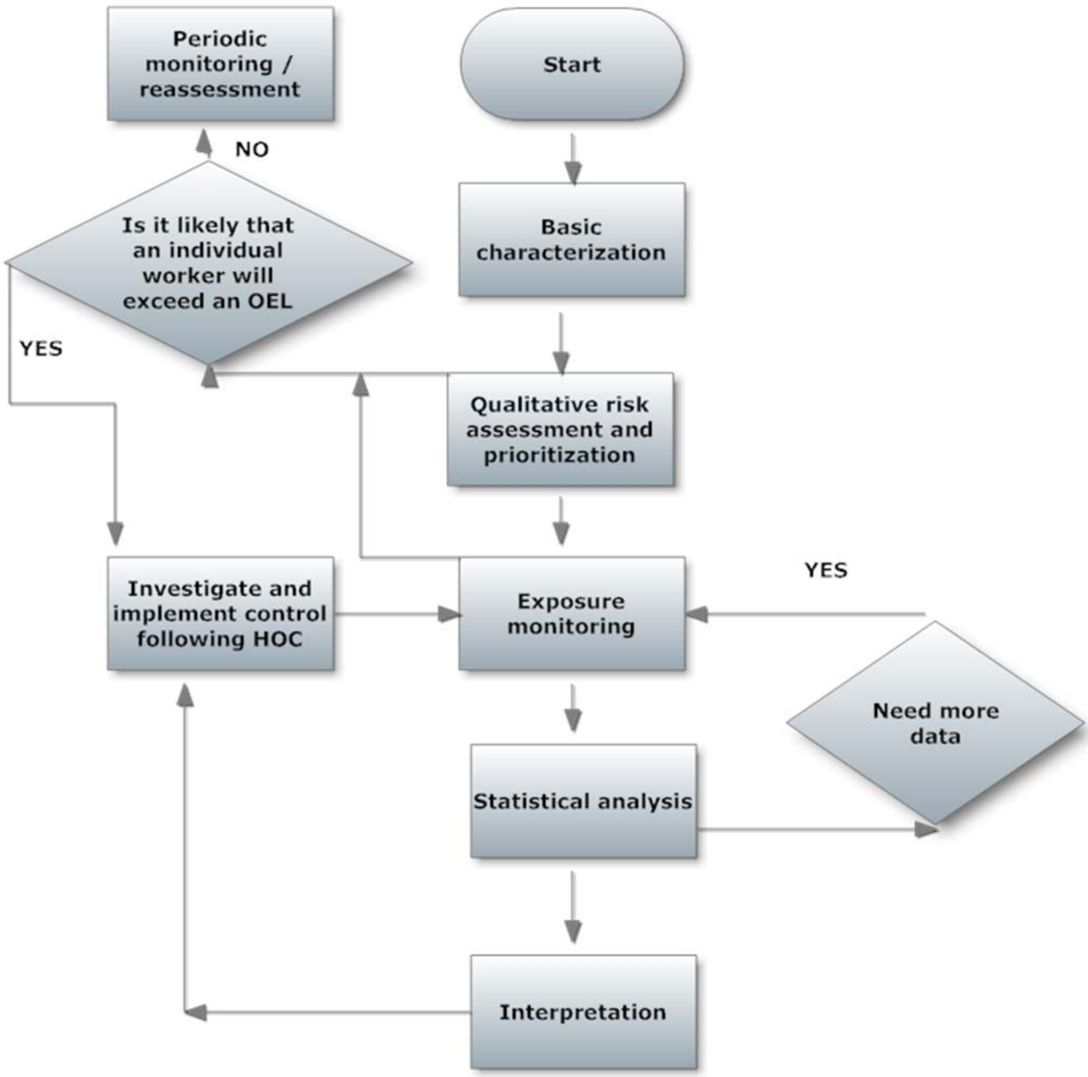
It aims to communicate performance in a meaningful way and promote continuous improvement.

The guideline also requires that "**oversight"** of the strategy, be provided by a certified or industrial / occupational hygienist recognised by the International Occupational Hygiene Association (IOHA) national accreditation recognition (NAR) committee charter.

The guideline also promotes the occupational hygiene training association (OHTA), for suitable training through OH learning.

OHTA promotes an international qualifications framework so that occupational hygienists are trained to a consistent standard recognised by all participating countries.

Figure 1 provides an overview of the strategy:



DISCUSSION

The recently published joint BOHS / Dutch guideline[1] and French[3] approach provides a strategy that aims to control exposures at the earliest opportunity, **through exposure screening**, as well as providing a statistical basis for exposure assessment.

A **critical** first step in any monitoring program is to properly identify similar exposure groups (SEG). Occupational exposure limits (OEL) apply to every worker, but where different workers are carrying out the same task in the same way, it is usual to limit the number of samples to be taken by dividing the workforce into similarly exposed groups (SEGs), and to make measurements on only some of the members of each group. Mulhausen and Damiano (2006) define a SEG as "A group of workers having the same general exposure profile for an agent because of the similarity of the materials and processes with which they work, and the similarity of the way they perform the task(s)." Allocating workers to a SEG will require careful examination of these three factors – the materials, the processes, and the ways of working. Using job titles to allocate workers to a SEG may not be sufficient. A detailed initial survey, and the information gained in the survey will be useful in forming SEGs.

The purpose of monitoring should be to identify individuals who may be at risk from unacceptable exposures. The SEG should be suitably defined so that statistical analysis confirms that the exposures are log-normally distributed and also allows the assessment to **"drill down"** and identify the task / source requiring additional exposure controls. For a more detailed discussion on properly classifying similar exposure groups refer to: *AIHA, A strategy for assessing and managing occupational exposures, 3rd Edition, pp.42-43.*

It is important that the laboratory selected for testing and that the analysis method can measure concentrations well below occupational exposure limits. Every effort should be made to use analytical methods and sample volumes that keep the LOQ < 0.1 x OEL. However with some substances it may prove impossible to keep the LOQ this low.

It is also important to properly treat exposure monitoring results less than the limit of quantification (LOQ). To obtain a better distribution of exposures where there are a number of values less than the limit of quantification (LOQ) additional statistical analysis may be carried out. Regression methods are available which use the distribution of results > LOQ to estimate the distribution < LOQ. Tools available for censoring results <LOQ include for example IHDataAnalyst, SAND, HYGINIST and AltrexChimie.

Where there are results < LOQ, carrying additional analysis as suggested may reduce the geometric standard deviation and confirm that the SEG group statistical analysis is log-normal which means that the results are in fact representative of this group and there is a degree of confidence in this data-set. Using LOQ substitution by the LOQ value or substitution with 50% of the LOQ value is not recommended. The decision making around the acceptability of exposure and actions must be clearly communicated.

The following table allows clear decision making and required actions from the baseline assessment.

Table 1. Decision from baseline exposure assessment

Exposure	Decision	Further actions
Upper confidence limit or 95 percentile < 50% OEL	**Tolerable (Tol)**	Maintenance monitoring.
Upper confidence limit or 95 percentile > 50% occupational exposure limit **and** ≤ occupational exposure limit	**As low as reasonably practicable** (ALARP)	May require more monitoring. Consider health / medical surveillance. Implement respiratory protective equipment for acute health hazards.
Upper confidence limit or 95 percentile > occupational exposure limit	**Unacceptable**	Investigate. Develop control plan (CP) following the hierarchy of controls (HOC). Use PPE as an interim control or where higher order controls are not practicable. Implement medical / health surveillance where practicable.

The guideline recommends that for a SEG the upper confidence limit (lands exact) (UCL) be compared with the occupational exposure limit. IHSTAT™, free software, is made available by the American Industrial

Hygiene Association (AIHA). It is emphasized that the 95th percentile is not precise unless there is a large sample number.

Where it has been shown that SEG exposures are unacceptable, operations require clear guidance, on how to control exposures.

Until higher level controls are identified and implemented, personal protective equipment will provide interim protection. Standards outlining requirements with a self-assessment will assist sites demonstrate that exposures are being effectively controlled. Table 2 provides an example of a self-assessment against the respiratory protective equipment standard.

Table 2: Self-assessment carried out across business units reported to CBU

Questions	BU 1	BU 2	BU 3	BU 4	BU 5	BU 6
Management engagement demonstrated.	Yes	Yes	Yes	Yes	Yes	Yes
Nationally Certified Hygienist	No	Yes	No	Yes	Yes	Partial
Training in RPE	partial	Partial	Yes	Yes	Yes	Yes
Designated RPE areas and compliance	partial	No	Yes	Yes	Yes	Yes
Documented selection process	Yes	Partial	No	Yes	Yes	Yes
Medical assessment	Yes	No	No	Yes	No	Yes
Clean shaven requirement	Yes	Partial	No	Yes	Yes	Yes
Face fit testing	No	Partial	No	Yes	Yes	No
Process for cleaning, storage, maintenance	Yes	Partial	No	Yes	Yes	Yes
Records kept	Yes	No	No	Yes	Yes	Partial
Score %	60%	20%	30%	100%	90%	80%

Where health hazards are obvious, and unacceptable exposures have been identified from statistical analysis, each business unit is required to develop a business plan to improve controls at the emission source. In addition, business units are being asked to conduct health risk assessments to systematically identify hazards and determine where to prioritise monitoring and control. Priority for monitoring is placed on those SEGs where exposures are uncertain or exposures are within 50% - 100% of the OEL. Medical / health surveillance, including biological monitoring where practicable, is also required to demonstrate that controls are indeed effective. The guideline has been revised a number of times with operational input. Stakeholder communication, involvement and input in this instance via a health and hygiene network, is seen as a key factor to the success for implementation.

CONCLUSION

Harmonisation of an exposure assessment strategy, through participation of operations, sustainable development and senior management, both centrally and locally, has provided additional impetus to meet standard 9 for health and hygiene. The guideline developed provides a transparent process, where the health risks are clearly communicated. Controls are planned and implemented using a risk based approach. Statistical analysis is an integral component of the assessment process to objectively identify where further controls are required to reduce exposure.

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RAPID TECHNOLOGY FOR ASSESSMENT OF THE BACTERIAL CONTAMINATION AND REMEDIATION EFFICACY AFTER FLOODING USING FLUOROMETRIC DETECTION

Morten Reeslev
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KEYWORDS

Bacteria, hydrolase activity, flooding, endotoxin, post remediation verification, cleaning

ABSTRACT

A rapid response assessment and cleanup after flooding is critical to recovery. In this study the level of contamination of bacteria on surfaces in flooded houses was estimated and compared to the level found on surfaces in non-flooded houses with a rapid field test based on hydrolase enzyme activity present in bacteria. This technology allows rapid result and can be done in the field. A correlation between endotoxin levels and levels of hydrolase activity was seen (R^2 = 0.6469, P<0.0001).

The median value and the variance of the result distribution were higher in flooded buildings as compared to non-flooded buildings. In the non-flooded buildings surfaces were divided into visually clean and visually dirty. As expected the level of bacteria were higher on the visually dirty surfaces and overall the hydrolase activity correlated well with the visual inspection. Using the results from the visual clean surfaces in the reference buildings as the criteria for clean, four methods of cleaning were tested for their ability to reach these criteria.

HOSPITALISATION OF OCCUPANTS FOLLOWING A FAILED BIO-REMEDIATION PROJECT

Dr Heike Neumeister-Kemp
Principle Mycologist and Managing Director
Mycologia

ABSTRACT

Occupants in a fire damaged building had to be hospitalised following failed bio-remediation of the property. Structural drying of the building envelope and contents was not conducted sufficiently, resulting in residual moisture remaining in the building. Furthermore, limited containment and improper bio-remediation techniques (use of bleach, one bucket and rags) resulted in mould proliferation and cross-contamination of contents.

This case study demonstrates the pit falls of undertaking a bio-remediation project without the appropriate methodology; trained visual inspection, risk assessment, structural drying, containment, appropriate use of personal protective equipment (PPE), source removal, and clearance testing. Due to these inadequacies, the financial costs of the project exceeded the value of the property and resulted in significant health impacts to the occupants. Document controls, chain of custody, development of a proper scope of work were not carried out during the initial bio-remediation efforts and this contributed to the failure of the process.

BIO-CONTAMINANT SOURCE REDUCTION IN SPLIT AIR-CONDITIONING SYSTEMS IN MASS ACCOMMODATION

Wayne Midson, Brad Prezant, Cedric Cheong, Heike Neumeister-Kemp, Kevin White
Mycologia

ABSTRACT

Split system air conditioning units were identified as a source of bio-contaminants and strong odours and contributed to perceived discomfort in indoor spaces in accommodation buildings in the North West of Australia. Due to the environmental conditions (high humidity, dusty environment) and the nature of the built environment (small enclosed living quarters), fungal growth and colonisation were observed on cooling coils, fan cowling and barrel and on the plastic louvers of split system air conditioning units.

This paper describes the abatement techniques utilised and discusses changes in bio-contaminant levels in indoor air spaces and on surfaces of the split system air conditioning components.

Results show a marked decrease in airborne fungi in indoor spaces and a decrease in surface fungi on critical surfaces of the air conditioning units. The results highlight the importance of conducting clearance testing and the importance of the application of the abatement technique as part of a wider holistic view of the maintenance of Heating Ventilation & Air Conditioning Systems (HVAC) systems in indoor spaces.

ELEVATION IN CORE BODY TEMPERATURE AS A POSSIBLE SOURCE FOR A TEMPORARY THRESHOLD SHIFT

Dr. Joseph Maté and *A/Prof Jacques Oosthuizen*
Edith Cowan University

ABSTRACT

Central fatigue due to elevated core body temperature (Tc) is known to cause a reduction in cognitive performance/function. This perturbation could therefore influence hearing acuity in hot persons. Purpose: to quantify the Temporary Threshold Shift (TTS) during elevated Tc. Methods: Air conduction hearing tests were performed on 8 males and 1 female before and after exercising to a Tc of 38.5°C. All participants had at least 16 hours of quiet and criteria 4 of Waugh and Macrae was not met. Results: A 10 to 15dBHL reduction in hearing threshold was observed between frequency ranges of 3k to 8k in both ears. Pre Tc and post Tc were the same. Discussion: Reduction in hearing threshold could possibly be attributed to decreased neural excitation from an elevated Tc due to exercise. These results support literature on neural fatigue associated with elevated Tc. Thus, maintaining body temperature could help attenuate TTS.

DEHYDRATION & ITS INFLUENCE ON HEAT STRESS INDICES

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AIM

To investigate dehydration among underground miners in a temperate region of Australia and to test the feasibility of interventions to promote water consumption.

METHODS

Pre-shift and post-shift hydration status of workers was studied using urine specific gravity. A three month intervention was conducted to determine the feasibility of sustainable workplace interventions to improve hydration status. Thermal stress assessments were also undertaken to investigate it as a possible contribution or as an outcome of dehydration.

RESULTS

Up to 60 percent of workers were starting their shifts in a dehydrated state. With an average water consumption of two litres, the post-shift hydration status remained unchanged for many workers. Intervention decreased pre-shift dehydration to 44 percent and thus the use of thermal indices based on a well hydrated workforce was inappropriate.

CONCLUSIONS

Dehydrated workers may be predisposed to thermal stress earlier. Sustainable workplace interventions improved hydration status of workers. Based on this outcome reliance by mines on any heat stress index which requires a well hydrated workforce is potentially flawed if the hydration status of workers is not known.

REDUCING EXPOSURE TO VIBRATION AT WORK – BUILDING A REGULATORY POLICY INTERVENTION FROM THE GROUND UP

Dr Paul Taylor and *Caroline Reid*
Safework Australia

ABSTRACT

Occupational exposure to hazardous levels of vibration is associated with a range of adverse health outcomes, including vibration white finger, carpal tunnel syndrome, musculoskeletal and neurological disorders. A Safe Work Australia self-reported survey[1] identified that approximately 24 % of Australian workers experience exposure to vibration in their workplace. The survey found there was low awareness of the adverse effects of exposure to vibration and little use of controls to reduce exposure to vibration.

The authors of the report recommended that consideration be given to development of a regulatory intervention for vibration, similar to the approach taken in the European Union contained in the Machinery and Vibration Directives, to address the gap currently in treatment and guidance on this workplace hazard in Australian Work Health and Safety laws at the current time.

In 2011 Safe Work Australia started a project to develop awareness in the area, build an evidence base for policy action and start developing regulatory guidance material. We detail the approach taken in the European Union, the steps undertaken so far, the guidance material published in 2012 and give a flavour of what is to come.

[1] National Hazard Exposure Worker Surveillance – Exposure to vibration and the provision of vibration control measures in Australian workplaces

CYTOTOXICITY AND GENOTOXICITY OF ULTRAFINE IRON-ORE DUST

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KEYWORDS

ultrafine particle, iron ore, exposure

ABSTRACT

BACKGROUND: Iron ore mining has been associated with cardiorespiratory diseases, and mainly attributed to contaminants, rather than iron ore. However, the potential toxic contribution of iron ore ultrafine particles (UFP) has not been explored.

AIMS: This in vitro study sought to clarify the cytotoxicity and genotoxicity of ultrafine iron ore.

METHODS: Twelve iron ore dust samples were collected from 6 locations at an iron ore mine. The mineral and elemental compositions were determined. The cytotoxicity and genotoxicity of the UFP component of these samples were tested on WIL2-NS and A549 human cell lines using the Thiazolyl Blue Tetrazolium Bromide, 3-(4, 5-dimethylthylthiazol-2, 5-diphenyltetrazolium bromide (MTT) Assay, the Crystal Violet Assay and the Cytokinesis-block micronucleus (CBMN) Assay.

RESULTS: Cytotoxicity was only found for plant fines, and this was comparable to the response of WIL2-NS to ultrafine quartz. No significant chromosome damage was detected by the CBMN Assay for any samples for either cell line. There was no apparent relationship between elemental content or mineralogical content of mine samples and cytotoxicity. Reconstruction dosing experiments with soluble ferric or ferrous iron, indicated that leaching of iron was not a major explanatory factor.

CONCLUSIONS: The UFP component of these iron ore dust samples did not show significant cytotoxicity and genotoxicity. Further work should be supplemented with electron microscopy and surface chemistry techniques.

Introduction

Iron ore mining is one of the most important industries in Australia. Production in Australia is around 500 Mt (Geoscience Australia 2011). In 2010, $47.2 billion worth iron ore was exported from Australia. Although occupational hygiene has been improved in the last 30 years, dust exposure still poses a potential health hazard to mine workers and the general public living near mining and port operations (Banerjee, Wang et al. 2006).

The airborne dusts arising from iron ore handling consists mostly of iron ore as well as clays (aluminosilicate and iron silicate) and quartz. The iron ore mainly comprises the iron oxide minerals such as hematite, Fe_2O_3 (70% Fe); goethite, Fe_2O_3s H_2O, (63% Fe); limonite, a mixture of hydrated iron oxides (up to 60% Fe); and magnetite, Fe_3O_4 (72% Fe).

Numerous epidemiological studies indicated that dust exposure at iron ore mines is associated with cardio-respiratory diseases (Chau, Benamghar et al. 1993; Hedlund, Jarvholm et al. 2004; Su, Guan et al. 2006; Bjor, Burstrom et al. 2009). However, the cancer risk has been attributed to crystalline silica exposure, underground radon gas or smoking behaviour rather than iron-containing component of dust exposure (Jorgensen, Kolmodin-Hedman et al. 1988; Banerjee, Wang et al. 2006; Bjor, Burstrom et al. 2009).

There is increasing interest in human exposure to ultra fine particles (UFPs, size ≤ 100nm). Due to the unique size and larger surface area of these small particles, it is suggested that they are more toxic than larger particles (Oberdorster 2001; Donaldson and Stone 2003; Englert 2004). Exposure to ultrafine particles in the iron ore mine may be generated from combustion, drilling and blasting processes, and diesel exhaust from transportation. As a consequence of the range of the activities, adverse health effects from exposure to fine and UFPs may vary substantially. However, the independent toxic contribution of ultrafine iron ore particles has not been explored.

MATERIALS AND METHODS

Source of iron ore dust samples

Twelve iron ore dust samples were collected at six different sites of an iron mine in Western Australia. The dust samples were scooped up from stockpiles and other areas and sieved to 200 µm. These samples were labelled as EAP (East Pit operation) 3 A&B, Haul Road A&B, Low Grade Stockpile A&B, Plant Fines A&B, Stockyard (Tail end of Co09) A&B, Waste Dump (North West Waste Dump) A&B. There was no difference between A and B as they were taken from the same location. The dust samples were further dried and mechanically sieved to 45 µm before toxicological assessment

Characterization of dust samples

X-ray Diffraction (XRD) and X-ray Fluorescence (XRF) were conducted by Australia's Commonwealth Scientific and Industrial Research Organisation (CSIRO) to determine mineralogy and elemental composition.

Preparation of iron ore dust samples for bioassays

The iron ore dust samples were suspended in RPMI 1640 culture medium (Trace Biosciences, Melbourne, Australia), supplemented with 5% foetal bovine serum (FBS, Trace Bioscience) and 50 IU/ml streptomycin/penicillin (Thermo Trace, Melbourne, Australia). The mixture was firstly vortexed for 5 minutes and sonicated for 5 minutes to ensure a uniform suspension. The mixture was then centrifuged at 1000 rpm for 5 minutes. The supernatant was removed, then filtered with a disc filter (pore size 0.10 µm, PVDF, Durapore) to sterilize and separate to ultrafine size. The concentrations of iron ore in suspension were estimated by spectrophotometer measurement at wavelength 570 nm, in comparison with iron oxide nano powder (Sigma Aldrich) as reference.

Cell line and Cell culture details

WIL2NS (American Type Culture Collection (ATCC), CRL 8155), a human B-cell Lymphoblastoid cell line, was maintained in RPMI 1640 culture media plus 5% FBS, 50 IU/ml strep/penicillin at 37^{o}C in a 5% CO_2 atmosphere. Media was renewed every 2-3 days. A549 (ATCC, CCL-185), a human lung carcinoma epithelial cell line, was maintained in RPMI 1640 culture media plus 10% FBS, 50 IU/ml strep/penicillin at 37^{o}C in a 5% CO_2 atmosphere. Cells were subcultured every 3 days. Cells at 5 x 10^5cells/ml were incubated with a range of doses of particles for 24 hrs. Cells were then washed and assayed as outlined below.

Bioassays

The bioassays applied in this study have been validated by the biotechnology laboratory at Flinders University for testing cytotoxicity and genotoxicity of potential toxic substances. The published studies have used the same protocol to test nanosize quartz and TiO_2 (Wang, Sanderson et al. 2007; Wang, Wang et al. 2007).

MTT Assay

Thiazolyl Blue Tetrazolium Bromide, 3-(4, 5-dimethylthylthiazol-2, 5-diphenyltetrazolium bromide (MTT) Assay is based on the activity of mitochondrial dehydrogenase in viable cells converting MTT into purple formazan dye (Young, Phungtamdet et al. 2005).

Briefly, after 24hours treatment, 1×10^4 WIL2NS cells were seeded into wells of a 96-well microplate. MTT solution was added to each well at 0.5 mg/ml, and then incubated at 37ºC for 18 hours. Then acidified 20% Sodium Dodecyl Sulfate (SDS) in 0.02 M HCl was added to each well and mixed. The plates were placed in the dark at room temperature for 1.5 hours. Optical density (OD) was read on an ELISA plate reader at 570 nm, with 630 nm as a reference wavelength. ODs were converted to cells/well using a standard curve run with each experiment. Survival percentage was calculated by comparing cells/well of exposed and unexposed cultures. 3 replicates were carried out for each dust sample for this assay.

Crystal Violet Assay

The Crystal Violet Assay is a sensitive bioassay to measure cell proliferation for monolayer cell culture by crystal violet staining (Kueng, Silber et al. 1989; Alfaro-Moreno, Martinez et al. 2002). In this study, Crystal Violet Assay was used to determine the cytotoxicity of A549 cell line.

After 24 hours treatment with iron ore dust samples, 50 µl 0.5% Crystal Violet solution was added to each well, staining for 10mins. Then gently wash away Crystal Violet solution and air dry for 2-3 hrs. 50 µl 33% acetic acid was added to each well to dissolve staining formation and incubate on bench for 10 mins OD was read on an ELISA plate reader at 570 nm with 630 nm as reference wavelength. OD values were converted to cells/well using a standard curve run with each experiment. Survival percentage was calculated by comparing cells/well of exposed and unexposed cultures. 3 replicates of each sample were done for this assay.

CBMN Assay

The CBMN assay is used to assess chromosome damage based on occurrence rates of micronuclei in dividing cells. This assay was validated and conducted using published protocols (Fenech 1993; Fenech 2007), with minor modifications as follows. Briefly, following treatment, Cytochalasin-B was added to each cell culture at 4.5 µg/ml and the cultures were incubated for 26 hours at 37ºC. The cells were collected onto slides by cytospin at 600 rpm for 5 min, air dried, fixed for 10 min in DiffQuick Fixative and then stained with 10 × 1 second dips of DiffQuick Stain 1 then Stain 2. The slides were scored under light microscopy (magnification × 250). Micronucleated binucleated cell (MNed BNC) frequency was determined in 1000 BNC on duplicate slides according to established criteria (Fenech, Chang et al. 2003). On the same slides, the frequency of necrotic cells and cells with nucleoplasmic bridges can also be scored (Fenech, Chang et al. 2003). 3 replicates were carried out for each sample.

Ultrafine Quartz and TiO_2 were chosen as positive control for both cytotoxicity and genotoxicity assessment.The bioassays applied in this study have been validated by the biotechnology laboratory at Flinders University for testing cytotoxicity and genotoxicity of potential toxic substances. The published studies have used the same protocol to test nanosize quartz and TiO_2 (Wang, Sanderson et al. 2007; Wang, Wang et al. 2007).

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Ultrafine Quartz and TiO_2 were chosen as positive control for both cytotoxicity and genotoxicity assessment.

Preliminary experiments with soluble Fe^{2+} and Fe^{3+}

A serial of preliminary experiments were first conducted to differentiate the independent potential toxicity of soluble iron. Iron (III) Chloride ($FeCl_3$,) and Iron (II) Sulfate Heptahydrate were both tested by 2 cell lines. The cytotoxicity and genotoxicity of soluble iron was assessed by the same bioassays at concentration of 1mM, 0.5mM, 0.1mM, 0.05mM, 0.01mM.

Statistical Analysis

The experiments were repeated at least 3 independent times. Statistical analysis of the cytotoxicity and genotoxicity results were carried out using ANOVA, followed by Tukey's HSD *post hoc* test (equal variances) or Dunnett's T3 *post hoc* test (unequal variances); otherwise, the nonparametric Kruskal–Wallis test was used. The analysis allowed for comparison within dose levels, and across samples. These tests were performed using SPSS software, version 12. Differences were considered statistically significant when the *P*-value was less than 0.05

RESULTS

Characterization of dust samples

The XRD analysis results are summarized in Appendix 1. It presents mineralogical component of these 12 samples. The majority of these samples are composed with hematite (Fe_2O_3, 25.9%-56.7%), goethite (FeOOH, 39.7%-58.1%) and quartz (SiO_2, 0.7%-14.8%).

The XRF elemental analysis results are presented in Appendix 2. The major elements (%) include Fe_2O_3, SiO_2, Al_2O_3, P_2O_5, SO_3, CaO, TiO_2, Mn_3O_4, MgO and K_2O. The minor elements (ppm) included SnO_2, V_2O_5, Cr_2O_3, Co_3O_4, NiO,CuO,ZnO, As_2O_3, PbO, BaO, Cl and Na_2O. The main component of these iron ore dust samples are iron oxide (Fe_2O_3, 58% -87%), SiO_2 (2.91%-19.67%) and Al_2O_3 (2.20%-9.39%). Except for EAP3 A with Fe_2O_3 content 58.2%, the content of Fe_2O_3 was higher than 78%. Due to limited sample numbers, statistical analysis was not feasible.

Preliminary experiments results of soluble Fe^{2+} and Fe^{3+}

Within the soluble iron concentration ranging from 0 to 5mM, both Fe^{3+} and Fe^{2+} did not show significant cytotoxicity or genotoxicity effect (no micronuclei were observed) on both WIL2NS and A549 cell lines.

Cytotoxicity Results

Table 1 illustrates the IC_{30} (Inhibitory concentration 30%) results for the 12 iron ore dust samples with the WIL2NS cell line by MTT assay. The positive controls were nanosized quartz and titanium dioxide. Nanosize iron oxide is also presented for comparison.

Compared with quartz no significant cytotoxicity was detected with the iron ore samples ($p > 0.05$). However, based on statistical tests, samples EAP3 A, Haul Road A&B, Plant Fine A&B, Stockyard B were more toxic in comparison to TiO_2 and nano Fe_2O_3. ($p < 0.05$)

Table 1: Comparison of IC30 between iron ore dust samples and positive controls with WIL2NS Cell Line by MTT Assay

Sample	EAP 3A	EAP 3B	Haul Road A	Haul Road B	Low Grade Stockpile A	Low Grade Stockpile B	Plant Fines A	Plant Fines B	Stockyard (Tail of Co09) A	Stockyard (Tail of Co09) B	Waste Dump A	Waste Dump B	Quartz	TiO_2	Nano Fe_2O_3
IC_{30} (μg/ml)	30	N/A	55	55	N/A	70	35	50	70	40	N/A	**N/A**	43	100	500

*N/A means even at the highest concentration, the dust sample could not inhibit cells proliferation by 30%.

For the cytotoxicity experiments with A549 cell line by Crystal Violet Assay, there was no consistent linear dose-response relationship. Thus IC_{50} or IC_{30} could not be predicted by the dose-response curve.

Genotoxicity Results

Compared with the positive controls (quartz and TiO_2), the iron ore dust samples showed no significant genotoxicity for either cell line ($p > 0.05$). There were no micronuclei observed for A549 cell line after exposure to 12 iron ore dust samples for 24 hours. No significant differences in genotoxiciy between the 12 iron ore dust samples was detected for the WIL2NS cell line ($p > 0.05$).

DISCUSSION

The main finding was that the UFP component of the iron ore dust samples did not show significant genotoxicity in comparison to the positive controls. Cytotoxicity was found for some samples, which, in the case of Plant fines, was comparable to the response of WIL2-NS to ultrafine quartz. There was no apparent relationship between elemental content or mineralogical content of samples and toxicity.

Reconstruction dosing experiments with soluble ferric or ferrous iron indicated that leaching of iron was not a major explanatory factor. These results are consistent with the work of Caicedo (2008) who compared cytotoxicity and genotoxicity of several metal ions by using Jurkat T-lymphocyte, using the same dose range as the current experiment. Caicedo (2008) found that iron Fe^{3+} did not show significant cytotoxicity and genotoxicity. No significant chromosome damage was detected by CBMN Assay for any samples for either cell line, which indicated that ultrafine iron oxide did not show any DNA damage *in vitro*. The same finding were also reported by Guichard (2012) and colleagues. They used the Comet Assay to detect potential DNA damage following exposure of Syrian hamster embryo (SHE) cells to nano size Fe_2O_3. After 24 hours exposure, no significant micronuclei induction was occurring.

There are several limitations to this study. Bulk dust samples were collected from the mine site, and therefore do not represent airborne dust samples. Mechanically sieving to 45 μm was carried out to separate dust that may have been airborne and then settled. Ultrafine particles were then separated by membrane filter filtration, but there was no information on particle size distribution in solution. One possible complication relates to the aggregation of ultrafine iron oxide particles in solution which is dependent on pH and ionic strength(Baalousha 2009). Electron microscopy and surface chemistry techniques could be used to explore these issues in the context of particle-cell interactions. Only three assays on two cell lines were conducted. More biological endpoints and cell lines could be explored to elucidate dose response relationships.

CONCLUSIONS

The UFP component of these iron ore dust samples did not show appreciable cytotoxiciy and genotoxicity when compared with positive controls. The findings are consistent with other evidence from epidemiological and toxicological studies.

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Appendix 1: Iron ore dust samples XRD analysis results

Sample Label	EAP 3A	EAP 3B	Haul Road A	Haul Road B	Low Grade Stockpile A	Low Grade Stockpile B	Plant Fines A	Plant Fines B	Stockyard (Tail of Co09) A	Stockyard (Tail of Co09) B	Waste Dump A	Waste Dump B
Quartz (SiO_2)%	14.8	1.4	1.6	1.1	1.6	1.5	1	0.8	0.9	0.7	0.7	0.7
Hematite (Fe_2O_3)%	25.9	56.7	44.9	47.9	40	36.7	55.4	56.7	52.9	53.1	49.3	49.1
Goethite (FeOOH)%	43.4	39.7	51.8	49.6	55.2	58.1	41.7	40.8	44.1	44.4	48.7	48.9
Kaolin ($Al_2Si_2O_5(OH)_4$)%	12.5	2.2	1.7	1.4	3.2	3.7	1.9	1.7	2.1	1.8	1.3	1.3
Mica ($KAl_2(Si,Al)_4O_{10}(OH)_2$)%	3.4	-	-	-	-	-	-	-	-	-	-	-

Appendix 2. Iron ore dust samples XRF analysis results

Major Elements (%)	EAP 3A	EAP 3B	Haul Road A	Haul Road B	Low Grade Stockpile A	Low Grade Stockpile B	Plant Fines A	Plant Fines B	Stockyard (Tail of Co09) A	Stockyard (Tail of Co09) B	Waste Dump A	Waste Dump B
Fe_2O_3	58.52	86.98	83.21	84.75	79.14	78.29	87.29	87.86	85.81	85.86	86.70	87.38
SiO_2	19.67	3.40	3.85	3.51	7.00	7.45	2.93	2.95	3.10	3.14	2.91	2.96
Al_2O_3	9.39	2.36	3.08	2.80	4.10	4.42	2.20	2.23	2.66	2.66	2.26	2.26
P_2O_5	0.22	0.20	0.21	0.21	0.13	0.13	0.18	0.18	0.21	0.21	0.19	0.19
SO_3	0.03	0.02	0.17	0.15	0.19	0.20	0.06	0.07	0.07	0.08	0.06	0.07
CaO	0.02	0.02	0.03	0.02	0.03	0.03	0.01	0.01	0.01	0.01	0.01	0.01
TiO_2	0.42	0.09	0.10	0.09	0.15	0.17	0.07	0.07	0.08	0.08	0.06	0.06
Mn_3O_4	0.69	0.15	0.12	0.12	0.09	0.10	0.08	0.08	0.12	0.12	0.10	0.09
MgO	0.46	0.10	0.08	0.06	0.06	0.08	0.06	0.07	0.07	0.06	0.06	0.06
K_2O	0.63	0.04	0.03	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01

*Lower Limit of Detection (LLD) for major elements: Fe_2O_3 0.001, SiO2 0.002, Al_2O_3 0.002, P2O5 0.001, SO_3 0.002, CaO 0.001, TiO_2 0.002, Mn_3O_4 0.001, MgO 0.007, K_2O 0.001

MORTALITY AND CANCER INCIDENCE FROM LEAD EXPOSURE: RECENT FINDINGS

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ABSTRACT

In 2006 IARC upgraded inorganic Lead to a Group 2A carcinogen inferring that the agent is probably carcinogenic to humans. The upgrade was primarily based on findings of increased stomach cancer and inconsistent evidence available for lung, brain and kidney cancer. In addition, recent findings have linked occupational lead exposure to increased risk of death from hypertension and cardiovascular disease.

We report our recent findings from a retrospective cohort study undertaken in the secondary lead industry in Victoria and NSW. The blood lead records of 4114 male workers in the secondary lead industry were retrieved and a cohort was formed from archival records dating back to 1970. Each cohort member was linked to the Australia Cancer Database (excluding Victoria), Victoria Cancer Registry and the National Death Index. All three registries are population based registries with high ascertainment. The observed mortality rate and cancer incidence in the cohort were then compared with expected rates (i.e. population rates) to give standardized incidence and mortality rates.

Overall cause of death was elevated (SMR=111; 95%CI:101-123) but overall incidence of cancer was significantly less than expected (SIR=83; 95%CI:73-95). There was no increased mortality for Ischaemic Heart Disease (SMR=95; 95%CI:76–119) or Stroke (SMR=125: 95%CI:84-186). Although there was no elevated risk of stomach, lung, brain or kidney cancer, there was an increased incidence for oesophageal (SIR=240;95%CI:129-447) and liver cancer (SIR=217;95%CI:103-454). For cases with blood lead levels above 30µg/dL, the incidence rate for oesophageal cancer was elevated (SIR=755;95%CI:314-1813), but this was based on only 5 cases.

There is no established biological mechanism linking inorganic lead exposure and oesophageal cancer. Smoking and alcohol consumption data were not available for this cohort and are known risk factors for esophageal cancer, so they cannot be ruled out as confounders in this study and may account for some of the excess oesophageal cancers.

HVAC SYSTEM COIL ODOURS - AN OCCUPATIONAL HYGIENIST'S PERSPECTIVE ON AN IAQ CONUNDRUM

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AECOM

KEYWORDS

Odour; Indoor Air Quality, HVAC and Mechanical Systems; Odours

ABSTRACT

Recurrent intermittent foul odours from Heating Ventilation and Air Conditioning (HVAC) system coils, known as "Dirty Sock Syndrome" (DSS) sometimes occur in air-conditioned spaces. Current information suggests DSS arises from Biofilms, but this does not fully explain why DSS also occurs from clean coils. While evidence exists for some Biofilm-related odours, a 1950's ASHRAE study showed that classic DSS results from the build-up of dilute airborne odorous chemicals on cold wet coils with subsequent release as a concentrated odour burst when the coil dries. The odour severity strongly related to coil metal with influences from other factors. Present beliefs of a microbial basis for DSS appear to reflect a combination of lost knowledge of previous studies, situations when Biofilms do cause odours, and perhaps the recent focus on microbial aspects of IAQ problems. This paper suggests that currently accepted DSS causes and treatments may benefit from a re-examination.

SPEECH AND ITS IMPACT ON CARBON DIOXIDE RE-BREATHING IN RESPIRATORY PROTECTIVE DEVICES

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KEYWORDS

Carbon dioxide re-breathing; phonic respiration; speech; respiratory protective devices

ABSTRACT

Carbon dioxide (CO2) re-breathing has been recognised as a concern regarding respirator use and is related to increased respiration, breathing discomfort, reduced exercise tolerance and impaired cognitive function. No previous investigations have evaluated the relationship between CO2 inhalation and phonic respiration (breathing during speech). A total of 46 workers trained in the use of respirators volunteered. Participants performed a graded exercise test on a cycle ergonometer that increased in resistance every five minutes. During the third minute of each stage participants read aloud a prepared text. Measures of expired (PECO2) and inspired CO2 (PICO2), and respiration were monitored. The results showed phonic respiration and sedentary work rates contributed to significantly higher levels of CO2 re-breathing. Aiming to reduce CO2 re-breathing is important to improve wear time of respirators in the workplace. As a result the impact of speech, sedentary activity and the design of respirators need to be considered.

THE ANALYSIS AND MANAGEMENT OF HEALTH RISK UTILISING A SEMI-QUANTITATIVE RISK ASSESSMENT (SQRA™) METHODOLOGY.

