LOOKING FORWARD
LOOKING BACK

2011 AIOH CONFERENCE

3-7 DECEMBER 2011

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CONFERENCE PROCEEDINGS

AIOH
AUSTRALIAN INSTITUTE OF
OCCUPATIONAL HYGIENISTS INC

29th Annual Conference & Exhibition of the
Australian Institute of Occupational Hygienists Inc

3rd to 7th December 2011

Sofitel Brisbane Central
Brisbane, Queensland

2011 CONFERENCE PROCEEDINGS

Editor Simon Worland

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A NOTE FROM THE 2011 AIOH CONFERENCE CHAIR

LOOKING FORWARD LOOKING BACK:
Reflecting on the journey so far, while striving toward the elimination of occupational illness.

Dear occupational hygiene practitioners, researchers, regulators, new hygienists, affiliated professionals, exhibitors, international guests and to all of you striving for a healthier workplace.

It is with great pleasure that, on behalf of the 2011 Conference Committee, I welcome you to the 29th Annual Conference of the Australian Institute of Occupational Hygienists here in Brisbane, the capital city of the Sunshine State, Queensland, where the weather is glorious one day, perfect the next!

Occupational hygiene has evolved and developed, significantly improving working conditions, and enhancing the long term health of workers.

This conference focuses on the achievements of our occupational hygiene pioneers and compares past conditions, practices and exposures with current conditions and methodologies used today. Despite the fact that we need new tools and new skills, the past provides important lessons about what can be achieved and what works and what does not work so well.

The conference has a varied and thought provoking plenary program and a wide range of con-current session papers that provide the latest data and many take home practical solutions. There are 19 continuing educations sessions running over the weekend giving you the opportunity to refresh and advance your knowledge.

The extensive trade exhibition provides first hand experience of the latest in technological advances and professional services for the identification, evaluation and control of the occupational hygiene hazards we face each day at work.

The networking and social activities ranging from our "ask the experts" and “speed networking” sessions to the formal dinner, the legendary 3M night and the AES Welcome Drinks and the Welcome Dinner are wonderful opportunities to maintain and establish your professional networks.

I would like to thank my Conference Committee for all the hard work they have put into bringing this excellent conference to fruition and I thank Council for the support they have given us over the two years this has been in the planning. I thank those organisations who have provided invaluable sponsorship and support to the conference.

So once again Welcome. Thank you for coming. It is your presence and input as a delegate that breathes life into the Conference. I hope you will find the next few days not only scientifically and professionally enriching, but also an enjoyable and lasting memory of your professional development.

Gerard Tiernan
Chairperson
AIOH 2011 Conference Organising Committee

A NOTE FROM THE 2011 AIOH PRESIDENT

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

It is with great pleasure that I welcome you, on behalf of Council, 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 Gerard Tiernan 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, MSA Aust, GCG Health Safety Hygiene, 3M, SEA, Drager Safety Pacific, Active Environmental Solutions, Honeywell and Thermo Fisher.

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

The occupational hygiene profession continues to enjoy substantial growth in Australia 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 Brisbane.

Kind regards
Gary Rhyder
AIOH 2011 President

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 Geza Benke - PhD, M App Sci, GDip Quant Methods, BSc, COH, FAIOH
- Dr Steve Brown - PhD, G Dip Occ HYg, M App Sc, B App Sc (App Chem)
- Dr Joseph Mate - PhD, MSc, BSc(Hons)
- Dr Deb Glass
- Dr Marcus Cattani - PhD and MSc
- Dr Dino Pisaniello - BSc(Hons) MPH PhD, FRACI FAIOH FSIA CIH COH CChem
- Dr David Bromwich - PhD(Griffith), MAppSc(Med.Phys., QIT), MSc(Occ.Hyg, Lond.), BSc(Hons. Physics, Adel.), FAIOH, MARPS, CIH, COH, COC(BERBOH)
- Dr Su Gil Lee - BSEng, MSEng, PhD, KOSOS, ACGIH, BOHS, MAIOH

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. Dr Geza Benke *"When will Australia have its own job exposure matrix (JEM)?"*
2. Lindsey te Brake, Sharyn Gaskin, Dino Pisaniello, John W. Edwards, David Bromwich, Sue Reed and Paul Scheepers, *"Effects of street clothing, sunscreen, and temperature on skin absorption of organophosphate pesticides – a review and case study of diazinon"*
3. Raymond Bott, Katherine Kirk and Michael Logan, *"Fire Fighter exposure to diesel exhaust in QFRS Fire Stations."*
4. Claire Bird and Sita Balshaw, *"Getting the Best Answer by Asking the Right Question – Case Studies in Occupational Exposure to Mould".*

Jacques Oosthuizen, PhD, MAIOH, COH
Chair of Paper Peer Review Panel 2011

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- WorkCover NSW

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- Workplace Health & Safety Queensland

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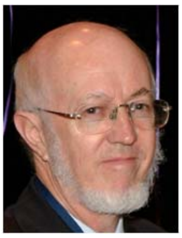

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Enquiries should be directed to the Administration Manager at the AIOH office.

BIOGRAPHICAL NOTES OF THE KEYNOTE & PLENARY SPEAKERS

Amanda Gore

Amanda Gore talks about connections that count, leading with the heart, motivating with laughter, and bringing out the best in people. With today's mergers and cross-cultural workplaces, Amanda stresses the importance of creating corporate communities that bring people together productively and profitably. Her thoughtful and intelligent assessment of what it takes to lead, coach and inspire has distinguished her as one of the world's most sought after experts in her field. Amanda has a background in psychology, physical therapy, group dynamics, neurolinguistics and occupational health. She has worked in corporations, colleges, hospitals and private practice, and has often been interviewed on radio and TV on her areas of expertise. Amanda blends these areas of expertise to connect body, mind and spirit to show people how to become more effective professionally and personally, and to become their real selves — to be authentic.

Dr David Zalk

David M. Zalk, PhD, CIH, is a Past President of the International Occupational Hygiene Association (IOHA) and currently serves as an IOHA envoy to the World Health Organization. He has led numerous national and international committees over the past two decades and is currently Vice President of the Foundation for Occupational Health and Safety. He has authored a book on Control Banding, is a member of the WHO/ILO International Technical Group on Control Banding, and has co-chaired five International Control Banding Workshops. David received his PhD on Control Banding from the Delft University of Technology and has an M.P.H. in Industrial Hygiene from UC Berkeley. David is an EHS Manager for the Site 300 Experimental Test Site at the Lawrence Livermore National Laboratory in California. David remains actively involved in field R&D including: nanomaterial science, metals capture and analysis, decontamination agents, and occupational risk management processes nationally and internationally.

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Alan Rogers

Alan has worked in the field of occupational hygiene for nearly 40 years with government and the private sector. He has been a member of the AIOH since its inauguration in 1980, is a Past President and Fellow. He has a Master of Science in Occupational Hygiene from the London School of Hygiene and Tropical Medicine, and is a CIH and a COH. He holds the honorary position of Visiting Fellow at the University of Wollongong lecturing in the Occupational Hygiene courses. For his achievements he has been awarded the Pam de Silva medal from the AIOH and the Yant Award from the American Industrial Hygiene Association. He currently runs his own consultancy business providing advice to industry associations and major corporations. Alan is recognised as a world authority on asbestos and mineral fibres and has major involvement in measuring and controlling respirable silica and diesel particulate in the mining sector.

Dr Doug Boreham

Dr Doug Boreham currently is a Professor in the Department of Medical Physics and Applied Radiation Sciences at McMaster University (2000-Present). He was an undergraduate of Laurentian University and earned his Ph.D. from the University of Ottawa in 1990. Before joining McMaster University, Dr. Boreham spent 14 years as a radiobiology research scientist at Atomic Energy of Canada Limited. Currently, Dr. Boreham conducts research in four state-of-the-art Radiation Biology Laboratories at McMaster University including one in which he built a multi-million dollar biological microbeam for irradiating cells with single atoms. He supervises undergraduate, graduate and post-doctoral students, has published over seventy peer reviewed scientific manuscripts, and has attracted over $9 million in research support and funding since joining McMaster University. His most recent grant ($1.2M) from the US DOE was to study life-time cancer risk associated with diagnostic radiation. His research interests include understanding the health effects of low dose radiation exposure and inducible DNA repair processes. Dr. Boreham has published research on low doses of ionizing radiation and the anti-carcinogenic processes induced at low doses. He has been an invited speaker around the world and been featured on television and radio broadcasts including CBC Passionate Eye – "Radiation Roulette", The Discovery Channel "Curious and Unusual Deaths", The Nature of Things "Nuclear Neighbors" and CBC Radio-One. Dr. Boreham has won several teaching awards including McMaster Students Union Teaching Award, McMaster President's Award for Excellence in Instruction, Canadian Nuclear Society - Canadian Nuclear Achievement Award for Education and Communications, McMaster President's Award for Course Design, the Hamilton Spectator Publisher's Award for Education, and recently received the Canadian Radiation Protection Association – 2009 Distinguished Achievement Award in Recognition of Outstanding Contributions in the Field of Radiation Protection. In 2010 he was awarded the Radiation Research Society – 2010 Mentor of the Year Award for Scholars in Training. In 2011 he was voted "Professor of the Semester in Life Sciences" by 800 first year biology students. Over the past four years, Dr. Boreham has also been working for Bruce Power, a large nuclear power company, and involved in 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.

Kevin Knight AM

Kevin W Knight is well known through his very active work in explaining and encouraging the use of Standards with respect to the management of risk. He is a founding member of the Standards Australia/Standards New Zealand Joint Technical Committee that produced the original AS/NZS 4360 Risk Management Standard in 1995 and its subsequent revisions in 1999 and 2004. Kevin was Convenor of the International Organisation for Standardisation (ISO) Working Group that produced ISO/IEC Guide 73:2002 – RM Terminology and he Chaired the ISO Working Group that developed ISO 31000:2009 Risk Management — Principles and Guidelines and the revised ISO Guide 73:2009 Risk Management Vocabulary published in November 2009. He currently Chairs the Project Committee on risk management established by ISO in February 2011.

Kevin has been very active in furthering the risk management profession and the professional development of its practitioners throughout the Asia - Pacific Region in particular, as well as globally over the past 30 years. He has been widely published and quoted by the risk management media throughout the world as a leading proponent of the management of risk. He has presented papers, lectures, seminars and workshops on the application of Standards to the management of risk in some 27 countries in addition to his extensive activities in Australia and New Zealand.

His work was recognised by his peers in 1996 when the International Federation of Risk & Insurance Management Associations Board presented him with an award in recognition and appreciation for outstanding contributions and leadership to IFRIMA and the Association of Risk & Insurance Managers of Australasia at its Annual General Meeting elected him an Honorary Life Member. The Australasian Institute of Risk Management Annual General Meeting in 2000 elected him as an Honorary Fellow.

He was the 2001 Asian Risk Manager of the Year. The citation accompanying the award noted his "long-term commitment to the development of robust corporate cultures committed to strong risk management practices and procedures".

In 2003, he was the recipient of the Standards Australia Outstanding Service Award (Committee Member) in recognition of his "contribution to the development of Australian and International Standards for risk management, for the ultimate benefit of the Australian community".

He was appointed a Member in the General Division of the Order of Australia in 2008 "for service to risk management through executive roles with professional associations and as a contributor to the development of principles and practices".

Kevin was included in the US Treasury & Risk's Magazine 2008 list of the 100 most influential people leaving their marks on the world of finance for his International Standards work.

Garry Gately

Garry holds degrees in Chemistry (Applied Chemistry and Advanced Analytical Chemistry) and has worked in chemical related industries and roles since 1971. He has worked in a diverse range of industries that has included pharmaceuticals, agrichemicals, petrochemicals, plastics, water chemistry, mining chemicals, explosives, power generation, timber processing and tertiary education.

Since 1981 he has worked as a professional occupational hygienist with Orica (formally ICI Australia) and since 2001 has also been the Orica Corporate Safety, Health & Environment Lead Auditor. In this role he has conducted more than 350 audits as Lead Auditor. As the Corporate Lead SH&E Auditor Garry also conducts formal risk assessments in factories in many countries.

Working for a large multi-national Garry has had the opportunity to see first-hand the EHS issues in many parts of the World and has had to develop practical solutions to fit the circumstances.

Garry is a Fellow of the Australian Institute of Occupational Hygienists and is a Certified Occupational Hygienist in both Australia (AIOH) and the USA (ABIH).

Dr Sharann Johnson

Sharann has over 25 years of experience working in occupational health and safety. She completed a PhD in Chemistry at Monash University and the Sydney University course in occupational hygiene.

She joined BP Australia in the manufacturing division and soon became their corporate hygienist working in the downstream oil activities as well as chemicals and mining sectors. Sharann was seconded to London to work for BP Oil International in the Group Health, Safety and Environment team to lead on Product Stewardship and Occupational Health initiatives. She returned to Australia to become the Health, Safety and Environment Manager for two of BP's international businesses. Since leaving BP, Sharann has worked in the mining sector for Newcrest and Zinifex managing their occupational health function.

Sharann has participated in a number of national and State OHS working committees including the National Occupational Health & Safety Committee, Hazardous Substances Working Group and has co-authored a book on the management of hazardous chemicals for the mining industry.

Sharann is a founding member and now a Fellow of the Australian Institute of Occupational Hygienists. She has served on the Council on several occasions and was the President in 2009.

Currently, Sharann manages her own OHS consulting company and advises several mining companies and government departments on occupational health and product stewardship issues.

Dr Michael Donoghue

Michael is representing the Australian Aluminium Council's Health Panel in his presentation. The Australian Aluminium Council is the peak body representing the aluminium industry in Australia. The Council's members include companies operating in bauxite mining, alumina refining, aluminium metal production, semi-fabricated aluminium production and distribution.

Michael is also the Director of Health and Chief Medical Officer of Alcoa of Australia, based at the corporate office in Perth. Alcoa of Australia operates bauxite mines and alumina refineries in Western Australia and aluminium smelters in Victoria.

Michael is a Fellow of the Faculty of Occupational Medicine of the Royal College of Physicians of London and a Fellow of the Australasian Faculty of Occupational and Environmental Medicine of the Royal Australasian College of Physicians. His professional experience and research has focussed on occupational and environmental health in mining and minerals processing. His PhD was on heat exhaustion in mining. He is a member of the International Aluminium Institute's Health Committee.

Dr John (Jack) Parker

Jack Parker is Professor of Medicine, West Virginia University, Morgantown, and Professor of Community Medicine, Institute of Occupational and Environmental Medicine, West Virginia University, Morgantown, and Chief, Section of Pulmonary and Critical Care Medicine, West Virginia University, Morgantown.

He is Attending Physician and Medical Director Sleep Disorders Clinic, West Virginia University Medical Center Morgantown, West Virginia and Medical Director Pulmonary Rehabilitation Mountain View Regional Rehabilitation Hospital, Morgantown, West Virginia.

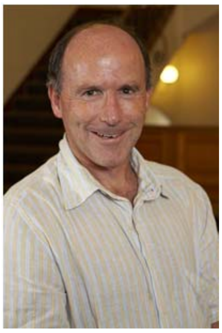
Dr Parker received a B.A., Chemistry from Oakland University, Rochester, Michigan, and received his MD at Wayne State University, School of Medicine, Detroit, Michigan. He completed his Fellowship in Pulmonary Diseases at the National Institute for Occupational Safety and Health and West Virginia University Health Sciences Center in Morgantown. He is a specialist in Internal Medicine and in Pulmonary Disease. He is a NIOSH B Reader for chest radiographs for pneumoconioses.

He has received the US Surgeon General's Exemplary Service Outstanding Service Medal and Commendation Medal.

He is a member of the American College of Physicians, American College of Chest Physicians, American Thoracic Society, West Virginia Thoracic Society, New York Academy of Sciences, American Public Health Association, West Virginia Public Health Association, Association of Occupational and Environmental Clinics, National Rural Health Association, International Society for Respiratory Protection, Association of Military Surgeons of the United States and West Virginia Medical Association.

His research interests include respiratory protection, pneumoconioses prevention, silica related respiratory diseases, chest imaging techniques and dust related diseases, organic dust and immunologic lung disease. He has been an invited peer reviewer for journals in industrial medicine, industrial hygiene, respiratory protection, epidemiology, agricultural safety and health and occupational and environmental medicine.

Dr Tim Driscoll



Associate Professor Driscoll is an Occupational Physician who specialises in epidemiology, particularly surveillance, data systems, burden of disease and occupational cancer. He works in the Sydney School of Public Health at the University of Sydney. His research interests include the surveillance and prevention of chronic diseases in the workplace.

Martin Roff

Martin Roff has worked at the UK Health and Safety Executive's research laboratories for over 30 years on a variety of innovative projects in workplace protection. His varied fields of research over those years have included breathing simulator designs, measurement of human breathing patterns during exercise, surface electrical charge measurement, and a novel visualisation technique for detecting and measuring skin contamination from chemicals such as pesticides in-situ (i.e. without need for recovery from the skin).

Martin has been a UK representative on international expert standards committees for filtering facepiece performance, dermal exposure measurement and surface monitoring methods. His current fields of interest are surface and dermal measurement, effectiveness of decontamination, and safe undressing procedures. He has contributed to the understanding of dermal exposure pathways and measurement processes. He is active in developing new monitoring methods, especially for in-situ monitoring of contamination.

PROCEEDINGS INDEX

Poster Papers

Looking Back, Moving Forward: Lessons learnt from Accreditation of Post Graduate Occupational Hygiene Courses

Jane L. Whitelaw[1] & Sue Reed[2]
[1]University of Wollongong [2]University of Western Sydney & Edith Cowan University

Keywords

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

Introduction

For many years AIOH has had a systematic method for reviewing and accrediting post graduate Occupational Hygiene Courses. Applying institutions would submit a range of course documentation which was then reviewed by a panel under the auspices of the Education Committee. During 2010, the Education Committee developed a set of Learning Outcomes (LO's) for Universities applying for accreditation to map their course against prior to applying. Whilst the system in place has served AIOH well and produced good Graduate outcomes; the inclusion of LO's will enable a more transparent and objective evaluation of courses.

In a recent study trip; the system for Course Accreditation in the United States was reviewed and their findings will be compared against the system Australia (AIOH) has in place.

This paper provides an important opportunity to look back and learn from organisations who have a more mature system than ours, to ensure the future of our profession by producing good Occupational Hygiene Practitioners and Full and active members of AIOH.

History of Occupational Hygiene Course Accreditation in Australia

Over twenty years ago, AIOH recognised the need to accredit Occupational Hygiene Courses that would meet the academic criteria for Provisional and Full membership of the Institute. The other components required for Full membership include: appropriate work experience, submission of suitable reports on work undertaken in the field of occupational hygiene and references provided by two Full Members which will not be discussed in this paper.

At that time, when a University applied for accreditation, Council reviewed the course content and assessment methods to determine if they met their agreed standard across the full range of comprehensive occupational hygiene practice (OHP).

The Deakin Universities Graduate Diploma in Occupational Hygiene was the first course to receive accreditation in 1988. Subsequent reviews at five year intervals have seen the course maintain its accreditation for over twenty years. It is currently offered as a two year part time course in an off campus mode.

In 2009, the University of Wollongong (UOW) applied for and obtained accreditation for its Master of Science – Occupational Hygiene Practice which is delivered in a flyin-flyout block mode; combining intensive lectures and practicals with online support. AIOH procedures required UOW to submit program documentation and all course materials which were subject to intensive review by the Education Committee. A site visit by a member of the Education Committee and President Elect confirmed that adequate facilities and equipment were available to deliver the course. The entire process took over six months and a review raised some opportunities to streamline the process, whilst ensuring that the rigour was maintained.

Following the application by UOW the AIOH Council requested the Education Committee to develop a timeline and revise the procedures for evaluation of future applications for accreditation. A review of accreditation procedures from other organisations, such as the British Occupational Hygiene Society (BOHS) the Institution of Occupational Safety and Health (IOSH) was conducted. The IOSH system of clearly defined learning outcomes (which the University maps their graduate outcomes against) was used as a model for the development of the AIOH policy incorporating both the process and graduate outcomes.

AIOH Development of Course Learning Outcomes

The AIOH Policy and Procedure for Accreditation of Occupational Hygiene Courses was developed over 2010-11 and was recently endorsed by council. Initially a workshop was held with members of education committee, including representatives of accredited courses, President and President Elect of AIOH and the Chair of the Membership and Qualifications Committee to scope the knowledge areas and delegate teams to develop specific learning outcomes for each area. These were then reviewed by the whole education committee, with editing occurring over several months. Once the final draft was completed it was sent to the universities that are currently accredited for comment. A meeting was then held with the co-ordinators of the two accredited University Programs to review their feedback on the procedure, including the draft learning outcomes. The final procedure then went before Council where it was endorsed.

It is expected that the new process will provide a consistent benchmark and give more transparency and clarity around the required graduate learning outcomes of courses seeking accreditation as well as assist them map their programs against the AIOH requirements prior to applying for accreditation. The role of the education committee will then be one of evaluation against the set criteria to ensure the outcomes are met; and a site visit to review facilities and equipment.

AIOH has set six categories of learning outcomes for accredited courses, each with numerous sub points:

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.
2. **Recognition**: Graduates should be able to identify, describe and prioritise chemical physical and biological hazards in the workplace.
3. **Evaluation and Assessment**: Graduates should be able to undertake exposure assessments, interpret the results, analyse and record the risk, using standard techniques.
4. **Control of Hazards**: Graduates should be able to select appropriate methods to either eliminate or control identified hazards.
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.

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. (AIOH, 2011)

To maintain accreditation, Universities are required to provide AIOH with an annual report covering the prior years activities and any proposed changes for the next 12 months. This includes changes to staff, curriculum, assessment or practical components as well as statistics on students.

Occupational Hygiene Course Accreditation in the United States

The system for specialised course accreditation in the United States in Applied Science, is conducted by an independent non-governmental commission, ABET (Applied Science Accreditation Commission,). The ABET quality standards are set by the relevant professional societies and the program criteria for Industrial Hygiene have been set by the American Industrial Hygiene Association (AIHA) as the lead society (using the American Board of Industrial Hygienists, ABIH rubrics as a framework to categorise the knowledge component) with the American Academy of Environmental Engineers (AAEE) as a co-operating society. In 2000 ABET set new criteria moving from the "process of education" to the assessment of student outcomes; and outcomes based criteria were first used to evaluate undergraduate and masters level industrial hygiene programs in 2001 (Olsen. et al, 2005).

As in Australia, accreditation is a voluntary process on the part of the institution who requests an evaluation of its program. Only programs that have produced at least one graduate are eligible for accreditation. The institution conducts an internal evaluation and completes a self-study questionnaire documenting students, curriculum, faculty, administration, facilities and institutional support meet the established criteria.

To gain accreditation, *"the program must demonstrate that graduates have necessary knowledge, skills, and attitudes to competently and ethically implement and practice applicable scientific, technical, and regulatory aspects of Industrial Hygiene. To this end, graduates will be prepared to anticipate, recognize, evaluate, and control exposures of workers and others to physical, chemical, biological, ergonomic, and psychosocial factors, agents, and/or stressors that can potentially cause related diseases and/or dysfunctions". (ABET,2010a)*

"More specifically, graduates must be able to:

a) identify agents, factors, and stressors generated by and/or associated with defined sources, unit operations, and/or processes;
b) describe qualitative and quantitative aspects of generation of agents, factors, and stressors;
c) understand physiological and/or toxicological interactions of physical, chemical, biological, and ergonomic agents, factors, and/or stressors with the human body;
d) assess qualitative and quantitative aspects of exposure assessment, dose-response, and risk characterization based on applicable pathways and modes of entry;
e) calculate, interpret, and apply statistical and epidemiological data;
f) recommend and evaluate engineering, administrative, and personal protective equipment controls and/or other interventions to reduce or eliminate hazards;
g) demonstrate an understanding of applicable business and managerial practices;
h) interpret and apply applicable occupational and environmental regulations;
i) understand fundamental aspects of safety and environmental health
j) attain recognized professional certification (ABET, 2010a)

While the institution seeking accreditation conducts its own program self evaluation, ABET forms an evaluation team to visit the campus. Once onsite, the team spend significant time reviewing course materials, student projects and sample assignments and interviews students, faculty and administrators. The team investigates whether the criteria are met and tackles any questions raised by the self-study. This is conducted over several days. The final evaluation report is reviewed at a large annual ABET commission meeting and members vote as to whether accreditation is granted. *(ABET, 2010b)*

So: What is the Same? and more importantly what are the Differences?

Accreditation Processes	**Australia**	**United States**
Standards for accreditation set by?	AIOH	AIHA
Specific Accreditation given to specialised programs, not the institution	Yes	Yes
Voluntary, and by request	Yes	Yes
Must have produced at least one graduate to apply for accreditation	No	Yes
Self examination conducted by the institution	Yes	Yes
External desktop evaluation by team against set LO's & program requirements (eg faculty & facilities)	AIOH Education Committee Members.	Qualified ABET team of academic, govt, industry evaluators.
Period of site review	1 day	Several days
Accreditation decision made by	AIOH council	ABET full meeting
Max accreditation period	5yrs	6yrs
Re-accreditation process	Review of program & site visit	Full re- evaluation process
No of accredited courses (@ 1/10/11)	2	26
Membership of Professional body (@1/10/11)	950	12,000

Table 1: summary of the similarities and differences in course accreditation processes between Australia and the United States.

As a general comment ABET seem to be more assessment, or outcome focussed (rather than delivery focussed) and require a significant project that consolidates the broad learning outcomes and demonstrates effective communication via report writing. Given that the majority of Australian OHP students work full time at a distance from their campus, one of the challenges is to provide innovative ways to incorporate practice principles into the curricula; and both the currently accredited programs offer a project component where the student demonstrates competent practice in an OHP area.

A number of United States Universities offer undergraduate and post graduate qualifications in Industrial Hygiene but have not sought ABET accreditation. Discussion at the 2011 AIHA Academic Special Interest Group (SIG), raised the cost issues of increased workload to maintain accreditation and ABET fees; as deterrents to seeking accreditation; and were seeking a reduction by ABIH in the professional practice period for graduates who were applying to sit their CIH exam. Their argument was that it would give them an advantage when marketing their courses to students and thus increase student numbers to offset the costs incurred in accreditation.

There are many similarities between the Australian and United States system but the biggest difference is in the administration of the review and the conferring of accreditation. In Australia, the entire process is managed by members of the peak professional body, AIOH whereas in the United States it is managed by ABET which is an independent commission specifically set up to provide course accreditation across a range of disciplines. The benefit of this is that it provides a separation of activities and independence but it is very expensive and seen as an impost by many Universities.

So; Why accredit programs and why choose an accredited one?

According to ABET there are a number of benefits of accreditation to both the University and potential students:

1. It provides the University with a structured mechanism to assess, evaluate, and improve the quality of their program,
2. It assists students and their employers choose a quality program to enhance their professional capacity,
3. It enables employees to recruit graduates that they know are well prepared, and
4. It is used by membership and certification boards to screen applicants

Feedback from students, employers and the AIOH Membership and Qualifications Committee also support these outcomes in the Australian context.

Conclusion

Looking back, AIOH has been on a journey with accreditation of OHP programs for over twenty years now, and the development of learning outcomes and a more defined process is the latest step in ensuring the quality of OHP educational programs and graduate outcomes. With membership of over 950 and growing, it is essential that the profession continues to seek to equip its members by providing a mechanism to discern quality education leading to competent Occupational Hygiene Practitioners.

Looking forward, as the demand for Occupational Hygienists continues to be strong; it is anticipated that other Universities will seek accreditation for their programs and the recently developed AIOH procedure incorporating defined learning outcomes will assist them in their program development and self evaluation, streamlining the work of the Education Committee but still ensuring a robust review of the of their program.

As more non members, associate and provisional members graduate from these accredited programs it will boost the number of Full Members and Certified Occupational Hygienists practicing in Australia which will only continue to strengthen the profession and provide a valuable career path in Occupational Hygiene.

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Airborne Mould: what should we be measuring and how?

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Abstract

Health and safety concerns relating to bioaerosol exposures have increased dramatically in recent years (Karvala et al., 2010, Rautiala et al., 2004, Szewzyk et al., 2009, Wiesmueller et al., 2008, Lee et al., 2011, Poole et al., 2010, Daneshzadeh Tabrizi et al., 2010, Persoons et al., 2010). However, there currently there is no Australian standard method for bioaerosol measurement. This paper will compare and discuss the results of viable airborne mould sampling using three commonly used methodologies based on international methods.

The most commonly applied method is described in NIOSH method 0800, which uses a 400 hole single stage viable microbial cascade Impactor operating at a flow rate of 28.3 L/min. This method requires that samples be collected over a 10 minute period. However, a 10 minute sampling period can be too long for many environments where high concentrations of airborne mould may occur and the sampling period is typically shortened to around 2 minutes or less. The alternative, is to use a 200 hole single stage viable microbial cascade Impactor operating at a flow rate of 14.15 L/min, as specified by the manufacturer. Another popular method is prescribed in a draft ISO 16000 standard. This method requires the use of a single stage viable microbial cascade Impactor with ≥ 300 holes operating at a flow rate of 100 L/min. This method recommends a 100 L sample be collected, minimum sample volume of 50 L.

This paper will present the findings from a pilot study comparing data collected simultaneously using the three aforementioned sampling methods in a variety of indoor and outdoor environments.

Keywords: Bioaerosol sampling, standards, methods, mould sampling

Introduction

In recent years the need for mould monitoring has increased at a dramatic rate in Australia. This increase has followed an upsurge in other countries, especially in relation to natural disasters (Heseltine & Rosen, 2009 and Health and Environment Alliance, 2009). It has been demonstrated that the various commercially available bioaerosol samplers can significantly influence results (Kirychuk et al., 2009, Gillespie et al., 1981, Yao and Mainelis, 2007, Grinshpun et al., 2007, Chang and Chou, 2011, Macher et al., 2008, Chang et al., 1995), making standardised monitoring methods essential to ensure that data is reliable and comparable (Reed, 2009). The first standardised method was published by the United States National Institute for Occupational Safety and Health (NIOSH) in 1998, followed by a series of indoor air standards, including mould sampling, developed by the International Standards Organisation (ISO) following research and extensive round robin testing in a number of laboratories.

The aim of this paper is present the results of a pilot project undertaken to determine if there was a significant difference in the airborne mould results from monitoring with three commonly applied sampling methods.

Background on Standard Sampling and Analysis Methods

The first standard sampling method published was by NIOSH in 1998 as the NIOSH 0800 Bioaerosol Sampling (Indoor Air). This method is very simple and requires the use of a 400-hole single stage viable microbial Impactor which samples at a flow rate of 28.3 L/min. The methods of analysing the microbial plates has not been specified, but has been left to analytical lab used.

The alternative to NIOSH 0800 is the use of a 200-hole single stage Viable Microbial Impactor rate flow rate of 14.15 L/min. The comparison of the two methods has been discussed by a number of researchers such as Macher (1989) and Yao and Mainelis (2007) and there has been suggestions made that if the 200-hole sample head is used then a positive may need to be made.

ISO 16000-17:2008 Indoor air — Part 17: Detection and enumeration of moulds — Culture-based method describes the method to be used in the identification and counting following the sampling using the methods detailed in ISO16000-18:2011. It can be also be used for other methods whether the sample may need to be cultivated such as gelatine filters in a button sampler or where a sample is collected on a filter (ISO16000-16:2008) and then transferred to plates for incubation and counting. This method describes both the microbial media to be used, the temperature and time of incubation and methods of counting and identification of colonies. The types of microbial media that is specified is MEA (Malt Extract Agar) DG18 agar (dicloran 18 % glycerol agar) and Potato dextrose agar. Personal communication with a German Mycologist indicated that DG18 is the most common ager used in Europe whereas MEA is the most common used in Australia.

ISO 16000-18:2011 Indoor air — Part 18: Detection and enumeration of moulds — Sampling by impaction was published in July 2011 and the body of the standard does not specify the required flow rates of the samplers although the minimum volumes to be samples have been specified. This final document varies from earlier drafts which specified a flow rate of 100L/min and was the main reason this paper was developed. This standard specifies the sampling protocaol to be used which includes a minimum of 5 samples to be collected at each sampling point in parallel which should have been specified as replicates. This and some other minor issues with the standard relate to the translation to English which will need to be address in the next edition or if the standard is adopted as an Australian standard.

The final ISO standard that is being reviewed here is ISO/FDIS 16000-Part 19: 2011 Sampling strategy for moulds which is a final draft. This standard is a good basis for a sampling strategy for mould assessments and covers a range of aspects that should be covered. Annexe B is also a good summary of a range of sampling methods that can be used in and assessment.

Method

The methods of sampling and analysis used in this project are based ISO 16000-18:2011(E), and NIOSH 0800and the analysis of the samples were undertaken according to ISO16000-Part 17: 2008. The monitoring was undertaken as follows:

Method A: Sampling at 14.15 L/min using a using a single stage Viable Microbial Impactor SKC Quick Take 30 Air Sampler Pump fitted with a 400 hole Impactor for 7 minutes.

Method B: Sampling at 28.3 L/min using a using a single stage Viable Microbial Impactor connected to a SKC Hi-lite 30 sampling pump fitted with a 200 hole Impactor for 8 minutes.

Method C: Sampling at 100 L/min using a using a MiniCapt® Portable Microbial Sampler (SN: 01-108-01) fitted with a slit sampler for 1 minute.

The flow rates for sampling pumps used to sample using Methods A & B were calibrated with DryCal Lite (SN 7812). The samples were collected on 2% Malt Extract Agar plates supplied by AMS Laboratories Pty Ltd. Three samples were collected at each site on Wednesday, 15 August 2011 between the hours of 1:30 pm and 5:30 pm in the following environments:

Site 1: Ambient Air (outside of Environmental Health Laboratory);

Site 2: Environmental Health teaching laboratory;

Site 3: Teaching Space (Small flat floor space);

Site 4: Shearing Shed (no shearing or other any other activities had been undertaken within 48 hours of the monitoring being undertaken)

Site 5: Microbiological teaching laboratory

Samples were either analysed at the UWS environmental health laboratories or at the AMS Laboratories for only total colony forming units (CFU) and no speciation was undertaken. Samples analysed at the UWS laboratories were incubated at 25±2 ^{o}C for 120 hours prior to counting. Samples analysed at the AMS laboratories were incubated at 25±2 ^{o}C for 120 hours prior to counting.

Results

It was interesting to note that sampling at 100 L/minute (Method C) had to be stopped due to the damage the sampler was making to the media on the plates as shown in Figure 1.

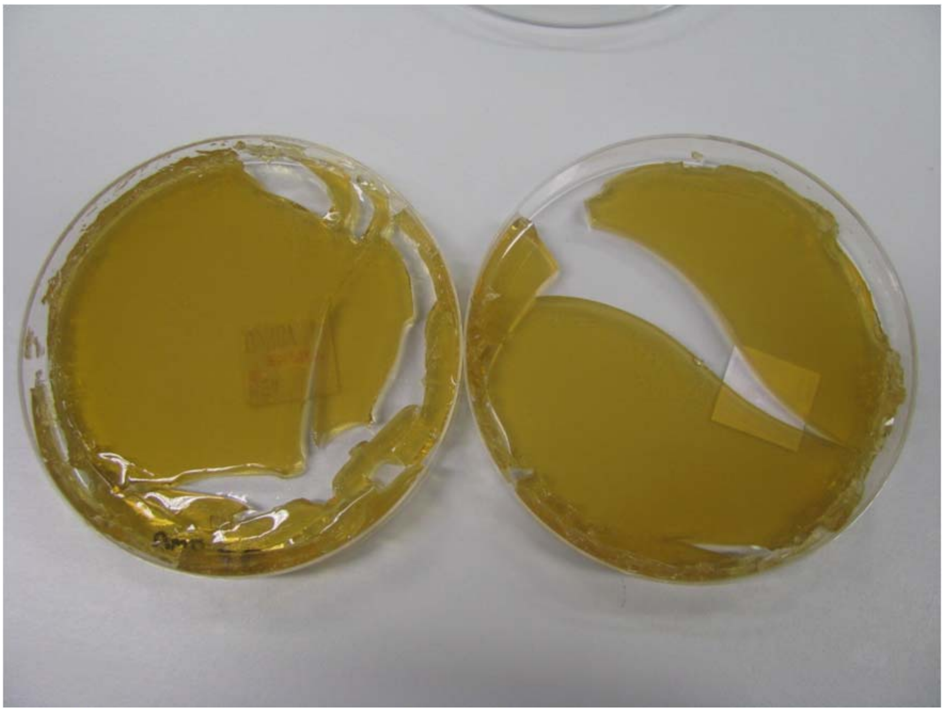

Figure 1: Damage to media plates when sampling at 100 l/min

There results of the sampling for methods A and B are presented in Table 1.

Table 1: Average Results (+/- SE) of air monitoring at using a 400-hole sampler 28.3 L/min and using a 200-hole sampler at 14.15 L/min

Flow Rate (L/min)	14.15	28.3	Temperature and Humidity
Volume sampled (Litre)	99	113	
Area Monitored	**CFU/m^3**		
Ambient Air	774 ± 112	760 ± 134	T_{air} = 23.1 °C; RH = 29.3%
EH Teaching Laboratory	293 ± 56	277 ± 57	T_{air} = 23.3 °C; RH = 37.5%
Teaching Space	518 ± 67	415 ± 40	T_{air} = 22.3 °C; RH = 29.0%
Shearing Shed	1047 ± 217	857 ± 182	T_{air} = 19.7 °C; RH = 28.9%
Micro Laboratory	64 ± 7	71 ± 6	T_{air} = 20.1 °C; RH = 29.4%

Discussion

A brief review of the results between sampling at the 2 lower flow rate indicate that the results achieve are similar abut as can be seen in Figure 2 where the slope of the line should be 1, this is not the case. The higher flow rates give slightly lower results in all cases.

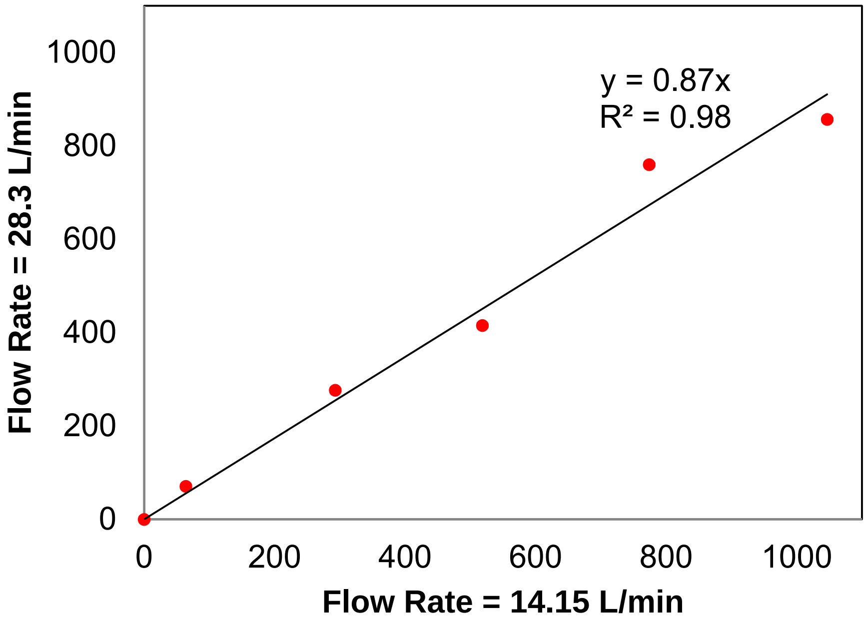

Figure 2 Relationship in Average CFU/min between 14.15 L/min and 28.3 L/min

When the individual results are achieved then a similar relationship is observed in Figure 3.

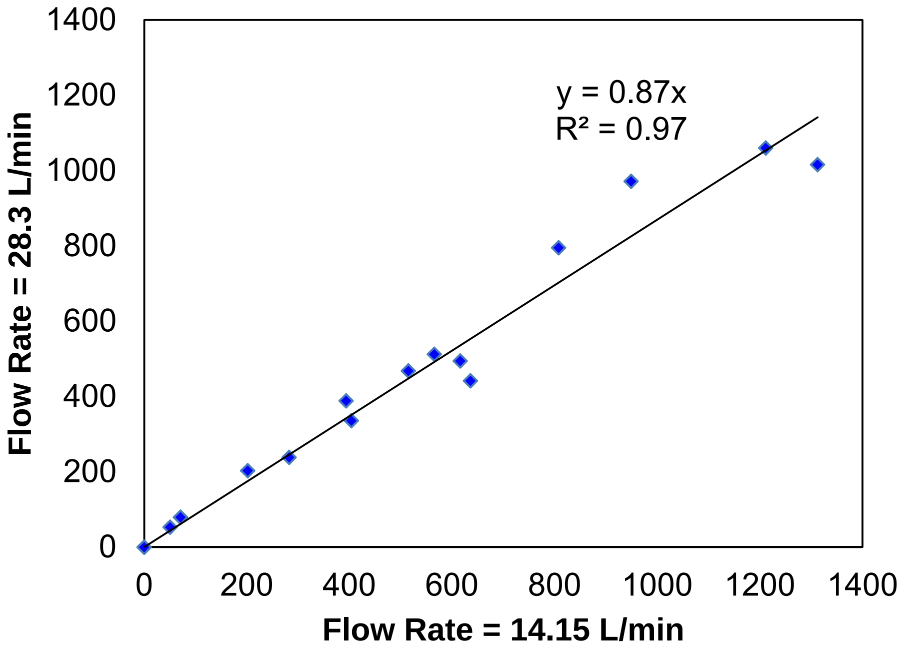

Figure 3 Relationship in CFU/min between 14.15 L/min and 28.3 L/min

The data was analysed using a range of statistical tests, including Regression Analysis and Durbin-Watson statistic as shown in Figures 4 and 5, which showed there was no statistical significance between the flow rates in the environments sampled. It should be noted that the new ISO method calls for five replicate samples to be collected whereas in this study only 3 replicates were collected.

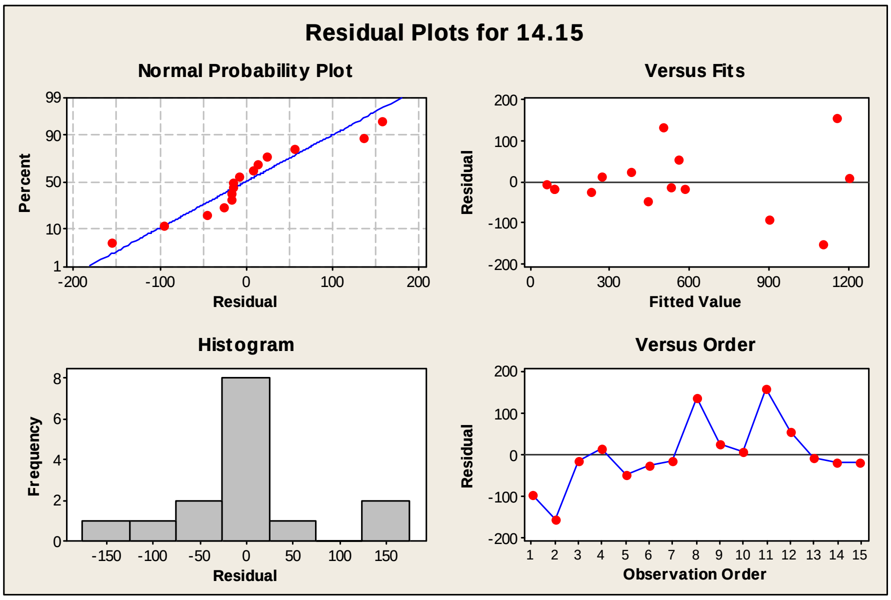

Figure 4 Regression Analysis: 14.15 L/min versus 28.3 L/min

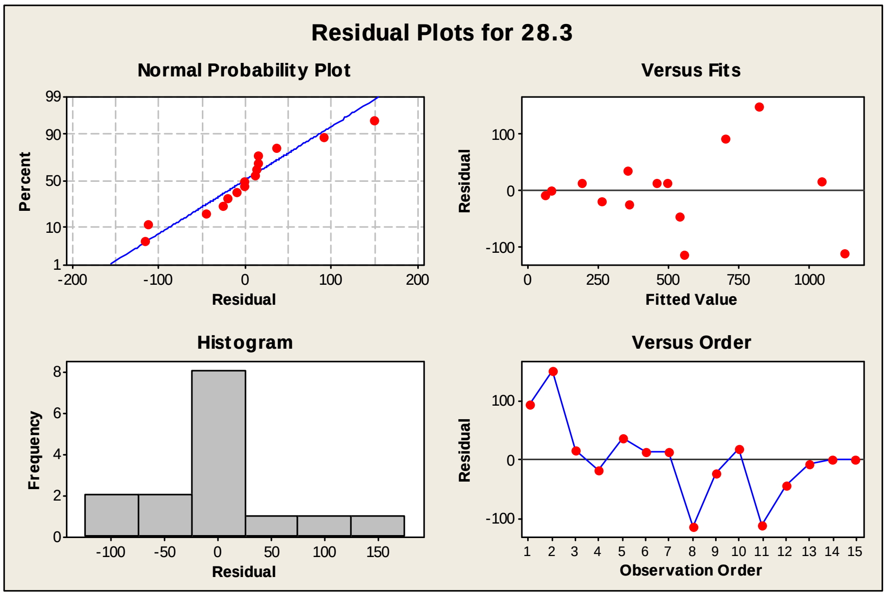

Figure 5 Regression Analysis: 14.15 L/min versus 28.3 L/min

The only concern from the results reports was than on average the higher flow rate of 28.3 L/min reported lower results than the samples collected at 14.15 L/min.

Conclusion

Based on the findings of this small project sampling at 100L/min is not appropriate in most indoor environments and special care may need to be taken in the selection of the media used to collect the sample at this flow rate.

In relation to the other two methods there was no significant difference in the results but this needs to be explored in more depth including using the alternative medias recommended in the ISO standards.

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Getting the Best Answer by Asking the Right Question – Case Studies in Occupational Exposure to Mould

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Keywords

Assessment, Bioaerosols, Hazard, Monitoring, Mould, Occupational, Risk

Raised awareness around personal exposure to workplace mould can result in concern of staff and employers in relation to health and business risks. Appropriate site assessment tools should be selected to ensure risks are managed or mitigated. The mould intrusion event, mould types and sources, exposure routes, and the susceptibility of individuals during building occupation and restoration vary significantly between individual sites and require diverse solutions.

A tiered method for site assessment, overcoming technical and financial barriers allowed meaningful risk management, as demonstrated by three case studies.

Initial assessment of a flooded 8-story building in South East Queensland allowed the client to terminate their lease and move to new premises. Personnel handling heavily mould-contaminated wood were exposed to >1000x greater mould concentrations than other workers, so the company pressurised their supplier. Moulds isolated from a kindergarten were qualified as toxic by DNA-based identification, and recommendations made for intrusive investigation.

Introduction:

Health risks associated with exposure to mould in the Occupational and indoor environment are of increasing concern. Currently no safe levels are set for airborne microorganisms (bioaerosols) in the occupational setting in Australia, although Canada maintains guidelines for mould in the workplace (WSHD, 2001; Health Canada, 1995).

Moulds arise in association with water ingress or condensation, and are potentially allergenic and pathogenic to sensitive individuals and those with compromised immune systems (Pettigrew *et al.*, 2010). Inhalation or ingestion of spores, or of toxigenic, teratogenic, mutagenic and carcinogenic fungal toxins (mycotoxins) can occur under favourable conditions. Understanding of toxicology relies heavily on tissue culture and animal-related dose-response data because, exposure in contaminated environments constitutes simultaneous inhalation and/or ingestion of multiple mould types and other pollutants, hampering epidemiological analysis (Gravesen, 1986).

Hazard severity is often microbial-strain specific (Kuhn and Gahnnoum, 2003), dependent on bioaerosol or surface concentrations, bioaeorosol particle size distribution and dispersal, and the source of origin. Identification to strain level requires powerful microbial DNA or antibody-based analyses that require expert analysis to assess strain-specificity, and the accuracy and quality of DNA matches (Bridge et. al., 2003). Risk of exposure and development of adverse health effects is dependent on age, physiological status and activity level of the receptor, exposure time, available exposure routes and spore viability. Non-viable spores can illicit allergic and toxic reactions, but are not pathogenic. Therefore it is important to plan any site investigation with these factors in mind.

In some cases it is effective to devise risk management strategies based on initial site investigation without intrusive investigation. In other cases where conventional techniques may miss hazardous microorganisms at low concentrations (approximately 90% of moulds in an air sample are non-culturable, and competition on agar plates prevents growth (Durand et al., 2002)) molecular approaches to mould identification maybe required.

Rapid, sound judgement is needed in relation to personal exposure, remediation procedures and re-occupation of restored buildings. Decision-making cannot be sidelined whilst awaiting better toxicological information from pending epidemiological studies that are inherently complex.

This paper presents three case studies where a tiered site assessment was coupled to the precautionary principle to manage and mitigate site-specific exposure risks. Selecting the appropriate tool for examining health risks was fundamental in the case studies presented.

A tiered approach to site assessment

Tier 1 - Initial site investigation

A hierarchical site assessment based on increasing detail using site observation and real-time measurement was devised. The approach is designed to show absence of mould, using a seral sequence of mould indicators comprising:

visible mould present >
"musty" or strong odour that may be associated with mould >
humidity higher indoors than outdoors (and >50%) and/or building fabric >17% moisture >
obvious source of bacteria or mould >
indication of "cold spots" in the building >
localised elevation of airborne particle concentration/volatile organic compound concentrations in the absence of a source.

Tier 2 – Sampling design

Personal, area and surface sampling can be used for hazard identification.

Personal sampling – Collection of bioaerosols in the breathing zone of workers over a work shift to provide an 8-hour time weighted average concentration of total spores.

Area sampling – Sampling of culturable or total bioaerosols based on impaction by grab sampling provides appropriate data on peak exposure. Sampling onto selective agar provides viability data, whilst adhesive impaction surfaces provide total microbial counts.

Surface sampling - Surface swabs and adhesive tape can be collected for culturing or direct microscopy respectively.

Tier 3 – Culture-based identification

Identification/enumeration of cultured microorganisms based on colony morphology and microscopic imaging to genus and sometimes species level.

If elevated concentrations or source-specific culturable moulds are detected, a decision may be made to evaluate risk based on genus-level identification. Likely sources were considered when deciding the most toxic or pathogenic strain that would be expected in a sample.

Tier 4 – Hazard description

More precise identification of a microorganism may be required based on antigen, or on gene sequence information. By selecting a gene common to all moulds that shows inter-species or inter-strain variability, it is possible to obtain confidence in the assessment of hazard severity of the organism. Based on readily available online gene sequence databases, identification to strain level is often possible.

Tier 5 – Remedial Action Plan (RAP)

Risk evaluation is crucial in devising a RAP, which can be constructed as soon as sufficient information is obtained under the earlier tiers. This requires consideration of the hazard, the chance of exposure and the susceptibility/response of the receptor. The RAP should consider risks to those entering the site during site assessment and restoration.

Tier 6 – Validation testing

Testing of premises post-remediation shows that the building is not contaminated at that time of testing.

Tier 7 – Long term storage for reference

Resting spores may remain in buildings and propagate when humidity levels rise at a later date. Risks are involved for insurance companies and individuals in the event of a later incident, when reference to the original sample maybe beneficial.

Where litigation is possible, or problems are perceived at a later date, long term storage of microbial isolates, their DNA, or an aliquot of the original sample is recommended.

Tier 8 – Protection from future events

Mould propagation follows moisture ingress. Whether a large-scale/flash flood compromised surface water management systems, or water breached damaged damp-proofing, assessing the probability of likely recurrence is critical. Meteorological and hydrological forecasting may be required.

Case study 1: Building A, Yeerongpilly, Queensland, January 2011.

Background

Building A comprised an eight-story purpose-built office block previously inundated to the second floor during the Queensland floods of 11 January 2011. The client occupied Floors 1-5 and Floor 7. The Brisbane River and Oxley Creek, the sources of flood water, were each located approximately 2 km from the building.

The building had been unoccupied for 14 days by the time of site investigation, having been evacuated since 10 January 2011. Standing water remained in the lift shaft base, whilst above-ground waters had subsided and residual water pumped out of the premises. Most internal wall linings on the Ground floor had been removed prior to site inspection.

The client was concerned for safety of personnel upon site re-entry if mould were present. The objective was to return employees safely back to work and minimise the impact on them and the business.

Method

A Tier 1 site investigation was completed. Only visual observation, temperature and moisture readings were necessary for site evaluation. Building fabric moisture (Protimeter moisture meter), temperature/relative humidity (RH) (Krestel Model 4000 meter) and carbon dioxide concentration (Landcom Series II gas analyser) were measured on each floor of the building.

Results

No visible mould was observed, however there was an overpowering mould odour by the building entrance. Odour was not discernable on higher floors. Internal walls of the 1st to 8th floors were made entirely of concrete, however desks comprised MDF and soft furnishings were present that were potential sites for mould infestation.

Moisture levels were elevated in internal walls and floors of the ground floor and Floor 1, where wall moisture reached 100 +/- 0% and 95.3 +/- 4.7% respectively (n=3) (Figure 1). Wall moisture content fell sharply on higher floors, and remained consistently below 17% conducive to mould growth. RH readings were elevated in the ground to 4th floors of the building, and fell in a linear fashion from Floor 2 to Floor 5, before reaching approximately 60% throughout the remainder of the building, 1.3% lower than that outdoors. Temperature increased from 29 +/- 0.5 °C on the ground floor to 31 +/- 0.5°C (n=3) on Floor 7. The saturated vapour pressure of the air was calculated as 27.4% in Floor 1 and 26.8% in Floor 7, indicating that the increase in RH was due to elevated air moisture content in the lower levels, and not to difference in temperature (List, 1951).

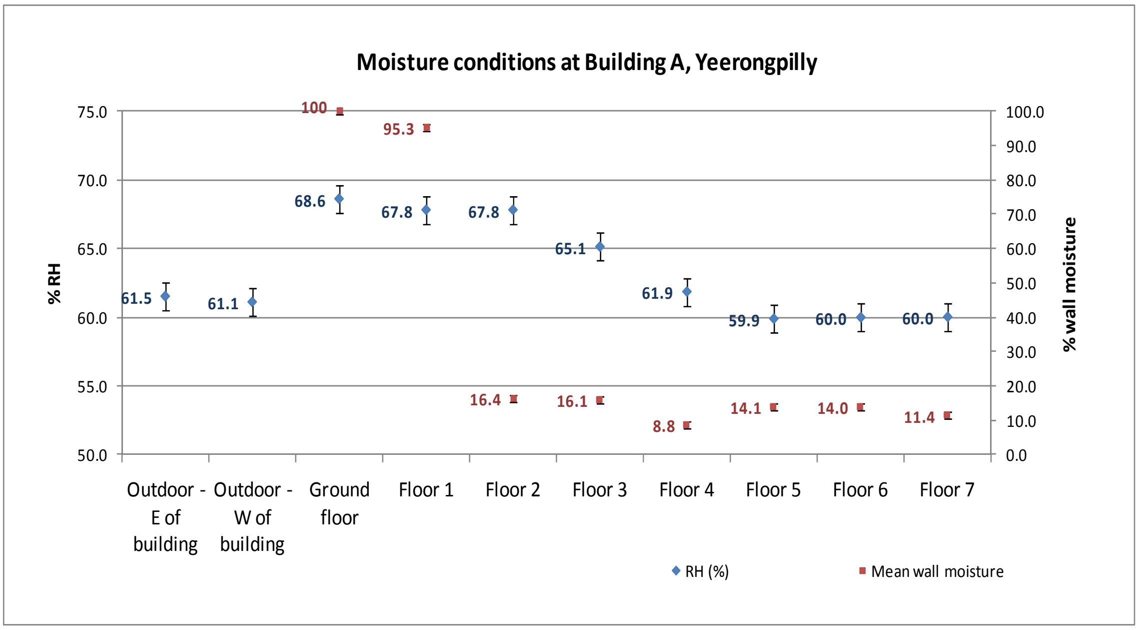

Figure 1: Moisture content of walls in building A

It was concluded that there was a high risk of mould contamination in the ground and first floors due to high moisture content of the building fabric, with potential for amplified mould growth through Floors 1 to 4 inclusive from elevated air moisture and possible mould spore intrusion from lower floors. Further, RH was elevated >55% with temperatures between 20 – 35 °C throughout the premises, conditions ideal for mould growth.

Outcome

The client terminated their lease without the need for further testing and put staff in new premises without the need for further testing.

Case study 2: Factory B, South East Queensland.

The client received concerns from staff handling several thousand pieces of untreated contaminated wood per week on conveyor belts. Wood was handled intermittently for ca. 10-minute intervals for a total duration of ca. 3 hours during a 12-hour shift. Workers were equipped with safety glasses and heavy duty gloves but no respiratory protection. Examination of exposure during hand-loading the conveyor and stacking the wood for storage was required.

An image of a piece of the most heavily contaminated timber is shown in Figure 2:

Figure 2: Contaminated timber handled by workers at Factory B

Methods

Personal monitoring of worker exposure to total mould spores was carried out during a 12-hour shift. Exposure in the conveyor/handling area was compared to exposure in an area of the factory without contaminated material. Air was sampled at a flow rate of 2 L/min onto 0.2 µm pore size, 37 mm diameter polycarbonate filters housed in IOM personal samplers. Culturable samples were impacted onto DBRC agar using a Surface Air System° single-stage cascade microbial impactor at a flow rate of 100 L per minute for 1 minute.

Samples were collected during conveyor belt loading at 1.5 m height with the impactor inlet facing downwards to optimise isokinetic sampling. Transect samples were collected at 5 m and 10 m intervals from the conveyor belt and stored wood respectively, up to a distance of 20 m.

Peak elevations in spore concentration during conveyor belt operation were monitored by collecting parallel samples at 1.75 m height, 2 m from the conveyor belt as described for personal monitoring. One sampler was operated only during handling, whilst the other was operated for the entire shift. Samples were analysed by James Smith Consulting and Biotech Laboratories.

Results

Personal exposure

Workers handling the contaminated material were exposed to total mould spore concentrations of 2.43 million spores/m^3 of air sampled in their breathing zone, 1000x greater than workers in the control location (Figure 3). Further, airborne concentrations during handling of the contaminated material within 2 m of the conveyor belt elevated from a 12-hour mean average of 1,467 spores/m^3 to 883 thousand spores/m^3 during peak periods (Figure 3). This suggested extreme elevation of mould concentrations during handling.

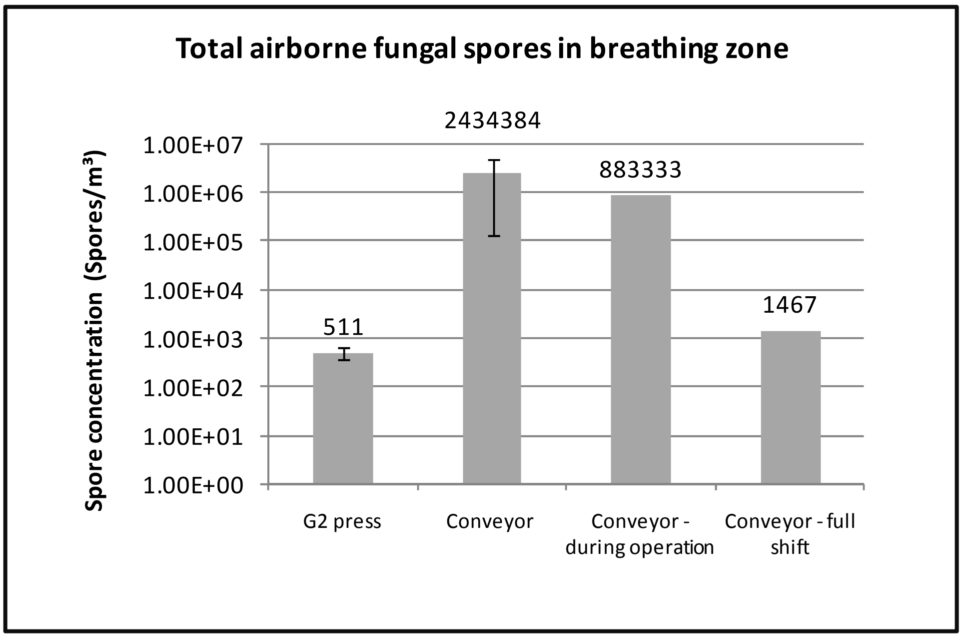

Figure 3: Total mould spore concentration in breathing zone of workers at Factory B.

Of concern was the dominance of airborne fungi by *Aspergillus/Penicillium* species (spp.), whereby 96.6% of the airborne mould spores immediately adjacent to the conveyor belt were identified as *Aspergillus/Penicillium.*

Spore dispersal

The proportion of *Aspergillus/Penicillium* inversely correlated with distance from the source, indicating that the timber was a source of *Aspergillus/Penicillium* (Figure 4).

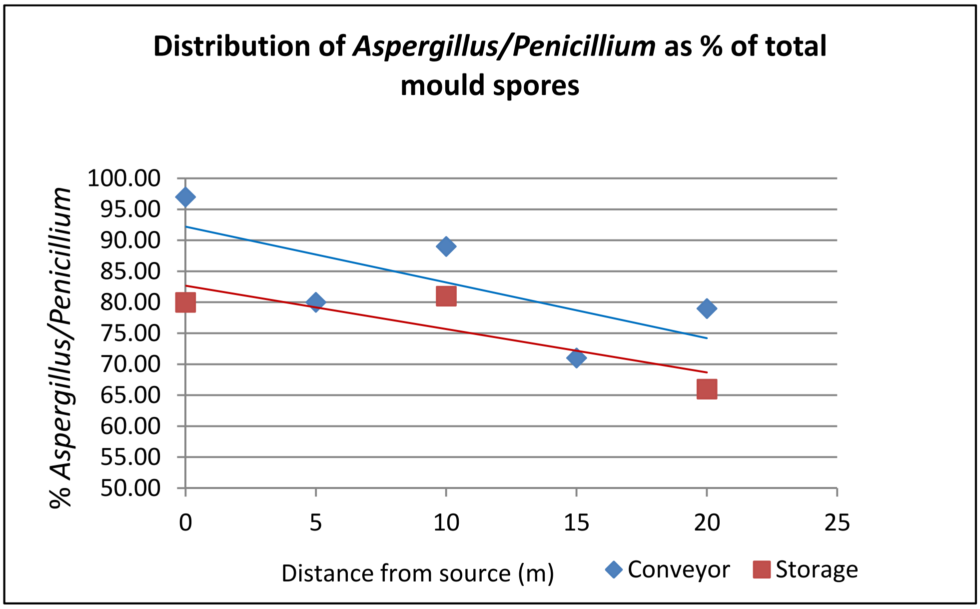

Figure 4: Trend in the proportion of *Aspergillus/Penicillium* spp. in the mould aerosol at Factory B.

