

# Occupational health

SOUTHERN AFRICA

Vol 16 No 1 January/February 2010

**Work-related fatalities in the South African construction industry: 2004 to 2006**

**Low level exposure to nine volatile chemicals in research and testing laboratories at a South African university**

**A preliminary investigation of the effects of exposure to multiple health stressors using the Physiological Strain Index**



Laboratory exposures

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# occupational health

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# From the Editor. . .



Linda Grainger,  
Editor

**W**e are already well into the new year as I write this introduction to our first issue of 2010! I have little doubt that you, our readers, are busily engaged with multiple work and personal demands. However, I trust that you will find that the time spent on reading this issue is worthwhile, as it contains a variety of topics and information, and there should be something of value for each of you.

The first paper concerns work-related fatalities in the South African construction industry between 2004 and 2006. The authors, Vekinis, Kielkowski, Wilson, Bello and Rees, of the NIOH and the University the Witwatersrand, analysed the data from a mutual assurance company for this study. It is important as there is a paucity of published research on fatalities within the South African construction industry, despite its known risks. The study by Eppenberger and Haupt (published in 2009 in this journal, Volume 15, No. 5, p. 6–13) examined age in relation to accidents in general and not fatalities. Therefore, this study provides further information on the sector, and indicates the need for continued research and better enforcement.

The second paper describes a study by Franken, Du Plessis, Eloff, Laubscher and van Aarde – all SAIOH members. Universities have many research and testing laboratories, and the workers in these laboratories tend to have multiple, regular but short periods of exposure to various hazardous chemical substances. The problem is how to measure such exposure and determine whether there is a health risk. A few international studies have focused on this, but no published South African studies were located. Franken et al. measured exposures for nine volatile chemicals most commonly used in one university and determined the effectiveness of fume cupboards.

Mineworkers are simultaneously exposed to multiple health stressors which can also act synergistically, thereby confounding the assessment of their physiological responses to them. Such an assessment requires information on the effects of the individual stressors, as well as their combined effects, and must be done in a controlled laboratory environment. Edwards, Franz, Schutte and Grové, all of the CSIR, conducted such a preliminary study on heat, noise and exercise. They used the Physiological Strain Index and an innovative physiological monitoring system to measure the effects of the stressors. Further studies using a similar approach would have practical relevance.

Writing from an insurer perspective, Deodat Kritzinger explains how to best manage compensation for occupational injuries and diseases to avoid bad experiences. Outlining the legislative roles of the different parties, he provides a clear explanation of the need for interaction between these parties for optimal functioning of the system. His data illustrates commonly occurring problems, such as Mets found in his study reported in 2006 of this journal (Volume 12, No 3, p. 16-22).

On the news front, the International Labour Organization has released reports on an expert meeting to revise the list of occupational diseases, which took place in Geneva in October

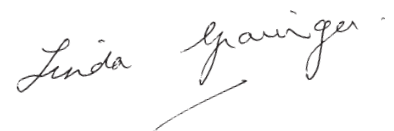


**WHO CC meeting delegates: Left to right:  
Barry Kistnasamy, Max Lum, Tom Robins,  
Sagie Pillay, David Rees**

2009.<sup>1</sup> Of particular interest is their deliberations on whether to include the following: radiofrequency radiations; malaria; extrinsic allergic alveolitis to include mists from contaminated oils; carpal tunnel syndrome due to extended periods of repetitive forceful work, work involving vibrations, extreme postures of the wrist, or a combination of the three; mental and behavioural disorders to be replaced by “psychological disorders”; and cancer caused by formaldehyde, hepatitis B virus (HBV) and C virus (HCV), and crystalline silica (possible inclusion as a carcinogen) (Merlod 2009/5).

At the same time, The Eighth Meeting of the Network of the WHO Collaborating Centres in Occupational Health was held in WHO Headquarters, Geneva. The 170 participants were from 42 countries and included many well-known South African experts. I had the privilege of attending the meeting. Jonny Myers of the University of Cape Town and I were leaders of the initiative to develop a global learning repository of digital learning materials, which is part of Priority 3.2. This initiative builds on discussions held during ICOH2009 and a WAHSA funded project headed by Amanda Ryan (then of the University of KwaZulu-Natal) to establish a southern African repository. Other SA project and initiative leaders are Claudina Nogueira and David Rees (NIOH), whilst many SA projects are included in the priority areas. The report, information and toolkits are most informative and can be viewed at: [http://www.who.int/occupational\\_health/network/collaborating\\_centres\\_meeting/en/index.html](http://www.who.int/occupational_health/network/collaborating_centres_meeting/en/index.html)

1. International Labour Organization. 2009. Reports: Merlod 2009/3,4,5 and 10. Meeting of Experts on the Revision of the List of Occupational Diseases. Recommendation No. 194. Accessed on 26 January 2009. Available at: <http://www.ilo.org/safework/info/meetingdocs/lang-en/index.htm>