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Rio Tinto

ABSTRACT

Occupational health risk identification, assessment and management are the staple activities of the occupational hygienist. In the most part it has involved a qualitative risk assessment methodology as presented in the AIOH publication "Simplified Occupational Health Risk Management Strategies". While the monitoring of exposures followed by comprehensive assessment by an occupational hygienist or other allied health professional has added a quantitative component to health risk assessment, it often has limited input from the employees. A number of years ago an Australian based engineering and consulting group, GHD, developed a semi-quantitative risk assessment methodology in response to the requirement to complete a formal safety assessment as part of the Safety Case Regime implemented for Major Hazard Facilities in Victoria, Australia. This process involves the identification of causes and controls to produce bow-tie diagrams of the risk scenario as well as producing a critical risk rating and identification and analysis of the critical controls being used. In conjunction with the consultant, Rio Tinto has modified and adapted this semi-quantitative safety-based methodology such that it can now be used to assess significant health risks in the mining, refining and smelting industries. It utilises SEG-based personal monitoring data and relates it to a dose response curve to include a quantitative component, while improving the analysis of health risks with increased input from the workforce and providing a better understanding of health risk and its control by line management.

BACKGROUND

Hazard identification and risk management at Rio Tinto is structured into a layered approach, levels 1 to 3, as a key component of their health, safety and environmental (HSE) management program.

The first level is utilised 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 environment and tasks and are more consequence based. They have strong ownership by the individuals as they are undertaking the assessment directly related to their day to day job. They are however, prone to significant subjectivity and 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 is used for jobs/activities with increased complexity. It introduces a degree of measurement and some limited consistency by utilizing the risk matrix, first formally introduced in Australia in AS/NZS 4360 (1995) and expounded upon by the AIOH publication "Simplified Occupational Health Risk Management Strategies" (Firth et al 2006). This allows the combination of consequence and likelihood/probability to determine the level of risk applicable to the scenario in question. This process is usually undertaken by a group of individuals familiar with an exposure scenario and often includes one or more participants with health and safety knowledge and skills. Repeatability is improved but there can be some potential loss of ownership of the risk if the health and safety professional is perceived to have imparted too much influence on the assessment.

The third level involves a more comprehensive analysis of the scenarios and attempts to quantify the risks by measurement, usually some form of monitoring of the individual and/or environment. Risks classified in level 2 qualitative assessments as critical are escalated to a level 3 quantitative assessment. Toxicological assessments can be incorporated to determine the 'toxic' dose and its potential effect on the individual or group of individuals. From the initial work after World War 2 conducted on radiological health and human uptake, numerous other forms of measurement of exposure to contaminants have been developed (Paustenbach 2002) and applied. These assessments are often quite complex, time consuming and expensive to produce. The resultant product is often a large and complex report with technical jargon. Whilst accurate and informative, their use in the production environment of an operation often extends to a cursory glance of the executive summary by the manager on submission and then relegation to a book shelf or an archive in some remote part of the office complex. Whilst accurate and repeatable, the ownership level is often quite low as it is seen as a product of an external group with a "black box" mystique about it.

Rio Tinto determined that a different approach to quantitative risk assessment was required with the following key objectives:

- Provide consistent quantification of critical health risks across the group.
- Provide a measure for comparison and alignment with other disciplines (eg safety) in the review of critical risk.
- Provide leaders with visibility of critical control performance in their areas.
- Ability to prioritise and manage controls.
- Enable competent health risk specialists to deliver consistent results.
- Reduce reliance on consultants.
- Facilitate our elevation to sector leader in critical health risk control.

SEMI-QUANTITATIVE RISK ASSESSMENT (SQRA™)

A tested and documented methodology embedded in a software tool was required. In 2001 an Australian based engineering and consulting group (formally Qest, now GHD) developed a semi-quantitative risk assessment methodology designed to meet the requirements of the "Safety Assessment" component of a Safety Case as required under the National Standard for the 'Control of Major Hazard Facilities' (NOHSC 2002) (after the Longford Gas Plant incident). This process involved the identification of causes and controls to produce bow-tie diagrams of the risk scenario as well as producing a critical risk rating and identification and analysis of the critical controls being used.

The methodology, referred to as a semi-quantitative risk assessment (SQRA™), *was designed to match the rigour and repeatability of quantitative techniques but enable site ownership as afforded through the simpler qualitative approaches* (GHD 2012). It was adopted within the safety discipline in Rio Tinto and was utilised for the assessment of critical safety risks with a potential fatality outcome.

In 2006 in conjunction with GHD, it was decided to trial the process (with some modification) in the assessment of potential critical health risks identified in the company. It is important to note that the following is a Rio Tinto adaptation of the GHD process and some interpretations and applications of the methodology will vary from those initially developed and applied by GHD in the safety SQRA™.

THE HEALTH SQRA™ PROCESS

The health SQRA™ process is undertaken at the site and utilises a number of individuals familiar with the exposure scenario to be assessed. A typical group would comprise:

- At least two members of the similar exposure groups (SEGs) to be assessed
- A member of the leadership team (i.e. crew leader, superintendent)
- Member/s of the occupational health team, no more than two (excluding facilitator)
- Lead facilitator
- Scribe
- Optional - additional specialists, such as maintenance personnel, engineers, occupational physician, monitoring technician; these may be part time or as required.

The process utilises seven steps:

1. Hazard identification and scenario development
2. Hazard dynamics (bow-ties)
3. Current risk
4. Selection of critical controls
5. Critical control adequacy assessment
6. Predicted risk
7. Reporting and improvement planning

In the *hazard identification and scenario development* step, the hazard, similar exposure group (SEG) and general scenario to be assessed are identified and described in simple terms, based on information obtained during level 2 qualitative risk assessment. For example: *Noise exposure to SEG 10 – Heavy Mobile Equipment Operators; includes all employees who operate water carts, graders, haul trucks, loaders, excavators and shovels.*

The *hazard dynamics* portion of the process involves group brainstorming to break down the risk scenario into causes. These in turn are grouped into pathways, which are a collection of common causes (eg human error, mechanical failure, etc) or activities (eg material handling, maintenance, etc) that lead to the exposure occurring. The next step delves deeper and identifies the controls currently in place to prevent the exposure. At this point participants are also encouraged to identify additional potential controls that may be introduced to further reduce the exposure.

Step two also gives rise to the bow-tie, which is a graphical representation of the hazard, its causes and controls. The bow-tie displays the inter-linkages between causes, controls, pathways, the loss of control event and the consequences or outcomes for each exposure scenario. It is a very visual component of the process and can condense a wealth of information about a particular risk scenario onto one page by using information boxes and colour coding. These can be quite simple or extremely detailed depending on the scenario being assessed. Figure 1 illustrates the general structure of the bow-ties used with figure2 providing an example of a small portion of an actual bow-tie and figure 3 a zoomed out view of a complex bow-tie for noise exposure in mobile equipment. It should be noted that figure 3 shows only the left hand side (preventative controls) of the bow-tie.

Figure 1: General bow-tie structure (GHD 2012)

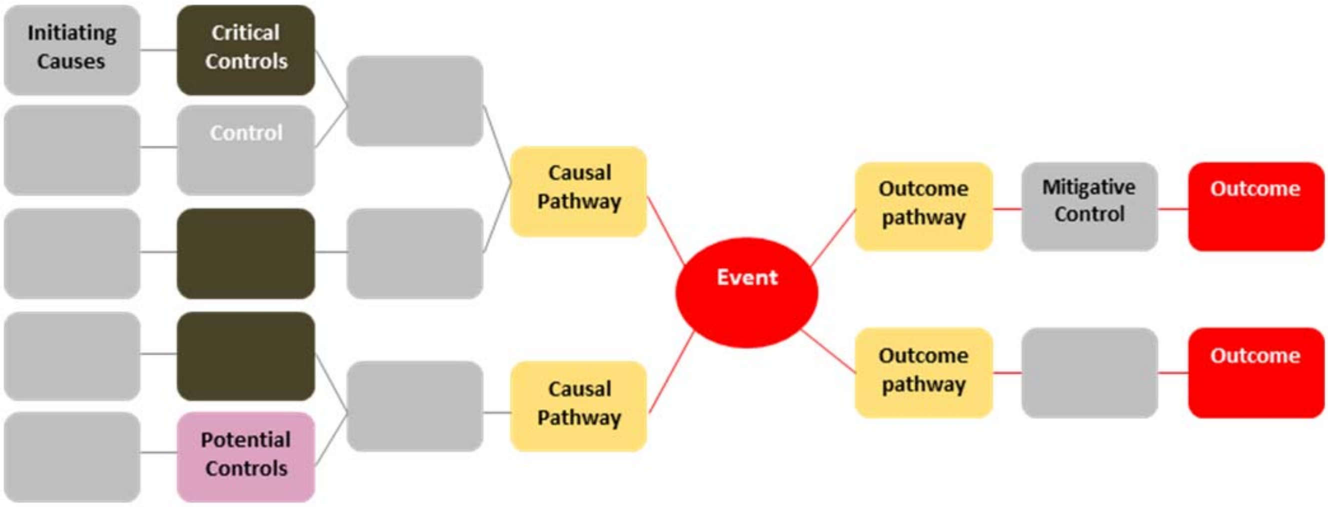


Figure 2: Illustration of causes, actual controls (white), potential controls (pink) and control hierarchy across the bottom of each box.

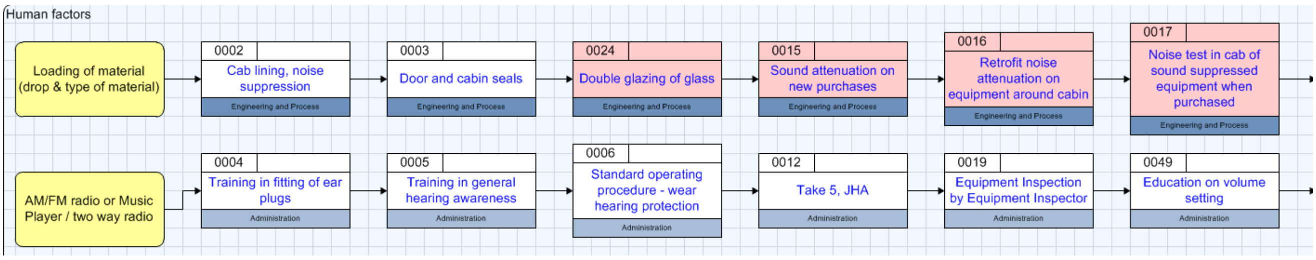
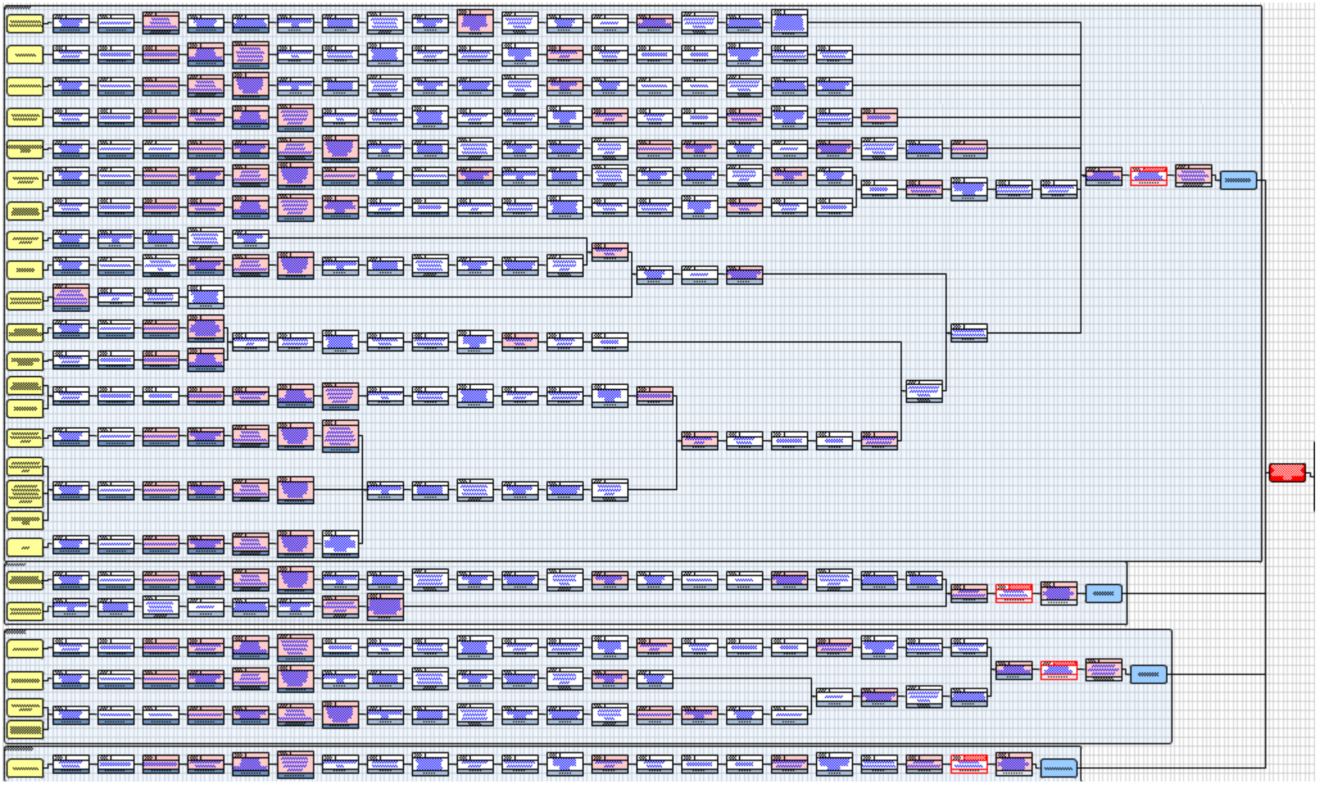


Figure 3: Comprehensive bow-tie



The *current risk* step is one area that differs significantly from the safety SQRA™ process. It is in this step that the results from the SEG's monitoring program are utilised to determine the risk level. Currently dose response curves from literature (where available) are incorporated into the calculation to estimate risk at the exposures measured. To date there are seven hazards or measures that have been developed into a format that can be utilised in the calculation. These are:

- Noise
- Asbestos
- Arsenic
- Crystalline silica
- Benzo(a)pyrene
- 1-hydroxypyrene
- Flouride

To date this has been one of the major limitations in the application of this methodology as not all substances have dose-response curves and some risk scenarios such as malaria, physiological stress, fatigue and thermal stress are key health hazards that also need to be addressed.

The current critical risk score represents the predicted fatality/morbidity/disabling illness rate per annum (ie risk per operating year). Factors such as relative risk, attributable risk, working life and impact of PPE are utilised in the estimate of the critical risk rating. The impact of PPE is assessed based on a prompt sheet detailing specific criteria expected to be included in a PPE program (Table 1).

Table 1: PPE impact assessment criteria.

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.

The *current critical risk rating* (CCR) is compared against the business' predetermined risk reporting criteria and all results above this level must then be reported through to the corporate head office on an annual basis, while still considered a critical risk. Details of exposure levels and control plans must also be included. As monitoring methods and the process for assessment limits are consistent and the level of subjectivity is minimised in these steps, the CCR can be used for relative comparison across sites and/or business units.

There are no absolute risk acceptance criteria that can be directly applied to evaluate the critical risk score derived from the SQRA process. This is largely because for both health and safety, the critical risk score is a 'societal risk' measure, meaning that it considers the exposure to the whole of the population (workforce) in a work area or SEG. A very large work area or SEG with a large number of people is likely to have a higher critical risk score than a smaller operation or smaller SEG with less people. The definition of a specific criteria number is still an area of research and development.

The next two steps, *critical control selection and assessment*, involve the selection of what is determined by the team to be the critical control(s) and then an assessment of the adequacy of those controls in preventing the exposure. Factors included in the selection include but are not limited to; severity of the consequences, pathway dominance, control dominance and repeatability. Once the critical control(s) has been identified the adequacy of the control is assessed via a series of questions targeting four areas:

- Planning / design
- Implementation
- Workforce involvement
- Monitoring

Each one of these categories is rated and then a final overall rating is applied to the control ranging through unsatisfactory, satisfactory to high. Where shortcomings are found in the control, actions must be identified to correct these and are recorded in the database.

The penultimate step, *predicted risk*, requires the team to assess each of the actions and determine their impact on the exposure of the hazard to the SEG(s). Consequently, an estimate is made of the overall impact and predicted reduction in exposure level. This figure is then substituted into the risk calculation form in the database to generate a new CCR and a comparison of the current and predicted CCR is made and the improvement estimated. It is worth noting that whilst this is a subjective estimate based on the knowledge and experience of those present in the team, it is actually quantified by the results of the subsequent workplace monitoring program to determine control efficacy.

The final step, *reporting and improvement planning*, collates the actions identified in the workshop into a risk reduction spread sheet for submission to the site management team for consideration in the development of the occupational health action plan. The process can generate numerous actions and this step is required so that the actions are reviewed by the management team and acceptance or rejection of the suggested actions can be undertaken and priorities allocated. This spread sheet forms the foundation of the action plan, which is used to allocate responsibilities for completing actions, deadlines and tracking year to date progress. The final report can comprise:

- Bow-tie diagram
- Risk reduction spread sheet
- SQRA final report containing graphs and charts
- Critical control monitoring plan (CCMP)

CONCLUSION

Due to the prior implementation of the SQRA™ process by the safety discipline, management and the workforce are familiar with the outputs and reports generated by the health SQRA™ process. This was an important benefit in that it was not introducing another assessment and reporting process, but building on one already established and understood.

The bow-tie visually displays the causes, controls, identified critical and potential controls in a very concise and clear form. The ability to display where on the hierarchy of controls they sit often paints a thought provoking picture and can demonstrate the over reliance on PPE as a control.

The adequacy assessment of critical controls can and will uncover truths about the effectiveness of controls. It thus provides confidence in a now demonstrated functionality or alternately, uncertainty as a result of inadequacies identified in a previously trusted control.

The database can be utilised to readily demonstrate the significant impact and benefit of engineering controls compared to PPE, where the former can reduce the exposure and the latter doesn't, a useful tool when building a business case.

A great deal of time and effort has been spent over the last few years in trying to incorporate an accurate quantification of the health risk resulting from exposure to a number of hazards into the database. This has resulted in the reliance on dose-response curves, and exposure/illness assessments undertaken to enable the risk calculation. Whether this level of effort was warranted for the final outcome can be debated but it has helped the acceptance of the methodology amongst health professionals in the organisation. This obsession with numbers can sometimes be a barrier and overshadow the true value of a tool. Being able to put a number on the risk is useful but the question is, does it need to be an accurate quantification of the risk or is a consistent approach that can be used for relative comparison of the risk, a possible addition to this process?

The health SQRA™ process has provided a systematic and methodical approach to analysing health risk. It enables the characterisation of the risk by breaking down the scenario, identifying causes and then each of the controls that are in place and importantly, potential controls. The formal participation of members of the exposed SEG has raised a greater awareness of the hazards to which they are exposed and also resulted in potential solutions identified by the employees and hence greater ownership by the workforce. It also presents this information in format that is readily displayed and communicated to the management team. These are where the true benefits of the method lie rather than the critical risk rating it generates.

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ACHIEVE HEALTH – REFLECTING ON THE CHALLENGES OF IMPLEMENTING A HEALTH AND WELLNESS PROGRAMME

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KEYWORDS

Health and wellness, biometric, health risk assessment, health risk factor, health risk profile

ABSTRACT

Aim: To provide a workplace based health and wellness programme aimed at reducing the cost of injury and illness, absenteeism and presenteeism, on Rio Tinto as a business.

Method: The Achieve Health programme was launched across Rio Tinto to provide a much needed strategic approach to addressing the health and wellbeing of our workforce. This paper will take a close look at the programme implementation at Mt Thorley Warkworth, an open cut coal mine in the Hunter Valley NSW. Reflecting on the challenges and success's since the programme's launch in 2009.

Results: Four years post implementation, the Achieve Health programme continues to flourish at Mt Thorley Warkworth, attracting voluntary participation of 77% of our workforce in 2011, and a 67% reassessment rate (based on total assessments undertaken in 2010).

Conclusion: With much of the adult population spending a large portion of their waking hours connected in some way to the workplace, the sheer volume of individuals who can be reached through work based programmes is vast. If factors which influence individual health at home and work combine to influence health in a synergistic manner, then there is definite benefit in coordinating health promotion and injury and illness prevention at the workplace.

INTRODUCTION

Research continues to show that common chronic conditions, such as cancer, heart disease and diabetes, are driving up total health related costs in the workplace. Adding to this expense is the pressure of an ageing workforce, a group who experience chronic conditions which require more care, are more disabling and more difficult and costly to treat.4 In the face of these ever present obstacles Rio Tinto continues to strive towards our goal of a zero harm workplace.

An unhealthy work environment poses many risks to the health of employees, including:

- A fivefold increase in the risk of certain cancers
- A threefold increase in the risk of heart problems
- A threefold increase in the risk of back pain
- A two- to threefold increase in the risk of on-the-job injuries
- A two- to threefold increase in the risk of infection
- A two- to threefold increase in the risk of conflicts
- A two- to threefold increase in the risk of mental health issues
- A twofold increase in the risk of substance abuse 3

In 2009 the Rio Tinto 'Achieve Health' programme was implemented at Mt Thorley Warkworth, an open cut coal operation in the Hunter Valley NSW. The Achieve Health programme provided a much needed strategic approach to addressing the health and wellbeing of our workforce. The programme assumes a proactive, preventative approach to assisting people identify their health risk factors, enhancing their awareness and skills and promoting and supporting change to achieve optimal health.

At the completion of 2009, 130 people were participating in the Achieve Health programme at Mt Thorley Warkworth. Of this 130, 25% presented with 6-9 modifiable health risks, with 9 representing the maximum number of modifiable health risks. Modifiable health risks have the potential to impact on the productivity and efficiency of an organisation and denote those risks which can be influenced by behaviour change and health programmes. A recent study found that individuals who report 3 or more risk factors are significantly more likely to not participate in the workforce compared to those who reported no risk factors.[1]

Now, four years on, the programme continues to flourish, attracting voluntary participation of 77% of our workforce in 2011 and 67% reassessment rate (based on total assessments undertaken in 2010). The programme has enabled Mt Thorley Warkworth to identify what the modifiable health risks are for our site and thus effectively tailor health programmes to suit the needs of our employees.

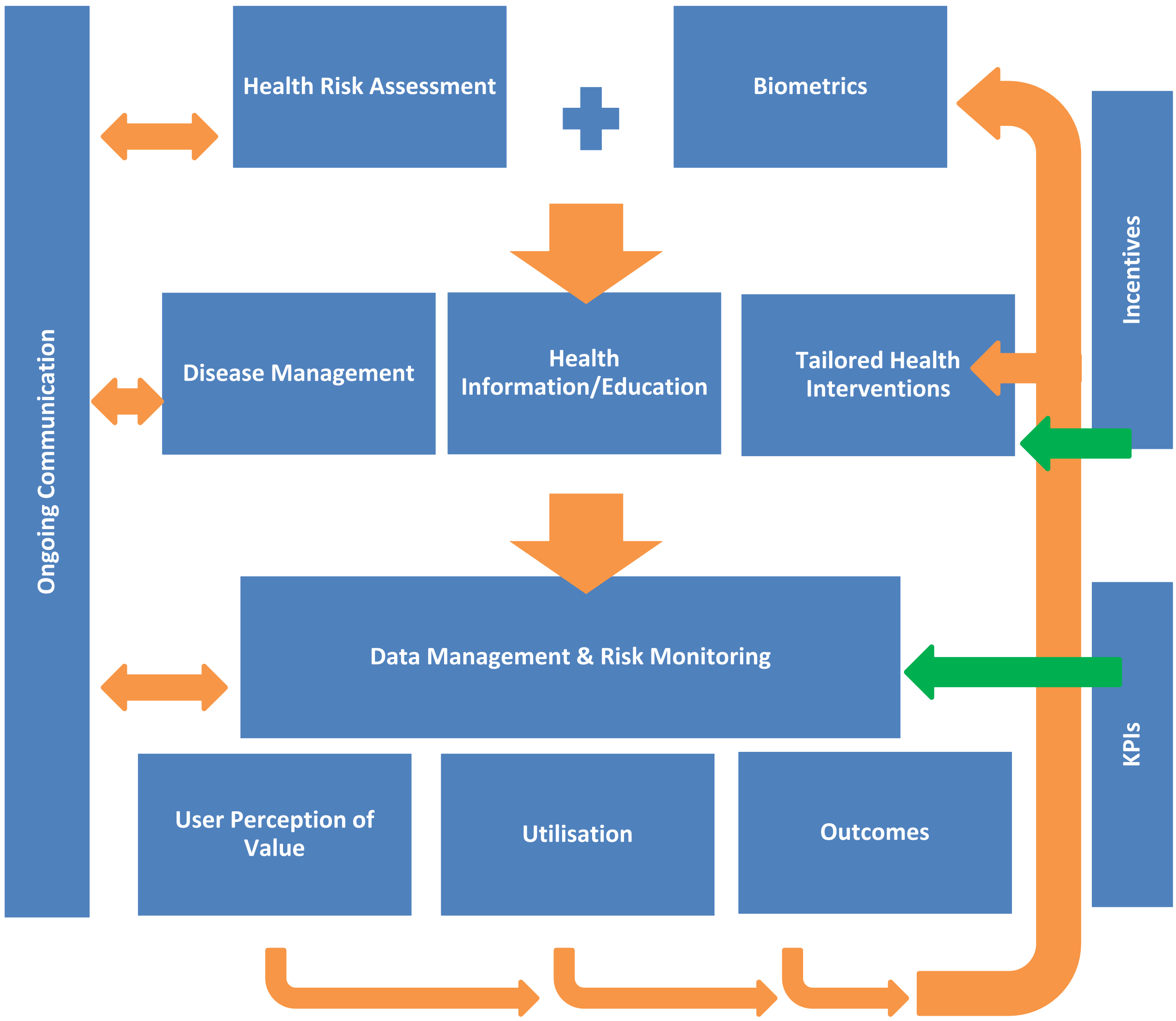
An analysis of the mining sector in relation to workplace health perception was conducted in 2011. Of those mining workers taking part in the study, 77% felt workplace health and wellbeing programmes had improved their health status.6 29% stated that these programmes have reduced the number of days absent from work for health related reasons and

47% considered that the number of hours at work that were not fully productive due to feeling unwell were reduced.6 Evidence such as this helps provide further value to the data collected from Mt Thorley Warkworth's Achieve Health programme. Whilst the numbers may take years to effectively demonstrate the benefit of the programme, the more immediate impact on worker perception is priceless.

METHODOLOGY

'Achieve Health' represents a workplace health and wellness programme that is currently being implemented globally by Rio Tinto. The program is based on the model shown in figure 1. This model provides flexibility in terms of its mode of delivery, thus allowing businesses to provide the program in a manner which best suits them.

Figure 1: Rio Tinto's Achieve Health Programme Framework



At Mt Thorley Warkworth the above model has been applied to delivery of the 'Achieve Health' programme and will be considered here in three main phases – assessment, intervention and re-evaluation.

ASSESSMENT

Participants undertake a voluntary onsite health assessment which consists of collection of biometric data and completion of an online health risk assessment (HRA). The biometric data collected includes height, weight, waist measurement, blood pressure and finger prick cholesterol (total and HDL) and glucose. The HRA asks a series of questions related to lifestyle and behaviour as well as risk factors for illness including family history and incorporates an assessment of 'readiness to change', in accordance with Proshka's readiness to change model.

Following input of the biometric data and completion of the HRA, a report is generated advising of the outcome of the individual's health assessment. The report provides feedback on any presenting health risk factors (providing advice on the immediacy with which they should be addressed), as well as feedback on opportunities for improvement and encouragement for those areas in which the individual is doing well. The individual is required to set health goals at this time, which they will work on over the coming twelve months.

All health assessments are undertaken by suitably trained and qualified personnel with a health background. The experience and knowledge of those undertaking the assessments ensures that individuals are provided with sound health guidance at the time of their assessment. Assessments can be undertaken on any shift, day or night, as the health centre is manned 24/7.

As a business we receive monthly de-indentified feedback on our health profile, as determined by health assessments completed for that month. This timely feedback enables us to ensure that worksite health campaigns are tailored to the presenting needs of our workforce.

INTERVENTION

Intervention strategies employed at Mt Thorley Warkworth are carefully tailored to the needs of our workforce. The nature of these interventions ranges from the provision of information/education to the whole workforce through to individual diagnosis and management of conditions. Interventions employed over the last twelve months include a skin check clinic, flu vaccination clinic and dietician clinic. In addition to these clinics we also provide ongoing onsite access to an Occupational Physician, Physiotherapist, Occupational Therapist and Nurse, which has enabled us to assist our employees with diagnosis and management of both work and non-work related injuries and illnesses. Employees are encouraged to utilise the onsite health services to monitor their health status on a regular basis, whether this be as simple as a blood pressure check or a more thorough assessment such as a fasting blood analysis.

Through participation in the Achieve Health program, employees are also eligible for a range of incentives which are financially supported by Mt Thorley Warkworth. Employees may choose between a fully funded gym membership or a re-imbursement toward other approved heath initiatives, such as a quit smoking programme. Access to these incentives has been a key factor in attracting participation in the programme.

RE-EVALUATION

Ongoing participation in the Achieve Health programme requires the individual to undertake an annual onsite health assessment (biometric data collection and HRA). Through presenting for an annual assessment the individual can track their progress against the health goals set previous and set new goals relevant to their health status at that time.

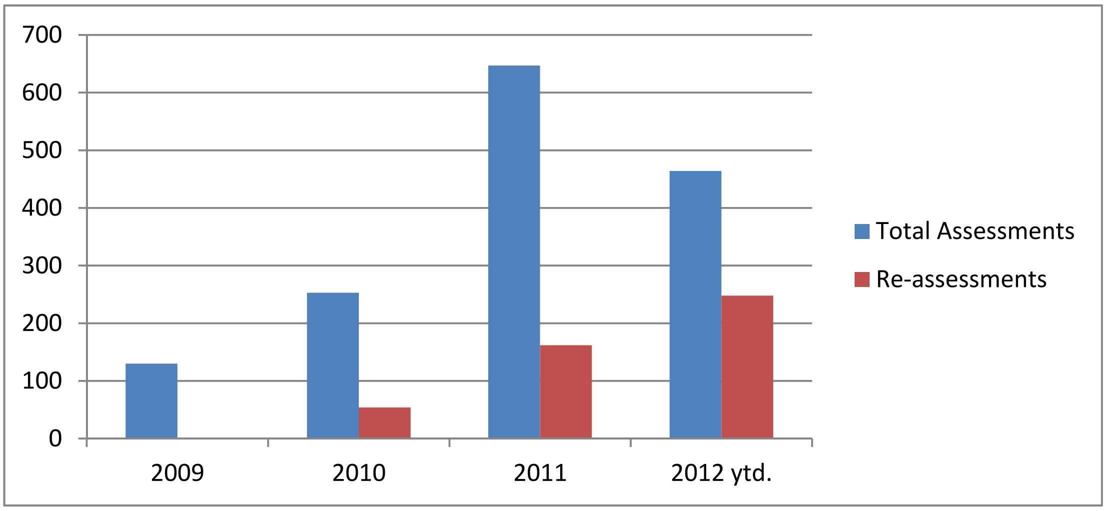
Ensuring that employees present for this annual assessment is also very important to Mt Thorley Warkworth, as it enables us to develop a health profile of our workforce and identify any trends in this profile over time. This data continues to guide the interventions that are employed at our site.

RESULTS

Since the program's inception in 2009, participation in the programme has continued to grow year after year, with 77% of our workforce participating in 2011.

High participation results in greater awareness of health status on both an individual and site level.

Figure 2: Mt Thorley Warkworth Achieve Health Participation



Mt Thorley Warkworth has been able to develop a health profile of our site, through review of data on a monthly basis and collation of this data annually.

Table 1 summarises the frequency with which key health risk factors have been identified in Achieve Health participants at Mt Thorley Warkworth.

Table 1: Health Risk Factors (%)

	2009	2010	2011
Smoking	15	18	14
Alcohol	48	39	60
Exercise	82	74	79
Nutrition	98	97	99
Sleep	76	64	62
Musculoskeletal pain	14	9	7
Anxiety	2	4	2
Depression	6	5	4
Stress	7	5	4
No regular medical advice	60	79	65

Through review of the above information it is clearly visible that our top four health risks (alcohol, exercise, nutrition and sleep) have remained constant over the three year period, making it clear where our interventions should be primarily aimed.

Table 2 provides us with further detail around these top four health risks by advising where participants sit in terms of willingness to change. This enables us to further determine where our efforts are best directed in order to get the' biggest bang for our buck' so to speak.

Table 2: Willingness to change (top 4 health risks)

Health Risk	Pre-contemplation	Contemplation	Preparation
Nutrition	12.5%	26.0%	61.4%
Physical Inactivity	7.6%	19.6%	72.7%
Sleep	21.3%	24.3%	54.3%
Alcohol	51.3%	23.9%	24.8%

Figures 3-7 provide examples of the data tracked through the biometric and HRA process. Each figure depicts the Mt Thorley Warkworth annual participant profile, as well as providing data for a comparison group.

Figure 3: Proportion of participants at risk due to cardiovascular disease 5 year risk score