Surface concentrations

Spores of *Chrysosporium* spp. were observed in a highly localised pattern. There were 2,569 +/-1,638 spores/cm^2 (n=3) on wood, 31,200 +/-3,270 spores/cm^2 (n=6) on the steel supports of the warehouse immediately adjacent to the storage area, and 3,435 +/-137 spores/cm^2 (n=3) on surfaces adjacent to the conveyor. No evidence of *Chrysosporium* was found elsewhere at the site or in air samples, thus accumulation on localised surfaces was observed.

Discussion

Qualitative risk analysis was conducted based on mould genera, as the client was prepared to undertake mitigation actions without describing culturable moulds in more detail.

Twenty of the 185 currently identified species of *Aspergillus* have been shown to elicit adverse health effects (de Hoog et. al., 2000). Collectively termed aspergillosis, recorded illnesses comprise allergenic aspergillosis (Galimberti et. al., 1998), invasive aspergillosis, allergic bronchopulmonary aspergillosis (Seltzer and Fedoruk, 2007; Harley et. al., 1995) and aspergilloma (Patterson, 2005).

Penicillium comprises >200 species and is commonly found in the environment growing on wood. The genus it is not generally known to cause infection. However, it is a proven allergen causing Type I and Type III allergenic activity (Shen et. al. 2007; Wilkin-Jensen and Gravesen, 1984). Acute exposure to high levels of *Penicillium* can cause bronchiospasm, whilst longer-term exposure may cause pulmonary emphysema (Crissy et al., 1995).

Penicillium species can produce a range of mycotoxins (Pitt et. al., 2000). Inhalation of spores containing mycotoxins has been shown to be connected with Organic Dust Toxic Syndrome (Mackiewicz et al., 2008). A recent study (Eduard, 2009) recommended exposure limits of 10,000 spores/m^3 *Penicillium chrysogenum*. Concentrations experienced by workers reached 14,300 spores/m^3.

These data suggested potential hazard in this case given that moulds were either *Penicillium* or *Aspergillus*. Handling timber over 3 hours, at an inhalation rate of 26 litres per minute (USEPA, 2009) potentially exposes a worker to approximately 1.5 m^3 of air and so to *ca*. 21,450 spores in an ongoing basis.

The hazards associated with the organisms identified at the site cannot be clarified, thus the precautionary approach dictated these concentrations may cause chronic adverse health effects to workers. Transfer of moulds offsite to sensitive receptors through shipping of goods, or on personal clothing was also an identified hazard.

Given that *Chrysosporium* spp. were present only on surfaces close to the source, risk from inhalation was considered small, and ingestion a more likely route of exposure. Recorded health effects are limited to patients with granulomatous disease (Rollides et al., 1999) and following bone marrow transplants (Morrison et al., 1993) where they have demonstrated high mortality rates. *Chrysosporium* spp. may cause skin and nail infections, as they have been isolated from skin and nails, thus avoidance of contact with hands, hand-washing and care to avoid ingestion was recommended.

Outcomes

All factory workers were in good health at the time of sampling, with no historical records of mould allergies or suppressed immune function. Therefore there was a low risk of retrospective infection or allergenic reaction amongst existing staff. A range of recommended risk management actions were made based on the Hazard Control Hierarchy (QOHS, 2003). In response to recommendations, the client informed its supplier that they would no longer accept the wood when contaminated, and developed a clean-up strategy using an accredited contractor.

Case 3: Kindergarten C, Victoria.

Introduction

PAEHolmes was contacted by EML Air Quality Consultants in response to their mould investigation at a water-damaged kindergarten in Victoria showing signs of visible mould. Moisture was seeping through a wall adjoining damp soil with compromised damp proofing. PAEHolmes and Toxikos were contracted to assess potential health risks associated with moulds that had been identified to strain level based on DNA analysis by MicroGenetix, Victoria. 26S rRNA gene sequence data and consequent identities were provided for three moulds.

Method

Sequence data was provided by EML to PAEHolmes. Given that not all strains of moulds are toxic, an understanding of phylogenetic analysis was essential for determining the relationship strength between sequenced strains and those on the database. Length of the DNA sequence and inter-mould sequence variability and specificity were evaluated to advise the restoration process.

Health risks were also examined based on the hazards associated with the moulds in relation to staff and pre-school children (Rosenblum *et al.,* 2010; Cho *et*. *al*., 2005), possible exposure routes and mould concentrations.

Results

Given that mould was visible on surfaces and airborne, there was high risk of exposure by inhalation and ingestion. The analysis revealed high confidence in the 26S rRNA sequence identities which indicated the toxic *S. atra (charatarum)* var. corda and *Aspergillus versicolor* var. fulvus strains, with 100% sequence homology only to these toxic strains.

Both strains can produce highly hazardous mycotoxins (Bae *et. al.,* 2009; Rakkestad *et. al.,* 2008; Islam *et. al.,* 2006; Rotoli *et. al.*, 2001; Peraica *et. al.*, 1999; Hodgson *et. al.*, 1998; Paul and Thum, 1979; Reiss, 1976) and grow on water-damaged building materials (Engelhart et. al., 2002).

Outcomes

Serious concerns about exposure of children at the site, hypervariability of the DNA sequence region studied, and the closeness of DNA sequences to known strains of highly toxic mould resulted in recommendations of detailed delineation investigations, and containment of the property until fully remediated.

Conclusions

In summing up, a flexible approach to site-specific mitigation following mould contamination events was successfully trialled. By following logical tiered progression, the correct level of detail was selected for site investigation. Whilst available techniques allow in depth mould assessment, there is a need for rapid assessment so that immediate risk mitigation can take place, such as immediately relocating personnel from Building A. In cases where sensitive individuals may be exposed, such as in the case of Kindergarten C, it is imperative to understand potential hazard severity of moulds. Until Australia adopts mould exposure guideline values, such an approach may assist those assessing and managing risks around mould exposure.

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Understanding and managing alcohol and drug related risk to workplace health and safety

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Workers' alcohol and drug use can have substantial negative implications for the workplace. It has been estimated that in the financial year 2004-05 alone, alcohol and drug use cost Australian businesses in excess of $5.2B in terms of lost productivity due to illness, injury, accidents and absenteeism (Collins & Lapsley, 2008). However until relatively recently, efforts to address these costs have been hampered by a lack of data concerning workers' alcohol and drug consumption patterns and a lack of understanding of the relationship between these patterns of consumption and the workplace (Allsop & Pidd, 2001; Pidd, Berry, Harrison, Roche, Driscoll, & Newson, 2006).

To address this knowledge gap the National Centre for Education and Training on Addiction (NCETA) has undertaken a program of research involving secondary analyses of National Drug Strategy Household Survey (NDSHS) data (Berry, Pidd, Roche, & Harrison, 2007; Pidd, Roche, & Buisman-Pijlman, 2011; Pidd, Shtangey, & Roche, 2009a; Pidd, Shtangey, & Roche, 2009b; Roche, Pidd, Berry, & Harrison, 2008; Roche, Pidd, Bywood, & Freeman, 2008; Pidd, Berry, Roche, & Harrison, 2006; Pidd, Berry, Harrison, et al., 2006). This research represents the most comprehensive examination of the prevalence and patterns of alcohol and drug use among the Australian workforce to-date.

Key findings from these analyses indicated that:

- Nearly half the workforce (44.6%) drank alcohol at levels associated with risk of harm[1] at least occasionally and 9.3% did so frequently (at least weekly)
- 8.7% of the workforce usually drink alcohol at work and 5.6% have attended work under the influence of alcohol at least once in the past 12 months
- 3.7% of the workforce reported taking at least one day off work due to their alcohol use in the past 3 months
- 17.5% had used some type of drug (apart from alcohol or tobacco) for non-medical purposes at least once in the past 12 months and 10.4% had done so in the past month
- 0.9% of the workforce usually used drugs at work and 2.0% reported attending work under the influence of drugs at least once in the past 12 months
- 1% of the workforce reported taking at least one day off work due to their drug use in the past 3 months
- There were significant demographic differences with young workers, single workers, and those with no dependent children being more likely to drink at risky levels, use drugs, attend work under the influence of alcohol or drugs, and report alcohol- or drug-related absenteeism compared to other workers

[1] Defined as more than 6 std drinks per drinking occasion for males and more than 4 std drinks per drinking occasion for females.

- There were also significant industry and occupation differences with workers employed in the hospitality industry and those employed as tradespersons the most likely to drink at risky levels, use drugs, attend work under the influence of alcohol or drugs, and report alcohol- or drug-related absenteeism compared to other workers.

The identification of prevalence and patterns of alcohol and drug consumption among the workforce has important implications for the design and implementation of interventions that address alcohol- and drug-related harm in the workplace. Such data allow for the identification of high risk workforce groups and the development of cost effective targeted interventions.

Data concerning the prevalence and patterns of alcohol and drug consumption among the workforce also highlight the need to take a 'whole-of-workplace' approach. Traditionally, workplace interventions have focused almost exclusively on 'addicts' and 'alcoholics' or 'problem' drinkers and drug users. While these workers are of concern, more attention needs to be placed on the much larger number of workers who are 'social' drug users and those who usually drink at low risk levels, but occasionally drink at high risk levels. For example NCETA research has identified that more than 2.6 million work days are lost each year due to alcohol-related absenteeism (Pidd, Berry, Roche, et al., 2006). While regular heavy drinkers accounted for around 51% of this absenteeism, the remainder was accounted for by workers who normally drink at low risk levels, but on occasion drink at high risk levels.

Understanding the relationship between the workplace and alcohol consumption is also important as it allows for the identification of factors that can contribute to either harmful or safe patterns of consumption. The research undertaken by NCETA concerning patterns of alcohol and drug use among the workforce shows that even when demographic factors associated with alcohol and drug use (e.g., age, gender, marital status, income etc.) are controlled for, significant differences in consumption patterns between industry and occupational groups remain (Berry, et al., 2007; Pidd, et al., 2011). Such evidence indicates that factors within the workplace environment may play a role. Theoretical explanations of the relationship between the workplace environment and workers' alcohol consumption patterns can be categorised as having a stress/alienation, control, or culture perspective. Each perspective has implications for the design and implementation of interventions.

Stress/alienation: Most research on the relationship between the workplace and workers' consumption patterns has adopted a stress or alienation perspective. The former proposes that some workplace experiences (e.g., physically or psychologically demanding work) and events (e.g., accidents or repetitive injury and disputes) result in elevated stress that can be alleviated by alcohol or drug use (Trice & Sonnenstuhl, 1990). The alienation framework proposes that the workplace conditions such as low autonomy or boring work can create a sense of dissatisfaction or powerlessness that is relieved by alcohol or drug use (Trice & Sonnenstuhl, 1990). The relationship between stress or alienation and alcohol or drug use is, however, indirect. Stress and alienation influence job satisfaction, which in turn, influences beliefs about the utility of drinking or drug use as a means of coping (Greenberg & Grunberg, 1995). From this perspective harmful patterns of consumption can be reduced or eliminated by removing, or reducing the impact of stressful and alienating factors, or by encouraging workers to adopt alternative coping strategies.

Control: The control perspective proposes workplace factors can restrict or encourage the availability of alcohol or drugs and, therefore, the use of alcohol or drugs (Ames & Grube, 1999). Factors such as the low visibility of workers (e.g., working away from the workplace), lack of supervision, and lack of formal alcohol or drug policies can lead to greater availability. From a workplace control perspective, harmful patterns of alcohol or drug use can be reduced or eliminated by the introduction and effective dissemination of a formal workplace alcohol and drug policy and improving the quantity and/or quality of supervision.

Culture: The cultural perspective proposes that the workplace is a cultural environment distinct from the wider community that can either support or inhibit alcohol or drug use. All workplaces have formal and/or informal rules and norms regarding appropriate work behaviour. Workplaces also have procedures developed from these rules and norms, to regulate work behaviour. These rules, norms, and procedures extend to alcohol and drug use, including defining what constitutes problematic and non-problematic use at work and may differ from the individual worker's norms for use away from the workplace. According to Ames and Janes (1992; Janes & Ames, 1993) there are four dimensions of workplace culture that contribute to use:

1. Workplace norms concerning use
2. The quality and organisation of work
3. Drinking drug using subcultures
4. Factors external to the workplace.

More recently, Pidd and Roche (2008) outlined an integrated cultural model that proposes that the workplace contain stressors, controls and subcultures, and interaction between these factors results in an overall workplace culture that either supports or discourages risky drinking and drug use. Moreover, it is argued that the influence of this model extends beyond the workplace. That is, workplace culture shapes not only the drinking and drug use behaviours of individuals and social groups within the workplace, but also the drinking and drug use behaviours of individuals and social groups external to the workplace, such as workers' families and the local community.

A cultural perspective has two important implications for interventions designed to minimise alcohol-related risk in the workplace. First, cultural models highlight the complexity of the relationship between work and alcohol or drug use. A range of factors both internal and external to the workplace can individually, or in combination, contribute to a specific culture of drinking or drug use. Thus, an assessment of the relevance of various variables needs to be conducted prior to the design and implementation of specific interventions.

The second implication is that workplace interventions need to acknowledge the pivotal role of workplace culture. Workplace culture not only has a direct influence on workers' consumption patterns but can also mediate the influence of workplace conditions, workplace controls and external factors. Central to the concept of a workplace drinking or drug use culture are the workplace alcohol- or drug-related norms of both management and workers and the way in which the workplace deals with alcohol- or drug-related issues. Thus, interventions need to go beyond a focus on individual 'problem' workers to include strategies (such as education and training programs) that target the pre-existing values, beliefs and behaviours of all employees.

Data concerning workers' patterns of alcohol and drug consumption and theoretical explanations of the relationship between the workplace and alcohol or drug use indicate a need to adopt a primary prevention, whole of workplace approach when considering workplace responses. Traditionally, responses to alcohol- and drug-related harm in the workplace have focused on secondary prevention and tertiary treatment. That is, the focus has largely been on identification and treatment referral of alcohol or drug impaired or dependent workers. While the identification and referral of these employees is important, this approach fails to consider the much larger number of employees who individually may experience few alcohol- or drug-related problems, but together account for a much greater proportion of alcohol- or drug-related harm in the workplace. Thus, contemporary Australian (e.g., Pidd & Roche, 2008), American (e.g. Bennett & Lehman, 2003), and other international literature (e.g. ILO, 2003) has argued for a shift away from the traditional approach to a much broader primary prevention focus. There are three basic components of such an approach that are central to effective workplace intervention strategies.

The development and implementation of a formal workplace policy

A formal written policy forms the basis of any workplace response. The policy document needs to be comprehensive and provide a clear statement outlining the organisation's position on alcohol and drug use and provide a set of guidelines and strategies for dealing with all aspects of alcohol- or drug-related issues in the workplace. The policy needs to clearly state the objectives of the policy, the methods of achieving these objectives, and the roles and responsibilities of those who implement the policy. To be effective, policies need to be:

- widely disseminated
- implemented throughout the workplace at all levels and
- specifically designed to meet the operating conditions of the workplace.

The provision of education and training

Awareness and education programs are effective ways of ensuring all workers are aware of the organisation's alcohol and drug policy. They can also contribute to the health and well-being of workers by providing information about alcohol- and drug-related harm in the workplace, workplace factors that may contribute to risk, and information concerning access to rehabilitation and treatment. To be effective education and awareness programs need to be regular and on-going.

The credibility, acceptance and success of any workplace policy is also dependent on the attitudes and actions of supervisors, managers, safety personnel, worker representatives, and other key staff who are responsible for the policy's implementation. Thus, the provision of training that builds knowledge of the policy and skills in managing workplace alcohol-related issues among key staff is an important component of any workplace response. In order to contribute to a culture of safe alcohol consumption among workers, education and training programs need to be regular, on-going, and adaptable to changing circumstances.

Access to rehabilitation and treatment.

An important component of any workplace response is access to rehabilitation and treatment. To avoid the costs associated with dismissal, workers with serious alcohol- or drug-related problems should be encouraged to seek treatment or counselling services and be provided with access to these services via the provision of paid or unpaid leave and assistance with locating and attending treatment services. Some employers may choose to provide these services via an employee assistance program (EAP) or pay for private services; others may use community based non-profit services. While access to treatment and rehabilitation may be compulsory when workers breach conditions of the alcohol and drug policy, workers should also be given the opportunity to access these services voluntarily.

Other strategies

A recent systematic review of workplace interventions for alcohol-related problems (Webb, Shakeshaft, Sanson-Fisher, & Havard, 2009) revealed few quality studies, however four strategies were identified that had the potential to produce positive results:

- health promotion
- brief interventions
- peer interventions
- psychosocial skills training.

Health promotion

Workplace health promotion programs have a long history and in general, have been shown to be effective for improving worker well-being and workplace productivity (Bergstrom, et al., 2008; Kuoppala, Lamminpaa, & Husman, 2008). However, the use of health promotion programs is a relatively recent strategy for responding to alcohol- or drug-related harm in the workplace. The limited research that is available indicates that alcohol and drug prevention programs can be introduced into wider health promotion programs without detracting from the overall objective of improving workers health in general (Cook, Back, Trudeau, & McPherson, 2003) and can reduce levels of risky alcohol consumption (Cook, Back, & Trudeau, 1996; Heirich & Sieck, 2000; Heirich & Sieck, 2003; Richmond, Kehoe, Heather, & Wodak, 2000).

Brief interventions

Brief interventions typically involve identifying an individual's alcohol or drug consumption patterns and providing feedback in the form of information and advice concerning any identified patterns associated with risk of harm. Research evidence indicates brief interventions can be an effective method of reducing levels of risky alcohol consumption in a range of settings (Ballesteros, Duffy, Querejeta, Arino, & Gonzalez-Pinto, 2004; Nilsen, et al., 2008; Roche & Freeman, 2004; Vasilaki, Hosier, & Cox, 2006) including the workplace (Anderson & Larimer, 2002; Doumas & Hannah, 2008; Walters & Woodall, 2003).

Peer interventions

Peer interventions involve the use of peers as agents of change and have been shown to demonstrate effectiveness for addressing a wide range of social and health-related behaviours (Rivera & Nangle, 2008). Applied to the workplace, peer interventions are based on the premise that co-workers are in the best position to recognise and respond to workers with alcohol or drug problems. Peer interventions involve the use of trained co-workers to recognise problems amongst their peers and intervene appropriately. Evaluations of these programs indicate that they have been effective in identifying and addressing problem behaviours and have contributed to achieving reductions in use and related harm (Sonnenstuhl, 1996; Spicer & Miller, 2005).

Psychosocial skills training

Psychosocial skills training involves the provision of training that focuses on an individuals' knowledge, attitudes and life skills and the limited research that is available indicates potential for workplace settings. Cook and colleagues (Cook, et al., 1996; Cook, Hersch, Back, & McPherson, 2004) evaluated a psychosocial skills intervention that involved the provision of workplace training to raise levels of awareness, motivation, and knowledge of the risks and benefits of alcohol use. Results indicated that the training had a positive effect on consumption patterns, motivation to reduce consumption, and personal problems associated with drinking. Similarly, Bennett, Patterson et al., (2004) evaluated a workplace psychosocial skills training program that focused on group dynamics and co-worker support and found the training reduced levels of problem drinking and levels of alcohol-related absenteeism.

Workplace drug testing

A strategy that is increasingly commonplace is workplace drug testing. One reason for the popularity of testing is its apparent logic. That is, testing may potentially identify workers who are impaired by alcohol or other drug use and safety and productivity can be improved by removing these workers from the workplace. Underlying this simple logic is the assumption that testing can detect impairment. However, while there is strong evidence for the efficacy of breath analysis as an indicator of blood alcohol content (BAC) and for a cut off level of 0.05g/100mL to be indicative of impairment due to alcohol intoxication, no such evidence exists for the most commonly used methods to detect other drug use (i.e., urinalysis or saliva testing). A detailed examination of the issues surrounding testing as response to alcohol- and drug-related harm is beyond the scope of this paper[2]. There is very little research concerning the effectiveness of workplace testing in reducing either use or related harm. In general, reviews of this research conclude that there is currently insufficient evidence to conclude that workplace drug testing improves workplace safety (Cashman, Roustsalainen, Greiner, Beirne, & Verbeek, 2009; Kraus, 2001; Macdonald, et al., 2010).

[2] For a detailed examination of the issues surrounding drug testing, see Roche, A.M., Pidd, K., Bywood, P. et al. (2007) *Drug testing in schools: Evidence, impacts and alternatives*. Australian National Council on Drugs, Canberra. Available at: http://nceta.flinders.edu.au

Summary

The evidence that has been reviewed indicates that the prevalence and patterns of alcohol and drug consumption among the workforce have important implications for workplace safety, workplace productivity, and the development and implementation of interventions to address alcohol- and drug-related harm. However, intervention strategies should also acknowledge the differing needs, resources, and environments of individual workplaces. It is unlikely that any single intervention strategy will be appropriate for all workplaces. In addition, the effectiveness of any intervention is likely to be contingent on the ability of the intervention to acknowledge and address the existing workplace culture concerning alcohol and drug use.

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Effect of Drugs on Workplace Exposures

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Abstract

TLVs are guidelines not specification standards. As professionals we must apply them in the context of our workplaces. Among other things we must take into account age and health of workers when applying them. Related to these factors is prescribed medication and over the counter medication usage. Medications may contain workplace materials or result in the same metabolites. This may affect routes of entry for workplace chemicals or rates of metabolism. As a guideline or performance standard, the professional is expected to take into account effects such as those from medications. Failure to do so could result in increased susceptibility to workplace materials. Being aware of conditions such as the potential effect of drugs on workplace exposures will help the occupational hygienist to address atypical reactions in the workplace when exposure monitoring shows exposures to be acceptable. When used properly as guidelines TLVs are a tool to help the occupational hygienist to protect all workers.

Keywords

TLV, exposure limit, pharmaceuticals, medications, drugs, adjusting exposure limits, interactions is between drugs and workplace materials

Introduction

Occupational hygienists utilize available information to anticipate and recognize unacceptable occupational exposures to chemical, physical, and biological agents.

Occupational exposure limits for acceptable airborne concentrations exist for a large number of chemical and physical agents. Among the best known and widely used occupational exposure guidelines are the threshold limit values (TLVs®) from the American Conference of Governmental Industrial Hygienists (ACGIH®). The TLVs are developed for chemical substances and physical agents. The TLV recommendations represent conditions under which it is believed nearly all workers may be repeatedly exposed, day after day, without adverse effect. TLVs are guidelines for occupational exposures that are intended to be used by individuals trained in the field of industrial hygiene.

Implicit in these values are certain assumptions regarding the conditions of the workplace and health status of the workforce, such as the age and health status of workers, exposure time, physical requirements and hazard mixture in the workplace. There is also the assumption that there are no other similar exposures. It is the job of the occupational hygienist to recognize when these standard conditions are not met, and to interpret the exposure limits in light of the current reality.

One of the conditions that the occupational hygienist must be aware of is the possibility that members of the workforce using drugs (prescribed and over-the-counter). Studies in the Netherlands (Borm and Barbanson, 1988) and United States (Rosenberg, 1994) the have shown that 15 to 30% of workers take prescribed drugs. An additional 8% take nonprescribed drugs.

With our aging workforce (or individuals within the workforce) there is likelihood that there will be an increase in illnesses in the workplace due to the aging process (Pleis, Lucas, and Ward, 2009). As the workforce ages, the portion of the workforce that uses prescribed drugs will also increase. Table 1 shows some of the conditions that can affect an aging population.

Disease	Percent by Age Range		
	18-44	45-64	65-74
Heart Disease (all types)	4.6	12.3	26.7
Cancer (any)	2.3	8.9	19.2
Diabetes	2.3	12.1	20.4
Kidney Disease	0.7	1.8	3.0
Arthritis Diagnosis	7.5	30.9	48.3
Hearing Trouble	6.9	18.4	27.8
Vision Trouble	7.2	13.8	14.3

Table 1: Health Conditions (2008) Shown as a Percent of the Age Group.

Unfortunately there is more research studying the effect of other chemicals (workplace, environmental) on drugs than drugs on other chemicals. Although the most comprehensive compilation of interactions is between drugs, there are significant differences in the reporting of interactions between drugs even where there is a regulatory interest in recording such information. It has been found (Litt, 2003) that the reporting of interactions between dugs and workplace chemicals are even sketchier. The literature has some near anecdotal references to workplace exposure pharmaceutical interaction which have to be checked with references such as the Compendium of Pharmaceuticals and Specialties to determine if such interactions are possible.

Adverse Effects of Drugs on Chemical Agents

The effect of drugs is similar to the effects of chemicals, conditions, or diet, on the rates of metabolism and toxicity. Illnesses or atypical health conditions can alter the effect that a workplace chemical may have on an individual. As a result of these conditions, a worker may be taking medications to ameliorate the conditions. These medications may bring additional complications to the workplace. It should be noted that, as one would expect, the drug will counteract the symptoms of the illness. An individual may not respond as expected to workplace exposures because of the underlying illness that caused drugs to be taken. Therefore, in assessing the total effect of an illness, not only the illness, but also the treatment must be considered.

Drugs can have many different effects with respect to workplace exposures. Some of these effects are due to the intended purpose of the drug, and in other cases is a side effect of the drug.

Often, the normal drug dose is above the no-observed-adverse-effect level (NOAEL) and undesirable effects can occur. If the drug contains a material that is used in the workplace, then normal drug dosages can result in worker exposure to materials above what would be considered acceptable in the workplace. These drugs will have an additive effect with occupational exposures. It has been noted (Alessio, Apostoli, and Crippa, 1995; American Conference of Governmental Industrial Hygienists, 2001) that where a drug metabolite is the same as that of a workplace chemical, a person taking the drug may show false high exposure where biological testing is based on the same metabolite.

Similarity to workplace chemicals

Taking of medications can result in exposures to materials that are the same as those in the workplace (Table 2). This will have an additive effect where the chemicals are the same, or affect the same organ in a similar way. This will exaggerate the workplace exposure or result in false biological tests.

Workplace Chemical	Drugs with the Same Material or Effect
Phenol	Antiseptics (phenol-camphor-petrolatum lotion)
	Throat lozenges
	Calamine lotions
	Antacids
Fluoride	Fluoride supplements
	Decongestants
	Tooth paste/mouthwash
	Fluorosteroids
Aluminum	Antacids
Bismuth	Bismuth subsalicylate
Arsenic	Homeopathic medicines

Mercury	Chinese patent medicine Dental amalgams
Ethanol	Non-medical part of medicines (Benedryl)
Warfarin	Blood thinners (Coumadin)
Aniline	Aniline as a contaminant in pharmaceuticals (Tipranavir)
Cobalt	Cobalt-containing medication for anemia Implants made from cobalt-containing alloys
Organophosphate and acetylcholinesterase inhibiting-carbamate pesticides	Alkyl sulfates and sulfonates (neostigmine, physostimine, pyridostimine, pethidine, some immunosuppressants, and various cytostatic agents)

Table 2: Examples of Drugs Containing the Same Materials as Those Found in the Workplace.

Effects of metabolites

Drug metabolites can be the same or similar to those of workplace chemicals (Table 3). Where the metabolite is the toxic material of concern the effects are additive with workplace chemicals. Where Biological Exposure Indices are used to estimate exposures the exposure will be overestimated.

Workplace Chemicals	Drug with the Same Metabolite
Analine	Phenacetin Acetanilide Phenazopyridine
Carbon disulphide	Antabuse
Benzene	Phenylsalicylate, Aspirin

Methemoglobin Inducers (Aniline, *m*-Nitroaniline, o-Chloroaniline, *p*-Nitroaniline [PNA], Dichloroaniline Nitrobenzene, Dimethylaniline, *o*-Nitrochlorobenzene, Dinitrobenzene [DNB]e *p*-Nitrochlorobenzene *p*-Dinitrosobenzene, Nitronaphthalene N-Isopropylaniline, Nitrotoluene *n*-Methyl aniline, *n*-Propyl nitrate)	Medications (generally prescribed) (Nitrites, benzocaine, lidocane, nitroglycerin, prilocaine, silver nitrate (burn dressing), sulfoamides, dapsone, chloroquine) Medications (generally over-the-counter) (Acetanilid, bismuth subnitrate, phenacetin)
PAHs	Ointments and shampoos, are used in some contexts for the treatment of psoriasis and dandruff.

Table 3: Examples of Drugs with the Same Metabolites as Workplace Chemicals.

In other cases, a drug can affect workplace chemicals by inhibiting their biotransformation (Table 4). This can be done by competition for existing enzymes, such as antabuse which competitively inhibits aldehyde dehydrogenase. Another way that biotransformation can be inhibited is when the drug destroys or inactivates an enzyme as with antineoplastic drugs. Where biotransformation is inhibited, biological testing may show false low exposures when the testing is based on the same metabolite.

Drug That Could Affect Workplace Chemicals	Workplace Chemical	Effect on Metabolism
Aspirin	Xylene	Reduced rate of metabolism
Ethanol	Carbon tetrachloride	Synergistic effect
Ethanol	2-Butoxyethanol, 2-Ethoxyethanol, 2-Methoxyethanol, Dimethylacetamide, Methyl Ethyl Ketone,	Reduced rate of metabolism

	N-Methyl-2-pyrrolidone, Styrene, Toluene, Trichloroethylene, and Xylene	
Isopropanol	Carbon tetrachloride	Synergistic effect
Paracetamol	Toluene	Toluene in blood significantly increased
Cimetidine	Warfarin	Increased blood levels
Some antineoplastic drugs	Various	Inactivates liver enzymes and affects kidney function

Table 4: Effects of Chemicals or Conditions in the Workplace on Rates of Metabolism and Toxicity.

Effects on Kidneys

Some drugs can result in impaired kidney function that will affect the kidneys' ability to clear toxic materials from the body. Table 4 is a partial list of drugs or drug classes that can have an adverse effect on the kidneys. If a material cannot be effectively removed from the body, its effective half life will be increased and the potential for harm increases.

- Non-steroidal anti-inflammatory drugs (NSAIDS) (Motrin, indomethacin, Celebrex, Indocin
- Sulfa drugs
- Antiviral agents
- Ciprofloxacin
- Aminoglycosides
- Radiocontrast media
- Ibuprofen (Motrin)
- angiotensin receptor blockers (losartan, telmisartan, candesartan, valsartan)
- Converting enzyme inhibitors (lisinopril, accupril, captopril, ramipril, enalopril)
- Diuretics (amiloride, diazide)

Table 4: Drugs that can Affect Kidney Function.

Effects on Liver

Some drugs alter blood flow through the liver either as a primary effect or as a side effect. Propanolol reduces cardiac output while cimetidine inhibits vasodilation; both reduce hepatic blood flow and thus rates of metabolism.

Other drugs may alter hepatic enzyme activity such as antineoplastic drugs or cimetidine which reduces hepatic enzyme activity and thus metabolic processes. For example this interaction may occur between cimetidine and warfarin.

Skin Absorption

Ointments, drug patchs and cosmetics can alter dermal absorption of workplace chemicals by acting as a barrier and decrease the rate of absorption. Or the ointments may act as a reservoir and increase the total absorbed.

Drugs and cosmetics can be applied to the skin. Like drugs there are methods by which they have an effect:

- They remain on the surface – disinfectants, sun screens, insect repellents, decoration
- They penetrate into the skin – moisturizers, anti-wrinkle control
- They penetrate the skin layers – mostly for systemic drugs

Materials that penetrate the skin can act as carriers to help transfer other chemicals through the skin. Where an ointment, drug patch, or cosmetic incorporates materials that penetrate the skin, they can increase the penetration rate of workplace chemicals with skin notations, or can assist a chemical, that will not normally penetrate the skin, to do so. This could increase the effect of workplace materials or cause unanticipated exposures where skin absorption was not expected.

There are many such materials. Osborne and Henko (1997), identified 275 materials as skin penetration enhancers (Table 5). The following is a list of groups of chemicals that are skin penetration enhancers.

- Sulphoxides
- Alcohols
- Polyols
- Alkanes
- Fatty acids, fatty alcohols
- Esters
- Amines and amides
- Terpenes
- Surface active agents

Table 5: Groups of Chemicals that can Penetrate the Skin.

Effect of Drugs on Physical Agents

Just as various medications can affect how an individual will respond to chemical exposure in the workplace, they can also affect how an individual will respond to physical agents such as heat and noise.

Hearing Loss

The following are examples of drugs that have an ototoxic effect. If a worker uses any of these, there is a risk of hearing damage. In some cases, such as aspirin, the effect may be temporary. In most cases, the effect will be noted only when dosages are large.

The effect of the drugs can be exaggerated when the individual has kidney or circulatory problems, or when there is previous hearing loss due to noise exposure.

Class of Medication	Medication
Antibiotics	Gentamicin
	Kanamycin
	Neomycin
	Streptomycin
	Tobramycin
	Amikacin
	Erythromycin
	Chloroquin
	Quinine
	Vancomycin
Salicylates	Aspirin
Diuretics	Furosemide (Lasiz)
	Ethacrynic Acid
Antineoplastic Medications	Cisplatinum
	Bleomycin
	Nitrogen Mustard

Table 6: Examples of Drugs that can Affect Hearing Loss

Hot and Cold Environments

It is reported (Department of the Army and Air Force, 2005) that drugs can have an effect on the body's reaction to physical challenges as well as to chemical challenges in the workplace. Any worker with an illness or taking any medication that interferes with thermal regulation should be carefully monitored when working in cold environments.

Examples of conditions that affect heat production and loss include:

- Cardiovascular
- Peripheral vascular disease
- Endocrinological disorders
- Psychiatric disorders
- Earlier cold injury
- Muscular disorders
- Neural disorders

Examples of conditions that may cause decreased heat production include:

- Hypopituitarism
- Hypoadrenalism
- hypothyroidism.
- Hypoglycemia
- Neuromuscular inefficiencies
- Stroke
- Severe arthritis
- Parkinson's disease
- Trauma
- Spinal cord injuries
- Burns
- Disorders that affect sensation in extremities (for example, nerve damage in the feet of people with diabetes)

The following drugs may cause heat intolerance by reducing the ability to sweat or increasing urine production. Workers in hot environments should consult their physician or pharmacist before taking medications (Table 7). The list below shows examples of such drugs, classes of drugs and the means by which they affect heat stress.

Class of Drug	Drug	Mechanism
Anticholinergics	Atropine Scopolamine Pyridostigmine	Impaired sweating
Antihistamines	Diphenhydramine	Impaired sweating
Phenothiazines	Thorazine Stelazine Trilafon	Impaired sweating
Tricyclic Antidepressants	Antitriptyline	Impaired sweating
		Increased motor activity and heat production
Amphetamines, Cocaine	Ecstacy	Increased psychomotor activity
Ergogenic Stimulants	Ephedrine	Increased heat production
Lithium		Nephrogenic diabetes, insipidus, and water loss
Diuretics		Salt depletion and dehydration
Beta-blockers	Propranolol Atenolol	Reduced skin blood flow, and reduced blood pressure
Ethanol		Diuresis
Sedatives		Affects thirst thresholds

Behavioral-modifying Drugs	Increases body temperature
Appetite Suppressants	Increases metabolic heat production and reduce heat distribution by affecting the peripheral circulation

Table 7: Drugs that Affect Heat Tolerance.

Because older individuals often have pre-existing diseases (atherosclerotic heart disease, diabetes mellitus, or alcoholism) and therefore may be receiving medication (phenothiazines, anticholinergics, sedatives, or diuretics) known to predispose the individual to the development of heat stroke; they are more susceptible to heat stroke.

A unique problem reported by Spaul et al. (1985) for outdoor workers is the protective creams or lotions used to prevent sunburn. Oil or alcohol based sunscreens appear to reduce the sweat evaporation rate but not the sweat production rate. This reduces the individual's tolerance to a heat stress environment, particularly at a moderate workload. Therefore workers using such lotions should have a more restricted workload than is currently recommended.

Summary

The impact of most drugs on workplace exposures is unknown. In some cases (aspirin on toluene) the effect is known, but the mechanism is unclear. Where it is suspected that a drug has an effect on the impact that a workplace chemical is having, the hygienist should work with the worker's physician to determine if the drug and the workplace chemical use the same metabolic pathways, or could interact in some other fashion. Given the potential problems, it is surprising that the effects of drugs on workplace exposures have not been explored more fully. These are not rare occurrences. For example, Jerome Z. Litt, M.D. has developed a list of 120 drugs that are known to cause photoallergenic, photosensitive, and phototoxic reactions. These can affect outdoor workers and contain such items as ibuprofen, saccharin, and streptomycin.

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Comparative Case Study of Emerging Technologies for Mould Remediation – Hydroxyls OH-, Hydrogen Peroxide H_2O_2 and Ozone O_3

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Abstract

With numerous buildings affected in recent floodings and natural disasters, mould damage and its health effects on inhabitants has received worldwide awareness. The recent popularity of emerging technologies utilised in mould remediation for surface decontamination has prompted significant debate over their effectiveness. This comparative study investigates the current research available on three such emerging technologies used for surface decontamination – hydrogen peroxide vapour, hydroxyls and ozone. Hydrogen peroxide (H2O2) is a strong oxidising agent and claims to be environmentally friendly and have nontoxic decomposition products. Hydroxyl (OH-) generators claim to be safe, producing naturally occurring molecules that are able to deodorize air, eradicate bacterial and other microorganisms. Ozone generators create high levels of oxidising ozone that remove unpleasant odours including those caused by mould. This is a side by side study to compare the advantages and disadvantages of all three emerging technologies utilised in the mould remediation industry and the current available scientific research on the effectiveness on treating mould.

Managing Risks Associated with Asbestos Contamination in Soil

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Abstract

The issue of managing asbestos contamination in soil is highly complex and has received increasing attention as a result of recent regulatory reviews. Asbestos contamination in soil is currently regulated in part under state based OH&S legislation as well as state based Environmental legislation. The May 2009 Western Australia Guidelines for Assessing and Managing Asbestos Contamination In Soil have provided regulators with a framework with which to introduce more consistent and practical approaches to managing these hazards.

Importantly the national harmonisation of OH&S legislating, together with the current redrafting of the National Environmental Protection Measure (NEPM) will set the regulatory framework for coming years for hygienists working in this field. Both of these important pieces of legislation have been issued in draft and both have introduced additional requirements for managing asbestos contamination in soil.

This presentation brings together the proposed changes and practical requirements for managing asbestos contamination in soil which have been proposed in the model OH&S regulations as well as the draft NEPM. The presentation will compare these new requirements with current regulatory requirements and will discuss the practical issues of risk assessment and the role risk assessment plays in the management and control of these hazards.

Hazard Surveillance: Residual Chemicals in Shipping Containers

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Abstract

Recent Australian and international research has shown that imported shipping containers may contain residual chemicals at levels that exceed relevant occupational and public health exposure standards. Residual chemicals may be present due to inefficient post-fumigation venting of shipping containers or the slow release of fumigants over time from products or packing materials that initially absorbed them. Other residual chemicals may be volatile organic compounds or other solvents that have been released from products during transit.

This project aims to identify if and where significant worker exposures occur when shipping containers are unpacked at consignment centres, retail warehouses or small importing businesses. The use of video exposure monitoring will be a key component of this work. Environmental monitoring of work areas will also be undertaken for periods of up to 48 hours as some products or materials may continue to slowly release residual chemicals after they have been unpacked.

Air and Biological Monitoring to Assess Exposure to Carbon Disulfide

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Abstract

Carbon disulfide (CS_2) has been widely used in the manufacturing of rayon, cellophane and carbon tetrachloride. Exposure can result also from CS_2 fumes emanating from the breakdown xanathate flotation reagents used in the mining industry. It is a concern for many analytical chemistry laboratories that are using the solvent in gas chromatography analysis. Occupational exposure to CS_2 has been associated with neurological, cardiovascular and reproductive system disorders. The assessments of the exposure to carbon disulfide in an analytical laboratory was conducted using both air and biological monitoring techniques. The metabolite of CS_2 in urine, 2-thiothiazolidine-4-carboxylic acid (TTCA) was used as the biomarker of the exposure. Low-level test results were found in both the air monitoring samples and the biological monitoring samples. The results indicate that no worker exceeded the American Conference of Governmental Industrial Hygienist (ACGIH) biological exposure index (BEI) of 0.5 mg TTCA /g creatinine (350 µmol/mol cr) in urine or the Safe Work Australia air concentration of 10 ppm TWA. However, a very low exposure was determined by biological monitoring the pre-shift and post-shift urine samples of individual workers using a "*Paired t-test*". This is shown to be a more powerful statistical technique than comparing Similar Exposure Groups (SEGs) using the usual method of ANOVA.

Keywords

Carbon disulfide (CS_2), 2-thiothiazolidine-4-carboxylic acid (TTCA), air monitoring, biological monitoring, paired t-test.

Introduction

Carbon disulfide is a toxic, flammable, volatile and disagreeably smelly chemical. It has been in production since the late nineteenth century and has been used in a variety of applications, including the production of rayon, cellophane, rubber and in the manufacture of organic sulfur chemicals in the agricultural, pharmaceutical sectors. Its properties as an organic solvent are useful in many industrial applications, particularly in extraction and cleaning processes. Carbon disulfide is no longer manufactured in Australia and its use in industry has also decreased. However, many chemistry laboratories still used carbon disulfide as a solvent in gas chromatography analysis. The use of sodium ethyl xanthate as a flotation reagent to concentrate ores in the mining industry is also a source of possible exposure. Xanthate has the tendency to decompose in the presence of moisture and/or heat to produce carbon disulfide. This release of carbon disulfide could pose as a potential exposure risk to the workers.

Occupational exposure to CS_2 has been associated with neurological, cardiovascular and reproductive system disorders. Exposure occurs by both inhalation and skin penetration. The American Conference of Governmental Industrial Hygienist (ACGIH) has a time-weighted average (TWA) threshold limit value (TLV) of 1 ppm in air [1]. Carbon disulfide is metabolised in the body to 2-thiothiazolidine-4-carboxylic acid (TTCA), which can be measured in post-shift urine. A number of studies have demonstrated satisfactory correlations between urinary TTCA and airborne carbon disulfide levels [2, 3]. Urinary TTCA has thus become an important biomarker for exposure to carbon disulfide. The ACGIH have a biological exposure index (BEI) of 500 µg/g creatinine in the urine of samples collected at the end of work shift [1].

The analytical methods for air monitoring of carbon disulfide have been well established [4]. A few research papers have published analytical methods for biological monitoring of carbon disulfide through analysis of the metabolite TTCA in urine [2, 3, 5-7]. However, for the most part they are complicated and time consuming. This paper presents a new method of analysis utilising the latest chromatography column technology of Hydrophilic Interaction Chromatography (HILIC) that allows the separation of polar compounds in a urine sample. This is performed using an Ultra High Performance Liquid Chromatograph and a tandem mass spectrometer detector (UPLC-MSMS).

The new method is employed in a case study of a small group of unexposed individuals working at a laboratory and a possibly exposed analyst. Personal breathing zone air was monitored concurrently with urinary TTCA biomarker levels.

It is shown that biological monitoring of pre-shift and post-shift urine samples can be a more powerful technique for determining low exposures than general data analysis of Similar Exposure Groups (SEGs).

Experimental

Similar exposure groups and work process

SEGs were selected from a working laboratory using CS_2. One group were unexposed to the chemical and the second comprised of one analyst who was using the chemical on most days of employment. The nature of the work involved the used of CS_2 to desorb compounds adsorbed onto charcoal in preparation for gas chromatographic analysis. The processes are briefly described below:

- On receipt of charcoal tubes or passive samplers into the laboratories they were stored in the refrigerator at 4°C until the analysis can begin
- The sample preparation was performed in a well functioning laboratory fume hood
- To desorb the compounds from the charcoal samplers, one or one and a half milliliters of CS_2 was used
- After the desorption process was completed, the vials containing the CS_2 solution were sealed with teflon/silicon lined screw caps
- The vials were then transferred to the auto sampler of the gas chromatograph for analysis.
- During the process the analyst was wearing a laboratory coat, safety spectacles and nitrile disposable gloves. The sample preparation and desorption process normally would take approximately one hour but on occasions could take 2 – 3 hours of possible exposure.

Air monitoring of exposure

The air monitoring was performed using a 3M Organic Vapor Monitor (OVM 3500) worn in the breathing zone of the workers of each SEGs. The analysis of carbon disulfide was performed by a modified version of the NIOSH 1600 method [4]. The modification of the NIOSH 1600 method was the utilization of a gas chromatography with a mass spectrometer detector (GCMS) instead of the stated gas chromatography with a flame ionisation detector (FID). The GCMS is a more sensitive instrument used in the single ion monitoring mode and is able to achieve a detection limit of 0.1 µg/sample tube which is 200 times lower than that of the NIOSH 1600 method of 20 µg/sample tube based on a FID detector.

Biological monitoring of exposure

Urine was collected from exposed worker twice per day at the beginning of each workday (pre-shift) and end of the workday (post-shift). The urine samples in the unexposed control group was collected randomly at any time of the workday. The subjects in the unexposed control group were working at the laboratory but did not perform any work that could potentially expose them to carbon disulfide.

The creatinine in the urine was determined using a Roche Cobas Mira Plus system purchased from Roche Diagnostic Systems, Basel, Switzerland. The analysis used the Jaffe reaction in which creatinine reacts directly with the picric acid under alkaline conditions [8]. Creatinine measurement is used to account for different volumes of fluids taken by the worker in a shift. This gives the level of hydration of the worker and is a useful way to account for the different volumes of urine excreted when a sample was taken. The CS_2 metabolite, TTCA, is therefore reported in relation to the amount of creatinine rather than per volume of urine. The ACGIH gives the normal range of creatinine concentration as 0.3 – 3.0g/L[1].

Analysis of 2-thiothiazolidine-4-carboxylic acid in urine

The analysis of TTCA was performed by taking an aliquot of urine and diluting it with acetonitrile, then centrifuging and directly injecting into an Ultra-high Performance Liquid Chromatograph Mass spectrometer (UPLC-MSMS). The limit of quantitation (LOQ) was found to be 0.5 µmol/mol creatinine (~1 µg/L urine).

Results and Discussions

Analytical Method

The analysis of TTCA is problematic as it is a very polar compound in a polar urine matrix. The recent introduction of hydrophilic interaction chromatography (HILIC) has now allowed the separation of the TTCA in such a matrix with relative ease. The work presented here utilizes a HILIC-silica column that has the advantage of using a high percentage organic mobile phase content, together with a volatile organic buffer. This not only gave good separation of the TTCA from the other constituents in the matrix but also gave high sensitivity with the mass spectrometer. This was achieved by rapid desolvation of the mobile phase and elimination of the buffer to minimise any ionisation suppression of the compound often encountered with this technique.

Air monitoring

The results of personal monitoring for 8-hour TWA breathing zone air samples (n = 12) of eight unexposed workers gave a CS_2 air concentration range of 0.009 – 0.052 ppm with a geometric mean of 0.029 ppm and a Minimum Variance Unbiased Estimator (MVUE) of 0.034 ppm with a geometric standard deviation of 1.77. According to the calculated values there is 95% confidence that 95% of the exposures are under 0.14 ppm. The exposed analyst results of personal monitoring (n = 4) gave a similar CS_2 air concentration range of 0.009 – 0.068 ppm (See Table 1) with a geometric mean of 0.028 ppm and a MVUE of 0.040 ppm with a geometric standard deviation of 2.53. According to the calculated values there is 95% confidence that 95% of the exposures are under 0.54 ppm.

The results are well below the Safe Work Australia national exposure standard of 10 ppm TWA and well below the ACGIH TWA of 1 ppm (adopted in the US in 2006). This is an indication that the ventilation controls in the workplace are adequate and that exposure by inhalation is low. The main ventilation control employed is the laboratory fume cupboard. These results are similar as those found in a survey done by Geyer *et al* [9] in the same laboratory about 13 years ago.

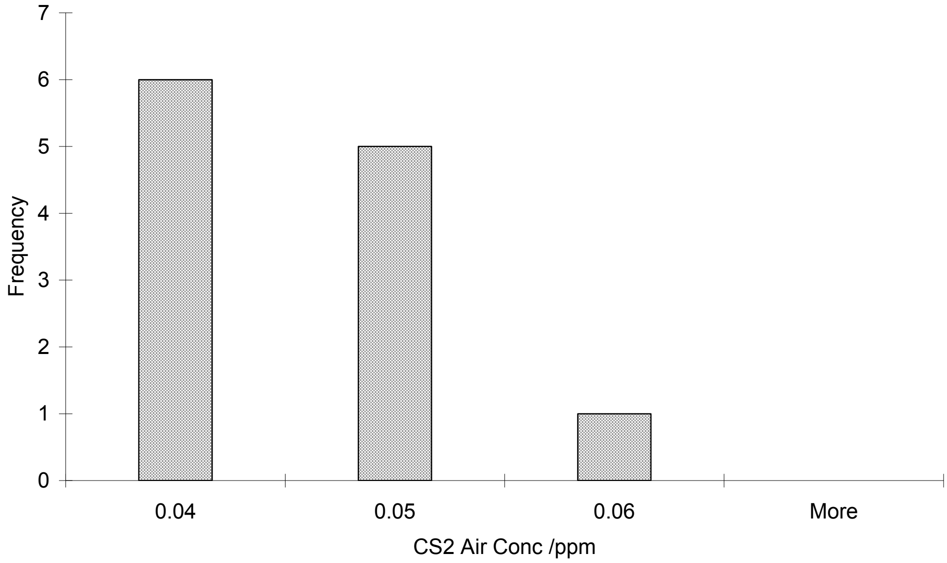

Figure 1. Concentration of CS_2 in air found in breathing zone of the unexposed workers in the workplace where CS_2 was used.

No	Concentration /ppm	Comments
1	0.068	Exposed worker
2	0.062	Exposed worker
3	0.016	Exposed worker
4	0.009	Exposed worker

Table 1. Air monitoring results of exposed worker.

A couple of static worst-case scenario samples were taken and the results can be seen in Table 2. The first sample was taken at the front entrance of the fume hood at bench height. This gave an air concentration of 0.681 ppm. The second one was taken 10 – 15 cm directly above the GC vials containing CS_2 on the auto sampler during the analysis. These vials were sequentially pieced during the course of the analysis batch by the injection needle of the chromatograph. The level found was 0.550 ppm. These worst-case scenario samples were taken directly from where positive test results were expected and their values over estimate typical exposure conditions. The samples were taken to evaluate the sources of exposure and to help identify where exposure controls could be improved. Even these worst-case scenario samples are well below the Safe Work Australia (10 ppm) and ACGIH (1 ppm) standards.

No	Concentration /ppm	Comments
1	0.681	Placed at fume cupboard entrance
2	0.550	Placed above vials on auto sampler

Table 2. Air monitoring results of Worst-Case Scenario static samples

The other possible exposure route is dermal. The main forms of PPE control used were the analyst's laboratory coat, spectacles and disposable nitrile gloves. The chemical resistance rating of the nitrile gloves to CS_2 is generally good with a good degradation rating and a 30-minute permeation breakthrough time. Other gloves such as one made from fluoroelastomer (Viton) or from supported polyvinyl alcohol (PVA) give better ratings but are not in the disposable surgical glove range. They tend to only be available in the heavy-duty industrial use range that doesn't allow the dexterity required for laboratory work.

Glove Permeation Study

An assessment of the nitrile gloves was undertaken. This was performed by placing a 3M Organic Vapor Monitor (OVM) inside the nitrile glove. The glove was found to be 0.1 mm in thickness. Therefore, to investigate whether wearing double or more pairs of gloves is effective for reducing exposure then a 3M OVM was placed inside double and quadruple gloves layers. They were sealed and placed inside a fume cupboard along with one OVM to monitor the air concentration in the fume cupboard. An approximate atmosphere of the working air concentration of CS_2 was generated by two open beakers that contain about 20ml of CS_2 in each and allowed to evaporate. The normal sample preparation processing time of 110 mins was selected. The results are tabulated in Table 3.

The results showed that permeation occurred through the gloves over the time period of 110 mins used to simulate the exposure time of the worker for that job and while the air concentration that has penetrated the glove does exceed the ACGIH TWA of 1 ppm in some samples, this does not necessarily mean that a large exposure has occurred as the TWA is really applicable for inhalation and does not correlated reliably to dermal exposure. However, the study does illustrate that the wearing of double gloves or thicker gloves will give better protection and that frequent changing of the gloves during the working day would reduce exposure also. These two control measures have now been implemented in the workplace.

No	Samples	Exposure time (*min*)	Atmospheric Concentration (*ppm*)
1	Inside fume cupboard	110	50
2	One glove	110	2.4
3	Two gloves	110	1.2
4	Four gloves	110	0.6

Table 3. The permeation of CS_2 through nitrile gloves in 110 mins.

Biological monitoring

Biological monitoring is a valuable tool that can be used to assess the exposure as it takes into consideration all routes of entry into the body. It is also useful to assess the effectiveness of PPE which air monitoring generally finds difficult to evaluate. However, on some occasions diet can be a confounding factor that can lead to a high background level of the analyte. Unfortunately, the metabolite of CS_2, TTCA, can be found in vegetables of the Brassica family[6, 10]. These include cabbage, cauliflower, broccoli, Brussels sprouts, Chinese cabbage, and turnips. This dietary influence leads to a background level of TTCA being found in most individuals' urine.

Background level of TTCA Study

To establish a background level of TTCA in unexposed population we recruited 10 volunteers to donate urine samples over the course of a week with the final sample pool of n = 60. The background levels found ranged from 0.49 – 79.81 µmol/mol creatinine with a geometric mean of 7.85 µmol/mol creatinine and geometric standard deviation of 2.74. The levels found in the exposed worker (n = 24) ranged from 0.22 – 278.6 µmol/mol creatinine with a geometric mean of 13.79 µmol/mol creatinine and a geometric standard deviation of 7.89. The background levels were compared to the levels found in the exposed worker in Figure 2 below.

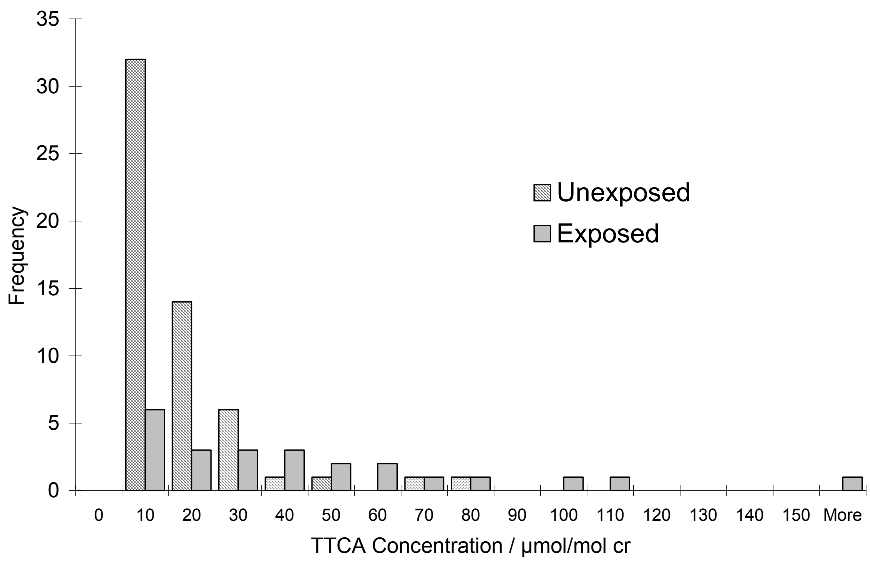

Figure 2. Comparison of TTCA levels found in exposed workers (*n* = 24) and unexposed workers (*n* = 56).

Dietary Study

To determine the relative influence of diet we asked 8 volunteers to agree to eat a 200g portion of coleslaw for lunch. It was estimated that the coleslaw consisted of approximately 75% raw cabbage. Many volunteers said that they found this 200g portion quite large and more than they would normally consume for lunch of this type of salad. Therefore, the test results of this study should predict the extent of the dietary influences that one would expect. The volunteers gave a urine sample before lunch and then another urine sample before they left the workplace. The difference between the pre-lunch and the post-lunch samples (n = 25) can be seen in Figure 3. One can see a large contribution from the eaten coleslaw, however, all levels were below the ACGIH BEI level of 350µmol/mol creatinine (~500µg/L). Therefore, for best exposure assessment it is good practice to ask the workers to refrain from eating any large amounts of Brassica vegetables for lunch. The graph shows the excretion half-life of the TTCA in urine to be approximately 4 hours.

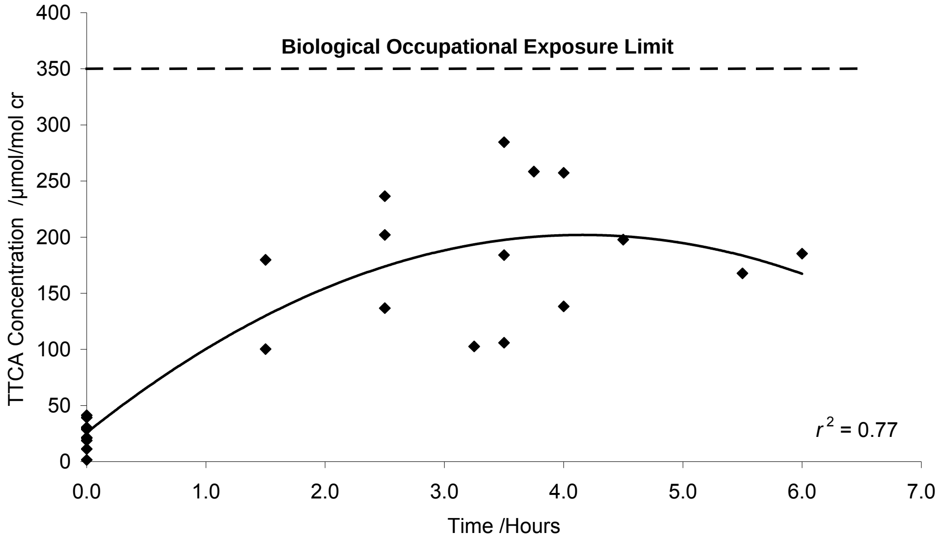

Figure 3. Shows the excretion of TTCA in urine after consumption of 200g of coleslaw salad.

Data Analysis

The shape of the data of the exposed and unexposed SEGs clearly shows the log-normal distributions. However, to correctly apply an ANOVA analysis of the logarithmic transformation to determine if the geometric means of the distribution are the same, the variance of each of the transformed distributions needs to be similar. This can be determined by the use of the Levene's test. In this instance the Levene's test fails with and *F*-value of 7.76 and the critical $F_{0.05, 24, 56}$ = 3.96 with p = 0.007 and therefore ANOVA is not the correct test to use.

Biological monitoring allows the use of a more powerful statistical test than ANOVA by comparing the pre and post-shift urine samples and using a "*Paired t-test*". This test is more powerful because it reduces the variance of the distributions that are to be compared. The variance of the difference of the pre–shift and post–shift urine samples is smaller than the variance of the unexposed and exposed distributions. This is due to the fact that the pre-shift and post-shift urine samples are correlated and hence reduce the variance. Therefore, applying the "*Paired t-test*" to the difference of the pre-shift and post-shift urine samples of the exposed workers we were able to find that a significant difference existed between the means of the distributions with a calculated *t*-value of 2.48 and *t*-critical value of 2.14 giving a p = 0.03 for a two-sided comparison at 95% confidence level. This shows that the worker had a very mild exposure to CS_2 at a level approximately 20% of the ACGIH BEI exposure level and moreover shows the power of biological monitoring to assess an exposure. See the data in the Table 4 below.

Day	**Pre-Shift /µmol/mol cr**	**Post-Shift /µmol/mol cr**	***δ* /µmol/mol cr**
1	1.49	15.21	13.7
2	18.48	19.08	0.6
3	4.37	44.10	39.7
4	8.13	32.61	24.5

5	11.01	98.67	87.7
6	3.15	0.82	-2.3
7	16.12	57.96	41.8
8	12.89	40.27	27.4
9	6.05	11.24	5.2
10	103.53	61.31	-42.2
11	11.11	57.42	46.3
12	7.97	0.44	-7.5
13	27.56	74.74	47.2
14	24.22	33.27	9.0
Geometric mean	10.71	21.06	

Table 4. The comparison of the pre-shift and post-shift urine concentrations of TTCA in urine of a worker exposed to CS_2.

Verification of Exposure Study

To verify the worker's exposure to the CS_2 a repeat study of morning and afternoon urine samples (n = 7 pairs) were collected when the subject was unexposed over the weekend. This study showed that there was no significant difference between the morning and afternoon samples taken when unexposed over the weekend. The "*Paired t-test*" gave a t-value statistic of 0.71 with p = 0.51 compared to a critical $t_{0.05,6}$ = 2.45 which indicates that there is insufficient evidence to reject the null hypothesis that the means are the same. Therefore, we can conclude that there is no significant difference between the morning and afternoon samples.

Verification of Control Study

The worker was asked to wear thicker gloves and to wear double gloves. This was equivalent in thickness to the quadruple set used in the permeation study. Pre-shift and post-shift urine samples (n = 5 pairs) were again taken and showed no significant difference. The "*Paired t-test*" gave a t-value of 0.31 with p = 0.77 compared to a critical $t_{0.05,4}$ = 2.78 indicating no significant difference between the means. This study has shown that a minor improvement to the worker's PPE can significantly reduced a worker's exposure to CS_2 vapours.