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# Upcoming events

## INTERNATIONAL CONFERENCES

DATE	PLACE	TOPIC	MORE INFORMATION
20–21 April 2010	Taipai, Taiwan	RHICOH – Int. Symp. on Reproductive Hazards in the Workplace and Environment	E-mail: rhicoh2010@gmail.com
21–25 April 2010	Taipai, Taiwan	Medichem – Occupational health under globalization and new technology	E-mail: epicohmedichem2010@gmail.com
14–17 June 2010	Amsterdam, The Netherlands	The changing world of work – 4th International Conference on Psychosocial Factors at Work	E-mail: paog@vumc.nl
19–22 June 2010	San Francisco, USA	4th International Conference on the History Of Occupational and Environmental Health	E-mail: Paul.blanc@ucsf.edu
6–9 August 2010	Yokohama, Japan	ICOHN & ACOHN Joint Conference 2010 Global challenges to Occupational Health Nursing	http://icohn-acohn2010.com E-mail: secretariat@icohn-acohn2010.com
28 Sep to 2 Oct 2010	Rome, Italy	IOHA 8th International Scientific Conference: Health, Work and Social Responsibility	http://www.ioha2010.org/ E-mail: info@ioha2010.org
18–24 Mar 2012	Monterrey, Mexico	30th ICOH – Occupational Health For All: Research, Training and Good Practices	E-mail: admin@icohcongress2012.org

## LOCAL CONFERENCES

DATE	TOPIC	REGION	TARGET	COST	CONTACTNAME
5 March 2010	Travel, driving, biological hazards	Kirstenbosch, Cape Town	Occupational health practitioners	MMPA, SASOHN, SASOM, SASTM members: R700.00 Non-members: R900.00	Jenny Acutt Tel/Fax: +27 (0)12 803 7418 E-mail: info@sasom.org
12 March 2010		The Ranch, Polokwane			
17, 18 March 2010	SAFECONEX Africa 2010	Indaba Hotel and Conference Centre, Fourways	OH&S professionals	Early bird registration before 31 Dec 2009 – R3500, thereafter R3800.	Conference: info@raysaf.co.za Tel: +27 (0)12 654 8349 Fax: +27 (0)12 654 8358 Exhibition: delinds@mweb.co.za Tel: +27 (0)11 886 5985 Cell: 083 266 6662 Submission of papers/posters: kevin.renton@nioh.nhls.ac.za
13 May 2010	SASOHN Academic Day – Managing the occupational health service	Emperors Palace, Johannesburg	OH&S professionals	To be advised.	Linda Stokes SASOHN National Office Tel: +27 (0)11 892 3174 E-mail: sasohnoffice@mweb.co.za
19 May 2010		Elangeni, Durban			
26 May 2010		Protea Hotel Marine, Port Elizabeth			
29–30 July 2010	Occupational health	Birchwood Hotel, Boksburg	OHPs	To be announced	Jenny Acutt Tel/Fax: +27 (0)12 803 7418 E-mail: info@sasom.org
19 Sep 2010	The role of the OHNP in risk assessment	Edenvale, Johannesburg	OH&S professionals	To be advised	Rene Jordaan E-mail: rene.jordaan@implats.co.za
26 Nov 2010	Occupational medicine	KwaZulu-Natal	OHPs	To be announced	Jenny Acutt Tel/Fax: +27 (0)12 803 7418 E-mail: info@sasom.org

## 2010 SAIOH COUNCIL AND CERTIFICATION BOARD MEETING AND EXAMINATION DATES

29 January 2010	OHPC Meeting/Oral assessments	17 or 18 March 2010	Annual General Meeting
12 February 2010	NatCouncil Meeting/Written assessments	9 April 2010	OHPC Meeting/Oral assessments

## HEALTH AWARENESS DAYS, WEEKS AND MONTHS

FEBRUARY		MARCH	
DAY	TOPIC	DAY	TOPIC
	Healthy Lifestyle Awareness Month Reproductive Health Month		TB Awareness Month
19	Healthy Lifestyles Awareness Day	8	International Women's Day
		11	World Kidney Day
		20	World Head Injury Awareness Day
		21	Human Rights Day
		21	World Down Syndrome Day
		24	World TB Day

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# The management of occupational injuries and diseases – from an insurer perspective

Deodat Kritzinger,  
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DOH, MBA),  
RMA – General Manager  
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**T**reatment of injured or diseased workers is almost always experienced as a nightmare for the different stakeholders involved. A clear understanding of the relevant legislation and the functions of the different role players is needed to pave the way for changing this experience and perception. The occupational medical practitioner (OMP) is in my opinion the most suitable to orchestrate and co-ordinate communication between the different role players.

## LEGISLATION

Workers' compensation in South Africa is governed by two pieces of legislation namely the Compensation for Occupational Injuries and Disease Act, No. 130 of 1993 (COIDA)<sup>1</sup> and the Occupational Disease in Mines and Works Act, No. 78 of 1973 (ODMWA)<sup>2</sup> and the Occupational Diseases in Mines and Works Amendment, No 208 of 1993.<sup>3</sup>

The control and administration of COIDA is under the auspices of the Department of Labour through the office of the Compensation Commissioner (CC) as appointed by the Minister of Labour. Two mutual assurances, Rand Mutual Assurance and Federated Employers Mutual, were granted a licence in terms of section 30 of COIDA, to administer on behalf of the CC.