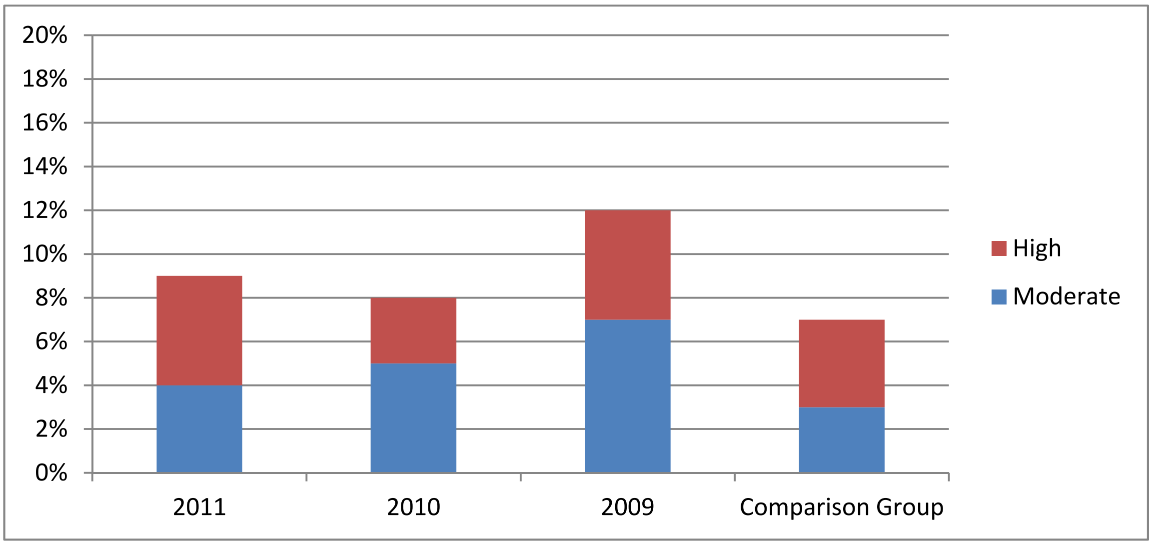


Figure 4: Proportion of participants at risk due to waist measurement

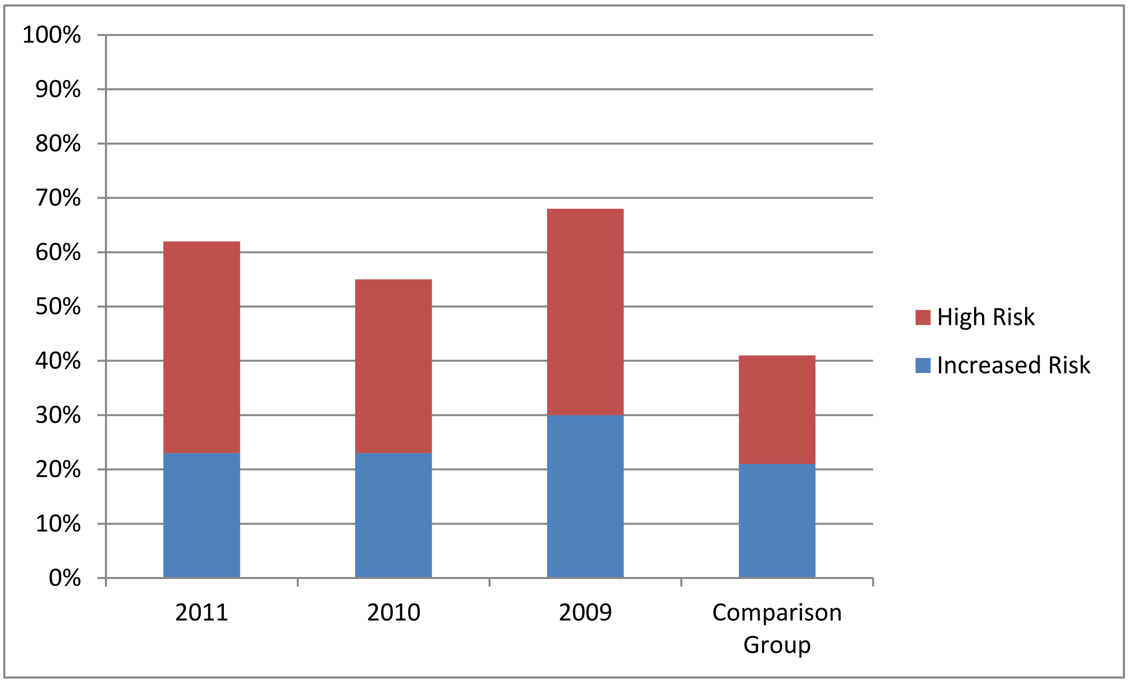


Figure 5: Proportion of participants at risk due to high blood pressure

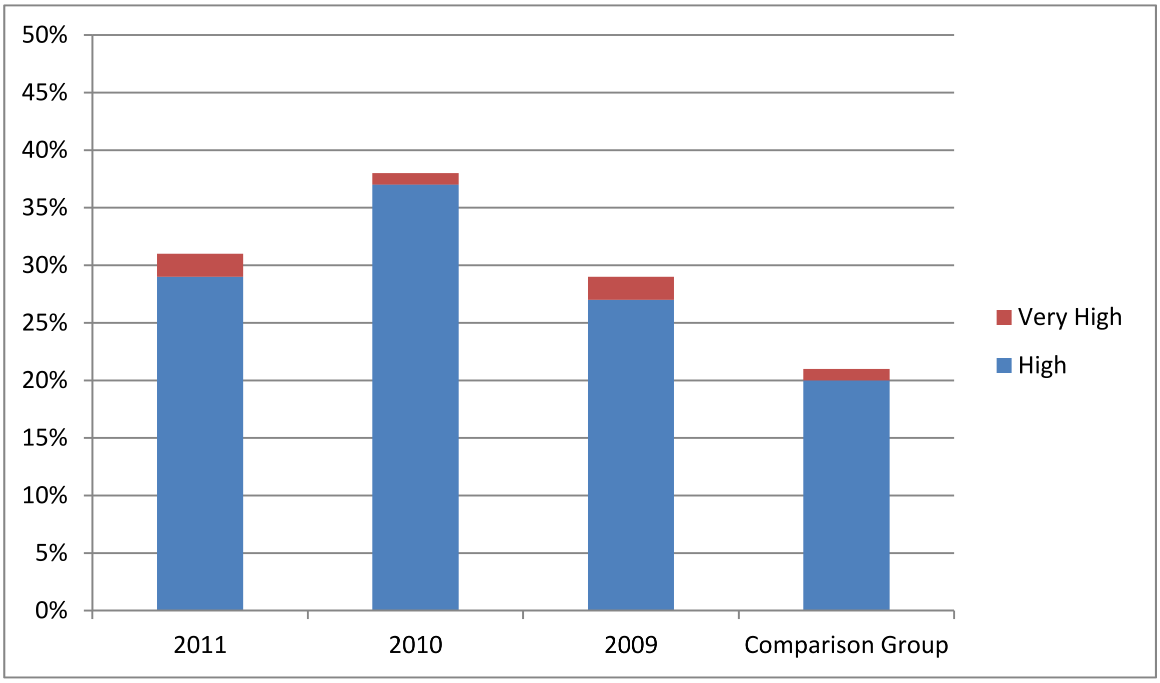


Figure 6: Proportion of participants at risk due to increased blood glucose

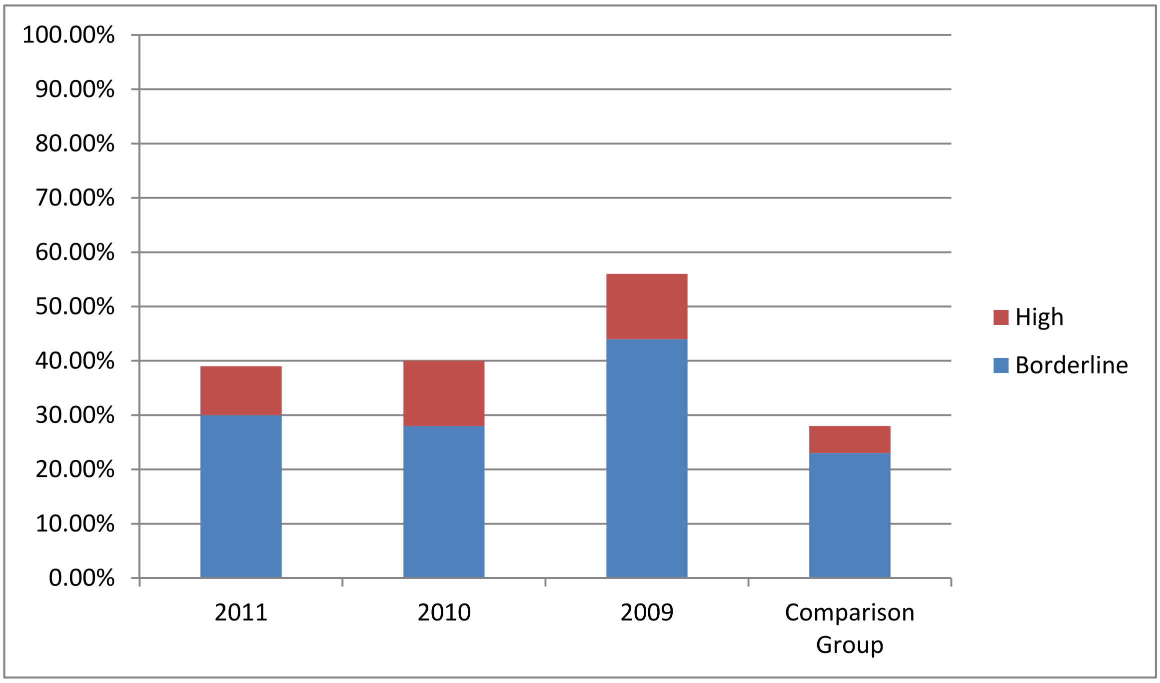
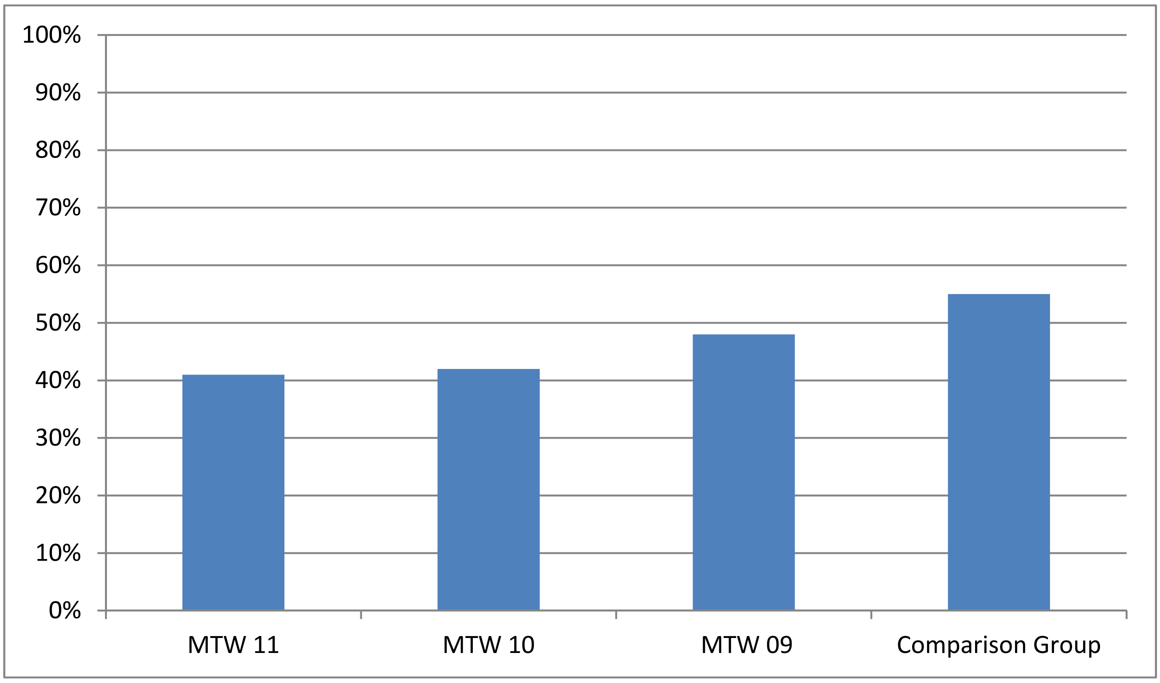


Figure 7: Proportion of participants at risk due to increased total cholesterol



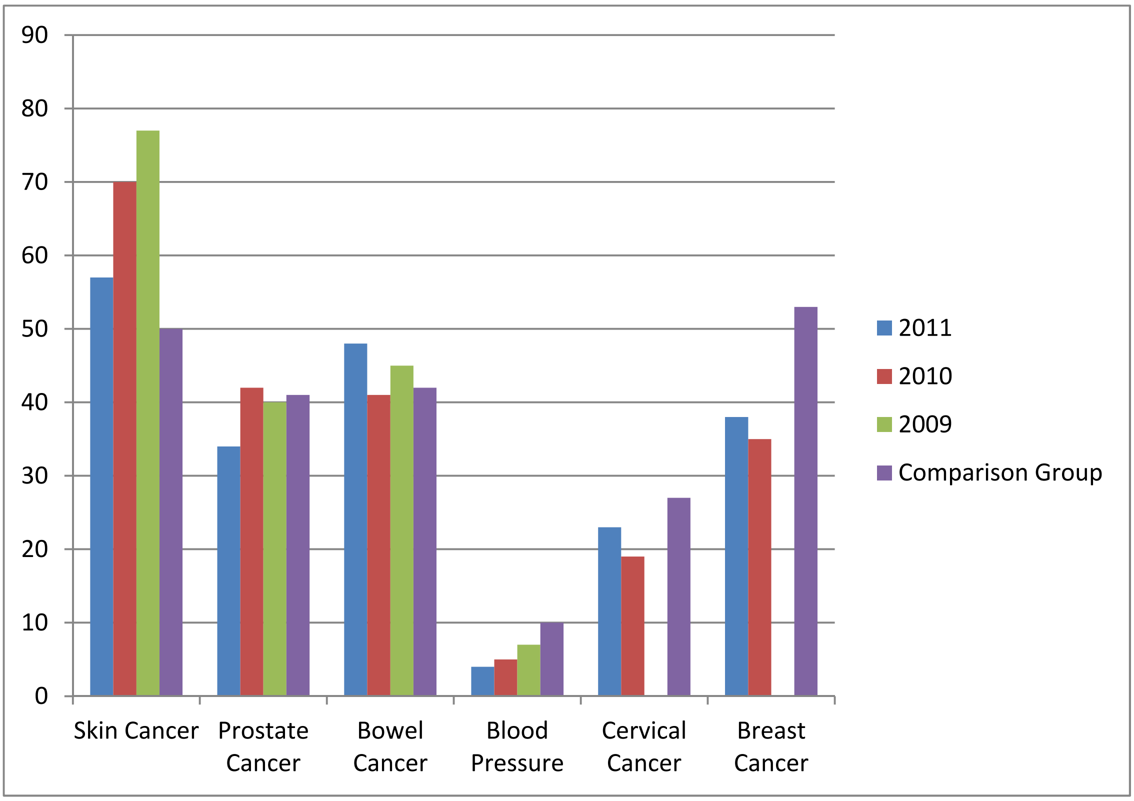
With precautionary screening being an essential component of disease identification, tracking the proportion of participants attending medical screenings has also enabled us to better tailor our intervention strategies.

With diseases such as cancers having the potential to be successfully treated if detected in the early stages, cancer has been a specific focus of this tracking. Cancer risk, as depicted below, has been determined based on attendance to cancer screens appropriate for both age and gender.

With the onsite skin check clinic being implemented in 2011, the decrease in those who are not attending skin cancer screenings, from 2010 to 2011, provides positive reinforcement that our interventions have had an impact.

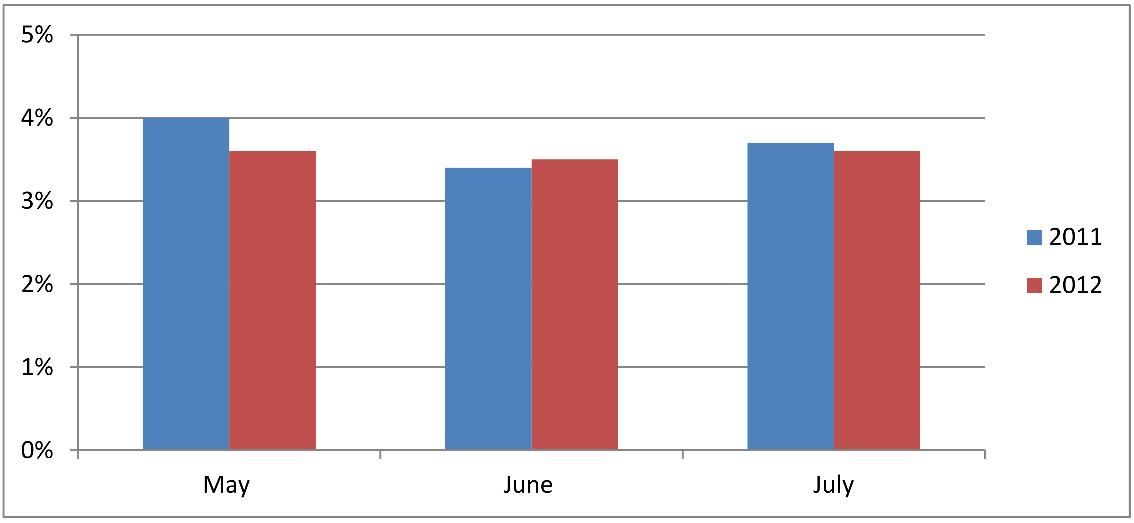
Similarly, the decrease in those not having their blood pressure checked could likely reflect the availability of this service onsite.

Figure 8: Proportion of participants who are not attending medical screenings



Tracking unplanned absenteeism is another means by which we can consider the effectiveness of the onsite health and wellness programme. When considering this data however, it is important to keep in mind that unplanned absenteeism may not always be the result of a health or medical related condition as opposed to an employee just taking a 'sickie'. Figure 9 compares unplanned absenteeism for May, June and July 2011 with the corresponding months in 2012. As can be seen, there is little variance in the unplanned absenteeism recorded.

Figure 9: Mt Thorley Warkworth Comparison of Unplanned Absenteeism



DISCUSSION

Whilst the above results don't show great variance from year to year; the top four health risks have remained constant, the health risk factor status remains largely the same and there has been little demonstrated change in unplanned absenteeism; the increased participation alone speaks to the success of the Achieve Health programme at Mt Thorley Warkworth. Through increased participation, Mt Thorley Warkworth has been able to positively influence the health knowledge and understanding of a broader range of employees. A programme which once attracted only the health conscious is now starting to attract the health challenged. A process that has been four years in the making and a process that will require ongoing nurturing.

Key to ensuring people remain motivated to participate in the program year after year, is the provision of a quality service, both in terms of the health assessment provided and the incentives offered as support towards achieving health goals. Leading into 2011,

Mt Thorley Warkworth undertook a review of the incentives offered in conjunction with the Achieve Health programme. Following this review came the introduction of a funded gym membership. Our participation rates demonstrate that this incentive proved very popular with our workforce. Offering this incentive facilitated access to a greater number of employees and thus enabled Mt Thorley Warkworth to have an impact on the health of a greater number of people.

Closely linked to the health incentives provided, are the onsite intervention strategies. It is vital that these intervention strategies are mapped to the sites risk profile so as to ensure that the services being delivered are of relevance to the employees, and in turn value to the company. Delivery of these services can be very time consuming, so it is crucial that the services delivered are those required.

Whilst increased participation is seen largely in a positive light, it can also be seen to have negative connotations, as with increased participation comes increased cost. The more people who participate in the programme, the more people eligible for support incentives and intervention strategies. The ongoing collection of quality data is invaluable here in order to demonstrate the benefit of the programme.

Delivering this programme on a mine site has been another ongoing challenge in terms of finding a mode of delivery that fits best with production pressures. Getting coal out of the ground is always going to be the priority at Mt Thorley Warkworth, so the challenge has been gaining the support of management and encouraging them to see that through creation of a healthy workplace we can maximise organisational performance. Again maintenance of quality data over the years is vital in providing substance to this long term benefit argument.

CONCLUSION

Health and wellbeing programmes can be measured in a number of ways but ultimately will only be as successful as the participation rate of your people. Health and wellbeing programmes must be tailored to reflect your organisational and industry risks, incorporate your risk profile, address the health profile of your people and their needs, be integrated into your overall business strategy, be regularly monitored and measured and most importantly be accessible and sustainable.

The impact of health promotion and injury and illness prevention activities on reducing the frequency and severity of negative health outcomes for workers, has been well documented. It has also been suggested that if factors which influence individual health at home and work combine to influence health in a synergistic manner, then there is benefit in coordinating health promotion and injury and illness prevention. Additionally, with much of the adult population spending a large portion of their waking hours connected in some way to the workplace, the sheer volume of individuals who can be reached through work based programmes is vast.4

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BETTER WORK TASMANIA - A STRATEGY FOR SAFE AND HEALTHY WORK IN TASMANIA

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WorkCover Tasmania

WorkCover Tasmania has identified a need and gained firm support, through extensive community consultations, for the development of a state-wide strategy to improve work health and safety (WHS) performance across all sectors. The proposed project is known as Better Work Tasmania – a strategy for safe and healthy work in Tasmania

The Steering Committee decided in January 2012 that it would be appropriate to use a prototype approach to meet this requirement. Hobart City Council has agreed to participate in this new initiative.

The Prototype approach has involved the Hobart City Council selecting a number of key networking organisations to choose priority areas in which they would like to improve WHS performance.

Key issues chosen to date are as follows:

1. Contractor management - communication and consultation (induction, roles and responsibilities, management systems/contractor vs. host)
2. WHS culture – change management (transparency, genuine buy- in process)
3. Ageing workforce – risk of injury – (fitness for work, alternative work duties, nominal insurer)

As part of the Prototype, participating organisations will be asked to:

- Participate in activities to address these key issues
- Work on key issues with other organisations participating in the Prototype program
- Report on results of activities undertaken
- Encourage and facilitate participation in the program Prototype program

The fundamental concept behind the Better Work Tasmania Prototype Program approach is to test and fine-tune activities and initiatives and assess the results that will eventually lead to the development of a Statewide work health and safety strategy, which workplaces across Tasmania will eventually adopt. At the same time the program will attempt to define those tangible benefits which would encourage participants to commit long-term to improving WHS.

The key deliverables from the prototype program process can be summarised as follows:

- Development and testing of a practical stakeholder driven strategy/ scheme to address WHS issues highlighted by the consultation campaign performed in the previous 18 month period.
- Opportunity for all participating organisations to focus on specific WHS issues collaboratively for a period of 12 months and evaluate the effectiveness of any improvements implemented.
- Opportunity for all participating organisations to develop additional networks to improve work health and safety
- Improved working relationships between participating organisations, WorkCover Tasmania and Workplace Standards Tasmania (WST)

USING 'YOUTUBE' TO DEMONSTRATE PRACTICAL OCCUPATIONAL HYGIENE TO DISTANCE LEARNING STUDENTS LOCATED ACROSS THE GLOBE

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The University of Newcastle, NSW, Australia

KEYWORDS

YouTube; video; education; training; distance learning

ABSTRACT

Many courses in occupational hygiene are taught through distance learning, but practical skills in hygiene cannot be learned remotely and laboratory/field training should be included in courses to prepare students for professional practice. There is a gap in knowledge between that acquired through written modules and that learned through practical experience. If it can be bridged using appropriate visual media to demonstrate techniques, the time available for field work can be used more effectively. However, commissioning professionally prepared videos of techniques can be prohibitively expensive and logistically difficult to distribute to students. At The University of Newcastle we have explored the use of 'YouTube' to demonstrate assessments of lighting, thermal environment and vibration. A digital video camera recorded demonstrations of the assessments. They were edited and uploaded to 'YouTube' for student access, but are also freely available for support of other occupational hygiene training programs.

INTRODUCTION

The profession of occupational hygiene continues to develop, both in Australia and internationally. In the 21st century hygienists can be called upon to address problems in ergonomics, safety and environmental science, as well as in the more traditional areas of assessment of biological, chemical and physical agents in the workplace. In concert with other occupational health and safety (OHS) professionals, hygienists are increasingly required to scope and formulate solutions to new and emerging occupational health hazards, and to contribute to the development of appropriate OHS policies and management systems. The Australian Institute of Occupational Hygienists (AIOH) has considered this developing role and has specified learning outcomes that should be met by educational courses in occupational hygiene, in order to equip graduates with the knowledge, skills and practical experience required for professional practice (AIOH 2011). Accredited programs that meet these AIOH requirements are all university level and postgraduate and increasingly are offered by flexible delivery. Over the last decade, the availability of new education technologies and virtual classrooms has stimulated an expansion in distance and on-line postgraduate education. There are many scholarly reviews of the potential benefits of multi-media and on-line teaching in distance education, for example Mishra (2001) and Tooth (2000). These developments have greatly improved access to education and training in OHS generally and occupational hygiene specifically, which has benefitted Australian students living and working in rural or remote areas, and international students.

Using Multi-Media in Distance Education

Distance education poses particular challenges for teaching practical skills and field work, essential for the professional occupational hygienist. Written materials can describe techniques and provide illustrations of equipment, but they cannot directly demonstrate practical skills. Hampton (2009) discusses a range of media that can be used to contribute to practical skill training and she outlines the particular advantages of video.

Video can integrate audio and visual information to show how a skill should be conducted, and recordings can be played and replayed multiple times until the content is grasped (Hampton, 2009). Edwards et al (Edwards, Jones & Murphy, 2007) explored the use of hand-held video to record real clinical scenarios, to help prepare health students for clinical placement. Their videos were effective in helping the students in the transition from classroom to clinical work, despite the recordings being made by 'non-professionals'. Donker (2010) compared the instructional effectiveness of print and video materials for distance teaching of practical skills in block laying and concreting. He found no difference in the acquisition of theoretical knowledge between print-based and video-based delivery of material, but practical skill acquisition and proficiency were both significantly increased in the group receiving video-based instruction. These are promising findings with applications for occupational hygiene distance education, and practical skill training.

Using Video for Distance Teaching of Practical Skills at The University of Newcastle

The University of Newcastle in New South Wales currently offers Masters and Graduate Certificate programs in OHS, through distance only education. The enrolment includes students from all States in Australia and from many other countries across the globe. The logistical difficulties of getting such students together for practical skill training are overwhelming - from both a cost and travel point of view - and the Newcastle programs therefore do not attempt to run 'on-campus laboratory classes or industrial field work. The Newcastle programs are aimed at the generalist OHS professional rather than the specialist hygienist, but it is nevertheless important to ensure the students can grasp the practicalities of hygiene assessments. The use of video for teaching practical techniques has therefore been explored.

There is a paucity of available instructional videos of occupational hygiene techniques and field assessments. It is likely that this is, in part, a reflection of the ethical and commercial difficulties of showing actual hygiene assessments in identified industries in an on-line forum. The excellent postgraduate learning materials for occupational hygiene that are freely available through the Occupational Hygiene Training Association website (OHTA, 2010) include little in the way of practical skill instructional videos. A search of YouTube resources also located little that could be used in hygiene practical skill training. Accordingly, in 2010 funding was sought from the University to engage the services of a commercial company to record, edit and produce a DVD, demonstrating air sampling and analysis and noise assessment. The demonstrations were performed by staff in laboratories and workshops of the university. After editing the final DVD was produced and multiple copies burned. These were distributed by mail to students studying occupational hygiene as part of the postgraduate programs in OHS.

The air sampling and noise assessment DVD met with some success and student feedback on its value was, and continues to be, positive. Since the recordings were made on University premises, there were few ethical or commercial confidentiality concerns. It was therefore straightforward to get the necessary permissions to show the video to an on-line student audience. However, the costs of engaging a company to produce a good quality DVD were considerable. Also, there were and still are logistical difficulties with distributing the DVD, since many of the students work in remote locations or reside overseas. The University uses virtual classroom software, Blackboard (BB), but there are technical difficulties in making the video available through BB, partly as a result of file size but also because it requires students to have access to specific computer hard and software. However, the relative success of the educational value of the DVD has resulted in further exploration of the possibilities of video instruction for practical skill training.

Using Non-Professionals to Prepare Video Instructional Materials

In the Newcastle OHS programs, the hygiene topics of assessing lighting, thermal environment and vibration are taught in a module of the Ergonomics subject. In 2012, videos demonstrating the equipment and techniques involved in these assessments were prepared, but without incurring the expense of employing external professionals. Excellent resources for recording and editing videos are now readily available in the University, so there was no need to commission commercial services. However, the logistical difficulties of distributing the recordings as a DVD remained and other modes of transmission were therefore explored.

YouTube offers a low-cost mode of distribution, which does not require students to have expensive software for viewing videos. It can be accessed from smart phones, tablets, notebooks, laptops and more traditional desk computers – from all but the most geographically remote areas. YouTube therefore can be accessed easily, whenever and wherever students wish. YouTube also allows general access – to anyone with an internet connection. In the spirit of sharing resources exemplified by OHTA, posting video instructional material on YouTube allows other students, professionals and educational institutions to view it. This enables international access to instructional materials and exposure to expensive equipment, which otherwise may not be widely available.

RECORDING VIDEOS ON ASSESSING LIGHTING, THERMAL ENVIRONMENT AND VIBRATION

The recording sessions were planned out prior to filming, so that the assessments were demonstrated efficiently and effectively. Permission was sought and granted to make recordings in corridors and a classroom, in the kitchen area of a commercially operated campus cafeteria, and in University grounds, where a tractor mower and a strimmer were being used. The sessions were not scripted as such, but commentary was provided by an experienced lecturer at the same time as the assessments were being demonstrated. The recordings focussed on the practical use of the instruments and students were referred to the written modules for background information. A JVC Everio digital video camera was used for the filming, which simultaneously recorded the visual and audio tracks. A technical officer from the School of Health Sciences, who was proficient but not professionally trained in the camera's use, was responsible for the filming.

Lighting assessments were conducted in a staff office, a main corridor and in an outside area of the University, to demonstrate the use of light meters in both artificial light and daylight, and to introduce students to the observations required of a qualitative as well as quantitative lighting survey.

Thermal environment was assessed for both thermal comfort and potential heat stress conditions. Thermal comfort was assessed in a classroom, using a Brüel and Kjaer Indoor Climate Analyser. The recording demonstrated the impact of changes in surface temperature, air movement and air cooling on the measured parameters of air temperature, relative humidity, radiant heat load and air speed. The potential for heat stress was assessed in the commercial kitchen of a campus cafeteria, using a Quest Wet Bulb Globe Temperature (WBGT) apparatus. The WBGT value was briefly discussed in relation to action levels and exposure standards. In addition, the thermal environment assessment video demonstrated the use of an anemometer and a sling psychrometer.

Both whole-body and hand-arm vibration were demonstrated, using a Brüel and Kjaer precision vibration meter. Whole-body vibration was assessed in a groundsman driving a tractor mower, with tri-axial accelerometers mounted in a seat pad placed under his buttocks. Hand-arm vibration was assessed with the groundsman operating a strimmer, using tri-axial accelerometers mounted on a hand-held adaptor. The acceleration values were briefly discussed with reference to the Australian Standards and students referred to the written module for further discussion.

After all recordings were completed, the raw file was downloaded from the camera to an Apple computer, for editing with iMovies. Using iMovies, title captions were added and the film segments edited to produce three separate video clips, which were then directly uploaded to YouTube.

VIDEOS ON 'YOUTUBE'

Clip 1 was entitled: "Assessing Lighting Environment". It can be located on YouTube by searching for *Assessing Lighting* and/or through the authorship, *uonhealth*. The clip is 4.02 minutes duration and has been viewed 46 times since it was uploaded to YouTube at the end of April (uonhealth a, 2012).

Clip 2 entitled "Assessing Thermal Environment" can be located on YouTube by searching for *Assessing Thermal Environment*, or through the authorship. The thermal environment clip is 10.45 minutes duration and has been viewed 45 times since being uploaded to YouTube (uonhealth b, 2012).

Clip 3 entitled "Assessing Occupational Vibration" can be located on YouTube by searching for *Assessing Vibration*, or through the authorship. The vibration clip is 5.04 minutes duration and has been viewed 91 times since being uploaded to YouTube (uonhealth c, 2012).

THE VALUE OF YOUTUBE FOR TEACHING PRACTICAL OCCUPATIONAL HYGIENE SKILLS

The video clips have only been available on YouTube for a few months and for just one offering of the Ergonomics course, so there has been no formal evaluation of the videos as a teaching tool. However, the numbers of views of the videos are testament to the fact that many students did download the clips as part of their self-directed learning. There were 80 students enrolled in the postgraduate course and a further 15 elective students enrolled in an associated undergraduate course.

The "Assessment of Occupational Vibration" video had over 90 viewings. Its relative popularity may reflect the fact that vibration assessment and vibration standards are quite complex and students have difficulty understanding the material when only in the form of written notes. It is likely that the video was particularly useful for distance learning of this topic.

Student informal feedback on the videos has been positive. The following two quotes are typical: of those received:

"Fantastic tool.... enables light bulb moments when trying to understand what you are reading and practical application.."

"I found them (the videos) very useful and they did help put into picture the concepts. I have found any multimedia to really compliment the course notes, especially in the distant learning environment where we can't interact with peers face to face to discuss ideas freely"

There have been no complaints of difficulty of access through YouTube and those students who have provided feedback have reinforced the value of the video as a medium to teach aspects of hygiene practice. The students at Newcastle are not training to be professional occupational hygienists, but the videos serve to bridge a gap between written theory and practice, so they can better understand the role and application of occupational hygiene to general OHS. No feedback has been received to indicate if the videos also have been viewed by other parties in other institutions or countries. However, the YouTube format means the videos remain as a potential resource for a much wider audience than The University of Newcastle.

It is not the intention to propose that all practical skill instruction and experience in Occupational Hygiene can be replaced with YouTube videos. Professional Occupational Hygiene rather than generalist OHS training requires actual practical experience, so that skills in techniques and in assessment of real industrial exposures can be appropriately taught and certified. Nevertheless, students can be introduced to hygiene equipment and taught elements of practical skills with appropriate use of video, which, if distributed via YouTube, can be available wherever and whenever required. Given the current requirement for postgraduate education to be sufficiently flexible to suit the needs of working adults, the use of YouTube video instruction can be a valuable addition to on-campus and industry teaching, enabling face to face teaching to be more effectively targeted to enhancing student proficiency in environmental assessment.

CONCLUSIONS

- Selected videos recorded ‘in house’ and uploaded to YouTube can be a low cost and effective way of teaching practical hygiene to distance students in OHS programs.
- The appropriate use of video instruction in distance learning courses can enable more effective and efficient use of laboratory and industry practical experience within professional Occupational Hygienist training programs.
- Instructional videos uploaded to YouTube are freely available via the internet, providing a useful resource, at no cost, for interested parties anywhere in the world.

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COMPARISON OF OHS COURSE ACCREDITATION PROCEDURES IN AUSTRALIA

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KEYWORDS

academic program evaluation, accreditation of occupational hygiene programs, core competency assessment, curriculum evaluation, occupational hygiene learning outcomes.

ABSTRACT

As OHS professional bodies have moved or are moving towards professional certification of their members, the need for accredited programs of study has developed. This move has been prompted by the requirement of the certification boards for the applicant to demonstrate that they have the minimum knowledge required to work at a professional level.

The AIOH has had a course accreditation procedure for over 20 years as discussed by Whitelaw and Reed (2011) which has been well recognised by the profession, but until 2009 only one course had been accredited. In the last two years the AIOH has revised its procedure and now requires any university applying for course accreditation to map their program against the learning outcomes as defined by the AIOH as well as the being at a minimum of a Graduate Diploma (AIOH, 2011) which is equivalent to the Australian Qualifications Level (AQF) level 8.

In 2011 a new course accreditation board was set-up to look at courses that are promoted to educate OHS professionals that are not considered specialists and are core OHS Generalists. The new board called the Australian Occupational Health and Safety Education Accreditation Board (AOHSEAB) is set-up under the SIA but has members from all OHS professional groups in Australia in addition to academics, OHS representatives from government, employer and employee groups. Programs being accredited under this scheme have to be mapped against the OHS BoK and need to meet the respective AQF level of 7 or above depending on the qualification.

This paper compares the two schemes in respect to both the procedure that is undertaken, and the knowledge required to meet course accreditation requirements.

INTRODUCTION

In recent years as the professional bodies have or are developing processes for certifying professionals in their respective areas the need for accredited courses has increased. This is because the processional bodies have or are specifying the knowledge base that the respective professional needs. The successful completion of an accredited course means that applicants for professional certification don't need to then prove their knowledge base.

The need for improved education of Occupational Health and Safety (OHS) professionals in Australia and related specialists such as occupational hygienists has been highlighted previously by a number of researchers (Olson et al, 2005; Borys et al 2006; Toft et al, 2010; Whitelaw and Reed, 2011). The benefits of occupational hygienists being appropriately trained has been highlighted by Vadali et al (2012) in their studies that showed that with appropriate training occupational hygienists are able to better estimate exposures and therefore potential health risks.

The need for people who have completed accredited courses will grow over the next few years as need for certified OHS professionals grows and the new education requirements for certification become implemented. In occupational hygiene this has been observed as the Australian Institute of Occupational Hygienists (AIOH) membership has more than doubled over the last two years and many contracts now require that a certified occupational hygienist is part of the team employed to do occupational hygiene related activities.

An interesting trend has been identified in the United States of America (USA) where there has been a decline in the types and depth of material covered in courses (Ellenbecker, 2012) as the National Institute for Occupational Safety and Health (NIOSH) has reduced the amount of funding for courses. This decline will hopefully not be seen in Australia because of the new course accreditation requirements but it is an issue that the OHS professions will need to keep under review as economic pressures are placed on courses. The benefits of using trained occupational hygienists as part of a team was also identified by Tyers et al (2012) as a major contributor towards the implementation of good workplace health practices at the 2012 London Olympics.

HISTORY OF OHS COURSE ACCREDITATION IN AUSTRALIA

The accreditation of university academic programs in both occupational hygiene and OHS started over 20 years ago in Australia. The occupational hygiene programs had to cover criteria as developed by the AIOH education committee (Whitelaw and Reed, 2011) whereas the OHS course accreditation was more informal but was undertaken by the Safety Institute of Australia (SIA). Because of the lack of a formal accreditation process in Australia for OHS courses, a number of universities had their programs accredited by Institute of Occupational Safety and Health (IOSH) based in the United Kingdom, and one or two had their programs accredited by the American Society of Safety Engineers (ASSE).

To meet the needs of accreditation of OHS courses which were developed to educate professionals in the broad field of OHS, a new accreditation board was formed in 2011 called the Australian Occupational Health and Safety Education Accreditation Board (AOHSEAB) under the auspices of the SIA.

COMPARISON OF THE AIOH VERSUS THE AOHSEAB COURSE ACCREDITATION PROCEDURE

Table 1 presents a comparison of the AOHSEAB accreditation process approved by the AOHSEAB early in 2012, with the AIOH procedure which was approved by the AIOH council early in 2011. As can be seen from Table 1 the major areas of difference between the two procedures are:

- Minimum levels of qualification: The AOHSEAB allows for degree courses to be accredited as long as 50% of the program relates to the Body of Knowledge (BoK) whereas the AIOH process does not accredit below a Graduate Diploma level.
- Fee for accreditation: AIOH currently does not charge for accrediting courses except that the institution being assessed for accreditation must fund the cost of the assessment panel visiting the institution. The AOHSEAB is charging a fee for accreditation (currently $7000/course) and if a visit is required then the institution will also need to pay the cost of a member of the panel visiting the institution.
- Assessment of the Accreditation Application: For AIOH accreditation the assessment is undertaken by all members of the education committee, unless they have a conflict of interest, whereas the assessment for AOHSEAB accreditation is undertaken by a 3 member panel on 1 day where they all

meet together to both discuss the application and to undertake telephone interviews with the Head of School, Head of Program, selected teaching staff including sessional teachers, and several current students.

Table 1: Comparison of the AIOH Courses Accreditation Procedure with the AOHSEAB Course Accreditation Procedure

Parameter	**AIOH Course Accreditation Procedure**	**AOHSEAB Course Accreditation Procedure**
Level of Qualifications	Graduate Diploma and Masters programs Minimum of AQF level 8	Bachelors Degree, Graduate Diploma and Masters programs which have a minimum of 50% of the program or 1 year (whichever is greater) related to the BoK. Minimum of AQF level 7
Course Accreditation fee	Nil	$7000/program (additional $3000 for imbedded courses)
Details of Applying Institution	Required	Required
Details of Contact person	Required. The course coordinator must be Certified Occupational Hygienist (COH)	Required. The course coordinator should be a OHS professional
Details of Program/Course	Required	Required
Date/Proposed date of first delivery of the course:	Required	Required
Mode of delivery:	Required	Required
Length of course (in months):	Required	Needs to be defined to ensure it meets AQF requirements
Minimum entry requirements:	Need to be specified	Need to be specified
Course curriculum:	Needs to be shown	Needs to be shown including any imbedded courses
Unit Outlines for all units presented in the study of program, including reading list and details of assessments.	Required in a format that shows the teaching processes	Required in a format that shows the teaching processes
Teaching and learning activities associated with the course	The applying institution needs to clearly define the teaching and learning activities that are undertaken in relation to both on-campus and off-campus activities and how the learning from these activities are assessed when mapped against the AIOH Learning Outcomes	The applying institution needs to clearly define the teaching and learning activities that are undertaken in relation to both on-campus and off-campus activities and how the learning from these activities are assessed when mapped against the BoKs.
Teaching Resources	Specific in relation to library and laboratory resources	Main area required in the adequacy of resourcing the teaching staff including sessional staff.
Course assessment	Needs to be described in detail including marking criteria to enable adequacy	Needs how the BoK is met
Teaching staff:	CV's for all staff who teach on the program	CV's for all staff who teach on the program
Proposed Student numbers:	Should be indicated	Should be indicated
Describe the students' facilities and support services provided:	Needs to describe the facilities available which may also be inspected when the panel visit	Needs to describe the facilities available
Details of the institutional quality assurance system and procedures that have been implemented to ensure that the administration and delivery of the course is up to the standard by AQF.	Needs to be defined	Assumed not an issue if the institution meets TEQSA requirements
Graduate Learning Outcomes	Yes	At the time of writing this paper they are only in draft form but should be based on the information provided in the BoK.
Assessment of Application	All members of the education committee unless conflict of interest	3 panel members, 1 academic, 1 professional and 3rd is either.

COMPARISON OF THE AIOH VERSUS THE AOHSEAB CONTENT REQUIREMENTS

It is when comparing the course content that must be covered that the two accreditation processes have major differences. These differences are expected as the courses being accredited are targeted at educating different types of OHS professionals. Both accreditation processes are based on the learning outcomes of the course and this allows universities to develop their programs to meet the required learning outcomes using the strengths of the academic staff employed.

When AIOH started the review of their accreditation process in 2010 a workshop was held that brought together members of the AIOH education committee, membership committee and council to determine what are the learning outcomes (or competencies) that a graduate occupational hygienist is expected to have. These were further developed by the AIOH education committee before being circulated for comment, to the Universities delivering accredited courses following a comment period, the revised procedure was approved by the AIOH council in the middle of 2011.

The development of the material required in courses accredited by the AOHSEAB took a different process. Initially it was developed as part of a project undertaken by the SIA on behalf of the Health and Safety Professionals Alliance (HaSPA). The BoK was developed as a project funded by the Worksafe Victoria to determine what an OHS professional needs to know. A workshop was initially held in 2010 consisting of both OHS academics, OHS professionals and government personal to determine what are the major areas that need to be covered and what the BoK may look like. The BoK was then written by a number of OHS professionals throughout Australia and then appropriately reviewed. Before the BoK was released in April 2012 it became apparent that for universities to map their course content to this material, the learning outcomes relating to the BoK needed to be developed, and this is currently in draft format.