Conclusions

This paper presents a new analytical method for the analysis of TTCA in urine by the use of new chromatographic packing materials and the use of the latest state of the art analytical instrument, UPLC–MSMS. The method is simple and easy to use and is able to obtain a very low limit of quantitation of 0.5µmol/mol cr (~ 1µg/L). The paper further shows that the use of pre-shift and post-shift urine sampling allows the use of the statistically powerful "*Paired t-test*". This provides the occupational hygienist with an easy and effective technique to evaluate low-level exposures to CS_2.

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Use of Video Exposure Monitoring to Characterize Peak Exposures

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Abstract

Video Exposure Monitoring (VEM) is a technology to provide a record of exposure to a variety of chemical, physical, or biological agents. VEM uses real-time monitoring coupled with a video recording of a worker as he or she performs tasks associated with varying exposures, and displays the two together on the screen. It is particularly suited to exposures that are highly variable, and can be utilized as a tool to better characterize exposure, and also permit interventions to reduce exposures.

Keywords

Video Exposure Monitoring, Peak Exposures, Real-time monitoring, intervention

Introduction

Video exposure monitoring (VEM) is a video-based technology that provides a real-time video record of exposure to substance of interest (e.g., a dust or volatile chemical), and a video image of the worker's activities at the time of the exposure. The two are superimposed on a video that then provides a permanent record of the time history of exposure and activity. VEM is particularly suited to variable exposures for which direct-reading instruments are currently technologically feasible. The technology is valuable not just for documentation purposes, but for understanding exposure determinants in a sufficiently detailed manner so as to permit interventions which will significantly reduce or eliminate peak exposures.

Background

Workplace exposures can be consistent over a work shift or quite variable. The variability is generally not measured, although it has been suggested that peak exposures may be associated with more severe health effects. For example abrasive or air-driven processes creating inhalable dusts may result in short-term (peak) concentrations orders of magnitude higher than "normal" airborne levels. For most substances, potential health effects are determined by the sum of the material inhaled and absorbed, classically termed "dose". Exposures to substances causing chronic health effects, representing the majority of substances of concern in the workplace, have historically been assessed in such a manner, and airborne levels measured as an average exposure over a 4 or 8-hour period (time-weighted average).

For compounds considered to be "acutely dangerous to life and health", such as carbon monoxide, and irritant substances, exposures over a very short period can be highly relevant. For these compounds, the ability to assess airborne concentrations in real time using direct-reading instrumentation is critically important. Current technology permits a microprocessor-based instrument, worn in a worker's breathing zone, to data log airborne concentrations over any time period of interest, alarm if necessary, and ultimately display the data in a graph of concentration vs. time on a computer screen or printout.

Real-time monitoring technology has now also become widely available for measuring gases, vapours, dusts, and fibres associated with chronic health effects. Small portable instruments capable of being worn on a worker support electrochemical, infra-red, and photo-ionization sensors to detect well over 30 specific gases and vapours, as well as total organic vapours, and photometric light-scattering sensors to detect both fibrous and non-fibrous aerosols. Real-time (direct-reading) technology is improving rapidly in its ability to become more sensitive and more specific for a wide variety of compounds of interest in the workplace.

A graph of concentration versus time produced by direct-reading instruments may be useful, but a significant improvement to organize and manage this information, and to provide additional insight into exposure, is to superimpose a real-time indicator of exposure, such as a bar graph of varying heights, on a real-time video background of the worker performing the task. This technology is known as Video Exposure Monitoring (VEM), and has been in development as a research tool for the last 20 years. Purdue University and the National Institute of Occupational Safety and Health (NIOSH) in the U.S., the National Institute for Working Life in Sweden, and the Health and Safety Laboratory (HSL) in the UK have developed systems and conducted studies demonstrating the effectiveness of VEM.

For many workplaces with exposures to dusts with variable exposure patterns, mathematically it is these peak exposures that are the main determinant of the time-weighted average. If the activities associated with the peak exposures can be identified (as is the case with VEM), the possibility of intervention to reduce these exposures through engineering controls, modification of equipment, work practices, or other means are significantly enhanced. Since a small reduction in peak exposures can have a large effect on reducing the time-weighted average exposure, the effectiveness of the intervention in reducing overall exposure and preventing disease can be much greater using VEM technology.

This combination of real-time exposure measurements for a wide variety of chemical, radiological, biological, and physical agents, synchronized with real-time video of the worker's activities, can now be accomplished through wireless technology.

VEM is a practical and proven technology capable of being used in a variety of workplaces for the following reasons:

- VEM is flexible and can be utilised to evaluate chemical, radiological, biological, and/or physical agents. It can also be utilised to analyze postural data and physiological data, such as heart rate. It can incorporate future technology such as biological monitoring or other tools representing body burden or absorbed dose and record these along with traditional exposure measurements.
- VEM permits a far more detailed permanent record of the work tasks performed and associated levels. Historically, standard time-weighted average sampling represents the vast majority of sampling performed. A worker's activities may have been described in general terms in a hygienist's field notes, but extensive descriptions of specific tasks, equipment utilised, associated levels; or identification of peak levels, was not typically collected.
- VEM studies have been able to identify exposure patterns previously unrecognized, allowing better and more cost-effective control of workplace hazards.
- Multi-channel VEM technology can add additional monitoring capability at relatively low cost and difficulty, providing monitoring of multiple hazards, such as dust, solvents and noise, in a single "job exposure" record. This will further assist in recognizing and mitigating workplace exposures.
- VEM technology provides improved baseline data of workplace exposures by both industry and government agencies that reflects current exposures and work practices.

- VEM can contribute information for the development of Codes of Practice and other standards development.
- VEM has been shown to be an effective motivational strategy for behaviour and cultural change in workplaces .

VEM is a technology that can be currently deployed. It promises to provide additional insight into exposure assessment, assistance in reducing workplace exposures through more effective intervention, improved data management and record-keeping, and improved motivational tools for worker training and behaviour modification. It will become an increasingly important component of exposure assessment in the next decade

With the assistance of Dr. Jim McGlothlin at Purdue University, the Centre for Public Health Research (CPHR) at Massey University in New Zealand has been using VEM for two projects this past year. One involves wood dust exposueres, as part of an effort to identify and eliminate tasks associated with high peak exposures.

A second study is currrently underway in Australia using VEM technology to explore patterns of exposure in workers entering and working with goods which have been fumigated, typically with methyl bromide.

These studies will be described and illustrations of the use of VEM presented.

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Wood Dust Assessment

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Abstract

A wood dust occupational exposure assessment was conducted for cabinet makers and wood machinists. The objectives of the assessment were to measure and assess occupational exposure and develop recommendations for control measures.

Personal exposure monitoring and direct reading equipment was used to understand the pattern of exposure and identify high exposure tasks.

Statistical analysis of the data was performed using the American Industrial Hygiene Association Exposure Standard Committee spread sheet IHSTAT. The upper and lower confidence limits of the estimated arithmetic mean (MVUE) and the group exceedance and individual exceedance were calculated for each Similar Exposure Group (SEG) to assist in assessing compliance.

Sampling data supported the decisions made through observation for classification of SEGs.

There was strong evidence of compliance to the WorkSafe Australia HSIS exposure standards for the majority of timber shop workers. In contrast the assessment showed that compliance was not achieved to the ACGIH exposure limits for all timber shop workers which which gives rise to indecision when recommending control measures.

On the basis of the ACGIH exposure limits the assessed inhalation risk of high for wood machinists, cabinet makers and cleaners requires active implementation and management of controls.

Recommended control measures focus on the effective capture of dust at the source, containment of dust during cleaning and transfer activities and eliminating high dust tasks such as sweeping dust and using compressed air to clean dust for surfaces.

More Than Three Sources of Ozone Exposure

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Abstract

Ozone is a naturally occurring gas that is produced by ultraviolet (UV) light in the upper atmosphere. Industrial and commercial sources include air pollution, high-intensity UV sources (lamps, welding arcs), and electrical equipment (high-voltage equipment, laser printers, photocopiers, electrical motors). Health effects include eye irritation, respiratory irritation and accumulation of fluid in the lungs (pulmonary oedema). Occupational hygiene case studies are presented from industries that include printing, electronics, metal fabrication, restoration, and water treatment.

Introduction

Sources

Ozone is a naturally occurring gas that is produced by ultraviolet (UV) light (in the upper atmosphere, near high-intensity lamps, and near welding arcs), the interaction of ultraviolet light and air pollution (in the lower atmosphere), and high-voltage electrical discharges (in equipment that includes photocopiers and some electrical motors).

Ozone as an Air Pollutant

Ozone air pollution is present at elevated levels in sunny cities like Los Angles, Mexico City and Sydney. The New South Wales Office of Environment and Heritage has a network of monitoring stations. Outdoor ozone levels in Sydney exceed the recommended 1-hour maximum of 0.1 ppm from 1-20 times per year, subject to weather conditions.

Potential Health Effects

Ozone can reduce lung function, damage the airway lining, and cause irritation of the eyes and respiratory system (National Environmental Health Forum, 1997). Respiratory irritants can trigger asthma attacks in people who already have this condition. Ozone has a sharp smell that can be misclassified as the odour of chlorine bleach.

Australia Exposure Standard

Ozone is listed in the Safe Work Australia Hazardous Substances Information System with a peak limitation of 0.1 ppm (0.2 mg/m3).

ACGIH Threshold Limit Value (TLV)

The American Conference of Governmental Industrial Hygienists (ACGIH) has four TLVs for ozone. 0.05 ppm for heavy work (8-hour), 0.08 ppm for moderate work (8-hour), 0.10 ppm for light work (8-hour), and 0.2 ppm for any work as long as the exposure is less than 2 hours. Impaired pulmonary function is listed as the basis for the TLV.

Methods

Several methods were used for ozone detection, including an aeroQUAL Series 500 hand-held gas detector for ozone gas (low range, 0-0.5 ppm), a Draeger CMS detector with a Draeger 6406430 chip, and detector tubes from several suppliers (Draeger, Gastec, Kitagawa, Rae Systems, Sensidyne).

Results

Case Study 1 (MSDS for Ozone)

A 2002 material data sheet (MSDS) by a 3rd-party supplier listed ozone as Not classified as hazardous according to the criteria of Worksafe Australia and Class 2.2 dangerous goods (non-toxic, compressed gas). The supplier was asked to make amendments because ozone is an irritant (Xi), at minimum. There is also a strong case for classification as toxic (T) and a Class 2.3 poisonous gas. Safe Work Australia does not list the classifications for this substance, a disappointing omission. The Australian dangerous good code does not classify ozone because it is not transported, but manufactured on site.

Case Study 2 (Aluminium Welding)

Ozone was measured during MIG welding of aluminium components. One welder reported an asthma-like condition when aluminium welding, which did not occur with other types of welding. Operators were required to hold the welding helmet and their head directly over the plume that had measured levels of 0.77 ppm and 0.14 ppm. Technical note TN 7-98 from the Welding Technology Institute of Australia (WTIA) recommends local-exhaust ventilation for aluminium welding.

Case Study 3 (Tape Degaussing)

Significant levels of irritant ozone were generated when using a degaussing machine (magnetic tape eraser) for extended periods. The levels were not typical of normal use, because extended operations were requested to assess the ELF magnetic fields. Exposure measurements were not conducted because an ozone monitor was not available at the time.

Case Study 4 (Potable Water Treatment)

Air monitoring conducted in a water-treatment room revealed satisfactory levels in the breathing zone during normal operations (0.02-0.07 ppm), but some high levels near the lid of a tank (0.8 ppm). High levels of exposure might be expected during spills.

Case Study 5 (Air Pollution Control)

Electrostatic precipitators are used to control the emission of fine particles by inducing an electrical charge with a high voltage. Maintenance operators can enter industrial scale units, and effective confined-space-entry procedures are required to prevent exposure to ozone. Incidents in Australia have been reported (Smit, 1993), and 4.5 ppm has been reported at the entry of a Portland cement kiln during the recreation of an incident in the United States (Sanderson et al, 1999)

Case Study 6 (Commercial Kitchen Exhaust)

Ozone systems have been developed to treat grease in kitchen exhaust systems. After an emergency attended by the fire brigade, a brainstorming session with the builders was required to identify this potential ozone source. A new unit in a city building had been installed without adequate interlocking to prevent the ozone generator operating without adequate air flow.

Case Study 7 (Photocopiers)

Photocopiers are a known source of ozone, and the levels of emission are controlled by the use of charcoal filters on each machine. Significant levels of exposure are not expected near well-maintained equipment. Ozone levels in print shops with high-speed photocopiers (near the exhaust fans) are typically below the limit of detection (less than 0.03 ppm), a transient of 1 ppb was detected during a busy period in one print workshop.

Case Study 8 (Ink Curing)

Some printing inks are cured by UV (ultraviolet) radiation. High levels of ozone emission can be expected if there is a breakage of the lamp envelopes. Ozone levels measured near normal lamps (but outside the lamp enclosure) have always been below the limit of detection (less than 0.03 ppm).

Case Study 9 (Air Cleaners)

Ozone generators as air cleaners have been manufactured and promoted, but are discouraged by many authorities (NSW Health, 2005; USEPA, 2011). Conditional support is offered for use in unoccupied buildings to control soot odours during fire restoration (USEPA, 2011).

Case Study 10 (Rubber Degradation)

Ozone measurements were requested as part of an investigation into the premature degradation of some rubber materials. All results were less than 0.03 ppm, an ambiguous result. The client was referred to Exelplas (a Melbourne polymer laboratory), who are able to test rubber to determine if the damage has been caused by ozone.

Discussion

Exposure Standards

Ozone exposure guidelines indoors, outdoors and at work were consistently at the 0.1 ppm mark for many years. This is no longer the case, but there has been no revision of the Australian exposure standard.

Control Measures

Other than generic ventilation guidelines, there is little available information on control of ozone. An exception is the German Institute for Standardisation DIN 19627 (Ozone Plants for Water Treatment). Ozone can also be absorbed by charcoal filters, with the potential emission of carbon monoxide.

Air Cleaners

The emission of a toxic substance as an air cleaner in occupied spaces does not have my support, but the potential for ozone as a last resort deodoriser is worthy of better research, particularly for indoor odours that require a faster solution that ventilation. More recent photocatalytic oxidiser (PCO) technology can operate with ozone levels below exposure standards (brands include Odorox hydroxyl generators and Biosweep), but they still require several days of ventilation after use. I have used the Odorox to halve indoor VOC levels (230 ppb to 130 ppb, measured with a photo-ionisation detector), but without elimination the odour of most concern to the occupant. One of the issues to avoid is the oxidation of materials, creating a worse odour.

Conclusions

Some applications of ozone and the results of ozone monitoring in several work environments have been presented.

Acknowledgments

Thank you to the clients who have authorised the publication of data obtained at their premises, for the sole purpose of professional education.

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A Personalized Biomarker to Determine Fit For Work in Extreme Environments

Dr Joseph Mate & Dr Jacques Oosthuizen
Edith Cowan University

Abstract

Through physical activity and other stressors, increased protein concentrations in and outside of cells have been measured. More specifically, the expression of heat shock protein 72 (HSP72) during heat stress has been observed to increase. This protein is believed to act as a chaperone and therefore protect the unfolding/denaturing of other proteins within the body during heat stress. By protecting proteins, the physiological damage incurred through elevated body temperatures is attenuated. When acclimated, elevated HSP72 have been recorded; however, the converse is true when not acclimated. If an individual is non-acclimated, decreased HSP72 concentrations are present therefore making an individual more susceptible to heat stress related illness and physiological damage. Therefore, by comparing the acclimated levels of HSP72 to that of returning to work acclimation level and in turn, fit for work could be estimated. Hence, a reduction in risk to personnel returning to a heat stressful occupation.

Glass blowing - Eye protection for infrared radiation

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Abstract

It has been known for many years that blowing glass exposes the craftsperson to hazards, including infrared (IR) radiation. When that exposure to infrared radiation is excessive, damage may occur to parts of the eye and skin. Of particular concern is injury to the eye's lens (causing cataracts) and retina.

This paper assesses infrared exposure to Glassblowers at the University's Glass Workshop, finding that through measurement, there is a risk that the relevant occupational exposure limits can be exceeded. Therefore eye protection to reduce infrared radiation is necessary.

To achieve a glassblower's acceptance, the eye protection requires certain characteristics. The performances of several safety glasses were evaluated in reducing exposure to infrared radiation. The Uvex InfraDura green lens and a new MinimIzeR® lens provide adequate protection for typical glass blowing and user acceptance. Additional protection is required for glass-batching.

Accepting appropriate protective eyewear should reduce the risk of long-term changes to a Glassblower's eyesight.

Overview

Safety glasses are an important form of eye protection for many artists. For Glassblowers, not only do they provide impact protection to the eyes, but the correct selection can provide protection from visible and infrared radiation emitted from the glass furnaces. In order to obtain user acceptance, glassblowers require reasonable colour perception in order to assess the properties (e.g. temperature, flexibility) of the hot glass. This is particularly important during a Glassblower's foundation years.

This study was undertaken to determine the effectiveness of some available safety glasses in protecting the eyes from infrared radiation and reducing the risk of Glassblower's cataracts.

Hazard Potential

All objects release energy in the form of radiation (black body radiation). An object will release more energy (radiation) in the visible region as it becomes hotter –changing from red-hot to white hot, the energy peak shifts towards the blue spectrum of light, becoming whiter and brighter. With the glass furnaces operating around 1100 to 1300 ˚C, they are significant sources of (infrared) radiation, but without an intense visual stimulus. Hence, the protection provided by the human body's natural aversion responses to bright light is not available, placing the eye at risk from significant and permanent decrements in vision from over exposure.

In the rationale for the exposure standard (ACGIH 2008, Sliney and Wolbarsht), the experimental evidence defines ocular effects as belonging to two classes of damage events:

1. Visible and IR-A energy deposited in the posterior of the eye,
2. Other IR wavelengths deposit energy in the anterior structures.

IR radiation may penetrate or be absorbed by certain parts of the eye (figure 1). In particular, IR-A penetrates the eye to the retina where it is absorbed, while IR-B is absorbed by the cornea and aqueous humour. This energy will be conducted to the lens, raising its temperature (ACGIH 2008).

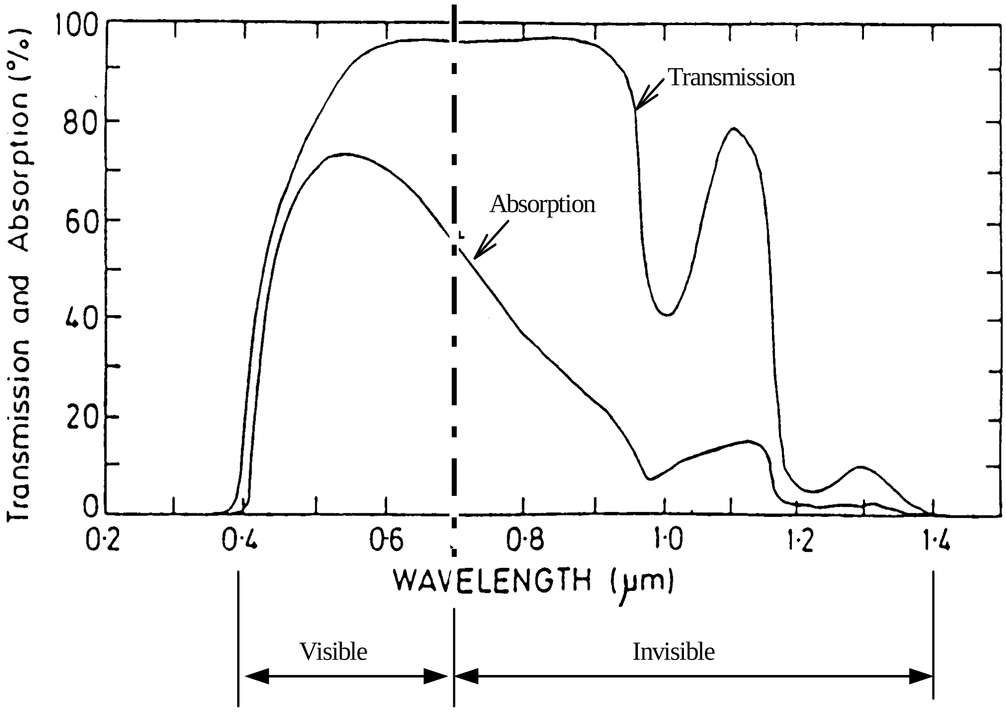

Figure 1 The optical transmission of the human eye, and optical absorption in the retina [Sliney and Wolbarsht, 1981, modified].

Thermal injury is strongly dependent upon exposure and heat conduction away from the irradiated tissue. To produce thermal injury to the skin very high irradiances are needed. In many situations the injury is rate-limited rather than a dose limited threshold.

Near infrared (IR-A) radiation reaches the retina, but is not perceived but may cause thermal or photochemical damage to the retina. Generally thermal injury to the retina requires an intense exposure within a brief period of time (seconds), typically from very high-radiance sources. However, exposure to large objects that produce large retinal images, pose an increased risk of injury as the heat is less likely to be conducted away. Repeated sub-threshold exposures do not appear to be additive (ACGIH 2008).

As the wavelength of light increases (i.e. the spectrum moves further away from the visible towards infrared-B and -C [Ψ]), more absorption occurs in the lens, cornea and in-between fluids (see figure 1). This absorption results in heating. Slow heating of the lens and iris from looking at hot objects, is believed to be responsible for the formation of lenticular opacities, commonly known as 'cataracts' (Repacholi, IRPA, 1988). In occupations involving glass the condition is commonly referred to as Glassblower's cataracts. The formation of cataracts may occur slowly over a period of years. Although, cataract surgery (replacement of the lens) is now a recognised medical procedure, prevention through proper protection remains the best option.

Further information on the eye and infrared radiation can be found in various references [1, 2, 3, 8, 9].

[Ψ] These wavelengths are generally preceived by the skin as warmth.

Exposure Benchmarks

To protect the eye from (infrared) radiation damage, several exposure criteria exist. For a glass furnace or glory hole furnace (photo 1), the main exposure is from infrared radiation, as a strong visible stimulus is absent. Two exposure conditions need to be met –

a) To protect against thermal injury to the cornea and lens (i.e. cataractogenesis) the total infrared irradiance must be less than 10 mW/cm^2, for exposures exceeding 1000 seconds (approximately 17 minutes per day). (ACGIH 2008, ICNIRP 1997).
b) To protect against retinal thermal injury from near infrared radiation, the total effective radiance must be less than (L = 0.6/⍰ =) 6000 $mW/(cm^2.sr)$ for exposures greater than 810 s (approximately 13 minutes per day). (ACGIH 2008, ICNIRP 1997).

Exposure limits may be increased slightly for daily exposure durations less than that stated above.

The above limits are levels to which it is believed that nearly all workers may be exposed without adverse health effects (ACGIH 2008). These levels do not apply to photosensitive individuals, aphakics (those who have had the crystalline lens replaced - which would normally block UV radiation), and those exposed to photosensitising agents (including some prescribed drugs).

Observations

Glass (melt) furnace temperature: 1130 to 1135 ˚C

Glass glory hole furnace: 1250 ˚C (1220 to 1280 ˚C)

The construction of a glass goblet was observed as a realistic exposure scenario. The goblet was made within 24 minutes; however, only 8 minutes involved working in the glory hole furnace and this consisted of approximately 35, 10 to 20 second bursts (a typical duty factor of 0.3 or 1/3 of the total time). Typically, the Glassblower would stand approximately 1.3 to 1.8 m (average around 1.5 m) from the furnace opening. The viewing angle is down, from standing height (say 1.7 m) to the centre line of the glory hole furnace (0.9 to 1 m). The typical line-of-sight distance is 1.5 m. See figure 2.

Subjectively, standing within 1 m of the furnace for more than a couple of seconds without the protection of a radiant heat shield is uncomfortable. Objects placed too close to the furnace opening are at risk of scorching or igniting.

In viewing the glory hole furnace, typical viewing conditions are:

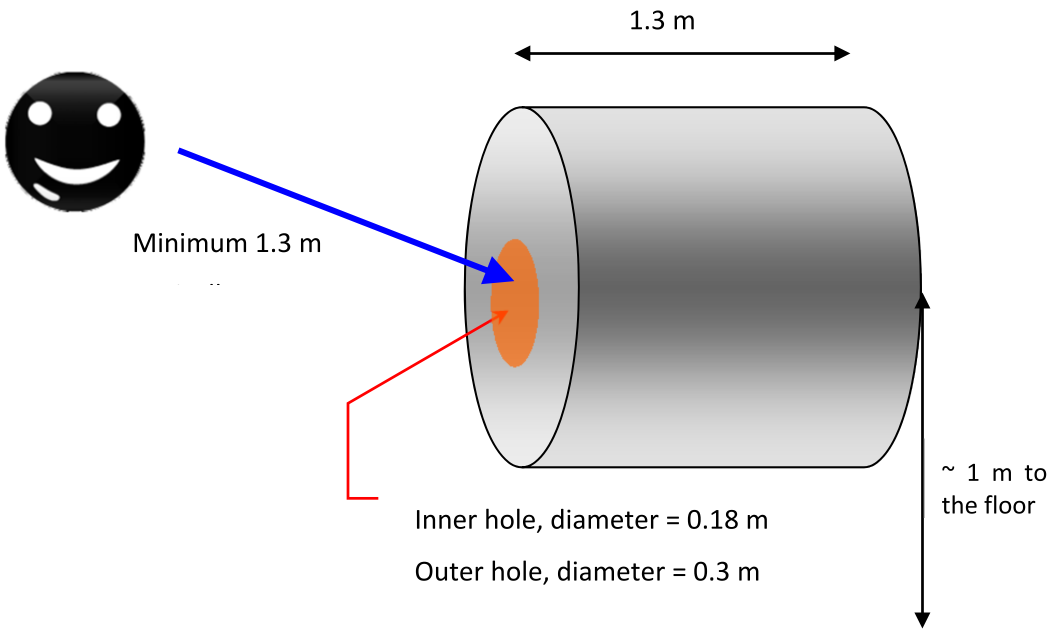

Figure 2 Furnace viewing conditions

The angular subtense, α (in radians) is

α = diameter / distance

= 0.11 to 0.23 radians maximum angular subtense is 0.1 radians (ACGIH 2008).

Comparison of two glory hole furnaces indicated good agreement between the amounts of infrared radiation emitted. A value of 40 mW/cm^2 was measured at 1.7 – 1.8 m in front of the glory hole furnaces.

The heating of the glass may be monitored by the craftsperson, more by feel, than by sight. So, as experience increases direct viewing of the furnace reduces to only that which is necessary.

Base on the source temperature, the Australian Standards (AS 1338.3:1992) suggests safety glasses are code 4 (infrared), shade number 2.5. However to assist in other tasks, a shade of 1.7 is commonly worn in the glass workshop. Face shields of shade 4 to 6 are worn for the glass batching.

This report did not consider the blue-light (intense visible) photochemical hazard nor ultraviolet hazards, as these are not significant for the glory hole furnaces investigated.

Photo 1 Glory Hole furnace

Workplace evaluation

The determination of infrared radiation levels and absorption of various safety glasses was undertaken in June 2010. This evaluation builds on previous safety glasses information provided to the Glass Workshop (Schmid 1998) and includes the evaluation of a modern infrared-reducing coated safety lens (MinimIzeR®).

A) Transmission of available safety glasses

The transmission spectra of some available safety glasses were measured using an Ultraviolet – Visible – Near Infrared spectrophotometer (Carey NIR/Vis/UV spectrophotometer) to determine whether they allowed the passage of infrared radiation to the eyes. Some transmission spectra can be found in the Appendix. Of particular note is that the Didymium glasses worn by lamp workers to remove the soda glass flare - does not provide significant reduction in infrared radiation.

B) Protection offered by various safety glasses

All irradiance measurements were undertaken with a Jelight radiometer/photometer (JL1400A, serial number 1215) with an infrared detector (SEL623/SCS695/W), calibrated in May 2010. The thermopile detector drifted less than 1 mW/cm^2 over the measurement period.

The workplace effectiveness of the safety glasses was found by measuring the infrared irradiance at a point (approximately 1.7 – 1.8 m, 40 mW/cm^2) from the glory hole furnace. The safety glass's lens was then placed directly in front of the detector and irradiance measured. The percentage of reduction is shown in table 1.

Safety Glasses/Lens	Irradiance (mW/cm^2)	Reduction (%)
No lens	40.0 #	-
Green lens (Code 4 shade 1.7)	4.0	90 %
MinimIzeR®	5.0 - 5.5	86 - 88 %
Clear polycarbonate	20 - 21	48 – 50 %
Didymium lens	31	22 %
Non-polarise sunglasses *	21.5	46 %
Polarized sunglasses *	22.5	44 %

Table 1: Reduction of infrared exposure for various (safety) lenses #

measured at approximately 1.7 - 1.8 m from the glory hole furnace opening, parallel to the floor at the glory hole's centre line height (~ 1 m).

* these sunglasses are provided for comparison.

C) Occupational exposure using the Glassblower's preferred (MinimIzeR®) safety glasses

To protect against thermal injury to the eye, it was determined that for the -

Glory hole furnace - Typical eye exposures (at a distance of approximately 1.5 m standing height) are 60 – 65 mW/cm^2 unprotected. Using the MinimIzeR® safety glasses the exposure limit of 10 mW/cm^2 was reached at 1.3 m in front of the furnace.

Glass furnace - when standing in the normal location to collect glass from the furnace (eye to furnace hatch distance of approximately 1 to 1.1 m), the exposure was 85 mW/cm^2 (without eye protection). With the MinimIzeR® safety glasses the exposure level decreased to 15 mW/cm^2 . The allowable exposure time for 15 mW/cm^2 is 10 minutes.

D) Thermal radiance

Radiance is a measure of the source strength (flux density per unit solid viewing angle, expressed in $W/cm^2/sr$). Radiance measurements were made with the same Jelight radiometer/photometer (JL1400A, serial number 1215) with the infrared detector (SEL623/SCS695/R) fitted with a radiance barrel – this configuration had not been calibrated. These measurements were problematic, ranging from less than 10 $mW/cm^2/sr$ to over 120 $mW/cm^2/sr$. A typical range of 80 – 100 $mW/cm^2/sr$ was recorded.

Discussion and Conclusions

The irradiance results indicate that it is possible for a glassblower to exceed the occupational exposure limit that protects against thermal injury to the cornea and lens. Therefore protection against infrared radiation is required to prevent thermal injury to the eyes whilst using the glory hole and glass-batching furnace.

The radiance results indicate a level not likely to exceed the occupational exposure limit that protects against retinal thermal injury from the glory hole furnace.

Of the safety glasses tested, the current green lens (UVEX Futura (9180.941) 4 - 1.7) and the proposed MinimIzeR® coated/clear lens (AOSafety) reduce the infrared irradiance at the required distance from the glory hole furnace to below the exposure standard.

By conducting exposure measurements and evaluation of safety glasses it is possible to determine safety glasses that provide adequate protection and importantly user acceptance.

Recommendations

Following the investigation, it was recommended that:

- Green lens safety spectacles (as used by welding trades) of a code 4, shade number 1.7 to 4 should be used to protect against infrared radiation where colour perception is not as critical;
- MinimIzeR® safety spectacles may be worn by Glassblowers for work around the glory hole furnace when colour perception is required. Note: as MinimIzeR® safety spectacles rely on an advanced coating to reflect or absorb infrared radiation, the spectacles must be replaced if the surface is scratched or damaged.
- Green lens protective face shield (code 4, shade number 4 to 6) must be worn for glass batching around the furnace (photo 2);
- Glass workshop students must be made aware of the infrared hazards of glass blowing and the requirements of appropriate safety glasses.

It must be remembered that this assessment should not be relied upon for aphakic individuals or those exposed to photosensitising chemicals.

Acknowledgements

The Occupational Health and Safety Branch wishes to thank the staff and students involved in the monitoring for their cooperation and patience.

The use of the ANU Research School of Chemistry's, Carey NIR/Vis/UV spectrophotometer (which was used to obtain the spectra) is much appreciated.

The mention of any product or manufacturer in this article is not an endorsement or criticism of their product. The tested products simply happen to be available at the time of the assessment.

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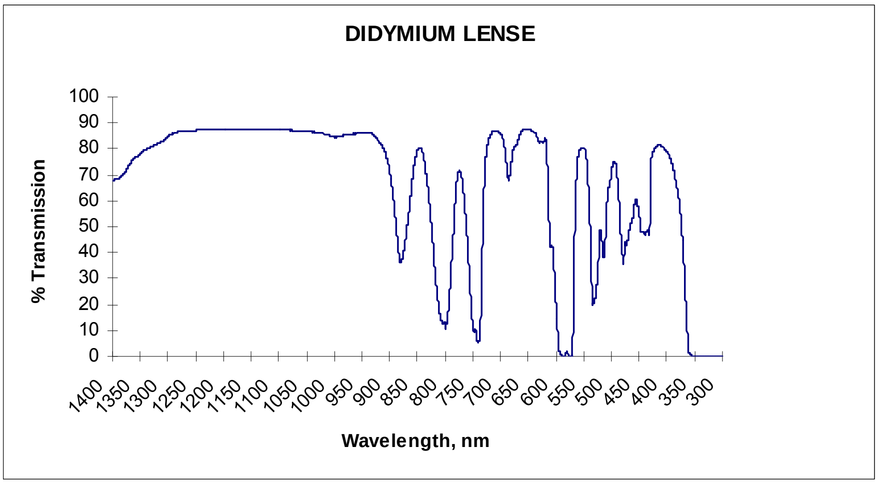
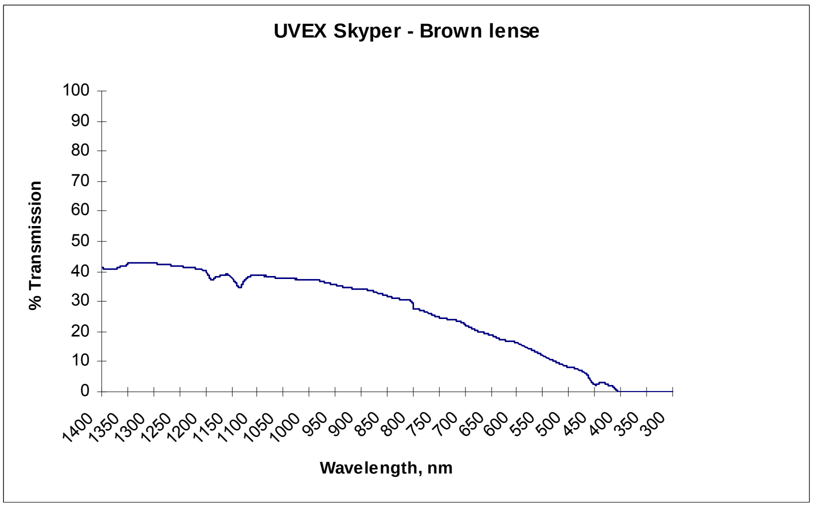
Appendix 1 - Safety Glasses Transmission Spectra

In an attempt to determine the suitability of different safety glasses for the task, several types were run through an Ultraviolet-Visible-Near Infrared spectrophotometer. The transmission spectra of the glasses tested are below.

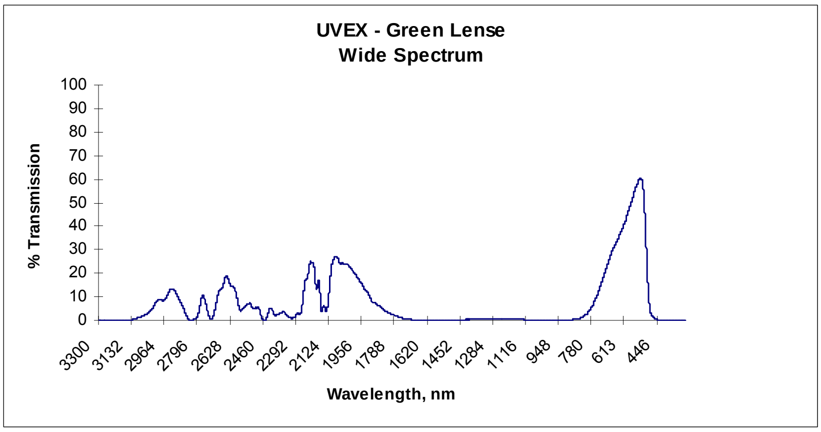


Spectrum 1 – Didymium Safety Glasses

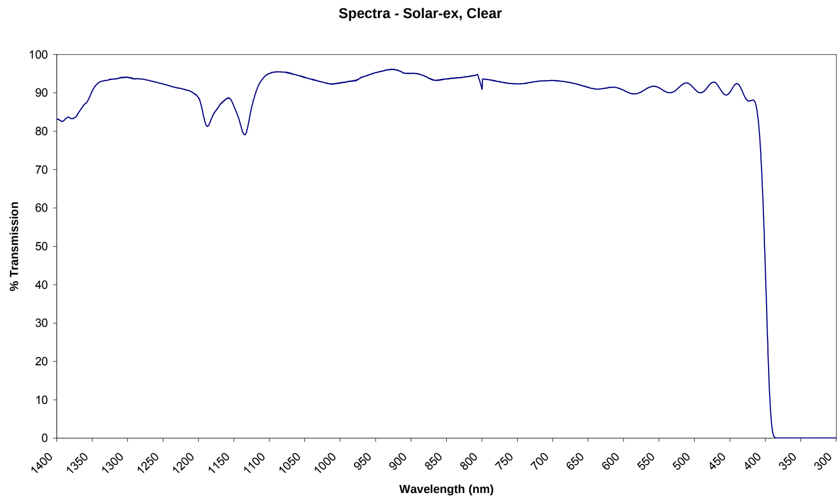
The Didymium safety glasses (Bouton 5900 series) are used for lamp work.



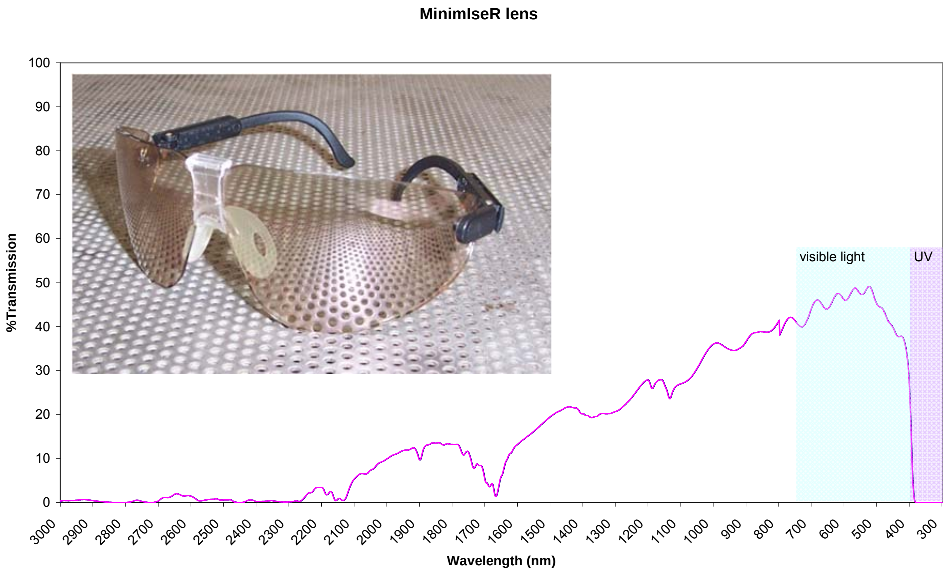
Spectrum 2 – UVEX Skyper, brown tint



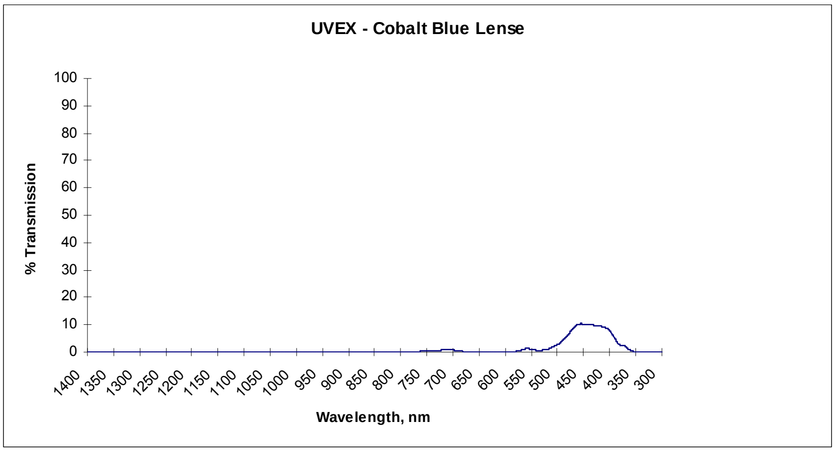
Spectrum 3 – UVEX, Duo-Flex, Green lens, wide spectrum



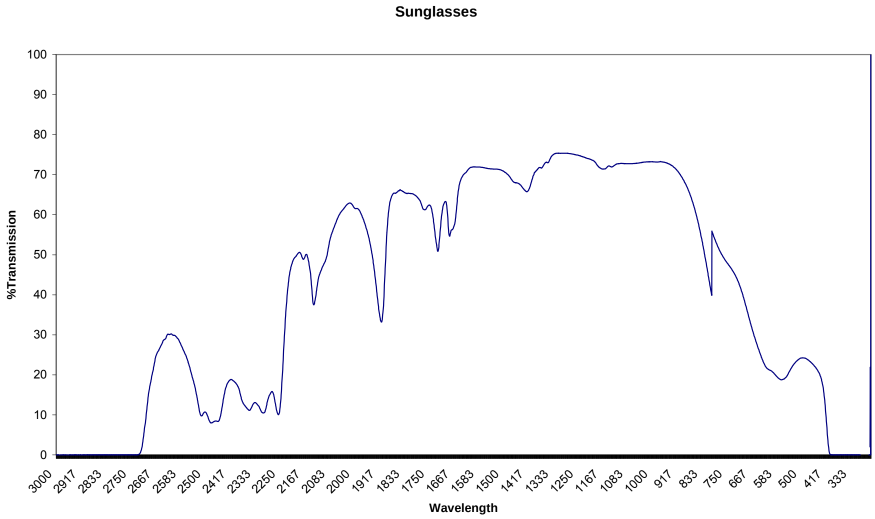
Spectrum 4 – Protector, Spectra Solar-ex, clear glasses



Spectrum 5 – MinimIzeR® Lens, wide spectrum



Spectrum 6 – UVEX cobalt blue furnace glasses



Spectrum 7 – (nameless) Sunglass, dark tint

Assessment of HAV Exposure During Main Landing Gear Fairing Maintenance - 37sqn Aircraft Structural Fitters - RAAD Base Richmond

Martin Calnin
Department of Defence

Abstract

Assess HAV exposure of 37SQN ASTFITT personnel when operating pneumatic power tools during the Main Landing Gear Fairing maintenance task.

Assessment of HAV was conducted IAW AS 2763- 1988: Vibration and Shock – Hand Transmitted Vibration – Guidelines for Measurement and Assessment of Human Exposure.

Vibration measurements were taken using the following devices Bruel and Kjaer - Human Vibration Analyser Type 4447, Type 4520 – 002 accelerometer for HAV and Hand Adaptors: UA – 3015 and, UA – 3016. Ambient temperatures were recorded using Tinytag temperature data loggers.

The assessment revealed that ASTFITT personnel were exposure to excessive vibration requiring effective risk management strategies to reduce exposure. Environmental and lifestyle choices including cold temperatures and smoking potentially exacerbated the risk of HAV symptoms.

It was recommended 37SQN managers develop a HAV management plan to assist in the reduction of exposure including a buy low vibration purchasing policy, HAV training and health surveillance.

Practical Experience of Monitoring and Managing Thermal Heat Stress in Roof/Ceiling Spaces

Cedric Cheong[1], Heike Neumeister-Kemp[1], Peter Kemp[1], Jacqueline Campbell[2]
[1]Mycologia, Mould Worx, [2]Effective Hazard Management

Abstract

Thermal heat stress has been highlighted as one of the main hazards when conducting work in roof/ceiling spaces particularly in the hot and humid conditions of the North West of Western Australia. This study was borne out of a risk assessment of mould remediation works on contaminated ducted air conditioning systems which required physical work to be conducted in the roof/ceiling spaces of properties undergoing remediation works. Remediation technicians were monitored for thermal heat stress, as part of fatigue management and dehydration prevention plans. Measurements in the roof/ceiling space were conducted with heat stress monitors and technicians monitored for any changes throughout their work activities over the various times of the day. The use of ice vests, scheduling of work at different parts of the days and the diet, urine and daily activities (diary) of the technicians were monitored and reported.

Thermal Stress Management at the Argyle Diamonds Underground Project (ADUP): A Multi-dimensional approach

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Thermal stress is a risk for all workgroups at the ADUP due to the geographical location of the mine in the humid East Kimberley region of WA and the additional heat sources present in the underground environment. This risk is expected to increase during the construction phase of the project as more vehicles and personnel will be employed underground. Therefore, the implementation of a thermal stress management program was a key objective for the Health team in preparation for the 2010/11 wet season and construction ramp-up. We developed a multi-dimensional program in collaboration with the ventilation engineer and management team.

The key elements of the thermal stress management program are as follows:

- Hydration testing
- Physiological monitoring
- Environmental monitoring
- Refrigeration / ventilation controls
- Training (all authority levels)

In particular, we would like to share the success and interdependency achieved in relation to the hydration testing program.

Keywords

Thermal stress, hydration, monitoring, underground mining, construction

Introduction

The Bureau of Meteorology (BOM) describes the East Kimberley Region, location of the Argyle Diamonds Mine, as being the least comfortable Australian summer climate (BOM 2011). During the hottest months, October to March, the region experiences high temperatures and humidity (maximum temperature range 41.9 °C – 44.0°C, mean temperature 39.9°C, mean humidity range at 0900, 34%-54%) (Rio Tinto 2010[3]). The initial thermal stress risk assessment conducted in 2005 by Argyle Diamonds Limited (ADL), identified underground as one of the work groups at an increased thermal stress risk as a result of their work activities. A recent review (2010) of the ADUP workgroups indicated that all similar exposure groups (SEGs) were at an increased risk of thermal stress due to environmental and/or work factors associated with the requirements of the role (on surface and in the underground mine).

The primary heat sources underground include equipment (heat load (MW)), virgin rock temperature (average temperature of 41.0°C), water ingress (pooled ground water in drains and sumps increases humidity), explosives (exothermic process) and fibrecrete/concrete curing (exothermic process). The body also generates heat through physical activity.

Body temperature is controlled through the thermoregulatory system, which helps to maintain internal temperatures between 36.5 °C -37.2°C. This becomes difficult when humidity levels and sweat rates are high and air movement is reduced or negligible. This can result in dehydration and a reduced capacity to keep core temperature within normal ranges (heat can no longer leave the body easily). Incidences of thermal stress (TS) and clinical dehydration (CD) (specific gravity (SG) of >1.030) are not uncommon at the Argyle Diamonds Underground Project (ADUP). In 2010 there were 7 cases of thermal stress reported (symptoms diagnosed at the onsite medical centre) and 18 cases of clinical dehydration. The majority of these 86% (TS) and 84% (CD) occurred during the wet season (October-March).

ADUP is currently experiencing a very aggressive ramp up schedule in order to complete the construction of the underground mine and associated infrastructure by April 2013. This means that in November 2011, peak manning numbers will be achieved with approximately 1200 people being employed directly by the project. This will also coincide with the 2011-2012 wet season.

Given the particularly stressful nature of the climate in this region, coupled with the hot and humid conditions underground and the physical nature of some of the work tasks, it was necessary to develop a multi dimensional approach to thermal stress management for the underground project. The key elements of the thermal stress management program at ADUP include: Hydration testing, physiological monitoring, environmental monitoring, refrigeration / ventilation controls; and training (see author's note). In particular, we would like to share the success and interdependency achieved in relation to the hydration testing program.

The ADUP hydration testing program was devised through a risk based approach and was designed to engage all departments and contracting groups and place ownership of the program into the hands of the leaders of these groups. A wet season and dry season testing program was devised by the ADUP Health team in collaboration with group leaders and HSE representatives and this formed the basis for the overall program. The results from the 2010-2011 wet season clearly indicate a verifiable behavioural change and reveal a demonstrable improvement in the hydration status of the overall workforce.

Materials and Methods

Hydration Program

In order to effectively introduce the program, months of preparation were needed to ensure all relevant procedures, work instructions and training packages be completed. Budgeting and ordering of equipment and consumables for the program required several months of prior planning. The importance of an effective implementation strategy was considered critical to gain support and ensure the sustainability of the program.

Defining Roles and Responsibilities

The *Procedure for Thermal Stress Management at the Argyle Underground Project* outlined the roles and responsibilities for those expected to undertake hydration testing across site. Shift bosses and supervisors were accountable for ensuring that their subordinates partook in the hydration testing program.

The hydration testing frequency by each group was incorporated into the HSE leading indicator targets (all groups were set the same target). To achieve success in such a novel program for the project senior management and group leaders needed to understand the risks associated with thermal stress and dehydration, and the potential gains that could be achieved (reduced workplace incidents) through improved hydration status of the workers. Support (resources and commitment) from these key stakeholders was a necessity.

Testing Regimes

As outlined in the *Procedure for Hydration Testing of Underground Personnel,* hydration testing is carried out for all personnel working at the underground project throughout the year (see Table 1.0).

Season	No. of tests / person / week	Time of day
Dry (April – September)	1	Anytime
Wet (October – March)	2	Once pre-shift Once mid or post-shift

Table 1.0 ADUP hydration testing regime

With this regime in place we could determine hydration status at various points in a shift. More importantly we could identify if workers were starting the shift hydrated and able to maintain this hydration level despite the physical demands of the role.

Training

The Health team provided hydration testing training to supervisors, HSE representatives and volunteers from all groups. The training package outlined how to use the testing equipment, recognising signs and symptoms of heat stress and heat stroke and how to interpret results.

In the months preceding the 2010-2011 hydration program, awareness sessions were provided to all groups across the site in preparation for the implementation on October 1st (official start of the program).

Thermal stress training was also developed for workers and supervisors and included:

Worker: This was a site specific package, including information on participation requirements for hydration testing; recognition of heat stress and heat stroke; emergency procedures and preventative measures; how to request workplace environmental measurements and additional resources for managing thermal stress at Argyle Diamonds.

Supervisor: Instruction on how to use the Heat Stress Index (HSI) as a risk assessment tool; a booklet detailing the requirements for workplace environmental monitoring which included training on the use of the Kestrel 3500 Pocket Weather Meter; and a guide to modified work levels for the underground environment. All underground supervisors were required to attend this training.

Hydration testing methodology – Equipment and materials

The *Procedure for Hydration Testing of Underground Personnel* outlines the method for hydration testing. It describes the methodology for use of Atago UG-α refractometers, the testing regime, set up of the testing environment, interpretation and recording of results and reordering consumables.

A refractometer measures the Specific Gravity (SG) of urine, which is defined as the ratio weight of a substance compared to the weight of an equal volume of distilled water; hence the SG of distilled water is 1.000 (Rio Tinto 2010[1]). The *Rio Tinto Heat Stress Potential Exposures Guidance Note* was used to determine the four hydration level ranges. Results were then separated for correlation analysis using the four ranges represented by colours (see Table 2.0).

Colour	Hydration Range (SG)	Explanation
Green	1.000 – <1.010	Well hydrated
Yellow	1.011 – 1.020	Minimal dehydration
Orange	1.021 – 1.030	Significant dehydration
Red	>1.030	Severe dehydration

Table 2.0 ADUP hydration level ranges

The colour coded ranges assisted with simplifying communication of results to participants.

Hydration Testing Kits were allocated to each group and contained the following equipment and materials: a refractometer; alcohol wipes; hand disinfectant; latex gloves; clear safety glasses; bin bags; 'blueys' (pads placed under the refractometer during testing); pipettes; paper cups; a pen; a copy of the hydration testing procedure and results recording sheets. Kits were distributed to a responsible person within each group. The provision of kits to individual groups aided consistency in testing protocols, helped to ensure testing was completed in a hygienic manner, provided a simple management strategy for consumables and transferred responsibility for restocking the kit to the group and therefore removing accountability from the HSE team.

In order to carry out hydrating testing, ADUP provided several designated testing stations. These were located inside change rooms and outside of toilet blocks. Rio Tinto 2010[2] stipulated the following environment requirements for testing: testing stations in close proximity to toilets (minimising the distance needed to transport samples); a nearby potable water source for rehydration purposes; and testing stations located in the shade to minimise heat exposure.

Collection of results

Results were provided to the HSE team for entry into a confidential database. Information collected for each individual included: Date of test; time of test; workgroup; name; number of days onsite; heat stress index for that day; result and hydration level.

The data was then analysed to identify trends in individuals, workgroups and across the project.

Results

Over 4000 hydration tests were conducted during the six month program (October 2010 – March 2011). Approximately 75% of tests indicated participants had hydration levels within SG range 1.000 – 1.020. At the completion of the wet season consistent hydration status (across the 4 ranges) was displayed across all workgroups (see Table 3.0).

	GREEN Good hydration	YELLOW Minimal dehydration	ORANGE Significant dehydration	RED Clinical dehydration	
*Work Group	SG 1.0-1.010	SG 1.011 – 1.020	SG 1.021 – 1.030	SG >1.030	Total Hydration Tests
1	32%	45%	23%	1%	747
2	34%	41%	23%	2%	1241
3	33%	42%	25%	0%	733
4	33%	45%	22%	1%	1393
Total	**1265**	**1788**	**1028**	**33**	**4114**

Table 3.0 2010-11 ADUP workgroup hydration results

* Workgroup Classifications:

Workgroup one : Out of cab. High intensity work.

Workgroup two : Out of cab. Physically demanding self moderated.

Workgroup three : In cab operators.

Workgroup four : Office based staff.

Figure 1.0 and Table 4.0 illustrate the number of samples collected from October 2010 – March 2011. The greatest number of samples collected was in February (1219). This represents a 20 fold increase on the number of samples taken in October (59) and again in November (49).

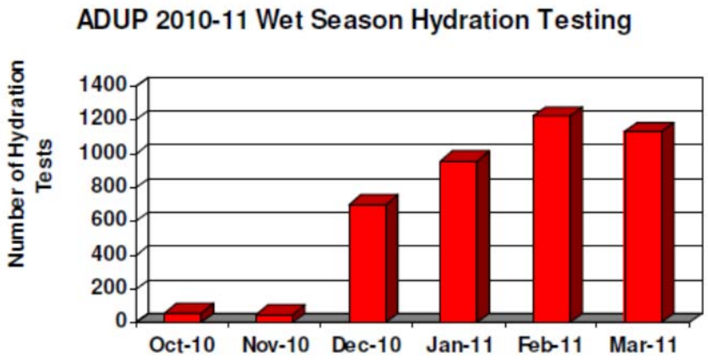

Figure 1.0 Number of hydration tests conducted during the 2010/11 hydration program

Month	Oct 2010	Nov 2010	Dec 2010	Jan 2011	Feb 2011	Mar 2011
Total Hydration Tests	59	49	700	959	1219	1128
Cases of Clinical Dehydration	3	7	13	4	3	3
% of Clinical Dehydration Cases	5%	14%	2%	0.4%	0.3%	0.3%

Table 4.0 2010-2011 wet season cases of clinical dehydration

Table 4.0 and Figure2.0 illustrate the percentage of incidences of clinical dehydration (SG >1.030) for the duration of the testing period. In November 2010 14% of results fell within the clinical dehydration range. By January 2011 the rate of clinical dehydration cases had reduced to less than 0.5% and continued to fall over the remaining months of the season.

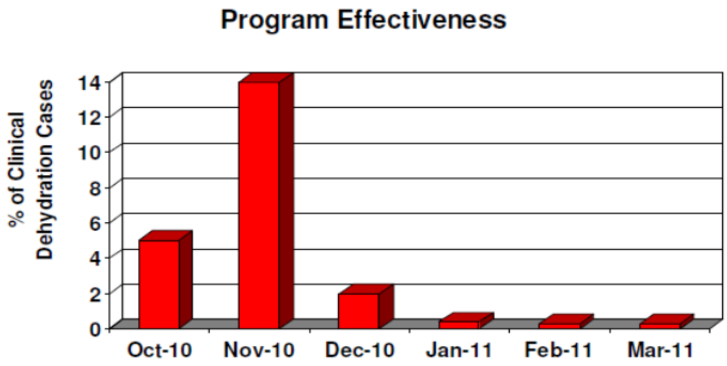

Figure2.0 Percentage of clinical dehydration cases by month

Discussion and Conclusions

The results from the 2010-2011 wet season show demonstrable improvement in hydration status across the course of the season. The authors concede that whilst we do provide correlation analysis of results there is no statistically significant data presented here and the conclusions drawn are largely subjective.

Overall, 30% of results fell within the Good Hydration range, 43% within Minimal Dehydration, 26% within Significant Dehydration and 1% within the Clinical Dehydration range for the 2010-11 wet season. When compared with results from 2009, a significant improvement is evident as those results within the Significant Dehydration and Clinical Dehydration ranges decreased from 65% in 2009 to 27% in 2010-11. This indicates that the thermal stress management program at ADUP has been highly successful in improving the overall hydration status of the project.

More importantly the number of clinically dehydrated personnel decreased from a peak in November of 14% to 0.3% in March 2011. We believe this was attributed to improved awareness of the importance of good hydration and also familiarity with the programs requirements.

The lowest incidence (%) of 'Good Hydration' (SG 1.000 – 1.010) was 32%, observed in workgroup one. This was only 2% less than the highest percentage observed in workgroup two (34%). This percentage range was similar for all hydration statuses. Clearly there is some work to be done in improving the hydration status for those people whose results fell within the minimal and significant dehydration ranges (Table 3.0). 68% of people (or 2816 tests) provided results within these ranges across the course of the season. We believe that with continual improvement in awareness and education and sustained efforts in maintaining the momentum of the program, we will continue to see improvements in the hydration status of workers.

Hydration monitoring will continue in 2011-12 with testing occurring throughout the year and an increased focus during October 2011- March 2012 (wet season) to sustain the improvements established in 2010-11.

We believe that the project has experienced a positive behavioural change (though we cannot substantiate this beyond anecdotal evidence and subjective assessment of results). Through educating new starters in their first days onsite in our core values, one of which is responsibility for personal health and safety, we believe new starters understand the high risk thermal stress poses to all workgroups. Moreover, our expectations are also conveyed regarding the hydration testing program and each individual's part to play in our continued success in maintaining good hydration status for all workers on the project.

Another positive change that has been noticed is the interdependency the hydration testing program has created across the project. Individual departments and contractor groups are responsible for having trained testers, stocked kits and management of the testing of their own work group. There was a danger in implementing this program that responsibility and management of the program would fall back onto the HSE team after several weeks. We believe that by engaging the key stakeholders in the early stages of the development of the program, they felt they had ownership of the program and choice over framework development. This coupled with incorporation of weekly group results into the HSE leading indicator targets meant that groups were held accountable for their performance (especially when compared to the performance of other groups).

There have been several key lessons learnt from this implementation of this program and they have been summarised below:

- Equipment quality- Refractometer quality was a significant issue in the early phase of the season, as the units were repeatedly broken or had calibration errors. This particular brand was replaced by a more reliable one and issues with the units all but ceased. Given that this piece of equipment is crucial for testing, a reliable unit is of vital importance for consistency in results and program adherence.
- Senior management support – The success of the implementation of the program was largely due to the support gained from senior management. Without it the program has the danger of becoming another HSE initiative and therefore encourages dependency on HSE team personnel to manage it. In the preplanning stages there was some reluctance to support the program as it was seen as time consuming and difficult to sustain. However, after a concerted effort from the Health team (conveying the current risk and providing evidence to support the program) these issues were addressed and the program was implemented.
- Hygiene concerns – One disappointing aspect of the program was the continual reference to the potential hygiene risks associated with the program. A minority of participants and testers refused to be involved stating various reasons which included: potential hepatitis infection, handling of biological waste, violation of privacy and confidentiality concerns. Each of these issues was

addressed through consultation with subject matter experts, occupational physicians and the concerned persons themselves. The program was not mandated at any point and we constantly encouraged participants and testers to raise concerns with the Health team for continual improvement opportunities.

- Data entry and resourcing – the data entry was conducted by Health team personnel and was a very time consuming aspect of the program (especially in the wet season) and was not considered in the planning phase of the program. A dedicated resource for this purpose is being allocated for the 2011-2012 season.

Overall, the hydration testing program has been a success story for the Argyle Diamonds Underground Project and though the program has had its difficulties over the course of the first season, the proof of its success is in the results. The results from the 2010-2011 wet season clearly indicate a positive behavioural change and reveal a demonstrable improvement in the hydration status of the overall workforce. The project employs a largely itinerant contractor based workforce of 800-1200 people on a fast paced construction project, with significant schedule compression. The working environment is largely unpleasant given the climate and conditions underground. Therefore, to have such marked improvement in overall hydration status in the first season of the program is a significant achievement.

Author's note: The other aspects of the Argyle Diamonds Underground Project thermal stress management plan are not detailed in this paper. Therefore, persons wanting more information are requested to contact the authors through the project for more information.

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Basic Thermal Risk Assessment eTool

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Abstract

A number of backpackers were working on a farm in regional Queensland, picking tomatoes during the summer months. Some of the backpackers were acclimatised, some weren't. None of them had had any training on heat stress. They wore light weight cotton clothing (long sleeve shirt, shorts or long pants and a hat). No respiratory protection was required, some backpackers wore cotton gloves. The work is continuous and requires bending over to pick tomatoes. At times, there is a light breeze, however on the day visited, no breeze was present. The backpackers pick from sunrise to sunset. The rest area is some 30 metres away and drinking water is available in the rest area. Most backpackers carry a litre of water with them while picking. The WBGT on the day was around 29ºC.

Effects of street clothing, sunscreen, and temperature on skin absorption of organophosphate pesticides – a review and case study of diazinon

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Abstract

There is increasing concern about occupational and community exposure to accidental or deliberate release of organophosphate pesticides (OPs). The protection afforded by street clothing and personal skin products for dermal exposure is poorly understood. A literature review was conducted and an in-vitro study carried out with diazinon, as a case example. The objectives were to assess the modifying effects of sunscreen, clothing, and temperature, on epidermal absorption and penetration.