The control and administration of ODMWA is under the auspices of the Department of Health, through the Medical Bureau for Occupational Diseases (MBOD). The bureau will process claims and then submit them to the Compensation Commissioner for Occupational Disease (CCOD).

Other pieces of legislation that regulate the health and safety conditions in the workplace are the Occupational Health and Safety Act, No. 85 of 1993 (OHS Act),<sup>4</sup> and the Mine Health and Safety Act, No 29 of 1996 (MHSA).<sup>5</sup> However, this article will focus more specifically on COIDA.

## COIDA<sup>1</sup>

The sections in COIDA clearly define the responsibilities of the different role players in order to process and make informed decisions with regards to liability and settlement.

The four important groups of role players are the:

- insurer;
- the employer;
- the employee concerned; and

- the service provider, which includes all the different disciplines of medical service providers that will render services to the injured.

A brief summary of the main roles and responsibilities of each group and a more in-depth discussion on the position of the OMP and medical service provider will highlight the importance of a systematic approach in the management of occupational injuries and diseases.

## ROLE PLAYERS

### Insurer

The insurer is responsible for administration of the act through:

- registration of employers (see exempted employers in the act);
- assessment of the industry and related risks involved;
- calculation and collection of premium and provision for reserve funding;
- exercise control over Mutual assurances and their provisional settlement powers;
- make informed decisions based on the documents submitted and in accordance with COIDA requirements;
- payment of benefits such as loss of earnings, medical treatment and permanent disability;
- informing injured and employer of decisions and final outcome;
- administration of the appeal process; and
- issue of different Instructions to clarify the position in regards to claims for specific conditions.

(COIDA<sup>1</sup> – Chapters II, III and IV, sections 1–37)

Although the insurer can develop and implement all systems to control and administer the whole process, the submission of documentation by the other role players is not only the initiating step of the claims cycle but will in most cases also determine the outcome.

Rand Mutual Assurance monitors the compliance of different role players and will then take action to solve specific problem areas identified through system reports. Most problems are encountered with the non-reporting of incidents, fragmented and incomplete submission of documents that all impact on claims registration, adjudication and eventually delays with decision-making, payment of accounts and financial hardship to the injured.

## Employer

The employer's role is most crucial. Duties of an employer are outlined hereafter.

- Registration of an employer with an insurer is compulsory with the start of any employer–employee relationship (excluding domestic workers and exempted employers).
- Employee information is not included in a specific section of the act, but is a critical aspect of the employer–employee relationship. It should include in-house incident reporting procedure, emergency procedure, explanation of benefits and appeal process.
- Accident reporting within 7 days of the date of the incident.

during the pre-employment medical examination and induction;

- participate in and make input on incident reporting and control;
- only the OMP can confirm a diagnosis of occupational disease after having reviewed workplace exposure, confirmed with the clinical features and diagnosis, therefore all occupational disease should be reviewed and assessed by the OMP;
- should regularly review and follow up complicated injury cases – the OMP needs to keep employer updated on progress and prognosis of the seriously injured;
- manages absenteeism in general and injured or diseased cases in particular;

**“A clear understanding of the relevant legislation and the**

**functions of the different role players is needed . . .”**

- Disease reporting within 14 days after (confirmation of) diagnosis of occupational disease.
- Although the most important step, most problems are experienced at the employer level and commonly involve non-reporting, incomplete details on documents or delay with submission of supporting documentation.
- Submission of medical reports within 14 days to insurer.
- Payment of loss of earnings calculated in accordance with the schedules of COIDA for the first three months.
- Submission of a claim from the insurer for temporary total (or partial) disability (TTD or TPD) after the first three months with supporting documents.
- The employer is the channel for communication between insured and injured.

(COIDA<sup>1</sup> – Chapters V and VI, sections 39,41,47,56 and 63; Chapter IX, sections 80–89)

The role and function of the employer is central to most aspects of work-related injuries and diseases. Failure of the employer to comply with COIDA has serious legal and financial implications and should be the responsibility of a dedicated department or individual. The appointed OMP is best positioned and legally obliged to accept responsibility for all health and safety matters on behalf of the employer. (Section 13 MHSA<sup>5</sup>)

Reasons for the need for OMP and/or occupational health nurse practitioner (OHNP) involvement:

- are experts on occupational health legislation and best equipped in terms of knowledge;
- have superior knowledge of Instructions published for reporting and management of occupational injuries and disease;
- can provide the employee with information on COIDA

- conducts fitness assessment and assists with placement of affected individual even before maximal medical improvement (MMI) is reached;
- assesses (or confirms) functional loss in terms of published Instructions with MMI; and
- controls and prevents unresolved compensation cases through exit medical examinations and follow up on outstanding issues.

As the custodian of the health and safety of the worker, the OMP or OHNP can assist with ensuring that all documents are timeously submitted (in chronological) order to expedite the processing and decision-making. Failure of medical service providers to submit medical reports will easily be identified and action taken to improve the level of care and support to the injured.

- In terms of MHSA<sup>5</sup> all mine employers need to appoint a section 13 medical practitioner to establish and maintain a system of medical surveillance and to deal with matters relating to occupational injuries and disease. This is not a compulsory obligation of OHSA<sup>4</sup> but should be onerously pursued to improve general health and safety standards in the workplace.