There are 6 major learning out outcomes covered in the AIOH course accreditation with more detail in sub learning outcomes. It should be noted that the majority of the outcomes need to be aimed at Recognition, Evaluation, Assessment and Control of Hazards. The AIOH major learning outcomes (AIOH, 2011) are:

- *Learning Outcome 1: General Sciences* - Graduates should appreciate, understand and apply, where appropriate, basic principles of physics, chemistry and human physiology as they relate to the discipline of occupational hygiene. This learning outcome may be achieved by a combination of undergraduate and postgraduate study. (4 Learning Outcomes)
- *Learning Outcome 2: Recognition* - Graduates should be able to identify, describe and prioritise chemical physical and biological hazards in the workplace. (9 Learning Outcomes)
- *Learning Outcome 3: Evaluation and Assessment* - Graduates should be able to undertake exposure assessments, interpret the results, analyse and record the risk, using standard techniques. (12 Learning Outcomes)
- *Learning Outcome 4: Control of Hazards* - Graduates should be able to select appropriate methods to either eliminate or control identified hazards. (8 Learning Outcomes)
- *Learning Outcome 5: Management* - Graduates should be able to contextualise, apply and appraise management practices in industry, commerce and public bodies particularly as it applies to occupational hygiene. (4 Learning Outcomes)
- *Learning Outcome 6: Communication* - Graduates should be able to effectively communicate (written and verbal) information such as technical data, clearly and concisely at a level appropriate to the

intended audience, as well as being able to organise arguments and discussion in a logical sequence. (3 Learning Outcomes)

Because OHS for the generalist is broader in its context, the content (concepts) required are also broader (AOHSEAB, 2012). The areas that need to be covered include:

- *Concept 1:* Socio-political context including OHS law in Australia and industrial, technological and business imperatives;
- *Concept 2:* Systems including systems thinking, management systems and systems of work;
- *Concept 3:* The organisation - Culture, leadership, organisational change, governance, management, organisational strategy
- *Concept 4:* Foundation science required for the understanding of hazards, mechanisms of action and control
- *Concept 5*: Human (individual) factors including the human as a biological system, basic psychological principles and basic principles of social interaction
- *Concept 6*: Hazards and their mechanisms of action and related controls including:
    - hazard as a concept;
    - biomechanical hazards;
    - chemical hazards;
    - biological hazards;
    - Psycho-social hazards including occupational stress, fatigue, bullying, aggression and violence;
    - Physical hazards including: noise and vibration, electricity, radiation, thermal (hot/cold environments, processes and objects), gravitational (people and things falling from heights), slips and trips, mechanical plant, mobile plant and vehicles and occupational road use.
- *Concept 7:* Risk - Uncertainty, perspectives, tolerance, acceptability, risk perception, exposure, likelihood, consequence, risk assessment/risk estimation.
- *Concept 8:* Causation including models of occurrence, causation for both safety and health determinants.
- *Concept 9:* Control - Philosophy of control, prevention and intervention, mitigation of health impacts and emergency planning.
- *Concept 10:* Practice including models of OHS practice and using research to inform practice

The current issues with the concepts that have to be covered is that they are not written as learning outcomes which makes it difficult to map courses, but this is currently being resolved, and it is anticipated that learning outcomes will be written for all the concepts by the end of 2012.

CONCLUSION

The strength of both the AIOH and AOHSEAB accreditation processes is that the quality and depth of content has been assessed by independent bodies. This is a positive for potential students and for professional certification bodies because they don't need to review the content in depth to ensure it meets the needs of an OHS professional.

The major negative of both processes is that it is not clear what percentage of the learning outcomes needs to be covered for a course to be accredited. This question is often asked but difficult to answer as it has too many variables. It is an issue the accreditation bodies may need to address in the future.

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HOW TO DESIGN AND IMPLEMENT EFFECTIVE TRAINING

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ABSTRACT

The wide availability of data and visual images on the internet make it easier than ever to assemble any OHS training course. However a range of studies in the past have indicated that OHS training may be ineffective as an intervention for achieving behavioural change. One reason for this is that it is common for OHS trainers to focus on teaching facts and what interests OHS practitioners, which means they can lose sight of the needs of the individual learner. When developing training we need to appreciate that each learner has their own individual world view. For effective behavioural change to occur the learner needs to be able to integrate the training into their own individual framework of knowledge and beliefs.

This paper will explore how to make training more effective by considering aspects of educational theory and psychology (including neural plasticity) with a focus on integrating these theories into the practice of training development and delivery.

Keywords: training, education, learning

INTRODUCTION:

OHS legislation requires training which takes time and money, however some studies have found that training is minimally effective (Karch et al, 2001, Palmer et al, 2012). This paper discusses how to design and implement effective training through:

- A review of the current state of knowledge about the effectiveness of OHS training.
- Practical aspects of educational theory and psychology:
    - A brief overview of training development methodologies.
    - An overview of how people learn, including:
        - A brief summary of how to manage cognitive load.
        - Prior knowledge of the learner and the instructor.
    - A brief discussion of neuroeducation (including neural plasticity).

EFFECTIVENESS OF OHS TRAINING

The effectiveness of OHS interventions has been an area of increased research over the last decade. For some well understood hazards, such as musculoskeletal disorders, there has been minimal visible improvement in injury rates even where interventions like training are routinely in place (Shaw et al, 2007, Palmer et al, 2012). In some studies of OHS training on other hazards, training appears to have minimal effects on safety measures (Karch et al, 2001).

Two of the most current reviews, the first by Robson et al (2010, 2012) and the second by Burke et al (2011) show that OHS training can be effective subject to certain conditions.

The review by Robson et al (2010, 2012) was done for Canada's Institute of Work Health and the United State's National Institute for Occupational Safety and Health. The purposes of the study included:

1. whether OHS training had a positive impact on employees work behaviours.
2. whether OHS training had a positive impact on injury and illness frequency.
3. whether the level of engagement provided by the training had a positive impact on safety outcomes (as had been identified by a study by Burke et al (2006)).

Engagement is related to how much interaction the learner has with the training (Clark and Mayer, 2011). An example of passive, less engaging training method is a lecture, whereas a hands-on training session is an example of a highly engaging method (Burke et al 2012).

Robson et al (2010, 2012) reviewed 22 randomised studies that were identified by literature review of research papers published between 1996 – 2007. Only 16 of the 22 studies were considered to be of sufficient quality to include in the meta-analyses for the first two of the study's purposes. Robson et al (2010, 2012) concluded that OHS training had a positive impact on employee work behaviours, but that there was insufficient evidence that it had an effect on injury or illness frequency. They also found insufficient evidence to identify any effects based on the level of engagement but they noted that this was due to the small number of studies (4) included in this part of the analysis. They recommended that training should be part of a range of interventions.

A more positive review by Burke et al (2011) considered a broader range of studies and included 113 studies in the meta-analyses the results of which are summarised in Table 1.

Table 1: Meta- analysis results (Burke et al).

	Less engaging methods	Highly engaging methods
Knowledge Acquisition		
All hazards	Small (ES 0.36)	Moderate (ES 0.61)
High severity hazards	Small (ES 0.36)	Moderate (ES 0.65)
Low severity hazards	Moderate (ES 0.53)	Small (ES 0.47)
Safety Performance		
All hazards	Small (ES 0.22)	Small (ES 0.42)
High severity hazards	Small (ES 0.20)	Small (ES 0.46)
Low severity hazards	Small (ES 0.31)	Small (ES 0.32)

* The results shown are the effect size as the estimated mean correlations corrected for dependant variable unreliability

** as per Clark and Mayer (2011), the effect size (ES) is classified as follows:

ES < 0.2 – insignificant

$0.2 \leq$ ES < 0.5 - small or weak effect

$0.5 \leq$ ES < 0.8 - moderate effect

ES $\geq$ 0.8 - large or strong effect

The purpose of the review was to determine whether:

4. highly engaging safety training was more effective than less engaging safety training in improving knowledge acquisition and safety performance.
5. the severity of the hazard has an effect on the effectiveness of the training.

High severity hazards are defined as having a higher potential for severe injury, illness or death.

As found in their 2006 study, Burke et al (2011) confirmed that highly engaging training for all hazards was associated with a moderate effect on safety knowledge acquisition and a small positive effect on safety performance when compared to less engaging training. Less engaging training had a small effect on both knowledge acquisition and safety performance for all hazards.

Burke et al found that highly engaging training was more effective for high severity hazard when compared with less engaging training. An interesting outcome of this study was that the level of training engagement did not appear to have any significant impact on the effectiveness for low severity hazards. Burke et al (2011) proposed that the reason for this difference was that learners were more motivated by the dread or concern over imminent injury, illness or death associated with high severity hazards than low severity hazards. This may also help to explain some of the variability found in different studies on the effectiveness of OHS training.

The review by Burke et al (2011) included both instructor led training as well as e-learning. Clarke and Mayer (2011, p.12) cite many studies where the effectiveness of e-learning has been compared with instructor led training and has not found significant evidence of any difference in effectiveness for these different modes of instruction.

Robson et al (2010, 2012) demonstrated that delivery of OHS training can have a positive effect on employee work behaviours. Burke et al (2011) demonstrated that delivery of OHS training can have a positive effect on knowledge acquisition and safety performance. This positive effect was independent of whether the training was delivered face-to-face by an instructor or via e-learning. The level of engagement of the training had the most significant impact on OHS training effectiveness (Burke et al 2011) especially for high severity hazards. So as OHS professionals we need to be able to create training that has a high level of engagement.

DEVELOPING EFFECTIVE OHS TRAINING

To illustrate the different outcomes of using the various approaches in the next section I will use an example of developing a safety training course for using liquid nitrogen to make ice cream.

Training Development Methodologies

In the past when developing training I have started with the standard OHS approach of deciding what should be in the course by writing down a list of topics that I think needed to be covered. In our example my first draft list might look like Figure 1.

Figure 1: List of training topics - first draft

"Using liquid nitrogen safely to make ice cream"

Item 1: Know that liquid nitrogen can cause burns and asphyxiation

Burns are due to it being very cold

Asphyxiation is due to oxygen displacement

Item 2: Be able to safely handle liquid nitrogen

A more effective approach is to ask what the learner needs to be able to do at the end of the course which can be done by defining learning objectives. Learning objectives describe the expected outcomes of learning in terms that define the skill level expected. We need to move beyond the basic descriptions such as "know this is a hazard" and "understand risk controls" to more accurate descriptions such as "recognise a specific hazard in a workplace setting" and "be able to assess the risk level of a hazard and choose an appropriate control". Bloom's modified taxonomy lists adjectives to describe six different levels of cognitive learning and this can be used to help define learning objectives

- Remembering (Knowledge) - recalling factual information
- Understanding (Comprehension) – understanding information
- Applying (Application) – using previously learned material in new situations
- Analysing (Analysis) – breaking information into parts and demonstrate understanding of the parts
- Evaluating (Evaluation) - making judgements
- Creating (Synthesis) – generating new ideas, planning and producing

(paraphrase Woolfork and Margetts, 2007, p. 462).

So our "Using liquid nitrogen safely to make ice cream" learning objectives might look like Figure 2.

Figure 2: Learning objectives example

Item 1 from my list of topics (see fig 1)	Learning Objectives (Blooms Taxonomy)
Know that liquid nitrogen can cause burns and asphyxiation Burns are due to it being very cold Asphyxiation is due to oxygen displacement	Recognise that liquid nitrogen has hazardous properties. (Cognitive level - Remembering) Describe what will happen when liquid nitrogen comes into contact with the skin or eyes (Cognitive level - Understanding) Describe how liquid nitrogen can displace oxygen (Cognitive level - Understanding) Recall the effects of low oxygen (Cognitive level - Remembering)

Instructional design models or methodologies go beyond learning objectives to clarify all of the course requirements as well as the training development and implementation process. The methodology that you choose will affect the approach that you take to developing learning materials and activities, which will affect the learning achieved by learners. For this reason it is important to decide what your process will be either before you commence or as the first step of your development process.

Here is a brief summary of some methodologies that are available:

ADDIE: A model that is used for all types of education and training is the ADDIE methodology. This consists of five phases: Analysis, Design, Development, Implementation and Evaluation. It was originally developed to describe the steps.

Action Mapping: The model that the author currently uses is Action Mapping (Moore, 2012) which has come out of the e-learning community. Action Mapping starts with the real world goals and then analyses the learning needs in terms of actions that can be taken to meet this goal. These actions are then used to design activities to practice the actions. Finally the information that must be included to support the activities is included. This last step provides an objective approach to reduce the amount of information that OHS professionals and other subject matter experts subjectively feel must be included in a course.

Systematic Scientific Approach: This approach has been detailed in a paper by Salas et al (2012) and is not formalised as a model at this stage. This approach breaks the training development into three logical stages:

1. what matters before training.
2. what matters during training.
3. what matters after training.

It includes a checklist for use for each of these stages.

How do we learn?

Clarke and Mayer (2011) advise that the current consensus among learning scientists is that learning is:

"…a change in the learner's knowledge due to experience. This definition has three main elements:

- Learning involves change
- The change is in what the learner knows
- The change is caused by the learners experience"

(extract Clarke and Mayer 2011, p. 32)

The theoretical processes for creating these changes in the learner's knowledge are called metaphors (or theories) of learning. The three metaphors of learning described in Table 2 are useful from a practical viewpoint as they explicitly define the roles of the learner and the instructor. For each of these metaphors the definitions of learning, the learner and the trainer are distinctly different.

Table 2: Metaphors of Learning (Clarke and Mayer, 2011, p. 34)

Metaphor of Learning	Learning is:	Learner is:	Instructor is:
Response strengthening	Strengthening or weakening of associations	Passive recipients of rewards and punishments	Dispenser of rewards and punishments
Information acquisition	Adding information to memory	Passive recipient of information	Dispenser of information
Knowledge construction	Building a mental representation	Active sense maker	Cognitive guide

From my experience, traditional OHS training uses the first two metaphors: with a passive learner and an instructor who is the provider of information and warnings. This type of training can result in passive learners being able to recall information but they are not necessarily able to act on it.

The aim of OHS professionals is to have people learn to work safely. To achieve this aim, learning must be integrated into the learners individual world view and belief set which can be achieved through *knowledge construction*. This integration increases the learner's ability to retrieve the information and use it on the job (Clarke and Mayer 2011 pp. 42-43, Ambrose et al 2010). This is supported by the OHS training effectiveness studies (Burke at al, 2011) have shown that higher levels of engagement, consistent with the *knowledge construction* metaphor, achieve better safety performance outcomes.

The knowledge construction metaphor is based on three principles from research in cognitive science, these are:

- Dual channels – we have two channels which are separate. One for processing visual and pictorial material and the other for processing auditory and verbal material. Processing similar information from different input sources reinforces memory and learning.
- What this means is that we can process different forms of information about the one topic together, this is called the multimedia principle. Irrelevant or distracting visuals do not assist learning in fact they have been shown to decrease the amount of learning achieved.
- Limited capacity – we can only process a few pieces of information at a time in each channel due to the limitations of our working memory. This means that we need to chunk or group material so that it can be readily held within working memory. If we don't take account of this it can lead to cognitive overload which can lead to less effective learning.
- Active processing - people learn when they actively engage in cognitive processing through a wide range of activities. When we practise or rehearse a task we engage in active processing and the more we practise the more effective the learning. The recall or retrieval of learned information and skills is also enhanced by practicing tasks in the context in which we use them such as contextualised information, case studies and scenarios.

(based on Clarke and Mayer 2011)

Managing Cognitive Load

The limited capacity identified in the knowledge construction metaphor means that we must manage cognitive load. The cognitive load means the amount of processing being done by the working memory a cognitive overload can decrease learning. Clark and Mayer (2011) describe a range of principles that apply to managing cognitive load when designing course material, these are:

- *The contiguity principle* – integrate text into images. If they are separate, learners will have an additional cognitive load to match the text to the image before they can start understanding it. Make text and images appear in time with spoken narration for the same reason.
- *The coherence principle* **–** avoid adding additional information and material that is for entertainment only as it does not aid learning. Simpler visuals have also been shown to be better than more detailed ones.
- *The segmenting principle* **–** break complex material up into smaller chunks (remember the chunking rule of "7 +/- 2") as this has been shown in studies to improve the effectiveness of learning as it allows the user to progressively integrate new information with existing knowledge.

Prior Knowledge of Learners

The prior knowledge of a learner and their individual world view has been shown to have an impact on the effectiveness of learning as follows:

- *Learner has accurate but insufficient prior knowledge* – the learner will find it more difficult to construct a mental representation if they do not have all of the components that are needed to understand a topic (Ambrose et al 2010). It is important to take account of the prior knowledge of learners so that any gaps can be addressed.
- ***Learner has inappropriate prior knowledge*** – if the learner transfers knowledge from another discipline or from everyday life it can lead to confusion and reduce the effectiveness of learning (Ambrose et al 2010). My experience has been that many learners have difficulties with separating the terms hazard and risk.
- ***Learner has inaccurate prior knowledge*** – if the learner has inaccurate prior knowledge (or beliefs) then a significant amount of learning effort can be spent on unlearning the prior knowledge before the learners can accept the new knowledge (Ambrose et al 2010). An example of this is to consider the amount of effort that is required to assist a learner who has already decided that one asbestos fibre is extremely hazardous.

It is interesting to speculate whether people's experience of hazards that are common in everyday life, such as musculoskeletal injury and fatigue results in then having both inappropriate and inaccurate prior knowledge. If this is the case this would be expected to adversely impact on the OHS training effectiveness for these types of hazards as has been described for musculoskeletal disorders (Palmer et al, 2011).

Prior Knowledge of OHS Professionals

As trainers OHS professional's prior knowledge and technical expertise can result in leaving out or shortcutting steps that may be critical to new learner (Ambrose et al, 2010). One of the ways in which we can reduce the risk of this occurring is to ensure that we have non-OHS professionals involved throughout the development process.

Neuroeducation

Neuroeducation (or educational neuroscience) is a field focussed on linking research about how our brain works to observations of how we learn using sophisticated imaging techniques (Kim, 2012). This field is still quite new and is currently focused at issues such reading disabilities (Dehaene). It is expected that in the future it will provide insight that can be used to create effective training (Kim, 2012).

At the 2012 Safety Institute of Australia's National Conference in Melbourne there were many references to neural plasticity. Neural plasticity means that the brain has the ability to reorganise it's neural connections due to either experience or direct damage. No role for neural plasticity in improving effectiveness of training has been confirmed at this stage (Kim, 2012).

SUMMARY

OHS training can have a positive effect on employee work behaviours, knowledge acquisition and safety performance. This positive effect was independent of whether the training was delivered face-to-face by an instructor or via e-learning. The level of engagement of the training had the most significant impact on OHS training effectiveness (Burke et al 2011). Educational and psychology research are demonstrating practical ways in which training effectiveness can be increased. The role of neuroeducation is currently not directly useful to the OHS practitioner. OHS professionals can use these findings to create more effective OHS training

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IMPLEMENTATION OF AN OCCUPATIONAL NOISE EXPOSURE REDUCTION PROJECT FOR DEFENCE

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KEYWORDS

Occupational Noise, Workplace Noise, Exposure Reduction, Noise Control

ABSTRACT

Noise is the single most ubiquitous hazard to which Australian Defence Organisation (ADO) personnel are exposed, and compensation payments made to ex-service personnel for noise induced hearing loss are projected to be of the order of $1billion over the next 10 years. To address this, recent advances have been made in the development of a 5 year Noise Reduction Project for occupational/workplace noise for the Department of Defence.

The outcome from the initial phase of the Exposure Reduction Plan (ERP) project was a complete review and assessment of noise management practices across Defence, which identified a range of deficiencies and recommendations for action, based upon the continuous improvement model in AS4801.

The ERP project's main goals are initially to ensure compliance with WHS legislation, then to proactively deliver minimisation of noise exposure and management of hearing loss risk throughout whole of Defence. A coordinated and systematic approach, including best-practice noise surveys and assessments at a representative sample of ADF Bases, has provided an evidence-based dataset to inform effective noise control actions.

The project and noise survey findings to date are highlighted, including tailored Noise Management Plans (NMP) with prioritised and practical noise control measures. A number of other management tools developed to support project implementation will be described briefly. The impact of the new WHS Legislative requirements will also be described, along with the next implementation phase across Defence.

INTRODUCTION

Defence has established an ambitious project in the area of occupational hygiene and health to reduce occupational noise exposure in all workplaces across Defence. Vipac Engineers & Scientists Ltd (VIPAC) has recently worked with the Defence Centre for Occupational Health (DCOH) and Work Health Safety Branch (WHSB) to develop an Exposure Reduction Plan (ERP) for workplace/occupational noise for the Australian Defence Organisation (ADO) [1, 2, 3]. The ADO comprises the ADF Services of Air Force, Navy and Army and the Defence Groups including Defence Materiel Organisation (DMO), Defence Support Group (DSG), Defence Science & Technology Organisation (DSTO) and the Joint Commands of JHC, JOC and JLC.

Workplace or occupational noise has been identified by the DCOH as a significant WHS hazard and one of the aims of the project was to understand the impacts of occupational noise across Defence, and how to develop an improved noise management system.

Development of an ERP for Occupational Noise will assist Defence in meeting objectives of the new Defence WHS Strategy 2012-17 [4]; in particular, Objective 4: Preventative Measures – Defence maximises the prevention of injury, illness and disease by identifying the threats to the workforce by process, procedure or materiel.

BACKGROUND

A Defence-wide review and assessment of noise management practices in the initial phase of the ERP project identified a range of deficiencies and recommendations for action. The levels of noise encountered in Defence exceed those experienced in virtually any other work environment or industry. The damage is evidenced by DVA compensation claims data.

Analysis of the Defence organisation and culture indicated that a number of factors pointed to the need to introduce a new approach - these factors included the multiplicity of stakeholders; operational tempo; the posting cycle; noise regarded as something that came with the job; failure of current approach (e.g. multiple 5 yearly surveys) with no resultant improvement.

The ERP was devised to address the cultural and organisational impediments to noise management. The approach needed to be evidence based and involve expert analysis and interpretation of data from monitoring programs, which are then used to determine most the appropriate course of action and controls. Noise controls need to be enduring, to ensure that there is no slippage and to ensure that gains are captured and used as a basis for further gains.

Evidence throughout Defence and across the ADF Services shows that there is a reliance on lower level noise control measures that involve administrative controls (e.g. change of operations, processes or personnel task rotation) rather than engineering noise control.

The alternative of engineering controls, however, often cannot be implemented quickly and is not necessarily practical in many cases in Defence due to physical or operational constraints, impracticalities or logistical issues. Many platforms in Defence are quite old and are either scheduled for upgrade or complete replacement and thereby do not justify control costs now.

Noise control requirements need to be incorporated early in the procurement and design phase of a platform. For some platforms procured overseas, installing effective engineering treatments may be difficult and the use of administrative and PPE options may be the only alternative. However, this has the danger that a residual liability for workplace noise may exist for the service life of the equipment or platform.

Initial ERP 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 benefits to Defence would include: 1) demonstrated WHS compliance, 2) reduced costs and lower liability for claims, 3) improved capability, as soldiers are less likely to be downgraded for medical reasons, 4) Defence's reputation as an employer.

The subsequent preparatory phase of the Noise Project involved best-practice noise surveys and assessments at a representative sample of ADF Bases. This systematic approach generated a comprehensive evidence-based dataset, which allowed the development of effective noise control actions in the form of tailored Noise Management Plans (NMP) [3].

NEW WHS LEGISLATION

The new harmonised Commonwealth Work Health and Safety (WHS) Legislation, the WHS Act 2011 and WHS Regulations 2011, came into effect on the 1st January 2012 [5]. One of the most significant changes is the move away from the old employer-employee duty of care relationship, to a new 'person conducting a business or undertaking' (PCBU) with a slightly different responsibility in addition to specific workers' responsibilities.

The WHS Regulations 2011 mandates that the PCBU must ensure that the noise that a worker is exposed to at the workplace does not exceed the exposure standard for noise, and that they must manage risks to health and safety relating to hearing loss associated with noise. The WHS Act 2011 states that where noise hazards are identified in the workplace, they are to be eliminated, or at least minimised to the level of 'as far as reasonably practicable'.

For plant, such as machinery and platforms, 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.

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.

DEFENCE POLICIES AND PROCEDURES

Defence's top-level workplace safety document is the Defence Work Health and Safety (WHS) Manual (formerly known as SAFETYMAN) [6]. The WHS Manual contains the WHS policies and procedures that applies to the whole of the ADO and all Defence workers.

The new Defence WHS Manual [6] is currently in the process of development, and it contains the Policies (Volume 2) and Procedures (Volume 3) that incorporate a revision of the previous Manual and align with the requirements of the new WHS legislation [5]. A draft of the policy and procedure for Noise and Hearing Loss Risk Management has also been recently developed.

The ADF Services have also developed separate Service-specific WHS policy and procedure manuals, which are aligned with the latest Defence WHS Manual.

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. A previous AIOH Conference paper in 2011 describes the process and findings from the initial project work [7].

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.

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 (which aligns with the new WHS legislation). Using the new SOW, comprehensive noise surveys were performed at a total of 8 ADF facilities throughout Australia including a field survey of Army combat exercise activities.

As part of each noise survey, a review was undertaken of the following:

1. The ADF Facility workplace composition and units/sections.
2. The WHS and Noise Management System currently in place at the ADF Facility.
3. Previous noise surveys, reports and data at the ADF Facility (including compliance).
4. Range of trades, personnel and Similar Exposure Groups (SEGs).

Noise measurements of all Base Units, areas, tasks and noise sources were performed, including sufficient personal dosimetry samples, extent of impulse noise and octave band noise spectra of major noise sources.

The measurement results from these noise surveys were assessed against the regulatory Exposure Standard for Noise; namely, $_{LAeq,8h}$ 85 dB(A) and L_{Cpeak} 140 dB(C).

Subsequent analysis and assessment of the noise survey data allowed determination of:

a) noise exposure levels and extent of exceedance relative to standard,
b) identification and ranking of noise hazards for each Unit, and
c) exposure risk profiles for Similar Exposure Groups (SEGs).

The existing Hearing Protection Areas (HPAs), their designation and signage, and the HPA zones required from the analysis, were also evaluated. The assessment also reviewed the currently provided and used Hearing Protection Devices (HPDs).

Noise exposure extent

Overall, most of the ADF facilities surveyed did not demonstrate legislative compliance in all areas nor did they fully meet Defence's own requirements.

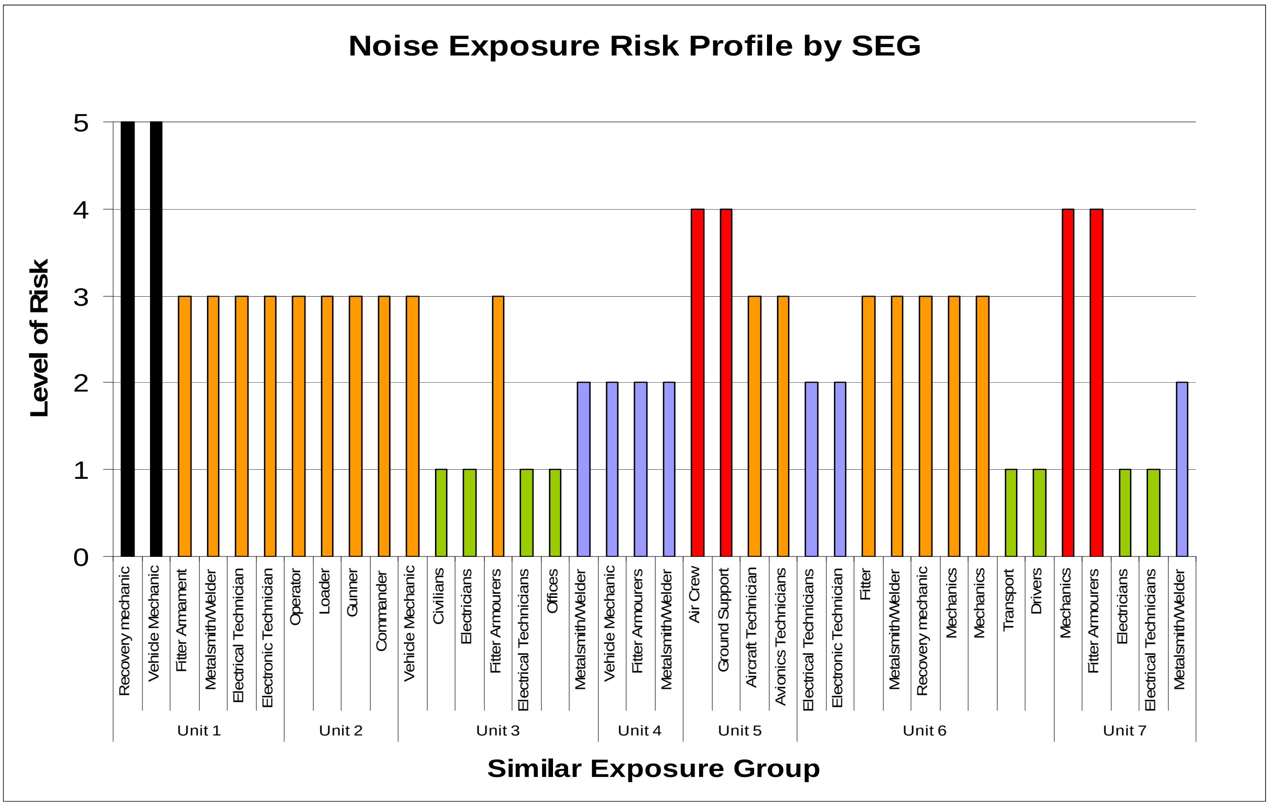
In general, the surveys confirmed that Defence showed:

1. Large number of high noise exposure areas throughout Defence.
2. Widespread significant exceedances of noise exposure standard.
3. Likely high levels and extent of hearing impairment (NIHL).
4. Limited noise control measures and noise management plans.
5. Incorrectly or non-existent signposted HPAs and insufficient type or use of HPDs.
6. Limited knowledge of synergistic effects of noise and ototoxic agents, vibration etc.

A Similar Exposure Group (SEG) risk assessment, based on a WHS consequence and likelihood matrix, showed that a wide range of trades/SEGs display moderate, high and very high risk ratings, with some specific groups registering extreme risk ratings. The purpose of this is to identify the most at-risk groups to focus priority control action.

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.



A number of Key Performance Indicators (KPIs) were developed to measure the current level of compliance and maturity at ADF facilities in relation to noise management.

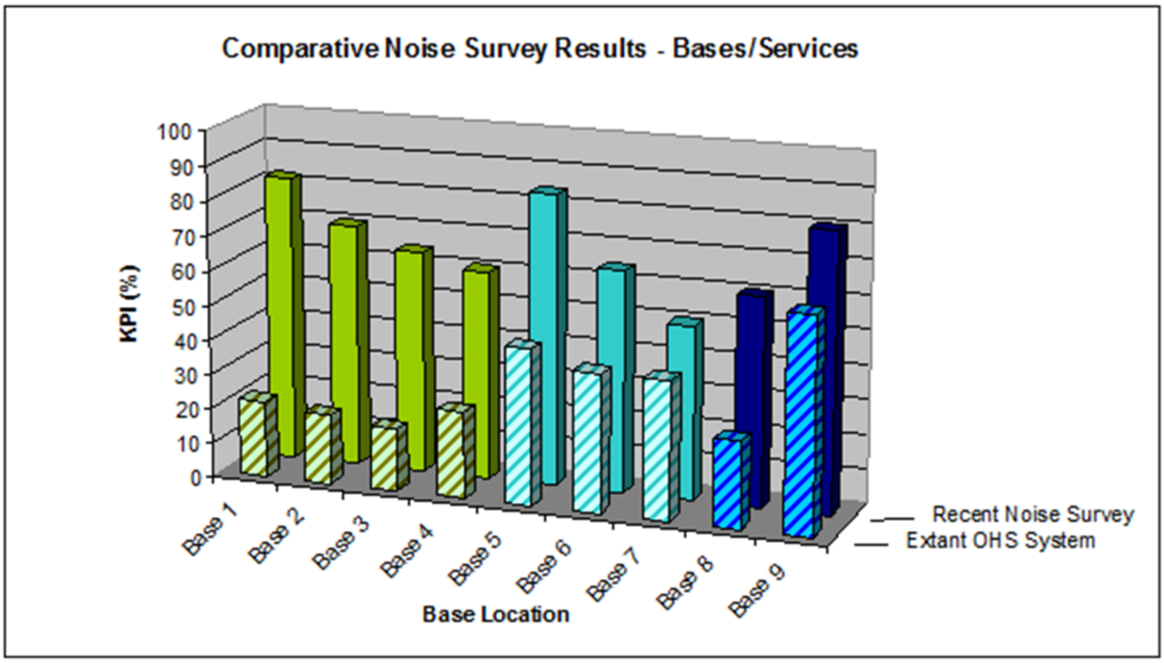
KPI scores were determined for 10 distinct KPI areas for each ADF Facility covering the:

a) Extant WHS Management System in place at the ADF Facility, and the
b) Noise Survey Assessment Results from the recent noise survey performed.

The total KPI score provides a realistic measure of the current WHS noise management system at the facility and a measure of the completeness of the recent noise survey and assessment. It also enables commanders and managers to see how they perform when compared to other facilities, and how they can improve their performance.

Figure 2 below shows a schematic comparison chart of these KPI results for the ADF facilities surveyed.

Figure 2: Comparison of Noise Survey Results and KPI Score between Services and Bases.



Noise control measures

Recommended noise control actions, including engineering controls where practicable, were provided in the Noise Survey Reports for each ADF Facility in the form of detailed Noise Management Plans (NMPs) for each Unit.

The actions to improve the noise management process at each of the ADF facilities surveyed were provided in the following areas:

1. Engineering noise control.
2. Administrative controls.
3. Hearing Protection Devices (HPDs) and Hearing Protection Areas (HPAs).
4. Further measurement data and audiometric testing.
5. New platforms/systems and procurement process.
6. Improved assessment and management tools.
7. Training and awareness, and revise policies/procedures.
8. Noise Management Plans (NMPs).

Noise control measures were prioritised based on the hierarchy of control and the action type/level/urgency required. The noise control measures were targeted, realistic and practical, and took into account any functionality and performance constraints that may apply.

Recommended actions included improved provision and use of, and fitting/training for, hearing protection for all ADF facility personnel. In addition, HPA signage needs to be improved throughout most facilities. Also, there is a need in Defence for better general and specific noise awareness programs in addition to running more regular refresher courses.

Regular audiometric testing, for 6-monthly to annual intervals, has been recommended for a range of SEGs/trades. 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.

Noise management tools

A number of specialised tools were developed to support project implementation and improve the noise management process throughout Defence.

A detailed Statement of Work (SOW) was developed to provide the minimum scope requirements for carrying out noise survey assessments (and aligns with the new WHS legislation). The development of a standard SOW was in response to the identified problem of inconsistent and poor quality reports, for uneducated clients. The SOW will assist commanders and managers in their contractor procurement process and help ensure a consistent best-practice approach across Defence. This consistency allows for comparisons across Defence, and longitudinally for repeat surveys.

A new innovative tool was developed for application to the primary noise sources in Defence, such as major plant, machinery and platforms. A Noise Safety Data Sheet (NSDS) provides a snapshot of the noise properties of the source and highlights the safety requirements associated with its operation/use.

The one-page NSDS clearly provides the measured noise levels (at the operator and different distances) and the octave band noise spectrum for the plant item. Safety requirements are provided, including maximum exposure time without hearing protection (HP), minimum safe distance (without HP), the applicable Defence HPA zone and the minimum HP requirement. NSDSs should assist ADF managers to achieve better management of workplace noise.

A clear Noise Management Plan (NMP) template has been developed for application to individual Units at a Base. Each NMP action, with a separate identifier, is described in plain terms and is given an action type based on the priority level and whether it is near, medium or long-term or whether it requires minor or major effort and resources. Noise control measures were developed based on the hierarchy of control. The NMP should be monitored and kept up-to-date by the relevant ADF managers, along with regular audit by WHSB/DCOH for monitoring and evaluation of progress against the recommended actions and agreed KPIs.

Given the distinct lack of risk registers in Defence, tailored noise-specific Risk Registers should be generated for use by each Unit and Base. In addition, noise-specific Standard Operating Procedures (SOPs) should be developed for all Units at Bases.

A guide on Buying Quiet Equipment should be developed for application to different areas. Importantly, a guide is needed on the critical aspects of Platform Procurement and at what stages (and how) to consider noise properties and their exposure risk implications.

An effective Communication Strategy needs to be developed with WHSB/DCOH. This would include development of clear information/awareness products for the WHS website and other existing Defence systems. Easily accessible information is needed to communicate key aspects associated with noise exposure, likely impacts, risk levels and noise control methods.

RECOMMENDED WAY FORWARD

Recommendations have been developed in this project to:

a) ensure compliance with relevant standards, new WHS legislation and Defence policies,
b) address key deficiencies in workplace noise management and reduce noise exposure,
c) provide a platform to enable a best practice approach into the future.

Actions detailed in the Noise Management Plans (NMPs) have been developed and prioritised to achieve real measurable improvements in the near and medium term. It is critical that Defence enables on-going monitoring and evaluation of these actions and workplace noise management programs, including formal auditing processes with applicable KPIs.

The next implementation phase will require commitment and ownership by all Groups. Workplace noise solutions will require the coordinated action of personnel across the ADF Services and Groups, in addition to the need for better communication flow; this in turn will align with the new WHS legislation emphasis in this area.

Ongoing review of the original ERP strategies should be undertaken along with monitoring the change in KPI score for each strategy. Strategies should be reprioritised over time depending on the KPIs/progress achieved and Defence requirements.

Implementing the recommendations will provide corrective and preventative measures that reduce the extent and impact of workplace noise throughout Defence, reduce the level of noise-induced hearing loss and claims, and provide substantial cost savings over time as well as improving Defence's capability and reputation.

Future phases of the project require commitment and additional funding by Defence to enable compliance with WHS legislation and continuous improvement in the area of workplace noise.

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ANALYSIS OF HEALTH SURVEILANCE DATA COLLECTED OVER TEN YEARS IN SOUTH AUSTRALIAN MINES AND QUARRIES.

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KEYWORDS

Spirometry, Lung function, Quarrying, Quarry, Health promotion, Respirable dust, South Australia.

ABSTRACT

The aim of this study was to retrospectively investigate if the lung function of South Australian quarry workers in specific operational roles deteriorated over a decade and, if so, whether it was related to measured dust exposure.

CHG was engaged by MAQOHSC in 2001 to study the health of the South Australian quarrying sector by measuring health surveillance data for workers. In recent years, a separate MAQOHSC-sponsored program compared South Australian quarrying job roles with on-the-job dust exposure rates, allowing CHG and MAQOHSC to link their on-going measured lung function results for this population (assessed over the past 10 years) to dust exposure in particular quarrying roles.

Retrospective analysis of a sample of the results initially indicates that there may not be a discernible decline in lung function for any category of job performed in the South Australian quarrying sector over the past decade, irrespective of measured dust exposure. The current authors postulate that this is due to the average age of quarry personnel remaining steady (potentially revealing an appreciable turnover of staff within the sector), improved controls for dust, increased awareness of individuals and companies in wearing respiratory protective equipment correctly, and the proactive lung function screening program raising the profile of respiratory disease within South Australia.

INTRODUCTION

The Mining and Quarrying Occupational Health and Safety Committee (MAQOHSC) proactively promotes good work safety and hygiene practices free of charge to the industry with the aim to prevent injury and disease in the South Australian mining and quarrying sector.

CHG is a specialized provider of occupational health services and offers a comprehensive suite of services in pre-employment medical and functional evaluations, in health promotion and training and in injury prevention and management.

CHG has provided health surveillance and skin screening health promotion programs for MAQOHSC since 2001. Initially, the aim of the health surveillance program was to merely gain an insight into the current health status of the sector's employees. However, the program has evolved to proactively improve the year-on-year results through both increased education and counseling by CHG staff and through follow up site audits of, and training sessions in, dust controls by MAQOHSC Officers.

MAQOHSC recognized the pool of health data had never linked an individual's lung function data in their role at the quarry to the individual's dust exposure in that role. However, MAQOHSC sponsored another program (two studies by Health Safety and Environment Australia Pty Ltd., in 2009 & a recent follow-up in

2012) that linked dust exposure - using 'similar exposure groups' or SEGs to collect employees together that have common risks and similar exposure profiles and factors - to categories of quarry worker roles; HSE identified 15 SEG groups at South Australian quarries. CHG was then asked by MAQOHSC to retrospectively map the trends of the effect of dust exposure on lung function results for different quarrying roles over the decade life of the health surveillance program delivered by CHG using the SEGs provided in the HSE report.