Diazinon in-vitro work was performed with static Franz cells in accordance with OECD protocols. Application of oil-based sunscreen on hydrated exposed skin was performed as per Australian Standard 2604:1998.

A formal review of the literature revealed a significant knowledge gap with respect to dermal exposure and uptake of OPs in civilian exposure incidents. Recent work in the United Kingdom showed cotton shirt material significantly reduced dermal absorption of dichlorvos and chlorpyrifos, and post-exposure removal of clothing with immediate skin surface decontamination further reduced absorption compared with removal of clothing alone. Diazinon in-vitro studies revealed the skin to be a good barrier to penetration. Sunscreen and denim fabric seemed to act as an extra barrier for absorption and penetration, whereas elevated temperatures (37˚C) seemed to aid diazinon penetration through the skin.

The findings suggest emergency responders and hygienists recommend removal of bulky clothing and early decontamination of the skin following OP exposure to minimise the potential for dermal absorption and localised toxicity within the skin. Further studies of street clothing and sunscreen should be conducted with a wide range of substances.

Keywords

Dermal absorption, in-vitro, diazinon, organophosphate pesticides, occupational hygiene

Introduction

There is a heightened concern about occupational and community exposure to accidental or deliberate release of chemicals, such as organophosphate pesticides (OPs). Dermal contact with various pesticides can occur during manufacture, formulation, transport, application, harvesting procedures, and under many home-use scenarios. Typically, agricultural and pest control workers are the primary occupational exposures (accounting for 60-70% of all acute pesticide poisonings (Pont et al 2004; Lee et al 2009)), but secondary exposures to emergency responders and health care professionals may also occur. Furthermore, individuals not directly using pesticides in the workplace may still be exposed by walking through a recently sprayed field. To evaluate the risk to workers and other exposed individuals to pesticides, it is important to understand the influences on their absorption. Studies have demonstrated that temperature, humidity and occlusion all have an influence on the extent of skin hydration and permeability (Jones et al 2003). In particular, higher temperatures and humidity can increase the penetration of liquid chemicals through the skin. The chemical protection afforded by street clothing and personal skin products such as sunscreen is poorly understood.

A literature review was conducted and an empirical in-vitro study carried out with diazinon, as a case example. Diazinon is considered a chemical of national security concern by The Council of Australian Governments (COAG), and is still currently in use in Australia. The objectives were to assess the modifying effects of sunscreen, "street" clothing, and temperature, on epidermal absorption and penetration with respect to OPs.

Methods

Literature review

A wide variety of public domain and proprietary bibliographic and full text databases were searched, including Medline, TOMES, HSEES and ARIA for accounts of dermal exposure to OPs. Generic search engines such as Google Scholar were also used. Reference lists from retrieved reports, as well as publications from selected authors, were also explored. The Hazardous Substances Emergency Events Surveillance (HSEES) system was established by ATSDR to collect and analyse information about acute releases of hazardous substances and threatened releases that result in a public health action such as an evacuation. The French ARIA (Analyse, Recherche et Information sur les Accidents) database includes more than 25,000 accidents or incidents both in France and abroad.

Diazinon experiments

Diazinon in-vitro work was performed in accordance with conventional approaches (static diffusion Franz cell with test chemical applied in a liquid form) (OECD 2004). Three variables affecting skin penetration were tested: temperature (23°C vs 37°C), oil-based 30^+ SPF sunscreen (Hamilton Pharmaceuticals, South Australia), and clothing (denim vs polyester). The chosen fabrics represent examples of light and heavy 'street clothing', thereby allowing characterisation of potential absorptive capacities of different common textiles. Infinite dose conditions of pure diazinon (purity 98.3%) were tested to eliminate the effect of additives present in the formulated products. Chemical application conditions (100 µl of 100 µg/ml diazinon in acetone) ensured that the amount of test chemical applied on the skin (in this case dissolved in an acetone vehicle) allows for a maximum rate of penetration of the test substance (per unit area of skin) to be obtained. Aqueous ethanol 50:50 v/v was the receiving fluid. Both human (abdomen) and pig skin samples (epidermis) were used in this study. Although the use of human skin represents the most robust approach, pig skin is more easily available and can be a very useful model for in-vitro dermal absorption studies (Davies et al 2004), provided that the skin integrity is checked prior to skin exposure. Ethics approval was obtained from Southern Adelaide Health Service Clinical Research Ethics Committee. Excised human skin was obtained (with written consent) from individuals undergoing cosmetic reduction surgery. Pre-exposure skin barrier integrity testing was performed in two steps: microscopy to exclude samples with obvious physical damage, and using a Tinsley LCR Databridge 6401 (Fasano & Hinderlliter 2004) to asses membrane electrical impedance.

Application of commonly available oil-based sunscreen (at 2 mg/cm^2) on hydrated exposed skin was performed as per *Australian Standard 2604:(1998) Evaluation and Classification of Sunscreen Products*. Typically worn fabrics were commercially available textiles including 100% cotton (denim) (thickness 0.7716 ±0.011 mm) and 100% polyester (thickness 0.2767 ± 0.005 mm) and were prepared for experimentation according to the Australian Standard AS 2001.5.4-2005 Methods (2005) of test for textiles.

Diazinon concentration was determined by HPLC analysis: GBC, LC 1120 pump connected to a Perkin Elmer Series 200 UV/Vis detector, SUPELCO, Supelcosil™, LC-18, 5-8985 column, mobile phase acetonitrile/water mixture of 70/30 (v/v), flow rate 1.0 ml/minute, with the UV detector set to a wavelength of 250 nm. The following variables were used as descriptors for the ability of diazinon to penetrate skin: lag-time for penetration (min), flux (µg/cm^2/min), permeability coefficient (cm/h) and maximum penetration (mass).

Results and Discussion

Literature review

There have been a number of occupational studies of dermal exposure to OPs (see review Gold et al 1984). The evidence of uptake potential of organophosphate insecticides is that OPs are generally well absorbed through skin, both in their concentrated formulations and when diluted to ready-to-use concentrations (Kamanyire & Karalliedde 2004; Riviere 2006). Dermal absorption following skin contact, especially to aerosols, can result in significant systemic symptoms in the absence of inhalation (for example if those exposed adequately cover the nose and mouth to prevent aerosol inhalation). The extent and speed of dermal absorption and the severity of symptoms depends on formulation characteristics and the inherent toxicity of the OP concerned. Furthermore, dermal uptake is not linearly related to applied dose; there is evidence at lower concentrations of OPs, preferential attraction to skin may occur (Edwards et al 2007).

Our objective was to assess the literature for evidence on the dermal protective (or uptake enhancing) properties of personal items (sunscreen) and "street" clothing, particularly in relation to OPs. The literature indicates that a variety of factors can play a significant role in the dermal absorption of chemicals. These include skin thickness and lipid content, occlusion, clothing, temperature and humidity and skin damage/disease. Some of these factors are correlated with anatomical region, age, gender and ethnicity. There do not seem to be any systematic studies of the chemical protection afforded by street clothing or personal items. Indeed, it is only recently that the community usage of personal items has been studied for risk assessment purposes (Loretz et al 2005; Loretz et al 2008).

Personal items effects on skin absorption:

Personal items applied to the skin, such as sunscreen and cosmetics may enhance, buffer or reduce dermal exposure. They may also act as a chemical reservoir. The ability to enhance or reduce skin uptake appears to depend primarily on whether the product is oil or water based (Bronaugh et al 1981), although some active ingredients can enhance penetration (Pont et al 2004). There are some studies on the influence of skin absorption of sunscreen with vehicles. With hairless mouse skin (Brand et al, 2002; Pont et al, 2004), the active ingredients of several sunscreen formulations (i.e. the UV absorbing components and insect repellents) on the skin significantly enhanced skin absorption of a herbicide, 2,4-dichlorophenoxyacetic acid within 24 hours, compared the control where sunscreen was not applied.

Agricultural and pest control workers and related outdoor workers are encouraged to use sunscreen to decrease the risk of UV-related skin cancer. Sunscreen use carries an added risk, however, as several commercial sunscreen formulations have been shown to enhance penetration of potentially harmful chemicals (Pont et al, 2004).

Clothing effects:

Clothing has the potential to act as a barrier to chemical exposure (protecting individuals) or as a reservoir (trapping or holding chemicals and facilitating uptake), or acting as an occlusive barrier to enhance absorption. As a barrier, chemical resistance is important, in the same way that intrinsic resistant properties are used in personal protective clothing. Street clothing may serve to initially protect and buffer the skin from toxic chemicals, depending on the material, thickness, cover and yarn twist (Lee & Obendorf 2005). However, significant skin uptake of chemical may occur if contaminated clothing is in contact with, or occludes, the skin.

The impact of clothing on dermal exposure of chemicals has been extensively studied in relation to chemical protective clothing (Davies et al, 1982; Fenske, 1988; Stull & Pinette, 1990; Leung & Paustenbach, 1994; Driver et al, 2007). Few studies have been undertaken on the effectiveness of general "street" clothing except in relation to spraying of pesticides and in one case exposure to mustard gas. In a study by Protano et al (2009) the impact of different clothing types on reducing skin exposure to a range of pesticides commonly applied using a sprayer was verified. The study showed that cotton clothing had a protection factor of greater than 84% whereas chemical protecting clothing (tyvek suits) had a performance greater than 97%. Recent work in the United Kingdom showed cotton shirt material significantly reduced dermal absorption of dichlorvos and chlorpyrifos, and post-exposure removal of clothing with immediate skin surface decontamination further reduced absorption compared with removal of clothing alone (Moore 2010).

Occlusion of the area of skin enhances skin absorption because occlusion causes increased hydration and temperature of the skin. Occlusion of chemicals on personal protective equipment (PPE-overalls, gloves, socks and hat) may increase skin absorption. From a recent study with pesticide spray workers applying OPs (malathion and fenthion) (Edwards et al, 2007), the deposition of OPs on PPE was determined rather than the amount present on skin as this acted as a surrogate model for the deposition upon unprotected skin. Contamination of cotton liner gloves within gauntlets was measured as an estimate of possible contamination during glove donning and removal and this contamination is able to persist within gloves representing an occluded exposure.

Temperature/Humidity effects:

One study by Chang and Riviere (1991) explored the effects of temperature and humidity on skin absorption of the OP insecticide parathion in an in-vitro pig skin model. Elevated air temperatures (42°C) and humidity (90%RH) were shown to significantly enhance (almost 2-fold) the penetration of parathion over an 8 hr period compared with lower temperature/humidity conditions (37°C, 60%RH). Meuling et al (1997) studied the dermal absorption of the pesticide propoxur at 30°C under various humidities (50, 70 or 90%). The percentage body burden attributable to dermal absorption increased from 13% (at 50% relative humidity) to 63% (at 90% RH), indicating that skin moisture is important in dermal absorption of propoxur.

In occupational settings, personal protective equipment will be affected by increasing temperature. One laboratory study assessed the degree of malathion permeation through PVC glove material in different temperature conditions (22±1 ^{o}C and 37±1 ^{o}C) (Lee et al, 2009). It was found that increasing temperature reduced breakthrough times and increased permeation rates which may cause increasing skin absorption, as reported by other studies (Klinger & Boeniger, 2002; Cherrie et al, 2004; Semple 2004).

Jones et al (2003) is one of few studies assessing both environmental conditions and clothing factors on dermal absorption, in this case for solvent vapours. An increase in 2-butoxyethanol vapour absorption was noted with increased temperature and humidity (as shown in Figure 1). Furthermore, the wearing of whole-body overalls did not attenuate absorption. This could have been because the rate of gas exchange through the clothing exceeded the absorption rate of 2-butoxyethanol through the skin. By combining several factors together in the 'industrial scenario', the authors noted dermal absorption of vapours was significantly increased with a mean of 39% of the total absorbed dose.

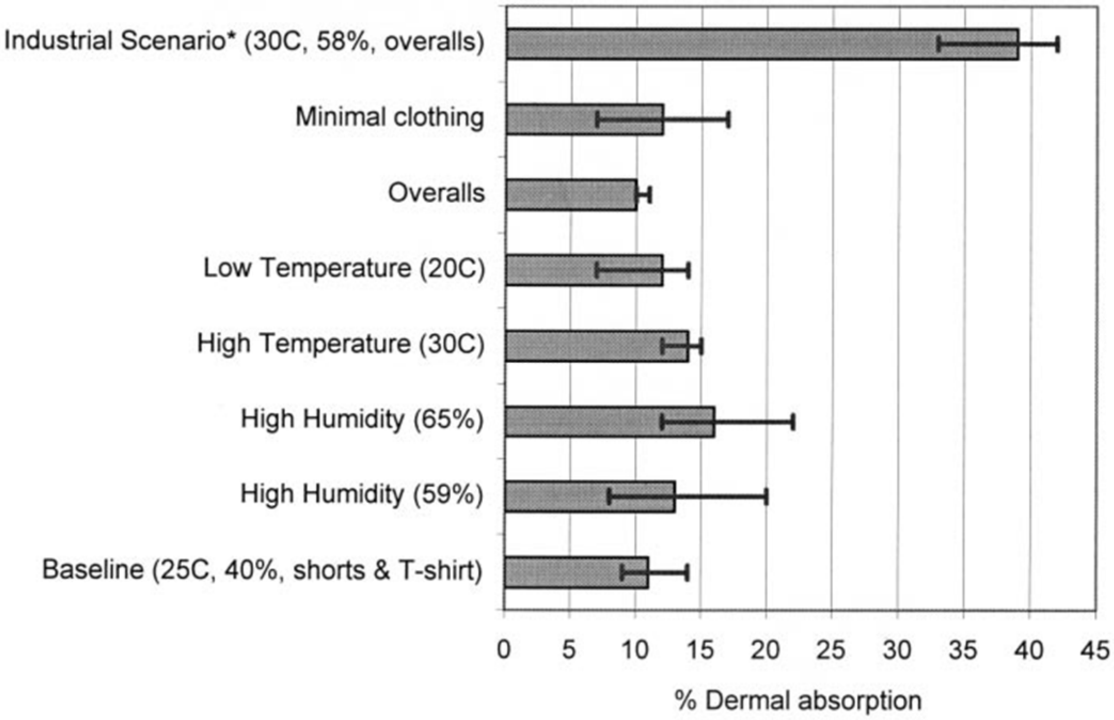

Figure 1: Effect of environmental conditions on dermal absorption (% mean with range, N = 4). *Statistically significant (P < 0.005) (Source: Jones et al, 2003).

Implications for Occupational Hygienists:

The importance of this review for occupational hygienists is in highlighting the significance of issues relating to clothing, personal products and environmental factors influencing the dermal absorption of OPs. Exposure can occur where workers are unprotected, or in the event of civilian exposure scenarios involving emergency response. In these circumstances occupational hygienists may be called upon to provide advice on the dermal protective (or uptake enhancing) properties of personal items and street clothing in the assessment of exposure. One such analogy can be drawn from the recent pandemic of avian influenza A (H1N1) where a shortage of disposable respirators occurred, and evaluation was sought on the respiratory protection afforded by common fabric materials (e.g. t-shirt, scarves) against infection (Rengasamy et al, 2010). The outcome was that common fabrics afforded marginal protection against aerosols/nanoparticles, but with obvious high variability due to not fit-for-purpose design.

Diazinon experiments

Table 1 shows the descriptors of skin penetration of diazinon in all set variable conditions: lag-time for penetration (minutes), maximum penetration (µg), flux (µg/cm^2/min) and permeability coefficient (cm/h). The set conditions were: pig skin in ambient (23°C) and in elevated (37°C) temperature conditions; pig skin with added oil-based 30$^+$ SPF sunscreen in ambient (23°C) and in elevated (37°C) temperature conditions; pig skin with added denim or polyester in ambient (23°C) temperature conditions; and human abdominal skin in ambient (23°C) and in elevated (37°C) temperature conditions. Results revealed the skin to be a good barrier to penetration. Less than five percent (3.1% ± 0.5) of applied dose penetrated the human skin. Sunscreen and denim fabric seemed to act as an extra barrier for absorption and penetration, whereas elevated temperatures (37˚C) seemed to aid diazinon penetration through skin (Table 1).

Experimental conditions	Lag-time (min)	Maximum penetration (µg) ± Std. Error of the Mean	Flux (µg/cm^2/min) ± Std. Error[b]	Permeability coefficients (cm/h)
Pig at 23°C	53	2.0 ± 0.4**/***	0.089 ± 0.022	0.0534
Pig at 37°C	7	2.8 ± 0.4*/****	0.105 ± 0.030	0.063
Pig + sunscreen at 23°C	118	1.0 ± 0.2	0.014 ± 0.006	0.0084
Pig + sunscreen at 37°C	78	0.9 ± 0.2*	0.031 ± 0.023	0.0186
Pig + denim at 23°C	204	0.2 ± 0.09**	0.002 ± 0.001	0.0012
Pig + polyester at 23°C	90[a]	0.8 ± 0.4	-	-
Human at 23°C	418	0.3 ± 0.05***	0.004 ± 0.002	0.0024
Human at 37°C	98	0.3 ± 0.07****	0.001 ± 0.001	0.0006

Table 1. Descriptors of the ability of diazinon to penetrate skin in variable conditions.

[a] Was not possible to calculate lag-time by linear regression. Value based on results of experimental data.

[b] Reported as Standard Error, displaying the standard error for the estimate of the slope, following linear regression.

*/**/***/**** Pairs of variables that show a statistically significant difference ($p < 0.05$).

Results presented in table 1 show that an elevated temperature decreases the time required for diazinon to penetrate the pig skin (lag-time). In addition, the maximum penetration seems to be higher, although the difference is not statistically significant. An elevated temperature also decreases the lag-time for diazinon penetration when sunscreen is added to (pig) skin. Furthermore, the lag-time of diazinon penetration is much longer when sunscreen is added on skin compared to when no sunscreen is added, under both temperature conditions. Also, the maximum penetration of diazinon with sunscreen added seems to be lower in both temperature conditions. However, a statistically significant difference is only found for addition of sunscreen on skin in elevated temperature (37°C) conditions ($p = 0.005$).

With respect to clothing, table 1 shows that the lag-time of diazinon penetration is much longer when denim is added on (pig) skin compared to when polyester is added. In addition, maximum penetration of diazinon with denim added on skin was found to be significantly lower from when no denim is added ($p = 0.003$).

Finally, the results in table 1 show that an elevated temperature (37°C) decreases the time required for diazinon to penetrate human skin, as found for pig skin. However, no comparable increase in the maximum penetration of diazinon in elevated temperature conditions can be observed. Overall, smaller amounts of diazinon penetrated human skin compared to pig skin. This difference is found to be statistically significant for ambient (23°C) ($p < 0.001$) as well as elevated (37°C) temperature conditions ($p = 0.001$).

Therefore, these results seem to indicate that sunscreen acts as an extra barrier for penetration. Comparable to sunscreen, also denim seems to act as an extra barrier for skin penetration. Denim increases the lag-time of diazinon penetration and, in addition, lowers maximum penetration significantly compared to when no denim is added. Polyester does not seem to show a similar trend.

When comparing the human skin penetration data to the pig skin penetration data, it can be concluded that human skin seems to act significantly more as a barrier, because lag-time is higher (6.97 h versus 0.88 h) and flux and maximum penetration (3.1 ± 0.5% versus 20 ± 4.2%) are lower. Therefore, it could be concluded that using pig skin in an in-vitro model, under the relatively short exposure times applied in this study, will probably result in conservative estimates for human skin penetration.

A study by Moody and Nadeau (1994) showed similar lag-times for penetration of diazinon compared to findings in this study, except they did not find a lower maximum penetration of human skin compared to pig skin. In their study, %-recovery in receiver solution amounted to 5.8 ± 1.31% for pig skin and 6.0 ± 1.36% for human skin after 48 hours of exposure. The lower amount of diazinon penetration through pig skin compared to findings in this study (20 ± 4.2%) could be explained by the use of dermatomed skin (0.5 mm) by Moody and Nadeau (1994).

Furthermore, other studies have reported higher percentage of applied dose penetrating the human abdominal skin compared to the results in this study (Wester et al 1993; Moody and Nadeau 1994). The in-vitro study of Wester et al (1993) showed that 14.1 ± 9.2% of the applied dose accumulated in the receptor fluid over 24 hr of exposure to 0.25 $\mu g/cm^2$. Most probably, the discrepancy with findings in this study can be explained by the longer exposure time applied in the mentioned studies. In the in-vivo study by Garfitt et al (2002), 1% of the dermal dose was excreted as urinary DAP metabolites, with 90% of the dermal dose being recovered from the skin surface after 8 hours of exposure. These results are comparable with the percentage of dose that penetrated human skin in this study (3.1 ± 0.5%). These data underpin the conclusion that pig skin in this study (maximum penetration 20 ± 4.2% of applied dose) overestimates the in-vivo human absorption of diazinon.

The importance of outcomes from this empirical study relate to the moderating effects of sunscreen, clothing and temperature conditions on dermal penetration of diazinon. This has not previously been explored. The findings show sunscreen and denim ("heavy") fabric act as an extra barrier for absorption and penetration, whereas elevated temperatures (37˚C) seemed to aid diazinon penetration through skin. This has important implications for assessment of exposure and uptake potential in occupational settings where diazinon is used.

Conclusions: Interpretation of review and case study experimental outcomes

Based on findings observed for different OPs, temperatures, sunscreen and clothing parameters a set of practical guidelines can be derived for occupational hygienists, emergency responders and medical personnel in the event of work-related or civilian exposures to OPs.

With respect to clothing, as a general rule "heavy" or bulky, porous fabric provides an initial buffer against but potential ongoing reservoir for contaminant exposure. Our literature search found evidence to suggest removal of the exposed individual's clothing eliminates 80-90% of the contaminants and minimises the risk of spreading the toxic agent to others (Levitin et al 2003; Houston et al 2005). If feasible this outer clothing should be removed as soon as possible after exposure. On the other hand, lightweight clothing is unlikely to represent a reservoir for ongoing exposure (as shown by diazinon results using polyester), and so the imperative is less apparent. This is in contradiction to the current dogma which is to remove all clothing.

Personal products applied to the skin may or may not enhance the barrier protection provided by naked skin. The passage of some chemicals into the skin may be assisted by sunscreen. For other hydrophilic substances, the barrier effectiveness provided by oil-based sunscreens can be quite marked. Conclusions able to be drawn from the sunscreen barrier effectiveness outcomes are limited, except where we may be dealing with hydrophobic contaminants, where physical removal of sunscreen is likely to be beneficial. More research is needed to clarify the role of personal items applied to the skin on dermal absorption of chemicals. In practice, the protective benefits of sunscreen for UV cancer risk in occupational settings will continue to outweigh the potential added risk associated with its use.

In summary, this research verified that in addition to the usual primary consideration of concentration/duration of chemical exposure, the fundamental parameters influencing dermal absorption of OPs is clothing, with secondary effects due to humidity and temperature, and sunscreen. The work also confirms that diazinon penetration can be influenced by ("heavy") clothing and sunscreen, with protective effects. This work will hopefully contribute to a better understanding of the issue for occupational hygienists who may be called upon to provide advice and assistance on these issues.

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Fire Fighter Exposure to Diesel Exhaust in QFRS Fire Stations

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Abstract

Diesel exhaust consists of a complex mixture of both particulate matter and gaseous substances. The Queensland Fire and Rescue Service commissioned research into the levels of diesel exhaust within fire stations to assess the exposure of Queensland fire fighters during normal station duties.

Seven fire stations varying in response workload and building age and design were selected. Concentrations of diesel particulate matter (DPM) and polyaromatic hydrocarbons (PAH) were measured outside the station and in key work areas over ten-hour daytime shifts and during specific station activities.

DPM concentrations for all internal station locations were less than 0.005 mg/m^3 elemental carbon, which was similar to the external environment (up to 0.007 mg/m^3 EC). Start-of-shift operational equipment checks conducted under reduced ventilation conditions resulted in engine bay DPM measurements above the level of concern for only one station which was operating a Firepac 3000 Mk 3 appliance (0.73 mg/m^3 EC).

Firefighter exposures to DPM and PAH are typically low within the fire station environment, although specific tasks should be conducted in well-ventilated conditions.

Keywords

Diesel exhaust, occupational monitoring, diesel particulate matter, DPM, polyaromatic hydrocarbons, PAH, fire station, fire fighter

Introduction

A number of expert groups and government agencies have categorised diesel exhaust as either a potential or likely carcinogen (United States Environmental Protection Agency, 2000; United States Mine Safety and Health Administration, 2001; Dabill, 2004; Australian Institute of Occupational Hygienists, 2007; Hesterberg et al., 2005). Occupational exposures to diesel exhaust vary significantly in intensity and duration depending on occupation and location (Pronk et al, 2009), and have been primarily investigated in the mining industry and among drivers, crew and maintenance workers for road and rail vehicles. To date there are few occupational or environmental exposure standards or guidelines published for diesel exhaust, and the majority of those that exist pertain to the mining industry (United States Mine Safety and Health Administration, 2001a,b; van Niekerk et al., 2002; Davies and Rogers, 2004; Wheatley and Sadhra, 2004; Irving, 2006; Australian Institute of Occupational Hygienists, 2007; Anyon, 2008).

Diesel particulate matter (DPM), particularly elemental carbon (EC), is typically used as a surrogate measure for the exposure to diesel exhaust and health effects (Frumkin and Thun, 2001), although diesel exhaust also contains components such as carbon monoxide, nitrogen oxides, and polyaromatic hydrocarbons (Liang et al., 2005; Pronk et al, 2009). Various polyaromatic hydrocarbons (PAH) are themselves categorised as possible, probable or known carcinogens (International Agency for Research on Cancer, 2006) and are therefore also of interest with respect to occupational exposures.

A study conducted of pre-exhaust-controlled vehicles using high sulfur diesel (Froines et al., 1987) found that the amount of DPM in fire stations varied depending on time of year (temperature effect), size of response area (city population etc.), the number of station appliance departures/returns, and ventilation conditions. Studies conducted by the United States Department of Health and Human Services on diesel exhaust in fire stations (National Institute for Occupational Safety and Health, 1993; 1998; 1999; 2000) found that engine bays and areas open to engine bays recorded the highest levels of DPM. DPM levels in living and work areas separate from engine bays (typically mess and dormitories) were significantly lower (< 0.001 to 0.03 mg/m^3 EC), especially if openings were kept closed. A recent literature review (Pronk et al., 2009) on the occupational exposure to diesel exhaust found that fire fighter exposure to DPM in the United States ranged from not detected to 0.05 mg/m^3 EC. This range is similar to vehicle maintenance workers and wharf workers, and substantially lower than exposure levels for underground mining and tunnel construction workers. However, the high end of this DPM atmospheric concentration range is half the United States mandated underground coal mine DPM exposure limit of 0.1 mg/m^3.

Investigations into the exposure of fire fighters to PAHs have to date been confined to exposures during firefighting operations and training (Feunekes et al., 1997; Bolstad-Johnson et al., 2000; Ruokojärvi et al., 2000; Caux et al., 2002; Laitinen et al, 2010).

The purpose of this study was to investigate the concentrations of diesel particulate matter (DPM) and polyaromatic hydrocarbons (PAH) in a sample of Queensland Fire and Rescue Service (QFRS) fire stations varying in response workload and building age and design, considering both concentrations during both specific station activities and during entire work shifts.

Methods

Selection of fire stations

The fire stations selected for this study were chosen to most widely represent the broad construction characteristics and activities undertaken across the QFRS, with selection based on call-out frequency, number and type of appliances and design/age of station as shown in Table 1.

Air sampling

Two separate sets of air sampling for DPM and PAH were conducted on separate days. The first involved measurement of start-of-shift equipment checks, turnouts and returning to station as described in Table 2. For these tests, sample collection devices were located 1.5 m above the ground and adjacent to the exhaust of the main appliance (behind the vehicle cabin on the off-side). The activity specific measurements ceased when the start of shift check was completed. The number of appliances involved in the turnout and return simulations is based on the standard station turnout scenario, and thus involved either one or two appliances as shown in Table 1.Table 1 Characteristics of fire stations selected.

QFRS Region	Profile and Year of Construction	Annual call-outs	Appliances – Start-of-Shift Tests	Appliances – Turnout/Return Tests
1	Urban Special	2736	Scania Urban Pumper Tanker Mercedes Sprinter Austral Firepac Mark III 3000	Scania Urban Pumper Tanker Mercedes Sprinter
2	Urban standard (pre 1970)	1666	Scania Urban Pumper Light Mercedes Atego Urban Pumper Isuzu Pumper/Tanker 4x4 Light Mercedes-Benz Emergency Tender	Scania Urban Pumper Mercedes Atego Urban Pumper
3	Urban standard (1970 – 1995)	1062	Mercedes Atego Urban Pumper Mercedes Atego Urban Pumper Austral Firepac Mark III	Mercedes Atego Urban Pumper
4	Urban standard (post 1995)	1316	Scania Urban Pumper Tanker Scania Urban Aerial Ladder Platform Mitsubishi Urban Pumper Tanker Isuzu Urban Pumper Tanker	Scania Urban Pumper Isuzu Urban Pumper Tanker
5	Urban standard (post 1995)	1758	Mercedes Atego Urban Pumper Ford Urban Rescue Tender Isuzu Urban Pumper Tanker Tieman Urban Fire Support Tanker	Mercedes Atego Urban Pumper Ford F450 Urban Rescue Tender
6	Urban standard (1970 – 1995)	1302	Lafrance Urban Pumper	Lafrance Urban Pumper
7	Urban standard (pre 1970)	2124	Scania Urban Pumper Scania Urban Aerial Ladder Platform Isuzu Pumper Tanker 4x4 Light Mercedes Atego Urban Incident Support	Scania Urban Pumper Dodge Urban Aerial Ladder Platform

Table 2 Description of start-of-shift, turnout and station return tests

Start of shift checks	• Physical check of equipment and operation of all mechanical devices (e.g. appliance engine, generators, ancillary petrol-driven equipment) • Front engine bay doors closed, rear doors closed where this was local practice (majority of stations) • Sample collection to continue throughout checking process for all appliances in engine bay, and cease on completion of checks
Turnout simulation	• Involves only primary response • Commence sampling, open engine bay doors and start fire appliance(s) • Idle appliance(s) for 60 seconds • Accelerate appliance to leave station • Close doors immediately after appliance(s) have left engine bay • Sample collection continues for 2 minutes post-departure • Cease sampling and ventilate engine bay area for 5 minutes • Repeat 10-15 times to ensure sufficient air volume sampled
Station return simulation	• Idle appliance for 60 seconds outside station with engine bay doors closed • Commence sampling and open engine bay doors • Drive appliance into place and shut down as per normal procedure • Close engine bay doors immediately after appliance(s) enter engine bay • After 2 minutes of sample collection, cease sampling and ventilate engine bay area for 5 minutes • Repeat 10-15 times to ensure sufficient air volume sampled

The second set of air sampling involved continuous measurement of DPM and PAH during a complete ten-hour day shift. The day shift was selected because of the more frequent appliance movement, fire fighters being more active during the day and the greater potential for contribution to fire fighter exposure from external sources. Sampling locations for these tests were:

- Engine bay (next to exhaust pipe of primary appliance, height 1.5 m from floor)
- Duty office (adjacent to door, height 0.8 m from floor)
- Dormitory (closest to engine bay and adjacent to door, 0.4 m from floor)

Sampling heights were selected to represent the likely breathing zones of personnel undertaking activities in these areas. A concurrent urban background sample was also collected outside the fire station, close to the nearest/busiest roadway.

Diesel particulate matter samples were collected on 37-mm diameter cassettes with quartz-filter fibre (SKC, Inc.), with flow rates of 1.8 – 2.0 L min^{-1} for the 10 hour samples and 4.0 – 5.9 L min^{-1} for the 2 minute simulated turnout trials. Analysis of DPM samples for total carbon (TC), elemental carbon (EC) and organic carbon (OC) was in accordance with NIOSH Method 5040 (National Institute for Occupational Safety and Health, 1994).

Polyaromatic hydrocarbon (PAH) samples were collected in 22 mm x 100 mm borosilicate glass tubes containing polyurethane foam (PUF) / Tenax / PUF layers (SKC Inc.), at flow rates of 4.0 – 5.0 L min^{-1}. PAH samples were analysed according to the principles of United States Environmental Protection Agency Compendium Method TO-13A (Center for Environmental Research Information, 1999).

Results

The DPM and PAH measurements for all stations and the averages of these measurements are listed in Table 3.

Polyaromatic hydrocarbons

Airborne PAHs that were detected at concentrations above reporting limits were: pyrene, fluoranthene, anthracene, phenanthrene, fluorene, acenapthene, acenaphthylene and naphthalene. None of these are currently listed as known, probable or possible carcinogens (International Agency for Research on Cancer, 2006). Results of PAH measurements at various station locations are shown in Figure 1. It should be noted for Figure 1 that if the measurement for a particular location was less than the reporting limit, the reporting limit was used to illustrate the worst-case concentration.

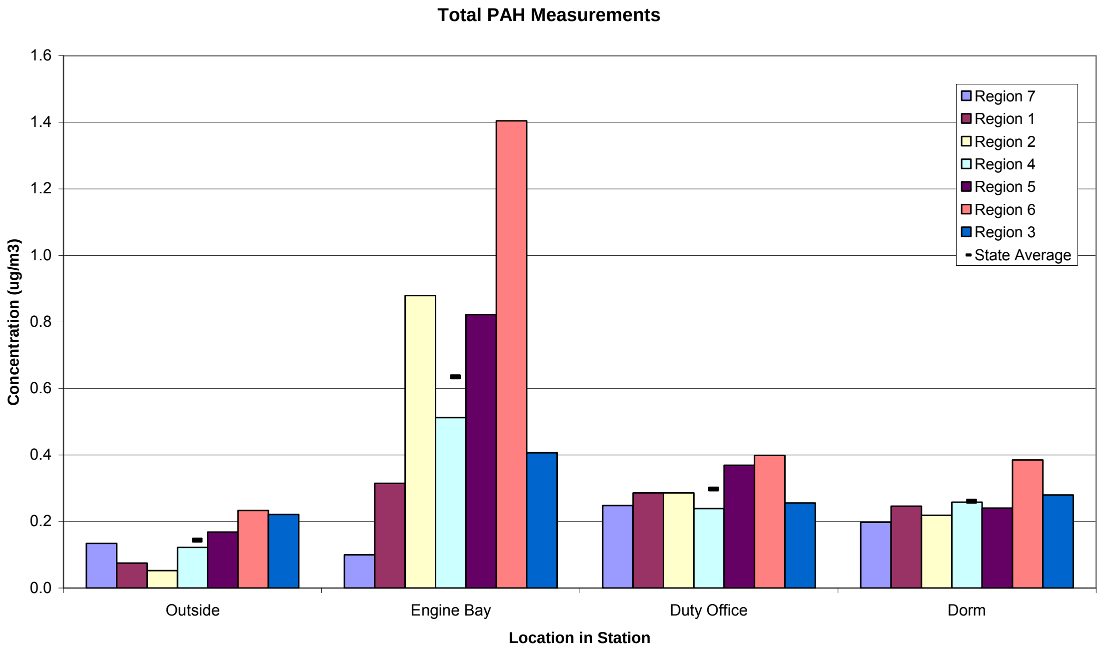

Figure 1 PAH concentrations for a ten hour day shift at fire stations across the state.

Sample Locations		Outside	Engine Bay				Duty Office	Dormitory
QFRS Region	Analyte	10 Hr	10 Hr	Start of Shift	Turnout	Return	10 Hr	10 Hr
1	DPM / (mg/m^3)	0.007	0.001	0.011	0.002	0.007	0.001	0.001
	PAH / (ug/m^3)	0.08	0.32				0.25	0.29
2	DPM / (mg/m^3)	0.001	0.002	0.06	0.027	0.032	0.001	0.002
	PAH / (ug/m^3)	0.05	0.88				0.29	0.22
3	DPM / (mg/m^3)	0.002	0.009	0.08 (0.73)*	0.01	0.02	0.005	0.002
	PAH / (ug/m^3)	0.22	0.41				0.26	0.28
4	DPM / (mg/m^3)	0.002	0.003	0.06	0.01	0.01	0.001	0.001
	PAH / (ug/m^3)	0.12	0.51				0.24	0.26
5	DPM / (mg/m^3)	0.002	0.005	0.06	0.01	0.02	0.001	0.001
	PAH / (ug/m^3)	0.17	0.82				0.37	0.24
6	DPM / (mg/m^3)	0.001	0.003	0.036	0.001	0.001	0.001	0.001
	PAH / (ug/m^3)	0.23	1.40				0.40	0.39
7	DPM / (mg/m^3)	0.001	0.001	0.002	0.001	0.001	0.001	0.001
	PAH / (ug/m^3)	0.13	0.10				0.20	0.25
State Averages	DPM / (mg/m^3)	0.002	0.003	0.044	0.019	0.013	0.002	0.001
	PAH / (ug/m^3)	0.14	0.63				0.30	0.26

Table 3 Polyaromatic hydrocarbons (PAHs) and diesel particulate (DPM) measurements

* start of shift measurement with Firepac 3000 (brought into service prior to introduction of diesel exhaust emissions standards)

Diesel Particulate Matter

Start of shift checks ranged between 20 to 60 minutes duration. One trial was repeated to test the influence of a Firepac Mark III 3000 appliance that was absent for the first trial, resulting in an almost ten- fold increase in DPM concentration as shown in Figure 2.

Discussion

Polyaromatic Hydrocarbons

In the absence of an Australian exposure standard for total airborne PAHs, the United States Occupational Safety and Health Administration Exposure Standard of 0.2 mg/m^3 for total airborne PAHs over an eight-hour working day may be adjusted to 140 µg/m^3 for a ten-hour shift (National Occupational Safety and Health Commission, 1995).

Outside Station (Background)

The highest total PAH measurement outside a fire station was 0.23 µg/m^3, which is more than 600 times lower than the 10 Hr level of concern of 140 µg/m^3. The average total PAH measurement concentration was 0.14 µg/m^3. Care should be taken in interpreting these total results as they are derived from the addition of mostly reporting limit concentrations. The majority of compounds were not detected above the reporting limits of the laboratory.

Inside Station

All duty office and dormitory measurements and six of the seven engine bay measurements were above the average external background concentration. The highest fire station engine bay concentration measured was 1.4 µg/m^3 (engine bay), which is 100 times lower than the ten-hour level of concern (140 µg/m^3). The highest fire station duty office and dormitory measurements were both 0.4 µg/m^3, which is 350 times lower than the ten hour level of concern. The same station recorded the highest engine bay, duty office and dormitory measurements.

Diesel Particulate Matter

In the absence of an Australian or international exposure standards for total airborne DPM, the underground coal mine guideline limit of 0.1 mg/m^3 EC (using elemental carbon concentration as a surrogate) was adopted. A note was also made of the US fire fighter DPM exposure being typically ≤ 0.05 mg/m^3 EC (50 µg/m^3 EC).

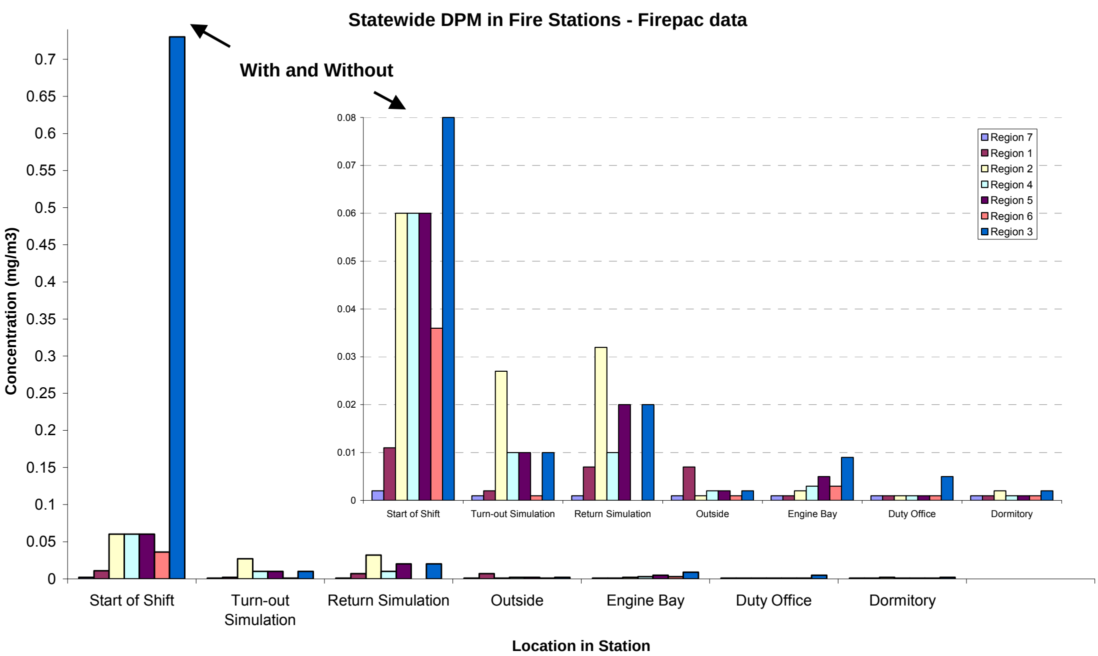

Figure 2 DPM results for ten hour shift (dormitory, engine bay, duty office and outside) and simulated time tests (start of shift, turn-out and return to station).

Outside Station (Background)

All stations, except one, had ambient background measurements below the average DPM background concentration of 0.002 mg/m^3 EC. The highest fire station measurement was 0.007 mg/m^3 EC which is more than 14 times lower than the ten-hour level of concern of 0.1 mg/m^3 EC.

Inside Station

Two of the seven engine bay measurements were above the average background concentration (0.002 mg/m^3 EC). All duty office measurements, except one, were below the average background concentration (0.002 mg/m^3 EC), and all dormitory measurements were at or below the average background concentration. The highest concentration measured in the engine bay was 0.009 mg/m^3 EC', which is more than 10 times lower than the ten hour level of concern (0.1 mg/m^3 EC). The highest fire station concentrations in the duty office and dormitory were 0.005 mg/m^3 EC and 0.002 mg/m^3 EC respectively. These values are 20 and 50 times lower than the ten-hour level of concern.

Start of Shift, Turn-out and Return Trials

The results demonstrate some variance between stations, and the variations are most likely explained by differences in appliances, station design and work practices. Figure 2 demonstrates that the majority of measurements were below the DPM underground coal mine guideline, which for this study has been adopted as the level of concern (0.1 mg/m^3 EC). and that the highest values were observed during the start of shift check. The average DPM concentration observed for start of shift checks without a Firepac 3000 Mark 3 appliance present was 0.044 mg/m^3 EC, which is substantially below the level of concern. However, the DPM measurement of 0.73 mg/m^3 EC that occurred during a start of shift trial with a Firepac 3000 Mark 3 appliance is more than seven times the level of concern. This type of appliance was subsequently removed from operational service with the QFRS.

The average DPM concentration obtained for the turn-out simulation trials was 0.009 mg/m^3 EC, which is 4.5 times higher than the than the background DPM concentration (0.002 mg/m^3 EC). The highest fire station engine bay concentration for turn-out simulations was 0.027 mg/m^3 EC, which less than one-third of the DPM level of concern (0.1 mg/m^3 EC). The average DPM concentration obtained for the return to station simulation trials was 0.013 mg/m^3 EC, which is 6.5 times higher than the background DPM concentration (0.002 mg/m^3 EC). The highest fire station engine bay concentration for station return simulations was 0.032 mg/m^3 EC, which is approximately one-third of the level of concern.

Conclusions

Emissions of PAH and DPM within QFRS fire stations over a ten-hour day shift were significantly below the established levels of concern, while DPM concentrations from start-of-shift checks exceeded the established level of concern for only one appliance. Areas in which fire appliances and mechanical equipment are being checked and operated should be well ventilated, either by opening the engine bay doors to provide natural ventilation or by conducting equipment checks outside with engine bay doors closed. Design of new and refurbished fire stations should consider the potential for air movement between the engine bay and the rest of the station, to reduce exposure of personnel to exhaust emissions.

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Monitoring Deadly Gases: Real Steps towards Preserving Lives

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Abstract

Many companies rely on gas detectors to protect their employees from acute gas hazards in the workplace. Historically, employers have had very little insight into the dynamics around their gas detection program - the behavior of their users, the number of gas alarms, readiness of the equipment to perform its duty in the field, and exposure of their employees to deadly gases. Too often, this data is pieced together as the result of an incident.

Industrial Scientific has been delivering gas detection solutions to industry for the last 25 years. In an effort to deliver better programs to its customers, the company developed iNet, a web-based monitoring tool. Today, almost 50,000 gas detectors in 19 countries are being monitored on the iNet system.

In recent years, Industrial Scientific has seen distinct trends that have changed how the company thinks about gas detection in the workplace. In this presentation, the company's President and CEO discusses these observations and makes recommendations to those companies dealing with monitoring and control of gas hazards.

Carbon Dioxide Levels in "Dongas" in Mining Accommodations – An Additional Problem in Fatigue Management

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Abstract

Significantly high levels of carbon dioxide have been detected in single room (donga) accommodations in a recent air quality audit of mining accommodations. Due to extreme shortages in accommodation as a result of the "mining boom" in Western Australia and Queensland, single room dongas have been built to service the accommodation shortages. In the majority of these structures, split system air-conditioning has been fitted into the room without any fresh air intakes built into the structure to provide dilution of pollutants and provision of fresh air. This study highlights the conditions resulting in such high readings being recorded, the effects on inhabitants and some practical suggestions to reduce carbon dioxide levels in such accommodations.

When will Australia have its own job exposure matrix (JEM)?

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Abstract

In 2002 a case was put to the AIOH for Australia to develop its own generic job exposure matrix (JEM), called AusJEM. A JEM is a listing of occupations and/or industries on one axis and exposure agents, which can be chemical or physical, on the other. JEMs will indicate the quantitative level, presence (0,1), intensity or probability of an agent in a specific occupation or industry.

JEMs are commonly used in occupational epidemiology and over 30 are accessible from Universities, research organizations and government bodies across the world. However, exposure to workplace chemical and physical agents is strongly dependent upon the geographical, cultural and technological environment in which workers are engaged. As a result, many countries have developed their own unique JEMs. Examples are the Finnish FINJEM, the French SUMEX, and a recently developed New Zealand JEM. Many countries have general population JEMs as well as industry specific or exposure specific JEMs.

Australia does not have its own general population JEM. Reasons for a lack of an AusJEM include lack of funding, confidentially concerns by data custodians/suppliers and lack of understanding for the need for a unique Australian JEM.

Introduction

Job Exposure Matrices (JEM) list occupations and/or industries on one axis, exposure agents on the other, and the cells indicate the presence, intensity or probability of exposure to the agents of interest (Nieuwenhuijsen Ed., 2003). In 2002 the author presented a paper to the Australian Institute of Occupational Hygienists conference at Deakin University, Victoria, outlining the case for an Australian JEM, called AusJEM (Benke, 2002). The three main areas where an Australian JEM could be utilized are in health studies undertaken by research workers, regulatory development by regulatory bodies and in the compensation field.

Since 2002, many countries have progressed in the development of their own unique JEMs and there have also been international collaboratives that have developed JEMs for specific research purposes. Some of the more recent JEMs include the French SUMEX JEM (Guegen et al, 2004), the Scandinavian NOCCA JEM (Kauppinen et al, 2009) and the new INTEROCC-FINJEM (Van Tongeren et al, 2011). We have remained stagnant in Australia in this area and the reasons for our stagnation are not readily apparent. The aim of this paper is to suggest reasons for our lack of progress in Australia by reviewing recent developments and describing current barriers in Australia, that may have resulted in the observed lack of progress.

Developments since 2002

There have been many JEMs developed and published in recent years these include:

i. The SUMEX JEM (Guéguen et al, 2004); this JEM was developed in France by researchers at INSERM, and was constructed for 80 chemicals by 1205 occupational physicians who questioned 48,156 workers.
ii. COPD JEM (Blanc et al, 2005): this is a JEM that has been specifically designed to investigate Chronic Obstructive Pulmonary Disease (COPD).
iii. Textile-JEM (Wernli et al, 2008): this JEM was developed for the Textile industry for estimates of quantitative levels of cotton dust and endotoxins.

iv. The NOCCA JEM in Scandinavia (Kauppinen et al,2010): this is a derivation of the Finnish FINJEM that has incorporated changes from the other Nordic countries. It was developed primarily for the Nordic Occupational Cancer Study, but could be used for other applications.

v. Asphalt JEM (Agostini et al, 2010): This is a JEM constructed for a study investigating European Asphalt workers. It may be applicable to other asphalt workers in other continents.

vi. INTEROCC-FINJEM (Van Tongeren et al, 2011): This JEM has been developed for the INTEROCC study and was recently compared with expert assessment using Canadian data.

vii. NZ-JEM (t'Mannetje et al, 2011): This is a New Zealand General Population JEM that has been recently reported and will be used in New Zealand occupational health studies. It has some limitations but could possibly be used in Australia.

viii. PCB-JEM (Rocheleau et al, 2011): this is a JEM that involves PCB exposure in the USA.

ix. Berylium-JEM (Couch et al, 2011): this is an industry specific JEM constructed for the assessment of Berylium exposure in the USA.

x. CANJEM (Siemiatycki, 2011): this is a Canadian JEM currently under construction which will be used to investigate Brain cancer in the Canadian population. It may be applicable to Australia.

These are only a selection of the many JEMs that have been developed since 2002 and indicates the range of exposures for which JEMs may be applied. The development of these JEMs have been expensive and paid by research funding, but their applicability will in time make them cost-effective.

Funding in Australia

Funding for the development of JEMs in most countries is usually provided by government research funding bodies. In Australia, the National Health and Medical Research Council (NHMRC) and the Australian Council for Research (ARC) are the primary funding bodies for research. In recent years, both have been approached for funding for an Australian JEM, but funding has not been forthcoming. Monash University and the NSW Dust Diseases Board have provided funding for small scale job and task exposure matrices for ionizing radiation (Karipidis et al, 2008) and asbestos (Hyland et al, 2010). However, private funding organizations that have been approached have been of the opinion that since such a project will benefit the community across a wide range of disciples, they are not the appropriate organizations to fund such a project.

OccIDEAS and JEMs

Besides the development of JEMs internationally in recent years, there has been some exciting developments in the area of the expert method of occupational exposure assessment. The main one being the development in Australia of the OccIDEAS platform (Fritschi et al, 2009). OccIDEAS is an expert assessment method and is considered the most accurate way to attribute occupational exposure in case-control studies, but it is a time consuming and expensive process. The novel aspects of OccIDEAS however are: combining all steps in the assessment into one software package; enmeshing the process of assessment into the development of questionnaires; selecting the exposure(s) of interest; specifying rules for exposure assignment; allowing manual or automatic assessments; ensuring that circumstances in which exposure is possible for an individual are highlighted for review; providing reports to ensure consistency of assessment. OccIDEAS and expert assessment methods are considered superior to JEMs in methodology (by reducing misclassification), but are not as versatile and more resource intensive. It is unlikely expert assessment methods will ever be more popular than JEMs. The development of OccIDEAS in Australia may have been a barrier to the development of an Australian JEM, since the limited funding in this area may have been diverted to the development of OccIDEAS in preference to an Australian JEM.

Discussion

Since 2002 we have seen little progress in Australia in the development of general population or industry JEMs. This may be due to a number of reasons, but the most likely are lack of funding, privacy concerns, lack of expertise and lack of a perception of need for a JEM. The first of these barriers, lack of funding is understandable in the context of the relatively limited research funding that the Australian government and private organizations provide on an annual basis. The author estimates that to construct a general population JEM for Australia, at least $500,000 would be required in funding. For a project that will not realize benefits for at least 5 years, this is a relatively significant amount of research funding.

A significant barrier to overcome in Australia for the construction of a JEM is the ascertainment of occupational exposure data. In Australia, unlike Finland, over 70% of exposure data remains the property of private industry or occupational and environmental consultants. In Finland, 90% of hygiene data is collected by the Finnish Institute of Occupational Health (FIOH). Limited data which Monash University collected from the VIEW study indicated that only a minority of private industry would be willing to provide occupational exposure data. The principal reason for the lack of provision of occupational exposure data is privacy considerations. This is unfortunate, since JEMs incorporate data in an anonymous fashion and so fears of identification of individuals or specific companies are unfounded. The third barrier to the construction of a JEM is the lack of expertise in Australia. There are only two or three research organizations in Australia that would be capable of constructing a general population JEM. Expertise is required in both Occupational Hygiene and Epidemiology. This scenario may improve in the next decade as expertise comes on line, then the likelihood for an Australian JEM will increase.

The fourth barrier to the development of a JEM in Australia is the lack of a perceived need for one. This is unfortunate as every year in Australia there emerge new cancer, respiratory studies and government reports that could benefit from an Australian JEM. The author has been involved in three cancer studies in the past 18 months that would have benefited from an Australian JEM. Instead, they have or will use overseas JEMs that are suboptimal for the Australian setting. Finally, as to the question: When will Australia have it's own JEM? There is no possibility of an AusJEM being constructed for at least 3 years and if one is published in the next decade then we have done well.

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Problems & Practical Applications of Control Banding in the Developed and Developing Worlds

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Abstract

Control banding is a risk-assessment procedure originally designed for small-to-medium enterprises in the developed world to decide upon appropriate controls for hazardous chemical substances. The approach has global popularity, particularly in the developing world, where IH resources are scarce. COSHH Essentials is the basis for many control banding models. The inherent simplifications and consequent flexibility in the elements of control banding represent an attraction for non-expert users, yet at the same time an obstacle to acceptance by regulatory regimes in the developed world, as employers must still demonstrate due diligence by ensuring that controls are appropriate, adequately designed, properly installed and routinely maintained and monitored. Control banding supplements the traditional IH approach and should never replace IH judgment; it is eminently suited to situations where the hazards are not clearly defined. This presentation will describe applications and challenges for control banding.

Keywords

Control banding, toolkits, COSHH Essentials, Stoffenmanager, SMEs, risk assessment, validation, hazard communication, nanomaterials

Introduction

Occupational health professionals face the problem of how to facilitate compliance with regulations concerning exposure to chemicals. Large companies have the personnel and financial resources to achieve compliance but operators of small-to-medium enterprises (SMEs) – the predominant demographic of global workplace distribution – traditionally have claimed difficulty in understanding, let alone complying with, legislation (Topping 1998; Muchnick-Baku and Warshaw, 1998; AIHA, 2007). In particular, small users of chemicals appear to have a very limited knowledge of occupational exposure limits (OELs) and a limited capacity to obtain professional expertise. Consequently, SMEs tend to lack effective controls; employers would, however, welcome the availability of practical control solutions presented in clear terms. The selection of appropriate controls for substances without OELs presents a further technical challenge to SMEs. An issue for developing nations is whether effective controls could be implemented without placing a strict reliance upon the traditional occupational hygiene requirements of air sampling and analysis, recognizing that such resources tend to be extremely limited. Perhaps in recognition of these issues, there has been a general shift from prescriptive regulations to models that require employers to conduct risk assessments as an initial step towards control strategies.

Control Banding is an outcome of this trend. Originally pioneered by the pharmaceutical industry (Farris et al., 2006), it has reached the industrial hygiene mainstream chiefly through a simplified model – COSHH Essentials – developed by the British Health & Safety Executive (HSE, 1999). Control banding is an opportune development, particularly for the developing world, and has experienced a favorable global reception. The widening interest in control banding can be gauged by the growing literature describing qualitative risk assessment and management strategies. Six international workshops, the active consideration or promotion by organizations such as AIHA, ACGIH, IOHA, NIOSH, ILO and WHO, and model development by several European and Asian countries testify that the concept merits the professional attention of occupational hygienists. Occupational hygienists practise predominantly in the developed world and the challenge there is to provide simple, practical advice that at the same time complies with regulatory requirements.

Exposure Assessment, OELs and Control Banding

Exposure assessment has a central role in industrial hygiene program management and compliance with regulatory exposure limits has always been a major focus for industrial hygienists. Chemical availability and usage is vast: there are 80,000 or so chemicals on the Toxic Substances Control Act inventory, with about 3,000 high production volume chemicals used in quantities of over a million lbs/year. However, only about 700 substances have Threshold Limit Values (ACGIH, 2011); a further hundred have Workplace Environment Exposure Levels (AIHA, 2007) and there are various additional company guidelines. Thus, only about 1% of chemicals have established exposure limits and, consequently, there is need for a new approach to exposure guidance; control banding is one such approach.

Control Banding and the COSHH Essentials Paradigm

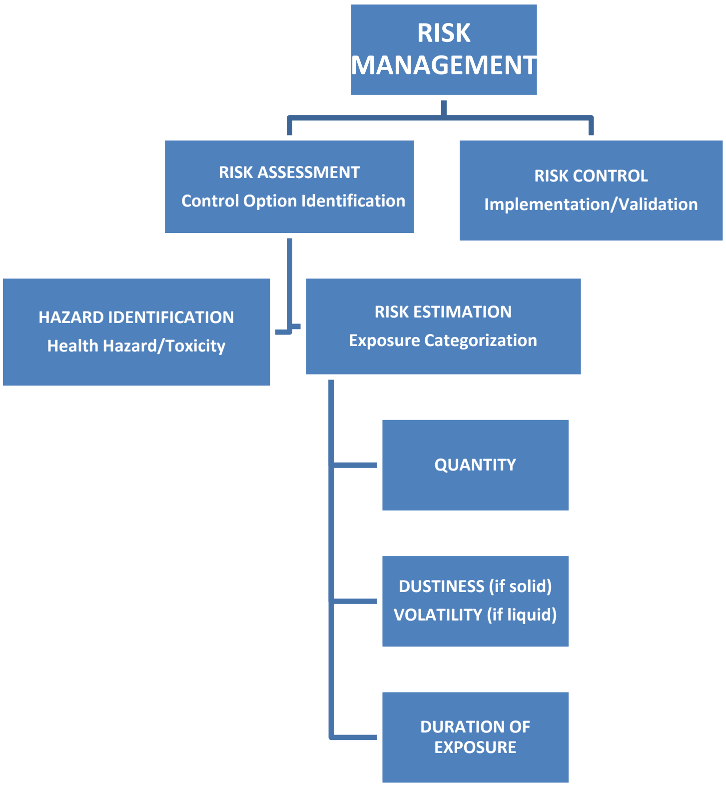
Control Banding is a qualitative or semi-quantitative risk-assessment approach to assessing and managing hazards associated predominantly with chemical exposures in the workplace. The approach simplifies control options. There are only a few (generally 4 or 5) levels of hazard control and it is easier to design a system to control chemical exposure to a concentration range rather than to a specific value, particularly if a general design already exists for agents of similar potency (AIHA, 2007).

The principle of Control Banding is the categorical grouping of similar hazards for managing risk. The approach is eminently suited to the pharmaceutical industry, where production of new, toxic and potent products is routine; although few of such compounds have official OELs, the industry has sufficient professional expertise to develop appropriate controls based on criteria for performance-based exposure limits, criteria which are more extensive than those for the average industrial chemicals. For example, classification criteria for pharmaceuticals include potency, acute warning properties, onset of warning properties, need for medical intervention, medical treatability, cumulative effects, reversibility and quality of life, as well as the usual severity of acute or chronic toxicity effects (Farris et al., 2006). For the pharmaceutical industry, the success of the approach stems from the extensive professional input; for general industry – for SMEs and the developing world in particular – a much simpler model is desirable and the COSHH Essentials model has attracted global attention.

In this model, control measures for chemicals are grouped into bands generated from a simplified risk assessment with parameters representing health hazard and exposure potential. Schematically,

HEALTH + HAZARD	EXPOSURE POTENTIAL	➔ GENERIC RISK ASSESSMENT	➔ CONTROL STRATEGY
Bands A-E based on R-phrases	Quantity Dustiness/Volatility Duration	Empirical risk matrix	General approach & specific guidance sheets

Or, in risk management terms,



According to Money (2003), control banding core principles include: comprehensibility (through simplicity) for users and affected parties; easy accessibility of information; provision of output in a transparent, consistent fashion; delivery of practical advice, acceptable across interest groups; stakeholder confidence in the approach and the output provided; flexibility towards changing industry patterns and evolving regulatory demands. The COSHH Essentials approach embodies these principles, making it attractive to operators in the developing world and to SMEs globally.

Control Banding: Validation, Limitations & Problems

The credibility of any model depends upon validation. Generic models tend to engender a low level of confidence because of the artificial limit on complexity needed to produce simple programs applicable to the widest range of users, not to be under-protective, nor be highly over-precautionary – reflecting adversely on credibility and deterring promotion and implementation.

According to Tischer et al. (2003), the assumptions in the components of the model should be plausible and consistent; predicted and performance-based results should correspond and the model should be appropriately applied by intended client group.

Internal (Concept) Validation

An inherent limitation of control banding is that the identification of control options represents only the risk *assessment* portion of Risk Management (see previous schematic) and is therefore only part of the Industrial Hygiene approach: there remains the consideration of the hierarchy of controls and then crucial step of risk control. Even in the original seminal publications regarding COSHH Essentials there was explicitly no intent for control banding to supplant the critical role of traditional industrial hygiene, or to undermine the role of OELs, in the overall process of contaminant control (Russell et al., 1998). In allowing non-expert management personnel to focus on control strategies, control banding provides just the first step along the road to controlling worker exposure.

SMEs in the industrialized world might desire to avoid the need and expense of professional occupational hygiene expertise but the reality for all employers is that professional review will still be necessary to ensure that controls are appropriate, adequately designed, properly installed and demonstrably effective (by exposure monitoring) in controlling worker exposure, particularly if OELs are applicable; also, it must be demonstrated that control systems are routinely maintained and tested, and that protective equipment and training are functioning. With mandatory due diligence, best practices and liability concerns in mind, professional advice will be crucial in the design, implementation and verification of controls, where there are significant financial outlays and the potential for serious health consequences. Currently and for the foreseeable future, regulatory authorities are unlikely to accept that uninformed adoption of any particular control banding scheme would automatically confer comprehensive compliance.