## Employee

All employees should be well informed about their (own) rights on health and safety matters in the workplace and their role as per COIDA, which are as follows:

- reporting of (all) incidents to supervisor within time frames as per COIDA (employer does not have the right to refuse reporting because internal procedure not followed);
- can report directly to the CC or mutual concerned in cases where the employer refuses;

- must visit medical provider and subject themselves to medical examination after an injury;
- request documentation of clinical findings;
- present for special medical examination when so requested by CC or mutual;
- take care of own health and safety;
- lodge an objection for increased compensation in case of employer negligence; and
- have the right to appeal against findings of CC.

(COIDA<sup>1</sup> – Chapter V and VI sections 38, 42, 44, 51; Chapter X, sections 90, 91, 98 and 99)

Our experience is that injured employees are easily influenced by supervisors to not report “minor” injuries and often then present later with claimed complications as a result of those injuries. The insurer will have no records and the employee then needs to submit proof of the alleged incident. Negligence in such a case on the side of the employer is a criminal offence and the Department of Labour may award a fine to the employer to pay for expenses and permanent disability.

### **Medical service provider**

Service providers are uncertain with regards to their role and rights in terms of COIDA. COIDA clearly indicates the functions, roles and rights of medical service providers as follows:

- should receive an accident report from employer stating the details of the injured and mechanism of injury;
- the insurer will cover all reasonable medical expenses related to injury or disease;
- treatment to be supported by a detailed medical report on clinical findings and treatment given;
- need for First, Progress and Final medical report depending on the length of active treatment;
- cost for the insurer according to published tariffs or deemed appropriate;
- may not levy a co-payment or additional charges to the injured;
- medical service providers to submit medical report within 14 days after treatment to employer (and/or insurer). Employer to submit to insurer;
- insurer can withhold payment if no medical report has been submitted;
- the insurer can request more detail on clinical findings at no extra cost; and
- must provide detailed medical report on the clinical findings and treatment in the prescribed format.

(COIDA<sup>1</sup> – Chapters VII and VIII, all sections)

Significant problems, with the major one being the delay in payment of accounts, are experienced by medical service providers as pointed out and are as a result of various reasons. The medical service provider can improve and assist the claim process under COIDA through the following measures:

- demand an employer report in case of all injuries reported by the injured or a witness;
- the submission of a detailed report on the clinical findings as well as the results and findings of special investigations;
- provide notes on the referral to specialists or other disciplines with follow-up on their report and findings;
- inform the injured of the process and the progress;
- be specific on:
  - o the presence of pre-existing conditions;
  - o the mechanism of the injury and the effect and relationship of the injury to the clinical findings;
  - o severity of the injury and impact on the injured person's ability to work; and
  - o sick leave note with clear indication of the dates and return to work;
- in the case of prolonged recovery, submit a monthly progress report together with a sick note to enable the employer to recover the loss of earnings;
- submission of final report when the injured has reached maximal medical improvement (MMI);
- detailed description of the clinical findings as related to the injury and in accordance with the relevant instructions;
- most injuries are musculo-skeletal in nature and the range of movement model or amputation level are used to document the functional level; and
- do not create any expectations, avoid recording or awarding a percentage of disability unless the percentages as published.

### **CONCLUSION**

Interaction between various role players is crucial for optimal functioning of the management of a fair and equitable compensation system for injured and diseased workers. Figure 1 shows the “ideal” claims cycle and steps with the interaction of different role players to achieve this. Tables 1 and 2 are provided to indicate the number of claims delayed for settlement or processing due to outstanding processes from the employer side and medical service provider reports or documents respectively. Although they depict the RMA experience, it is likely to be similar at the CC but more pronounced because RMA actively drive and collect outstanding documents in order to reduce them. Mets reported and identified many such problems.<sup>6</sup>

The OMP and OHNP are the most appropriate to manage the administration of the various processes and make sure that the injured or diseased receive the benefits to which they are entitled. At the same time the employer should also be informed about the health status of employees injured in the workplace and the cost and socio-economic implications as a result of injuries in the workplace.