Spirometry is a common type of pulmonary function test that measures how quickly full lungs can be emptied and the total volume of air expired. (National Heart, Lung, and Blood Institute, 2012). Hence, spirometry is used in the MAQOHSC health surveillance program to track the lung function of workers over time and to proactively identify who may be susceptible to respiratory disease in the South Australian quarrying sector. Measurements analyzed as part of the health surveillance program include the forced vital capacity (FVC), forced expired volume in one second (FEV_1) and FEV_1 expressed as a percentage of the FVC (FEV_1/FVC). The FVC is the maximum volume of air that can be expired during a single expiration using maximal effort following a full inspiration. The FEV_1 is the volume of air that can be forcefully expired in the first second of the FVC expiration and is a measure of how quickly full lungs can be emptied. The measurement of FEV_1/FVC is used as a marker for the degree of obstruction (Burton, D, Johns, DP, Swanney, MP, 2011).

Owing to its ease of measurement and good reproducibility, FEV_1 is the most widely used lung function test in clinical practice and in epidemiological studies (Kertsjens, HA, Rijcken, B & Schouten, JP, et al 1997); this health surveillance program therefore uses this measurement. It is further well understood that increased exposure to (silica-containing) dust lowers lung function over time (Meijer, E, Krombout, H, & Heederik, 2001; Soutar, CA & Hurley, JF, 1986).

A total of 5010 workers had spirometry results collected over a 10 year period from 85 Mining and Quarrying sites in South Australia. CHG has taken a sample of 1728 workers for the purposes of this preliminary study to determine retrospectively if any lung function deterioration has occurred relating to high dust exposure for known roles in quarrying. This sample included all sites assessed as part of the HSE Australia dust exposure analysis report (2009) that were seen as part of the CHG health surveillance program and the remainder were selected sequentially in alphabetical order from our filing system; they included metropolitan and rural sites across the State.

METHODOLOGY

Health Assessment of South Australian Workers: The patient's height was measured (standing up with back to the wall and shoes off) and then asked a series of questions including: age; occupation / job role; smoking status; if any past history of lung complaint; if any family history of lung disease; if taking any medication; if being treated by a doctor for any illness and, if they were currently suffering from any respiratory ailment such as coughing, wheezing, shortness of breath, chest pain, bronchitis or tuberculosis.

The lung function test was then conducted using the open circuit method. The patient performed the test in a seated upright position using a portable spirometer (copd-6) with no nose clip. During the test, verbal encouragement was given to ensure maximal effort was obtained. A minimum of two acceptable blows were undertaken, with the highest values for FVC and FEV_1 chosen. Features of an acceptable test include; a forced expiration that starts immediately following a full inspiration, a rapid start, continuous maximal expiratory effort throughout the test (no stops or starts) and no cough or premature termination (John, DP & Pierce, R, 2011). All results were recorded in a medical record.

The job roles identified in the CHG-delivered health assessment were separated into Similar Exposure Groups (SEGs) according to the classification used in the dust analysis report produced by HSE Australia in 2009. The following five SEG's were selected for this study, because CHG had a large sample size for the lung function test results for these particular groups. The present authors note that exposure to respirable dust generally varied from acceptable (SEG 1) to unacceptable (SEG21)(HSE Australia Report, 2009):

- SEG 1 is categorized as a driller, drilling or cutting
- SEG 7 is categorized as the quarry supervisors and managers
- SEG 13 contains the maintenance workers
- SEG 21 is categorized as the loader operators or crusher operators
- SEG 23 was all other tasks that have not been included in other SEG's.

It should be noted that SEG classification is normally performed at each workplace, but given the very similar operations at the mine quarry sites, a SEG classification embracing all was deemed appropriate. This allowed broad comparison of the lung function results measured in this study to be compared against the dust exposure actually measured for each job type / exposure group by HSE Australia in 2009.

RESULTS

The sample size was found to be male-dominated (approximately 86%). The mean age of workers assessed (in years) has decreased from 41.6 in 2001 to 40.6 in 2011; this is still above the average age of Australian workforce - as of 30th June 2010 - at 36.9 years old (ABS, 2010) and shows that the South Australian quarrying workforce is getting younger and converging upon the average national age.

The following figures show the change in FEV_1/FVC over time for each SEG.

Figure 1 - FEV_1 percentage versus year for SEG 1. (SEG 1 is categorized as a driller, drilling or cutting job; the HSE report in 2009 indicated their exposure to respirable dust was acceptable).

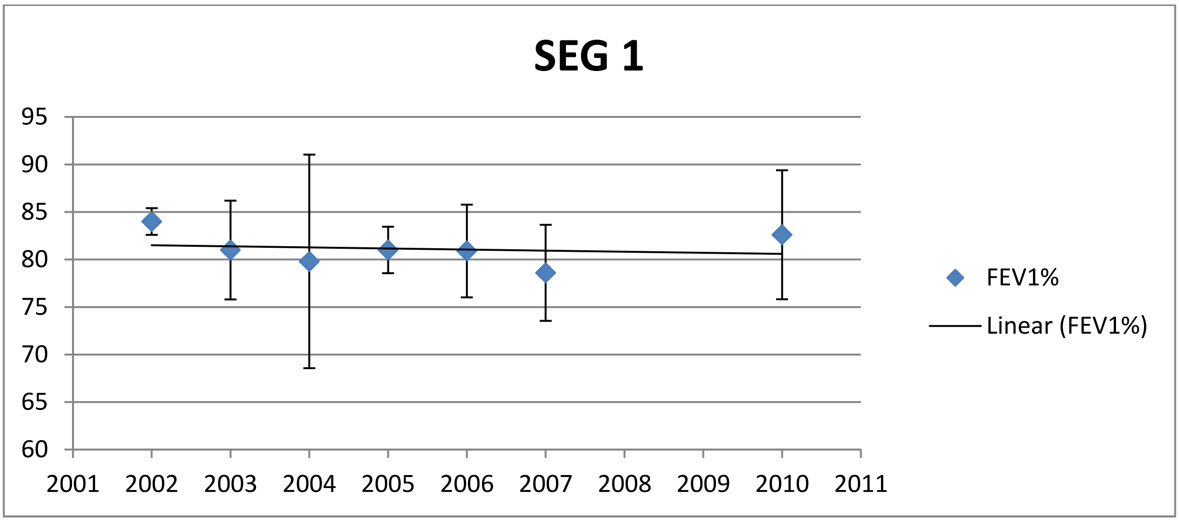


Figure 2 - FEV_1 percentage versus year for SEG 7. (SEG 7 is categorized as the Quarry supervisors and managers; there was an insufficient number of samples of SEG 7 in the HSE report (2009) to perform a statistical analysis re: respirable dust exposure. Mean respirable dust concentration = 1.03mg/m^3.)

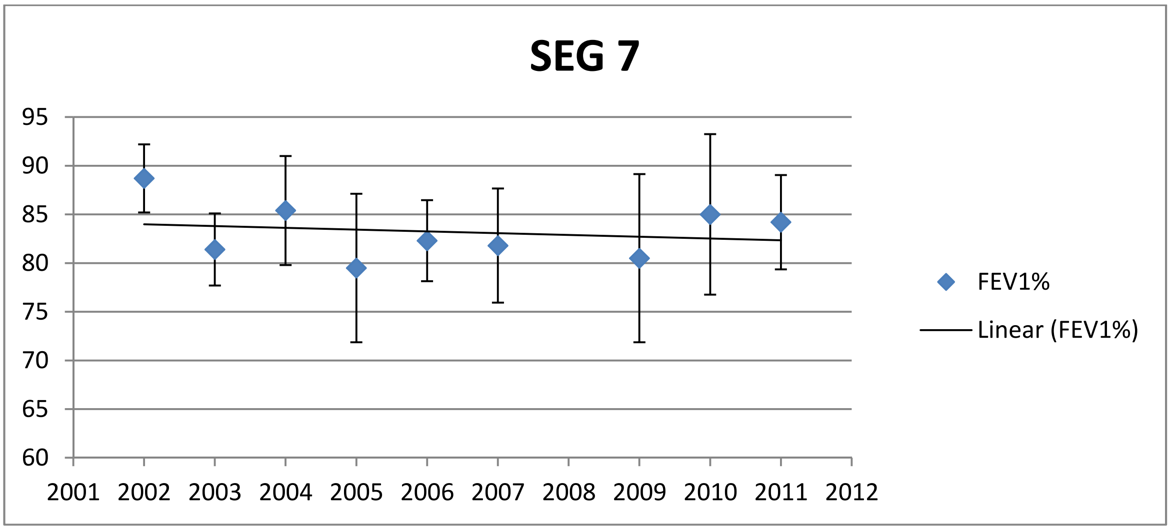


Figure 3 - FEV_1 percentage versus year for SEG 13. (SEG 13 is maintenance workers. There was also an insufficient number of samples of SEG 13 in the HSE report (2009) to perform a statistical analysis re: respirable dust exposure. Mean respirable dust concentration = 2.42mg/m^3.)

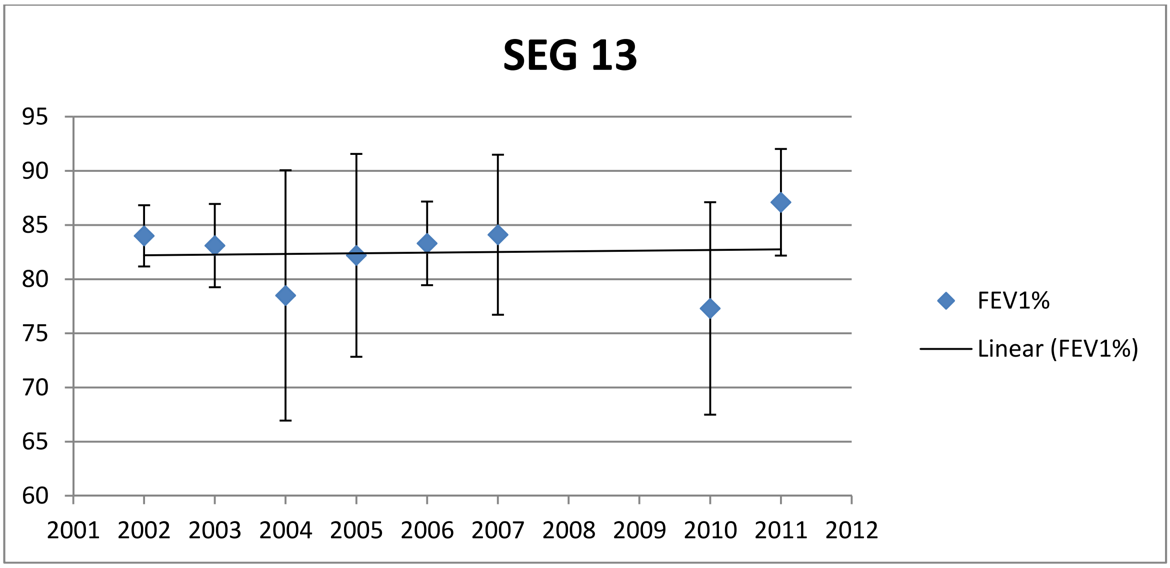


Figure 4 - FEV_1 percentage versus year for SEG 21. (SEG 21 is categorized as the Loader operators or crusher operators. The HSE Report (2009) concluded their exposure to respirable dust was unacceptable).

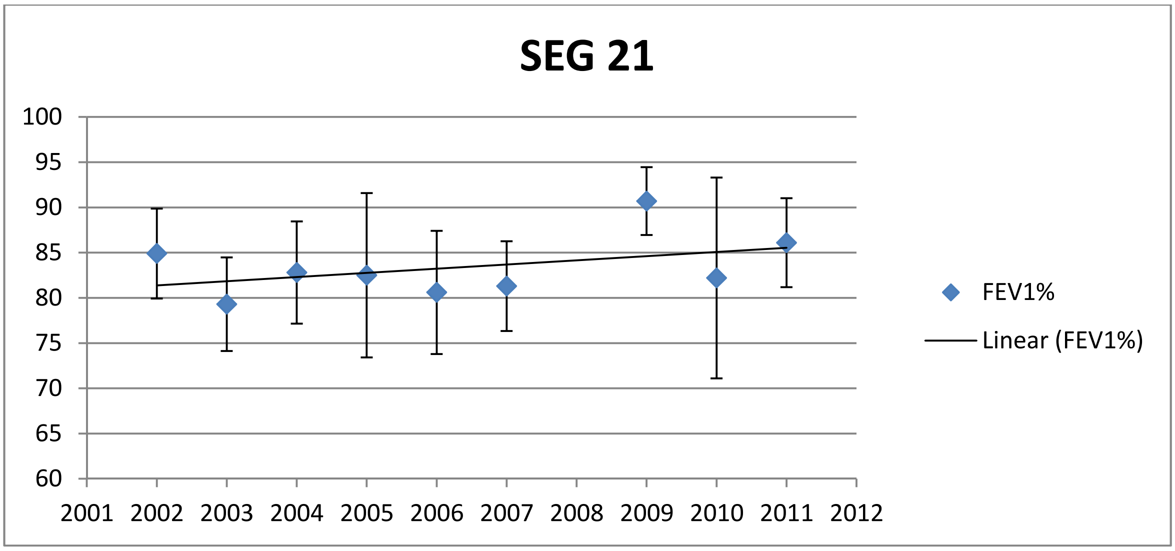
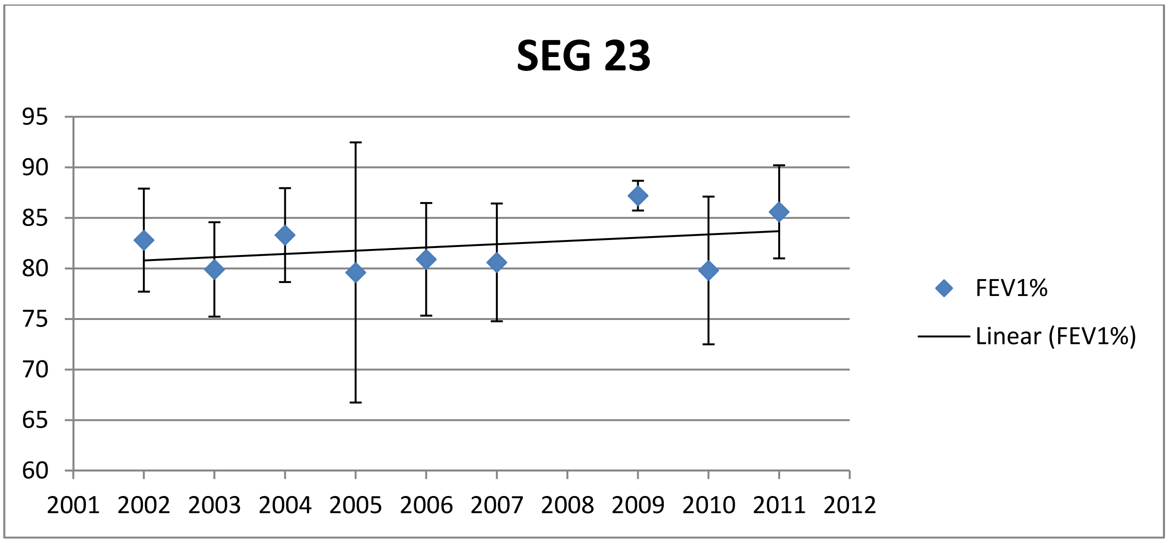


Figure 5 - FEV_1 percentage versus year for SEG 23. (SEG 23 was all other tasks that have not been in included in other SEG's. Once again there was an insufficient number of samples of SEG 23 in the HSE report (2009) to perform a statistical analysis re: respirable dust exposure. Mean respirable dust concentration = 3.59mg/m^3.)



DISCUSSION

The aim of this preliminary investigation was to retrospectively investigate if the lung function of South Australian quarry workers in specific operational roles deteriorated over the past decade (2001-2011) and, if so, whether it was related to measured dust exposure.

The initial results show there was no apparent change in lung function for any of the identified similar exposure groups analyzed in this study, although detailed statistical analysis has not been utilized to date and will be the subject of future work. This lack of change appears less than the annual decline predicted in previous studies (Ulvestad, U, Bakke, B & Eduard, W, et al 2001, Soutar, CA & Hurley, JF, 1986) and is tentatively taken as a positive result for the health of South Australian quarry workers.

In normal, healthy adults, lung function declines with age. The rate of decline in adults that have never smoked and do not have respiratory symptoms has been analyzed as a continuous variable. Numerous studies predict the rate of lung function decline in non-smoking, non-exposed workers to be between 21mL/year (Bakke, B, Ulvestad, B, Stewart, P & Eduard, W 2004) and 25mL/year (Ulvestad, U, Bakke, B & Eduard, W, et al 2001). A US study by Hankinson and colleagues (1999) found that generally the decline increased with age and was larger in men than in women, with an average decline of 23.4mL/year for males and 15.3mL/year for females aged between 20-40 years old. This increased to a decline of 30.4mL/year in males and 23.2mL/year in females aged 41-60 years and 37.3mL/year and 31.0mL/year for males and females respectively aged between 61-80 years of age. Over the life of the health surveillance program, the average age of workers assessed has remained around 40 years old; this may explain why we have not apparently seen any notable age-related decline as seen in other studies.

This can be explained by the turnover of staff in the expanding South Australian quarrying sector and exposes some limitations of this type of retrospective study and the current South Australian health surveillance regime: lack of tracking of individuals (without so-called 'health passports') allowing potential health problems to be moved about the industry unmonitored by the regulator. Hence, this emphasizes the importance of quarrying companies' own pre-employment checks to identify any such potential health problem before recruitment. Another limitation of retrospectively trying to gain any link in this way (between two different studies) is that occupations recorded over the decade of the health assessment program may not be matched easily into a specific SEG code and, therefore, may be erroneously recorded under SEG 23 – 'other tasks', but this would be expected to effect this SEG much more than the other four analyzed.

When other variables are taken into account, the annual rate of decline in lung function significantly increases. Various studies show the average decline for a smoker ranges from 35mL/year (Ulvestad, U, Bakke, B & Eduard, W, et al 2001) to 37.6mL/year (Cowie, RL & Mabena, SK 1991). The annual decline in FEV_1 in non-smoking workers exposed to respirable dust of some degree is significantly higher (53-63mL/year) (Ulvestad, U, Bakke, B & Eduard, W, et al 2001). When the rate of decline is separated into job roles of non-smoking tunnel construction workers, it was found that tunnel concrete workers have the largest decline at 55mL/year, compared with drill and blast workers (50mL/year) and shotcreters (45mL/year) (Bakke, B, Ulvestad, B, Stewart, P & Eduard, W 2004). This does not appear to be a factor at play in this retrospective study.

A more detailed (non-statistical) analysis reveals that two SEG's (1 – Driller, drilling & cutting, and 7 – Quarry supervisor / manager) did show a slight decrease in FEV_1%: for SEG 1, the rate of decline was -0.114; and, for SEG 7 it was -0.183. For the remaining SEG's assessed (13, 21 and 23), there was a slight improvement in FEV_1%: for SEG 13, the rate was 0.0597; for SEG 21, the rate was 0.462, and, for SEG 23, the rate was 0.321. These results go against the trends highlighted by other studies and against our initial hypothesis - that the SEG's with the highest exposure to respirable dust may have a significant reduction in lung function over time. However, as previously highlighted, these rates of change are small and there has been no discernible change for any of the SEG's lung function results analyzed.

CONCLUSIONS AND RECOMMENDATIONS

Analysis of a sample of workers in the South Australian Quarrying and Quarrying sector revealed that over the past 10 years, there initially appears to be no appreciable change in the lung function results (conducted as part of a more wide-ranging health surveillance program) across any of the five categories quantified in terms of dust exposure in a separate study.

More specifically, when individual worker lung function results (conducted by CHG on behalf of MAQOHSC) are grouped together retrospectively into specific quarry job role categories and compared to the MAQOHSC-sponsored dust exposure results (conducted by the HSE Australia in 2009, initially establishing the similar exposure groups used in this study), there appears to be little link between the lung function results and dust exposure for the job categories, although full statistical analysis awaits.

This would appear to be counter-intuitive to the recognized decline in lung function with increasing age of workers, until one recognizes that the average age of the South Australian quarrying & quarrying sector has remained steady over the decade of the health assessment program. This can be explained by the turnover of staff in the expanding South Australian quarrying sector, generally moving from quarrying into the more lucrative and remote underground mining. This underlying turnover of staff further exposes lack of tracking of individuals in the South Australian extractive resources sector. Without a regulatory requirement for personnel to carry a 'health passport' or for a body to centrally track health statistics, then this emphasizes the critical importance of quarrying companies' own pre-employment checks to identify any such potential health problem before recruitment.

On the ground, MAQOHSC notes that there has been improvement in dust control across the South Australian quarrying and mining sector over the past decade reducing levels of airborne dust, partly due to interventions by their own Senior Field Officers and Inspectors of Mines' located in SafeWork SA. Higher awareness of individuals and companies in using and wearing respiratory protective equipment correctly, combined with the proactive lung function screening program (sponsored by MAQOHSC and delivered by CHG) further raises the profile of potential respiratory disease within South Australia.

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OCCUPATIONAL AND ENVIRONMENTAL HYGIENE IN THE US DEPARTMENT OF DEFENCE - CURRENT AND EMERGING ISSUES

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ABSTRACT

The US Department of Defense (DoD) is one of the largest and most complex organisations. This complexity not only includes significant differences in culture, structure and function, but in the diversity of occupational and environmental health (OEH) hazards and challenges.

The US DoD works with allies and partners to mitigate potential threats to US and global security. Consequently, US DoD employees can be deployed to some of the world's most challenging environments, facing extreme hazards. Even when not deployed but garrison based, they work in demanding industrial and military environments. This paper presents case studies to illustrate some of the current and emerging OEH issues and opportunities facing US DoD personnel.

This paper also describes how US DoD has being working to improve its occupational and environmental hygiene capability, the leadership skills required to provide this capability and how it has addressed major occupational health related issues at an organisational level.

FATIGUE: A CASE STUDY OF SLEEP OBTAINED VERSUS SLEEP OPPORTUNITY IN MINING

Liam Wilson
Rio Tinto

KEYWORDS

Actigraph, sleep opportunity, circadian rhythm, obtained sleep, sleep debt, wake time, sleep time, non absolute, absolute, average sleep per day, effectiveness, average increased accident risk.

ABSTRACT

The goal of a shift roster from a fatigue management perspective is to ensure that it is designed to give individuals the opportunity to obtain adequate sleep. This is to ensure that everyone is operating at an effective level. (Industry and Investment NSW, 2009). Once the roster is designed and validated against a scientific bio mathematical model, the actual sleep that workers are obtaining needs to be quantified and verified against the shift roster model. This will confirm that the roster design is providing sufficient supporting sleep obtained by the employees (Office of Research and Development, 2006).

This paper outlines the sleep opportunity versus sleep obtained for shift work operators in a mining environment. It also determines whether there were differences in the individuals sleep patterns and effectiveness. Twelve operators voluntarily wore actigraphs for a month covering a number of shift roster cycles to determine their individual sleep/wake patterns. Each individual was given a comprehensive individual report and feedback on their statistics, positive behaviours and areas for improvement in their sleep hygiene. It also identified any abnormal sleep patterns for further investigation.

The roster analysis utilising FAST® showed that the roster was designed to provide an opportunity for eight hrs of good sleep (Archinoetics, 2006). On average the operators recorded 7:17hrs sleep/day (SD = 0:42min), however five out of the 12 operators recorded less than the recommended minimum average of 7hrs/day (National Sleep Foundation, 2011).

Actigraphs are one tool that can be used as a part of a holistic fatigue management system to determine individual sleep/wake patterns and provide a potential opportunity for improvement in individual sleep hygiene and increased individual effectiveness (Circadian Technologies Inc., 2006).

INTRODUCTION

"Fatigue can be defined as a state of impairment that can include physical and/or mental elements, associated with lower alertness and reduced performance" (Industry and Investment, 2009). There are a number of contributing factors to fatigue, but they usually relate to lack of sleep quantity or quality, extending the time someone is awake or other work related or individual factors ((DEEDI, 2010). Signs include tiredness even after sleep, psychological disturbances, loss of energy, and inability to concentrate. Levels of work related fatigue are similar for different individuals performing the same task. Fatigue can lead to incidents as workers are not alert and are less able to respond to changing circumstances (Industry and Investment NSW, 2009).

Humans were not designed for night work. Due to our circadian rhythms, we have a natural tendency to feel sleepy at night and alert during the daytime. Circadian rhythms never fully adapt to the night shift because of sunlight's effect on the biological clock and people return to a daytime sleep schedule on their days off. Due to this process, people may not get adequate sleep to prevent fatigue. (Moore-Ede, 2011). A shift roster analysis can be used to ensure that the roster allows adequate sleep opportunity for workers to obtain a minimum of 7hrs sleep per day. (Archinoetics, 2006).

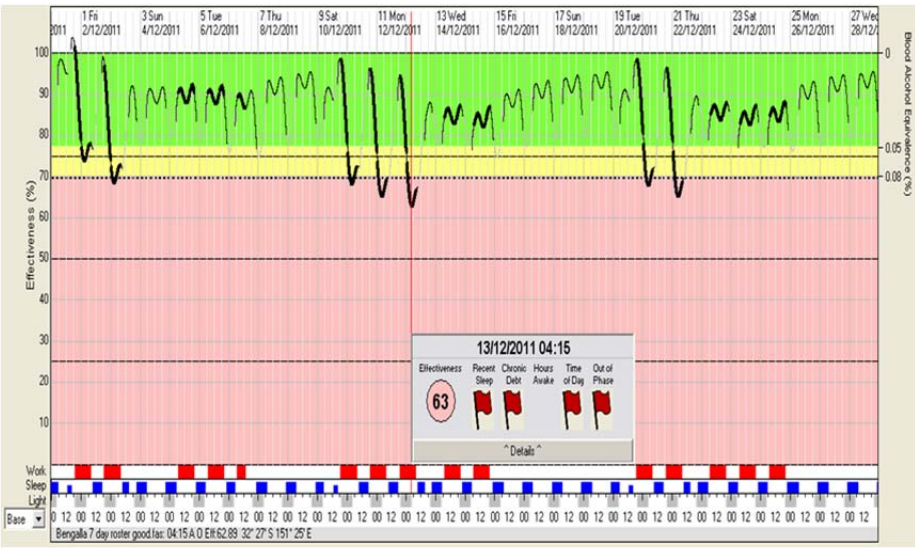
The operating surface mine has a village on site 1km from the operation with accommodation providing a good sleep environment[1] (e.g. ensuite, split A/C, heavy curtains/blackout) (Archinoetics, 2006). The operators reside at the village during their shift roster and are bussed in/out of the operation at the start/end of the roster. The obtained sleep was compared to the roster modelled sleep opportunity and recommended sleep guidelines to determine if the sleep obtained was different to the modelled opportunity of 8hrs or the minimum recommended sleep guideline of 7hrs. Each individual was given a report and feedback on positive behaviours and areas where sleep hygiene could be improved to increase effectiveness. If abnormal sleep patterns were identified, further investigation was recommended. Individual sleep patterns have been compared to determine if significantly different.

This paper is based only on recorded wake/sleep patterns from data recorded on the actigraphs. It does not take into account controls that are implemented at the operation to manage operational hazards and increased accident risk of the shift roster.

METHODOLOGY

12 actigraphs were worn by volunteers to measure individual wake time/sleep time patterns (obtained sleep) and potential fatigue levels over a 28 day period. The period covered4 panels (crews) and a number of cycles of the forward rotating three days on, one day off, three nights on, five days off (3,1,3,5) 12.5hr shift roster. The study was conducted during November to December 2011. The sleep opportunity for the roster was modelled using the FAST® software programme (Archinoetics, 2006). The roster was designed by the operation in consultation with workers to provide an opportunity for eight hrs of good[2] sleep. Figure 1 shows an example roster modelled using the FAST® programme. The model has been scientifically validated (Office of Research and Development, 2006).

Figure 1. Modelled roster using FAST®



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[2] Good Sleep environment defined as 2 interruptions per hour providing 50 minutes per hour of effective sleep. An interruption is not necessarily a full awakening, but may be a change in sleep quality caused by outside interference.

The actigraphs used to measure awake/sleep time were Texas eZ430 Chronos (Texas Instruments, 2010). The actigraph also operates as a normal digital watch, having functions including time, date and stopwatch. The actigraph measures activity through sensors by movement of the watch on the wearer's wrist. The sensors have the capability to measure activity, temperature and altitude. The actigraph has a maximum memory in that the more frequently set measurement interval, saving interval and the recording of activity, temperature and altitude, the reduced duration that data can be recorded and stored. For this study the temperature and altitude settings were not used as not being the focus of the study and to increase the amount of data that could be collected. The actigraph has capability to be set to start immediately or on a set date/time. For this study the start/finish date/time was set for each participant. The actigraphs were set to local time, to record a measurement interval of five (5) seconds and a saving interval of 240 seconds. Individuals who volunteered to wear the actigraph wore the actigraphs for 28 days. The individuals were given the watch at the start of shift on the first day of a shift cycle. A total of 318 sleep times were used for the analysis. Where sections of data were invalid, these were removed from the calculations.

The actigraphs use the software program FRMSWatch® to set and download data (Fachhochschule Schmalkalden 2011). The data is analysed using the software program FRMSAnalyse® (Fachhochschule Schmalkalden 2011). Figure 2 shows an example print out of a typical actigraph worn for 28 days.

Figure 2: Actigraph activity print out

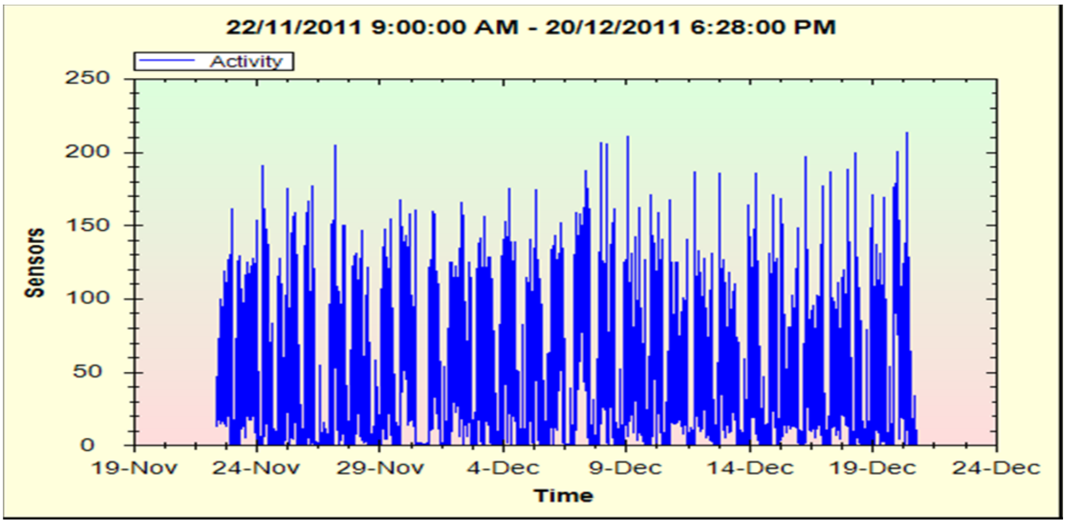


Figure 3 shows an example print out of a break down into seven days for a wearer's activity in non-absolute format. The non-absolute format provides the time the individual went to bed (Bedtime), woke up (Waketime) and the amount of sleep for the major sleep period (Sleeptime). This is shown on the right hand vertical axis.

Figure 3: Actigraph seven day activity print out (Non Absolute)

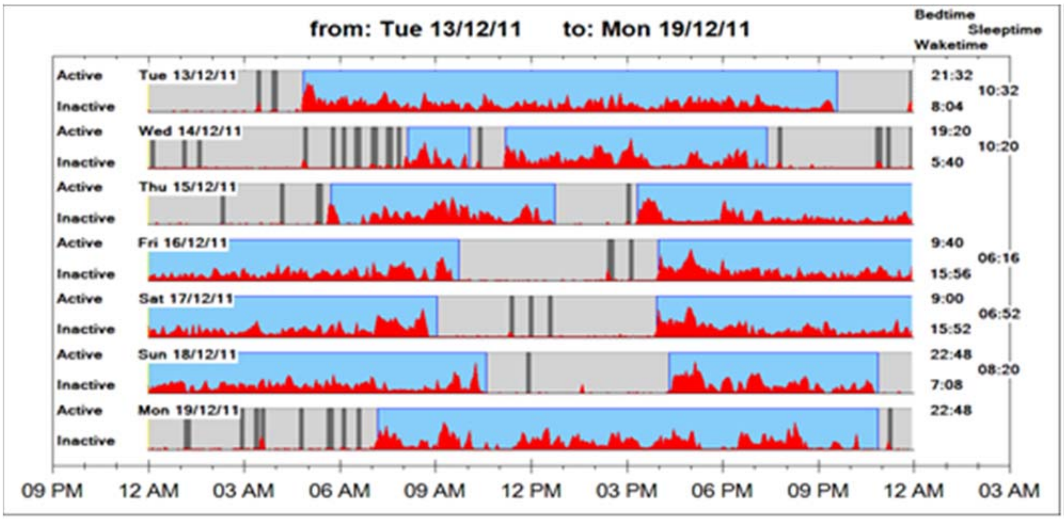
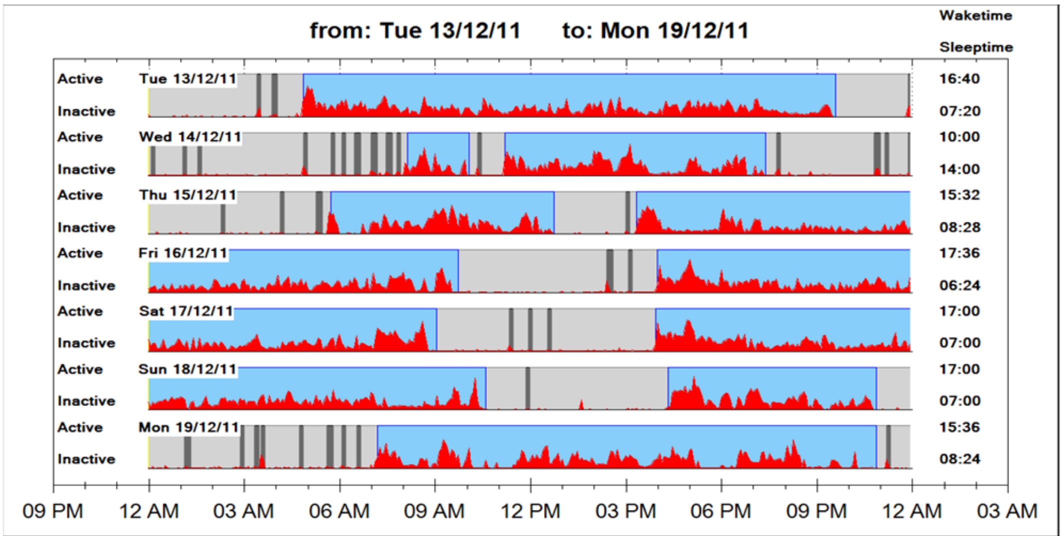


Figure 4 shows an example print out of a break down into seven days for a wearer's activity in absolute format. The absolute format analysis provides the total wake time and sleep time in the 24hr period, midnight to midnight. Absolute data was used for the analysis. On all of the print outs, the Blue areas are classified as: wake time, yellow: invalid data (watch may not be worn), light grey: sleep and dark grey: movements while bed time (awakening events).

Figure 4: Actigraph seven day activity print out (Absolute)



The data was analysed using Minitab® statistical analysis software programme (Minitab, 2012).

The key Statistics provided in each individual report were:

- Range of sleep per day;
- Average sleep per day;
- Longest single sleep;
- Shortest/longest overnight/day sleep;
- Range of awake per day;
- Average awake per day;

- Longest single awake period.

RESULTS

The results are summarised in Table 1 below and statistically in Figures 5-7.