Although there are significant and substantial assumptions in the COSHH Essentials approach, arguably the success or usefulness in implementation of what is really only a tool, will ultimately depend on its conformity with professional experience, irrespective of the many assumptions inherent in its derivation. There are various alternatives for the number of toxicity bands (Sullivan and Malik, 2007); the non-standardization of classification and risk phrases, together with inaccuracies in supplier information disclosed on material safety data sheets, preclude precision in toxicity banding. In order to encompass Quantity in industrial production, an inordinately large range – several orders of magnitude e.g. grams to tonnes – is required; exposure, however, is somewhat independent of production volume, and very much associated with factors such as agent surface area, task, process design, room configuration and work practices, few of which are captured by control banding models and consequently make such models unreliable (Kromhout, 2002). The delineations in Dustiness and Volatility are arbitrary. Although there are several quantitative methods for determining a dustiness index, the delineations in COSHH Essentials are vague and subjective, in a continuum of particles with no clear-cut boundaries (Tischer et al., 2003). Dustiness criteria rely on visibility but toxic solids of small particle size could be virtually invisible at concentration hazardous to health; the issue of inhalability versus respirability is also not addressed. It was considered that uncertainties associated with the allocation of the higher dustiness bands do not impact the model outcome (Tischer et al., 2003).

Volatility of mixture components is more complex than for single substances and COSHH Essentials adds an additional feature of operating temperature; as this refinement would affect liquids with borderline volatility ratings, the model must already be robust enough to accommodate minor deviations such that the same control measure will still apply to substances with similar volatilities but with arbitrarily different volatility ratings. Although the uncertainties related to the allocation to volatility bands were considered as low, it was recognized that vapour pressure in mixtures is complex but is treated as simplistic in the core model (Tischer et al., 2003).

Task Duration and Frequency receive minimal weighting in control selection; the use of respiratory protection is not considered in the model although it might be the most practical option for brief or infrequent exposures.

There are alternatives for the number of control levels: COSHH Essentials has four (cf. the four biosafety levels for infectious agents) and pharmaceutical models have up to six, but separate levels for highly toxic materials are essentially only a refinement of "Containment", after "General Ventilation" and "Engineering Control". "Specialist Advice" seems redundant as a distinct control strategy: design, implementation and verification of controls – particularly where there is almost certainly the potential for serious health consequences – are unlikely to be undertaken *without* professional advice. Carcinogens and sensitizers such as asbestos, cadmium compounds, silica, insoluble chromium(VI) compounds, di-isocyanates, formaldehyde and glutaraldehyde are allocated to the "Special" category but industrial hygienists would consider "Engineering Control" applicable.

Risk assessment is intentionally designed for practical results, with incorporation of pragmatic adjustments to align the matrix outputs in conformity with reality, matrix design and size being tailored to suit specific needs (CCOHS, 2011).

External (Performance) Validation

Comparing data derived from the model and measurements from independent sources is essential for validation. Such data is sparse. In order to design efficient and effective exposure control strategies, the inherent variability in workplace exposure must be better understood (Kromhout, 2002), otherwise the implementation of deterministic exposure models is premature, and potentially injurious if under-protective. Originators of the COSHH Essentials model contended that it represented a cautious approach to worker exposure (Russell et al., 1998). From the (admittedly) limited data available (and excluding highly toxic substances), coupled with extensive peer review, Maidment (1998) and Brooke (1998) concluded that the identified control strategy in "almost all circumstances…controls the risk to health to a level at which that risk is minimal or non-existent" and is "agreement with or more stringent than [the target ranges expected for] expertly-derived health-based OELs." The results from German field studies (Tischer et al., 2003; 2009) indicated that for the limited (medium-scale) scenarios examined, exposures mostly fell in the predicted ranges; scenarios involving low or high quantities of low or high volatility/dustiness were not examined. Findings in recent evaluations for a small printing plant (Lee et al., 2009) and a medium-sized paint producer (Lee et al., 2011) suggested that the COSHH Essentials model worked reasonably well. Also, studies at a Japanese petroleum company demonstrated that control banding provided "safe-sided judgment" comparable with in-place professionally-developed control technologies (Hashimoto et al., 2007). However, for bag filling and vapour degreasing operations, measurements indicated significant deficiencies in the model for both operations (Jones and Nicas, 2006a). Problems were noted for the "identification of appropriate toxicological information…mistaken identification of tasks in need of additional control technologies (over-controlled errors) and inadequate efficacy of control technologies (under-controlled errors)." Validation studies often involve considerations of margins of safety. There is no standardized approach: results vary considerably, depending on where the focus is directed in the target range.

The American Conference of Governmental and Industrial Hygienists assessed the control banding approach, extensively examining the main components: Hazard Group Prediction Model, Exposure Limit Prediction Model, Exposure Prediction Model, and Predefined Control Strategies (ACGIH, 2008). Although not dismissive of control banding, the report cautioned that the approach as it currently exists, requires considerable refinement; it also emphasized the admonition against premature, uncritical adoption and restated the essential role for health professionals in the process, and the recommendation that the approach provide a preliminary assessment as part of a more formal exposure assessment and control program. In the developing world, however, there is an imperative need for urgent action.

Control Banding and the Developing World

The World Health Organization has estimated that over 90% (about 2.7 billion) of workers globally do not have access to occupational health services (WHO, 1995). Because of the exposure to potentially serious occupational hazards, there is a dire need for practical controls but many obstacles hinder implementation of controls: insufficient awareness, education and political will; inadequate technical and financial resources; inadequate preventive approaches; deficiencies in, and lack of access to, information (WHO, 2004). Controls need not always be financially or technically prohibitive for, as we are reminded (Grantham, 2007), new cases of occupational ill health occur because of failure to implement known and often simple control techniques. Of course, these obstacles are not exclusive to the developing world but are certainly more pronounced there.

The immediacy for controls has encouraged the development of control banding in the developing world and, in particular, the toolkits to implement the process, without waiting for scientific certainty in all components of the process. The wide dissemination of practical control solutions is essential, to have a positive impact on worker health globally; continued international development of databanks such as Solbase (Swuste et al., 2003) is needed. The current Workplace Health Without Borders movement has exposure-reduction goals, and control banding will likely be a major focus of responses (Pilger, 2011). The International Chemical Control Toolkit (Jackson, 2002; ILO, 2006) was developed by IOHA for the ILO, WHO and the UN Environmental Programme. International collaboration strengthens national capabilities for health hazard control and worker protection, and shared knowledge and experience minimize duplication of efforts and the consequent waste of technical and financial resources.

The ICC Toolkit contains shortcuts addressing pesticides and about a dozen common solvents but the general approach is largely based on COSHH Essentials, with additions relating to skin and respiratory protection, as well as safety (fire and explosion) and environmental issues. The Toolkit was seen to perform slightly better – affording better protection – than the COSHH Essentials model, probably because the toxicity band ratings are more accurate for the former, being based on the Globally Harmonized System of Classification and Labeling of Chemicals (GHS) rather than the European Union (EU) classification system (Jones and Nicas, 2006b). Both models, however, predicted exposures comparable with contemporary OELs.

Control Banding in the Industrialized World

The prime focus of control banding in the industrialized world continues to be SMEs, for whom control banding – specifically the COSHH Essentials model – was originally developed. Ideally, SMEs would like to control chemicals, meeting all health, safety and environmental regulatory requirements using the simplest, most practical and cost-effective means.

Regulatory authorities typically have difficulty fulfilling their mandate to communicate with, and disseminate information to, SMEs. Control banding seems an attractive vehicle for this purpose and, while mindful of its limitations, government agencies generally support development of the concept. In Europe and South-east Asia, there are numerous examples (Zalk and Nelson, 2008; NIOSH, 2009). Of these, the Dutch 'Stoffenmanager' (Marquart et al., 2008) is noteworthy. It addresses an omission of the COSHH Essentials model, by including critical exposure-determining factors such as task, building and ventilation characteristics; being web-based also, its availability is maximized.

The extent to which regulatory authorities will embrace control banding will depend significantly on the degree to which validation of qualitative risk assessment and management strategies, tools, and control-focused solutions can be demonstrated.

The U.S. Situation

The acceptance of Control Banding will probably face its greatest challenge in the U.S., where there are extensive legal requirements for – and protracted legal challenges of – legislation relating to workplace controls. AIHA, ACGIH, NIOSH and OSHA are cognizant of the limitations of control banding and see merit in the approach but the degree to which official acceptance is realized will be contingent upon the outcome of continuing validation efforts. Control banding will be seen as part of a comprehensive safety and health program; its use will not alleviate the need for environmental monitoring and industrial hygiene expertise. With increased awareness and standardization of the concept, the private sector, including SMEs, will more readily adopt control banding strategies on a voluntary basis, for task-specific, hazard-control guidance. To capture and retain Industry's attention, the approach will have to be recognized as cost-effective and practical, by the dissemination of favorable cost-benefit analyses and effective solutions; Industry buy-in is essential for regulatory acceptance.

Broader Application of Control Banding

The drivers for the development and evolution of control banding continue currently. In the developing nanotechnology industry, there are numerous obstacles to overcome. For example, there is little toxicological information, together with a lack of consensus on a relevant index of exposure and consequent sampling methodology. There are parallels with the pharmaceutical industry, concerning the production of new and potentially toxic products without OELs. As with the latter, the control banding approach suggests promise (Paik et al., 2008) and is considered by a number of countries (Zalk and Paik, 2010), including Canada, Australia (Safe Work Australia 2010), the Netherlands – Stoffenmanager Nano (Fransman et al., 2011) – and South Korea.

The procedure involves a 4x4 Severity/Probability risk matrix with four risk levels. Arbitrary, weighting values are given for Severity parameters to account for the major factors suggested by the literature as determining nanomaterial toxicity: surface area, particle shape and diameter, solubility and, for both nanomaterials and parent substances, carcinogenicity, reproductive toxicity, mutagenicity and dermal toxicity. Probability parameters include those of COSHH Essentials, and the number of employees in the representative group. The overall scores for Severity and Probability are determined by summation. The application to five operations was given; controls derived from the model were consistent with those already implemented on the basis of professional judgment. The model is dynamic, allowing for changes based on progressive refinement of the determinant factors.

Other Applications

Publications of the AIHA Control Banding Working Group (AIHA, 2007) and of NIOSH (2009) list examples of actual and potential application of the control banding approach, to such diverse topics as: silica; noise; mould; beryllium; asthmagens; concentrated flavourings; IDLH situations; indoor air quality in damp buildings; ergonomics; safety – injury prevention management in the common professions; high-level disinfectants (glutaraldehyde) in health care. Control guidance sheets for Silica Essentials (HSE, 2011) have been developed for quarries, slateworks, brick and tile making, ceramics, construction, foundries and stonemasons; evaluations are being carried out in Africa and Latin America. Although the application of control banding to ergonomics has been the subject at most International Control Banding Workshops, with involvement and interest of the International Ergonomics Association, a practical toolkit has not yet been developed.

Specific available practical examples of control banding application are not widely disseminated. The HSE has control guidance sheets for about twenty applications, including printers: the printing industry in Australia is a current user (Safe Work Australia 2009). Detailed description is given of the risk assessment tool successfully used by Hallmark Cards, Inc. (AIHA, 2007), a multinational leader in the personal expression/greetings industry; in the limited number of exposure scenarios evaluated with this tool, it has routinely confirmed exposure strategies recommended by company industrial hygienists.

Impact of the Globally Harmonized System of Classification and Labeling of Chemicals (GHS)

Supplier-produced hazcom information can be unreliable and, for the development, promotion and acceptance of control banding, it is important that product classifications and hazard statements be accurate and consistent, as well as standardized and updatable. Through the GHS, and centralized data repositories, global consistency is becoming possible, and the GHS is receiving International acceptance. The EU classification for acute toxicity alone contains almost one-quarter misclassifications in 992 substances, according to Rudén and Hansson (2003). The better performance of the International Toolkit relative to COSHH Essentials was in part linked to the toxicity ratings for the Toolkit being based on the GHS classifications rather than the EU system (Jones and Nicas, 2006b).

Summary

Control banding strategies for assessing and controlling occupational hazards have global appeal – particularly in the developing world – and are here to stay. Control banding is a potentially valuable tool for risk management of chemical agents, chemicals lacking an OEL (such as nanomaterials) and potentially, non-chemical hazards. Control banding is intended to supplement traditional occupation hygiene as the first step of a comprehensive safety and health program. It is unlikely to be viewed by regulatory authorities in the industrialized world as a substitute for OELs, nor will its adoption be considered to confer automatic compliance with health & safety legislation; compliance will still need to be demonstrated by employers.

There has been over a decade of validation studies directed at control banding. Much of it is positive despite the obvious limitations, perhaps not unexpectedly since the control options matrix array is based on professional experience in order to produce a realistic outcome. Data and validation scenarios are limited; the GHS will provide the opportunity to place toxicity ratings on a firmer footing; considerably more validation is needed before whole-hearted Government buy-in. Practical applications are poorly disseminated; for Industry buy-in, there needs to be more demonstration of practicality, perhaps through international co-operation in solutions databases. Meanwhile, control guidance for specific tasks and industrial sectors continues to be developed and control banding strategies will continue to provide hazard control guidance for SMEs.

In the medium term, control banding strategies can be expected to be more readily adopted in the developing world, owing to the urgency in providing some degree of reasonable control where little or none currently exists, and where professional expertise is sparse. The developed world can afford to – and must – await more definitive validation.

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Occupational Respiratory Health Surveillance at Minara Resources, Murrin Murrin Mine Site

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Abstract

A longitudinal study was conducted to ascertain the prevalence of respiratory symptoms and lung function of employees at the Murrin Murrin Operation. The lung function parameters of the study group, corrected for age and height were compared using linear regression analysis with both a control group and predicted normal values. Lung function data were analysed to determine whether there was an effect due to the area worked, and the employee's length of service. Repeat lung function tests were conducted on a sample of the original study group approximately two years after the initial study and statistically analysed to determine whether there was an effect on lung function over this time period. In addition, lung function tests were conducted for a cohort of refinery workers at the start and end of their two-week work period to determine whether there was a before-and-after effect due to their working conditions.

Noise Exposures and Risk of Hearing Loss in Fitness Gyms

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Keywords

Fitness; hearing loss; noise; aerobics

Abstract

Gyms play music during fitness classes. However, noise exposures and risks of hearing loss in fitness gyms have not been systematically investigated. In this study noise exposures of fitness instructors and their clientele were assessed.

Equivalent continuous sound levels (Leqs) for the duration of the class and during warm up, the middle and cool down periods, were measured. Selected instructors were assessed with audiometry.

Noise levels during fitness classes typically exceeded 85dBA and frequently exceeded 90dBA. The loudness of the music was greater for high impact/high energy and circuit classes. It was also louder during warm up and the middle of the class compared with cool down. The audiometry revealed hearing loss in some instructors.

These findings have implications for regulating the loudness of music in fitness gyms and for education and training of instructors in the risks of hearing loss from excess noise.

Introduction

In May 2010 Safe Work Australia held a symposium focussed on effective prevention of hazardous occupational noise (Safe Work Australia, 2010). The symposium also highlighted noise exposure in children using personal music devices (Leishman, 2010). A risk of hearing loss associated with loud music has been recognised and a number of studies have demonstrated hearing loss in orchestral and rock band musicians, patrons and workers at entertainment venues playing live or recorded music (Drake-Lee, 1992; Gunderson et al, 1997; Phillips et al, 2010; Vogel et al, 2010; Zhao et al, 2011). In addition there have been a number of studies that have explored hearing loss in adolescents and young adults associated with listening to personal music devices (Fligor & Clarke Cox, 2004; Leishman 2010; Vogel et al, 2011).

Over the last decade aspects of noise and hearing in fitness gyms have been investigated Findings have been variable but noise exposures have averaged well above 85dBA and frequently above 90dBA in aerobics classes (Nassar, 2001; Torre & Howell, 2008; Yaremchuk & Kaczor, 1999). Some studies have indicated temporary threshold shifts in fitness class participants (Nassar, 2001; Torre & Howell, 2008; Wilson & Herbstein 2003).

Exposure to music in a gym class is generally not viewed as unwanted sound that can be harmful to health. Fitness gyms promote fitness – and that is generally assumed to be healthy. The ‘Fitsound’ study was initiated some years ago to profile noise levels associated with fitness classes in typical commercial gyms, to attempt to characterise potential exposures to noise from all sources (fitness classes, paid work and entertainment) and to explore the perceptions of and motivations for playing music loud. In addition audiometric assessments of hearing in instructors were conducted to see if there was any indication of threshold shift. The objectives were to:

- Identify if instructing or participating in fitness classes presented a risk of noise-induced hearing loss (NIHL);
- Identify reasons for selecting the loudness of the music played and perceptions of its impact on participants;

- Identify if there were any self –reported effects on hearing associated with the conduct of fitness classes;
- Identify if instructors and/or clientele were typically also exposed to other sources of noise, through other work or recreational activities.

The Safe Work Australia 'Getting Heard' symposium (2010) provided an impetus to review the 'Fitsound' data, with a view to comparing it with current conditions. The National Acoustic Laboratory is currently assessing noise and hearing in fitness gyms. The intention is to compare current data with the 'Fitsound' data, to identify if changes in the noise and hearing environments of fitness gyms have occurred.

The 'Fitsound' data reported here were collected at the end of 1997 and the beginning of 1998. The profile of noise levels associated with fitness classes and the instructor audiometric data have been analysed. Analysis of questionnaire responses pertaining to instructor and client perceptions of loudness, motivation for turning up the volume, other sources of exposure to noise and general hearing health, is still ongoing.

Methods

Two large commercial gyms located in different postcodes in the mid-North coast of New South Wales were selected for the study. Permission was obtained from the management of the gyms and from the instructors to survey noise levels during selected classes, to conduct audiometry and to distribute questionnaires to both instructors and clients.

Each gym conducted fitness classes at a range of times throughout the day, the busiest time being from 4-7pm on weekdays. Classes at all times of day were assessed, but the majority were in the busy late afternoon/early evening time. Classes that were assessed were coded as follows:

- Power/high energy/high impact
- Low impact and body shape
- Fat burner
- Step
- Pump
- Cross-training
- Light and low – for older participants
- Circuit classes
- Some recordings were made of each type of class.
- Measuring Noise Levels

Prior to commencing recording, all noise meters were checked for calibration, using a Bruel and Kjaer portable calibrator, type 4230. Before the class started, the instructor was informed of the requirements for conducting personal noise exposure assessment. A Larson Davies Personal Exposure Meter (PEM), type LD720 was used to assess instructor noise exposure. The microphone was positioned on the shoulder and the meter on the belt. The assembly was checked to ensure the microphone would not get knocked and would not interfere with instructing. The PEM was turned on at the beginning of the fitness class and turned off when the instructor signalled that the class was finished. The duration of exposure in minutes, the equivalent continuous sound pressure level (Leq), maximum and minimum sound pressure level (SPL) all in decibels 'A' weighted (dBA) and the unweighted peak in decibels (dB) were recorded.

In addition to recording the SPL at the instructor ear, the researcher recorded the same parameters of duration, Leq, maximum and minimum SPL in dBA and the unweighted peak, using a hand-held Bruel & Kjaer precision sound level meter, type 2231. The researcher was located in the client area and moved around during the class to simulate client activity. The microphone was held out from the body and at head height. In addition, during the class the same noise meter was used to record spot SPLs in the four corners and, where possible, the centre of the client exercise studio. The nature of the fitness exercises sometimes made it impractical or unsafe to attempt to get a recording in the centre of the studio. The spot measures were taken at three separate times during the class, during warm-up, the middle of the class and during cool-down.

Audiometry

Suitable times for conducting audiograms were negotiated with consenting fitness instructors. They were asked to present for an audiogram after a period of quiet, ie, not immediately after conducting a class. In order to have flexibility for audiometric testing, it was not possible to fix a specific minimum time of quiet or to have a set location with an audiometric sound proof booth. Testing took place in a range of venues, including home environments and personal office spaces. Any specific interferences or unusual circumstances were noted on the audiometric record.

The testing used a manual Welch Allyn AM232 audiometer which could deliver pure tones through head phones to each ear separately. The procedure was explained and the subject permitted some practice and familiarisation before the test proper commenced. Pure tones of 250, 500, 1000, 2000, 3000, 4000, 6000 and 8000 Hertz (Hz) were then presented to each ear separately. For each frequency the intensity of sound was increased in 5dB steps, starting at 10dB below the 'threshold' identified in the practice session. Each presentation was of 2 seconds duration. The subject signalled when the sound could just be heard and the threshold for each frequency was manually recorded on a chart after three presentations.

The thresholds from all audiograms were tabulated with the questionnaire responses and summarised. Data were excluded where there was clear interference from outside noise sources, or if a pre-existing hearing impairment was reported.

Results

Noise Exposures

Noise exposures and SPLs were assessed for a total of 60 fitness classes. The distribution of class types assessed in the two fitness studios is shown in Table 1. Circuit classes (type 8) were conducted more frequently at both studios and were therefore assessed on more occasions. Power/high energy/high impact (type 1) classes were only held at studio 1, whereas cross-training (type 6) classes were only held at studio 2. However, these two class types were both high impact and of a similar degree of intensity.

CLASS TYPE	1	2	3	4	5	6	7	8	TOTAL
STUDIO 1	2	3	3	3	4	0	2	11	28
STUDIO 2	0	3	3	6	4	3	1	12	32
COMBINED	2	6	6	9	8	3	3	23	60

TABLE 1: Distribution of fitness class types assessed for noise exposure

The summarised noise exposure data for instructor and researcher are presented in Table 2. The average class duration was 51 minutes at studio 1 and 52 minutes at studio 2.

The mean and median values were generally very close together for the Leq, maximum, minimum and linear peak SPL, indicating that the data fitted a normal distribution. 57.9% of all instructor and 46.6% of all researcher Leqs were equal to or >90dBA. Only 3.5% of instructor and 5.2% of researcher Leqs were <85dBA. When data from both studios were combined, the instructor Leq mean was 90.7dBA, the median 90.8dBA and the range 84.0-98.0dBA, and the researcher Leq mean was 89.9dBA, the median 89.7dBA and the range 83.0-95.3dBA.

PARAMETER	STUDIO	CLASS Leq dBA	MAX SPL dBA	MIN SPL dBA	PEAK dB(Lin)
MEAN	1	I: 90.3 R: 89.0	I: 100.4 R: 98.9	I: 67.1 R: 67.1	I: 124 R: 119.0
MEDIAN	1	I: 90.8 R: 88.9	I: 100.0 R: 95.7	I: 68.4 R: 67.5	I: 125.7 R: 119.8
RANGE	1	I: 88.1-94.5 R: 83.0-94.5	I: 91-108.6 R: 90.3-111.2	I: 54-75.1 R: 55.3-74.7	I: 107.7-125.7 R: 109.6-125.4
MEAN	2	I: 91.0 R: 90.7	I: 101.6 R: 100.4	I: 62.3 R: 64.4	I: 123.3 R: 116.6
MEDIAN	2	I: 90.7 R: 90.4	I: 100.8 R: 99.9	I: 61.4 R: 64.1	I: 121.8 R: 117.0
RANGE	2	I: 84.8-98.0 R: 85.6-95.3	I: 92.9-116 R: 92.9-107.3	I: 54.2-71.2 R: 56.6-73.5	I: 110.5-137.7 R: 109.6-124.5

TABLE 2: Instructor and Researcher noise exposures

I: Instructor R: Researcher

The mean instructor Leqs were compared for the different class types. The mean Leqs for low impact, fat burner (which includes low impact activities) and light and low beginner classes were in the range of 85.5-88.4dBA, whereas for all other class types the mean exceeded 90dBA and for circuit classes was 92.3dBA.

A student t test was applied to determine if there was a statistically significant difference between instructor and researcher Leq values and between studios, at the p=0.05 level. There was no significant difference between Instructor Leq and Researcher Leq at either studio separately or when combined. There was also no significant difference between the studios for the instructor Leq. However, there was a just significant difference (p= 0.0454) between the studios, when researcher Leqs were compared.

Spot SPL data obtained during warm up, the middle of the class and during cool down, for each studio separately and combined, are summarised in Table 3. The mean and median values for cool down were lower than the corresponding values for warm up and the middle of the class.

PARAMETER	STUDIO	WARM UP dBA	MIDDLE dBA	COOL DOWN dBA
MEAN	1	88	88	83.5
MEDIAN	1	87.5	88	84
RANGE	1	80.5-101	80-102	70.5-93.5
MEAN	2	90	90	87
MEDIAN	2	90	90	87
RANGE	2	80.5-100	80-100	68.5-101.5
MEAN	COMBINED	89	89.5	85
MEDIAN	COMBINED	89	89	85.5
RANGE	COMBINED	80.5-101	80-102	68.5-101.5

TABLE 3: Spot SPL readings during warm up, the middle of the class and cool down

A student t test was applied to determine if there was a statistically significant difference between spot SPLs during warm up and the middle of the class, between warm up and cool down and between the middle of the class and cool down, at the p=0.05 level. There was no significant difference between SPLs in warm up and the middle of the class at either gym. However, there were highly significant differences between warm up and cool down (p<0.0001 at studio1 and p=0.0004 at studio 2) and between the middle of the class and cool down (p<0.0001 at studio1 and p=0.0003 at studio 2)

Instructor Demographics

11 instructors at studio 1 and 16 instructors at studio 2 completed a questionnaire. 77.8% were female, reflecting the gender distribution of employed instructors. The mean instructor age was 24 years at studio 1 and 26 years at studio 2 and 77.8% of all instructors were aged 20-30 years. The oldest instructor was 39 years.

Audiometry

11 instructors from studio 1 and 8 instructors from studio 2 presented for audiometry. The majority self-reported that they had experienced a preceding period of quiet of at least 12 hours and the minimum reported quiet period was 6 hours. Of the 8 instructors from studio 2, 1 was excluded from analysis because of a pre-existing hearing loss diagnosed in childhood. Two other instructors from studio 2 only completed an audiogram for the right ear. There were therefore 16 bilateral and 2 additional right ear only records available for analysis.

Since audiograms were recorded with variable background noise, a relatively conservative criterion for identifying hearing loss was adopted. The criterion selected was 20 or more decibels increase in the threshold of intensity of sound for each presented frequency of sound. At 250Hz, 7 of 16 subjects met the criterion and demonstrated at least 20 decibels of hearing loss in both left and right ears, with a maximum of 35dB loss. A further 2 subjects just reached the criterion of 20dB of loss in the right ear only. At 500Hz, 3 subjects met the criterion in both ears, with a maximum of 30dB loss and one further subject just met the 20dB criterion in the left ear. No instructors met the criterion for hearing loss at 1000, 2000, 3000 or 4000Hz. However, at 6000Hz 3 of 16 met the criterion in both ears with a maximum loss of 35dB, 3 met the criterion for the left ear only and 4 for the right ear only and at 8000Hz 2 met the criterion in both ears, 2 for the left ear only and 4 for the right ear only.

Of those subjects exceeding the hearing loss criterion at 6000Hz, 1 demonstrated a 'notch' in both ears, 2 others for the left and 1 for the right ear only, whereby hearing loss was greater at 6000Hz than at 8000Hz.

The proportion of instructors showing decrements in hearing at 250, 500, 6000 and 8000Hz was considerably increased if the criterion was 15 rather than 20 decibels of loss. 7 of the 16 bilateral recordings at 6000Hz and 6 at 8000Hz showed more than 15dB of hearing loss in both ears. In addition 3 of the 16 showed a 6000Hz notch in both ears at the 15dB criterion of hearing loss.

Discussion

There was no significant difference between Leqs recorded for the instructor and researcher and no significant difference between the studios, with the exception that the difference between researcher Leqs at the two studios did just reach significance. This may have reflected differences in the positioning of loud speakers and general acoustics of the studios. When the studios were combined, the mean and median instructor Leq exceeded 90dBA and the mean and median researcher Leq was only just below 90dBA (89.9 and 89.7 respectively). These data are comparable to noise levels recorded during fitness classes in previous studies. Torre & Howell (2008) reported a mean noise level of 87.1dBA, Nassar (2001) reported a mean of 89.6dBA and Yaremchuk & Kaczor reported 79% of their readings exceeded 90dBA. These studies did not distinguish type of fitness class and used variable methods for noise exposure assessment. The current study identified that noise levels were typically louder for high impact, advanced and circuit classes and lower for low impact and beginner classes. Spot SPLs were also significantly greater during warm up and the middle of the class when compared with cool down. Preliminary analysis of questionnaire responses has indicated instructors clearly prefer to set the volume higher for high impact and advanced classes and lower for beginner classes and cool down. This adds support to the differences in noise levels recorded for different class types and activities.

The class duration was just over 50 minutes, so the Australian and New Zealand (2005) Noise Standard of $Leq_{8\ hours}$ 85dBA was not exceeded solely on the basis of the fitness class exposure. However, preliminary analysis of questionnaire data has revealed instructors spend on average 10.5 hours instructing or participating in fitness classes per week. The mean and median instructor Leq of >90dBA recorded in this study would therefore approach 85dBA for a 40 hour week. Given approximately three quarters of the instructors also indicated they engaged in additional paid work for an average of 27 hours per week and also attended entertainment music venues, nearly half of them for more than 5 hours a week, it is important that the risk of NIHL takes into account all possible exposures. Noise levels in fitness classes demonstrably contribute to NIHL risks for instructors.

The audiometric data suggested some degree of hearing loss at the low frequencies of 250 and 500Hz and at the high frequencies of 6000 and 8000Hz. This frequency distribution of hearing loss has previously been demonstrated as temporary threshold shift (TTS) in rock musicians (Drake-Lee 1992). The hearing loss was more marked if a criterion of 15dBA hearing loss was adopted, as in Phillips et al (2010). A number of studies have demonstrated maximum hearing loss at 6000Hz, when associated with noise from loud music (Drake-Lee 1992; Phillips et al, 2010). The presence of a notch at 6000Hz in some audiograms further supports the presence of hearing loss related to noise exposure. Most audiograms were completed more than 12 hours after noise exposure. However, it was not possible to determine if hearing loss was all related to TTS, or also to some permanent NIHL.

Conclusions

The noise exposure and audiometric data are supported by the literature and point to a risk of NIHL in fitness class participants. There is a need for better awareness of the effects on hearing of playing music too loud and of better control on the volume of music played in fitness classes.

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Occupational Hygiene in the RAAF - A Perspective on Deployments

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Abstract

There are significant environmental and occupational health hazards associated with military activities and operations. Without recognition and treatment of these hazards, the health of the deployed force can be at significant risk. In the Royal Australian Air Force (RAAF) Environmental Health Officers (ENVH) are responsible for providing basic occupational hygiene services in support of these activities and operations in both the garrison (on base) and deployed settings (exercises and operations). This presentation will highlight some of the health hazards associated when deploying on operations and more importantly some of the issues involved in trying to measure, monitor and implement control strategies for these hazards.

Cyclone YASI from a volunteer's perspective

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Abstract

During February 2011, the NSW State Emergency Service (SES) deployed a number of taskforces to far north Queensland to assist locals with storm damage resulting from tropical cyclone YASI. Taskforce Alpha Charlie deployed from Sydney to Cardwell from February 14th to February 19th 2011.

This paper examines the occupational hygiene factors which affected the members of Taskforce Alpha Charlie and what control strategies were employed to combat these. Facing extremes of heat, humidity, dampness, fatigue, physical and biological hazards and exposure to stressful incidents and distressed individuals were challenges that required significant planning to overcome.

The SES developed and implemented a number of strategies, targeted at pre-deployment, during the operation and then post-deployment to minimise the risks associated with the environment into which the taskforce was sent.

The outcome for the residents of Cardwell was the completion by Taskforce Alpha Charlie of just under 300 storm damage tasks by fit and well NSW SES volunteers.

Introduction

On 12th February 2011, I received a page from my Duty Officer regarding deployment to Far North Queensland to assist with storm damaged premises resulting from Cyclone YASI. 73 SES personnel assembled at Bankstown SES headquarters at 9:30 am on Monday 14th February to begin preparations for deployment to Cairns. At this point, we knew we would fly to Cairns, but we did not yet know our area of operation.

The 73 members of Taskforce Alpha Charlie (TFAC) didn't know each other, and had arrived from across the state, from the Illawarra to Forbes and Parkes, to northern NSW. The purpose of assembling at Bankstown was to allow the taskforce commander to meet us, and to assess our capability for deployment. Capability was assessed across a range of criteria, including health and fitness, SES experience and SES competencies. Following that assessment, which took most of the Monday we were briefed and sent on our way.

Methods

Risk identification

A risk identification process had been undertaken prior to the initial SES deployment to Far North Queensland (FNQ) and a number of issues were identified which required appropriate planning and risk mitigation strategies. These included:

- Communication on the ground in QLD
- Medical infrastructure at our area of operations
- Health and safety issues

Communication

Communication systems were severely disrupted across FNQ as a result of Cyclone Yasi, and it was expected that the communications systems we relied upon would continue to be less than optimal whilst we were operational. This meant that mobile phone reception may be problematic, and radio transmissions may also be less than optimal. Each unit which contributed members to TFAC was required to bring their own portable radios and back up batteries. A battery charging station was to be available at our destination.

Telephone numbers for the taskforce were provided to members so that in the event of an emergency at home, the taskforce could be contacted. Satellite phones were taken as back-up.

ATMs were also expected to remain out of action, so credit card and eftpos transactions were likely to be problematic. Each member of TFAC was advised to bring along a supply of cash, to enable small personal purchases to be made.

Medical infrastructure

Before any members of TFAC were cleared to proceed to Cairns, we underwent a medical assessment. In particular, cardiovascular fitness was assessed. We were going into a hot, humid climate to do heavy manual work. A number of members of TFAC required clearance from their GPs before they were permitted to travel. Some members were excluded if presenting with high blood pressure. Self exclusion was recommended for asthmatics, diabetics, those prone to respiratory conditions and / or susceptible to extreme temperatures. Self exclusion was also recommended for those with restrictive dietary requirements. We were asked to self-declare current or previous psychological injury, including PTSD and its cause. Those whose history of psychological injury for which exposure in Queensland may bring about recurrence were excluded.

The health risk assessment was predicated on there being little or no hospital or GP support and little pharmacy support in our area of operations. Members who used medication were required to bring sufficient supplies for the duration of the deployment, (and then some), in the event that we were delayed in leaving. Members who could not self-manage a medical condition were also excluded.

Health and Safety Issues

Additional risks identified by the forward command team included:

1. Biological contaminants from floodwaters
2. Heat and humidity
3. Contaminated water
4. Damaged utilities, especially electricity
5. Mosquito borne diseases
6. Native wildlife especially cassowaries, spiders, green ants and snakes

As a result of the identification of the above risk factors, a number of controls as identified above were implemented as follows:

- Issues 1 and 3 - TFAC members received voluntary vaccinations for Hepatitis B, mandatory vaccinations for Hepatitis A and a tetanus booster. Bottled water was provided for us.
- Issue 2 - All taskforce members were issued with water bladders (camelpaks), thick socks with good wicking ability,
- Issue 4 – Education and team briefings focused on identification of this particular hazard as part of the routine “Take 5” process used by SES. The electricity company also visited our site daily.

- Issue 5 - Bushman's insect repellent with sunscreen was issued. We also received hand sanitiser, talcum powder, and a small personal first aid kit.
- Issue 6 – Some education regarding identifying wildlife and potential locations was provided.

Upon arrival in Cairns, we were advised that our area of operations was Cardwell, around 185km south of Cairns, and that we would be accommodated at Innisfail, around 90kms south of Cairns, at the Innisfail racecourse.

Basic accommodation was provided at the racecourse, in two large halls. Beds were camp stretchers with a pillow and pillow case, two sheets, a blanket and a towel. One hall was air conditioned, and the other hall had ceiling and pedestal fans for air movement. Showers and toilets were in demountables in the field, and meals were prepared for us onsite by a local charity.

Results

Taskforce Alpha Charlie completed just under 300 jobs. There were 2985 logged jobs completed by all units during the operation, and when our last team left Queensland, there were 120 outstanding.

Unit	Outstanding RFAs	Completed RFAs	Total RFAs
Cardwell	31	637	668
Innisfail	38	778	816
Mission Beach	16	675	691
Tully	35	895	930
Total	120	2985	3105

Discussion

During our deployment the following health and fitness issues were encountered:

Comms Officer Activity

We required a repeater station for our radio communications. The repeater station was located on top of the highest hill in Cardwell, so as to give the best coverage. It ran on generator power, and required refuelling twice per day. The road ended about 200m from the top of the hill, and the last 200m had to be walked. In addition to having to refuel the generator twice daily, the generator and repeater had to be returned to base each evening, once work finished (at around 6pm). That meant three trips up the hill every day.

These tasks could not be dispensed with, and refuelling had to be done at one point each day in the heat of the day. The risk of illness or injury to the Comms officer was reduced by the following means:

- the first and last trip was done as close as possible to the start and end of the day
- where possible two people made the trip
- the Comms officer was required to radio in when he left the truck to start up the hill, and again when he returned to the truck
- fuel was taken up at the start of the day so that the middle trip did not involve carting heavy items up the 200m to the hill top.

The Comms officer reported feeling unwell on one occasion, on around day three of the deployment. He was rested and moved to radio operations for the next day.

Operations Centre

There were 14 people in the Operations Centre team, most of whom were working inside the ops centre for most of the day. The ops centre air conditioning was not working. Cross ventilation was difficult to achieve, and ceiling and pedestal fans were impractical in our less-than-paper-free ops area. It was very warm.

Control measures to prevent heat stress included the following requirements:

- Compulsory outside breaks every hour (it was hot outside but at least there was some breeze, and it occasionally rained)
- Mandatory water on everyone's person, with audits by the Deputy Taskforce Controller of how much had been consumed
- Daily visit by Paramedic who checked temperatures, BP and pulse.
- Where possible, rotation to a field activity on alternative days, for half a day.

Bandanas were also available for wetting and wearing.

Field teams worked in hot, humid, wet and sunny conditions. The risk of heat stress and heat stroke was high. Controls for mitigating this risk included:

- Mandatory water carrying – large eskys filled with ice and water were on every truck – camelpaks were issued to all field personnel
- Iced water was available on return to staging area
- Every fourth bottle of water was supplemented with an electrolyte replacement mix – yum…
- Each field team member was issued with sunscreen and a bandana, and long sleeved shirts were worn.
- Team members were encouraged to get wet when it rained.
- Mandatory stand down in the resting area, with shade, water and snacks on 4:1 work:rest cycle.

One team encountered three brown snakes on one job. There was also a brown snake camped under a large generator at the front of our staging area.

- Education was provided on how best to disturb piled rubble where snakes may be present
- Information on known snake locations was circulated as it came to hand.

One TFAC team member suffered from a gastric illness.

- This team member was quickly isolated from the rest of the deployment once it was determined that he wasn't suffering from heat stress, he was given first aid onsite (IV drip) by the paramedic and then taken to Tully Hospital. On his return to our accommodation later that evening, he was also placed in a segregated area, kept comfortable and looked after by a team leader.
- He was well enough to make the return journey home with the task force.

Mosquitoes

It was mosquito season, and we were in an area where dengue fever had been reported and was being transmitted by mosquitoes. Innisfail experienced an outbreak of dengue fever whilst we were operating in the area. To protect against mosquito bites, each evening at dusk, team leaders ensured that all members applied the Bushman's insect repellent that had been provided for us. This protected against mosquitoes, but was a source of some hazard itself. Application to plastic surfaces (eg sunglasses) had to be minimised (the glasses melted), and similarly, application to the forehead (where glasses may touch) also had to be appropriately managed. We were thorough in applying it to exposed arm and leg areas, the main area of mosquito attack. Hand washing immediately following prevented irritation to more delicate skin areas (eyes in particular).

Injuries

There were two injuries to TFAC members during our deployment. Both resulted from trips; one was a sprained ankle and one was a badly bruised arm which was initially thought to be broken. First aid was administered, and follow up assistance was provided by the Queensland paramedic on-site at Cardwell. A precautionary x-ray of the arm revealed no breaks, and both team members were rotated into ops centre tasks such as radio operation and online data entry functions.

The team was structured so that all ops centre staff were also available for operational duty in the event that an operational team member was injured or ill. This meant that the two injured team members replaced ops centre staff who then became operational.

Psychological injury

Volunteers were asked to self-exclude if they had a history of psychological injury, in particular a previous diagnosis of PTSD, and also if not excluding themselves, to declare any past injury to the medical staff during the assessment process. The team were to be together for six days, and in an area where devastation was widespread, and where residents remained in the area. Conflict, dealing with distressed individuals and the potential for exposure to gruesome sights were the major areas of concern.

- To mitigate against the risk of psychological injury, an SES chaplain was despatched with the team, and lived with us. The chaplain visited all teams on-site, and specifically attended where team members had expressed concerns about resident health and safety.
- There were a number of callouts to residents who were elderly, unable to leave their residences, low on food or unwell. Whilst these jobs were referred to appropriate agencies, the initial attendance and any follow up included the chaplain where possible.

Management

The taskforce commander deployed to FNQ immediately the team was finalised so that he had the opportunity firstly to meet with the Emergency Management QLD (EMQ) Incident Controller and his team in Cairns and also to spend an hour or so in Cardwell with the outgoing taskforce commander getting a briefing from him. That way we had everything in place ready for a walk-up start on the first morning. Likewise the commander returned home later than the rest of the team, which allowed him to brief the incoming (and final) taskforce commander as well as update the EMQ people in Cairns on what had been happening in Cardwell. Both of these overlaps allowed our commander to get and pass on valuable OH&S tips which helped us to keep our people safe.

Daily briefing/debriefing included input from operations team leaders, ops centre staff, logistics team leader, the chaplain and the paramedic where possible. This ensured that teams had as much information about the situation on any day as was possible.

We had a full debrief prior to our departure from Cardwell, after which a handover to the incoming taskforce was given.

Upon return to NSW, medical follow up of team members occurred at the six month point to ensure hepatitis boosters were administered.

Conclusion

A comprehensive risk management process undertaken by the SES ensured that Task Force Alpha Charlie deployed fit and well into an environment where risks were as far as possible eliminated or reduced to as low as reasonably practicable. The focus on selection of appropriate team members, reviewing their mental and physical health status, training and competency and complementing that with a thorough risk assessment of the operating environment produced a top performing team which achieved exceptional results for the community of Cardwell.

Can New Technology Help an Old Issue? Promotion of the Use of Hearing Protection Devices in an Offset Printery

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Abstract

The purpose of this study was to assess the relationship between perceived noise levels and the use of hearing protection devices (HPD's) among offset printing workers; and to use an intervention strategy of education coupled with the use of personal noise level indicators (NLI's) to determine if individuals would modify their behaviour to increase HPD use, given education and instant and visual feedback of their exposure to noise.

An extensive noise survey was conducted to determine actual personal noise exposures during operation of various pieces of equipment, alone and in various combinations.

Baseline observation of HPD use, and worker self reporting via a daily log of their use of HPD's was done prior to "toolbox" training sessions and the introduction of the NLI's.

The observations and self reporting of HPD use were repeated after a period of time using the NLI's in the workplace. A control group of workers were given the toolbox training session but not the NLI's to determine the effect of education alone and to counter the placebo effect of a workplace intervention in a small workforce.

'Listen to the warnings' hearing conservation DVD

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Abstract

In 2006, an internal health and safety audit identified a number of gaps across Rio Tinto's Coastal Operations division in respect to hearing conservation and noise awareness. It was evident that the education of employees and contractors on the risks of noise induced hearing loss (NIHL), prevention of NIHL and how to correctly fit and wear hearing protection was a priority. In 2008, the hearing conservation program was updated to include the production of a DVD entitled "Listen to the warnings". The DVD provides information on the importance of hearing and the impact on your quality of life if you lose it, testimonials from employees who have suffered noise induced hearing loss, the mechanics of the ear including anatomy and physiology, the early warning signs of hearing loss, the risks associated with working in noisy environments and selection and fitting of appropriate hearing protection. A workplace survey was conducted in the form of a questionnaire several months after the release of the DVD to determine whether or not the DVD added value and in particular increased the understanding of noise and hearing conservation awareness. The results showed that the DVD increased the workforce knowledge about noise induced hearing loss and how to correctly fit hearing protection.

Introduction

Excessive noise is a pervasive occupational hazard with many adverse effects, including elevated blood pressure, reduced performance, sleeping difficulties, annoyance and stress, tinnitus, noise-induced hearing loss (NIHL) and temporary threshold shift. Of these, the most serious health effect is NIHL resulting from irreversible damage to the delicate hearing mechanisms of the inner ear. NIHL typically involves the frequency range (pitch) of human voices, and thus interferes with spoken communications.

Adult-onset hearing loss has been described as the "fifteenth most serious health problem" in the world, with profound effects ranging from social isolation and stigmatization of individuals to serious national economic burdens (Smith, 2004). Estimates of the number of people affected worldwide by hearing loss increased from 120 million in 1995 (WHO, 1999; WHO, 2001) to 250 million worldwide in 2004 (Smith, 2004). Much of this impairment may be caused by exposure to noise on the job. The purpose of this study was to estimate the global burden of adult-onset hearing loss resulting from occupational exposure to noise.

Materials and methods

In 2008, the hearing conservation program was updated to include the production of a DVD entitled "Listen to the warnings". A local creative media consultancy specialising in the conceptualisation, writing, production, direction and post-production of interactive DVD, film, multi-media and television productions was consulted. A script was developed which focused on the mechanics of the ear including anatomy and physiology, the early warning signs of hearing loss, the risks associated with working in noisy environments, selection and fitting of appropriate hearing protection, testimonials from employees who have suffered noise induced hearing loss, noise reduction controls and maintenance for exposure controls.

A workplace survey was conducted in the form of a questionnaire a few months after the release of the DVD to determine whether or not the DVD added value and in particular increased the understanding of noise and hearing conservation awareness. The survey comprised of yes or no answers to questions like:

- Has your awareness of NIHL and tinnitus increased?
- Has your awareness of how to fit hearing protection increased?
- Has your knowledge of noise sources that contribute to hearing loss increased?
- Has your knowledge of how the ear works and how it is affected by hearing loss increased?
- Are you more like to wear hearing protection in noisey areas and for noisy tasks?

A follow up survey was conducted mid 2011 which was 3 years after the release of the DVD. This was conducted to determine if the information in relation to NIHL from the DVD was retained by employees. The same questions were raised to compare to the initial survey.

Results

Results from the two surveys were as follows in Figure 1 and 2.

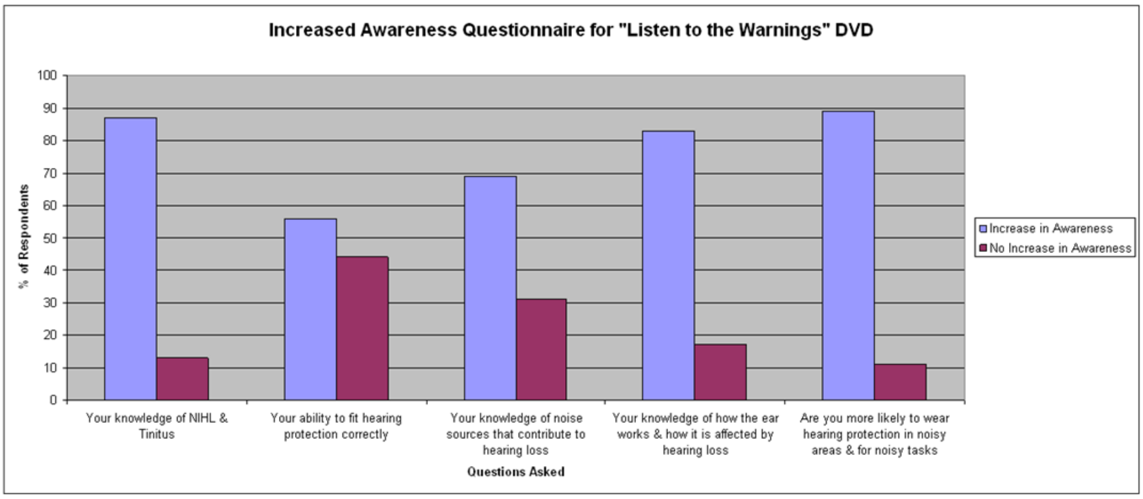

Figure 1. NIHL awareness after watching listen to the warnings DVD in 2008

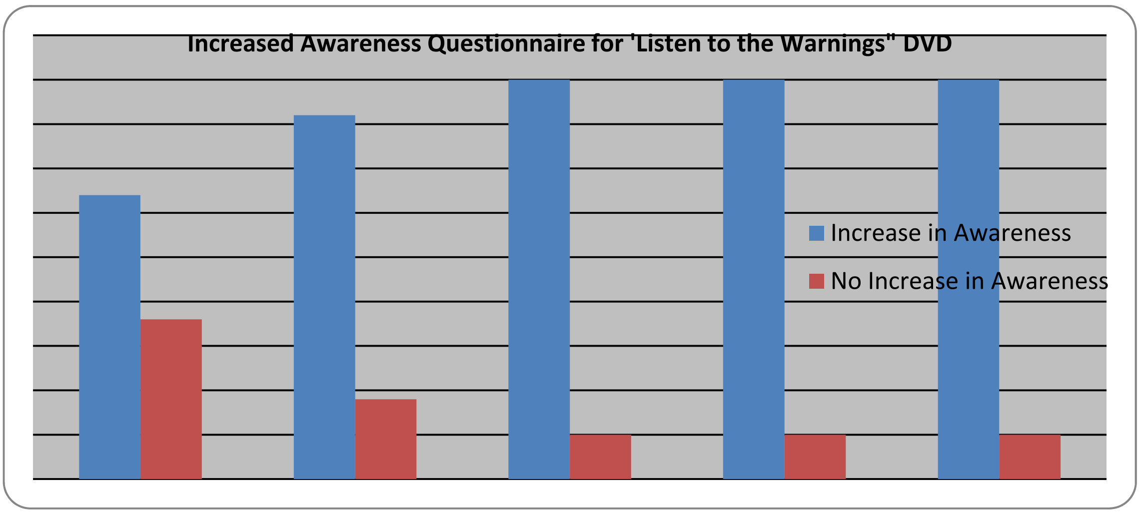

Figure 2. NIHL awareness after watching listen to the warnings DVD in 2011

Discussion

The results from the first survey showed that the DVD increased the workforce knowledge about noise induced hearing loss and how to correctly fit hearing protection. The next survey in 2011 showed that NIHL awareness improved over the 3 years following the DVD release. This result is not unexpected as the DVD is a mandatory qualification which is to be reviewed every year.

Conclusion

The findings show that successfully implementing hearing conservation programs requires commitment and resources, however they are proven to be effective in raising awareness of NIHL. The implementation of such programs in particular a short educational DVD, has resulted in an increased awareness of the physiology of the ear, increased awareness of NIHL, and increased awareness of noise controls enabling workers to take action to prevent hearing loss.

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Development of an Occupational Noise Exposure Reduction Plan for Defence

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Keywords

Occupational Noise, Exposure Reduction

Abstract

A new forward-looking project has been established to develop an Exposure Reduction Plan (ERP) for occupational noise for the Department of Defence. A complete review, analysis and assessment of current occupational noise management practices for all Services and Groups in Defence has been undertaken.

The project's goal of achieving 100% compliance with all relevant Defence occupational hygiene standards will assist Defence in meeting objectives of the current Defence OHS Strategy 2007-12. The evidence based approach, including extensive stakeholder consultation and statistical analysis of large quantities of data, determined deficiencies and gaps in the current Defence system and identified areas where the most significant benefits could be realised.

Project findings, emerging issues and priority areas for future focus are highlighted. Project outcomes included tailored Exposure Reduction Plans, which detailed a range of prioritised high-level strategies and practical control initiatives. Future phases include implementation of the recommended actions across the complex Defence organisation and on-going monitoring, evaluation and continuous improvement.

Introduction

A new project in the area of occupational hygiene and health has been established within Defence to reduce occupational noise exposure. Vipac Engineers & Scientists Ltd (VIPAC) was engaged in 2009 by the Defence Centre for Occupational Health (DCOH) to develop an Exposure Reduction Plan (ERP) for occupational noise across the Whole-of-Defence in Australia [1, 2]. Defence determined the need to go down this path as a means of addressing systemic problems that prevented Defence having an effective noise management program.

Occupational noise has been identified by the DCOH as a significant OHS hazard and one of the aims of the project was to understand the performance, capability and financial impacts of occupational noise across Defence, and how to develop an improved management system.

The ERP project forms part of the implementation of key Defence plans, including the Defence Occupational Medicine and Occupational Hygiene (OMOH) capability and the Defence Occupational Hygiene Plan (DOHP). Development of an ERP for Occupational Noise will assist Defence in meeting Objectives of the Defence OHS Strategy 2007-12 [3].

The ERP for Occupational Noise has been prepared to primarily assist in the achievement of the following outcome objectives (in particular, Objective 4) of the Defence OHS Strategy:

a) Objective 3 – to reduce the frequency and severity of risks to people's health & safety.

b) Objective 4 – to improve the prevention of occupational injury, illness and disease.

c) Objective 5 – to reduce the impact of occupational injury, illness and disease.

The ERP will also assist with achieving other enabling objectives, 6 to 8, that outline aims for the training and support of personnel, a systematic capability for managing hazards in design and planning activities and managing the OHS performance of third parties (e.g. contractors). Importantly, the ERP will assist with achieving the DOHP objective of achieving 100% compliance with the relevant Defence occupational hygiene standards within 5 years (2007 – 2012) as well as addressing deficiencies in the current system.

The project commenced in October 2009 and involved the following main phases:

1) Discovery, Research and Consultation,
2) Analysis and Interpretation,
3) Recommendations in an ERP,
4) Implementation of the ERP, and Evaluation and Continuous Improvement.

The evidence based approach, including extensive stakeholder consultation and statistical analysis of large quantities of data, determined deficiencies and gaps in the current Defence system and identified areas where the most significant benefits could be realised.

Initial project outcomes included tailored Exposure Reduction Plans [2] tailored to the specific requirements of each of the stakeholder Services and Groups, which detailed prioritised strategies and practical control initiatives to enable improve occupational noise management.

The Australian Defence Force (ADF) Services include Air Force, Navy and Army and the Groups include Defence Materiel Organisation (DMO), Defence Support Group (DSG), Defence Science & Technology Organisation (DSTO) and the Joint Commands of JHC, JOC and JLC.

Research and Consultation Phase

The first phase of the project involved desktop research, literature review, data collection and consultation with a range of stakeholders throughout Defence Services and Groups. Existing relevant information from a range of sources included anecdotal information, relevant Defence documentation, previous noise surveys and other pertinent and acoustic data.

This involved investigation and research of the current Defence standards, policies and procedures and the extant management and control measures for occupational noise hazards, risks and exposure, as well as the current practices at all levels of the Defence organisation.

The current status of Defence occupational health and safety (OHS) management systems in relation to occupational noise was undertaken 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.

Figure 1 shows a schematic overview of the process employed in the research phase.

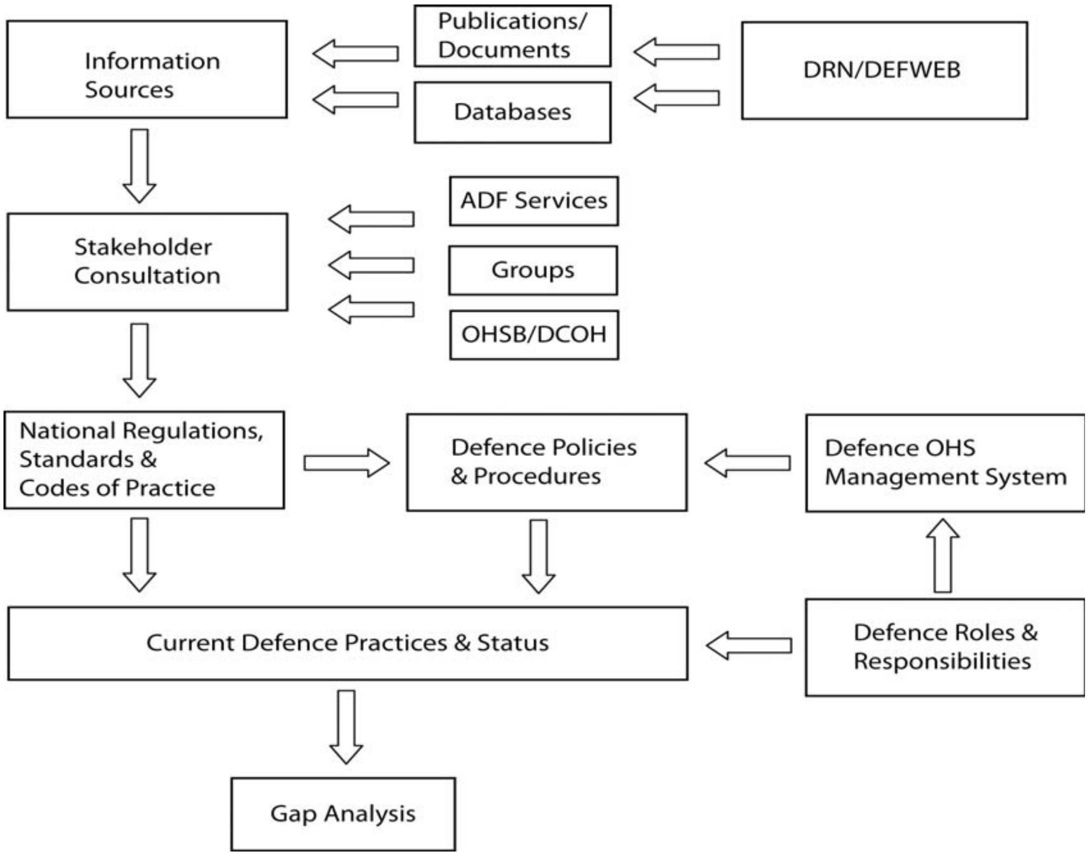

Figure 1: Overview of the research and consultation process.

Desktop research and a literature review were performed to enable collection of relevant data, and information was obtained from a range of sources including stakeholders, the Defence Restricted Network (DRN) and website searches.

An important component of the first phase involved consultation with a wide range of Defence stakeholders in Canberra, Defence establishments around Australia, other Defence groups and relevant external stakeholders. The extensive consultative process included face-to-face, structured interviews and telephone discussions with the stakeholders.

Initially the aim was to produce an ERP that applied to the Whole-of-Defence but after initial investigation it was found that there was a requirement to develop an ERP in Service and Group specific components; this would enable ownership of the initiatives, and action resulting, which could be undertaken by each individual Service or Group.

Defence Policies and Procedures

The top-level occupational/workplace safety document in Defence is the SAFETYMAN (Defence Safety Manual) [4], which contains the OHS policies and procedures that applies to the whole of the Australian Defence Organisation (ADO) and all Defence employees.

SAFETYMAN and its policy chapters are authorised as a Defence manual by Defence Instruction (General) PERS 19–18—Defence Safety Manual, and through the authority of the Chief of the Defence Force (CDF) and Secretary of Defence (SOD). This provides the guidance necessary to deliver best practice management of Defence safety related issues.

It is managed and reviewed by the Defence Occupational Health and Safety Committee (DOHSC) and the Occupational Health and Safety Branch (OHSB). SAFETYMAN has been developed to incorporate and comply with the legal requirements of Occupational Health and Safety Act 1991 (OHS Act) and Regulations.

Occupational Noise Management (ONM) is covered in SAFETYMAN and relevant Annexes, including the requirement for implementing Noise Management Plans (NMPs).

The SAFETYMAN document [4] primarily covers policies and procedures at the higher management and strategic level, which are also provided for application at the workplace and operational level. However, this presents a compromise whereby the policies are not always completely appropriate for application to the specific OHS issues in each Service and Group.

This makes the process of implementation across the diversity of Services and Groups very difficult and why the Services and some Groups have developed separate safety policy manuals. Service specific OHS policy and procedure manuals include: RAAFSAFE (Air Force Safety Manual), NAVSAFE (Navy Safety Manual) and ARMYSAFE (Army Safety Manual).

Other Defence groups have, or are establishing, OHS manuals such as Defence Materiel Organisation (DMOSAFE, released in July 2009) and DSTO OHS Policy & Procedures Manual. SAFETYMAN has sections devoted to ADF and Service specific OHS policy in Volume 2 and 3.

Another applicable OHS manual includes the ADF Health Manual (HEALTHMAN, or HLTHMAN) that applies to the Australian Defence Forces. Other Defence documents that provide policy directives include Defence Instructions (DIs), Health Directives, DEFGRAMS and DEF(AUST) specification documents. Also, lower level instructional procedures, such as Standard Operating Procedures (SOPs) and Base Level Instructions (BLIs) exist at Base/Unit level.

The SAFETYMAN is currently being revised, and draft sections of the new Defence safety manual, the Work Health and Safety (WHS) Manual, are being developed. New requirements in the national harmonization legislation (on 1 Jan 2012) will need to be addressed.

Findings, Analysis and Interpretation Phase

The output of the second phase of the project included a description of the information collected from the first phase and a detailed analysis and interpretation of the findings. The second project report [1] provided an informed background and evidence-based foundation to the recommendations and strategies in the ERP [2].

A gap analysis of the current Defence Occupational Health and Safety Management Systems (OHSMS) and Occupational Noise Management (ONM) showed the following:

1) Defence OHSMS is an incomplete system and has limited level of maturity.
2) Variation and inconsistency in OHSMS structure between the Services and Groups.
3) ONM across Services/Groups/Bases varies substantially.
4) ONM is not proactive, consistent or coordinated throughout Defence.

5) Good examples of ONM were evident in parts of Defence, but were not well managed elsewhere in Defence.
6) Non-compliance with ONM Defence policy and national standards in many areas.
7) Review, evaluation, continuous improvement at the OHSMS level is basic or not operational.
8) OHSMS and ONM are still in process of development, revision and implementation.
9) The ERP needs specifically tailored sections for the individual Services and Groups.

Even though some parts of Services and Groups are well resourced, there is strong evidence that there is limited coordination and cooperation across Defence and therefore substantial inefficiencies as a result. There are also restrictions due to entrenched practices.