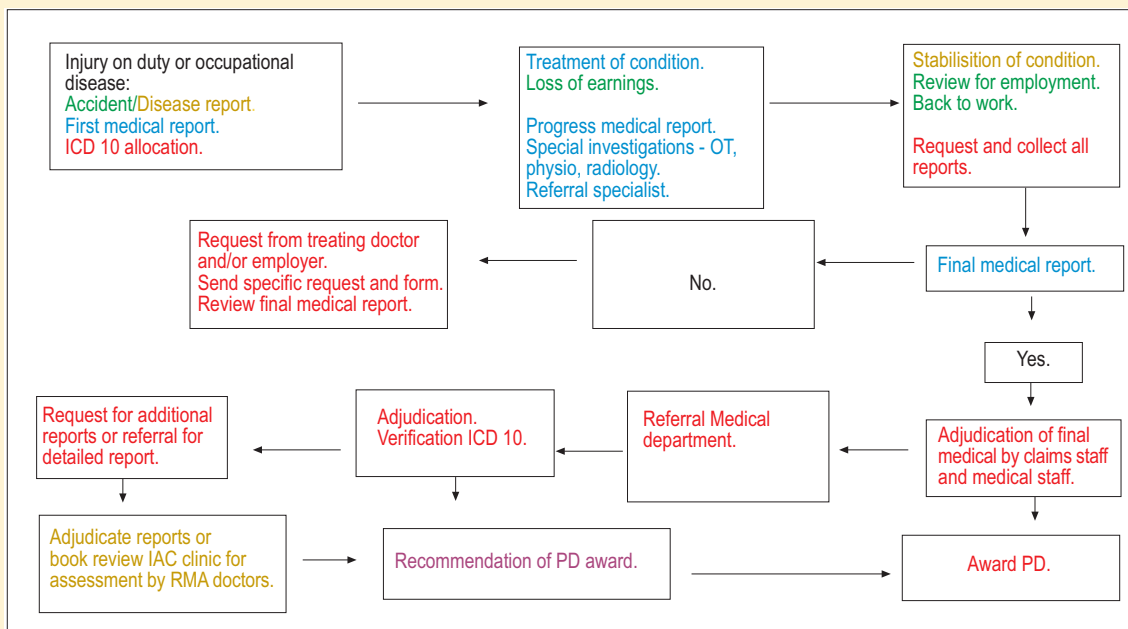
**Table 1. Outstanding documentation from employers as at 31 December 2009**

Comments	Total
Days Off Interim (RM16) outstanding	351
Liability decision outstanding	238
Identity documents outstanding	170
Earnings at the Time of accident / disease	85
Confirm earnings	84
Employee banking details (RMD20)	66
Future probable earnings	52
RMD1 – Signed Accident Claim Form outstanding	51

**Table 2. Outstanding medical reports and attendance of assessment clinics because of incomplete medical reporting as at 31 December 2009**

Description	Number of claims
First medical report outstanding	115
Progress medical report outstanding	153
Final medical report outstanding	462
Inconclusive final medical reports	10
Outstanding medical assessment	100
1st Impairment assessment clinic not attended	12
2nd Impairment assessment clinic not attended	7

**“Most problems are encountered with the non-reporting of incidents, fragmented and incomplete submission of documents . . .”**



**Key: Insurer, Employer, Employee, Medical service provider**

**ICD 10 – International Classification of Diseases 10; IAC – Impairment Assessment Clinic;**

**PD – permanent disability**

**Figure 1. Typical claims cycle flow with medical department involvement, referral and recommended medical requirements**

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# Work-related fatalities in the South African construction industry: 2004 to 2006

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## ABSTRACT

There has been little research on fatalities within the South African construction industry, despite its known risks. Our study uses data from a mutual assurance company to analyse fatalities in the South African construction industry for 2004 – 2006 to report fatality rates and reported cause of these deaths. The annual fatality rates per 100 000 workers calculated for this industrial sector were similar to those reported in other middle-income countries, but much higher than high-income countries (calculated rate: 2004 = 36.34, 2005 = 37.48; 2006 = 30.29). In addition, 43.1% of the 195 deaths were coded as due to motor vehicle accidents, with the majority of these arising from trucks, lorries and dumper accidents. Further research over a greater number of years is needed to establish trends in rates and types of injuries and underlying causes; however, there is a clear need for the implementation and enforcement of comprehensive policies to protect construction workers.

**Key words:** construction industry; motor vehicle accidents; occupational fatalities

## INTRODUCTION

South Africa's construction industry has seen a boom in growth in recent years, with an associated 26.3% increase in the number of employees working in the sector from 2004 to 2007, as shown by Statistics South Africa reports.<sup>1,2,3,4,5</sup> However, worldwide, workers in the construction industry have been shown to be among the most vulnerable and exposed to poor occupational health and safety,<sup>5</sup> with large numbers of injuries and fatalities per year reported internationally.<sup>6,7</sup> Fatality rates in the construction industry are important *per se* – high rates clearly deserve attention, but also because these rates have been used as indicators of health and safety performance in the industry and more

generally for a country as a whole.<sup>8,9</sup> Additionally, analyses of causes of and risk factors for these fatal accidents are necessary to target prevention strategies at vulnerable groups and high risk settings.

Though there are few recent published studies focusing on fatalities in the sector, research has been carried out in Turkey, the United States, Australia, Israel, Germany and Yugoslavia, for example.<sup>10-15</sup> In Turkey<sup>10</sup> and Israel<sup>12</sup> the construction industry was responsible for the largest number of work-related fatalities. In Yugoslavia construction had the highest fatality rate of any industry<sup>15</sup> and in the USA and Australia rates were more than double national averages for all industry.<sup>14</sup> Recent data for South Africa are scant, although information obtained from Federated Employer's Mutual Assurance Company (FEMA) from 2006 and 2007 showed 74 deaths among 9 184 claims in 2006 and 60 among 10 231 claims in 2007.<sup>16</sup>

The direct causes of fatal construction accidents vary by country and region. In the USA and Australia falls (26% and 28% respectively) were followed by motor vehicle accidents (MVAs) –16% for both countries – as leading causes. However, in North Carolina during 1978–1994, and in Turkey from 1969 to 1999 electrocutions were more common than MVAs, although falls still headed the list: falls 26.7% and 39.1% of fatalities respectively; electrocutions 20.4% and 13.8%; and motor vehicle accidents 18.9% in North Carolina.<sup>17</sup> In the 1990s in Yugoslavia, MVAs accounted for 57% of fatalities and falls only 15%.<sup>15</sup> Studies of cause-specific fatalities have not been published for South Africa, but Eppenberger and Haupt<sup>16</sup> have reported that MVAs make up a large proportion of all deaths: 36.5% and 46.7% in 2006 and 2007 respectively.