Table 1: Sleep Statistics Summary

Parameter	Normal Range	Study Result	Standard Deviation	Outside Normal Range
Range of Sleep per day (hours/day)	7 - 9	0 – 18:12	-	Y
Average sleep per day (hours/day)	7 -9	7:17	1:49 (all data) 0:42 (individual ave)	N
Longest single sleep (hrs)	7-9	20:28	-	Y
Shortest single sleep (hrs)	7-9	2:26	-	Y
Range of Awake per day (hours/day)	15	5:48 – 24	-	Y
Average awake per day (hours/day)	15 - 17	16:42	0:42	N
Longest single awake period	15 - 17	46:44	-	Y
Range for single nap*	-	1:08-3:08	-	-

*Not main sleep for day/night

Figure 5: I-MR Chart of Hours Sleep

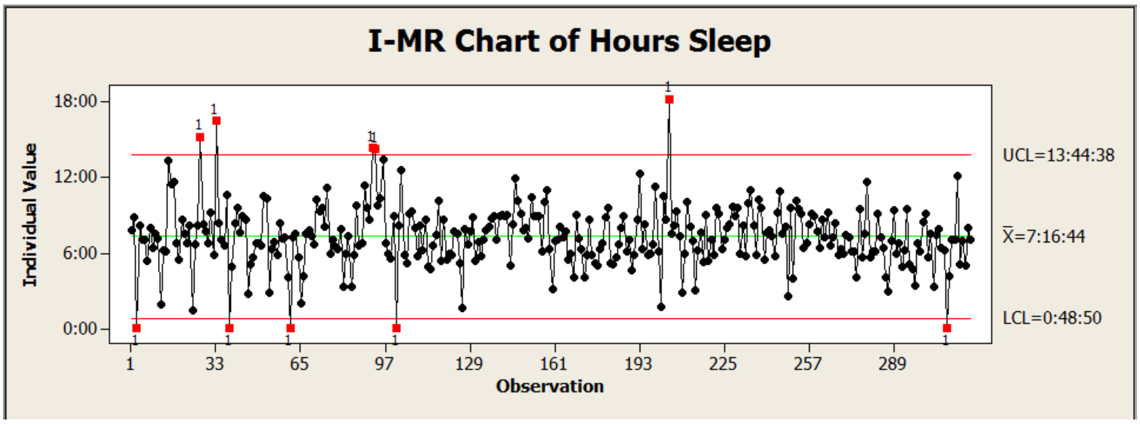


Figure 6: Hours of Sleep Statistical Analysis

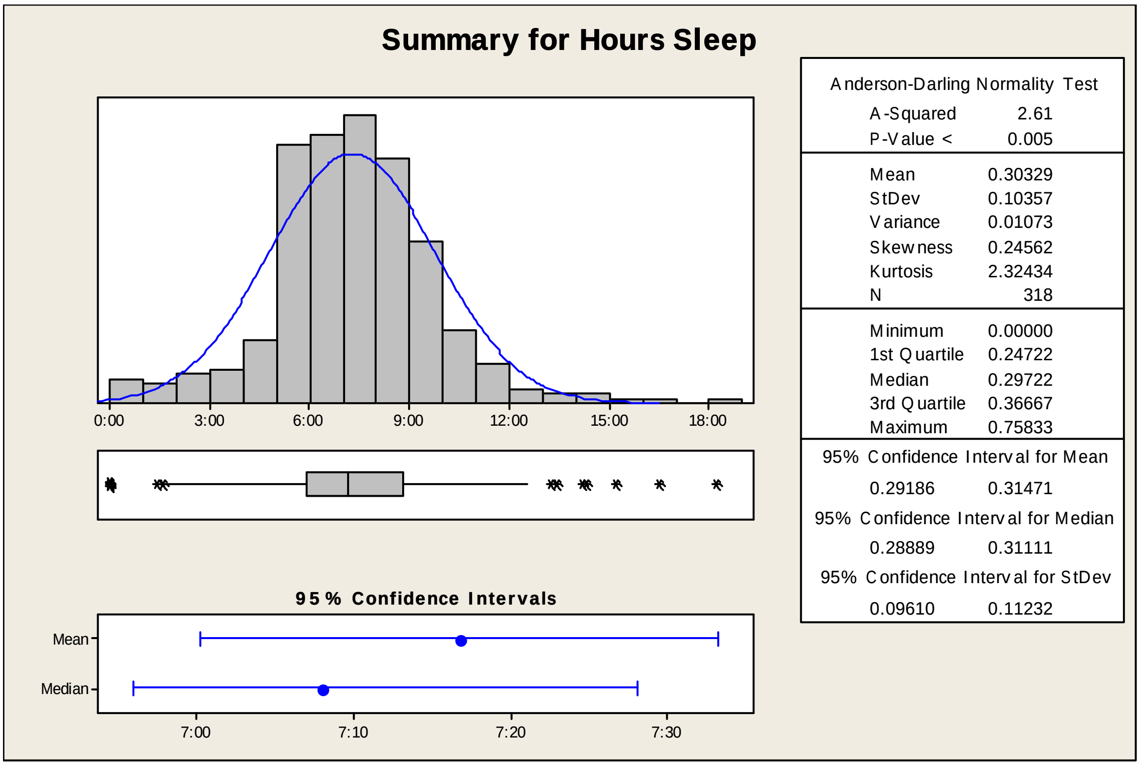


Figure 7: Non Parametric Mood Median Test

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Mood Median Test: Hours versus Person


Mood median test for Hours

Chi-Square = 29.30    DF = 11    P = 0.002


                                Individual 95.0% CIs
Person  N<=  N>  Median  Q3-Q1  -----+---------+---------+---------+-
 1       14  15   0.314  0.081             (------*----)
 2       17  12   0.286  0.122           (--*-----------)
 3       10  11   0.300  0.089         (-------*--)
 4       12  15   0.328  0.164      (---------------*------------)
 5       16  12   0.282  0.099     (-------*-------)
 6        4  20   0.369  0.052                       (------*)
 7       20   8   0.264  0.095     (----*-----)
 8       11  12   0.306  0.122        (---------*----------)
 9       12  15   0.331  0.133          (------------*-------)
10        8  20   0.331  0.113                  (----*---------)
11       18  10   0.265  0.064       (--*------)
12       18   8   0.274  0.107  (---------*----)
                                -----+---------+---------+---------+-
                                   0.250     0.300     0.350     0.400