This ONM variability and lack of system maturity appears to be caused by a large number of reasons including, but not limited to:

a) the vast diversity of work types across Defence and different nature of operations, activities/tasks, equipment and responsibilities of each Service or Group area,
b) different type/extent/level of noise sources/exposure in each Service or Group area,
c) wide acceptance that risk and exposure to noise comes with the job in Defence,
d) perception that occupational noise is not a major issue or priority,
e) management structure, culture, attitude, chain-of-command/promulgation,
f) disconnect between top and lower levels (limited flow-down and bottom-up diffusion),
g) disruption or distraction caused by other priorities, pressures and responsibilities,
h) disruption and discontinuity caused by the ADF (and APS) posting/rotation cycle,
i) blockers caused by bureaucracy, administrative difficulties and inefficiencies,
j) localised focus and basic reactive system (not proactive in general),
k) limited funding (budget constraints), resources and capacity,
l) limited or inadequate capability, expertise and training,
m) limited leadership/direction, commitment/initiative & coordination/communication,
n) limited records/reporting functionality, traceability and monitoring/review/action.

There is a substantial amount of data collected in the area of occupational noise throughout Defence. However, the amount and quality of data and frequency of data collection (e.g. via noise surveys) varies substantially depending on the Service, Group or Base [1].

Noise data, surveys and assessment

In the area of occupational noise, a review and assessment of the acoustic data collected and reported in Defence to date was undertaken [1]. The flow diagram in Figure 2 provides a schematic overview of the noise review and assessment process employed.

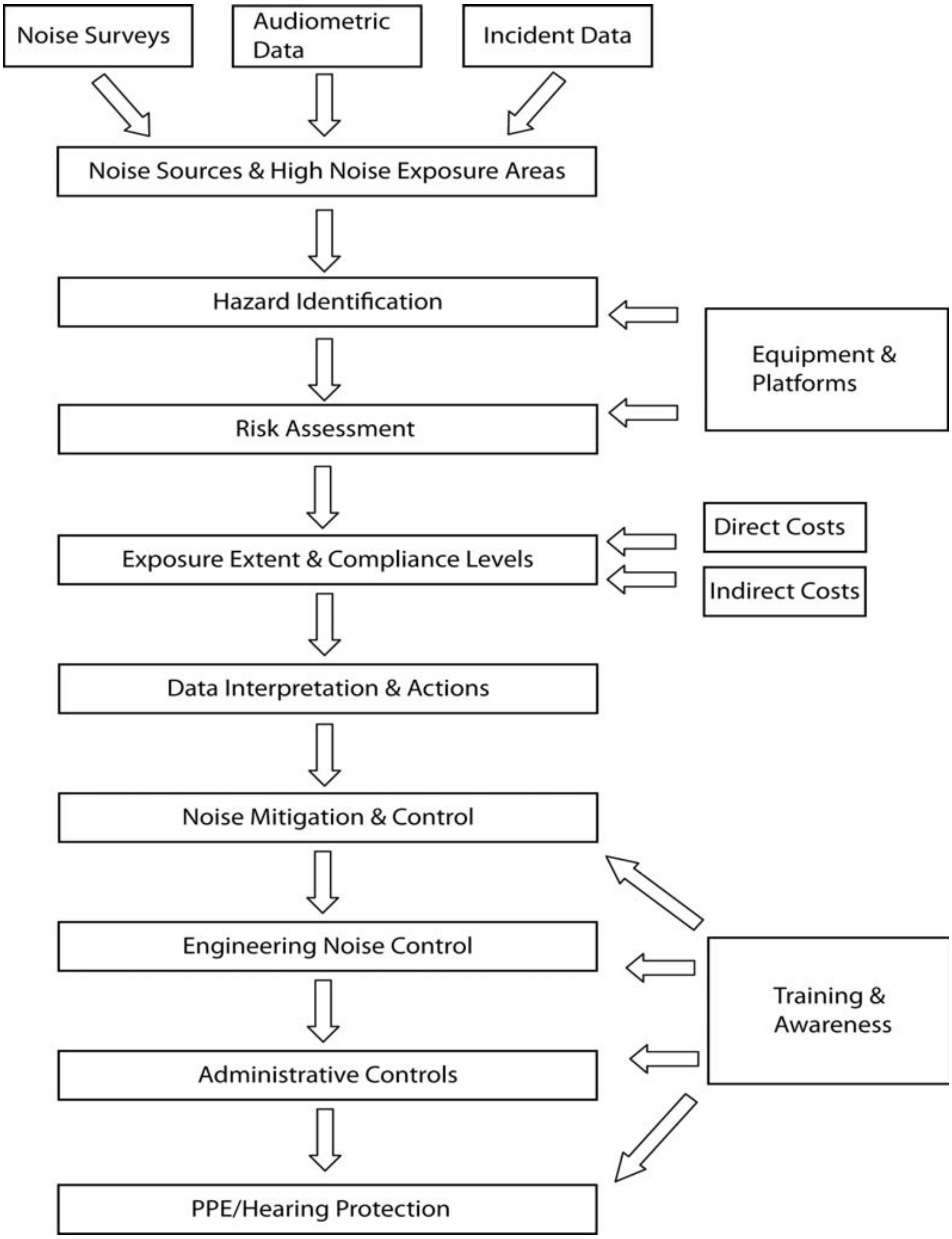

Figure 2: Overview of the noise review and assessment process.

In the area of occupational noise, acoustic data can be collected for the following:

1) Noise measurement surveys (at bases, sites, platforms), including attended noise measurements (with sound level meter);
2) Personal dosimetry data (usually during noise surveys);
3) Hearing Protector Device (HPD) testing data;
4) Audiometric (hearing) testing and audiogram data;
5) Incident reporting for noise events and hazards.

Noise surveys and audits (including noise assessment and recommendations) are typically performed every 5 years for a particular area or platform, especially within Navy and Air Force. In some cases, if an area or platform is modified significantly this would initiate a noise survey.

Audiometric or auditory testing is initially completed as part of health checks within the recruitment process. This first test provides the reference audiogram for all subsequent tests. Ongoing audiometric testing is standard practice within the ADF, and is completed as part of wider health checks, in compliance with Defence Instructions. A gap analysis of the current noise data, survey and assessment process throughout Defence showed the following:

1) Data collection varies substantially depending on the Service, Group or Base.
2) Quality and frequency of data is variable across Defence.
3) Evidence of quality noise surveys in some areas, e.g. parts of Navy, Air Force.
4) Many areas do not perform regular noise surveys, e.g. Army, DMO.
5) Defence does not fully comply with National Standard/Regulations (5 yearly surveys).
6) Some report recommendations can be too generic or impractical.
7) Noise dosimetry is not carried out to a sufficient extent.
8) Impulse noise not adequately measured, assessed and dealt with.
9) Data is not always centralised, traceable and easy to source.
10) No evidence of consistent process for analysing audiometric data and NIHL trends.
11) Over 20,000 Threshold Shifts registered since 2004 from Defence audiograms.
12) Incident database has questionable reliability and completeness.

Noise exposure extent

A review of the noise exposure extent and compliance throughout Defence was performed [1]. This included the investigation of the levels of noise exposure reported and a comparison against the occupational exposure limit (OEL) for noise (LAeq, 8hr of 85 dB(A) and LCpeak of 140 dB(C)), in addition to other legislative and Defence requirements.

Defence was found to generally comply with the intent of the standards and regulations, but a detailed gap analysis showed that:

1) Large number of high noise exposure areas throughout Defence.
2) Widespread significant exceedances of noise OEL or criteria.
3) High levels and extent of hearing impairment (NIHL) demonstrated.
4) Limited knowledge of impact of noise exposure outside work.
5) Defence does not achieve compliance (legislative or Defence) against many aspects.
6) Minimal information in Defence on the extent of non-auditory effects.
7) Further work needs to be undertaken in area of emerging issues, including acoustic trauma/shock, infrasound, ultrasound, ototoxic effects and vibro-acoustic disease.

Noise control measures

Evidence from stakeholders and Defence documents shows that, throughout Defence and in the various Services, there is a reliance on noise control measures that involve administrative controls, rather than engineering noise control. Administrative control of noise involves either a change of operations, processes (of a platform or equipment) or personnel task rotation [1].

The alternative of engineering controls, however, cannot be implemented quickly and is not necessarily practical in many cases in Defence due to constraints (physical, operational etc), impracticalities and logistics issues. Many platforms in Defence are also quite old and are either scheduled for upgrade or a complete replacement.

The quantity of engineering analysis and design required for engineering controls is large, and will be required across many bases and equipment/platform types. 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. This has the danger that a residual liability for occupational noise may exist for the service life of the equipment or platform.

Personal hearing protection

Personal Hearing Protection (PHP), which forms part of Personal Protective Equipment (PPE), is managed through the use of Hearing Protection Devices (HPDs), or Hearing Protectors (HPs).

The use of Hearing Protection Devices (HPDs) is often relied upon throughout Defence and in the various Services for effective noise control. The selection and provision of HPDs is undertaken in accordance with SAFETYMAN [4] and AS/NZS 1269-3.

Hearing Protection Areas (HPAs) are defined and signposted throughout Defence in accordance with SAFETYMAN [4] and AS 1319. Different HPA levels or zones are designated based on the noise exposure level in the area and are effectively managed in general. However, there is evidence where HPAs have been incorrectly designated or signposted.

There is large uncertainty and variation associated with HPD use and appropriateness throughout Defence [1]. There is widespread evidence in Defence of either incorrect use of HPDs or incorrect type of HPDs being worn in noisy HPAs. There are numerous examples of incorrect HPD selection, testing and maintenance. In addition, appropriate fitting and comfort levels, and resulting irritability and effects on task operation, have been major issues.

There is well-demonstrated need in Defence for better general and specific noise awareness programs in addition to running more regular refresher courses [1]. Training programs will be required for different levels, sites and roles/tasks. A training needs analysis (TNA) is needed to accurately describe the technical training needs across Defence for occupational noise.

Costs and compensation

The real costs associated with noise exposure and noise induced hearing loss (NIHL) include a range of direct and indirect costs.

Direct costs include:

1) Injuries to personnel & disability,

2) Compensation (in-service & post),
3) Rehabilitation & treatment,
4) Property damage.

Indirect costs include:

1) Stress (e.g. PTSD) & fatigue,
2) Morale, loyalty & annoyance,
3) Public/community relations,
4) Lost work capacity & capability,
5) Lifestyle, and family of the injured,
6) Cost of replacing or training employees.

About 15% of the active clients of the Department of Veteran Affairs (DVA) have claimed a hearing related disability and over 50% of DVA clients have claimed hearing related disability in combination with other disabilities [5]. There are a total of over 75,000 current or active claims (and over 130,000 veteran claims to date). Total DVA costs in FY 08-09 for noise related claims and hearing services was over $50M, for a total of 103,000 DVA clients [5].

Noise is, and has been, the largest cause of claims by numbers of people claiming, relative to Veteran Entitlement Act (VEA). Noise injury is ranked No. 1 (SNHL, Sensorineural Hearing Loss) and No. 2 (Tinnitus) in the VEA claims lists based on numbers of people claiming [5].

Over the next 10 years, based on the DVA information available, a forecast of the future liability is that total costs to DVA for hearing related claims and services may be of the order of $1 billion, comprising about $600M to $700M for noise related claims and hearing services and about $300M to $400M for disability pensions [1]. These figures could be 10 to 20% higher than this due to the additional claims, service/product cost increases and CPI adjustments.

Summary of findings

The findings from the occupational noise ERP project [1] has determined that:

a) the occupational and life impacts of occupational noise within Defence is substantial;
b) the number of Defence workplaces and activities where occupational noise levels exceed the standard for unprotected hearing is large;
c) there is a high level of injuries and claims due to noise induced hearing loss;
d) occupational noise causes substantial direct and indirect costs;
e) there is an urgent need to address extensive non-compliance issues.

There is a high risk that short periods of exposure without appropriate PPE in these workplaces damages the hearing of personnel. The impact of the high level of injuries and claims will probably occur for many years. Due to the long-term nature of hearing loss, reduction in compensation claims will only be seen when a substantial change has occurred for a reasonable time in Defence workplaces and environments.

In addition, there was little evidence in Defence of on-going monitoring and evaluation of occupational noise management programs, and auditing processes were lacking. Generally, even though there were some good programs in areas, there was not much evidence of formal reporting of evaluations or OHS improvements at various management forums.

Recommended Strategies and Actions

A wide range of recommendations, formulated from the analysis and interpretation of the findings, were provided in an Exposure Reduction Plan (ERP) for Occupational Noise [2]. These recommendations are required to: a) ensure compliance with relevant standards and regulations and Defence policies, b) address key deficiencies in occupational noise management and reduce noise exposure, as well as c) providing a platform for aiming for a best practice approach into the future.

The 10 key recommendations (from a total of 28 recommendations), critical to be focussed on during the immediate next phase, included:

1) Need a more coordinated/consistent approach, and centralised data management.
2) Improve the equipment/platform procurement and lifecycle process.
3) Consider a Defence Instruction General and ONM business case submitted to DOHSC.
4) Need well-defined and agreed roles and responsibilities for OHS personnel.
5) Need standardised procedures and templates for presentation/reporting of data.
6) Need more noise surveys in some areas, more focussed/streamlined surveys in others.
7) Need more dosimetry, spectral and impulse noise data.
8) Improve the consideration and application of engineering noise control.
9) Improve PPE/HPD provision and effective use.
10) Improve training and awareness provision.

The specific strategies and initiatives to be implemented by Defence (and Services and Groups) from the Exposure Reduction Plan (ERP) were grouped into the categories shown in Figure 3.

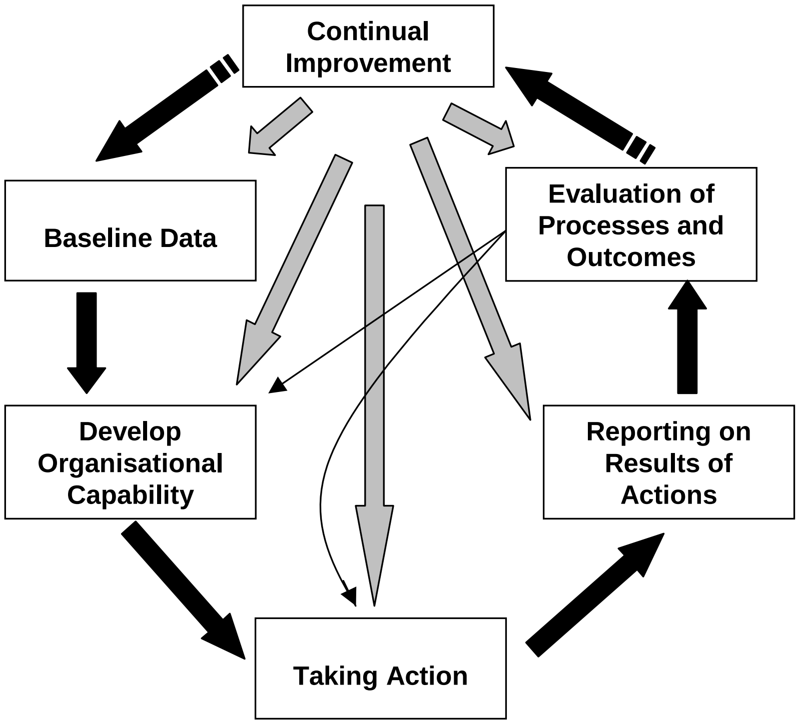

Figure 3: Overview of the broad ERP strategy areas.

Separate ERP documents (and action summary tables) were specifically tailored for each of the Groups and Services. This series of ERP documents established a range of strategies/initiatives and actions to reduce exposure to occupational noise and to promote good hearing conservation and noise management practices.

The strategies in the ERP have been developed to be reasonably achievable, as far as practicable, and will be dependent on budgetary and other constraints within Defence.

The ERP actions have been developed and prioritised to achieve real measureable improvements in the near term (i.e. direct actions to reduce noise hazards/exposure), legislative and policy compliance over the medium term and with a view to aiming for best practice in the future.

Discussion with and feedback from stakeholders during the implementation phase will enable further refinement of ERP actions for application to, and ownership for, the particular Group. Some solutions to occupational noise issues will require the coordinated action of personnel across Services, Groups and Divisions, in addition to the need for better communication flow.

The implementation of the ERP recommendations will be designed to generate the following main benefits to Defence:

1) Reduce the extent and impact of occupational noise throughout Defence.
2) Reduce the level of noise-induced hearing loss and claims in Defence.
3) Assist in achieving legislative and policy compliance.
4) Improve the measurement and control of noise at the source.
5) Provide mechanisms for better noise management and prevention.
6) Improve the working and living conditions of Defence personnel.

7) Provide cost savings through more efficient processes.

Future phases of the project will include implementation of the recommended actions across the complex Defence organisation and on-going monitoring, evaluation and continuous improvement (including measuring KPIs) in the area of occupational noise.

A number of pilot noise survey and assessment programs have been initiated by DCOH to achieve early results against main actions within the Service level Exposure Reduction Plans.

This ERP project is a new initiative for Defence that is looking to the future, where Defence is prepared to commit significant resources, over a prolonged period, to a very comprehensive approach which looks at improving all aspects of its noise management program.

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Opportunities for Occupational Noise Control for Harbour Control Vessels

Dick Benbow
Dick Benbow & Associates Pty Ltd

Abstract

Vessels used for harbour control activities in a major city such as Sydney take up many forms.

There may be two personnel on board powered boats to a myriad range of motor vessels with both outboard and inboard motors. Pilot boats with ocean going capacity are also amongst the vessels used. These have a 3 person crew and are powered by twin in board diesels mounted under the deck in a vessel fabricated from aluminum.

Noise assessments were undertaken and options for noise controls to reduce the occupational exposure to below 80 dB(A) over 8-10 hour shifts will be discussed.

Engineered noise controls of the pilot vessels were highly successful and will be discussed examining the assessment techniques to be used, the practical difficulties of locating the sources and then devising means of reducing the noise levels.

State Government Marine Vessel Noise Survey

Richard Jackson
Injury Prevention & Management

Abstract

A noise level survey was conducted at a State Government Department to assess the potential for employee exposure above $L_{Aeq,8hr}$ 85 dB(A) Standard on one of their marine vessels. Preliminary noise results indicated that employees had the potential to be exposed to levels that greatly exceeded the $L_{Aeq,8hr}$ 85 dB(A) Standard under normal operating conditions. It was recommended that controls be investigated and implemented to reduce the level of noise in the wheel house, living quarters and rear deck. Acoustic and vibration insulation was installed on bulk heads and in the engine room of the vessel. Final measurements found that whilst there was still potential for employees to be exposed to levels greater than the $L_{Aeq,8hr}$ 85 dB(A) Standard noise levels in the engine room and rear deck, noise levels had decreased to below the $L_{Aeq,8hr}$ 85 dB(A) Standard in the wheel house and living quarters.

Keywords

Marine, vessel, noise, acoustic damping.

Introduction

Area noise monitoring was conducted following the commissioning of a new State Government operated marine vessel. Monitoring was conducted to determine the potential for the vessel's crew to be exposed to noise levels in excess of the $L_{Aeq,8hr}$ 85dB(A) Standard during patrol operations. It was communicated that the marine vessel will be typically operated for 10 to 12 hours each day, increasing to 14 hours during busy periods.

Method

Noise monitoring was conducted in accordance with *AS/NZS 1269.1; 2005 'Occupational Noise Management Part 1: Measurement and assessment of noise emission and exposure'.*

Area noise level measurement was conducted using a Bruel & Kjaer Model 2250, Type 1, Precision Integrating Sound Level Meter. Noise levels were measured at head height in typical work locations. Noise monitoring was conducted under test conditions in the local river system. Due to the limited nature of the vessels operations, monitoring was conducted at six different engine speeds ranging from idling at 700 rpm, through running at 1800 rpm to a maximum of 2300 rpm.

Results

Area noise monitoring results are presented in Table 1. All measurements were taken at head height for 1 minute and are an average of three measurements.

Location		Wheel House	Engine Room	Rear Deck	Living Quarters	Fly Deck
700 RPM	Initial $L_{Aeq,8hr}$	**89.5**	**103.7**	**91.3**	-	-
	Post Insulation $L_{Aeq,8hr}$	69.9	93.3	78.8	69.3	61.9
1000 RPM	Initial $L_{Aeq,8hr}$	**92.7**	**104.1**	**96.9**	**90.2**	**85.5**
	Post Insulation $L_{Aeq,8hr}$	73.8	98.2	83.2	73.6	68.5
1500 RPM	Initial $L_{Aeq,8hr}$	**91.9**	**105.7**	**103.7**	-	-
	Post Insulation $L_{Aeq,8hr}$	78.2	98.9	90.9	79.7	75.2
1800 RPM	Initial $L_{Aeq,8hr}$	**91.2**	**105.3**	**100.8**	**92.6**	**93.5**
	Post Insulation $L_{Aeq,8hr}$	80.6	103.1	92.2	81.7	77.5
2000 RPM	Initial $L_{Aeq,8hr}$	**92.5**	**105.4**	**103.1**	-	-
	Post Insulation $L_{Aeq,8hr}$	83.8	-	94.9	-	-
2300 RPM	Initial $L_{Aeq,8hr}$	**100.1**	**105.8**	**102.2**	-	-
	Post Insulation $L_{Aeq,8hr}$	83.6	-	96.0	-	-

Table 1: Patrol Vessel Area Noise Monitoring Results

All monitoring was conducted in sheltered water, with wind speeds of less than the 10 ms^{-1}, and choppy water with waves of less than 1 m.

Discussion

The results displayed in bold in Table 1 indicate that initial noise levels on the marine vessel during simulated conditions had the potential for employee noise exposure above the $L_{Aeq,8hr}$ 85 dB(A) Standard after only short periods of exposure. For example, under normal operating conditions (running at 1800 RPM), the noise exposure was L_{Aeqt} 91.2 dB(A); an unprotected person in the wheel house would receive the equivalent of the allowable daily noise exposure ($L_{Aeq,8hr}$ 85dB(A)) in less than 2 hours.

The initial survey identified that the main noise source was from the vessel's engines. An inspection of the engine room, insulation was observed on the bulkhead of the engine room access hatch which consists of a synthetic mineral fibre and foil wrap which is about 35 mm thick. It was recommended that additional engineering or isolation controls, in the form of acoustic dampening, be investigated to reduce emission of noise from the engines and structural born transmission of noise to the wheel house and living quarters. The most economical and simplest control was found to be the installation of further acoustic damping inside the engine room.

Acoustica Vybar© Marine high density polyester acoustic insulation was installed on the hull in the Engine Room and the deck head, bulk head and hull. A follow up survey conducted following the installation of acoustic insulation indicated that the noise levels and potential for employees to be exposed to noise above the $L_{Aeq,8hr}$ 85 dB(A) Standard has decreased significantly. For example the wheel house, under normal running at 1800 RPM, recorded a sound level at $L_{aeq,t}$ 80.6 dB(A) compared to $L_{aeq,t}$ 91.2 dB(A) in June 2010.

The results indicate that the noise levels recorded under the simulated operating conditions, in all areas monitored decreased significantly. Noise levels in the engine room and on the rear deck, continue to have potential for employee noise exposure above the $L_{Aeq,8hr}$ 85 dB(A) Standard.

Administration controls in place during the monitoring included, when the vessel is operating at 1800 RPM or higher crew only spend short periods of time on the Rear Deck with hearing protection and they do not enter the Engine Room.

Conclusion

Noise monitoring conducted on the marine vessel, under the conditions monitored, indicated that acoustic damping installed in the Engine Room and Bulk Head had successfully reduced the noise in the Wheel House, Living Quarters and Fly Deck to less than the $L_{Aeq,8hr}$ 85 dB(A) Standard under normal operating conditions.

Shaken but not stirred – the link between whole body vibration and lower back conditions in truck drivers

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Abstract

The intention of this research is to explore the link between Whole Body Vibration (WBV) and lower back injuries in mine site truck drivers.

It is proposed that exposure to WBV will fatigue core muscle structures, increasing the risk of low back injury if exposed to sudden loading, or a cumulative muscle weakening effect over extended periods of time. Causing symptoms of stiffness and decreased mobility.

Thirty-five subjects had their stabilizing muscle function assessed with real-time ultrasound imaging (RTUI). Muscle function was unchanged pre-shift to mid-shift, but demonstrated fatigue by end of shift.

Fifteen subjects were taught to perform stabilizing muscle contractions. Subjects who performed these exercises demonstrated decreased muscle fatigue and reported less back ache/stiffness. Control subjects continued to demonstrate muscle fatigue.

Based on our current research we believe a link between WBV and core muscle function can be established, which will enable effective controls to be recommended to prevent occurrence of lower back pain (LBP.) In addition this research has the potential to provide an intervention to identify high risk individuals and develop proactive programs to strengthen, preventing injury.

Introduction

The industry focus on the control and prevention of strain and sprain injuries has primarily been directed at health and medical teams. The intention of this research is to explore the link between Whole Body Vibration (WBV) and lower back injuries in mine site drivers of heavy vehicles by using a multi disciplinary approach. Combining hygiene data and expertise in relation to vibration, with knowledge of functional muscular skeletal injury causation and control provided by the health professional., we have been able to explore an intervention that has resulted in a decrease in LBP amongst drivers of heavy vehicles.

Whole body vibration occurs when individuals are exposed to mechanical energy oscillations through a supporting system such as a seat or platform. It has been well published that whole body vibration can lead to lower back pain and musculoskeletal injuries in professional drivers (Bovenzi, 2010, Bovenzi 2009, Tiemessen et al, 2008, Noorloos et al, 2008, Robb and Mansfield, 2007). The incidence of low back pain in people driving heavy equipment vehicles (HEV's) has been shown to be up to two times higher than those not exposed to driving HEV's (Waters, et al, 2008). There have been many hypothesis of why this is the case, including ergonomic and occupational-psychosocial factors and physical fitness.

However, a review of current literature suggests that there has not been any significant research investigating a possible link between core muscle strength and function and the incidence of LBP in drivers of HEV's. One study has used a finite element model of the spine (Bazrgari et al, 2008) to determine that there is a significant role of muscles in trunk biodynamics and associated risk of back injuries related to WBV.

A qualitative review of injury trends has led us to a hypothesis that there is a link between fatigue of the core muscles that protect the spine due to WBV exposure in HEV operations and the incidence of LBP/ injury.

The intent of this study is to identify if a relationship exists between exposure to levels of WBV for extended time frames and core muscle fatigue, thereby increasing the risk of lower back injury if exposed to sudden unexpected loading, or a cumulative effect over a prolonged shift causing a weakening of stabilizing muscle function and symptoms of stiffness and decreased mobility.

Methodology

The initial phase of the study involved a WBV sampling program as part of the 2010 baseline on site. This data enabled a qualitative comparison against injury trends and symptoms such as "waking up stiff" demonstrating a link between high risk groups and injury reports. A Bruel and Kjaer 4447 Human Vibration Analyser was purchase and key individuals from both production and health teams undertook training to enable testing to be conducted on a regular basis.

A list of HV mining equipment was obtained from the mining department to determine the type and quantity of machines onsite. This information was then used to create a 3 month monitoring plan to measure the vibration levels across a range of machinery and locations. Measurements were recorded using the Bruel and Kjaer 4447 Human Vibration Analyser across both day and night shift crews, with measurements lasting between 2-4 hours. The unit was set up in the vehicle by individuals trained in the use of the equipment, instructions were provided to the operator advising them to sit on the unit as they would normally sit on the seat. The measurement was started once the operator was comfortably positioned to avoid any misleading information being collected at the start of the measurement.

Operators were instructed how to cease the measurement once they left the seat for their break, and the unit was collected from the machine. The results were stored in the unit until the following day when they were downloaded by the exercise physiologist using the 4447 Vibration Explorer Software loaded onto the laptop.

Following the baseline monitoring program, the next phase was to identify high risk tasks and monitor these specific activities. A quantitative review of injury data was completed to determine the tasks that resulted in a minimum of a Medically Treated Case, the tasks identified consisted of

- Ripping with Dozers
- Shovels pulling batters.

It was determined, due to the ad-hoc nature of these tasks being completed in the field that a monitoring plan could not be created. Instead, mining safety representatives were informed at pre start meetings if these activities would be taking place and the unit was placed in the required machine. This project remains ongoing.

Due to the study being conducted on an operating mine site, it was necessary to have flexibility when conducting sampling. Although training was completed by individuals setting up the vibration equipment, it should be noted that this could not be controlled, nor could the activities of the operators, therefore a potential for error exists in the method of data collection. The information gathered to date is consistent with the studies qualitative hypothosis.

Research has shown that even in a "healthy" spine, if the stabilizing muscles are not functioning correctly, the chance of injury to the spine is greatly increased (Hides et al, 1994). Screening of the stabilizing muscle function with RTUI can detect dysfunction in muscle activity and timing during sustained postures and during functional movement. Implementation of a specific daily retraining program to improve the function of these muscles may decrease the potential for pain or injury (Hides et al, 1998).

The real-time ultrasound imaging (RTUI) assessments of low back stabilizing muscle function were undertaken by a trained physiotherapist, using a Mindray 6600 Real-time ultrasound imaging unit. An initial study was undertaken to ensure reliability and repeatability of the testing methods (Kermode, 2004).

Subjects were all volunteers from three different mining crews all operating HEV's. Subjects with ongoing LBP currently undergoing medical or physiotherapy management for their injury were excluded. Subjects who had undergone previous assessment and retraining of low back stabilizing muscles were also excluded. Subjects were informed that they were able to withdraw from the study as any stage with no repercussions.

For the RTUI testing, 35 subjects were assessed in a sitting position, mimicking their work situation driving HEV's. The automatic function of Transerve abdominis (Tra), Pelvic Floor (PF) and Multifidous (Multf) were all assessed during basic movements and postural correction in sitting, reaching and leg movements. The initial trial comprised the assessment of subjects from three mining crews both pre and mid shift (after 6hrs exposure of WBV) and again pre and post shift (following 12hrs exposure of WBV). Subjects were also assessed at mid swing (after one week of work) and at the end of a two-week swing.

Stabilizing muscle function was found to be unchanged pre-shift to mid-shift in all subjects, but demonstrated fatigue or global over-activity in most subjects by end of shift assessment. These changes in muscle function and signs of fatigue were more obvious in subjects assessed at end swing compared to mid swing.

Fifteen subjects were then taught to perform specific stabilizing muscle contractions for Transverse Abdominis (TrA), Pelvic Floor (PF) and Multifidous (Mult) at particular points during their working day related to significant increases in vibration levels (previously recognized during the WBV testing and from subjective accounts). Subjects were instructed to perform these exercises on a daily basis for a minimum of 10 minutes per day.

Results

At three months, all subjects were re-assessed. The subjects who performed these stabilizing muscle exercises demonstrated improved stabilizing muscle function at base line (pre swing). They also demonstrated significantly decreased muscle fatigue by end of shift and reported less low back ache and stiffness by the end of their two-week swing. At six months the subjects performing these exercises demonstrated no stabilizing muscle fatigue by end of shift, demonstrating that their stabilizing muscle function had continued to improve. This was despite the fact that most subjects admitted to performing these specific exercises on a less regular basis.

Control subjects assessed at three and six months continued to demonstrate stabilizing muscle fatigue by the end of their twelve hour shift, with these changes in muscle function continuing to increase by the end of the two week swing.

These results indicate the likelihood of sustaining a back injury increases throughout the working day, however, these risks can be minimized by completing regular core strengthening exercises during periods of high vibration or sudden or unexpected movements or jolting.

Conclusion

Heavy Vehicle Equipment Operators on mine sites may work twelve hour shifts for two weeks at a time. Low back symptoms reported include waking up sore, repetitive lower back ache and discal irritation post heavy loading or jolting. The lumbar spine stabilizing muscles, transversus abdominis (TrA), pelvic floor (PF) and lumbar multifidus (Mult) provide protection and support for the lower back during all activities and sustained postures. They produce a corset-like effect, bracing the spine during movement and controlling the spinal movement at a segmental level. The muscles provide shock-absorption for the lumbar spine by contracting just prior to movement avoiding a jerk or jolt to the spine and decreasing the effects of vibration forces. These muscles are also constantly active on the spine, even when we are at rest or in sustained positions or postures.

These results support a link between WBV and low back stabilizing muscle fatigue, with the loss of stabilizing muscle function increasing the risk of lower back pain, stiffness and/or injury towards the end of a 12 hour shift in drivers of HEV's. Based on our current research we believe a credible link between WBV and core muscle function can be established.

This project has identified core muscle fatigue as the potential root cause for low back strain and sprain injuries in Heavy Equipment operators, by using assessment and retraining of core muscles with Real Time Ultra Sound Imaging (RTUI) as an intervention strategy.

It is the intention to further identify specific high-risk tasks and equipment through comparison between stabilizing muscle function and WBV exposure. Ongoing implementation of this project has the potential to effectively understand and manage exposure risk and identify effective controls to prevent the occurrence of Lower Back Pain.

In addition, the use of RTUI as an assessment tool could also be developed into a medical surveillance strategy to assist in the proactive identification of individuals at risk of such injuries, which combined with effective control strategies in the field will significantly decrease strains and sprains in the workplace.

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An analysis of international studies to assess silica exposure and health effects: Can exposure monitoring and health surveillance raise awareness to improve worker health in Queensland quarries?

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Abstract

Exposure to respirable crystalline silica (RCS) is a major concern for worker health in quarries and mines. This paper reports the findings of an ongoing study of RCS exposure in Queensland quarries.

Lung function tests and exposure monitoring results for 40 workers, from dimension stone, road base and aggregate quarries and a silica sand mining and processing plant in Queensland were analysed. In 3 of 8 quarries studied, exposure exceeded the Safe Work Australia Exposure Standard (ES) for respirable crystalline silica occupational exposure limit (OEL) of 0.1mg/m^3. When data were pooled and analysed within similar worker exposure groups (SEG) there was a positive correlation between reduced lung function and exposures at or above the exposure standard. The distribution of exposures for each SEG, were log-normally distributed, which indicates that the data were representative for each job type. Using Australian Exposure Standards 7 out of 13 SEGs monitored had unacceptably high exposures. These data indicate the importance and need to reduce RCS exposures in Queensland quarries, to conduct ongoing exposure monitoring, and to carry out regular health surveillance of workers, with prompt follow-up action when required.

Strengths and weaknesses of a long term study of granite workers in Vermont USA, and a study of lifetime-risk of silicosis among a cohort of pottery workers in China are also discussed in relation to data collected in the current study. A study of West Australian (WA) miners has also been evaluated. The data collection methods used in the Vermont and WA studies are compared with methods used in the Queensland study.

Keywords

Silica exposure, Lung function, Exposure assessment

Introduction

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 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 is being 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. However, fifty seven percent (57%) of workers monitored were smokers, and smoking is also known to reduce FVC.

Background: National and International Studies

Western Australian (WA) Miners

In a study of Western Australian miners (Hewson, 1996) exposure estimates made between 1925 and 1993 demonstrated reduced exposure to respirable dust (Figure 1). These measurements were based on a method that used different types of konimeter to monitor short-term exposures between 1925 and 1977. In 1950 the Kotze konimeter was replaced by a Watson Victor circular konimeter. In 1961, a different type of illuminator was used with the konimeter, which revealed that there were differences in the particle size collected by each of these konimeters. Nevertheless, Hewson (1996) attempted to transform the konimeter results from short term samples of particles per cubic centimetre (ppcc) to full shift samples of respirable dust as mg/m^3.

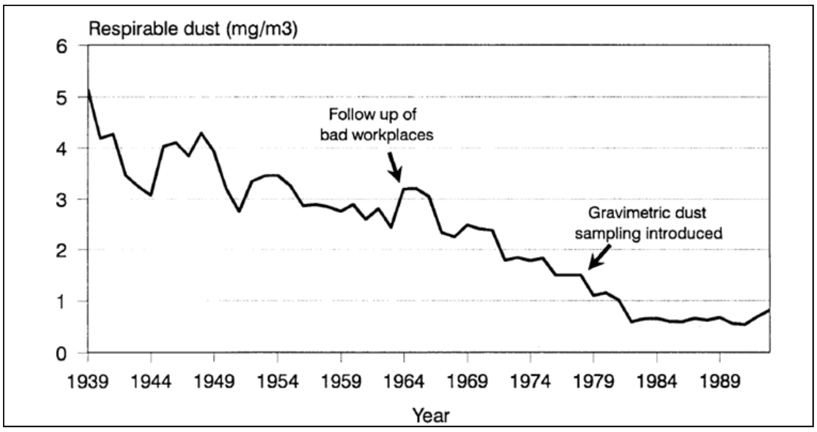

Figure 1: Estimates of mean respirable dust concentrations in Western Australian underground metalliferous mines (1939-1993). Pre-1979 data have been converted from konimeter count data using a factor of 1 mg/m^3 per 100 ppcc
(Source: Hewson 1996, p873)

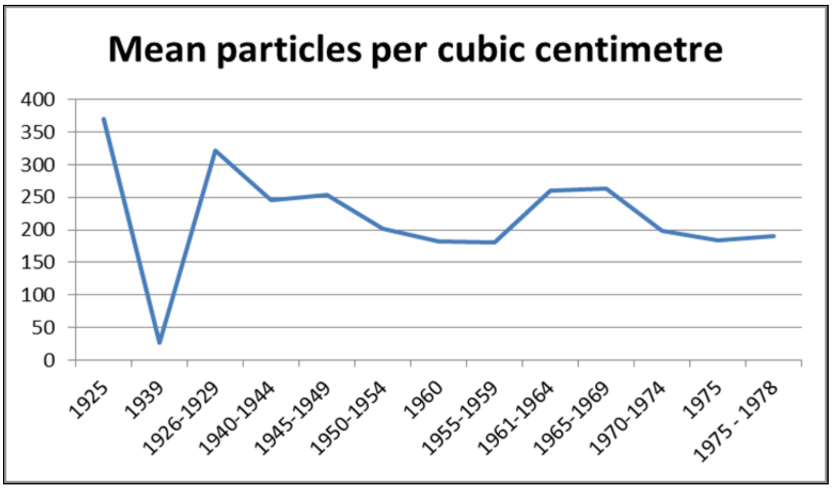

Figure 2: Mean Particles per cubic centimetre in Western Australian underground metalliferous mines (1939-1993)
(Adapted from: Hewson, 1996)

It is interesting to note that when the original data were graphed as shown in Figure 2, the downward trend over time for particles per cubic centimetre (ppcc) is not as obvious. Figures 3 and 4 show the results of tabulated respirable silica concentrations for underground metalliferous mines for exposure results (1979 to 1993).

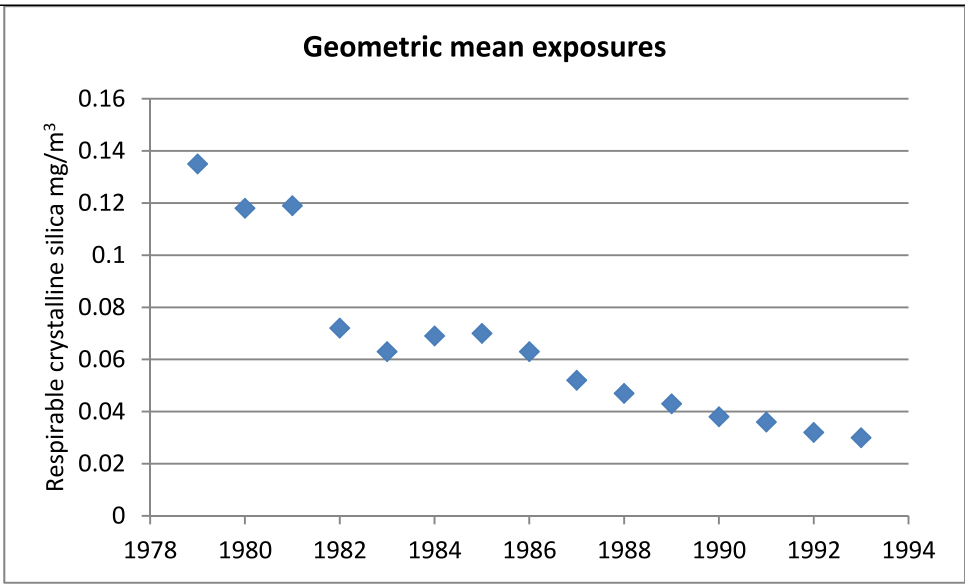

Figure 3: Mean Exposure to respiarble silica in undergaround metalliferous mines in WA (Source: Hewson, 1996, p.873).

When (measured) respirable crystalline silica exposures are compared between 1979 and 1993, there is a reduction in geometric mean exposures (Figure 3). However this is not the case when maximum exposures are graphed (Figure 4).

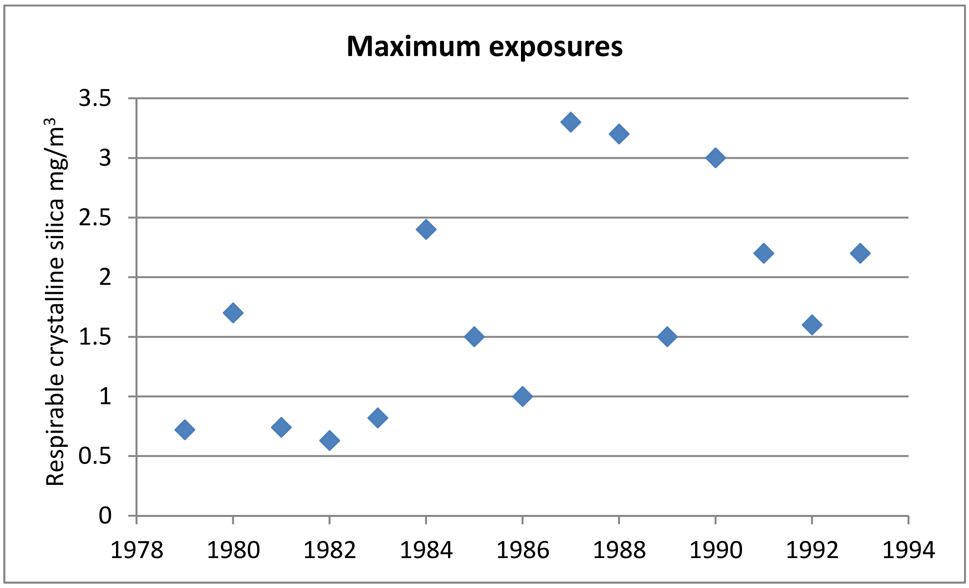

Figure 4: Maxiumun exposures to respiarble silica in undergaround metalliferous mines in WA (Source: Hewson, 1996, p.873).

In the same study, Hewson (1996) reported the incidence of silicosis since 1925 (Figure 5). A new silicosis case is one defined previously as normal but on re-examination indicated early silicosis (>ILO classification1 / O). The X-rays were read by independent respiratory physicians employed by the WA health department (Hewson,1996).

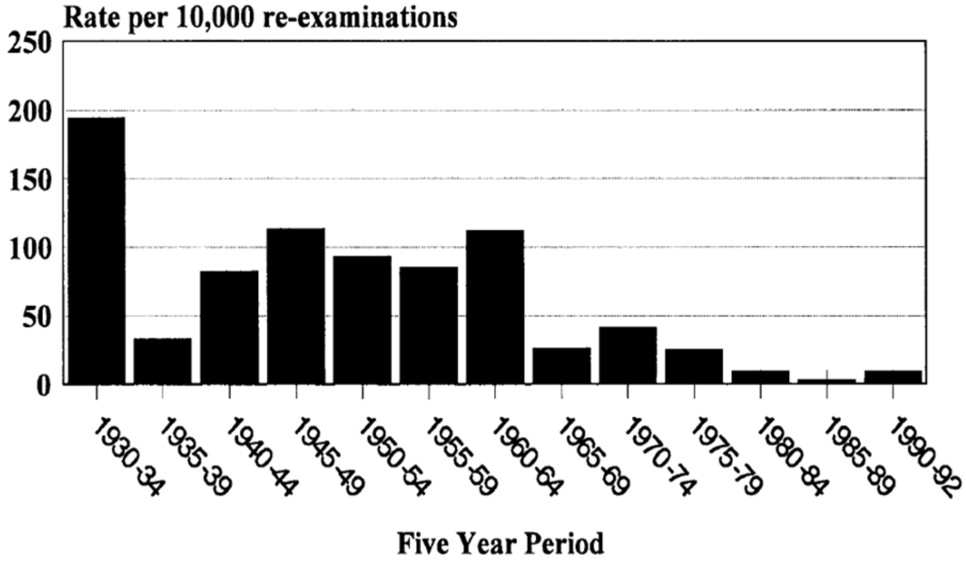

Figure 5: Incidence of new cases of silicosis following X-ray re-examination of Western Australian metalliferous miners form 1925 to 1992 (Adapted from: Hewson, 1996)

Hewson (1996) cited a study by Larcombe (1912) undertaken in the early 1900s where the mass of dust collected on the surface of respirators was used to indicate exposure. In that study it was estimated that inspirable dust concentrations typically exceeded 10mg/m^3, and concentrations of 110mg/m^3 were estimated for dry boring operations. Most cases of silicosis are likely to have been from workers performing high exposure tasks. The improvement in work conditions in the 1950s (lower dust exposures) was attributed to the increased use of water sprays and improved ventilation for most SEG's.

Buchanan et al (2003) noted that quantifying the risk of silicosis should take into account the variations of quartz exposure intensity, particularly for exposure to concentrations of greater than 1mg/m^3, even if exposure is for relatively short periods. These authors also implied that the risk of silicosis rises dramatically with brief exposures to high quartz concentrations.

USA Vermont granite workers.

One of the most extensive studies published is the silica exposure assessment and mortality study of Vermont granite workers (Verma et al, 2010). In that study a job exposure matrix was developed that used 5204 exposure measurements collected from 1924 to 2004. The percent free silica (alpha-quartz) in respirable dust was estimated to be 11%. About 60% of all measurements made prior to 1972 were obtained using the impinger method which had a typical sampling time of 20 – 25 minutes.

In the study by Verma et al (2010) NIOSH recommended the use of a conversion factor of 10 million particles per cubic foot (mppcf) for equivalence to a RCS concentration of 0.1mg/m^3. This is different to conversion factors used in other studies, for which there is inconsistency. The study by Verma et al (2010) also categorised (SEGs) arbitrarily and it is difficult to verify whether SEGs were classified and grouped correctly for analysis.

Vacek et al (2011) studied mortality records for 7052 workers employed in the granite industry from 1947 to 1998. They found no significant link between low level exposure to airborne silica and lung cancer, but reported an odds ratio (OR) of 1.13 (1.05 to 1.21) for silicosis for each 1 mg/m^3 increase in cumulative exposure equating to 0.1 mg/m^3 for 10 years or 0.05 mg/m^3 for 20 years. Although an excess risk was estimated for < 0.1mg/m^3 RCS long-term exposure of 55 deaths resulting from silicosis, only 6 began work after 1940 and 3 began work after 1949 but only worked for less than 10 years in the Vermont granite industry (Vacek et al, 2011). Using mortality records to examine a relationship between silica exposure and silicosis is questionable because the number of workers affected from low level exposure (during their lifetime) has not been established.

Vacek et al (2011) has estimated levels of exposure for each "job class". From this dataset geometric means have been calculated for all job types combined for each period and reported along with maximum exposed job class as shown in table 1.

Period	Geometric mean RCS mg/m^3	Maximum (exposed) job class RCS mg/m^3
<1940	0.16	1.07$^{\#}$
1940 - 1949	0.12	0.56$^{\#\#}$
≥1950	0.04	0.10$^{\#\#\#}$

Note: $^{\#}$ Jackhammer; $^{\#\#}$ Jackhammer; $^{\#\#\#}$ Labourer

Table 1: Estimated exposure concentrations of respirable crystalline silica by time period, for all job classes. (Source: adapted from Vacek et al 2011)

Vacek et al (2011) did not provide any analysis where RCS exposure for each job-type was compared with mortality from selected diseases.

Reassessing the historical data and comparing the level of pooled exposure for each job-type with mortality from disease will be worthwhile. This will allow statistical analysis across all job types and grouping workers where the nature of exposure, including particle size distribution, would be similar. It may improve how dose response assessment is undertaken and identify "job-types" that have an increased risk of disease.

Chest x-rays were investigated in 1983 to determine whether low level granite dust exposure could lead to lung abnormalities after a lifetime exposure to dust containing silica (Graham et al, 1991). Workers who had been exposed to dust from 1938 to 1940 were assessed. In that study 972 out of 1,400 chest x-rays were read by 3 "B" readers using the ILO classification system. Of these, 28 (3 percent) were interpreted as showing (1/0) pneumoconiosis and 7 (0.7 percent) showed uncomplicated silicosis. Of those remaining, 21 showed irregular opacities, which were reported as having: "uncertain significance". The average dust concentration was estimated to be 0.06 mg/m^3 with 12% exceeding 0.1 mg/m^3 (Graham et al, 2001). Years worked in the industry ranged from 9 to 60 years. Many of the chest x-rays were irregular and interpretation varied between readers. The estimated exposure to RCS for the 0.7% of workers diagnosed to have (1/0) silicosis was 0.06 mg/m^3. This reported risk generally agrees with a similar Scottish study which estimated that an exposure of 0.04 mg/m^3 for 15 years resulted in a increased silicosis (2/1) risk of 0.5% (HSE 2002).

A study by Graham et al (1994) examined lung function where exposures were below the OSHA permissible exposure limit of 0.1 mg/m^3. After adjusting for variables such as age, height and smoking status, the assessment failed to demonstrate a relationship between low level silica exposure and loss of lung function. In the study of tunnel workers, it was noted that lung function would have been affected by smoking, but it was found that at low exposures for alpha quartz (0.02 mg/m^3 to 0.04 mg/m^3), an annual decrement of FEV1 of 50 to 63 mL was observed (Ulvestad et al, 2001). Gamble et al (2004) noted that smoking must always be considered, as adverse changes in lung function have been attributed to smoking. This means that all studies of lung function will be biased if workers who smoke are not considered. A relationship between smoking and radiographic opacities has also been reported however this is not independent of respirable crystalline silica (RCS) exposure and pneumoconiosis (Hessel et al, 2004). There is a weak association between loss of lung function, smoking, and dust exposure, and increased loss of lung function with higher categories of silicosis (Gamble et al, 2004).

The American College of Occupational and Environmental Medicine ACOEM (2006) recommended that both cross sectional and longitudinal spirometry needs to be carried out to provide a better estimate of risk.

Canada Ontario hard rock miners.

Muir et al (1989) examined 2109 miner's x-rays which were read by 5 "B" readers. Of the 32 cases of 1/1+ silicosis identified; years since first exposure and age at diagnosis was recorded. Where 3 or more readers agreed on the classification, the case was confirmed and allocated into an exposure band which was based on historical exposure data (Table 2).

Reader	No. of cases	Mean respirable silica exposure (mg/m^3)[a]			
		0.05	0.10	0.15	0.20
1	14	0.5 (0.2–0.9)	1.2 (0.7–2.1)	2.1 (1.3–3.6)	3.2 (1.8–5.7)
2	24	0.6 (0.3–1.1)	2.0 (1.3–3.0)	3.8 (2.6–5.6)	6.1 (4.0–9.3)
3	24	0.5 (0.2–0.9)	1.8 (1.1–2.8)	3.9 (2.6–5.7)	6.7 (4.4–10.0)
4	14	0.4 (0.2–0.8)	1.1 (0.7–2.0)	2.2 (1.3–3.8)	3.6 (2.0–6.3)
5	7	0.1 (0.0–0.4)	0.5 (0.2–1.1)	1.1 (0.5–2.4)	2.1 (1.0–4.5)
Any reader	32	0.9 (0.6–1.5)	2.7 (1.9–3.8)	5.0 (3.5–7.0)	7.7 (5.3–11.1)
Majority (3 or more)	15	0.4 (0.2–0.8)	1.2 (0.7–2.1)	2.4 (1.4–3.9)	3.8 (2.2–6.5)
All readers	6	0.1 (0.0–0.4)	0.4 (0.2–1.1)	1.0 (0.4–2.2)	1.0 (0.4–2.2)

Table 2: Ontario hard rock miners - Estimates of cumulative risk and range in brackets corresponding with an "estimated" mean respirable silica exposure (mg/m^3) after 40 years of exposure. (Source: Muir et al, 1989, p.40).

Table 2 demonstrates the importance of having more than one "B" reader classify chest x-rays, and conducting health surveillance many years after exposure. (Muir et al, 1989).

Chinese pottery workers.

Sun et al (2011) in their study of 3250 Chinese pottery workers estimated the exposure response relationship between RCS and the incidence of category 1/1 silicosis for workers until the age of 65. The follow up period was approximately 37 years. This study differed from the previous studies in that both long term average concentrations were estimated as well as the highest annual concentration and the time since initial exposure. The risk of silicosis was 1.5 /1,000 (0.15%) for workers with a long term average exposure < 0.1mg/m^3.

Figures 6 and 7 show that low long term average exposures with a relatively lower maximum annual exposure (over a lifetime), 0.05 – 0.1 and < 0.1 respectively, have a much lower risk of causing silicosis than do lower average exposures with relatively higher maximum annual exposure of 0.05 – 0.1 and 0.1 – 0.5 respectively.

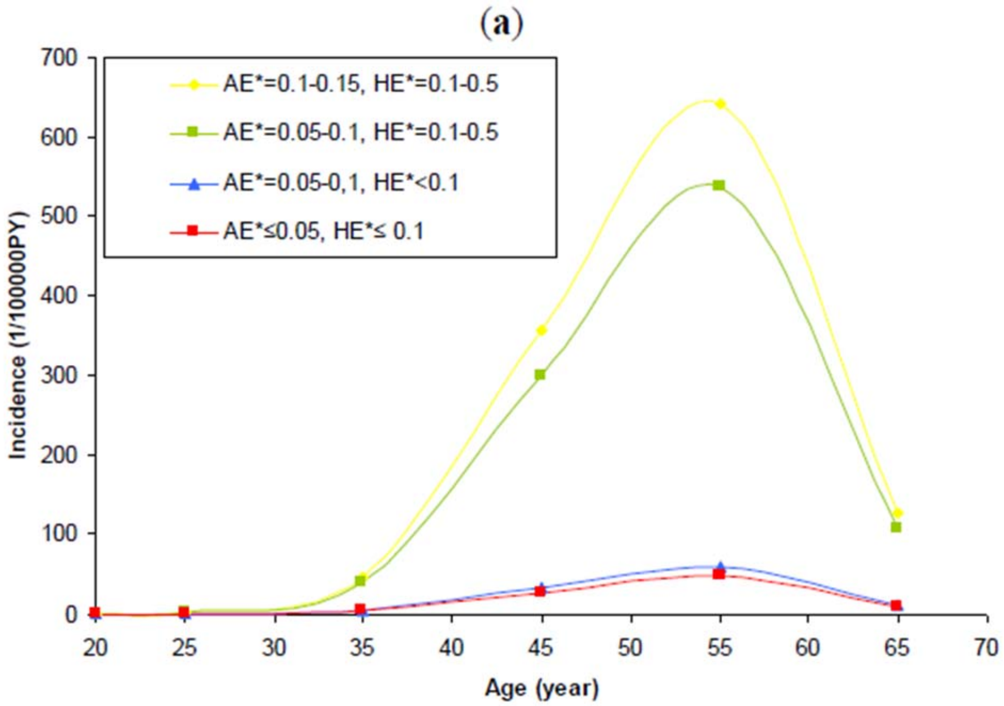

Figure 6: Chinese pottery workers incidence of silicosis, estimates of exposure and age that silicosis was determined.
(Source: Sun et al, 2011, p.2931)

Note: AE refers to long term estimated average exposure whereas HE means highest annual estimated average exposure.

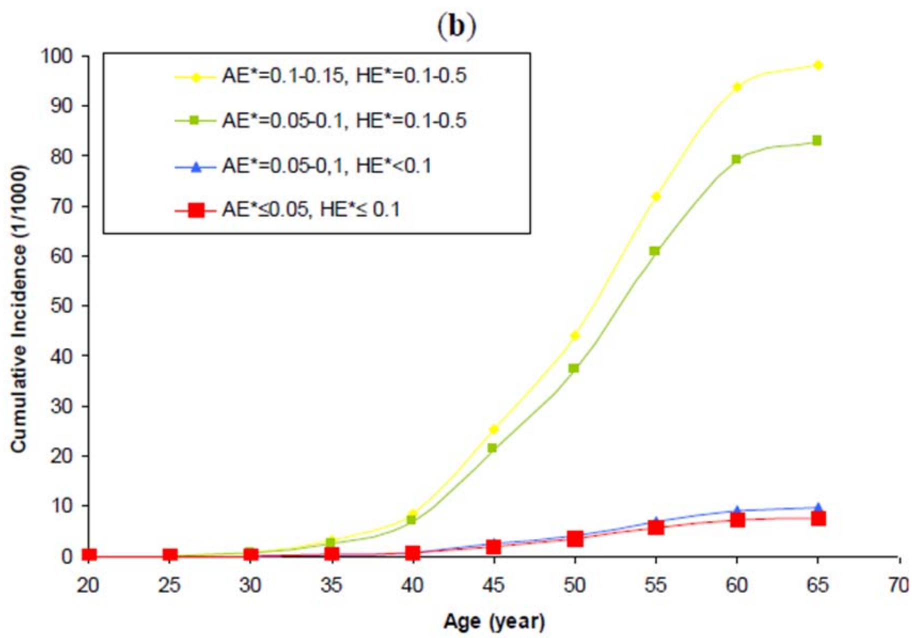

Figure 7: Chinese pottery workers cumulative incidence of silicosis, estimates of exposure and age that silicosis was determined. (Source: Sun et al, 2011, p.2931)

Note: AE refers to long term estimated average exposure whereas HE means highest annual estimated average exposure.

These results challenge the findings from previous studies, which have indicated that the risk of contracting silicosis is higher with an increase in cumulative RCS exposure based on a time weighted average long-term exposure typically reported as mg/m^3 years.

Methodology

Respirable crystalline silica (RCS)

Personal samples were collected according to AS2985-2004 using a cyclone sampling head attached to a sampling pump at a flow rate of 2.2 ($\pm$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 AS2985-2004. A correction factor was calculated and all sampling volumes were adjusted to align with the primary standard.

The 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 National Health and Medical Research Council NH&MRC (1994) document – Methods for Measurement of Quartz in Respirable Dust by Infrared Spectroscopy.

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 Simtars (nd):

$$RF = \frac{40}{h} * \frac{168 - h}{128}$$

Where: h = average hours worked per week over full roster cycle.

Lung function testing (spirometry)

Lung function testing was carried out using an Easyone® spirometer (Model 2001, Serial No 66033/2008). The method used to undertake the lung function test followed the method detailed 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.

Results

Respirable crystalline silica (RCS) exposures

Results from personal exposure monitoring, carried out in 8 quarries including dimension stone and sand processing operations, shows that many sites have respirable crystalline silica exposures in exceeding the Safe Work Exposure Standard (ES) (8-hour TWA) of 0.1 mg/m^3 as seen in Figure 8.

Of the 40 workers monitored, 34% (14) exceeded the shift adjusted occupational exposure standard (ES) and 22% (9) had greater than twice the ES. The majority of workers whose personal exposure exceeded the ES were not wearing respiratory protective equipment and indicated that they do not routinely wear respiratory protective equipment.

Figure 8 provides a comparison of the pooled exposure data for each quarry. As the working hours for many operators exceeded 8 hours the occupational exposure limit has been adjusted accordingly.

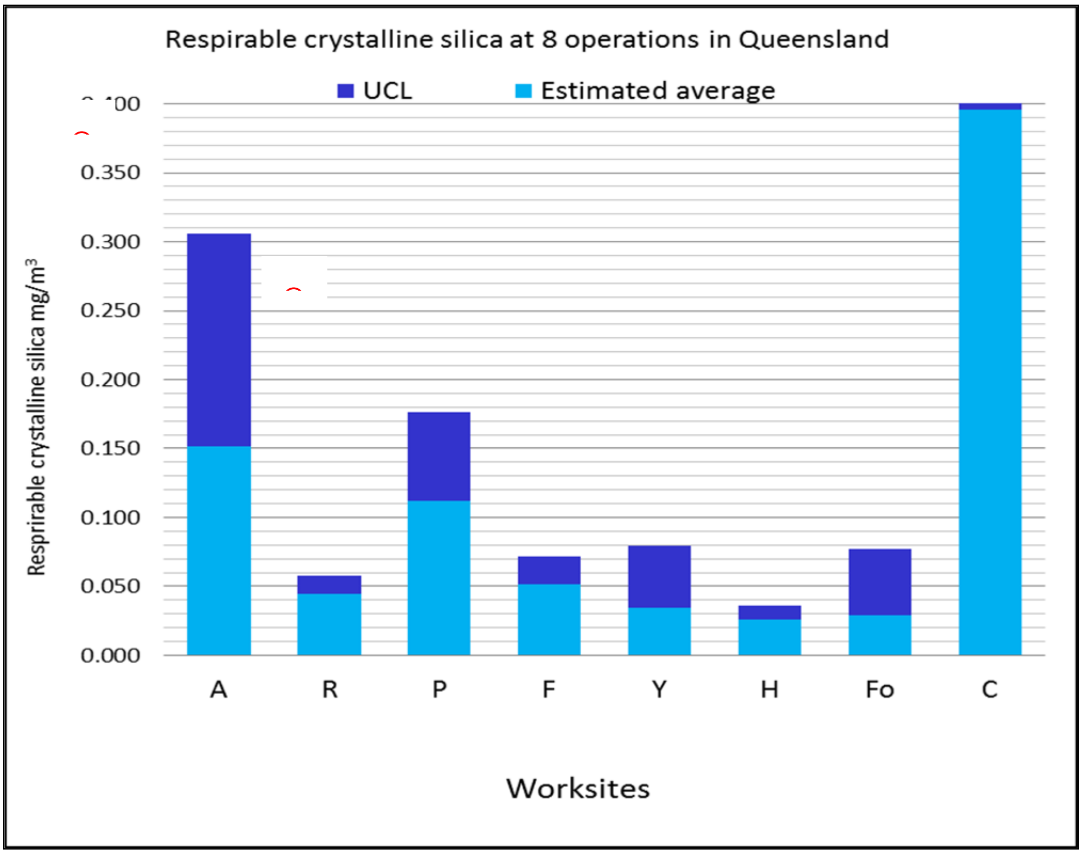

Figure 8: estimated average exposures and upper confidence limits to respirable crystalline silica each across eight operations throughout Queensland.