A large number of studies have investigated risk factors



associated with construction fatalities and again they vary by region and country, but the nature of the work or occupation,<sup>10-12,18</sup> the length of tenure at the workplace<sup>10</sup> and migrant or foreign worker status<sup>2</sup> have been found to be important in some settings. In South Africa, only age has been examined recently, but in relation to accidents in general and not fatalities.<sup>16</sup>

In spite of the well-documented dangers of working in the construction sector, there are no recently published rates on South African fatalities within the industry. The Department of Labour's Compensation Commissioner's Report from 2005, which uses the latest available statistics for South Africa from 1999,<sup>6</sup> does not report rates, only absolute numbers of deaths per sector. The report shows that 15% of the 889 reported fatalities in 1999 were in the construction sector, second only to the mining industry (19%).

This paper aims to report fatality rates and reported cause of fatalities in the South African construction industry for 2004 – 2006. These years were selected as a dataset covering them was available for analysis. The benefits of this information would be as an indicator of

of fatality. Age at death was calculated using date of birth and date of fatality. Age was then collapsed into five groups (18–29; 30–39; 40–49; 50–59; 60–71 years). The thirty-five occupations recorded were collapsed into three groups: unskilled workers; skilled workers; and manager, professional and qualified persons. Unskilled workers included those identified as cleaners, labourers or watchmen. Skilled workers were those identified as having a position that necessitated training on the job; for example, bricklayers, drivers, painters, plasterers and welders. Managers were identified as those recorded as foremen, charge hands, supervisors or managers in the original dataset. Qualified workers' listed occupation required a tertiary degree or higher (for example, engineer or surveyor). The professional group included those that required more than a year of training for their occupation, such as mechanics and electricians. Tenure at current employer was collapsed into four groups according to the distribution of the variable (0–30 days; 31–364 days; 1–5 years; more than 5 years). The original coding of cause and agency of the fatalities, as used in the insurer database, was retained to present the distribution of the variables as standard descriptors.

**“... worldwide, workers in the construction industry have been shown to be among the most vulnerable and exposed to poor occupational health and safety”**

occupational health and safety performance in the industry, and identifying the major causes would highlight areas for targeted intervention and improvement.

## METHODOLOGY

### Study design

A retrospective study was carried out on all work-related fatalities reported to a construction industry mutual assurance company between January 1, 2004 and December 31, 2006. South Africa's Department of Labour does not hold available, up-to-date statistics on fatalities within specific industries; therefore the data acquired were the most accessible.

### Study data

Information was obtained from the mutual assurance company regarding the number of organisations holding policies during the study years, as well as the corresponding number of employees covered. Based on these records, and Statistics South Africa industry employment data, the company covered approximately half of all construction employees in South Africa (2004 = 59.5%, 2005 = 43.2%, 2006 = 47.8%).<sup>1</sup> Personal communication with their Chief Information Officer indicated that their policy holders were mainly large-scale formal sector construction employers.

The dataset was compiled from the records of each fatal incident. Variables in the dataset included: sex, date of birth, occupation, tenure at employer, cause of fatality, and agency



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### Data analysis

In calculating annual fatality rates (annual number of fatalities per 100 000 workers), the denominator used was the number of employees from the construction industry covered by the mutual insurer during each of the study years. The company did not have data on the number of employees by age, occupation and sex in order to produce fatality rates for each stratum within these variables. Consequently, only proportions across strata could be calculated.

Fatalities were analysed in terms of demographic, occupational and accident variables to identify patterns and key risk factors. Proportions were calculated for calendar year of fatality, sex, age groups, occupational group, length of tenure at the workplace, and cause of death. Accident data was then further examined by the major cause of death,

motor vehicle accidents (MVAs), for a more detailed analysis. Pearson's chi-square test of association was carried out using a binary cause of death variable; death by MVA and deaths from all other causes. Proportions were also calculated for the agency of all MVA fatalities to establish the principal cause of MVAs.

### RESULTS

There was a total of 195 work-related fatalities among construction workers employed by companies insured with the mutual assurance company between January 1, 2004 and December 31, 2006. Of these, 33.3% fatalities occurred in 2004, 35.9% in 2005 and 33.9% in 2006.

Table 1 shows the fatality rates for the years 2004 – 2006. No trend is evident for this short period of analysis.