Overall median = 0.297
```

The sample size was 318. The average (mean) sleep/day for the study period (318 samples) was 7:17 hrs/day with a standard deviation of 1:49 hrs as shown in Figure 6. 10 samples (hrs sleep/day) exceeded the Upper Control Limit (UCL = 13:44 hrs) or Lower Control Limit (LCL = 00:48 hrs). Five exceeded the UCL and five the LCL (zero [0] hours sleep in a 24hr period) as shown in Figure 5. The Lower Confidence Limit of the mean for all data was 7:00 hrs and the Upper Confidence Limit of the mean for all data 7:34 hrs as shown in Figure 6. The sleep patterns of the individuals were significantly different as shown in Figure 7. Individual 6 is significantly different to 3, 5, 7, 11 and 12. Individual 10 is significantly different to 7, 11 and 12.

There was a standard deviation of 0:42 hrs on the 12 participant's average (mean) sleep/day . The average hours of sleep/participant/day ranged from 6:23 to 8:39 hrs. Five (5) of the 12 participants averaged less than the recommended minimum of 7hrs sleep/day. The shortest overnight/day sleep time 2:26 (hrs) was recorded for an individual after being up for a period of 22:30 hrs. The range for the group was 2:26 hrs to 6:00 hrs. The longest sleep time was 20:28 (hrs). The range was 9:12 hrs to 20:28 hrs.

The shortest day of wake time was 5:48 (hrs). The longest period of wake time 46:44 (hrs) was recorded from 3:36am on Friday 25/11/2011 to2:40am on Sunday 27/11/2011. This person was awake from 3:36am on their last day shift until 2:40am into their 2nd R&R shift, 31:34hrs after finishing the shift. The individual was operating at 34% effectiveness at 2:30am on Sunday 27/11/2011.

Studies have shown that after 17hrs without sleep a person's reaction time is equivalent to a blood alcohol level of 0.05%, after 21hrs 0.08% and after 24hrs 0.1%. Table 2 outlines the reaction time equivalent Blood Alcohol Content (BAC) and effectiveness for the longest wake time. At 0.1%, the risk of a crash is seven times greater than driving with a BAC of zero (Dawson and Reid, 1997).

Table 2: Equivalent BAC and Effectiveness for the longest wake time during study

Date	Time	Reaction time Equivalent BAC %	Effectiveness %
25/11/2011	8:36pm	0.05	77.5
26/11/2011	00:36am	0.08	70
25-26/11/2011	8:36pm – 00:36am	0.05-0.08	77.5 – 70
26/11/2011 – 27/11/2011	03:36am – 2:40am 27/11	>0.1	70-34

Figure 8 shows the effectiveness and BAC equivalent for an extract of 10 days of the individuals 28 days where the awake period of 46:44hrs occurred. Figure 9 shows the effectiveness and BAC equivalent of the individual with the shortest average sleep obtained (6:23 hrs). Figure 10 shows the effectiveness and BAC equivalent of the individual with the longest average sleep obtained (8:39 hrs). Figure 11 shows the sleep opportunity of the 3,1,3,5 roster as modelled. Table 3 outlines the effectiveness comparison for sleep opportunity versus sleep obtained.

Figure 8: 10 day extract for individual with longest wake period

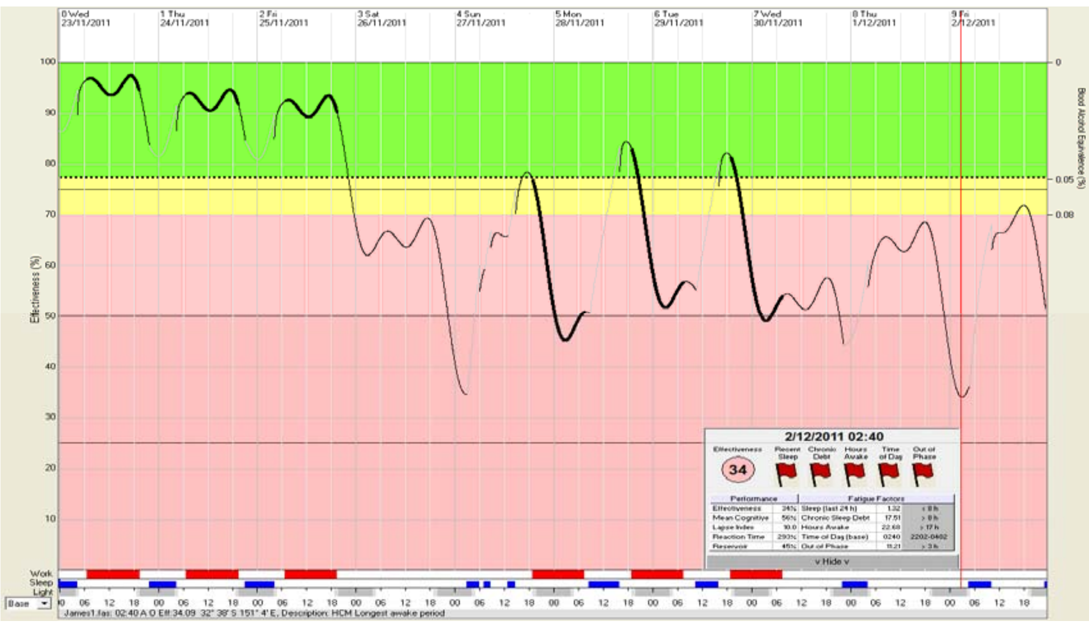

Figure 9: Shortest average sleep obtained by an individual

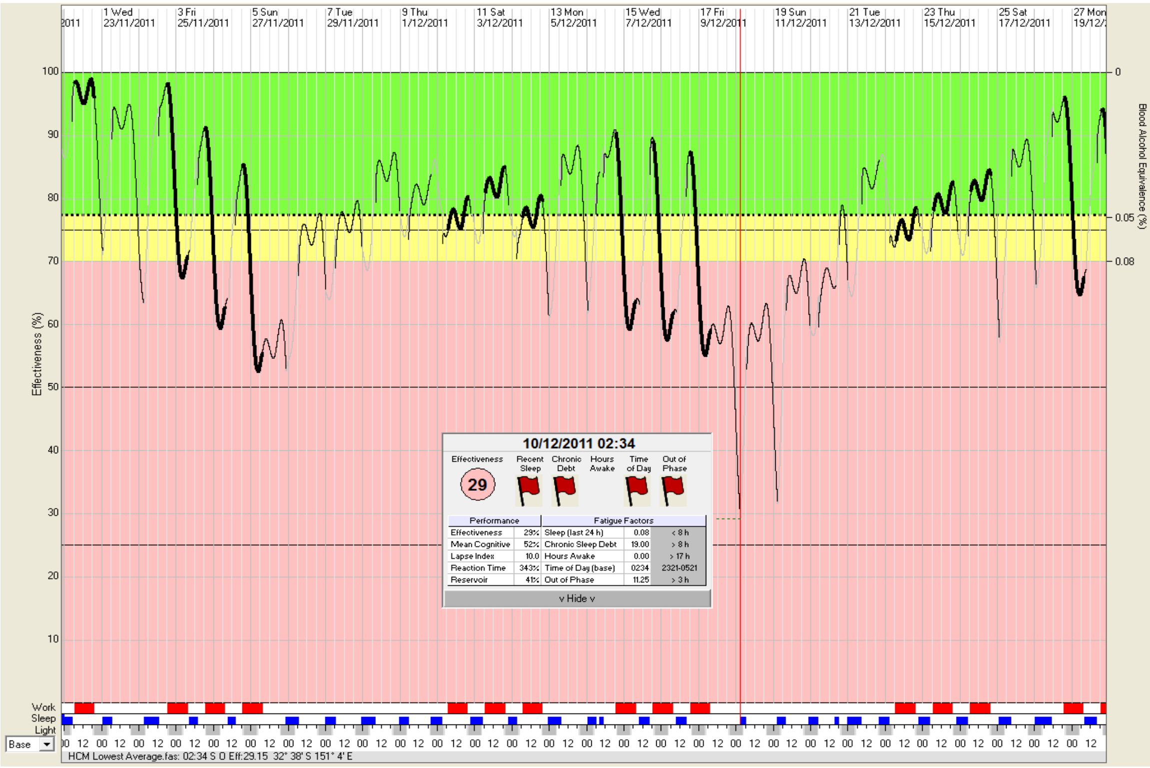

Figure 10: Longest average sleep obtained by an individual

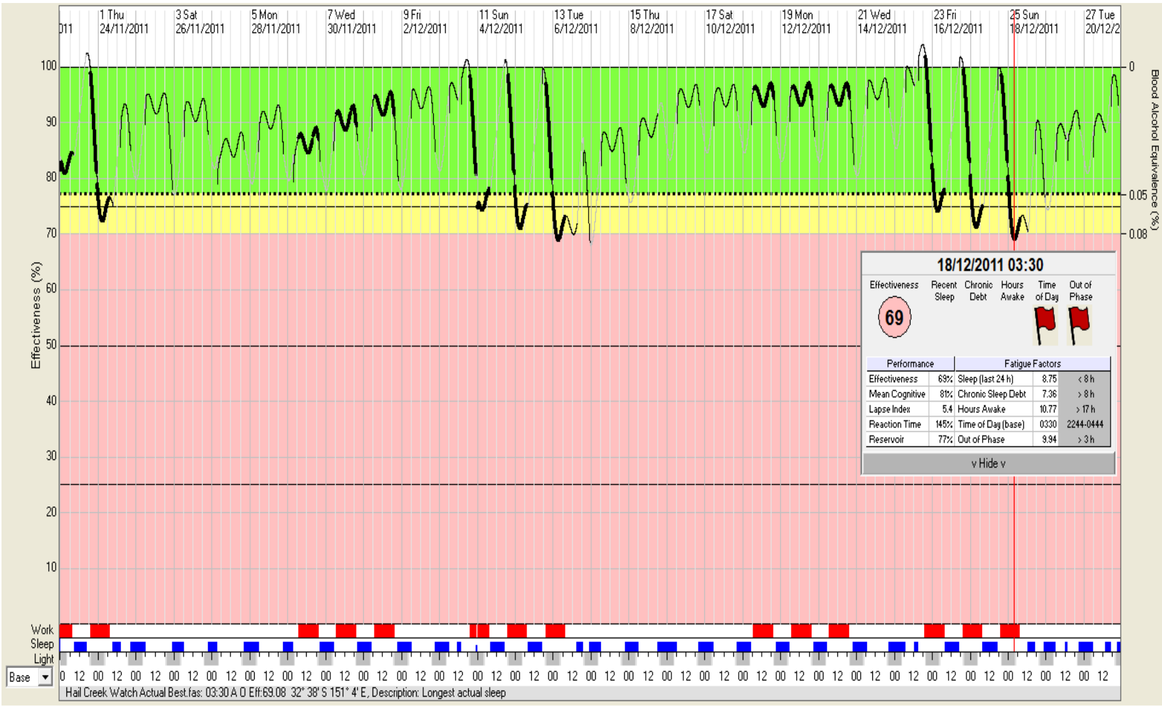

Figure 11: Modelled Sleep opportunity for 3,1,3,5 roster

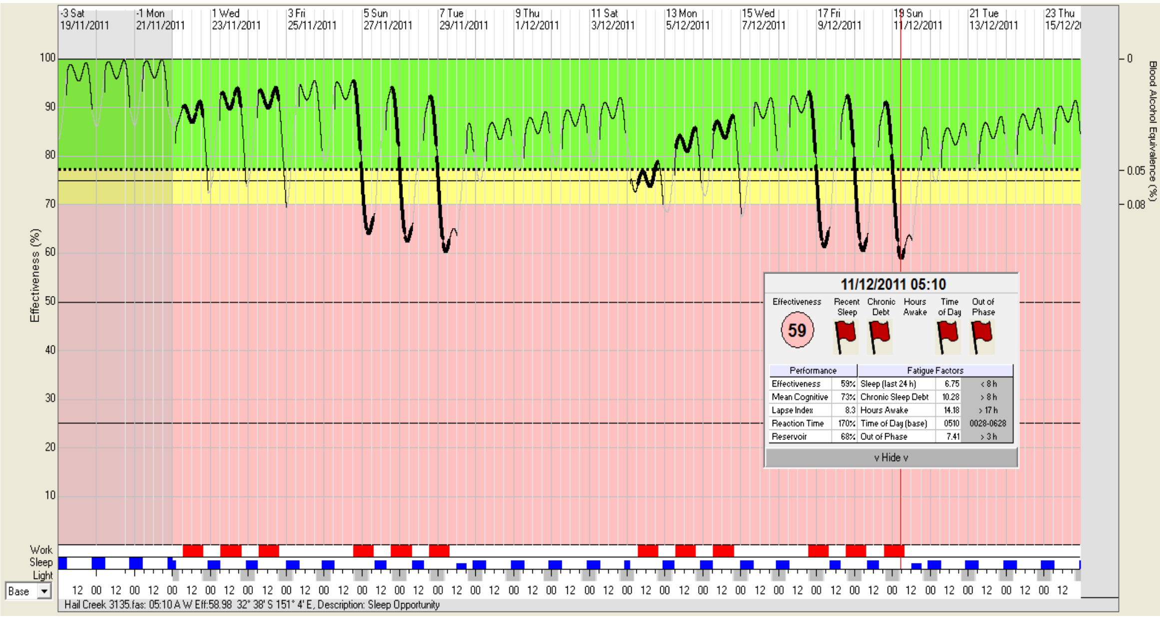

Table 3: Effectiveness comparison of Sleep Opportunity versus Obtained Sleep

	Modelled 3,1,3,5 Roster		Longest awake period, first 10 days		Longest awake period		Shortest Average hrs sleep/day		Longest Average hrs sleep/day	
	Work	Wake	Work	Wake	Work	Wake	Work	Wake	Work	Wake
Average Increased Accident Risk (%)[3]	11	13	22	25	19	17	16	16	6.8	7.1
Average Roster effectiveness %	83		77		76		76		88	
Average Work effectiveness %	81		76		76		76		86	
90% effectiveness	72	74	80	77	80	74	89	88	55	45

[3] Average Increased accident risk: Percentage increase in risk of a "human factors" incident occurring at work over the baseline – which is considered working Monday to Friday 9 – 5 where the effectiveness score does not drop below 90.

80% effectiveness	40	22	48	69	45	47	61	58	33	17
77.5 % effectiveness	37	20	46	67	41	42	48	49	30	15
70% effectiveness	24	13	40	61	35	36	28	30	3	2
60% effectiveness	2	1	33	32	27	19	11	12	0	0
50% effectiveness	0	0	11	11	6	5	0	0	0	0
40% effectiveness	0	0	0	4	0	2	0	0	0	0

The modelled sleep opportunity for the 3135 roster predicts a work average increased accident risk of 11% and the wake average increased accident risk of 10% based on effectiveness prior to implemented controls.

DISCUSSION

The average (mean) sleep/day for the study period was 7:17 hrs/day with a standard deviation of 0:42 hrs. The average hours of sleep/day ranged from 6:23 to 8:39 hrs. There was a significant difference in the sleep/day between participants. Although the average was greater than 7hr sleep/day, five (5) of the 12 participants averaged less than the recommended minimum of 7hrs sleep/day (National Sleep Foundation, 2011).

The individual with the longest single awake period had an average increased accident risk at work of 19%, however their average sleep (6:43hrs) was longer than the shortest average sleep per day (6:23hrs). This individual had a higher increased accident risk (19% versus 16%) as a result of the amount of time they spent below each individual % effectiveness as shown on the left vertical axis in Figure 8 i.e. below 90, 80, 70% etc. The individual recovered some of the sleep debt incurred during the single awake period (44:46hrs) over the study period. In analysing the individual actigraph data it is important to look at all parameters to determine outcomes.

The individual with the shortest average sleep per day (6:23hrs) resulted in an average increased accident risk of 16% (work and wake) compared to the individual with the longest average sleep per day (8:39hrs) with an average increased accident risk of 6.8% (Work). All other individuals were within the range of 7-19% compared to the modelled sleep opportunity with an average of 11% (Work).

Although education and awareness around fatigue and its management is provided, a number of individuals are not managing their sleep habits, decreasing their effectiveness and increasing the risk of incident occurring at and away from work.

The results show that the roster provides adequate sleep opportunity to get the minimum obtained sleep and that some participants did get this or an even greater amount (Office of Research and Development, 2006).

CONCLUSION

This study has shown that modelling is a useful tool to design an effective shift roster, however once implemented it is important to measure the actual effectiveness of the roster as there can be a significant difference between both individual sleep patterns and the actual sleep obtained versus the opportunity. The use of actigraphs can be a very effective tool for one on one awareness and education of individuals on their current sleep habits and where improvements can be made to increase effectiveness.

The results of the study show the importance of a robust and effective Fatigue Management System (Sufficient staffing levels, sufficient sleep opportunity, sufficient obtained sleep, controlled workplace environment, alertness, behaviour and incident investigation & prevention) to ensure all risks are identified and managed effectively through a shared responsibility approach, between employers and employees.

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MANAGEMENT OF SPONTANEOUS COMBUSTION EMISSIONS. COLLINSVILLE COAL MINE: A CASE STUDY

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ABSTRACT

The Collinsville Coal Operations Project is an open cut coalmine located at the top of the Bowen basin in Queensland. A recent increase in emissions from spontaneous combustion of naturally occurring pyritic soils and carbonaceous material was reported at the mine in early 2012. Those emissions were the suspected cause of a string of events that involved potential inhalation exposure to miners in early 2012.

An immediate need eventuated to design and implement an improved system to assess and predict those emissions in real time to enable the proactive management of controls and consequently, the prevention of worker exposure to those gases.

This paper presents details of that system, which included primary source characterisation, static real-time monitoring stations with telemetry alarm capacity, mobile monitoring devices for workers, a qualitative and quantitative exposure assessment, and extensive worker training.

BACKGROUND

The Collinsville Coal Operations Project (CCOP) is an open cut coal mine located at Collinsville, QLD. The mine is owned by Xstrata and operated by Thiess Australian Mining (Thiess) and produces approximately 4.5 million tonnes of coking and thermal coal per year and removes approximately 30 million bcm of over burden per year. The gaseous emissions at Collinsville are generated from the spontaneous combustion of carbonaceous material and the oxidation of pyritic material. In early 2012, several health related incidents were reported by mine workers that were attributed to possible exposure to gaseous emissions at the mine.

Gaseous emissions that form from spontaneous combustion can include a range of potentially hazardous substances. In late 2011, Thiess commissioned both aerial and ground-based thermal imaging surveys as part of a proactive approach to confirm the location of anticipated source areas or 'heatings'. Static sampling was then conducted to quantify the concentrations of gaseous emissions at the source of these heatings (Simtars, 2011 and Simtars 2012). Sampling and analysis was conducted for polycyclic aromatic hydrocarbons (PAHs), volatile organic compounds (VOCs), sulphur dioxide (SO^2), carbon monoxide (CO), hydrogen sulphide (H_2S), particulate sulphates, mercaptans, aldehydes and acid mists. Where the results of source monitoring demonstrated that concentrations were not detected above 10% of the occupational exposure standard (OES) or as in most cases, not above the laboratory limit of detection, they were not included in the ongoing exposure assessment program. It is for this reason that PAHs, particulate sulphates, mercaptans, and aldehydes are not included in the personal exposure assessment described in this paper.

In March 2012, five workers were taken to hospital with symptoms ranging from nausea, irritation of the eyes and respiratory tract, and difficulty in breathing during night shift operations. A further nine people were taken to hospital as a precaution. All workers were able to return to work to perform their regular duties.

Extensive media coverage of that event ensued which described the mine to contain 'a cocktail of…deadly gases' (Townsville Bulletin, 2012a) with interviews with the CFMEU stating that 'more than 250 workers had been allegedly exposed to toxic and deadly gases from the mine', that 'workers were risking their lives unnecessarily' (Townsville Bulletin, 2012), and that it was due to 'years and years of mismanagement' (Daily Mercury, 2012). Additional reports that 'benzene, which can cause leukaemia…was found in two locations' (Townsville Bulletin, 2012b) created great angst amongst mine workers and management alike.

Thiess voluntarily suspended night-shift operations for a period of time and commenced thorough investigations to quantify the risk of exposure to the workforce. As part of that investigation, a qualitative and quantitative occupational exposure assessment was commissioned to assess the risk of occupational exposure. In parallel to this, a static real-time monitoring system was implemented to measure the concentrations of gaseous emissions in real-time in order to alert mine management of potential changes as soon as they occurred.

MATERIALS AND METHODS

Real-time monitoring

Five stationary real-time monitors were installed between known source areas and the locations of mine workers at the CCOP as part of a trial that commenced in April 2012. The trial utilised AreaRAE monitors provided by RAE Systems which were configured with H_2S, SO_2, PID, O_2 and LEL sensors. AreaRAEs were powered by a SolarRAE system which eliminated the need for ongoing battery or generator power. Yagi-Uda array directional antennas were fitted to each AreaRAE and five repeater stations, which were necessary to transmit real-time data wirelessly to a remote host computer located at the mine office. ProRAE Guardian software was used as the communication interface on the host computer which enabled real-time data to be compared to set Trigger Action Response Plans (TARPs) and in turn send alarm notifications via email or SMS text message. Data was also logged and stored on the ProRAE Guardian program which was communicated graphically to the workforce on a weekly basis.

In addition to static monitoring, workers were provided with calibrated and bump tested iTX portable multi-gas monitors sourced from Airmet Scientific. iTX monitors were configured with H_2S, SO_2, CO, O_2 and LEL sensors. Over 100 portable iTX units were in circulation, and were required to be carried by mine workers to access certain parts of the mine. In addition to this, the open cut examiner (OCE) utilised an UltraRAE photoionisation detector fitted with a RAEsep tube for the specific measurement of benzene in real-time on an ongoing basis.

Trigger Action Response Plans (TARPs)

Thiess utilise a range of TARPs to monitor and assess the results of the air-monitoring program. The TARPs exist as triggers for the implementation of appropriate management measures, which may include withdrawal of personnel from the area. TARPs are based on the long-term exposure limit concentrations as listed in the Coal Mining Safety and Health Regulation (2006) and are measured as peak concentrations and not as a short term exposure limit or as a time weighted average.

Identification of Similar Exposed Groups

A qualitative occupational exposure assessment was performed to identify the main chemicals, or agents of concern, the potential exposure pathways, and the groups of workers with observed similar exposure profiles. The potential for over-exposure to gaseous emissions of spontaneous combustion was assessed per similarly exposed group (SEG). SEGs are groups of workers who have the same general exposure profile for an agent due to the similarity and frequency of the task(s) they perform, the similarity of the materials and processes within which they work, and the similarity of the way they perform the task(s) (Ignacio & Bullock 2006). In order to define the SEGs on the CCOP, walkthrough observational surveys of the operational and maintenance areas of the mine were performed during April, May, June, and July 2012. During those walkthrough surveys the following items were investigated:

- the potential for inhalation exposure from emissions of spontaneous combustion;
- the process or task performed by each work group, specifically looking for common risks and common exposure pathways;
- the location that each worker group operates, whether that be a fixed location such as the coal handling preparation plant (CHPP) or a mobile location such as workers that relocate dewatering pumps to and from various pits;
- signs of visible dust in the air or settled dust on nearby surfaces; and
- the presence of elevated noise and the use of hearing protective devices in the work area.

Nine SEGs were defined primarily based on their potential exposure to gaseous emissions with exposures to noise and particulate matter forming a secondary selection parameter. A holistic approach was taken to the management of occupational hygiene hazards and thus the qualitative and quantitative occupational exposure assessments also included the assessment of inhalable and respirable dust, crystalline silica and noise exposure for each SEG. This paper focusses on the emissions from spontaneous combustion, and therefore these parameters are not incorporated into the discussion. During SEG definition, office and administration staff were not considered in the assessment due to the distance of the support areas to the delineation areas of the mine and the low likelihood of exposure to spontaneous combustion emissions. The SEGs identified were:

1. Excavator and Dozer Operators
2. Dragline Operators
3. Rear Dump Truck / Grader Operators
4. Shot Fire, Drill and Blast Crew
5. Mobile Services Crew
6. Workshop Maintenance Workers and Tradesmen
7. Ground Support and Supervisory Personnel
8. CHPP Personnel
9. Dewatering Pump Personnel

Exposure Assessment Methodology

The exposure monitoring strategies and associated data collection and interpretation were conducted in accordance with the general principles outlined in Grantham (2001), BOHS (1993), and the AIHA (Ignacio & Bullock 2006). Data Quality Objectives (DQOs) were implemented to ensure compliance with the objectives defined in the qualitative occupational exposure assessment and that the type, quantity, and quality of data used in decision making were appropriate for the intended application.

Personal samples used to assess exposure were selected to comply with the requirements of the relevant Australian Standards (AS), the NIOSH Manual of Analytical Methods, and AIOH publications. All personal exposure samples were collected randomly during both day and night shift and were collected over a representative period of the workers' 12-hour shift. All samples were collected within the workers breathing zone and where applicable were analysed by a NATA accredited laboratory. The methodology used is listed below:

- Sample collection and analysis for benzene, ethyl benzene, toluene, and xylene (BTEX) were conducted in accordance with AS2986.2 (2003) on passive sampling devices in accordance with NIOSH analytical method 1501.
- Monitoring for CO was conducted using a calibrated iTX multi-gas monitor fitted with a CO sensor in accordance with Occupational Safety and Health Administration (OSHA) Method ID 209 (1993).
- Monitoring for H2S was conducted using a calibrated iTX multi-gas monitor fitted with a H2S sensor in accordance with OSHA Method ID 209; and also undertaken as specified in AS2986.1 (2003) in accordance with NIOSH analytical method 6013.
- Monitoring for SO2 was conducted using a calibrated iTX multi-gas monitor fitted with an SO_2 sensor in accordance with OSHA Method ID 209; and also as specified in AS2986.1 (2003) in accordance with OSHA Method ID 200.
- Samples for an acid screen were collected as specified in AS2986.1 (2003) in accordance with NIOSH analytical method 7903. The acid screen included the analysis of hydrofluoric acid, hydrobromic acid, nitric acid, sulphuric acid, phosphoric acid and hydrochloric acid.

Training and Communication

Initially, fact sheets on the main chemicals of concern, including information on the associated exposure standards and their health effects were developed which were provided and communicated to workers at pre-start meetings. Training on the selection, use, and maintenance of respiratory protective devices (RPDs) including fit testing was also provided for all workers who entered a known 'spon com' area. It is noted that RPDs were designated for use in the event of an escape only, and not as part of routine work activities. Weekly occupational health and hygiene reports were discussed, presented, and made freely available to mine workers in their various muster areas. Numerous presentations were also delivered to the workers on the status of management measures in place to control spontaneous combustion.

RESULTS

Real time monitoring

AreaRAEs recorded concentrations of H_2S (peak of 2.3 ppm), SO_2 (peak of 0.2 ppm between source and workers; peak of 1.2 ppm at source), VOCs (TWA up to 10.8 ppm), oxygen (ranging from 19.8% to 21.5%), and LEL (0.0%). Alarm notifications were sent to a select group of personnel to notify of an increase or change in conditions in real time. Data was recorded and presented as graphs to the workforce each week as a communication tool.

Personal exposure data

A total of 550 valid samples were collected from within the breathing zone of workers over a four month period. A minimum of six samples were able to be collected per parameter per SEG to enable statistical analysis to be performed. The AIHA exposure rating categorization system (Ignacio & Bullock 2006) was adopted for the purposes of identifying and prioritising SEGs which may require the implementation of exposure controls. The exposure rating category assigned to each SEG was dependent upon the comparison of the 95th percentile with the relevant occupational exposure standard (OES) as per the table below.

Rating	Description
4	>5% exceedance of the OES (95th percentile > OES)
3	>5% exceedances of 0.5 of the OES (95th percentile between 0.5 x OES and 1.0 x OES)
2	>5% exceedances of 0.1 x OES (95th percentile between 0.1 x OES and 0.5 x OES)
1	Little to no exceedance of 0.1 x OES (95th percentile < 0.1 x OES)

Results are summarised below with comparison to the shift-adjusted time weighted average (TWA) exposure standard or the short-term exposure limit (STEL) as applicable;

- All samples collected to assess a TWA exposure to H_2S were below the laboratory limit of detection (LOD), below the resolution of the direct reading instrument, or insignificant (less than 3%) in comparison to the OES.
- All samples collected to assess TWA exposure to SO_2 were below the OES. Most results were below the laboratory LOD, below the resolution of the direct reading instrument, or minor (less than 9%) in comparison to the OES. SEG6 (Workshop Maintenance Workers and Tradesmen) and SEG8 (CHPP personnel) had an exposure rating category of 2 due to exposures from welding, oxy-cutting, and grinding activities performed in the workshop. SEG 5 (Mobile Services Crew) was assigned an exposure rating category of 1 due to similar activities.
- All samples collected to assess TWA exposure to CO were below the OES. Samples collected to assess the TWA exposure to CO were below the resolution of the direct reading instrument, or minor (less than 6%) in comparison to the OES for all SEGs with the exception of SEG6 (Workshop Maintenance Workers and Tradesmen) and SEG8 (CHPP personnel) who were assigned an exposure rating category of 2 due to concentrations detected whilst workers were performing welding, oxy-cutting and grinding activities.
- Samples collected to assess TWA exposure to acid mists were below the laboratory LOD or minor (less than 10%) in comparison to the OES for all SEGs. Acids detected in minor concentrations included phosphoric acid (0.06 mg/m^3), hydrochloric acid (0.05 mg/m^3) and sulphuric acid (0.05 mg/m^3).
- All samples collected to assess TWA exposure to benzene, ethyl benzene and xylene were below the laboratory LOD. Two samples reported an insignificant detection of toluene at less than 1% of the OES.

DISCUSSION

A quantitative occupational exposure assessment was primarily performed to assess mine workers exposure to the emissions of products of spontaneous combustion. Over 550 personal samples were collected from within the breathing zones of workers and assessed for exposure to H_2S, SO_2, CO, BTEX, acid mists, inhalable dust, respirable dust and crystalline silica. Throughout the assessment period, weekly occupational health and hygiene reports were discussed, presented, and made freely available to mine workers. Those reports included the results of personal exposure data received that reporting week, along with graphical summaries of data recorded from the AreaRAE monitoring system. Gradually, over a number of weeks, the increased presence of occupational hygienists collecting and communicating exposure data resulted in a general increase in confidence from mine workers on the effectiveness of management controls in place and the actual risk of exposure.

The implementation of a real-time monitoring framework in parallel to compliance with internally adopted TARPs (based upon OESs), afforded the opportunity for intervention at selected thresholds and enabled the selection and implementation of appropriate real time controls to reduce exposures to persons working at the CCOP.

By following the protocols currently in place, personal exposures to the products of spontaneous combustion have been adequately controlled as confirmed through statistical analysis of personal exposure data. Statistical analysis highlighted areas where the implementation of additional controls would be beneficial to reduce personal exposures to levels as low as reasonably practicable. Personal exposures are deemed to be under control if they are measured typically at a value below half of the exposure standard (i.e. exposure category rating 1 or 2). The following controls were recommended:

- Control exposures of SO2 during welding, cutting, and grinding activities by:
  a) Reviewing ventilation practices;
  b) Providing training to anticipate and control potential exposures; and
  c) The possible use of respiratory protection.
- Continue to assess the exposures of SEGs to airborne contaminants on a six-monthly basis to account for seasonal variations at the mine. Priorities should be given to SEGs where an exposure rating category value of 2 or greater has been calculated;
- Continue to comply with the TARPs implemented at the CCOP; and
- Ensure that the results of the assessment are communicated to participants.

CONCLUSION

Often the perceived risk of exposure can be vastly different to the risk quantified through rigorous statistical analysis of personal exposure data. An exposure assessment performed over a four-month period demonstrated that exposures to the products of spontaneous combustion were adequately controlled at the CCOP. The continued use of a real-time monitoring framework to assess the concentrations of gases in real-time is a necessary ongoing control strategy for the early detection and prevention of over-exposure of mine workers at the CCOP.

ACKNOWLEDGEMENTS

Thank you to Xstrata Coal and Thiess Pty Ltd who have authorised the publication of data obtained at their premises. Thank you also to Mr Phillip Hibbs from Hibbs and Associates for being a great mentor throughout the process of producing this work.

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OTOTOXICITY IN MINING: DO YOU WANT DEAFNESS WITH THAT CHEMICAL?

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AECOM

ABSTRACT

Noise Induced Hearing Loss (NIHL) risk associated with mining is well known. Less known is that a range of minerals, chemicals and medications may cause deafness or reshape the risk factors for NIHL. There are as many as a thousand chemical compounds and substances capable of producing ototoxic impact on mine workers. Earliest accounts of ototoxicity date back more than 1000 years linking medical treatment using mercury with increased risk of deafness.

Within the mining industries, claims for NIHL in the coal mining sector presents as both the highest by number and by incident rate. Whilst not distracting from the main deafness risk factors: noise exposure in NIHL and aging in presbycusis; this paper extends and updates occupational hygienist knowledge of ototoxic agents and their impact. This paper: explains how chemicals can damage hearing, identifies ototoxic chemicals in mining and advise how the practitioner may account for ototoxicity potential in their NIHL prevention strategy.

DUST AND NOISE LEVELS IN A TEACHING PODIATRY LABORATORY

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KEYWORDS

Podiatry, dust, noise, ventilation control

ABSTRACT

The use of Podiatry services is increasing and the exposure to dust and noise in Podiatry facilities has not been well documented in the literature. Concern for exposure to dust and noise has been raised due to the amount of particles seen when grinding and sanding custom moulded shoe inserts. Shoe inserts are made from a range of materials including polypropylene, polyurethane foams, ethylene/acetate copolymers, vinyl acetate and aluminina trihydrate.

Monitoring for $PM_{2.5}$, PM_{10} and noise was undertaken in a teaching podiatry laboratory on two days to ascertain if they were at a level hazardous to health. In addition the ventilation system was assessed to determine if the capture velocities were sufficient to determine if the current ventilation system is sufficient to control the potential hazards. Because the laboratory is used by a variety of students during the day, static monitoring was undertaken in preference to personal sampling so that a broad range of exposures could be determined.

The results of the dust monitoring shows that the levels of $PM_{2.5}$ and PM_{10} were within levels considered adequate from a public health viewpoint although peaks did occur during the clean-up of the laboratory.

Noise monitoring highlighted that although the average levels were acceptable there is concern that a number of machines have noise levels exceeding 80 dBA. The ventilation system was assessed from a qualitative (smoke tubes) and quantitative (velocity measurements) viewpoint, and because of the action of the spinning wheels and belt it was determined that they were not adequate.

INTRODUCTION

Concerns have been raised that there may be potential for people fabricating shoe inserts may be exposed to dust and noise levels which could have adverse health impacts. Monitoring for dust and noise was undertaken in a teaching podiatry laboratory for the fabrication of shoe inserts by grinding, sanding and polishing using a range of equipment as seen in Figures 1 and 2. The main aim of the assessment was to determine if the current ventilation system needs upgrading and if the students and staff using the laboratory need to wear respiratory and hearing protection. A review of the literature showed there were limited published assessments of podiatry laboratories and what has been published was in relation to bioaerosols when podiatrists were working on clients' feet.

Figure 1: Redwing Sander/Grinders

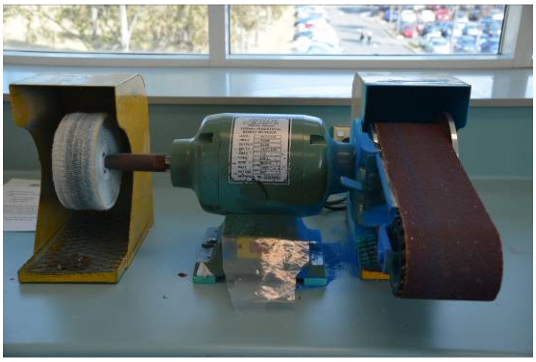


Figure 2: JBS Belt Sander and Buffer

Currently the Laboratory has the requirement that all people entering the laboratory are required to wear safety glasses, respiratory protection and hearing protection.

Monitoring was undertaken on two days. The first in May 2012, when a limited number of samples were collected, and then again in August, when all of the parameters were measured. The limits in monitoring were due to when the laboratory was in full use as it is restricted to the period of the teaching semester.

METHODS

Because the laboratory was used by a variety of students during the day static monitoring was undertaken in preference to personal sampling so that a broad range of exposures could be monitored. Sampling was undertaken between 10 am and 4 pm so that three separate laboratory sessions were monitored. A number of sets of monitors were located in the laboratory in the regions where the students were working. The parameters monitored included noise, a variety of dust size concentrations and the ventilation system to determine if it meets minimum requirements.

The products used in the laboratory were analysed from the information provided in the MSDS's provided by the product suppliers and held in the laboratory for review by people using the area.

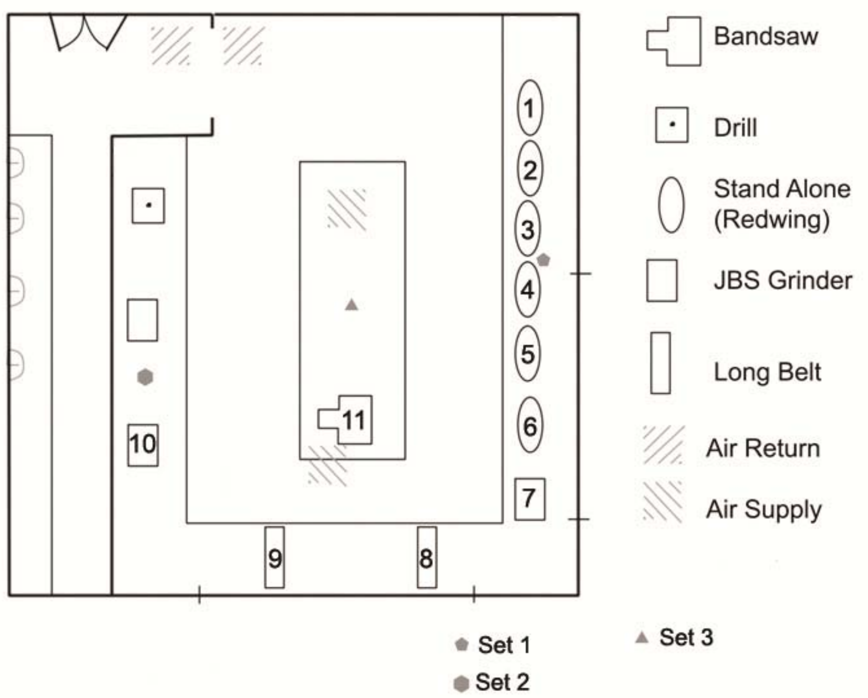
PM_{10} and $PM_{2.5}$ were monitored from a public health viewpoint as the health status of students using the laboratory is unknown and the results will be compared against the standards for ambient air which are designed for everyone. Monitoring was undertaken for PM_{10} using TSI DustTrak™ Model 8250 (Serial Nos. 23645 and 85201525) monitors and $PM_{2.5}$ using TSI Sidepak™ Personal Aerosol Monitor AM510 (Serial Nos. 10610094 and 10611057). Two sets of dust monitors were setup in the areas where the students were working, as indicated on Figure 3, and as close as possible to their breathing zone. Each set of monitors consisted of a TSI DustTrak™ Model 8250 measuring PM_{10} and a TSI Sidepak™ Personal Aerosol Monitor AM510 measuring $PM_{2.5}$. Monitoring was also undertaken in the centre of the laboratory for PM_1, $PM_{2.5}$, PM_4 (respirable), PM_{10} and total dust using a DustTrak™ DRX Aerosol Monitor 8533 (Serial No. 8533084003).

General workplace noise levels were measured using a Brüel and Kjær Sound Level Meter Model 2250 (Serial No. 2506131) using a ½ inch Brüel and Kjær Microphone Type 4189 (Serial No. 2543040) both of which comply with AS IEC 61672.1. Larson Davis Model 703 Dosimeters (Serial Nos: 20915 & 21918) and a Model 706 Dosimeter (Serial Nos: 20915) were also set up in conjunction with the air samplers to determine the variation in noise levels within the laboratory and determine if the noise levels are within acceptable levels as defined by the WHS Regulation 2011, Safe Work Australia (2012a) and AS/NZS1269:2005. Noise dosimeters were located at the same positions as the dust sampling equipment.

The ventilation system was assessed by using a Dräger smoke tube to determine the area of influence of the extraction systems. The face velocities for each of extraction slots and as well as the capture velocities and distances for each were assessed using a TSI Model 8345-M-GB (Serial Nos. 98110157) anemometer.

Figure 3: Layout of Podiatry Laboratory with Monitoring Positions Indicated

(Note: Numbers 1 to 10 relate to the sanding and grinding machines and measurement positions for noise and ventilation)



RESULTS AND DISCUSSION

Review of Chemical and Health Related Data Provided in MSDSs

An analysis of the current MDSDs in the laboratory showed that the majority were over 5 years old and did not meet the Australian guidelines for MSDSs published by Safe Work Australia either in the current format or the previous format. The two main chemical groups in the products used in this laboratory are Polypropylene and Urathane, and no exposure standards beenwere reported on the MSDSs for either of these products. The information available on other chemical constituents is very poor.

The main products ground, sanded and polished in the laboratory are:

- Alveolux – Orthotic Foam Material (sponge)
- Polypropylene
- Polystone P-ORTHO-NATURAL, homopolymer
- PORON XRD Urethanes
- Polyurethane Foam PPT (rolls and Sheeting)

The only product MSDS which included the exposure standard is the Ethylene/Vinyl acetate copolymer which has a exposure standard of 35 mg/m^3 TWA and 70 mg/m^3 STEL (Safe Work Australia, 2012b) for vinyl acetate in the vapour phase.

Dust Monitoring

The results of the dust monitoring for both days was undertaken over six hours which included two sessions, where a large number of students used the laboratory and a clean-up occurred at the end of each session. The time period covered was 10 am to 4pm.

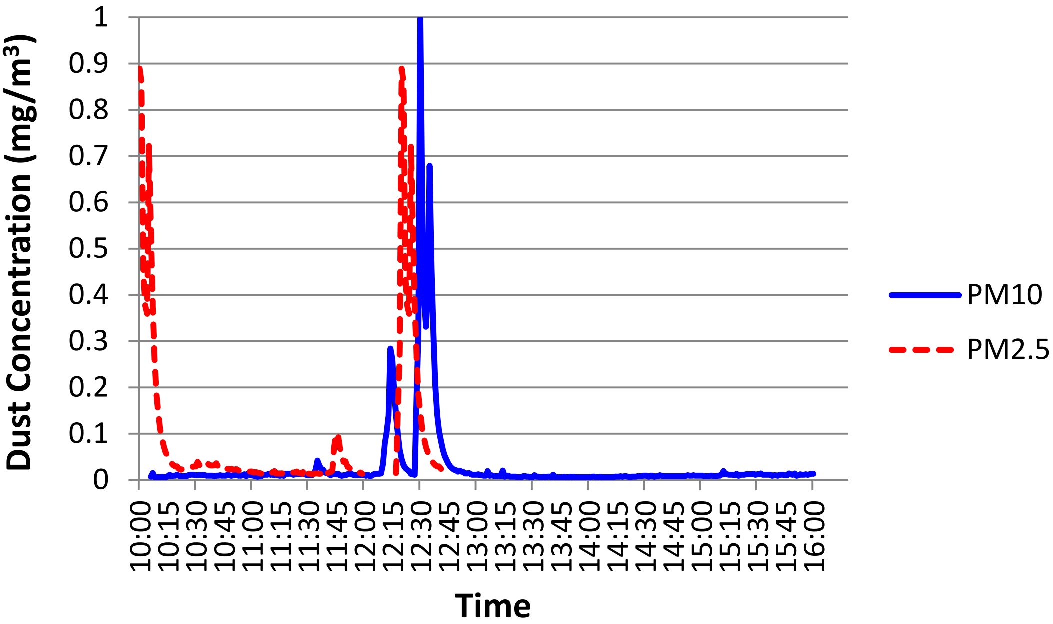
Table 1: Summary of Real-time Dust Monitoring

Location	Parameter Monitored	Date	Average	Minimum	Maximum
1. Between two Redwing Sanders on the window side of laboratory	$PM_{2.5}$ (mg/m^3)	8/5/12	0.011	0.003	0.194
	PM_{10} (mg/m^3)	8/5/12	0.012	0.004	0.241
	$PM_{2.5}$ (mg/m^3) #	28/8/12	0.070	0.012	0.889
	PM_{10} (mg/m^3)	28/8/12	0.028	0.006	0.998
2. Between two JBS Grinders on the wall side of laboratory	$PM_{2.5}$ (mg/m^3)	8/5/12	0.014	0.000	0.277
	PM_{10} (mg/m^3)	8/5/12	0.039	0.004	0.731
	$PM_{2.5}$ (mg/m^3)	28/8/12	0.039	0.006	1.48
	PM_{10} (mg/m^3)	28/8/12	0.025	0.006	1.711
3. In middle of room near band saw	PM_1(mg/m^3)	28/8/12	0.010	0.001	0.357
	$PM_{2.5}$ (mg/m^3)	28/8/12	0.012	0.001	0.711
	Resp (mg/m^3)	28/8/12	0.015	0.001	0.715
	PM_{10} (mg/m^3)	28/8/12	0.040	0.001	1.710
	Total Dust (mg/m^3)	28/8/12	0.114	0.001	7.280

sampler only ran for just over 2 hours as students turned the power off accidently to the instrument

When compared to standards for ambient air quality which have been developed to protect the general public the dust concentrations measured are not significant. The standards for ambient air quality are 0.050 mg/m^3 (50 µg/m^3) for PM_{10} and 0.025 mg/m^3 (25 µg/m^3) for $PM_{2.5}$ over 24 hours (*Department of the Environment and Heritage*, 2005). The results of the monitoring have not been compared to the occupational exposure standards because the particulate sizes monitored do not occupational exposure standard published by Safe Work Australia (2012).

Figure 2: Dust Concentration measured in the Breathing Zone of Students using the Redwing Sanders 3 and 4 on the window side of laboratory on 28 August 2012



The results of the instantaneous monitoring, shown in Figures 2, 3 and 4, show that although the standards are exceeded for a short time it is not very long. The average exposures are well below the recommended 24 hour standards as published by both WHO and *Department of the Environment and Heritage. It should be noted that if the respirable dust levels are averaged over 8 hours they are only 0.5 % of the respirable exposure dust standard of 3 mg/m^3 published by ACGIH (2012), the maximum measures at any time was less than 25 % of the exposure standard.*

The ambient air quality standards were used because the health status of students using the laboratory is unknown, the standards for the ambient air quality are significantly below what limited workplace exposure standards exist for the products being handled including ethylene/vinyl acetate (ES = 35 mg/m^3), calcium sulphate and urethane foam (ES = 10 mg/m^3).

An area of major concern is the current practice of dry sweeping in the laboratory to clean-up following the student work. This is the major source of the peaks in dust exposures as can be seen in Figures 2, 3 & 4 around 12:00. A similar peak is seen in Figure 4 just before 16:00. These peaks are the major source of the dust concentrations that in most cases are just above what are considered normal ambient dust concentrations.

Figure 3: Dust Concentration measured in the Breathing Zone of Students using the JBS Grinders on the inside wall side of laboratory on 28 August 2012

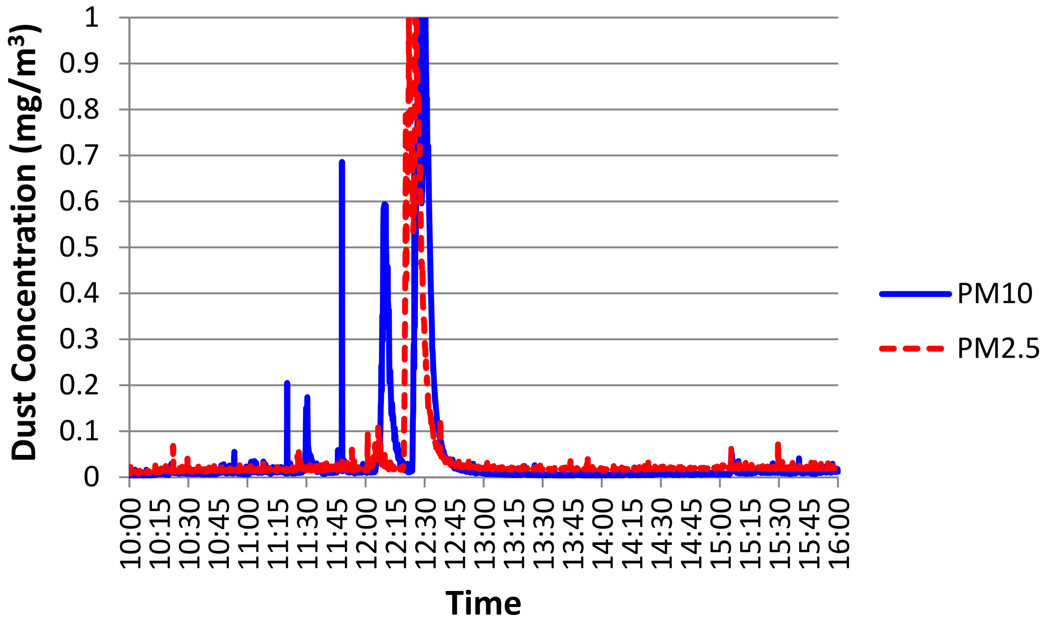
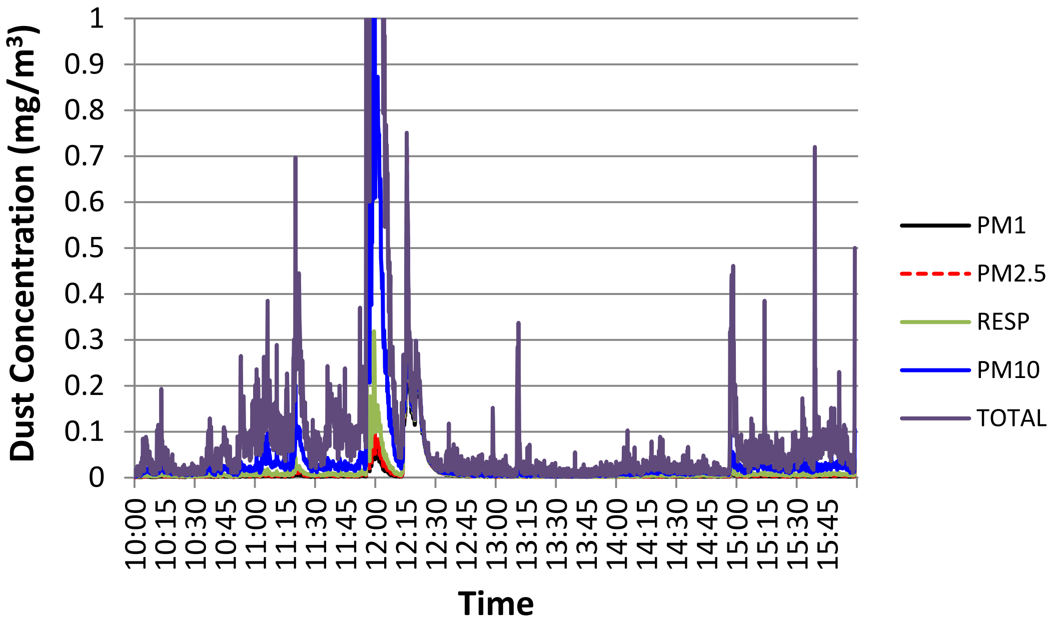


Figure 4: Dust Concentration measured in the Breathing Zone of Students near the Bandsaw in the middle of the laboratory on 28 August 2012



The results of the monitoring for dust shows that the current ventilation system is keeping the levels of inhalable and respirable dusts below that which is considered not hazardous to health, even though the extraction systems do not produce flow rates sufficient to capture particles generated with a velocity. Although large dust particles may be observed in the laboratory is it not at levels that are considered hazardous to health. The current compulsory requirement for the use of respiratory protection is not considered to be required, although students and staff may elect to wear dust masks for personal reasons.

Noise Monitoring

As with the dust monitoring the noise dosimeters ran over a six hour period from 10 am to 4pm and a summary of the noise dosimeter results is shown in Table2. Individual noise levels were measure at each workstation initially with all the machines running and then with only the machine being assessed running to determine which machines made the highest contribution to the noise levels in the laboratories.

Table 2: Noise monitoring of Individual machines in the Podiatry Laboratory

Location	All Machines Working		Individual Machines Working	
	L_{eq} (dBA)	Noise Peak (dBC)	L_{eq} (dBA)	Noise Peak (dBC)
1. Redwing Sander/Grinder	79.8	100.4	64.3	90.5
2. Redwing Sander/Grinder	80.6	100.4	66.8	92.0
3. Redwing Sander/Grinder	82.3	100.6	63.5	85.7
4. Redwing Sander/Grinder	82.8	98.9	68.9	93.3
5. Redwing Sander/Grinder	83.6	101.0	73.4	93.3
6. Redwing Sander/Grinder	85.5	105.1	65.0	88.1
7. JBS Long Belt & Polisher	89.7	104.3	91.0	104.4
8. JBS Long Belt &Buffer	87.8	104.1	87.8	104.4
9. JBS Long Belt & Buffer	85.9	102.8	82.7	100.1
10.JBS Long Belt & Grinder	88.4	104.2	88.4	102.7
11.Bandsaw	86.6	103.5	82.0	98.4

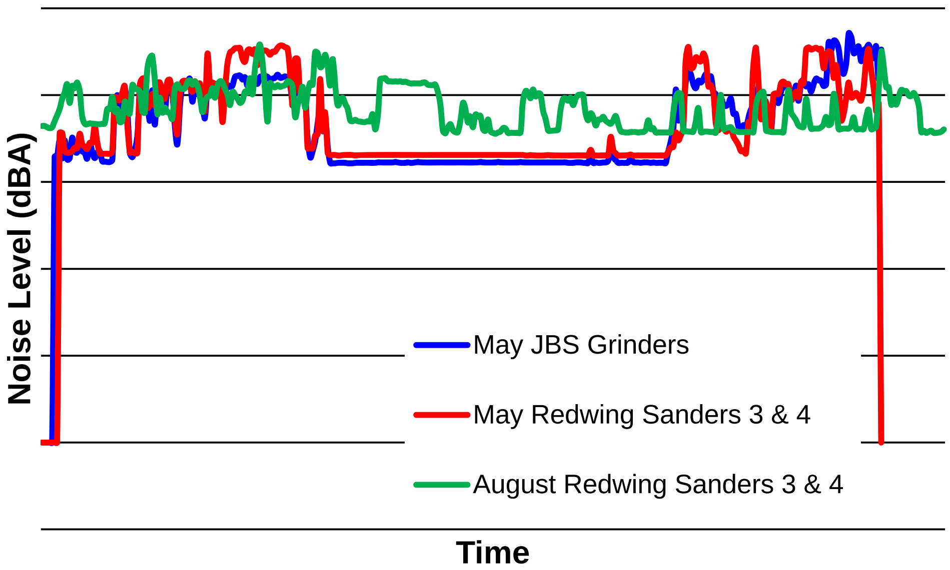
The results from the noise dosimeters logged over 6 hours are tabulated in Table 3.

Table 3: Summary of Real-time Noise Monitoring

Location	Date	Average L_{eq} (dBA)	Minimum (dBA)	Maximum (dBA)	Noise Peak (dBC)
1. Between two Redwing Sanders on the window side of laboratory	8/5/12	80.8	64.3	94.2	117.6
	28/8/12	78.3	64.3	98.5	121.4
2. Between two JBS Grinders on the wall side of laboratory	8/5/12	82.6	66.1	91.4	119.5
3. In middle of room near the band saw	28/8/12	78.8	65.2	99.6	125.4

The noise monitoring shows that noise exposures, although within the current limits, are dependent on the amount of time that the grinders and sanders are used on any one day. On the days of monitoring, (refer Figure 5), there was a two hour period when the sanding and grinding equipment were not used. When the grinders and sanders were in use the noise levels were typically over 85 dBA (refer Table 2). It should be noted that students and staff wore hearing protection when the sanders and grinders were in use.

Figure 5: Noise Levels measured in the Hearing Zone of Students using the JBS Grinders and the Redwing Sanders in the laboratory on 8 May and 28 August 2012



Based on the noise levels measured it would be good practice for the students and staff to wear a Class 2 hearing protector when either the sanders and/or the grinders are being used.

The current signs in the laboratory which relate to the wearing of dust masks and hearing protection need to be modified to indicate that hearing protection is required when the sanders and grinders are in use. The current signs indicate that both hearing protection and respiratory protection, in addition to safety glasses, are required at all times even when there is no inhalation or noise hazard present.

Ventilation Assessment

Initially the ventilation assessment involved using the Dräger tubes to look for the capture zones of each extraction system. Each of the Redwing Sander/Grinders only had dust bags attached to the extraction system as can be seen in Figure 4, where the Long Belt sander/Buffers and the JBS Grinders had an improvised extraction system attached to vacuum cleaners located in cupboards under the benches (Figure 6 & 7).

Figure 6: Effect of the Dust Extraction System for Redwing Sander/Grinders using Dräger Smoke Tube

Figure 2: Effect of the Dust Extraction System for JBS Belt Sander and Buffer using Dräger Smoke Tube

None of the ventilation systems worked adequately as can be seen in Figures 6 and 7 and if the capture distance was more than several centimetres from the extraction hood/slot the system collected limited smoke. The systems currently installed are affected by the spinning grinding wheel or belt which travels away from the extraction hood. They are also impacted on where on the wheel or belt the operator places the item to be grinded or sanded.

Table 4: Capture and Face Velocities at each Extraction Head

Location	Face Velocity m/s	Capture Velocity m/s
1. Redwing Sander/Grinder	1.78	0.14
2. Redwing Sander/Grinder	2.6	0.12
3. Redwing Sander/Grinder	1.4	0.13
4. Redwing Sander/Grinder	0.7	0.2
5. Redwing Sander/Grinder	2.0	0.17
6. Redwing Sander/Grinder	5.2	0.7
7. Polisher	4.1	0.23
7. Long Belt	3.85	0.41
8. JBS Long Belt &Buffer	0.7	1.04
9. JBS Long Belt & Buffer	6.65	0.76
10.Polisher	3.89	1.7
10.Long Belt	2.39	0.76

The face velocities and the capture velocities at each of the machines are indicated in Table 4, were measured at the face inlet (Face Velocity) to the extraction system and at the working position closest to the extraction inlet (Capture Velocity) which ranged from approximately 5 to 15 cm from inlet. Due to the particles being generated at a velocity it is recommended that the minimum capture velocity should be 0.25 to 1.0 m/s (ACGIH, 2010). Some of the capture velocities measured met the guideline of 1 m/s but only for machines 8 and 10 which were not commonly used.

CONCLUSION

The results of the monitoring on the 8 May and 28 August 2012 indicates that dust levels in the laboratory are within acceptable levels. However the current practice of using a broom to dry sweep the benches and floor should be replaced with a wet or vacuum system as it is the major source of the dust generation in the laboratory.

The noise monitoring highlighted that when some of the sanders and/or grinders were in operation the noise levels would exceed 80 dBA and in some areas 85 dBA. The majority of the noise was generated by the JBS belt sanders and wheel buffers which were at one end of the laboratory. These machines need to be replaced with quieter machines.

The assessment of the current ventilation systems that have been installed in the laboratory showed they are not adequate for collecting dust that is generated at speed. Consideration needs to be made when the current machines are replaced to ensure that the extraction ventilation is upgraded to suit the new equipment. The Redwing Sander/Grinders need to have extraction ventilation installed that is not dependent on the machine operating such as the current bag system. It needs to surrounds the working area of the machine and be able to capture the dust particles as they are generated.

The other major issue identified early on in the project was the current quality of Material Safety Data Sheets available in the laboratory. They need to be replaced with more current sheets and also need the Australian guidelines for Safety Data Sheets

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ABATTOIR NOISE STUDY - DOSIMETRY VS SAMPLES

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ABSTRACT

For many years there has been on-going debate concerning the best and most appropriate method for estimating long term, workplace noise exposure. An extensive noise management survey of a "meatworks" illustrates the difficulty of appropriate estimation of workplace noise exposure.

While personal noise dosimetry may offer better accuracy (trueness and precision) of the day's exposure is a one day sample sufficient to estimate long term exposure? Noise sampling of tasks may provide a better indication of the noise exposure generated by the task itself but how reliable is the exposure time guestimate?

Both techniques, Dosimetry or Sampling, have their respective advantages and disadvantages dependent on the availability or lack of resources, and neither may give a complete picture of the actual exposure. The solution may be the judicious and thoughtful use of both methods.

AMATEUR ORCHESTRA MUSICIANS:

ARE THEY AT RISK OF NOISE INDUCED HEARING LOSS?

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ABSTRACT

A Study was carried out to measure noise exposures for amateur orchestra musicians and determine the risk of noise induced hearing loss (NIHL). Results indicated noise generated by the musicians during various rehearsal and performance sessions was high when compared to the noise Exposure Standard.

Dosimeter results indicate exposures ranging from LAeq,2.9h 91 – 100 dB(A) with a mean result of 96 dB(A) for theatre performances. Generally, musicians who play brass instruments have the highest exposures with results ranging from LAeq,2.9h 97 – 100 dB(A). Calculated for an 8 hour day, 75% of results (i.e. 21 out of 28) were higher than the Exposure Standard of LAeq,8h 85 dB(A). The LCpeak Exposure Standard of 140 dB(C) was exceeded during performances for some musicians.

Therefore, risk of NIHL from noise exposure is present and controls should be employed to minimise noise exposures for the amateur musicians. The results of this Study has generated valuable information and hearing awareness within the Orchestra regarding noise exposure and risk of NIHL.

APPLICATION OF COMPUTATIONAL FLUID DYNAMICS (CFD) FOR DETERMINATION OF CHEMICAL VAPOUR DISPERSION

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ABSTRACT

Computational fluid dynamics (CFD) is a computer-aided engineering tool for the analysis of complex physical phenomena, including fluid flow, heat transfer and dispersion of chemical substances. CFD can be applied to the prediction of airflow patterns, air quality, temperature distribution and pollutant dispersion.

Formaldehyde is the principal component of embalming fluid, used to prepare cadavers at funeral houses and for research or teaching purposes in gross anatomy laboratories. A CFD modelling study was undertaken in the design of a new anatomy teaching facility to predict the dispersion of formaldehyde generated during the preparation and study of cadavers. The CFD results were used to identify potential dispersion based on a variety of work spaces and consideration of the effects of ventilation techniques.