Statistical analysis carried out for each site failed to demonstrate any positive correlation between loss of lung function and RCS exposure. To get a clearer picture of the risk, further analysis was undertaken, initially to estimate average exposures for each job type (Figure 9) and then to examine if there was a correlation between RCS exposure for each job type and loss of lung function measured as FEV1 % of predicted (Figures 1 to 4 in *appendix A*).

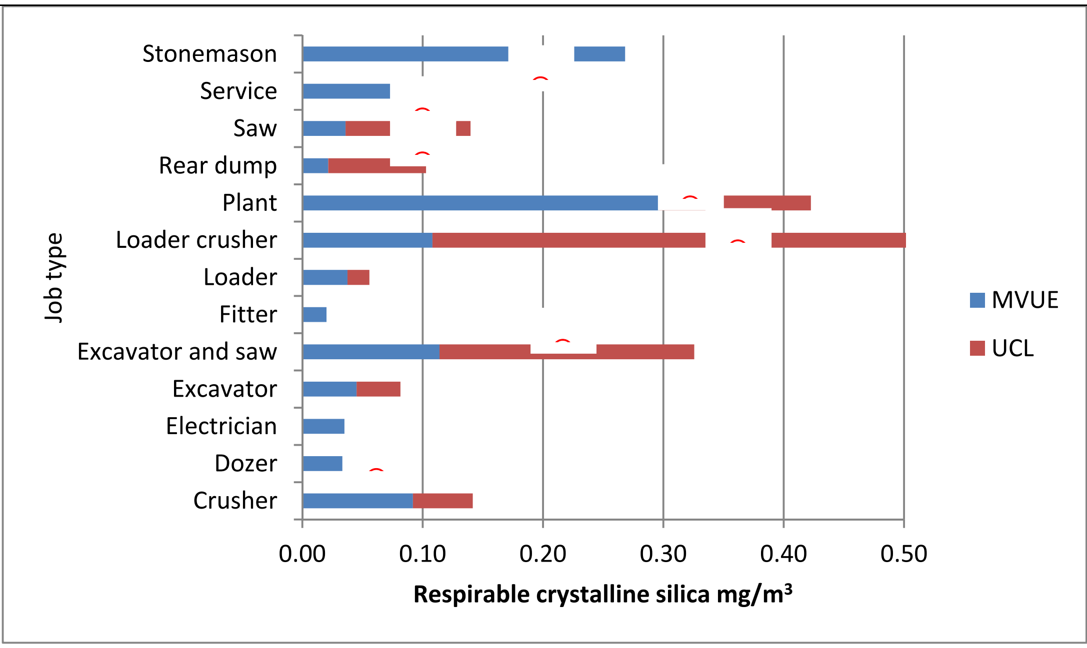

Figure 9: estimated average exposures and upper confidence limits to respirable crystalline silica for each SEG across eight operations throughout Queensland throughout Queensland.

Note: MVUE: Estimated average of a log-normally distributed data set.

UCL: Upper confidence limit (lands exact) of a log-normally distributed data set.

☹ : Unnaceptable exposures where respiratory protective equipment is not used.

In Figure 9, when exposures were pooled for each job type the exposure distributions for each job-type were found to be log-normally distributed. When the upper confidence limit UCL (Lands exact) was calculated for each job type and compared with the occupational exposure limit 7 of the 13 job types had an upper confidence limit that exceeded the OEL which means that these exposures are unacceptable where respiratory protective equipment is not used.

Initially the correlation between RCS exposure and loss of lung function was weak. However, when the analysis was repeated without the higher values of RCS exposure above 0.2mg/m^3, the correlation was much stronger.

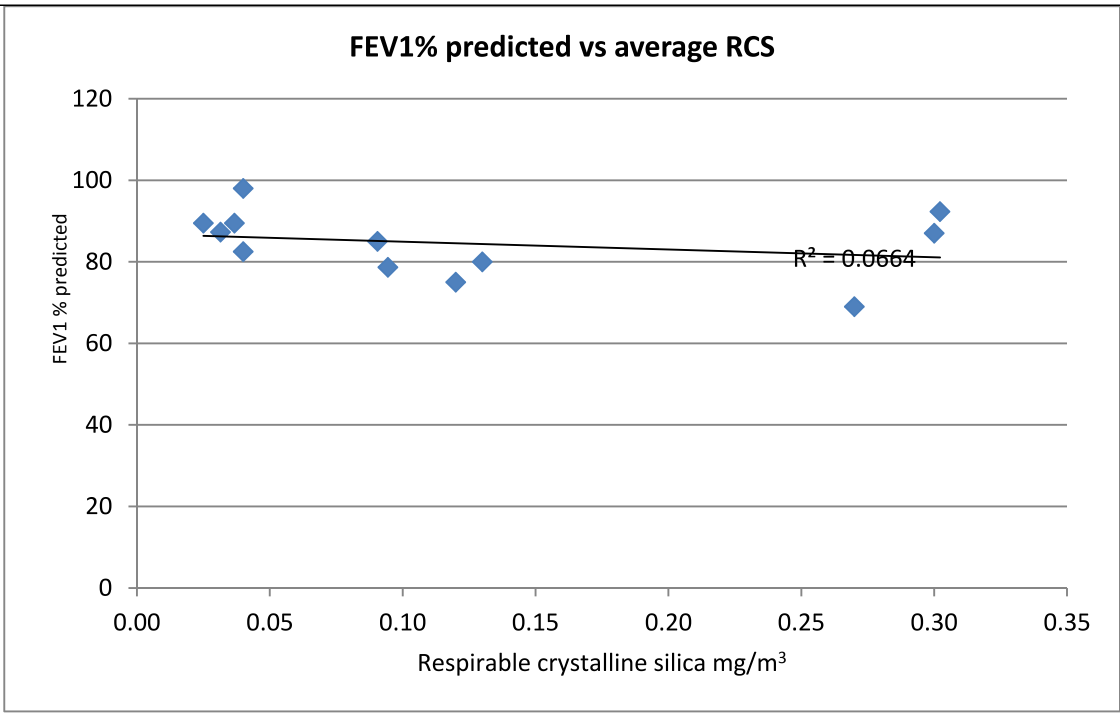

Figure 10: Graph showing correlation between FEV1% of predicted and average full shift exposure for each job type.

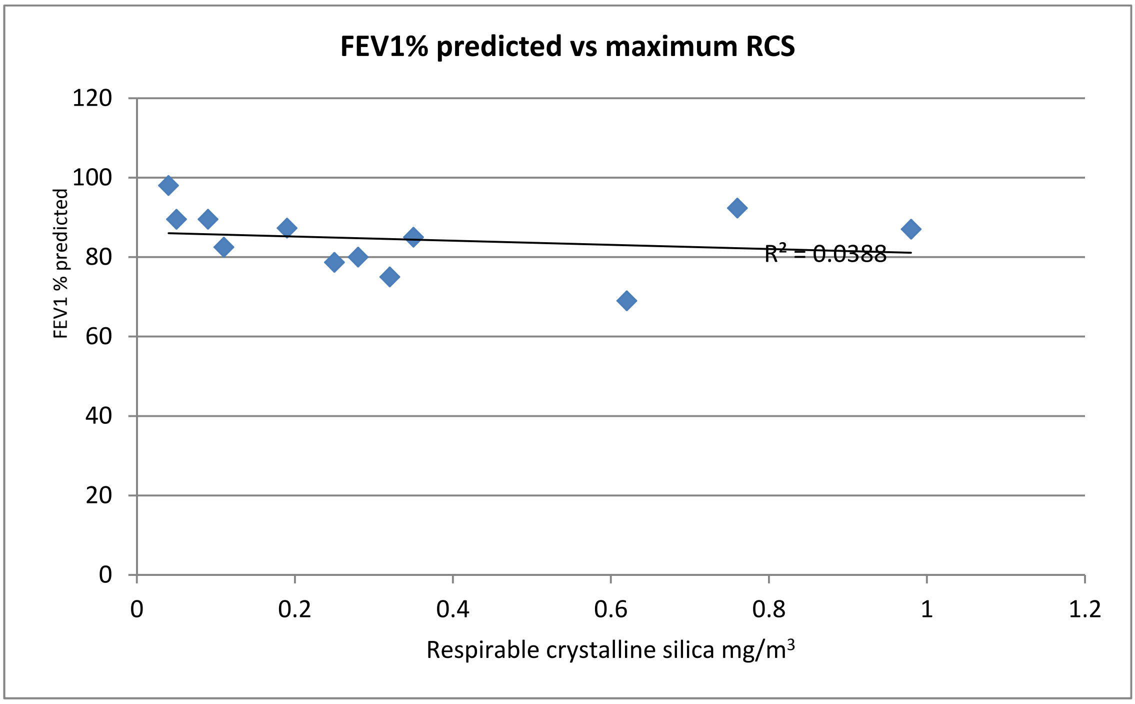

Figure 11: Graph showing correlation between FEV1% of predicted and maximum full shift exposure determined for each job type.

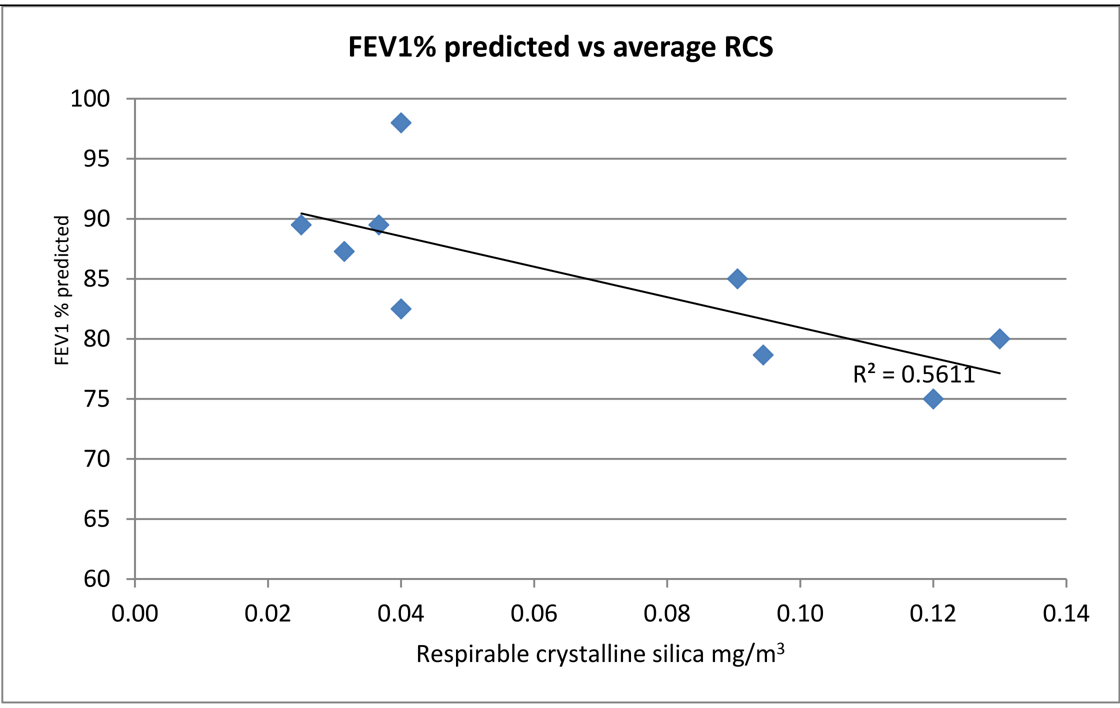

Figure 12: The same plot as figure 10, with a reduced y-axis scale and without including data points above 0.2mg/m^3.

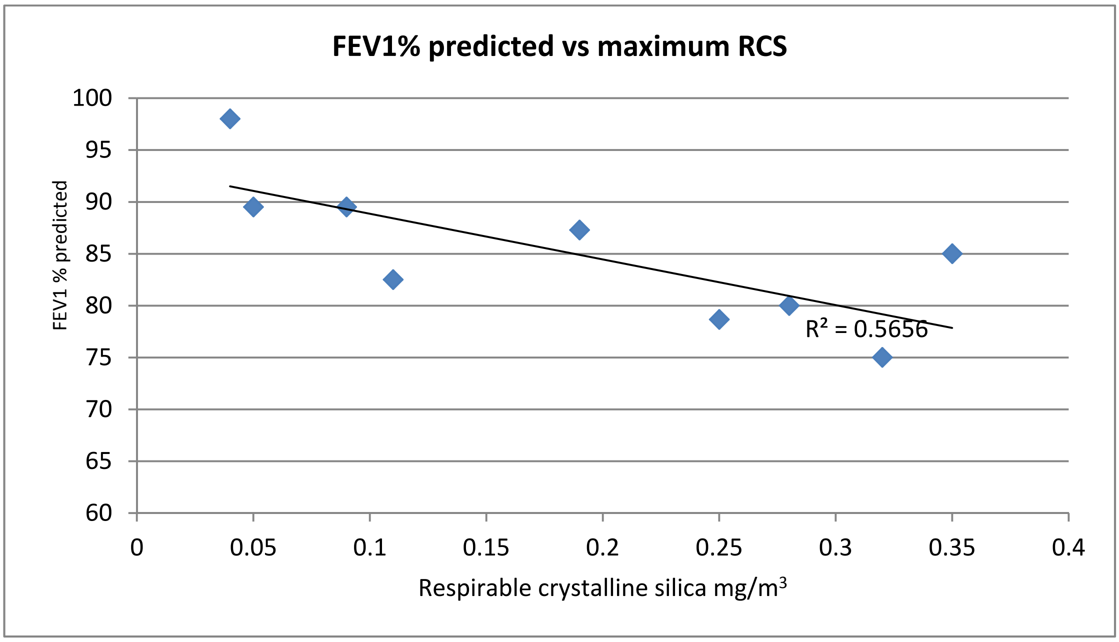

Figure 13: The same plot as figure 11, with a reduced y-axis scale and without including data points above 0.4mg/m^3.

Figures 10 and 12 use average RCS exposures for each job type, whereas Figures 11 and 13 use maximum RCS exposures. The difference between using average RCS exposures compared to maximum exposures is minimal. Comparison between Figures 11 and 13 show a marginally stronger correlation when maximum RCS exposures are used.

Discussion

In the last 25 years many consider that the risk of silicosis has been greatly reduced. However, in Australia it is unclear what impact long-term low level exposure to RCS has on health as monitoring is not undertaken once a worker leaves the industry, such as in retirement.

Shortcomings of studies, described in this paper, including studies of Western Australian miners (Hewson, 1996),Vermont granite workers (Vacek et al, 2011, Graham et al, 1991, Graham et al 1994, Verma et al, 2010), Ontario hard rock miners (Muir et al, 1989), and Chinese pottery workers (Sun et al, 2011) are discussed. All of these studies used historical data based on either: konimeter, impinger or Chinese total dust measurements. The accuracy of the konimeter varied based on the illuminator used, as discussed by Hewson (1996). Conversions were made using different conversion factors and results from short-term samples were used to estimate long term average exposures. All of the studies were based on either mortality or classification of silicosis, which is not curable.

If a correlation can be confirmed between loss of lung function and low level RCS exposure the authors believe that the appropriate use of lung function measurement (spirometry) can further prevent progression of lung disease resulting from RCS exposure. In this study, of the 40 workers tested for lung function, 3 were found to have restrictive lung function patterns and 10 had obstructive lung function patterns, although 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 RCS exposure (Figures 13 &14) was demonstrated, showing that there is a downward trend of lung function performance with higher RCS exposure. Further statistical analysis is required to determine the level of significance.

Of the 8 sites monitored, 3 had average exposures to RCS across all personal samples collected that exceeded the Safe Work Exposure Standard (TWA) adjusted for extended shifts. The study by Vacek et al (2011) assessed the risk from mortality records while studies by Hewson et al (1996), Muir et al (1989) and Sun et al (2011) determined the incidence of silicosis diagnosed as part of a longitudinal study. As noted previously silicosis is irreversible and monitoring to identify early symptoms of lung disease (such as lung function) is preferred.

The study of Chinese pottery workers described by Sun et al (2011), demonstrated that periods of higher exposure with a relatively low long term exposure greatly increased the risk of silicosis. This means that long term averaging of exposure may not be the best indicator of risk and challenges cumulative exposure measured as mg/m^3/year as the best indicator of risk. The study of Chinese pottery workers has reinforced the importance of considering both average and maximum exposure.

The American College of Occupational and Environmental Medicine (ACOEM), recommends health surveillance where exposure to respirable crystalline silica is > $0.05mg/m^3$ (ACOEM 2005). ACOEM noted that, as specified in the OSHA Special Emphasis Program (OSHA 2006), components of the surveillance evaluation should include the following:

- Occupational and medical history (questionnaire)
- Physical examination
- Purified protein derivative (PPD) tuberculin skin test
- Chest radiography
- Spirometry

OSHA (2008) now has a national emphasis program and the program also recommends that a respiratory questionnaire be included in health surveillance. The test results from the current study show that 14 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.

Spirometry should therefore be an integral part of exposure assessment and health surveillance, and results of spirometry testing should be clearly explained to the worker and manager.

Conclusion

Historical exposure monitoring data including results from the use of a konimeter or impinger has been used to estimate past exposures. Conversion factors used to convert particles per cubic centimetre (ppcc) to respirable crystalline silica (RCS) have varied depending on the study and organisation. Converting short term sampling data to exposures representative of full shifts is questionable. A number of organisations including NIOSH have endorsed these conversions and most studies discussed have relied on these conversions to quantify the risk. However, these data should be replaced with full shift monitoring for RCS wherever possible, using a method that conforms to the particle size distribution and collection efficiency curve according to ISO 7708. Monitoring should also be ongoing at quarries, and data collected in cross sectional and longitudinal studies.

Even though the sample size of the current study is small when compared with international studies, the data show how useful spirometry can be in determining lung function. Communication of results to both workers and the Senior Site Executive (SSE) or manager, along with results from RCS exposure monitoring, can raise awareness and prompt further health assessment and dust control.

This study serves as a prompt to re-evaluate how worker health and health surveillance should be managed and regulated in Queensland mines and quarries. It has also highlighted that controlling exposure to RCS should still be seen as a priority in mining and this is reinforced by findings from international studies described in this report.

Further follow-up, including assessment of chest x-rays by trained "B" readers for the workers in this study may strengthen the findings. Tracking these workers with regular dust monitoring, and health surveillance will also increase the focus and raise awareness for worker health at industry and Australian Government levels.

Further research is required, to look at how exposures are monitored and assessed, incorporating both maximum and average exposures. It may be that a short term exposure limit (STEL) is considered for the mining industry, and when the measurement is technically feasible the Government should consider setting a STEL for RCS.

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Queensland's Foundry Industry and Dust Exposures – Looking Forward, Looking Back

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A respirable dust and RCS survey undertaken on 12 foundries in 2009 is compared with much the same foundry group between 1982 and 2002. We also surveyed the foundries for their knowledge about regulatory requirements, exposure standards, information sources, control strategies, air monitoring and health surveillance. Historical data were all converted to ISO measured equivalents. Of six similarly exposed groups (SEGs) examined, 3 had improved significantly, 2 remained stationary and 1 had worsened. Although the use of RPE increased significantly, some 14.5% of all workers remained at potential risk through failure to use any additional RPE. In the companion administrative audit, lack of knowledge and lack of monitoring programs contributed to poor performance; workplace size was not a reliable predictor of compliance on dust exposure compliance. Likewise high administrative compliance audit scores were not reliable for predicting the likelihood of compliance on dust exposures.

Introduction

Foundries have been an industry with a long-term use of silica, and have historically been associated with cases of silicosis. Little data on actual incidence or prevalence of respiratory disease in foundries has been recorded in Queensland. A survey of 1118 foundry workers conducted between 1946 and 1948 (GORDON, 1950) showed that amongst those having worked long enough to show radiological change (388), there were only 13 cases, 10 of whom were Cat. 1. Similar studies have not been subsequently conducted, although data from the Queensland Employee Injury Data Base 1999 - 2007 identified 2 cases of silicosis in foundry workers and 3 others in engineering production processes, possibly foundries. The number of foundries has fallen in the 60 years prior to 2010 from around 60 to fewer than 20.

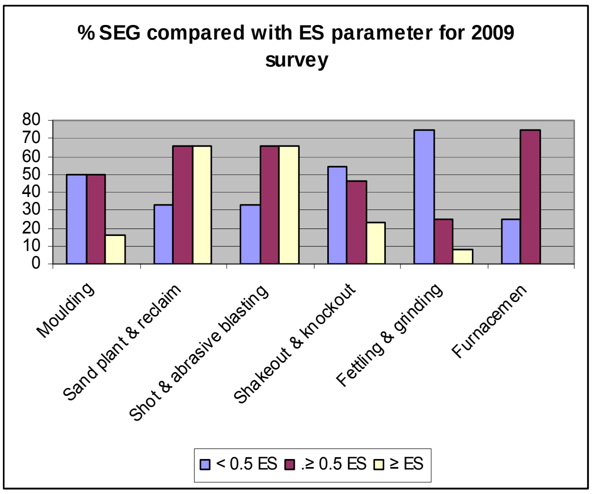
Nonetheless, respirable crystalline silica (RCS) remains a significant agent of interest for occupational health because of its widespread workplace occurrence and the large number of those potentially exposed. Other respiratory conditions are now more likely than silicosis. The National OHS Strategy 2002-2012 identified two diseases – respiratory morbidity and cancer – in both of which silica exposures are implicated. Foundries are faced with a range of airborne contaminants which can cause adverse respiratory outcomes including isocyanates, sulphur dioxide, formaldehyde and various amines. During the 10 year period of the OHS Strategy, the exposure standard (ES) for RCS was reduced from 0.2 mg/m^3 measured according to the BMRC penetration curve to 0.1 mg/m^3 measured according to the ISO penetration curve. Following that change of the ES, NOHSC expressed to the jurisdictional regulators, their interest in determining whether Australian workplaces had demonstrated any reduction, or any effort to make reduction in RCS exposures. Although changes in disease outcomes would not be directly identifiable in such a short time frame as a result of either any newly embraced industry strategy or the reduced ES, opportunity did exist through using historical foundry exposure data and a new survey to compare the risks represented by previous and current RCS exposures. Any improvements might be apparent by reduction in industry average exposures. In addition, as hazardous substances legislation had been in place for 15 years, the opportunity presented itself to make an assessment through a questionnaire of how the industry used the different tools available to manage the RCS issues in their workplaces, and whether they really were effective. Thus we could compare the real exposure performance of individual workplaces with their use of administrative tools to manage the RCS risks and perhaps identify those tools which were most effective. The tools of interest spanned information and its sources, knowledge about RCS, use of air monitoring and knowledge about controls and training and education.

Audit program methodology

Around two thirds of all Queensland foundries comprising small, medium and large workplaces were audited for respirable dust and respirable crystalline silica across all 5 Workplace Health and Safety Queensland (WHSQ) regions during 2009 and early 2010. Personal gravimetric dust samples were collected using AS 2985 (1987 and 2004) techniques over 6-7 hour periods, and RCS was measured by infrared spectrometry. Sixty measurements are available from the earlier survey and 76 from the 2009 survey. An administrative audit was also simultaneously conducted in each workplace to assess their use of the critical resources in controlling RCS risks. Scores from the administrative audit could be compared with the percentage of exceedances of the RCS ES to see if there was any correlation between the way foundries reportedly managed their silica exposures and the real performance in terms of controlling RCS exposures. This has some application as Australia moves into its new harmonised legislation with the need for regulators to establish reasonable belief about possible non-compliance for issuing improvement notices. Regulators might otherwise require vastly expanded resources to carry out confirmation of non-compliance where a person in control of a business or undertaking genuinely believes they are already compliant. Regulators may now have to prove non-compliance.

Results of respirable dust and RCS exposures

Figure 1 Compliance performance for SEGs in 2009



Results for six different SEGs (refer to Table 1 for all SEG types) are presented graphically in histogram Figure 1 for the 2009 survey (WHSQ, 2010). In the initial pre-2002 surveys, there were 11 foundry surveys and 12 in the 2009 survey. Some bias in comparing the 2009 with the pre-2002 surveys may have been introduced because the 2009 survey included two very small foundries whilst the pre-2002 survey data were collected predominantly from medium and large foundries. The small foundries generally had low silica exposures. The direction of bias is not revealed. Data treatment presented some challenges: these were (i) constructing useful SEGs, (ii) comparing the exposures which were made by two different measuring conventions (BMRC and ISO), (iii) making some compliance decisions against an ES when the shift length was different in different workplaces, and (iv) dealing with truncated RCS data which are lower than the limit of detection (LOD).

For practical purposes, a cross-workplace approach was used to construct the six separate SEGs, treating the same task in the different workplaces as pieces of data all belonging to a specific SEG. To address the difference in measuring conventions and allow a reasonable degree of confidence in comparisons between the two survey periods, a reduction of 30% is applied to the pre-2002 measurements determined by converting the BMRC to the CEN-ISO-ACGIH curve with a division of the original BMRC results by an average of 1.4 [based on the range GROVES et al. (1994) 1.55; LIDEN and KENNY (1993) 1.1; HEALTH & SAFETY EXECUTIVE (not dated) 1.33].

Varying shift length posed problems. Foundries surveyed worked from eight to nine and three-quarter hour shifts. To facilitate simple treatment of grouped results in the different SEGs, the exposure standard has been adjusted slightly (and uniformly) downward to account for a slightly longer work shift. A review of the industrial relations working conditions for the 1981–2002 surveys confirmed that foundry workers during that time were most likely to have worked similar hours with regular overtime arrangements. At 9 hours, the Brief and Scala shift-adjusted RCS exposure standard is 0.083 mg/m^3 and for 9.5 hours it is 0.076 mg/m^3. This analysis adopts an average adjusted RCS exposure standard of 0.08 mg/m^3. To prevent the statistical lognormal analyses from being distorted by a significant number of zeroes (GSD becoming unrealistically large) all RCS non-detects were set to the value of the LOD.

What were the trends in exposure?

Exposure trends could not easily be determined just by comparing extent of compliance where both the RCS standard and the method of measurement changed between the two survey periods and shift length varied from workplace to workplace. Since a compliance statement is non-parametric, to enable a comparison of the trend between the two time periods for the different SEGs, resort has to be made to the use of averages. In this case we have used the Geometric Mean (GM). An Arithmetic Mean could also be considered suitable for substances with chronic health risks. Table 1 presents some useful average figures from a forced log-normal probability analysis for each of the different SEGs.

However, the use of simple averages can be misleading for making judgements about the overall extent of compliance. For interest, all SEGs where sufficient data points were available (n>3) were subject to rough analysis using IHSTAT® to see if there was any likelihood of "industry compliance" for each of the SEGs.

SEG	<2002 mean RCS conc. mg/m^3	2009 mean RCS conc. mg/m^3	Apparent Relative average compliance performance
Moulders	0.03	0.03	No change
Sand plant, mix & reclaim	0.18	0.08	Much better
Shot & abrasive blast	0.06	0.16	worse
Shakeout & knockout	0.09	0.03	Much better
Fettling & grinding	0.13	0.02	Much better
Furnace men	0.05	0.05	No change

Table 1 Comparative RCS exposure in two surveys

Using some conventional measures such as the 95th percentile being below the ES, there was no "sector" compliance for any SEG. The 95th percentiles in mg/m^3 were moulders (0.14), shakeout operators (0.51), fettlers (0.10) or sand plant/reclaimers (1.32). The shift adjusted ES was 0.083 mg/m^3. As an industry sector, there would be little chance of being able to claim regulatory compliance. However, this particular analysis suffers from the fact that within each of moulder and fettler groups, there are possibly two distinct SEGs, one of good performing foundries and another of more poorly performing ones. This is evidenced by lack of lognormality and/or high GSDs (ranging around 2.4). Some individual foundries were better than others. Nonetheless, it is instructive to consider a compliance measure which takes into account the likely probability of results when making judgement about the real performance of the overall industry sector.

Relative performance and trends in controls

Foundries have recognised the risks of silica exposure and have made significant investment in control of this hazard, principally though use of exhaust ventilation systems and use of particulate respiratory protection. Therefore the exposure data reflect only the atmospheric contaminant concentrations but do not reflect the actual personal exposures, some of which were reduced considerably by using respiratory protective equipment (RPE). Twenty one percent (21%) of individual RCS exposures in the 2009 survey exceeded the ES. Comparable performance in the UK foundry industry (COTTON and UNDERWOOD, 2009) showed that 13% of RCS exposures exceeded the WEL of 0.1 mg/m^3.

Overall, the wearing of particulate respirators rose markedly from 8 per cent in the earlier studies to 26 per cent in the 2009 survey. However, use of RPE was not confined to, nor always worn by, those with the highest RCS exposures. While nearly all workers with excessive exposures in the pre-2002 surveys failed to wear any RPE, in the 2009 survey overexposed workers without protection fell to 68 per cent.

Figure 2 compared with Figure 3 shows that for most SEGs, the proportion of workers with no RPE amongst the heavily exposed has fallen dramatically except amongst moulders. All moulders with excessive RCS exposure wore no RPE. RPE was available to more workers in many foundries, but was not always used. Reasons for non-use varied from comfort issues to abhorrence of using it. In the main, for many operations in foundries, there is a genuine lack of perception about the risk since there are no real visual clues about the existence of a hazard. This is because respirable dust is essentially invisible and many foundries have not undertaken any independent sampling in recent times which would have confirmed the need for use of RPE or other controls.

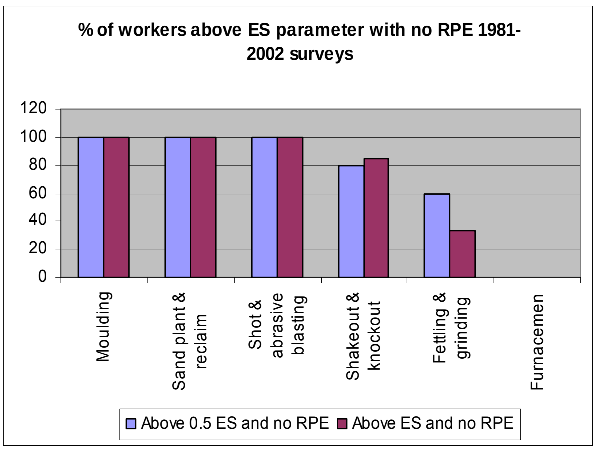
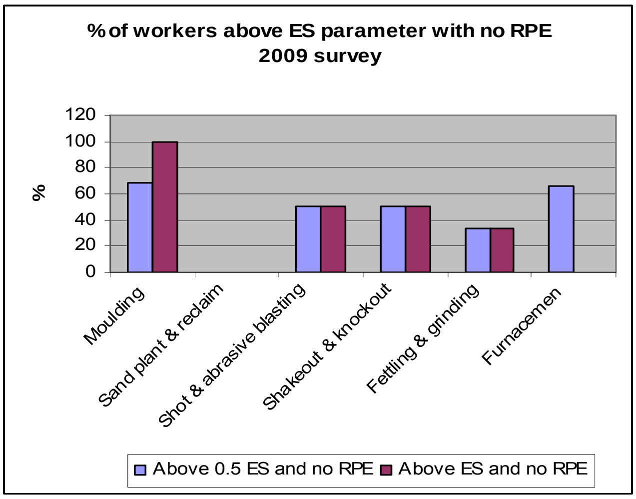


Figure 2: Proportion of workers in each SEG who exceeded either the 0.5 ES (Action Level) or the ES who wore no RPE 1981-2002

Not all those with the highest exposures were properly protected. Of the 16 of 76 (21 per cent) workers who had the highest personal RCS exposure ≥ES, 11 of the 16 (or 68 per cent) wore no RPE in conditions where exposures ranged up to more than three times the exposure standard for RCS. The majority were either moulders or shakeout operators.



Another eight per cent of workers wore RPE for part of their task, sported beards or used only one strap on disposable respirators. In the 2009 survey, 48 per cent of all monitored exposures were ≥0.5 $ES_{adjusted}$ for RCS, and of these, only 30 per cent wore RPE of varying effectiveness. Some foundries which may have extensive use of powered air purifying respirators (PAPRs) were not included in the most recent survey.

Figure 3: Proportion of workers in each SEG who exceeded either the 0.5 ES (Action Level) or the ES who wore no RPE 2009

The moulder SEG is probably the largest silica exposed SEG in the industry, but improvement has not really been noted. It may be that this is a group for which, perforce of the kind of work involved, is at an irreducible level of exposure in terms of the higher order controls that can be successfully implemented. However, in terms of the individuals within this SEG, the 2009 survey showed that 100% of the over-exposed moulders wore no RPE as an additional control, and that position has remained unchanged since the previous survey. In nearly every other SEG, the proportion of over-exposed not wearing RPE has decreased greatly. A survey of random Queensland foundry workers taken in 1945 (FOLEY, 1945) found a prevalence of 5% silicosis (in workers with more than 5 yrs of exposure) and identified moulders as a group of significant concern. Noted at the time that the workers could not "see" the dust hazard, this invisibility of the hazard today, some 65 years later, still remains a significant barrier to the wearing of RPE when it is needed.

Local exhaust ventilation is effectively used in many fettling, dressing and grinding operations (generally with a high level of compliance on RCS exposures). In some moulding sand delivery, hand mould shaping, and other operations involving sand pouring or pneumatic pumping that have recorded very high peak exposures (in excess of 10 mg/m^3), and where ventilation could prove very beneficial, there is mostly absent or poorly functioning ventilation and dust control.

What did administrative auditing reveal about capability to manage RCS risks?

Sources of regulatory Information: government information (website, Foundry Industry Guide) was used by 66% of the group, and industry sources by 16 %. About 20 % sought no information about RCS.

Knowledge about RCS: the MSDS was used as a source of information on risks by about two-thirds of the group. Low professed level of knowledge about silica and its risks was loosely correlated with non-compliance on RCS exposures. Some very small workplaces had low levels of knowledge but also had low levels of risk.

Risk assessment processes: these were conducted in just over half the workplaces. Foundries which did not undertake formal risk assessments were more likely to have multiple unprotected RCS exposures ≥ES than those which did risk assessments. There was little effort to determine risk by reviewing exposures through air monitoring on a timely basis. The administrative risk assessment procedure introduced with the National Model Regulations of 1995, and which had become understood, if not well adhered to, is set to disappear in 2012 with the new harmonised legislation.

Knowledge about the RCS ES and its use: only 33% of respondents were acquainted with the ES and had used it actively in controlling exposures. Another 33% thought that a consultant had used the ES in assessing their workplaces. The role of the ES in compliance is undervalued.

Air monitoring and health surveillance: two-thirds of workplaces reported that air monitoring had been conducted, but of these, only 25% had conducted any air monitoring in the previous two years. External consultants usually conducted monitoring, but for some, a distant past monitoring by the regulator was their only connection with this essential tool. Only two of twelve foundries undertook health surveillance. However, the dust monitoring results revealed need for limited health surveillance in another three workplace unless dust levels could be sharply curtailed.

The way controls were selected: Workplaces which did risk assessments were able to prioritise choice of control from the hierarchy. Except for the smallest foundries with low throughput which were able to record very low exposure without conducting a formal risk assessment, risk assessment was used by some for organising ventilation, and for others in the selection of their respiratory protective equipment.

Having conducted a risk assessment did not, however, always result in protected or low RCS exposures. In one such instance, the risk assessment failed to recognise that additional controls were required – 38% of monitored workers in that workplace were unprotected with exposures > ES for RCS. This was an example of too much reliance being placed on uncritical use of higher order controls (different ventilation regimes) without assessing their effectiveness.

Training and induction: general training was undertaken in all foundries, and training on RCS in all but one foundry, but was not complemented by proper use of RPE in 33% of foundries. This was observed in practice with workers seen using one strap of respirator, sporting beards or using RPE inconsistently during dusty work.

How do the audit results compare with the RCS monitoring?

To compare the audit with the RCS monitoring outcomes for each foundry, the following Table 2 has been constructed by combining three measures

- a score on the administrative compliance audit
- percentage of RCS exposures ≥ ES
- percentage of unprotected exposures ≥ ES

High audit scores indicate that the workplace has implemented all the main elements of the hazardous substances regulation in a systematic way, and has informed itself widely about silica issues.

Score from audit	% Exposures ≥ ES	% Unprotected exposures ≥ ES	Admin outcome
33	0	0	3
39	11	11	
14	38	38	1
23	17*	8	
27	57	43	1

30	25	25	
27	0	0	3
28	0	0	3
18	44	11	2
8	0	0	
7	28	28	1
9	**0**	**0**	**3**

Table 2 Cumulative scores on administrative audit and measured RCS compliance

* includes a bearded RPE wearerworkplaces marked pink or (1) tend to have low score and high proportion of their overexposed workers who are unprotected workplace in yellow or (2) have a low score and low proportion of their overexposed workers who are unprotectedworkplaces in green or (3) all have either a high or a low score BUT no overexposed workers

This comparison shows that the administrative audit score is an indeterminate indicator of compliance on actual RCS exposures. Monitoring of RCS is more reliable indicator on compliance.

What are some implications of the administrative audit?

The audit provides several key findings relating to the purpose of the intervention. They are

A conventional audit of the suite of activities specified by regulation can be an indeterminate predictor of actual compliance. It may be an indeterminate means on which to establish reasonable belief for non-compliance.

Lack of a risk assessment was more often linked to a larger number of potential overexposures.

Those workplaces with a good knowledge about silica tended to know about the ES for RCS, and their workplaces had fewer or no non-compliances.

Workplaces tended to choose RPE as the most utilitarian control, though this was used by only 26% of individual workers.

Training was clearly valued in terms of informing about risk.

Air monitoring was highly regarded as a premium informative tool, but much less observed in practice.

The full regulatory process, followed comprehensively including dust monitoring, can be confidently expected to achieve its aim of controlling risks from RCS.

For most medium and small foundries, their audit responses showed that the complex compliance process mandated by regulation was difficult to implement.

The relatively low knowledge base of about half the respondents on silica, and low use of the Code of Practice and the ES, suggest there is still room for improvement.

Conclusion

The recent respirable dust and RCS survey of Queensland foundries has identified overall that silica exposure has improved since the pre-ISO measurement period for some RCS exposed tasks but not for all. The RCS standard change is unlikely to have been the catalyst for the small improvement seen since foundries have not, with one or two exceptions, been pursuing regular dust monitoring. There remain a significant number of workers exposed above the RCS ES who are not adequately protected by use of RPE, notably moulders. A number of local exhaust ventilation controls performed poorly. Extensive administrative auditing of risk control processes proved a poor indicator of compliance performance or compliance capability. The “invisibility” of the dust hazard and its subsequent realised risk is a longstanding barrier to achieving high level of compliance in control of RCS.

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The role of a chemical assessment agency in enhancing OHS − the contribution of NICNAS in Australia

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Keywords

NICNAS, assessment, industrial chemicals

Abstract

Since 1990 the National Industrial Chemicals Notification and Assessment Scheme (NICNAS) has been assessing the risk of individual chemicals to workers, the public and the environment. This is done through evaluation of the hazards and exposure relevant to the chemical and the situations in which it is used. The recommendations arising from NICNAS assessments are directed to industry and other regulatory and non-regulatory bodies, allowing NICNAS considerable influence in the management of industrial chemicals in Australia. This paper will give an overview of NICNAS's place in the Australian regulatory framework, and consider its impact on the management of industrial chemicals, using examples relevant to occupational health and safety. The paper will also outline one of NICNAS's proposed key initiatives for the future − implementation of a framework for the assessment and prioritisation of existing chemicals. This initiative seeks to address concerns regarding the large number of unassessed chemicals potentially in use in Australia.

Regulation of chemicals in Australia

There are many contributors to the safe use of chemicals in Australia. For occupational use, this includes the workers themselves, employers, professional bodies and industry associations. Government has an important role in risk identification and risk management through a range of national and state/territory agencies. These may be peak standard setting bodies or the regulators of particular sectors or geographical regions.

The current system of chemicals management operates within a complementary, whole of Australia regulatory framework. The roles of different agencies include policy oversight, hazard and risk assessment, standard setting and risk management, and administration and enforcement. The framework is acknowledged to be complex, and there are several reasons for this. Firstly, chemicals are used in very different sectors , e.g. food, cosmetics, therapeutic, agricultural and veterinary products. Secondly, chemicals regulation is mainly associated with generic regulatory frameworks that cover more than just chemicals, such as those for workplace safety, transport, protection of the environment or security matters. A third factor that has shaped regulation is the distribution of responsibilities between Commonwealth and States/Territories under Australia's constitution. For efficiency and consistency, work is often carried out at both levels of government, e.g. in developing national standards for implementation by States/Territories. Because of the inherent complexity, good communication systems and coordination are important for effective functioning of the overall system.

NICNAS' place in the Australian chemicals regulatory framework

Regulatory role

At the national level, chemicals are regulated under different schemes depending on their end-use. Industrial chemicals regulated by NICNAS are defined as all those not classed as therapeutic goods, agricultural chemicals, veterinary medicines or as food additives. The business sectors and range of applications for industrial chemicals are diverse because of the nature of the definition, and range from cosmetics to coal processing. Most industrial chemicals will be used in workplaces as part of their life-cycle. Only those household or cosmetic products imported fully formulated and packaged for consumer use will not have the potential for significant worker exposure.

NICNAS sits within the Commonwealth Department of Health and Ageing (DoHA), with its Director holding a statutory position. The core functions of NICNAS are set out in the *Industrial Chemicals (Notification and Assessment) Act 1989* (the ICNA Act) and associated regulations, and provide for:

(a) a national system of notification and assessment of industrial chemicals for the purposes of:

(i) aiding in the protection of the Australian people and the environment by finding out the risks to occupational health and safety, to public health and to the environment that could be associated with the importation, manufacture or use of the chemicals; and

(ii) providing information, and making recommendations, about the chemicals to Commonwealth, State and Territory bodies with responsibilities for the regulation of industrial chemicals; and

(iii) giving effect to Australia's obligations under international agreements relating to the regulation of chemicals; and

(iv) collecting statistics in relation to the chemicals;

(b) national standards for cosmetics imported into, or manufactured in, Australia and the enforcement of those standards.

NICNAS is therefore an entity-based notification and assessment scheme, i.e., it does assess industrial chemicals in the context of their use but does not assess products (mixtures of chemicals) or articles. The scope of the risk assessment covers three elements: risk to workers, to the public and to the environment, and considers the full life cycle of the chemical in Australia. Integrated reports including the conclusions and recommendations of each assessment are publicly available via the NICNAS website.

Assessment programs

NICNAS has two major assessment programs: one evaluates the safety of new industrial chemicals prior to importation or manufacture; the other focuses on the assessment of chemicals already in use in Australia, in response to specific concerns about their health or environmental effects. The distinction between chemicals new to Australia and those considered to be "existing" is made on the basis of whether or not they are listed on the national inventory maintained by NICNAS, the Australian Inventory of Chemical Substances or AICS. The majority of the approximately 39,000 chemicals on AICS are the 38,000 chemicals nominated as already being in use in Australia when NICNAS was set up in 1990. The remainder of the chemicals have been added to AICS after being notified and assessed as new chemicals in certain (certificate) assessment categories.

Although there are many similarities between the assessments carried out on new and existing chemicals, there are some significant differences. In general, new chemicals must be notified and assessed by NICNAS before they are introduced into Australia for the first time. Some exemptions to this apply, such as low volume chemicals that meet certain requirements. However only a small subset of the 38,000 grandfathered existing chemicals have been assessed, with these being selected as a priority on the basis of concerns. The scale of a new chemical assessment is often much smaller than an existing chemical assessment. Existing chemicals may have extensive and complex toxicological data to be evaluated, with the overall effect of requiring more resources for assessment. Where existing chemicals have been in use for many years in a range of uses, substantial work may be needed to determine the exposure of humans and the environment through the life-cycle of the chemical.

NICNAS contribution to chemical safety

Assessment outcomes

NICNAS makes its major contribution to chemical safety through its assessments of individual chemicals. NICNAS aims for the risk assessment effort to be commensurate with the hazard and/or exposure to the chemicals, where this can be sufficiently defined in advance of the assessment. Key outcomes of the assessments include recommendations to industry on the use of the chemical and recommendations to other bodies to implement control measures, illustrating that much of NICNAS' influence occurs through others. To facilitate this, NICNAS recommendations are framed in accordance with nationally agreed frameworks e.g. for hazardous substances, dangerous goods or poisons scheduling. Strong connections with industry and community stakeholders, researchers, and with other national, state/territory and overseas agencies is crucial to NICNAS carrying out its work effectively within the regulatory framework.

There are five possible outcomes from NICNAS assessments for existing chemicals and for new chemicals in certificate categories:

- Recommendations to industry on the safe use of the chemical. These are based on the identified human health and environmental effects of the chemical and the proposed use and exposure.
- Regulatory action by NICNAS through annotation of the chemical on the AICS with conditions of use.
- Recommendations to other agencies with regulatory/standard setting responsibilities to implement control measures.
- Post-market responsibilities on introducers such as notification of changed circumstances of use or new information becoming available. These changes may be sufficient to require re-assessment of the chemical.
- Dissemination of chemical safety information, including published reports.

For new chemicals assessed in permit categories, permit conditions of use are specified, and brief details of the assessment are published.

New chemicals assessments

In 2010-11, NICNAS assessed 282 new chemicals, which is a typical number per year. Of these, 165 chemicals were assessed in certificate categories, where recommendations are made and reports published. The remaining 117 chemicals were introduced into Australia under permit categories.

OHS was considered in all assessments. Most frequently, specific recommendations were made to industry on safe handling, referring to the hierarchy of controls and national codes of practice under the Safe Work Australia framework. Recommendations were made to agencies with regulatory / standard setting responsibilities, including hazard classifications for 54 chemicals, and dangerous goods classification where appropriate. Over 280 MSDS were reviewed for compliance with the National Code of Practice. (MSDS are required for all assessments and are available for inspection). Conditions were specified for secondary notification (when re-assessment may be needed because of changed circumstances).

While the hazard profile of the 282 chemicals is varied, and many are non-hazardous, an example of a health hazard frequently identified in new chemicals assessment is skin sensitisation. For such chemicals recommendations are made regarding hazard classification, and hazard communication through MSDS and labels. Recommendations to industry include workplace controls to minimise exposure, and health surveillance for workers.

Recent reforms to new chemical assessment categories have been designed to encourage the introduction of chemicals with low hazard profiles or those used in highly controlled settings, and this is an additional contribution to chemical safety.

The use categories of new chemicals assessed in the last three years are shown in Figure 1 below.

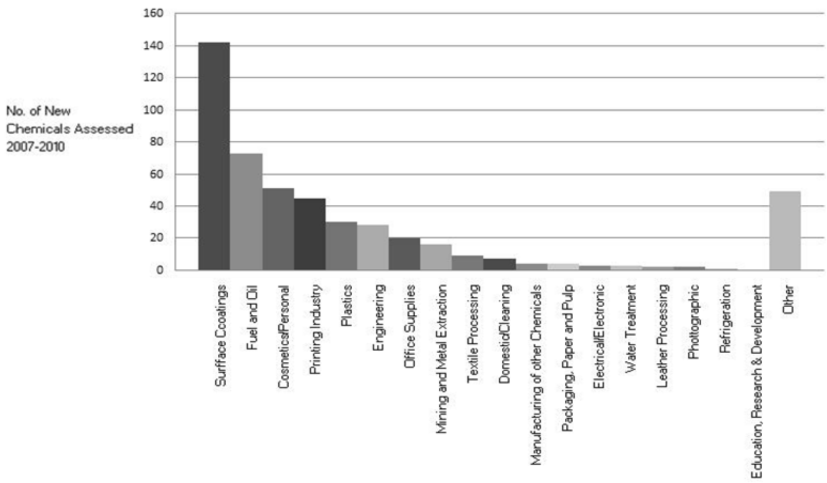

Figure 1

Existing chemicals assessments

Over 200 existing chemicals have been assessed by NICNAS overall, with several more in progress. The majority of these have been Priority Existing Chemical (PEC) assessments, chosen from chemicals nominated because of health or environmental concerns. Many PEC chemicals are in wide use e.g. benzene and formaldehyde, and the outcomes of the assessments have had had considerable impact on chemical safety in Australia, through changes in workplace practices, MSDS and labels, and regulatory standards such as hazard and ADG classification and exposure standards. Chrysotile asbestos was phased out on the recommendations of the PEC assessment. The recent review of Triclosan was the first comprehensive assessment of this chemical internationally, covering health and environmental risks. Nine PEC assessments have also been used for OECD or WHO international hazard assessments. Information on selected PEC assessments and outcomes is in Attachment 1.

Other existing chemical assessments (non-PEC) include those carried out to address specific current concerns that arise. For example, 1,4-butanediol was assessed because of adverse effects in children who ingested toy beads containing it. Nineteen chemicals were reviewed for skin sensitisation, and workplace hazard classifications implemented where warranted. .

Dissemination of the information

NICNAS risk assessments are used by workers, the public, industry and other Australian, state and territory government agencies. Information about the conclusions and outcomes of the assessment is the most critical, however information gathered on use and exposure is often not available elsewhere. As well as the published reports of the assessment, specific information sheets may be prepared for existing chemicals, focusing on particular uses or industry sectors. All published information is on the NICNAS website.

Addressing emerging issues

Perfluorinated chemicals (PFC) are known to be persistent in the environment. Some have adverse health and environmental effects, with these concerns mainly for chemicals of chain lengths of C8 and above. NICNAS has been alerting industry to the hazards of these chemicals and monitoring their status overseas since 2002, has implemented specific data requirements for perfluorinated new chemicals, and is currently carrying out an assessment of a shorter chain perfluorinated chemical.

Nanotechnology is a fast--developing field with some uncertainties about hazards and risk. NICNAS is advised on nanotechnology matters by an external committee, takes part in OECD initiatives, and has recently introduced administrative changes requiring declaration and NICNAS assessment of new chemicals introduced in nanoform.

Assessment and Prioritisation of Existing Chemicals

Impetus for change

Governments and international agencies have recently acknowledged that the conventional approach to identifying and assessing existing chemicals of concern is inadequate to deal with the large number of poorly understood chemicals in a timely and comprehensive manner. Major problems identified are that:

- There is still insufficient knowledge of the health and environmental toxicity and risks for most chemicals on the market;
- Currently, risk assessment is slow and resource intensive, and only a small subset of chemicals on national inventories are being assessed; and

- The lack of human and environmental exposure data makes it more difficult to carry out accurate and timely risk assessment.

Overseas initiatives

This has led to major and varied initiatives being undertaken by other countries, with the work in Canada, Europe and the USA being the most fully developed. The European Union have re-set the framework for their existing chemicals program as REACH (Registration, Evaluation, Authorisation and Restriction of Chemicals), requiring registration of chemicals to enable continued import or manufacture. Canada has completed the categorisation of the 23,000 chemicals on its Domestic Substances List (DSL) using screening tools developed to streamline the process. The US Environmental Protection Agency is initiating a comprehensive approach to enhance the agency's current chemicals management program, within the limits of its current authority.

Australia's approach

In Australia, planned reforms have arisen from an independent review of the NICNAS Existing Chemicals Program that was finalised in 2006 and a subsequent review in 2008 by the Productivity Commission. As part of these reforms, NICNAS is implementing a new framework for the assessment and prioritisation of the approximately 39,000 existing chemicals on its inventory (AICS). The new framework aims to deliver:

More timely information on the hazards and risks of industrial chemicals
Identification of chemicals which require risk mitigation in order to ensure safe use; and
Identification of chemicals requiring a more in-depth assessment to fully determine their effects on human health and the environment.

Composition of Australia's inventory

AICS lists chemical name, CAS number and molecular formula for each chemical. A broad analysis of the inventory indicates that just over half of the chemicals are Organics (discrete) and the remainder UVCBs (materials of Unknown and Variable composition, Complex reaction products and Biologicals), inorganics (including organometallics and metal salts) and polymers. See Figure 2 below. It is not known if all the original chemicals nominated to AICS are still in use today.

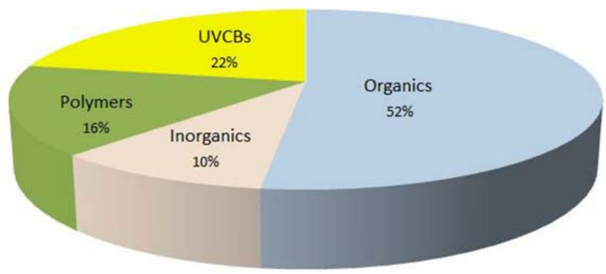

Figure 2

A tiered assessment and prioritisation framework

NICNAS has developed, in consultation with stakeholders and technical experts, a science and risk based framework for the assessment and prioritisation of chemicals on the AICS. This inventory multi-tiered assessment and prioritisation framework, known as IMAP (Inventory Multitiered Assessment and Prioritisation), is illustrated in Figure 3 below:

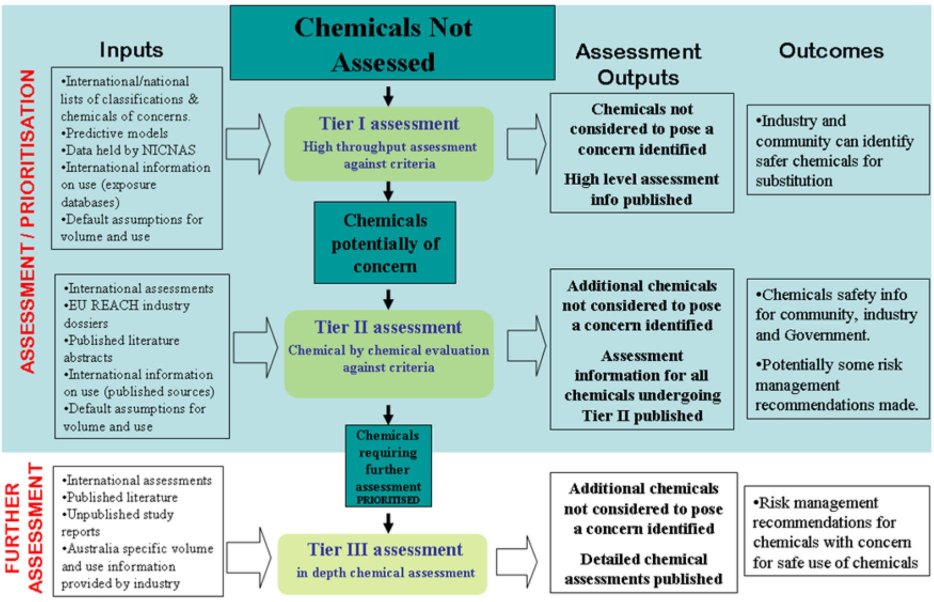

Figure 3

The framework will allow a larger number of existing chemicals to be efficiently and systematically evaluated in a stepwise manner, in order to identify those which may pose risks to human health or the environment.

Key features of the framework are:

- A scientifically robust risk-based approach;
- Achieving assessment outcomes early in the process;
- Use of overseas data, where available and appropriate for the Australian context;
- Use of internationally recognised assessment methodologies, for example, Quantitative Structure Activity Relationship (QSAR) models for predicting toxicity; and
- Use of surrogate exposure information or conservative default values in the early stages (first and second tier assessments)

Implementation

The new IMAP framework will be implemented in a staged manner, focusing on a subset of chemicals meeting certain criteria. This includes chemicals for which NICNAS has exposure (volume) information, chemicals that are already risk-managed overseas, and chemicals detected in human blood. This first stage is expected to involve the first two tiers of the framework, address approximately 3,000 chemicals and take four years to complete, commencing in 2012-13. This stage will also include at the end an external review of the framework by an independent expert, who will make recommendations on the most efficient and effective approach to managing the remainder of chemicals on AICS.

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Moving Forward to Reduce DPM Exposure

Emily D'Alterio
Rio Tinto, Kestrel Coal

Abstract

Rio Tinto Coal Australia's Kestrel Mine is the only underground coal mine in the Rio Tinto business. It is located 40 km north east of Emerald in central Queensland and supplies world markets with up to 4.2 million tonnes of coking and thermal coal per annum. The mine is currently extending the mines to access additional resources and increase mine capacity to up to 5.7 million tonnes per annum. Coal extraction is conducted using the longwall mining method. Underground transport and mining support services are provided by a fleet of diesel vehicles consisting of loaders, drift runners and various other types of mobile equipment. As a result of the method and equipment required to efficiently mine, diesel particulate matter (DPM) is a health hazard requiring management, reduction and continuous improvement to limit exposure and health risks to the coal mine workers.

This paper examines the case study of Rio Tinto Kestrel Mine and DPM management. The management programmes has linked multiple facets of the business, health and hygiene, mechanical and ventilation together to form a strategy to understand the exposure and implement controls to reduce the risk of potential over exposure to the underground workforce.

The hierarchy of controls has been used throughout the programme with specific focus of utilisation of new technology, technical expertise in underground ventilation combined with education and administrational controls to combat the exposure and accommodate site restraints (e.g. ventilation capacity).

The workforce has been consulted with during the programme to improve engagement and assist with behavioural controls and ownership by the workers. The DPM management plan and improvement programme has assisted with understanding and reducing exposure levels of DPM in the underground environment due to the cross departmental approach, engagement of the workforce and ability to trial and implement various different types of controls.

Kestrel Mine will share the lessons learnt to benefit others to improve the management of DPM and the health of workers.

Hearing Conservation Principles: Why aren't workers hearing our message?

Benjamin Elsey
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Abstract

The warning statement, 'the ear can be damaged by noise' has been repeated ad nauseam. We possess the knowledge regarding decibels and how long we can be exposed to them. In addition, we are aware of what can be done with engineering controls, work rotations and personal protective equipment. So why is the incidence of hearing loss approaching epidemic proportions? Why are compensation payouts at $41 million per year and on the rise? Why is the current economic cost of hearing loss to Australia reported to be $11.75 billion per year? This paper examines what the true cost of noise-injury is, and more importantly, why the message is not resonating within the workforce. Is the message too complicated? How can we simplify it? What are some creative but simple ways of explaining complex concepts like noise dose and the accumulative effect of hearing loss on quality of life? How can visual effects to aid learning be effectively implemented into hearing conservation training in the workplace? How do we invoke a change in culture when it comes to hearing conservation? This paper will provide a brief yet comprehensive insight into the present climate concerning hearing loss and noise exposure, as well as, engaging preventive strategies to educate individuals at the workplace so as to bring about effective change.

Background

In 1873, the 15 year old Chester Greenwood was testing new ice skates when his ears became cold. Realising that his scarf was too bulky to be wrapped around his head, he proceeded to cut it up and had his grandmother sew the material between two loops of wire. In 1877, he had his invention patented, and the earmuff was born (O'Donnell 2001).

At the National Research Corporation in 1967, Ross Garner devised expanding memory foam as part of a project for sealing joints. The properties of this material were so amazing that further applications for it were considered. Five years on, the foam earplug came into existence (Garner Jr. & Berger 1994).

Given that we have been toiling away to engineer out the noise, and we have invested in the field of hearing protection for thirty eight years or more, why is hearing loss from noise exposure still an eminent problem?

When it comes to how much a human ear can be exposed to, the verdict is in. The Hearing Standard, shows that, statistically, to limit the hearing loss inflicted on (95% of) the workforce to no more than 10dB over their lifetime, exposure has to be curbed to no more than the equivalent of a continuous A-weighted sound pressure level of 85 dB(A).over an 8-hour working day (AS/NZS 1269:2005).

The most frustrating aspect about hearing loss from noise exposure is not that we don't possess the knowledge on how to prevent it, but the fact that we do. We are well-informed of all the facts necessary to how Occupational Noise Induced Hearing Loss (ONIHL) occurs and how it can be prevented, yet hearing loss continues to thrive in almost pandemic proportions.

So, if knowledge is power, and we have the power, then why do we not seem to possess the ability to curb the progression of noise induced hearing loss? Why is hearing loss costing Australia $11.75 billion per annum (Access Economics, 2006). Why was there a staggering 16,500 hearing loss compensation claims for permanent injury due to noise approved between July 2002 and June 2007? (Safe Work Australia 2010). Therefore the need for understanding the barriers obscuring the message from getting through to the workforce, is essential.

In August of 2010, a paper was published discussing the barriers and enablers that play a role in effective noise control and hearing loss prevention. (Safe Work Australia 2010).

The report describes a variety of concepts such as: fatalism; the belief that no matter what we do, hearing loss is inevitable. Optimism; the belief that it 'will not happen to me'. Low self-efficacy; a lack of confidence to be able to do anything about noise. Nevertheless, it is important to note that none of the barriers uncovered were described as 'impossible' to overcome.

The report's highly favoured recommendation is education. This entails, promoting awareness about the dangers of exposure to loud noise, the roll hearing loss plays in reduced quality of life, and the real options that are available to prevent hearing loss.

In conclusion, the report highlights that, "employers, managers and workers need to be made aware of the real risks and available solutions – and they need clear, concise, and readily available guidance on how to achieve these solutions".

Discussion

A pattern had now emerged. The theory of how ONIHL occurs is known, genuine solutions are available, but the vehicle of how to get this information to employers and their workers has proven to be difficult.

In the professional arena, concepts involving neural conduction, cell attrition, sound pressure levels, Pascal squared hours, and decibels, are commonplace. However, medical and technical jargon which relay how damage to hearing can occur, scientific methods which depict how noise and hearing loss are measured, as well as, precautionary measures, have rendered the information inaccessible to the layman.

In turn, a lack of understanding about the subject matter will not induce any action to be taken at the workplace. The greater challenge faced is to represent these concepts in an accurate, yet uncomplicated manner.

In human communication science, it is considered the fault of the speaker if the listener has not understood the intended message. As communicators of these hearing conservation principles, the focus should be placed on the finesse of the education we provide. In other words, the aim would be to channel this information across effectively so as to strike at the core of the listener; the employer and the employees who are exposed to hazardous noise.