Table 2 shows the fatalities across sex, age group,

**Table 1. Fatality rates in South African construction industry: 2004–2006**

Year	Number of employees	Number of fatalities	Rate per 100 000 workers
2004	162 364	59	36.34
2005	186 767	70	37.48
2006	217 881	66	30.29

**Table 2. Fatalities in South African construction industry 2004–2006 by sex, age group, occupation group and tenure**

Variables	Fatalities		
	n	%	
Sex	Male	188	96.4
	Female	7	3.6
Age groups (in years)	18 – 29	51	26.2
	30 – 39	52	26.7
	40 – 49	42	21.5
	50 – 59	37	18.9
	60 – 71	13	6.7
Occupation group	Unskilled labourer	91	46.7
	Skilled labourer	60	30.8
Tenure	Manager, professional or qualified	44	22.6
	0 – 30 days	56	28.7
	31 – 364 days	61	31.3
	1 – 5 years	38	19.5
	>5 years	40	20.5
Total number of fatalities		195	100.0

**Table 3. Distribution of fatal motor vehicle accidents relative to other causes of fatalities, by age, occupation and tenure**

Variables	MVA fatalities		All other causes		Pearson's $\chi^2$ p-value	
	n	%	n	%		
Age groups (in years)	18 – 29	19	37.3	32	62.8	0.48
	30 – 39	27	51.9	25	48.1	
	40 – 49	17	40.5	25	59.5	
	50 – 59	14	37.8	23	62.2	
	60 – 71	7	53.9	6	46.2	
Occupational group	Unskilled labourer	37	40.7	54	59.3	0.57
	Skilled labourer	25	41.7	35	58.3	
	Manager, professional or qualified	22	50.0	22	50.0	
Tenure	0 – 30 days	31	55.4	25	44.6	0.15
	31 – 364 days	22	36.1	39	63.9	
	1 – 5 years	14	36.8	24	63.2	
	> 5 years	17	42.5	23	57.5	

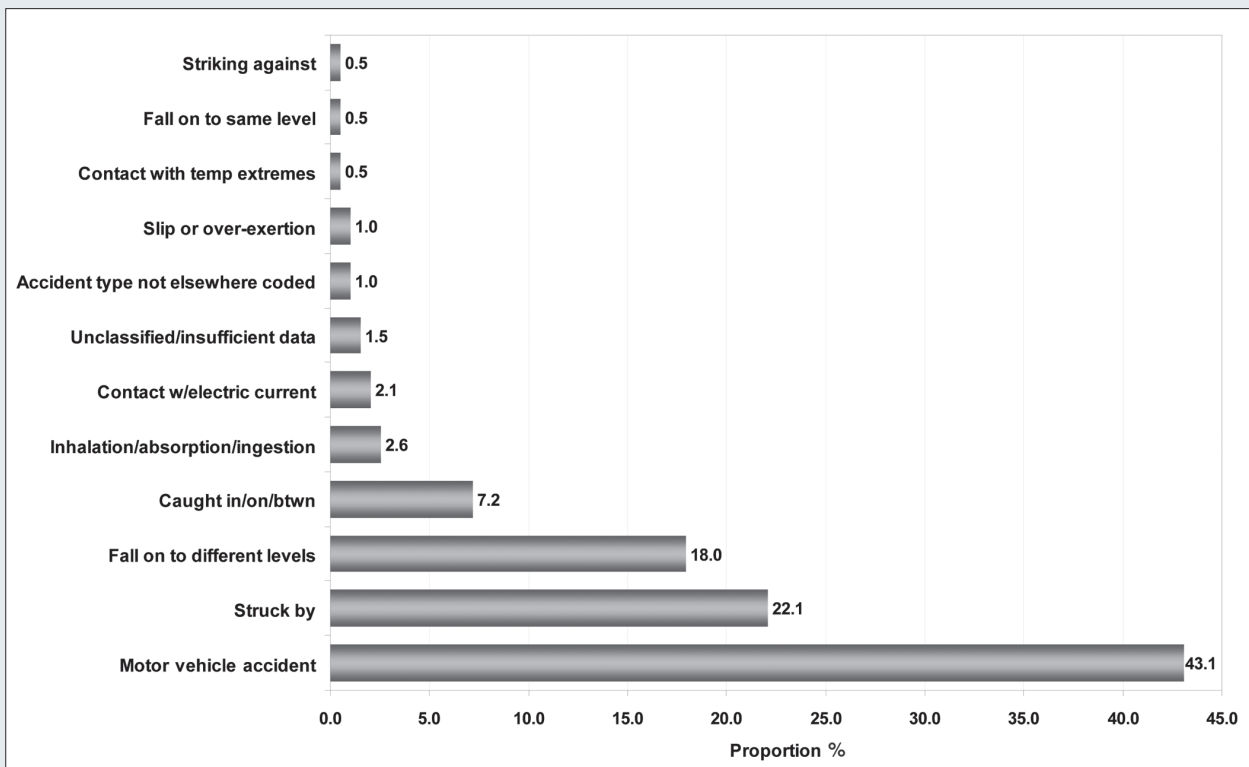


Figure 1. Percentage distribution of causes of death 2004–2006


**“Fatality rates in the construction industry are important because these rates have been used as indicators of health and safety performance in the industry”**

occupation group and tenure at company. The majority of fatalities were among males (96.4%), with only 7 deaths among women. The age of those fatally injured ranged from 18 – 71 years, with a mean of 39.2 years. Almost half of the fatalities in the data set were workers classified as unskilled labourers (46.9%), with 30.9% skilled labourers. Length of tenure at company of employment varied greatly. Sixty percent of fatalities occurred in those who had worked with their company for a year or less. Thirty-four of those fatalities were also reported in employees registered as working for zero days.