This paper provides an overview of the application of CFD modelling as an occupational hygiene tool and identifies potential benefits and disadvantages associated with the application of this tool.

PEAK PERSONAL EXPOSURE AND TWA SAMPLING OF FUMIGANTS AND RESIDUAL OFF-GASSING CHEMICALS IN SHIPPING CONTAINERS USING RAGS (REMOTE ACTIVATED GRAB SAMPLER) AND VEM (VIDEO EXPOSURE MONITORING)

Prezant, BD[1,2], Wagstaffe, M[1], McGlothlin, J[3], Scharp, M[3], Brewer, N[2], Prince, B[4], Gray, J[4], Douwes, J[1]

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KEYWORDS

fumigant, shipping container, video exposure monitoring, peak exposures, unloading, off-gassing

ABSTRACT

Previous studies of fumigant and residual off-gassing chemicals in shipping containers have frequently indicated air concentrations in excess of applicable WES levels. However, these studies have measured only ambient levels within unopened containers, prior to any venting and have not measured personal exposures during unloading or inspecting. This study is the first study to report TWA and peak personal exposures to methyl bromide, other fumigants, and residual off-gassing chemicals. Sampling of workers unloading 80 randomly selected containers containing mostly non-palletized products in cardboard boxes was conducted in Melbourne & Brisbane. A novel sampler was developed in order to assess peak (20 second) personal exposures. Worker activities during sampling were documented with video exposure monitoring (VEM). All sample analyses were conducted via SIFT-MS. Results indicate fractional TWA and peak exposures, well below applicable WES concentrations, to both fumigants and residual off-gassed compounds. Imported products in cardboard boxes (but not stacked on wood pallets) may not require fumigation, therefore, these results may not apply to containers containing wood or earthenware contents which may have been fumigated. In these circumstances, personal exposures to fumigants may exceed those measured in this study.

ACKNOWLEDGMENTS

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USE OF ISOCYANATE BASED ADHESIVES DURING THE MANUFACTURE OF VINYL WRAPPED DOORS AND CABINETS

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ABSTRACT

In early 2011, routine inspection activity by the WorkSafe Victoria's Occupational Hygiene Unit (OHU) discovered an employee suffering from occupational asthma caused by uncontrolled spraying of a two pack isocyanate based adhesive during the manufacture of vinyl wrapped doors and cabinets. The adhesive includes an isocyanate hardener similar to that used in two pack automotive paints. Further investigation revealed that inadequate health and safety information was provided in the material safety data sheet (MSDS) and on the product label. Isocyanates are known to be potent respiratory sensitisers and a high level of control is required to prevent susceptible persons from developing occupational asthma.

As a consequence, OHU commenced a program to ensure appropriate controls were in place for the spraying of two pack isocyanate containing adhesives in Victorian workplaces manufacturing vinyl wrapped doors and cabinets. This paper details the findings of that program.

ADHESIVE SUPPLIERS VISITS

The approach taken with the program was to first target the suppliers of the two pack isocyanate containing adhesives to ensure that end users were being provided with appropriate information through the MSDS and labels for the product. The authors visited eight adhesive suppliers and identified four primary suppliers and two distributors of the isocyanate containing adhesive. The visits resulted in the issuing of seven improvement notices (five relating to MSDS and two relating to labels) to three of the primary suppliers. The issues identified in the MSDS included no statement that the substance was a hazardous substance, inadequate disclosure of the chemical ingredients, incorrect hazard classification, incorrect risk and safety phrases, inadequate advice on necessary engineering controls and/or personal protective equipment, inadequate health effect information, inadequate first aid information and no Australian Exposure Standards. Issues associated with the container labels included no 'Hazardous' (or equivalent) signal word, inadequate disclosure of the chemical ingredients, incorrect risk and safety phrases and inadequate importing supplier/manufacturer information. Only one primary supplier had correctly classified the adhesive as a respiratory sensitiser and had complying MSDS and labels. The adhesive suppliers were also required to provide lists of Victorian workplaces to which they had supplied the two pack isocyanate containing adhesive in the previous twelve months.

ADHESIVE USER VISITS

The next phase of the program involved visiting all of the workplaces identified by the adhesive suppliers and distributors. Prior to the visits, a letter was sent to each of the workplaces informing them of the hazards associated with the spraying of isocyanate containing adhesive and the risk control measures required by WorkSafe Victoria if spraying of the adhesive was to continue. The controls detailed in the letter included:

- obtaining the current manufacturers MSDS for the adhesive (including the hardener);

- ensuring the spraying was performed in a spray booth with an airflow of at least 0.25 metres per second for a full down draught booth or 0.5 metres per second for all other booths (as recommended in AS/NZS 4114.1 Spray painting booths, designated spray painting areas and paint mixing rooms); and,
- ensuring the spray operator wears a full face air-supplied respirator or hood complying with Australian Standard AS/NZS 1716 Respiratory protective devices.

In addition, employers would be required to provide spray operators with health surveillance for isocyanate exposure. The letter also advised that WorkSafe Victoria would be visiting the workplaces in the near future to ensure compliance.

Over the next three months the authors conducted inspections of all workplaces known to be using the isocyanate containing adhesive. Enquiries during these visits revealed a number of other workplaces which were suspected of also using the isocyanate based adhesive. In total, 29 workplaces were inspected. These initial inspections found that:

- nine workplaces were spraying a two pack isocyanate containing adhesive;
- three workplaces were spraying a 'non-hazardous' adhesive which did not require an isocyanate hardener additive; and
- eight workplaces were using a vinyl with a pre-applied adhesive.

The remaining nine workplaces were either no longer manufacturing vinyl wrapped doors and cabinets or had outsourced the manufacturing to other companies.

A total of four Prohibition Notices, thirteen Improvement Notices and seven Voluntary Compliance statements were issued on a broad range of matters including not providing an air supplied respirator, no breathing air quality testing, incorrect spray booth construction, insufficient spray booth air flows, inadequate spray booth design for the spray application, inadequate spray booth maintenance, inadequate (non-English) labelling of spray booth controls, no health surveillance for operators potentially exposed to isocyanates and inadequate hazardous substances registers.

It was found that almost without exception employers readily accepted the compliance issues identified in their workplaces and were happy to implement the required controls, primarily because they had been forewarned by the letters about WorkSafe's expectations in relation to the spraying of the isocyanate based adhesive.

CONCLUSIONS

The intervention in this relatively small Victorian industry was considered highly successful and resulted in:

- the upgrading of all importers and suppliers MSDS and labels for the isocyanate based adhesives to required regulatory standards;
- the provision of necessary health and safety information (through the MSDS and container labels) to all users of the two pack isocyanate containing adhesives;
- most Victorian manufacturers of vinyl wrapped doors and cabinets modifying their practices so that they are now using adhesives that are not classified as hazardous substances or dangerous goods;

- four of the larger manufacturers of vinyl wrapped doors and cabinets continuing to spray the two pack isocyanate containing adhesive but all are now using the necessary risk control measures to ensure that their workers should not be at risk of developing occupational asthma; and,
- advising the relevant interstate health and safety authorities of the outcomes of the program as the health risks associated with the spraying of this adhesive in this industry had not previously been recognised to the best of the authors knowledge.

WHAT PARAMETERS ADVERSELY IMPACT LUNG FUNCTION OF WORKERS EXPOSED TO RESPIRABLE CRYSTALLINE SILICA?

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KEYWORDS

Silica exposure, Lung function, Exposure assessment

ABSTRACT

The findings from this study and others presented in the literature indicate that the current exposure standard is not adequate to protect workers respiratory health. The results of electron micrographs show that particle size and shape of the crystalline silica particles that some workers are exposed to relate to the sampling efficiency curve for respirable dust.

The recently introduced ISO13138 (2012) "Sampling conventions for airborne particle deposition in the human respiratory system", presents new particle size conventions for sub-micron particles that can reach the alveolar part of the lung by deposition. The conventional method AS2985-2009 refers mainly, to particles, with a theoretical median aerodynamic diameter of 4.25 µm that can reach the lung by penetration. In the current study particles both smaller and larger than 4.25 µm were measured in accordance with AS2985-2009.

A weakness of the AS2985-2009 standard however, is that sampling larger particles may not provide an accurate estimate of risk where particles less that 2 µm are considered to be much more hazardous. In this study it is also suggested that the particle shape (morphology) is a key factor which warrants further investigation when assessing the impact particles have on the lung.

The main aim of this study is to assess exposure and what impact exposure has on lung function for quarry workers in Queensland.

The exposure assessment presented in this study will evaluate the risk of exposure to RCS and contributing factors including Exposure profile; Particle size distribution; and Morphology.

INTRODUCTION

A number of studies have demonstrated that there is indeed a loss of lung function for quarry and stone workers as a result of exposure to respirable crystalline silica (RCS) (Ghotkar et, al 1995, Ulvestad et al, 2001, Glass et, al 2003). In Queensland, the Mining and Quarrying Act (2000) and Regulation (2001) place the obligation on the Site Senior Executive (SSE) to assess risks and ensure that appropriate control measures are in place to reduce respirable crystalline silica (RCS) exposures to acceptable levels. A survey sent to small mines and quarries in Queensland found that many sites were unaware of the hazards of silica exposure and many did not conduct ongoing health surveillance as required by legislation (DEEDI 2009). In a project being undertaken collaboratively between the University of Western Sydney (UWS) and Queensland Department of Mines and Energy (DME), monitoring has been conducted to assess the risk of silica exposure in quarries, dimension stone mines and a silica sand mining / processing operation. Hedges et al, (2010) previously reported that 34% of air samples monitored in Queensland quarries exceeded the shift adjusted

Safe Work Australia Exposure Standard (ES) for silica of 0.1 mg/m^3. They also reported that lung function testing showed a correlation between predicted forced vital capacity (FVC) and respirable crystalline silica exposure, with higher exposures associated with reduced lung function. Hedges et al (2011) demonstrated that 8 of 13 similar exposure groups (SEG) pooled across 8 operations including quarries, a stone forming mine and sand processing site, exceeded the Safe Work Australia Exposure Standard (TWA) for respirable crystalline silica of 0.1 mg/m^3. Most of the SEGs were shown to have a log-normal distribution, which indicated representative exposures typical for these activities. A correlation was also indicated between loss of lung function measured as FEV1 % of predicted when plotted against both average and maximum exposure at concentrations around the exposure standard (Hedges et al, 2011)

The aim of this study was to reassess previous exposures in conjunction with more recent monitoring data and lung function testing.

This paper presents the results of additional statistical analysis to better understand the correlation between RCS exposure and loss of lung function for Queensland quarry workers at RCS concentrations around 0.1 mg/m^3 which is the Safe Work Australia 8-hr exposure standard.

METHODOLOGY

Respirable crystalline silica (RCS)

Personal exposure monitoring was carried out on 47 workers across 9 quarries, including dimension stone and sand processing operations. Personal samples were collected according to AS2985-2009 using a SKC cyclone sampling head attached to a sampling pump at a flow rate of 2.2 (±5%) L/min using SKC AirCheck 2000 Model 210-2002 sampling pumps.

The pumps were calibrated using a TSI 4100 series (Serial No.4146 0629 001) mass flow meter. The TSI secondary flow-meter was calibrated against a primary soap film flow-meter as per appendix B of AS2985-2009. A correction factor was calculated and all sampling volumes were adjusted to align with the primary standard.

The dust samples were collected on SKC GLA-5000 PVC 25mm 5 µm pore size filters. The analysis of samples for respirable silica was undertaken at the Simtars (Safety in mines testing and research station) laboratories in Queensland in accordance with the method published by National Health and Medical Research Council in their document "Methods for Measurement of Quartz in Respirable Dust by Infrared Spectroscopy" NH&MRC (1994).

Exposure standards for respirable dust and respirable silica were adjusted applying the Brief and Scala model using the average weekly hours adjustment equation as recommended by Safe Work Australia (2012):

$$RF = \frac{40}{h} * \frac{168 - h}{128}$$

Where: h = average hours worked per week over full roster cycle.

Lung function testing (spirometry)

Lung function testing was undertaken using an Easyone® spirometer (Model 2001, Serial No 66033/2008). The method used followed the method described by Brusaco, Crapo and Viegi cited by Miller et al, (2005). The spirometer prediction parameter was set on NHANES III, the system interpretation was GOLD/Hardie, and the best value result was used for interpretation. The parameters measured and recorded included:

- FEV1 (Forced Expired Volume in 1 Second) measured in Litres, which is the volume of air exhaled in the 1st second.
- FVC (Forced Vital Capacity) measured in Litres, which is the total amount of air exhaled.
- FEV1/FVC is the ratio of the two measures (%) and provides an indication of airflow obstruction.

Fibre characterisation by scanning electron microscopy (SEM) with elemental analysis by energy dispersive spectroscopy (EDS).

The filter samples which were initially analysed for RCS sample were sent to Microanalysis Australia for a more detailed analysis. A representative sub-sample, of approximately 6 mm by 6 mm, was cut from each filter membrane close to the centre. The sub-sample was placed on top of a double sided carbon tab before being carbon coated. The sample was analysed using a JEOL 5800LV scanning electron microscope (SEM) fitted with an Oxford INCA energy dispersive spectrometer (EDS). EDS is a semi-quantitative technique on prepared, optically flat samples which has a spatial resolution of ~5 µm. This means that spectra from particles less than ~5 µm may contain elemental concentrations biased by their surroundings.

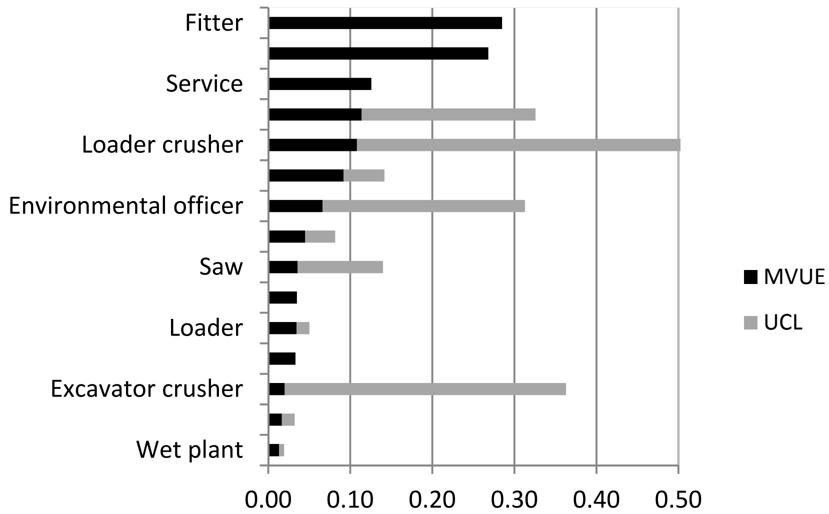
All images were acquired using measuring backscatter electrons. Image brightness is proportional to average atomic number: the brighter the pixel, the higher the atomic number of the element. Images were taken of each sub-sample and the particles present analysed for their elemental composition and size. When the particles were not spherical, the largest dimension was determined.

RESULTS

Respirable crystalline silica (RCS) exposures

Results from personal exposure monitoring, show that many sites have respirable crystalline silica exposures, exceeding the Safe Work Australia Exposure Standard of 0.1 mg/m^3 (Figure 1).

Figure 1. MVUE estimated average concentrations of respirable crystalline silica, as measured in the breathing zone of workers. These are the worker exposure levels if respiratory protective equipment is not used.



Respirable crystalline silica mg/m³ estimated average (MVUE) for each similar exposure group (SEG).

Note: MVUE: Estimated average of a log-normally distributed data set.
UCL: Upper confidence limit (lands exact) of a log-normally distributed data set.

When exposures were pooled for each similar exposure group (SEG) the exposure distributions were found to be log-normally distributed. When the upper confidence limit UCL (Lands exact) was calculated for each SEG and compared with the occupational exposure limit, 9 of the 15 job types had an upper confidence limit that exceeded the OEL, which means that these exposures are considered unacceptable unless respiratory protective equipment (RPE) is used.

Respirable crystalline silica (RCS) exposures vs loss of lung function.

To obtain a clearer picture of the potential risk of RCS to health, further analysis was undertaken to better define the exposure profile by calculating the minimum variance unbiased estimate (MVUE) for each SEG (Figure 2) which was compared with the loss of lung function measured as FEV1 % of predicted and FEV1/FVC % of predicted (Figure 3).

Figure 2: Estimated (MVUE) full shift exposures pooled for each SEG correlated with lung function measured as FEV 1 % of predicted (p<0.05 as confirmed by the Kolmogorov goodness of fit test).

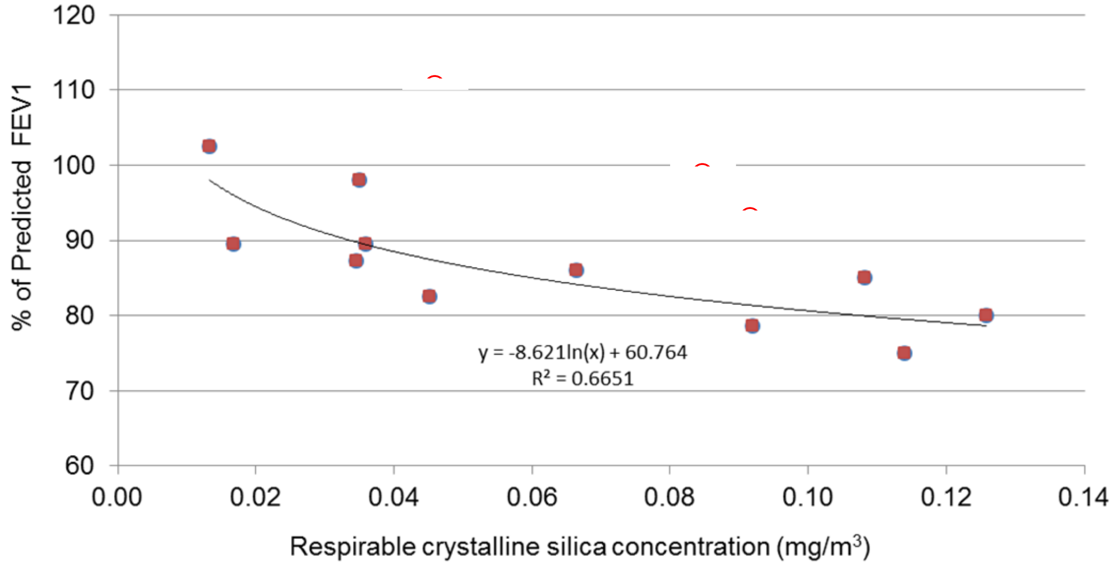
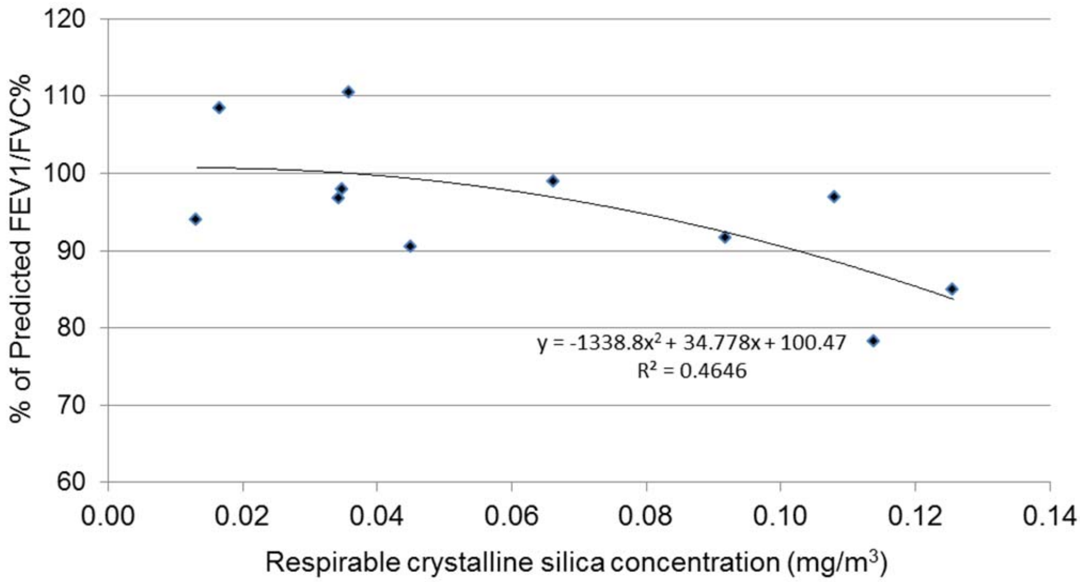


Figure 3. Correlation between % of predicted FEV1/FVC and minimum variance unbiased estimate (MVUE) full shift exposures pooled for each SEG.



Figures 2 and 3 demonstrate the relationship between respirable crystalline silica exposure and loss of lung function. Although the analysis shows a positive correlation it is not a linear function. In Figure 2 the correlation is a natural log function whereas in Figure 3 it is a polynomial function.

According to Townsend et al (2011), "FEV1/FVC is the first measurement to be evaluated to distinguish obstructive from non- obstructive patterns. When the FEV1/FEVC and FEV1 are both less than the lower limit of normal (LLN), airways obstruction is present" (Townsend et al, 2011, p.578).

The FEV1 % of predicted is generally used to grade severity in patients with obstructive, restrictive and mixed pulmonary defects. Pellegrino et al (2005) provided data which can be used to rate the level of severity (Table 1).

Table 1: Severity of any spirometric abnormality based on the forced expiratory volume in one second (FEV1). (From Pellegrino et al, 2005, p.957).

Degree of severity	FEV1 % of predicted
Mild	> 70#
Moderate	60 - 69
Moderately severe	50 - 59
Severe	35 - 49
Very severe	< 35

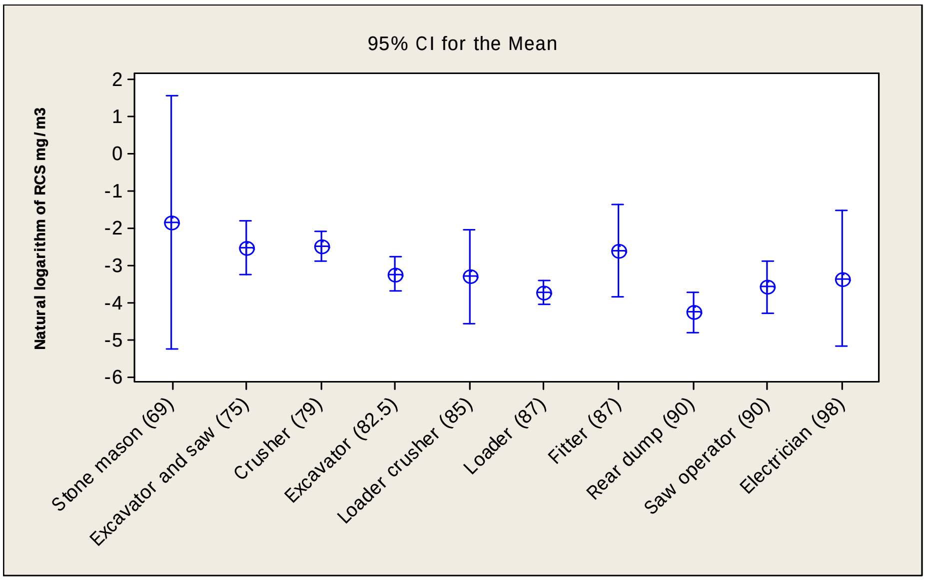
note: # see discussion on what is considered lower limit of normal (LLN).

7 of the 45 (16%) of workers tested for lung function had an FEV1 % of predicted that falls within the category of moderate severity shown in table 1.

Analysis of variance (ANOVA).

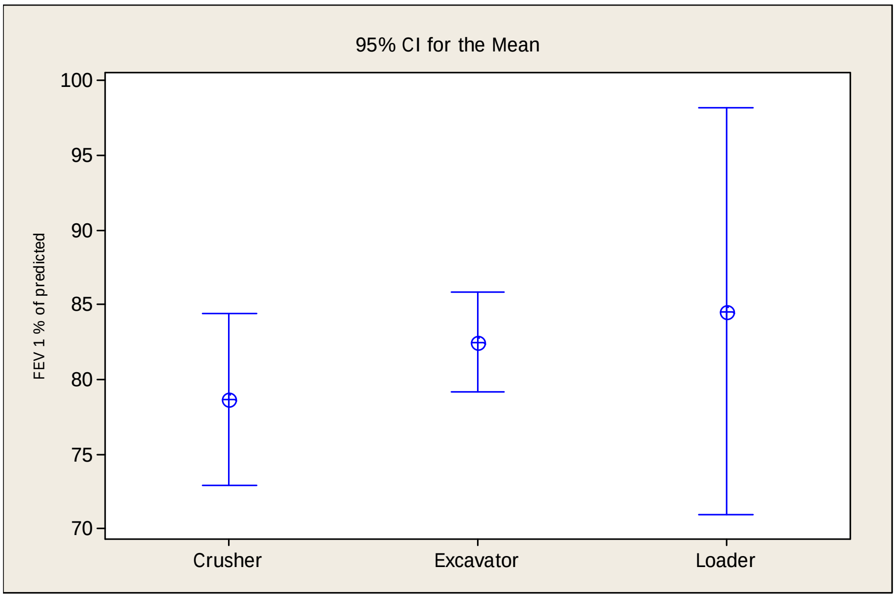
To validate if there is a significant difference between exposures of similar exposure groups (SEGs) to RCS, natural log (LN) transformed mean confidence intervals were calculated and compared (Figure 4) using Minitab.

Figure 4: Natural log transformed values comparing arithmetic means and 95 confidence intervals for each similar exposure group RCS exposure. The number in brackets is the average maximum FEV1 % of predicted.



The average RCS concentrations differed between SEGs specifically for the crusher operator, excavator operator and loader operator as shown in figure 4. When additional analysis was carried out to determine confidence intervals around the mean FEV1 % of predicted, there was no significant difference, as shown in Figure 5.

Figure 5: Average maximum FEV1 % of predicted and confidence intervals for the crusher, excavator and loader operators.



To validate whether there is a real difference in RCS exposure between SEGs, analysis of variance (ANOVA) was undertaken for all measured exposures. The analysis demonstrated that there was a significant difference (p=0.0007, df=9) between all SEGs for RCS exposure. A further analysis for 3 SEGs, crusher, excavator and loader showed a stronger significant difference (p=0.0005, df=2) between exposures.

The ANOVA analysis of the FEV1 % of predicted did not show a similar significant (0.824, df=2) difference between SEGs but there does appear to be a marked difference between the crusher and the excavator (0.069, df=2)

Particle size distributions.

To determine what particle sizes were predominant in the respirable dust samples, particle size analysis was conducted (Tables 2, 3 and Figure 6). The distribution of particle sizes in the samples was also determined (Table 3 and Figure 6).

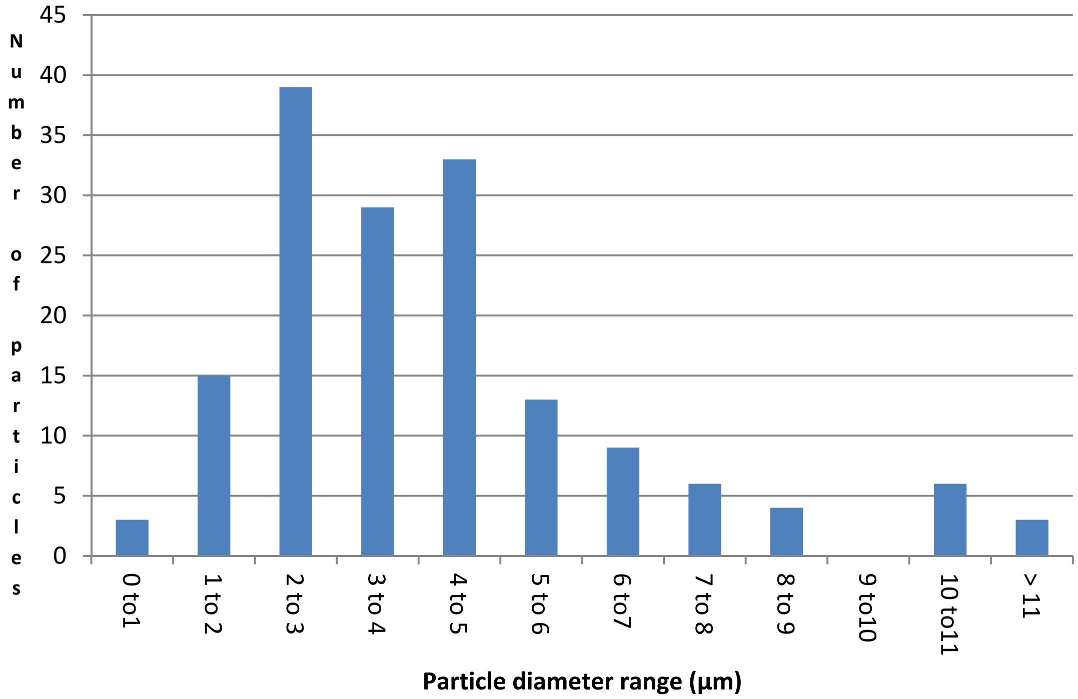
Table 2: Median diameter for each sample and distribution of particle diameters as determined by SEM.

Filter number	SEM median diameter	Distribution of particles
F 6727	3.6	Normal
F 6725	3.1	Log normal and normal
F 6348	4.0	Log normal and normal
F5225	3.2	Log normal and normal
F5243	2.8	Log normal
F5007	4.3	Log normal
F5137	4.4	Log normal
F6439	4.1	Log normal
F4999	2.8	Log normal

Table 3: Summary of particle size analysis.

Number of counts	165
Number of filter samples	9
Maximum diameter (μm)	22
Minimum diameter (μm)	0.6
Geometric mean (μm)	3.8
Geometric standard deviation	1.76
Median (μm)	3.9

Figure 6: Distribution of particle diameters in respirable dust samples



Morphology.

To get a better understanding of particle morphology, micrographs of the dust samples were examined. One sample (Figure 5) showed particles with irregular morphology whereas another sample (Figure 6) showed elongated particles resembling fibrous minerals.

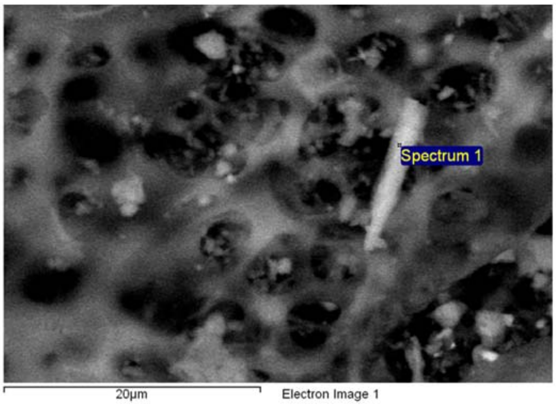


Figure 7. Micrograph showing particles with irregular morphology

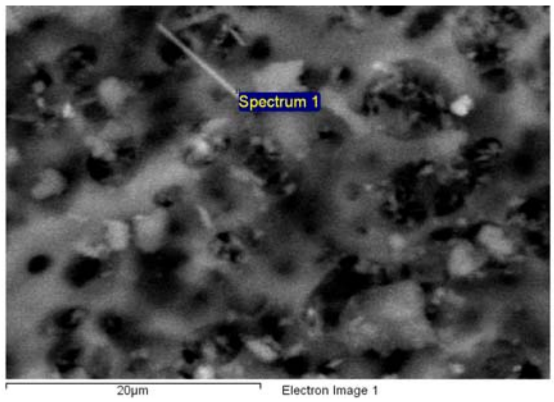


Figure 8. Micrograph showing elongated particles resembling fibrous minerals

Two micrographs (Figures 7 and 8) showed anomalies in morphology. Further investigation is required to characterise and identify the source of this fibrous mineral.

The filters examined for the other samples resembled more regular morphology.

DISCUSSION

Risk Profile

A correlation of the results in this study has demonstrated a loss of lung function even at exposures near or at the current exposure standard for RCS. More data collection with follow-up statistical analysis will add power to this study. The results of this study show the importance of the use of lung function measurement (spirometry) in prompting the implementation of appropriate control measures to assist in the prevention of the progression of lung disease resulting from RCS exposure. In this study, of the 45 workers tested for lung function, 3 were found to have restrictive lung function patterns and 10 had obstructive lung function patterns. It is important to note that the majority of workers monitored were smokers.

The correlation between forced expiratory volume in one second as a percentage of predicted (FEV1 % of predicted) and FEV1/FVC as a percentage of predicted and RCS exposure (Figures 2 & 3) has been demonstrated ($p<0.05$), showing that there is a downward trend in lung function performance in relation to higher RCS exposures. This data however, can only be interpreted collectively as a trend has been established across all of the SEGs. Analysis of variance (ANOVA) has demonstrated a level of variance that is not significantly different between SEGs for FEV 1% of predicted. Albeit, ANOVA carried out between the crusher and excavators FEV 1% of predicted, demonstrates that the difference between these similar exposure groups (SEGs) are close to being significant ($p = 0.069$). Carrying out more lung function testing for different workers across these SEGs will increase the sample number and therefore increase the power of this study.

Townsend et al (2011) recommended health surveillance where exposure to respirable crystalline silica is > 0.05 mg/m^3. Townsend et al (2011) further noted that, as specified in the OSHA Special Emphasis Program (OSHA, 2008), components of the surveillance evaluation should include:

- Occupational and medical history (questionnaire)
- Physical examination
- Purified protein derivative (PPD) tuberculin skin test
- Chest radiography
- Spirometry

In OSHA (2008) there is also a recommendation that a respiratory questionnaire should be included in any health surveillance program, and the authors agree with that position based on the data reported in the current study.

The test results from the current study show that 13 workers have an abnormal lung function pattern. A restrictive lung function test result may indicate interstitial lung disease that includes silicosis. Although changes in lung function may not be seen in simple silicosis, changes in lung function are likely to occur in workers who have been exposed to intense levels or excursions of airborne dust. Spirometry can indicate that further investigation is warranted and that the worker may be exposed to elevated airborne concentrations of airborne respirable dust and crystalline silica prompting the need for urgent control.

Although an arbitrary general lower limit of normal (LLN) is used at 80% of the predicted value, The American College of Occupational and Environmental Medicine (ACOEM) recommends that this should not be used in an occupational health setting (Townsend et al, 2011). Using 80% of predicted as a lower limit of normal is considered acceptable for children, but can lead to errors when interpreting lung function in adults (Pellegrino, 2005). Townsend et al (2011) have also recommended that there should be increased attention to the interpretation of lung function over time or longitudinally. Nevertheless, Figures 1 and 2 do show a decline in lung function with low level exposure to RCS at concentrations close to the current Safe Work Australia exposure standard. In addition 7 of the 45 (16%) of workers monitored had an FEV1 % of predicted that falls within the category of moderate severity (Table 1).

Further follow-up, including assessment of chest x-rays by trained "B" readers for the workers in this study may strengthen the findings.

Health surveillance that includes dust monitoring of quarry workers over time (longitudinally) will add to the weight of evidence that their respiratory health is being impacted by exposure to RCS.

Particle size distribution

The median maximum physical diameter was found to be 3.9 µm as shown in Table 3, which is close to the theoretical median aerodynamic diameter of 4.25 µm provided in AS 2985 -2009. The geometric standard deviation of 1.76 µm is also close to the theoretical size reported as 1.5 µm. The equivalent aerodynamic diameter incorporates stokes diameter and density in the algorithm. The aerodynamic diameter for all particles greater than 0.5 µm can be approximated using the equation.

$$dpa = dps\sqrt{Pp}$$

Where dpa = Aerodynamic diameter µm
dps = stokes diameter µm
Pp = particle density, gm/cm^2

The stokes diameter is assumed to be the same diameter as the physical diameter and since α-quartz has a density of 2.65, this means that a diameter of 3.9 µm equates to an aerodynamic diameter of 6.3 µm for pure quartz. As the amount of α-quartz in respirable is much lower than 100%, the true median aerodynamic diameter will be somewhere between 3.9 µm and 6.3 µm.

The true aerodynamic diameter can only be determined if the density of the material is known. As the median physical diameter determined of 3.9 µm is close to the theoretical aerodynamic diameter of 4.25 µm it is likely that the actual density of respirable dust is close to 1.

A recent development discussed in ISO 13138 (2012), is that the conventional design of a cyclone is based on particle penetration and does not incorporate deposition. As the sampling and analysis using a cyclone is mass based and the median cut is 4.25µm, sampling the larger particles may not provide an accurate estimate of risk where particles less that 2 µm are considered to be much more hazardous.

The pathogenicity of silica dust is thought to be dependent on particle size, with the most fibrogenic size of quartz dust particles in lung tissue reported to be 1 – 2 µm (IARC, 1986). As most particles identified and measured by SEM had a diameter of 2 µm in this study, then the observed loss of lung function indicative of obstructive and restrictive lung disease would be expected. The current sampling methodology AS2985-2009, includes sampling larger particles, inclusive of those greater than 3 µm. This means that because analysis is mass based, these larger particles will provide a greater contribution to the overall analysis and therefore provide an inaccurate assessment of risk.

Morphology

An unexpected finding was the identification of particles that had needle-like morphology. Further investigation is required to characterise the shape, size and mineral content of these particles, and to determine if certain particle shapes results in frustrated phagocytosis more than others. It is considered likely that the combination of size, shape and mineral content of RCS particles, rather than size alone, might lead to increased pathogenicity.

The micrographs of a sample collected from an excavator saw operator, at a stone forming mine, showed that some particles have needle-like morphology (Figures 6 and 7). Champion (2006) cited by Hedges et al (2007) noted that the shape of a particle in the lung, plays a dominant role in the capacity of macrophages to engulf and remove the particle.

The term "frustrated phagocytosis" refers to the inability of a macrophage to fully engulf a particle and remove it from the lung, which can increase the risk of fibrosis. The more elongated the particle, the longer it takes for phagocytosis to occur (Champion, 2006) Where there is longer exposure time for the macrophage to free-radicals from the freshly cleaved quartz crystal the initiation of steps leading to fibrosis is exasperated.

It is therefore proposed that a combination of characteristics results in respirable crystalline silica toxicity, and that morphology must be considered as an important factor. More research is required to investigate this proposition.

CONCLUSION

The data provided in this paper reveal that loss of lung function will occur from exposures to RCS at the Safe Work occupational exposure limit of 0.1 mg/m^3.

It is well known that chronic obstructive pulmonary disease (COPD) can be caused by exposure to RCS and the presence of both obstructive and restrictive lung disease is a significant predictor of earlier death (Mannino et al, 2003).

Spirometry should therefore be an integral part of exposure assessment and health surveillance, and results of spirometry testing should be clearly explained to each worker tested, and managers should be made aware of results without identifying individual workers.

The risk profile evaluated in this study showed a high proportion of workers with restrictive and obstructive lung function patterns of varying severity, and these data serve as a prompt to re-evaluate how worker health and health surveillance should be managed and regulated in mines and quarries.

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DIESEL EXHAUST EMISSIONS - WHAT'S CHANGED

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Callander & Johnson OHS Consultancy Services

ABSTRACT

In June 2012, IARC classified Diesel Exhaust emissions as a Group 1 Human Carcinogen. Diesel fuel is widely used in industry, particularly the mining sector, and hence there is a significant potential for a spectrum of exposures and health risks. This paper will provide a background on changes such as:

- Australian diesel fuel specifications over the past 20 years,
- Vehicle technology changes impacting on occupational exposure to exhaust emissions,
- Poor work practices which cause high DPM exposures and
- DPM exposure standards

The paper has been written to assist occupational hygienists respond to management and workers, through better awareness and understanding of the issues.

ON THE RESURGENCE OF SILICOSIS

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AECOM

ABSTRACT

Silicosis, one of the oldest known occupational diseases, peaked in industrialised countries in the late 19th and early 20th century, but remains prevalent in the developing world. Sadly it has not been eliminated from the developed world; on the contrary, Silicosis is rising in the developing world and resurging within the OECD – primarily, to construction workers. This latter situation appears related to a combination of: lost knowledge - gained at the cost of many lives, changes in tool technology, increased use of subcontractors and ineffective enforcement. In the developing world, rising Silicosis rates are linked to globalisation of the mining industry and novel uses of silica sandblasting, such as manufacturing "distressed" designer jeans. Besides causing pneumoconiosis, Silica causes other organ system damage, predisposes victims to Tuberculosis, and causes bronchial cancer similar to asbestos. The application of proven Occupational Hygiene control measures can reverse this unfortunate trend.

WORKSHOP

INFECTION CONTROL FOR OCCUPATIONAL HYGIENISTS

Irene Wilkinson
SA Health

ABSTRACT

Infectious agents include bacteria, viruses and fungi, and these can be transmitted in a number of ways, either by ingestion, inhalation, by direct or indirect skin contact or by vectors such as insects or rodents. The development of disease depends both on successful transmission of an infective dose and the susceptibility of the host. For the more common infectious diseases, particularly those normally acquired in childhood there are vaccines available to provide immunity, which lowers the risk of acquiring infection dramatically. However, not all infectious agents have an effective vaccine, and some, such as influenza, require an annual vaccination to cover the multiple circulating strains. Influenza is probably one of the most difficult diseases to prevent in the workplace because of the ease of transmission via respiratory droplets and by contact with contaminated surfaces.

The influenza pandemic of 2009, although finally proved to be less severe than predicted, provided health authorities with an opportunity to develop an emergency response to the threat of a serious pandemic, and caused health departments to consider how the community might be affected. Several lessons were learned which have informed the revision of the national and state response strategies.

The pandemic experience also taught us a good deal about how little we really know about the dynamics of infectious disease transmission, and there was no real consensus on the degree of importance of the airborne route of transmission of the influenza virus. This highlighted a much needed gap in the research agenda. In the face of the inability to precisely quantify the hazard, SA Health took a precautionary approach and decided to adopt a respiratory protection program for its healthcare workers. This program and some reflections in hindsight will be presented as a case study.

There are several good resources available to hygienists on the topic of infection prevention. These include the *Wash, Wipe, Cover – don't infect another!* resources developed by the Infection Control Service, the publication *You've Got What?* developed by SA Health's Communicable Disease Control Branch, and the Australian Guidelines for the prevention and control of infection in healthcare. Links to all of these can be found on the SA Health website.

POSTERS

AIRBORNE FUNGAL PROFILES IN OFFICE BUILDINGS IN METROPOLITAN ADELAIDE, SOUTH AUSTRALIA: BACKGROUND LEVELS, DIVERSITY AND SEASONAL VARIATION

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ABSTRACT

Microbial contamination (such as fungi and moulds) of the indoor working environment is an increasingly common OHSW concern. There is a paucity of published survey information in Australian workplace environments under non-complaint or background conditions. This limits the comparisons that can be made against measurements taken in workplaces that have indoor microbial air quality issues. This study **aimed** to obtain profiles of indoor airborne fungi in typical South Australian office environments, including seasonal variation and indoor-outdoor air relationship.

Air monitoring was conducted at representative South Australian indoor office workplaces in order to identify and enumerate fungi (viable) common to indoor work environments. A range of workplaces across metropolitan Adelaide were sampled to ensure buildings were of varying age, usage, geographical distributions, and neighbour proximity and type (industry, residential, commercial, landfill etc). A total of eighteen buildings were assessed between Spring 2011 and Winter 2012, yielding a total of 89 indoor office air samples, and 39 outdoor air samples for the study period. Concurrent measurements of general indoor air quality indicators (temperature, relative humidity, carbon dioxide) were monitored at each sampling location.

The outcomes of this study can be broadly summarised as follows:

- Indoor fungal counts were generally 75% lower than corresponding outdoor samples, with an average spore concentration (CFU/m^3) of 131 (± 120) for indoor environments and 509 (±459) for outdoor environments.
- Indoor and outdoor fungal concentrations in air fluctuated seasonally, with the highest counts obtained in warmer months, Summer and Autumn.
- No single indoor air quality parameter (temperature, relative humidity, carbon dioxide) was strongly correlated with fungal concentration in indoor environments, but weak trends/associations were notable and may be useful measurements when carrying out assessments.
- Similar dominant fungal genera (*Aspergillus*, *Penicillium*, *Cladosporium* and *Alternaria*) were isolated from the majority of workplaces, regardless of their use or location, and broadly mirrored results obtained from outdoor environments.

The outcomes obtained in this study from non-complaint buildings may be beneficial to those involved in interpreting results obtained in IAQ assessments. Information gathered may also help to address lack of empirical data and inform local guidelines on indoor microbial air quality under Australian conditions.

THE ASSOCIATION BETWEEN HEAT EXPOSURE AND WORKERS' INJURIES IN SOUTH AUSTRALIA, 2001-2010

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ABSTRACT

Many ecological studies have revealed that extremely hot weather contributes to excess morbidity and mortality in the community. Extremely hot weather may also place many types of indoor and outdoor manual workers at increasing risk of heat-related illnesses and injuries in the workplace. Prior to 1990s, studies about workplace heat exposure mainly focused on the adverse impacts of process-generated heat in workplaces such as foundries, metal plants, and underground mines. With predicted increasing frequency and intensity of heat waves, weather-related heat exposure is presenting a growing challenge to occupational health and safety.

This paper aims to explore the relationship between heat exposure and workers' injuries in South Australian workplaces, identify which industrial sectors, age groups and occupations are most vulnerable to work-related injuries during extreme heat periods, and summarize which types of illnesses and injuries are most prevalent during extreme heat periods. This was achieved by analyzing historical data about workers' compensation claim data obtained from SafeWork SA and temperature records of metro Adelaide areas (Kent Town) in the period from 1st July 2001 to 30th June 2010.

The original workers compensation claim data was transformed into time series format and merged with meteorological data. The impacts of workplace heat exposure on daily workers' compensation claim rates were assessed by using generalized estimating equation (GEE) model with negative binominal distribution accounting for over-dispersion, a log link function and a first order autocorrelation structure. A piecewise linear spline function with one knot was utilized to handle the issue of non-linearity and quantify the effect of workplace heat exposure below and above threshold temperatures on workers injury. Threshold temperatures were estimated graphically by the method of 31-day moving average, and confirmed quantitatively using the hockey-stick model. For controlling seasonality, the analysis was restricted to the warm period of the year (1 October-31 March). Confounding factors were adjusted, including day of the week and long-term trends.

This poster will summarize the major findings from the historical data analysis. It may provide some evidence-based recommendations for prevention and adaptation strategies of work-related injuries during extreme heat periods.

BASELINE HEAT STRAIN ASSESSMENT USING THERMOMETER PILLS OF AN OUTDOOR WORKFORCE IN NORTHERN AUSTRALIA

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SLR Consulting Australia Pty Ltd

ABSTRACT

SLR Consulting conducted a baseline Heat Strain assessment of the workforce at port facility located in a tropical region of Australia.

Summer temperatures can reach well above 40oC and workers are required to do manual work outdoors.

Representative workers from Similar Exposure Groups (SEGS) were chosen and their body core temperatures monitored during a shift.

The CorTemp® core body temperature monitoring system was utilised for the assessment. This comprised a CorTemp® Ingestible Thermometer Pill and a CorTemp® Data Recorder.

The results indicated some workers in all exposure groups were inadequately controlling their thermal strain, both at work and outside work time.

To reduce risk of heat strain to the workers, it was recommended that the company provide repeated training relating to heat strain, where possible allowances should be made for self pacing of work based on an individual's needs during work activities and mentoring of new workers by experienced workers.

A GUIDE TO THE WHS REGULATIONS FOR THE OCCUPATIONAL HYGIENIST

Shelley Rowett
SafeWork SA

ABSTRACT

A flow diagram poster with descriptions of the Sections of the WHS regulations that are relevant to Occ Hygiene.

Specifically Hazardous Chemicals Exposures and Noise

ACCURACY OF RESPIRABLE DUST SAMPLERS: A FIELD COMPARISON PILOT STUDY

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ABSTRACT

Occupational Hygienists, and the broader Occupational Health and Safety (OH&S) community, rely heavily on the accurate measurement of a worker's exposure to atmospheric contaminants, including respirable dusts. Inaccurate or otherwise unreliable readings can place workers at risk of serious harm.

Within Australia all respirable dust samplers must be calibrated and operated in accordance with Australian Standard AS 2985-2009, with the sampling flow rate defined for the specific size selection device used. It might be presumed then that the measurements obtained by different samplers when operated according to the standard will provide the same results.

Is this the case?

By operating three commonly used respirable dust sampling heads, in accordance with the standard, this field comparison/pilot study tested this theory. The three sampling head types were:

- Aluminium cyclone
- Plastic SIMPED
- IOM (Modified with foam insert)

At a gravel quarry in Melbourne, three [3] sets of three [3] sampling heads were tested over three [3] days and the results analysed.

The data, when analysed using ANOVA (Analysis of Variance) indicates a statistically significant difference between the three sampling heads' capture results.

The key recommendation from this pilot study is the need for further study to confirm, and perhaps quantify this performance difference. The further studies should extend the sampling regimen to include:

- an increased number of sampling days, for better understanding of "operator effect";
- a variety of sampling sites, to allow for extension of the concentration range based statistics, and
- a broader selection of particulate types, to identify possible matrix bias.

Additionally, this study has raised concerns that the modified IOM sampler has significant field based shortcomings and may not be suitable for respirable dust sampling.

HEARING PROTECTION EFFECTIVENESS: A PILOT STUDY USING IN-EAR ATTENUATION MEASUREMENTS

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RMIT University, Melbourne

ABSTRACT

According to Worksafe Victoria [2012], more than 100,000 Victorian workers are exposed to high levels of noise on a daily basis in their workplace, so there is an obvious potential for Noise Induced Hearing loss to continue as an on-going industrial hazard.

In such identified situations the immediate choice of worker protection is Personal Protective Equipment [PPE], and although this is at the lowest end of the Hierarchy of Control, this solution often remains the only available method due to engineering or financial practicality, thus it is essential that this method of protection be used in an optimum manner.

This Pilot study used two [2] workforces to assess the effectiveness of hearing protection, by measuring the actual noise levels within the receipents' ears. The study used the 3M EAR-Fit equipment, and standard issue ear plugs, at two [2] workplaces.

Workplace 1 has a workforce which is expected to use hearing protection on a daily basis, if not continuously, and which had in place an on-going commitment to hearing protection via training on a regular basis, and tool-box topic on a regular basis. This workforce qualifies as a trained workforce.

Workplace 2 has a workforce which has only very casual usage of hearing protection, although working in an area adjacent to high noise levels. This workforce qualifies as an untrained workforce.

Results of testing are reported which indicate a satisfactory level of fit efficiency in the trained workforce, but a total failure of workers in the untrained workforce to satisfactorily fit plugs.

The results clearly indicate that the mere provision of ear plugs, as a preferred form of hearing protection, without on-going training, fit monitoring or a noise awareness campaign, is a totally unsatisfactory situation for an employer to attempt to meet their worker protection requirements.

ASSESSMENT AND CONTROL OF WORKER NOISE EXPOSURE IN THE RE-CYCLING INDUSTRY

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ABSTRACT

With the continued expansion of the re-cycling industry there are several areas which require examination, due to processes and machinery which may contribute significantly to worker noise exposure.

The recycling of glass products has several areas of concern at the sorting, separation, transfer and crushing stages which require more detailed consideration.

In this pilot study, we looked at two [2] Similar Exposure Groups [SEG's] working at a local commercial facility.

SEG 1 comprised workers who manually sorted glass bottles and separated them by colour into a variety of vats. These workers typically had a shift length of 5 – 5.5 hours per day, were trained in noise awareness and wore hearing protection during the activity.

SEG 2 was a pair of workers who functioned as supervisors and transfer/crushing process operators. This Group typically worked an 8 hour day, drove a fork lift, as required.

A site noise map established that the entire site had high noise levels, whenever activity was undertaken.

Personal noise dosimetry, on both SEG's demonstrated significant over-exposure.

The pilot study report features simple engineering control , basic operational procedures and better PPE training and management as some of the approaches which would result in lower worker exposure hazard.