To do this effectively, we can extrapolate from previous proven models of behavioural modification for adult learners. This is even used in effecting change in addiction; for example the Australian National Tobacco Campaign (NTC), or as it is more commonly known, the quit-smoking campaign. Launched in 1997 with the infamous advertising slogan, "every cigarette is doing you damage" (Wakefield, Freeman & Donovan 2003). The approach taken by the NTC was to abandon the cognitive appreciate of scientific facts by translating the risks of smoking into an experience which could be "felt" by viewers (Wakefield, Freeman & Donovan 2003). Each advertisement brought a fresh take on the harms of smoking so as to optimise the effect on behaviour by employing several devices:

a) Shifting the focus away from long-term clinical damage onto the ongoing effects of smoking
b) Highlighting smoker moments which are definitively awkward yet familiar, so as to appeal to the smoker and convey sympathy for their circumstance
c) Exposing smokers to graphic images so as to obtain a strong visceral response

(Wakefield, Freeman & Donovan 2003)In addition, a free smoking cessation hotline number was displayed at the end of every advertisement to encourage smokers to take an easy step towards quitting (Wakefield, Freeman & Donovan 2003).

Results from the NTC 's review study found that an estimated half of smokers who had seen the advertisements reported that it was effective in making them more likely to quit and 60% of recent quitters reported that the advertisements made them more inclined to 'stay off cigarettes' (Wakefield, Freeman & Donovan 2003).

Explain the effect.

Similarly, if time is invested to explain to workers how their ears actually work, a smooth transition into the topic of how damage from noise occurs and why, can take place. The process of explaining the effect of noise on hearing is not necessarily time consuming. Many excellent yet concise video clips exist that can be shown to provide this education.

As the majority of people are visual learners, demonstrating that some processes can occur in the absence of visual awareness, will deliver shock value to the audience viscerally. In this case, seeing is not believing.

Most importantly, when workers understand that they hear not with their ear, but rather with their brain, they begin to understand why defective messages being sent from the ear can be so debilitating. This provides an easy transition into talking about quality of life issues.

Show the consequences

A stylised video clip showing how and why the hearing instrument is damaged by noise is only a starting point. It is only 'interesting' for the viewer if it is not converted into an experience for them. The worker has to know what it will sound like to have an ONIHL before they can start to appreciate what will be the impact of this type of hearing loss on their quality of life. This can be accomplished by conducting an auditory demonstration. This can be done either live, or by playing an MP3 file through speakers. The more of the workers senses we can appeal to in order to get this message across the better. Another effective tool is to present a personal impact story. This is best done if a speaker with an ONIHL can be found to speak to the workers. The more relevant, the more powerful the impact will be. A retired worker from the same workplace makes an ideal choice.

The true cost of ONIHL is not the dollars paid out in a worker's compensation claim nor the economic strain it puts on Australia, is it the isolation that an individual feels from their friends and family when they can no longer hear what is being said.

Provide solutions

In order for the workers and their employers to truly 'take-on' this message, it needs to be taken one step further. It is necessary for them to understand the concepts of exposure and dose. These are well understood concepts, but just need to be applied to noise. Workers understand that if they expose their skin to long periods of sunlight and hence ultraviolet rays, they will sustain sunburn. Although the skin will repair itself over time, repeated exposures have the propensity to produce skin cancers. Describing the ear with this analogy may assist the worker to make the link that although there is an acute symptom; such as temporary threshold shift or tinnitus, with repeated exposures, permanent hearing loss and tinnitus will ensue. Alternatively, making the education a demonstration, will appeal to the visual learners. Dose and exposure can be well represented by pouring water into a number of glasses. By taking a concept that is 'invisible' like noise, and representing is as something visual like water filling a glass, makes the concept of exposure over time and dose easy to understand. This can be used to represent the three different key concepts of hearing protection. 1. By working a longer shift, a slower pour rate has to be adopted so as not to overflow the glass. 2. If a worker has to be exposed to higher than 85dB (simulated by pouring faster), the glass fills much more quickly and so the activity can only be done for a much shorter time. 3. If the worker is wearing hearing protection, but they compromise it in some way; such as lifting up of an earmuff when communicating with other workers, this can be simulated by a steady controlled pouring of the water with sporadic 'glugs' to represent times when the earmuff has been lifted shows very visually how the glass will overflow before the workday ends.

Conclusion

For an educational campaign for adult learners to be effective, it must contain a number of fundamental elements. Firstly, the workers must be exposed to the campaign and remember it. Secondly, they must appraise that the information they have received is both believable and relevant to them. Thirdly, it must stimulate their thinking about their own behaviour, and finally, it must effect a durable change in any undesirable behaviours. It is vital that the message of hearing conservation be pitched in such a way as to have maximum impact on workers. To do this, it is essential to present high quality, informative content in an easy to understand format. Furthermore, the format should not only be clear, but novel, interesting, engaging and even fun. This makes it easier for the worker to commit this information to memory, to be recalled when they are back on the job and analysing their behaviours with 'fresh eyes'; and hopefully fresh ears.

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Noise Levels during excavation and initial stages of Construction

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Abstract

Construction noise levels are often at their loudest during the excavation and the initial building stages of construction work. During civil works excavators using attachments and other machinery generate significant general ambient noise levels that can result in Noise Induced Hearing Loss not only for the civil labourers and machine operators but other workers on the building site. Other workers are often involved in the initial construction stages where high noise levels are generated at close quarters by form working processes. This paper made assessment of building sites where the excavation and initial building processes are being carried out and is looking at the best methods of estimating the noise exposure of groups and individual construction workers. The study looks for ways of findings the correct combination of dosing verses measurements to make the best noise exposure estimate, specific examples of measured noise levels and measurement combinations are summarized.

Keywords

Construction, Noise Induced Hearing Loss, Noise exposure, Noise Measurement, PSEM, SLM

Introduction

The National Acoustics Laboratories (NAL), in collaboration with 2 construction companies, made preliminary noise assessments on three building sites for an investigation into workplace noise in the construction industry.

The participating construction companies provided work site access for NAL to collect data on noise exposure in the workforce as part of research titled, “Barriers to Noise Exposure Reduction”. NAL is working with companies to reduce risk associated with excessive noise exposure; and looking at methods of decreasing noise exposure based on a practical and experienced understanding.

This paper describes the first of three stages of a construction project. For the purposes of noise measurement we expect to make measurements during these three major stages, which are:

- Foundations and superstructure
- Basic internal and external finishing and fitting out up to lock-up
- Detailed internal finishing up to Practical Completion

These stages are not necessarily consistent with the construction stages within a project management plan, but we have observed that major noise sources like tools, machinery and work practices change significantly at these times.

During the foundations and superstructure stage civil works machinery, form work construction and out-door works such as concreting and brickwork dominate the work site. The gathered data is important, in that it will hopefully be used to target and shape OH&S education programs.

Measurements were made using both hand-held Sound Level Meters (SLM) and PSEMs. The results of these measurements are being used to determine the most efficient methods in terms of time, equipment cost and accuracy to make a preliminary noise assessment on a construction site.

Warrington D (2005, p349) investigated the advantages and disadvantages of using PSEMs and SLM's to make noise assessments. He concluded that effective measurements were made, "when using a combination of both sound level meters and personal sound exposure meters".

Our findings support this view and we have noted that for construction work where noise levels vary significantly, and it is not possible to safely or practical to measure the noise levels near the ear of a construction worker, a PSEM can provide a superior measurement compared to a SLM in these cases. However, a SLM in the hands of a trained user is often required to gather the more detailed information about that noise hazard so that remedial action can be taken.

The results of the preliminary noise assessments indicate all of the sites had significant construction noise levels.

Site Descriptions

The work sites will be identified as follows:

Site 1 - Multi-story mixed commercial/residential development located near the Sydney CBD

Two sets of measurements made on this site (day 1) concentrated on Form workers and on day 2 concentrated on the Civil workers

Site 2 – Commercial building purpose-built for multiple research based companies

Site 3 - Development of a series of prestige town houses located in the northern Sydney region

Measurement Methods

The methods used will be examined and reported so that OH&S personnel with basic training in the measurement of noise can undertake more accurate and timely preliminary noise exposure assessments.

Measurements in this study used a Brüel and Kjær 2250 integrating sound level meter and Castella dB35 Dosimeters (PSEMs). We note that the Brüel and Kjær 2250 SLM (a professional quality instrument) mostly used by acoustic consultants and researchers. In our opinion, a simple integrating or non-integrating SLM could be used in its place to reduce the training requirements for the noise assessor.

We have assumed that readers of this paper will have access to and be notionally familiar with the Australian/New Zealand Standard AS/NZS 1269.1:2005 "Occupational noise management Part 1: Measurement and assessment of noise immission and exposure". Measurement procedures are in accordance with this standard.

The general procedure of measurement was to assign PSEMs to volunteer workers at the start of a shift and pick the PSEM up at the end of the shift. When collecting the PSEM a short interview was completed if possible, or alternately the written log kept by the worker was studied, to identify the type of noise exposure and their expectation of the severity of noise exposure.

Direct Measurement of Exposure - PSEM Method

For site 2 and 3 the PSEM was collected by the foreman at the end of the day, as the author could not be present for the whole of the shift.

With the assistance of managers from the participating companies, the workforce for this "Foundations and Superstructure" stage of construction work was grouped into categories:

- Operators - Operators of large machinery
- Labourers
- Form workers - Includes scaffolding and steel tiers

- Supervisors
- Trades

Measurement of Immission Levels – Hand held SLM

During the shift or as close as possible, the author made hand-held SLM measurements of immission sound pressure levels experienced by workers in the above groupings. Measurements were targeted in the areas of the work site where PSEMs participants were operating.

The microphone locations were generally chosen to be near to the worker at a similar distance from the noise source to the worker's ear, but not interfering with the task of the most affected worker. Due to safety and practicality considerations it is usually not possible to measure at the recommended standard (AS/NZS 1269.1 ~ 100 mm but ≤200mm from the ear canal) close to the ear canal of a construction worker. However, techniques were employed to ensure that the immission noise close to the ear of the affected worker was measured.

For example, measurement of power sawing activity by the form worker was made on the opposite side of the power saw, but at the same distance as the saw operator.

For each site assessed, ambient noise levels were measured in areas of the site where there was no direct activity but the noise levels were dominated by sources that arose from the construction work in general.

AS/NZS 1269.1:2005, Section 7.3, notes that PSEM's data can be compromised by "confounding effects" and that the SLM is the preferred method of measurement for noise assessments. However, the same section of the standard also notes that PSEM's can provide useful information.

The case of an excavator operator is a prime example of where the information provided by the PSEM could be considered superior to measurement with a SLM. This is because the PSEM can measure the noise in the cabin without disturbing the working environment, and can indicate the time of exposure more accurately.

Measurement Results

A summary of the measured noise levels is given in Table 1 below. Overall 29 working days were measured using PSEM's and 27 measurements of ambient noise levels and construction activity were made with a hand held SLM. The arithmetic averages of the measured ambient levels have been separated from the averages of measurement for construction activity and are listed separately in Table 1.

Sites	Description of measurement types	PSEM $L_{Aeq,8hr\ (SD)}$	SLM $L_{Aeq\ (SD)}$	SLM $L_{Aeq,\ Amb}$
Site 1 – Day1	**SLM:** 3 site activities, 3 Ambient. **PSEM:** 2 Supervisor, Site lift Operator, 4 Form workers	90 (5)	94 (10)	78
Site 1 – Day2	**SLM:** 8 site activities, 2 Ambient. **PSEM:** 1 Working Supervisor, General labourer, Operator – Large Excavator, Operator – Small excavator	90 (5)	90 (7)	79
Site 2	**SLM:** 2 site activities, 5 Ambient. **PSEM:** 1 Site Supervisor,1 Working Supervisor, labourer, Electrician, Plumber, Operator – Small excavator	85 (4)	88 (4)	72
Site 3	**SLM:** 3 site activities, 1 Ambient. **PSEM:** (2 days/volunteer) Site Supervisor, labourer, Bricklayer, Plumber, 2 Form Workers	85 (4)	79 (4)	71

Table 1: Number of PSEM and SLM Measurements and Measurement Summary

The construction activity noise levels for each of the above sites are listed in Table 2. All measurements were made at a position that was representative of the operator position for hand tools and for general activities at a location where affected workers would likely be located.

Sites	Description of measurement types	dB L_{Aeq}	dB $L_{C,\ Peak}$
Site 1 – Day1	Large Concrete Hammer Drill – Operator Position	102	126
	Power Saw – 3 events of 2 minutes duration	103	121
	Site Lift Operation – 5 minutes of exposure of typical operation	86	123
Site 1 – Day2	Large Excavator with Hydraulic Hammer – 10 m	84	114
	Large Excavator with Hydraulic Hammer – 5 m	98	123
	Skid steer loader in operation - 5 to 10 m	85	106
	In Cabin of Skid Steer Loader – High Idle	89	112
	Two Small excavators in operation – 5m	85	110
	Small Dredge Pump Operation 5 HP petrol – 3 m	85	113
	4 large Excavators one using Hydraulic Hammer – 10m	90	120
	Rock Drill – at operator position (high frequency shrill noise)	105	120
Site 2	Jack hammer operation – Operator position	85	123
	Drilling Rig Operation – 4 m	90	121
Site 3	Form worker – finishing touches to scaffold – 10 minutes	82	124
	Chairing up steel – Essentially ambient noise levels	74	104
	Unloading Scaffolding from truck	80	116

Table 2: Results of Construction Activity Noise measurements

Table 3 compiles the results of PSEM's readings into the categories noted above. The table lists the number of sample working days, average of the $L_{Aeq,\ 8hr}$ and $L_{C,\ Peak}$ results for the grouping of workers. Warrington D (2005) p348 notes that $L_{C\ Peak}$ data recorded by a PSEM can be subject to errors due to the accidental knocking or tapping of the microphone creating artificially high peak noise levels; this is likely in the field of construction. However, the $L_{C\ Peak}$ data has been included here as it still provides information relative to the noise assessment and consistent with noise levels measured using a SLM.

Description of Worker Grouping (n)	**PSEM $L_{Aeq,8hr\ (SD)}$**	**dB $L_{C,\ Peak\ (SD)}$**
Machinery Operators (4) – site lift and excavators	89 (5)	137 (6)
Form workers (8)	88 (6)	142 (2)
Labourer (3)	87 (3)	137 (2)
Trades (6)	84 (5)	135 (5)
Supervisors (7)	83 (5)	137 (2)

Table 3: PSEM Results for Worker Groupings

Measurements at **Site 1** were conducted on the 13 March 2011 and 17 June 2011 for days 1 and 2 respectively, for Day 1 the measurements concentrated on concrete form workers, Day 2 measurements concentrated on civil workers using heavy earth moving equipment. Site 1 was located in a pit approximately 20 metres in depth.

Site 2 is located in a shallow pit (5 to 10 metres deep) during the time available for the measurements relatively few construction activities were in progress. Measurements at site 2 were made on the 25 August 2011.

Site 3 is in a residential area. SLM Measurements were made on the 19 August 2011 while the PSEM Measurements were made on the 17, 18 August 2011. The SLM measurements did not capture the higher levels of activity that had occurred on the previous two days of construction work. Additionally, rain cut short the time to take SLM measurements of construction activity

Discussion

The summary of the results in Table 1 indicates that for all of the noise assessments there is a risk that construction workers are exposed to excessive noise.

For site 1 (days 1 and 2) and site 2, the averaged hand-held **SLM measurements** in Table 1 showed that the noise levels were 94dB L_{Aeq}, 90dB L_{Aeq} and 88dB L_{Aeq} respectively. The hand held SLM measurements, as they are detailed in Table 2, reveal that nearly all of the construction activity noise levels recorded on sites 1 and 2 were at or exceeded 85dB L_{Aeq}, with three instances of activity being 102, 103 and 105dB L_{Aeq}. Thus workers exposed to these levels over a work day of 8 hours or more would receive an exposure that exceeded the NSW legislated maximum of 85dB $L_{Aeq,\ 8\ hour}$, for workers exposed to noise levels as high as 105dB L_{Aeq} the allowable exposure time is no more than 5 minutes.

Hand held SLM measurements recorded for Site 3 averaged to 79dB L_{Aeq} and this was mostly due to the measurements on the day being cut short due to rain and there being low activity on the day of the SLM measurements.

From this study we found that the main value of the hand held SLM measurements was to gain reliable data about the significant noise sources on the construction site and as we were using a high function SLM the frequency data would be of value for detailed acoustic assessment however this frequency based information may be of little use to an industrial hygienist making a preliminary assessment of a construction site. As it is often very difficult to determine the time that a construction worker spends on any particular task short of following them around all day we found that the PSEM provided a much better estimate of daily exposure.

Another useful function of the SLM is to identify areas of the site where low noise environments exist. Seixas N et al (2001) p618, 620 notes that on a construction site workers are often affected by noise generated by the activity of co-workers; a quick survey with a simple sound level meter will assist with good work planning by providing refuge areas that have lower ambient noise levels or where shielded from the general construction noise.

The averaged **PSEM results** listed in Table 1 indicate that on average all workers who volunteered to participate by wearing a PSEM in the program received an exposure of 85dB $L_{Aeq,\ 8hr}$ for sites 2 and 3. On site 1 the average PSEM reading was 90dB $L_{Aeq,\ 8hr}$ and although we have not individually listed PSEM results 80% of participants on site 1 exceeded 85dB $L_{Aeq,8hr}$ and 40% of the participants on site 2 exceeded 85dB $L_{Aeq,8hr}$.

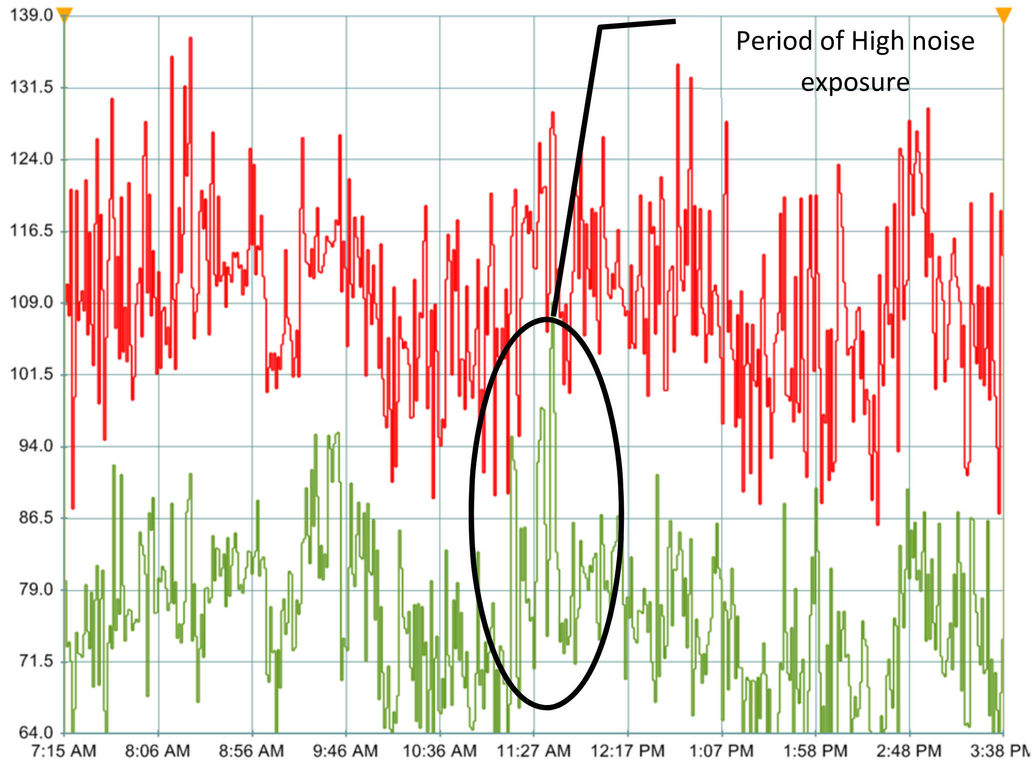
On Site 3, although hand held SLM measurements indicated that it was a quieter site, the PSEM results conducted on the two days before with 12 working days of data recorded by the PSEM participants reveal that 50% of the participants exceeded 85dB $L_{Aeq, 8hr}$.

This confirms the value of using a combination of PSEM measurements and SLM measurements to gain additional information about noise exposure in a given workplace and especially in industries like construction where the day to day noise exposure can vary significantly.

The PSEM results aggregated into worker groupings in Table 3 give an insight into the order of importance of workers that need to be included in a hearing protection programme. The worker groups were formed using the advice of experienced construction managers and leading supervisors and we thus consider the groupings to be a good basis for the PSEM analysis.

From Table 3 we can see that Machinery operators, Form workers, and Labourers could be target groups in hearing protection programs (HPP). HPP are not a key part of this study but it is worth noting the value of analysis of the PSEM noise level log plots can give in finding ways to reduce the workers' exposure.

The noise plot for a labourer is notable, refer to the figure 1 below, the main source of noise that caused his exposure to exceed 85dB $L_{Aeq, 8\,hr}$ was a period of about ½ hour of high noise levels between 11am and 12pm. On this occasion we did not get an opportunity to interview the labourer. However, a guided interview (especially after review of the noise plot) may be able to determine the source of the high noise level and ways that this immission noise could be engineered out of the job or if this is not practical protected exposure in the form of hearing protection could be mandated for that activity.



Another grouping of interest was excavator operators. PSEM measurements revealed that operators using small open cabin units received significant noise exposure generally above 92dB $L_{Aeq, 8hr}$. However, operators on large machines with enclosing cabins had sufficient protection for operators to avoid exceeding the legislated daily noise exposure. The SLM measurements of noise due to operation of excavators and other heavy earth moving equipment provided information about the safe distances for noise exposure from an excavator. Table 2 Indicates a distance ~ 10 metres or greater on site 1 was required to avoid a noise level greater than 85dB L_{Aeq} from an excavator using a hydraulic jack hammer.

The site ambient noises should be reduced where it is possible to do so; if ambient noise levels are high across the whole of the worksite there is minimal area for workers to work in a quiet area that can provide a refuge to reduce overall daily exposure.

Conclusions

From the above study we conclude that noise levels within the construction industry represent a high level of risk in terms of NIHL. Companies that are committed to providing a safe working environment to their workforce need to be constantly practicing good worksite planning to reduce noise hazards as much as possible by engineering administrative means and if this is not possible to provide PPE so that workers can have protected exposure that is within safe limits.

PSEM and SLM both provide important information in making preliminary noise assessments and are particularly useful for the assessment of construction sites. Simple SLM can be used to reduce the training required for their correct use during the assessment. Regular follow-up noise assessments will confirm if noise management plan are successful.

An assessor can save significant time by having sufficient PSEM's to distribute to workers for use over a number of days to capture a data to assess the site. The grouping of workers can make the assessment using PSEM's more efficient by allowing the targeting of groups that are of concern.

This is the first study in a three staged approach to look at construction noise we hope to complete the two additional stages as the opportunity arises on the chosen sites.

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Quieter by design - An ALARP demonstration for offshore facilities

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Abstract

A person conducting a business or undertaking (PCBU) in Australia has a legal obligation to provide and maintain a working environment in which other persons are not exposed to hazards. This objective is governed by the various OH&S Acts that are enforced around the country in both State, Territory and Commonwealth jurisdictions.

In relation to occupational noise, all reasonably practicable steps must be taken by a PCBU to avoid exposing other persons to hazardous noise or, noise levels that exceed prescribed exposure standards.

This paper presents Chevron's approach to incorporating engineering noise controls in the design of an offshore production facility in Australia and discusses the challenges encountered, methodology and solutions applied to demonstrate that noise risks are as low as reasonably practicable (ALARP).

Keywords

Noise, exposure, risk, duty of care, facility design, offshore, PCBU, ALARP.

Introduction

Noise is a common physical health hazard encountered in the offshore petroleum industry. Offshore facilities are typically compact in nature and contain a relatively high proportion of noisy equipment and processes per area of occupancy. It is also one of the most prevalent occupational health hazards faced by offshore workers, which has the potential to cause noise-induced hearing loss (NIHL) and sleep disturbance, with subsequent fatigue and stress (Chandran, 2008).

So, clearly there is an ethical need to manage noise and noise exposures to people in order to protect them from harm, but is that really enough on its own to drive change when you're designing a multi-billion dollar facility? Often, it is not.

What then are the key drivers behind choosing to minimise noise during front end engineering and design (FEED), rather than addressing it retro-actively on an existing operational facility? In summary, there are two major drivers for a design engineering solution:

The perceived risk of future legislative non-compliance, and
Cost minimisation and freedom to affect design changes

This paper examines these drivers and provides an overview of the methodology employed during the design of Chevron's Wheatstone offshore production facility to demonstrate that noise risks are ALARP.

Discussion

Legislative drivers

Current OH&S legislation in Australia typically imposes an obligation on a person conducting a business or undertaking (PCBU) to take all reasonable steps to prevent a person under their control from being exposed to hazards, which includes occupational noise.

This is often supported by a prescriptive requirement. In the case of the offshore petroleum industry the prescribed noise exposure standards are LAeq,8h of 85 dB(A) and LC, peak of 140 dB(C) (Commonwealth of Australia, 2010). Therefore, noise exposures on a facility must not, as far as is reasonably practicable, exceed these values.

During the design of a facility it is becoming an established industry practice to conduct noise exposure modelling in order to predict future operational noise levels. The traditional model for noise control during design of oil and gas projects involves commissioning a noise study, which in-turn makes recommendations for reducing noise levels in a report format. Often the project then considers the recommendations in isolation, and any potential detriment (be it operational, maintenance, layouts, safety), may result in the recommendation being rejected.

Often, this process does not allow the reason for the rejection to be challenged, or even weighed against the potential benefits.

Chevron chose to embed noise experts in the design process to address these short comings so that corrective actions could be included in the design to ensure future legislative compliance. After all, a PCBU is ultimately accountable to the laws of tomorrow (Jennings, 1999). For example, using a conventional platform design with "off-the-shelf" equipment packages, daily noise exposures (in LAeq,8h) were estimated as being 93.3 dB(A) and 88.3 for routine facility operators and maintenance workers, respectively. This scenario suggests that the PCBU operating the facility would be non-compliant with the legislation, possibly on a daily basis.

Hence, it was established early on in the Project that the effort required to achieve legislative compliance in the future would be minimised by considering engineering noise controls during FEED, firstly by ensuring that predicted daily exposures (in LAeq,8h) did not exceed 85 dB(A) and, secondly, by providing a written record that all reasonable controls had been considered in order to demonstrate that noise exposures were ALARP.

Cost drivers

Not surprisingly, the second major driver for incorporating engineering noise controls during FEED was cost minimisation. This statement might seem at odds with the "time value of money" concept, which states that a given sum of money is worth more today than that same amount of money paid at any time in the future. This is due to the effects of inflation and the level of return one could expect to generate in the future on a present sum of money.

So, why then is it cost effective to spend money up front on engineering noise controls instead of reinvesting that sum in another profit-making enterprise? There are several reasons.

Firstly, at the start of FEED, large pieces of production equipment (e.g. gas turbines, compressor piping and pumps) are often procured as a priority to meet a demanding procurement schedule (Ondet and Sentier, 2007), so there is the opportunity to budget for capital expenditure (CAPEX), like engineering noise controls, at the outset with negligible labour costs involved.

If engineering noise controls were not considered until the project moved to the end of FEED then additional labour costs would be imposed, such as re-engineering costs and equipment variations. There's also the risk that original capital costs have increased in the interim period, due to inflation.

Finally, if engineering controls were left for implementation in the operations phase, further costs become tangible, such as further re-engineering costs and variations as well as additional installation costs, piping modifications, commissioning costs and loss of production.

In fact, based on some research conducted by Chevron and SVT Engineering Consultants in 2010, it was shown (as an example) how an initial CAPEX of $300k to enclose a simple compressor package and install a duct array resonator to connected pipe-work during FEED could potentially blow out to $725k by the end of FEED to a staggering $2.275m if retrofitted during the operations phase of the facility. That's close to a tenfold cost increase within a span of a few years!

Furthermore, as a project moves beyond design to production, the freedom to implement robust engineering noise controls diminishes considerably. The following diagram illustrates this relationship:

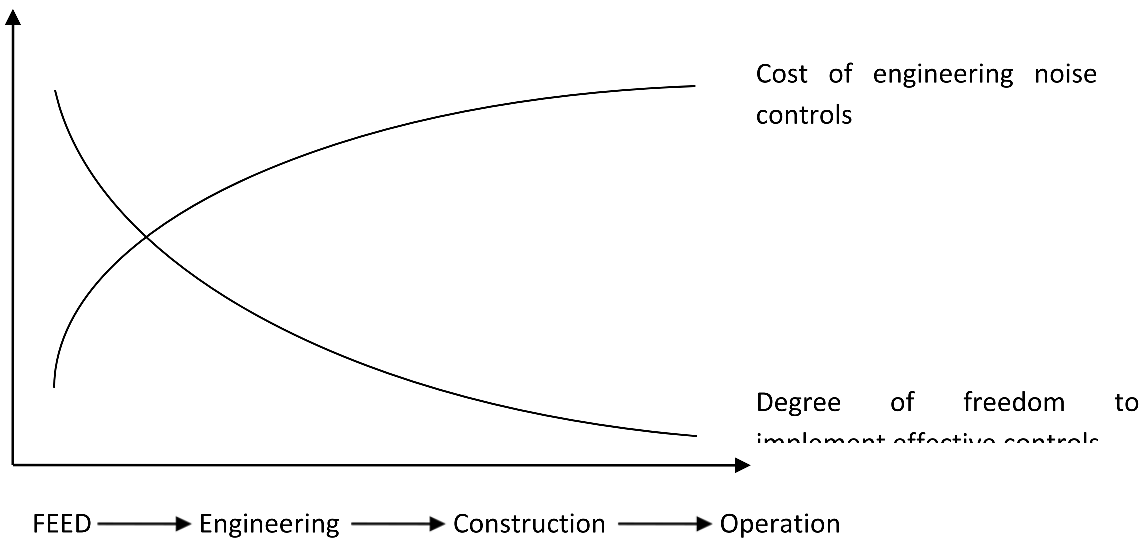

Figure 1 – The Cost vs. Time application of engineering noise controls

Source: Adapted from Ondet and Sentier, 2007.

Therefore, it is often more cost effective and technically convenient to implement the correct engineering noise controls during the design phase of a facility.

So, how do you know what engineering noise controls represent the best value for money? The simple answer is that it's not just about financial cost. You must weight up the benefits of each control in terms of the overall reduction in noise exposure it provides versus the costs associated with its implementation. These include:

Costs/ Impacts	Descriptor
Financial costs	What is the monetary cost of the control?
Operability costs	Does the control impact operation of the equipment?
Maintainability costs	Does the control impact equipment maintenance?
Process costs	Can the control impact overall facility performance?
Project execution costs	Is the project schedule impacted?
Occupational Health & Safety (OH&S) risks	Does the control increase or introduce certain OH&S risks?
Integrity of the solution	Is it proven or novel technology?

Table 1 – Potential costs/impacts of control measure

The following discussion provides an overview of the methodology employed by Chevron during the design of its Wheatstone offshore production facility to demonstrate that noise risks are ALARP.

Method and Process

Demonstrating that noise risks are ALARP

During Transition Engineering the Basis of Design (BoD) (Chevron Australia, 2011), FEED Noise Management Plan (Chevron Australia, 2010a) and Specification for Noise Control (Chevron Australia, 2010b) were drafted. These documents set overall noise limits for the platform that would, if achieved, mean that the platform was a low noise workplace. Based on achieving this cumulative 'work area limit', the specification for noise control set a general equipment noise limit for each individual piece of equipment.

For major production equipment to be used on the facility, achieving the limit was a significant challenge. The limit represented what was believed to be best practice in Australian waters, and ranked amongst the most stringent noise limits for equipment in an offshore environment worldwide.

- An ALARP analysis process was also defined, and triggered in one of the following circumstances:
- Noise levels above the project work area limit were predicted,
- Noise levels above the equipment noise limit were presented by the vendor, after the vendor had provided all 'off-the-shelf' noise controls, and
- Vendor or the project had proposed several mutually exclusive noise controls, and a decision between them was required.

SVT performed an initial noise risk assessment using quantitative computer noise modelling. This involved setting up a detailed noise model with two sets of inputs: all equipment at specification levels, and, all equipment at levels as measured on existing facilities.

The model results demonstrated the overall effectiveness of the project noise limits in controlling noise levels, and highlighted the potential risk associated with procuring 'off-the-shelf' solutions from vendors. This allowed a hit list of equipment items to be drawn up early in FEED.

Based on the outcome of the noise modelling, several high risk equipment items were identified for ALARP analysis during FEED. Particular equipment was selected on the basis of the following criteria:

- Long Lead items for which purchasing decisions would be made during FEED, or very early in Detailed Design,
- Dominant noise sources which, if not controlled, would nullify the effect of noise control on most other sources on the platform,
- Equipment where 're-arrangement' would be an effective control measure (such as piping), and thus a high priority during FEED, and
- Equipment that presented a risk of permanent hearing damage from short-term exposure.

SVT and the Project defined a workshop format and set the process for assessing whether noise risks were ALARP, based on a similar process developed by SVT and used successfully on other projects in Australia.

This process involved identifying the benefits and detriments of any particular noise control for each specific noise source under consideration. The 'detriments' considered went beyond simply the cost of the treatment, and included all the potential factors that could lead to a recommendation being rejected.

By conducting the process in a workshop format the view of all relevant parties was included, and allowed assumptions to be challenged, concerns raised and if required addressed. This resulted not only in a more robust determination of 'reasonable practicability' but also, importantly, in an agreed and documented ALARP position.

The following factors were considered in the ALARP determination process, and specifically discussed during the workshop:

Benefits

a) Reduction in Noise Exposure Levels, and
b) Noise Reduction across the affected areas of the Platform.
Some noise sources may have affected local noise levels but were relatively insignificant in regard to the overall module deck area. Others (e.g. piping) may have affected a large area of the platform. This factor attempted to quantify the greater area impact of the noise source and its treatment.

Practicability

a) Impact on Operability:

This factor addressed how the noise control treatment impacted on how the operator interacted with the equipment. For example, if it caused personnel to spend more time in hazardous areas, or if it required an increase in manning, etc.

b) Impact on Maintainability of the equipment (including the noise control treatment) or the facility:

This factor assessed the maintenance impact of the treatment, including the requirements for maintenance of the treatment and equipment, impact on access or material handling and maintenance interval.

c) Impact on the Process:

This factor assessed the noise control treatment's impact on the plant process. For example, whether the treatment degraded or improved the process performance or if there was a potential for a significant impact on process performance if the treatment failed.

d) Solution integrity (or additional benefits):

This factor assessed the noise control treatment integrity with regard to good industry practice, and if it was proven or novel technology.

e) Impact on Project Execution:

Potential impacts were related to environment, project schedule, cost associated with delays etc, additional weight, or impacts on facility layout size or arrangement.

Occupational Health and Safety (OH&S)

a) Impact on Occupational Health and Safety

This factor graded the operational safety hazards introduced or removed by the noise control treatment. Aspects of safety considered here excluded 'noise issues'.

Cost

a) Cost of Treatment

Cost of the treatment referred only to direct cost of implementing the solution. Costs associated with added safety or manpower or reduced production were considered separately.

For each of the above impacts (cost, practicability and OH&S) a Rating was assigned based on how they were affected by any proposed treatment, with a high Rating representing no impact, and a low Rating representing unacceptable impact. Similarly, Ratings were also defined for the benefit gained in terms of overall noise level and noise exposure reduction.

The product of the Ratings was used to identify the ALARP position for the item under consideration.

Results

The ALARP consideration was conducted for the following items:

a) Compressor Piping

Both the specification case and expected case noise models showed that compressor piping noise would be a dominant noise source across all process areas of the platform, which had the potential to nullify the effects of other noise controls being considered for individual equipment packages.

b) Gas Turbine Compressor (GTC) Packages

High noise levels were predicted around the GTC Packages in the 'off-the-shelf' noise model. This area of existing platforms was commonly identified as a very high noise area and historical data indicated that noise levels would be high from the particular equipment planned for this package.

c) Gas Turbine Generator (GTG) Packages

High noise levels were predicted around the GTG Packages in the 'expected case' noise model. This area of existing platforms was commonly identified as a very high noise area and historical data indicated that noise levels would be high from the particular equipment planned for this package.

d) Condensate Export Pumps

Based on the size and service power of the export pump packages, and the proximity of the booster pumps, noise levels were predicted to be high in the areas around these pumps.

The ALARP workshops recommended a range of noise controls to be implemented including:

- Custom build noise enclosures for the gas turbines,
- Special silencer inserts in the compressor casings,
- Acoustic insulation of compressor piping,
- Special low noise motor and skid for the condensate pump, and
- A partial enclosure over the fluid drive-coupling on the condensate export pump.

Additionally, on a number of smaller equipment packages, vendors rose to the challenge and re-examined their standard offering and modified their design to achieve reduced noise emissions.

The above recommendations resulted in a reduction in noise exposures (in LAeq,8h) for operations staff from 93.3 dB(A) to 78.1 dB(A) and, for staff conducting routine maintenance, from 88.3 dB(A) to 74.8 dB(A). Additionally significant reductions had been demonstrated for non-routine maintenance activities and noise levels across the platform process area.

Conclusion

- In summary, an ALARP process used was successfully by Chevron during the design of its Wheatstone offshore production facility to proactively demonstrate compliance with the legislation in a cost-effective manner.
- Key features of the process included:
- Effective workforce consultation and participation, which allowed the opinions of relevant stakeholders to be voiced, assumptions to be challenged, objections to be aired and "work-shopped" as part of a robust decision-making process,
- Evaluation of reasonable engineering controls, using a cost-benefit analysis tool,
- Selection of engineering noise controls that conformed with the facility's design intent, and
- A demonstrated and documented ALARP decision.

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Hearing Protection Afforded by HPD's based on 'Real World' Measurements

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ExxonMobil

Executive Summary

As part of a broader study centred on further enhancing the efficiency of hearing conservation programs, a a field study of the effectiveness of hearing protection devices (HPDs) s was completed to determine if single hearing protectors reliably provide at least 15 dB of attenuation under actual conditions of use. REAT (real ear attenuation at threshold) tests were completed on 90 workers located at four different installations wearing a variety of foam and custom moulded earplugs. In addition, MIRE (microphone in real ear) tests were also completed on 28 workers wearing earmuffs. Actual hearing protector attenuation was measured to be less than 15 dB for 38% of the subjects. Average attenuation and reliability did not vary significantly by device type or model. Most subjects (87%) did achieve at least 9dB attenuation. In addition, dual hearing protector attenuation was evaluated to determine what level of attenuation could be provided in the field. Most subjects (93%) did achieve at least 20dB attenuation.

Introduction

As part of any concerted hearing conservation program, control of exposure to noise should be put in place to ensure workers are not subjected to levels of noise than can induce noise induced hearing loss. Engineering controls are typically the most effective long-term solution to reduce worker exposure to noise, although in some instances there is still a requirement for workers to use personal protective equipment in the form of hearing protection devices (HPD).

One criterion used in hearing conservation programs to select hearing protection devices (HPD) is the noise attenuation provided by the device. HPD manufacturers provide noise attenuation information by different measures that vary by country. HPD manufacturers in the U.S. are required by the EPA to provide a Noise Reduction Rating (NRR) that is determined in conformance with ANSI S3.19-1974.1,2 Outside the U.S., either the Single Number Rating (SNR) or High/Medium/Low (HML) are reported as specified in ISO 4869-Part 2.3,4 Both the ANSI and ISO methods rely on laboratory studies using trained subjects that reflect the optimal performance of the devices. A number of published studies have shown that these measures overestimate the attenuation workers actually achieve in the field (i.e., 'real-world' attenuation). As a result, a common practice within many organizations was to derate the NRR or SNR by 50%, consequently most sites select HPD with an NRR or SNR of at least 30 dB to be sure that workers achieve adequate attenuation under field conditions.

As part of a broader program focused on better understanding the "real world" performance of HPDs in the field, a study was designed to determine if the HPD used at ExxonMobil operating sites consistently provide at least 15 dB of attenuation under actual conditions of use. Measurements of 'real-world' attenuation were collected at four diverse operating locations on a variety of foam earplugs, custom moulded earplugs, and earmuffs. The operation locations used were selected because they had long standing, proactive hearing conservation programs, which included strong emphasis on the proper selection and use where HPD's are required.

Dual hearing protection, earplugs worn in combination with earmuffs, is specified where noise levels exceed the attenuation capabilities of a single hearing protection device (HPD). Hearing conservation programmes require that hearing protection attenuate noise exposures to below the 85 dBA TWA exposure limit. ExxonMobil operating sites typically require dual HPD in any work area where noise levels exceed 100 dBA, irrespective of TWA exposure levels. While it is generally recognised that the attenuation provided by dual HPD is greater than either HPD worn individually, the field performance and limits of dual HP attenuation have not been fully evaluated. Standard laboratory attenuation testing of various combinations of earplugs and earmuffs found noise reduction rating (NRR) values between 25 and 35 dB(A). An extensive search of the literature did not identify any published reports of 'realworld' attenuation testing on dual HPD. This study was designed to measure the attenuation provided by dual HPD under actual field conditions at an ExxonMobil manufacturing site. Measurements of field attenuation were collected while 28 workers wore earplugs in combination with earmuffs using the microphone in real-ear (MIRE) technique.

Methods

Two methods were used to measure real-world attenuation: real-ear attenuation at threshold (REAT) and microphone in real ear (MIRE). All workers were tested on their routine HPDs as worn at the time of testing and after completion of a set of typical, routine external tasks immediately on completion of the task.

Real Ear Attenuation at Threshold (REAT)

The REAT method is a standard method for measuring HPD attenuation and was used for all of the tests on earplugs. This method involves two measures of a worker's hearing threshold (i.e., the lowest sound level that can be heard): one with the subject wearing their HPD (occluded), and the second without HPD (open). The REAT is calculated from the difference between the occluded and open thresholds. Workers wearing their earplugs in the plant environment were asked to participate in the study and provided with an informed consent form. Those who agreed to participate were escorted to a nearby quite location, such as a control center, to perform the hearing threshold tests. A portable type-4 audiometer (HP iPaq Pocket PC_ with Pocket Hearo_ software) was used with large circumaural ear-cups (Madsen ME-70) and earphones (Telephonics TDH-39) to measure occluded and open thresholds at eight frequencies (250 Hz, 500 Hz, 1 kHz, 3 kHz, 4kHz, 6 kHz, and 8kHz). Sound pressure level measurements were also collected in the work area at the same eight frequencies using a 1/3-octave band sound pressure level meter. These measurements were made in up to three representative high noise areas to establish the typical spectral noise field the hearing protection would have to attenuate.

Microphone in Real Ear (MIRE)

It was not practical to perform REAT testing on earmuffs in the field, so an alternative attenuation test method was used. Microphone in real ear (MIRE) is another standard procedure for measuring HPD attenuation. The MIRE procedure consists of mounting small microphones inside and outside a hearing protector while it is worn by a worker in a hearing protection mandated work area. The attenuation value is calculated as either the difference in spectral sound pressure levels or the difference in A-weighted sound pressure levels. Workers who normally wear earmuffs as their preference choice for ‘single hearing protection’ were asked to participate in the study. The worker was fitted with a microphone to be worn underneath the earmuff. The microphone was attached to a Cesva SC160 sound level meter/spectrum analyzer, and the worker was escorted to a work area within his typical working environment where noise levels were above 85 dBA. The A-weighted and spectral sound pressure level at six frequencies (250 Hz, 500 Hz, 1 kHz, 2 kHz, 4 kHz, and 8 kHz) was measured simultaneouslyboth beneath the earmuff and outside the earmuff with a second sound level meter.

Results

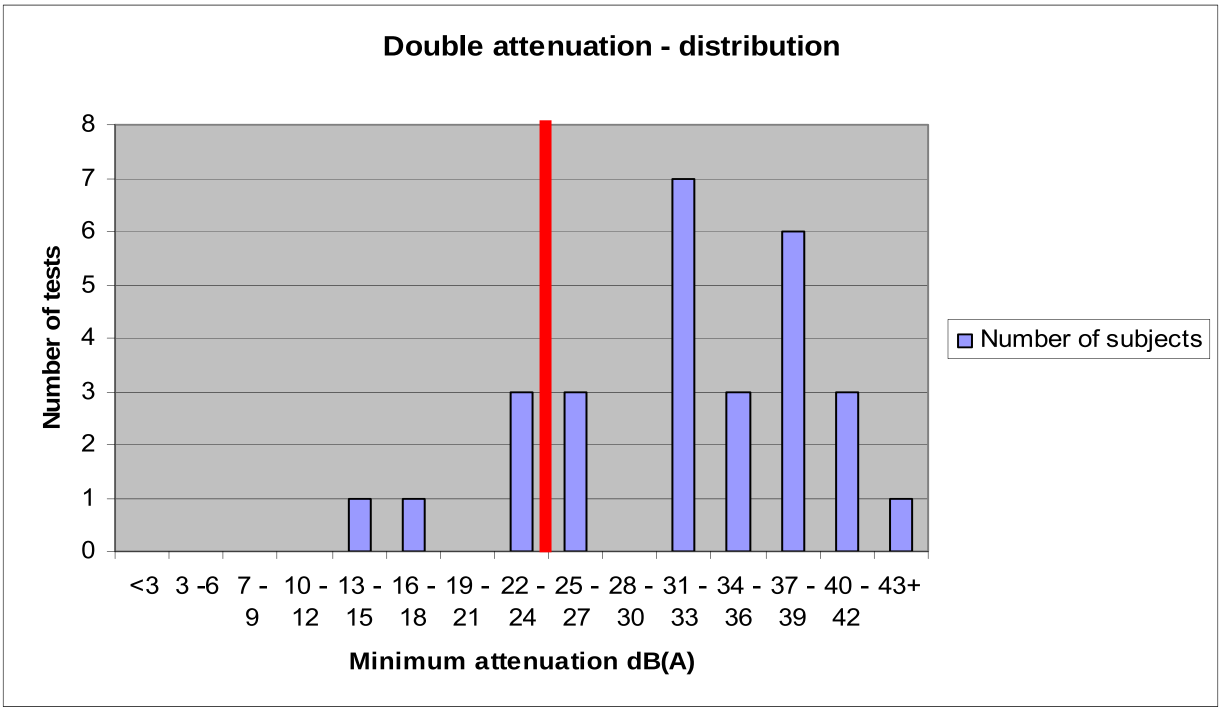
A summary of the attenuation testing results is shown in Table 1. The 'real world' attenuation (NRR84) was calculated for each device model and type. The NRR84 were computed following the approach described by Berger and estimates the minimum attenuation achieved by 84% of wearers. This value is computed by subtracting 1 standard deviation from the mean attenuation values using 'pink noise' (i.e., equal intensity at all frequencies) instead of the actual spectral sound field in the workplace. The noise attenuation in dB was also calculated for each subject using the measured workplace noise spectral data. Actual work area spectral noise is important for attenuation calculations because hearing protectors do not attenuate noise equally at all frequencies. Most hearing protectors attenuate more high frequency noise than low frequency noise. The percentages of subjects with less than 15 dB and 9 dB of measured attenuation using the workplace spectral sound field data are also shown in the table. There were no instances where test participants had obviously, based on visual observation, improperly inserted their foam earplugs. In cases where the attenuation was less than 15 dB, the subject was asked to reinsert their foam earplugs or try a different model earplug for a retest. Seven of the of the 27 subjects were re-tested: of these, 5 achieved better attenuation on the second test. At the site where custom moulded earplugs were used, about one half of the workers that had been issued custom moulded earplugs complained that the earplugs where uncomfortable and did not use them. These workers preferred to use the foam earplugs that were also available on site. All of the workers wearing earmuffs also wore safety glasses. For several of these it appeared that the arm of the glasses created a gap between the head and the cushion of the earmuff. Retesting without the safety glasses was not performed.

For dual HPD the NRR84 was calculated to be 24.6 dB. Only 2 of the 28 subjects tested (7%) achieved less than 20 dBA attenuation.

HPD device	**No. of subjects**	**NRR84 dB**	**% subjects < 15dB**	**% subjects < 9dB**
Foam earplug 1	25	13.5	36	12
Foam earplug 2	3	5.9	67	67
Foam earplug 3	33	9.8	42	12
Foam earplug 4	5	5.2	42	0
Foam earplug 5	4	7.9	50	25
Custom moulded earplug	20	11.8	35	10

All earplugs	90	10.7	40	13
Earmuffs	28	12	32	11
All HPD	**118**	**10.8**	**38**	**13**

Table 1 attenuation testing results



Discussion

Since 1975, there have been 22 published studies evaluating hearing protector attenuation under actual field conditions. These studies have consistently shown that 'real-world' attenuation is significantly less than the laboratory measured attenuation reported by the manufacturers. The reasons for the deviation between the laboratory and field measurements of attenuation vary by hearing protector type but are mostly attributable to the subject selection, fitting, and training. The laboratory methods for measuring earplug attenuation require the investigator to insert the earplug deeply in the subject's ear to maximize attenuation. Also, subjects that cannot achieve a good fit because of the size or shape of their ear canal are excluded as well as those with significant hearing loss. Workers in the field may not insert the earplug as deeply as in the laboratory tests and some workers may not be able to achieve a good fit due to the size or shape of their ear canal. Laboratory evaluations of earmuffs use new earmuffs that are fitted on the head of the subject by the investigator. In practice, earmuffs are reused and rarely in 'new' condition, are mostly mounted on helmets where the spring can get stretched and the ear cushions deformed, and are worn with various types of safety glasses where the arm of the glasses may affect the seal of the ear cushion.

Numerous organizations have reviewed attenuation results under actual field conditions and have made recommendations on how to 'derate' the manufacturer's NRR to estimate real-world attenuation. In the 1998 revised criteria for a noise standard, NIOSH recommended the derating of the NRR for earmuffs by 25%; formed earplugs by 50%; and other earplugs by 70%. Appendix B of the OSHA Noise Standard describes methods for calculating the adequacy of hearing protector attenuation that involve derating the NRR by 50%. And in 1983 OSHA instructed its compliance officers to derate the manufacturer's NRR by 50% in enforcing the engineering control provisions of the standard. ExxomMobil operating sites typically require a minimum NRR of 30 for earplugs and a minimum NRR of 25 for earmuffs when selecting hearing protectors.

Earplugs or earmuffs are required to be worn where noise levels exceed 85 dBA. In addition, dual hearing protection (earplugs and earmuffs worn in combination) is typically required where noise levels exceed 100 dBA, which effectively derates HPD's by 15 dB. The requirement for double hearing protection at 100 dBA is based on the assumption that workers will reliably achieve no more than 15 dB of attenuation from their earplugs or earmuffs even though typical SNR ratings for these HPD are 25 or greater.

Very little information is available to verify the level of protection provided when two hearing protectors are worn in combination. HPD manufacturers label their products with a noise attenuation rating determined following standard laboratory procedures, but do not provide this information for combinations of HPD. Several researchers have attempted to identify a correlation between the attenuation of earplugs and earmuffs worn individually, and the attenuation provided by the devices worn in combination. If such a relationship were uncovered, it would allow the estimation of dual HP

attenuation for any combination of single HPD. In 1956, Von Gierke reported that on average the combination of earmuffs and earplugs gave 5 dB more attenuation than the higher attenuating individual protector. This seems reasonable, considering that a 5 dB increase in attenuation means that more than twice the sound energy is being blocked, given the logarithmic scale for decibels (using the 5dB exchange rate). ExxonMobil now apply the 3dB exchange rate when calculating noise attenuation. OSHA devised a formula to estimate the attenuation provided by dual HP, that applies the 5 dB increase found by Von Gierke. The formula is used by OHSA inspectors to assess the adequacy of hearing protection provided to employees.

The OSHA formula to estimate dual HP attenuation is:

Dual HP attenuation = (NRRmax - 7)/2 + 5

In this formula, 7 dB is subtracted from the higher of the two devices' laboratory-based noise attenuation rating (NRR) to correct for A-weighted noise measurements. A safety factor of 50% is applied to account for real-world hearing protector performance. Finally, 5 dB is added to account for the added protection from the second device. OSHA does not cite any empirical study to support the use of this equation.

Conclusions

The subjects in this study achieved less than 15 dB of attenuation in 38 % of the tests performed. None of the hearing protectors evaluated appeared to provide better or more reliable attenuation. However, most workers (87%) did achieve a minimum of 9 dB attenuation. Hearing Conservation Program practices and procedures were modified to reflect these results.

Further study is needed to identify the reasons for low attenuation performance. Effective methods for improving attenuation cannot be developed until the relative contribution of the reasons underlying poor performance are understood. For example, if poor earplug fit due to the variability of ear canal physiology is responsible, then individual fit testing with a variety of earplug models may improve performance. However this intervention may not result in improved attenuation if workers are not trained and motivated to consistently insert their earplugs properly. Likewise, there are a variety of possible reasons for the low attenuation observed with earmuffs. The effect on attenuation of safety glasses, earmuff age, and mounting (cap, head, or neck) has not been quantified, so specific recommendations for improving attenuation cannot be made.

The dual HPD evaluated in this study consistently provided at least 20 dBA of attenuation. Only 2 of 28 subjects achieved less attenuation. Most of the tests were performed on workers wearing MSA Soundblocker earmuffs; only a limited number of tests were performed with four other earmuff models. There was insufficient data to determine if earmuff model significantly affects dual HP attenuation. Additional field testing on other earmuff models should be conducted to verify that similar performance can be obtained from different types of ear muffs. None of the workers achieved more than 43 dBA attenuation, and half achieved less than 33 dBA. The NRR84 (an estimate of the minimum attenuation achieved by 84 % of workers) was calculated to be 24.6 dBA. In operations where time weighted average noise exposures exceed 105 dBA (which is 20 dBA above the 85 dBA Noise TWA) engineering and / or administrative controls should be instituted to ensure that 8-hour Leq exposures do not exceed 105 dBA, thereby ensuring that the in-ear Leq will not exceed 85 dBA.

The ExxonMobil hearing conservation policy indicates that if noise cannot be reduced by other means, hearing protection devices should be provided and used on the proviso that all other conditions are met (e.g. proper selection and user training, appropriate to wearer, health surveillance where required).

- For noise levels equal to or greater than 85dB(A), single hearing protection
- For noise levels greater than 94dB(A) double hearing protection
- For noise levels greater than 105dB(A) double hearing protection, with limits on the amount of time in the area.

By putting in place these control measures there is reasonable confidence that workers will not be exposed to noise levels greater than 85dB(A) at the ear.

Noise Exposure and Hearing Protection Calculator

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Abstract

A number of workers at a metal fabricator are exposed to noise in their workplace and were supplied with class 5 hearing protection to use while working. Management was concerned that the workers were being exposed to excessive noise levels and that the hearing protection provided may not be appropriate. A consulting occupational hygienist was brought in to conduct a noise survey of the activities carried out by the workers. The hygienist used a calibrated class 1 integrating sound level meter to measure the noise levels generated by the various pieces of equipment used by each worker.

Welding, Leather Tanning and Orthopaedic Surgery - The Story of Cobalt and Chromium So Far

Ross Wenzel & Karly Hesp
Pathology North

Abstract

Cobalt and chromium are two industrially important metals that can affect employee health. Routes and sources of exposure are varied. Cobalt exposure can occur thorough welding and metal fabrication processes. The same sources exist for chromium with exposure also possible through leather tanning, preserved timber and industrial paints. Chromium toxicity is defined by metal valency with hexavalent chromium a carcinogen while trivalent chromium is an essential trace nutrient. A lack of controlled workplace studies has resulted in a relatively poor understanding of appropriate biological monitoring regimes to assess exposure to these metals. In recent years we have been involved in studies to assess prosthesis wear in patients with knee and hip replacements made from alloys of cobalt and chromium. Using our study results and those from other international studies, we address some of the limitations currently confronting occupational hygienists responsible for assessing employees working with cobalt and chromium.

Hazard Surveillance: Exposures at small scale horticultural farms

Mark Wagstaffe, Bradley Prezant, Samuel Keer, Brett Bissett, Jenny Job & Amanda Grey
Massey University & Safe Work Australia

Abstract

Safe Work Australia conducted a National Hazard Exposure Worker Surveillance (NHEWS) Survey in 2008. The 2008 NHEWS Survey interviewed 4500 workers around Australia about hazards they may have been exposed to in workplaces, including farms, assuming that that the workers performed routine tasks each day or week. This small-scale study will collect data within the horticultural industry where exposures may vary due to the seasonal nature of work activities.

Researchers will measure exposures to sunlight (UV radiation), heat, noise, dusts, and workplace chemicals. Site visits will be planned around key events in the production cycle, such as planting, weed and pest control activities, and harvesting. The researchers aim to identify specific activities or tasks where exposures occur, particularly peak exposures, measured through a combination of workplace observations and real-time monitoring techniques. The use of video exposure monitoring during peak activity periods will be a key aspect of this work.

Workplace Urinary Arsenic Analysis, Why Speciation Is Better. Analysis of Arsenic in Urine Using Hplc/Icpms

Nick Serbin and Greg O'Donnell
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Abstract

Exposure to arsenic is widespread and can occur in a number of industries including mining, smelting and timber preservation. The International Agency of Research on Cancer (IARC) classifies inorganic arsenic as a Category 1 human carcinogen. Ingested arsenic is mostly excreted in urine. Therefore urinary determination is a good marker for arsenic exposure. However, the different forms of arsenic are known to have different toxicities. ArsenicIII is known to be more toxic than ArsenicV and the organic forms of monomethyl arsonic acid (MMAV) and dimethyl arsinic (DMAV) are less toxic by a factor of 400. Arsenobetaine is the form of arsenic found in seafood and is known to be virtually non-toxic. However, DMAV has been reported to be present in some types of seafood.

In methods of analysis where only total arsenic is measured without differentiating between the different forms may lead to a false positive interpretation. If the test result was for DMA, then interpretation may still not be possible due to the uncertainty of the source. If however, inorganic arsenic or MMAV were present then it is more likely that exposure to inorganic arsenic has occurred.

The speciation of the individual arsenic species is achieved by separating them initially by HPLC and quantitating them by ICPMS. A study was conducted on high arsenobetaine containing urine samples spiked with inorganic arsenic species and showed that the method is both robust and effective. The arsenic species had a limit of quantitation of 0.02µmol/L.

Determination of Elements in Welding Fume by X-Ray Spectrometry and Uniquant®

James Hurst, John Volpato and Gregory O'Donnell
TestSafe Australia (WorkCover NSW)

Abstract

X-ray spectrometry (XRF) is commonly used to determine elemental concentrations of welding fume collected on membrane filters as part of occupational hygiene investigations. Methods generally use conventional calibrations such as those based on Health and Safety Laboratory (HSL) analytical method MDHS91. Unfortunately, these types of calibration require dust or fume generated standards for all elements determined. Such calibration standards may not be available, are difficult to prepare or are hazardous in nature. In recent decades calibrations have been made simpler with the use of commercial fundamental parameter calibrations. A method is proposed using a fundamental parameter software package known as UniQuant®. A conventional calibration and UniQuant calibration were set up and elements found in welding fume were determined from Sn to Ti. Samples obtained from the HSL Workplace Analysis Scheme for Proficiency (WASP) welding fume program were analysed by both methods for Ni, Fe, Mn and Cr. For the conventional calibration, average recovery results for the WASP samples were between 92-103% of the target value with RSD of 3-7%. For the UniQuant calibration, average recovery results for the WASP samples were between 97-112% of the target value with RSD of 3-10%. These results are well within analytical performance expectations for the type of welding fume matrix analysed. The method was applied to real welding fume samples collected from workplaces.

Worker Noise Exposure in the Food Retailing Industry – A Pilot Study

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RMIT University
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Abstract

The rapid growth of fast food venues in shopping strips, especially vendors selling health shakes and smoothie type drinks has produced a new set of workplaces with potentially high noise exposure for employees on extended shifts.

This pilot study assessed worker noise exposure, via personal noise dosimetry, during normal working hours of operation, at a number of stores within the one franchise chain, to obtain representative data from three [3] venues.

The study also measured general equipment noise performance, via a sound level meter at each location, during customer quiet periods.

The initial personal monitoring data indicated exposure close too or slightly above 85dB[A], and these results indicate a situation which requires consideration of state of the art noise reduction engineering controls [mainly top of the range interlocked enclosures for product processing], as well as Administrative Controls, via shift length monitoring, to ensure there is no on-going staff over-exposure.

Worker Thermal Load Exposure at a Metal Recycling Plant - A Pilot Study

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Abstract

Metal re-cycling requires significant heat to melt separated materials prior to their take off for the forming of ingots for re-use.

Workers in most smelters are required to perform duties [dross removal, pot tapping, etc] in close proximity to the furnace kettle, an area which constitutes a possible thermal load hazard.

This study examined the application of the AIOH Heat Stress Standard & Documentation Developed for Use in the Australian Environment, in unison with ACGIH input via WBGT measurement, and application of the Work/Rest table.

The study observed workers' normal activities associated smelting over a period of several shifts and time periods, and simultaneously collected thermal data with WBGT equipment.

When the obtained data was compared with AIOH risk scores and the WBGT index tabulation, the results did not allow for uninterrupted operational smelting, however, this workplace has never experienced any incidence of heat stress.

Experimental design, data, and practical project observations and recommendations are reported, along with recommendations to ensure future worker safety.

Worker Wood Dust Exposure in a Small Manufacturing Facility – A Pilot Study

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Abstract

There are approximately 10,000 small to medium employers [SME's] in the Australian workforce using wood or wood based product on a daily basis.

Most SME's, especially the smaller companies have multi-tasking staff, and thus the workforce can be classified as a single Similar Exposure Group [SGE].

This study completed measurement of inhalable wood dust, and local exhaust ventilation [LEV], at a small cabinet making facility using mainly treated pine and medium density fibreboard [MDF] as starting materials.

Personal sampling indicates significant wood dust over-exposure, [on average 15 – 20 mg/m3] at the site, on a series of representative work days, with all staff impacted at this level.

Testing of LEV performance indicated low capture velocities and poor procedural placements prior to cutting.

Recommendations upon Engineering, Administrative and finally PPE are presented.

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