#### Causes of fatalities

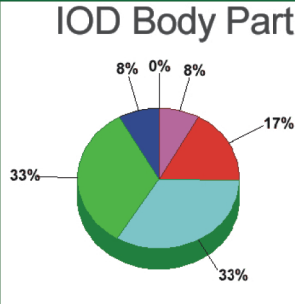
The three leading causes of death were: motor vehicle accidents (MVAs), ‘struck by’ and ‘fall on to different levels’, with MVA and ‘struck by’ accounting for 65.2% of the fatalities and “fall on to different levels” 18.0% (Figure 1).

MVAs included any incident where a motor vehicle was involved on a public road. This excludes accidents that took place on site or on private roads. MVAs were the leading cause of fatal accidents, causing 84 deaths (43.1%). In assessing whether there was an association between deaths caused by MVAs, relative to another cause, and demographic factors, no significant differences between the proportions of deaths caused by MVAs were found for sex; age groups; occupational groups; or tenure (as shown in Table 3).



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When analysed by sub-type, the 'Trucks/Lorries/Dumpers' group was responsible for 45.2% (n=38) of all MVAs (Figure 2). Other motor vehicles, the second leading cause of MVAs, was responsible for 22 deaths (26.2%).

## DISCUSSION

The fatality data from a construction industry workers' compensation insurance company presented in this paper emphasise the need for more occupational health and safety protection for construction workers in South Africa. The fatality rate from 2004 to 2006 ranged from 37.5 to 30.3 per 100 000 workers. By comparison, the rate for South Africa's mining industry in 2006 was 43.7 fatalities per 100 000 workers.<sup>11</sup>

However, South Africa's rate of fatal injuries within the construction sector was much higher than those published for high income countries: three times higher than that of the United States (10.8 fatalities/100 000 workers), and almost 8 times that of the United Kingdom (4.0 fatalities/100 000 workers).<sup>11,12</sup> A study using data from the US state of Oregon, covering 1990–1997, reported an annual death rate of 8.5/100, 000 workers (95% CI; 8.1–8.9).<sup>11</sup> In the most economically developed part of Yugoslavia, the Autonomous Province of Vojvodina, rates during the 1990s averaged 15.3/100 000.<sup>15</sup>

Nevertheless, the South African rate is similar to other middle-income countries (as defined by the World Bank classification of countries). For example, Colak et al. found construction fatalities in a Turkish province of 28 per 100 000 workers for the years between 1990 and 2001; slightly lower than that for Turkey's

construction sector as a whole (31 fatalities/100 000 workers).<sup>10</sup> Malaysia also reported a similar rate in 2000 (32.6 fatalities/100 000 workers).<sup>11</sup> For Argentina, the calculated fatality rate in 2006 of 41.6 fatalities per 100 000 workers is higher than that calculated for the same year in South Africa.<sup>11,12</sup>

Comparing causes of fatalities across countries is problematic because the application of classification systems varies. Nevertheless, international studies on fatalities in the construction industry have shown that the three biggest causes of death have been due to falls from height, motor vehicle accidents and electrocution, with falls from height the most common in developed countries.<sup>14,15</sup> Both Colak et al. and Jackson and Loomis reported approximately two thirds of fatalities caused by these three factors.<sup>10,11</sup> Studies of fatalities within the occupational setting have also shown that MVAs account for a large proportion of deaths in the construction industry<sup>10,11,12,17</sup> but the 43.1% found in this study is unusually large.

It is unfortunate that denominator data on the insured workers were not available as this prevented an analysis of risk factors; only simple frequency tabulations by a small number of factors (e.g. sex, age, occupational group and tenure) were possible, and this makes comparison with other studies of little if any value. However, we observed 60.0% of construction workers injured with only one year of tenure which suggests lack of training or use of casual labour.

Our findings suggest that prevention efforts are needed in the industry, but that the biggest improvement would occur in controlling MVAs, as they accounted for over 40% of fatalities. Additionally, MVAs occurring on private roads or on construction sites were coded as 'struck by' in accordance with the insurer classification, so the proportion of deaths involving vehicles is actually even larger. There was a wide range of vehicles responsible for the deaths but trucks, lorries and dumpers were the main cause. Workers being transported to and from their work site, those transporting materials, or those working on public roads would make up a large proportion of the victims.

The Construction Regulations of South Africa's Occupational Health and Safety Act (1993)<sup>11</sup> cover the operation and maintenance of construction vehicles and mobile plants. This includes the design of vehicles, training of operators, controls of operations, signalling, preventative measures against crushing of operators and other workers, and the safety of pedestrians and other vehicles. Furthermore, the Regulations specify that "vehicles used to transport employees have seats firmly secured and adequate for the number of employees to be carried and . . . when workers are working on or adjacent to public roads, reflective indicators



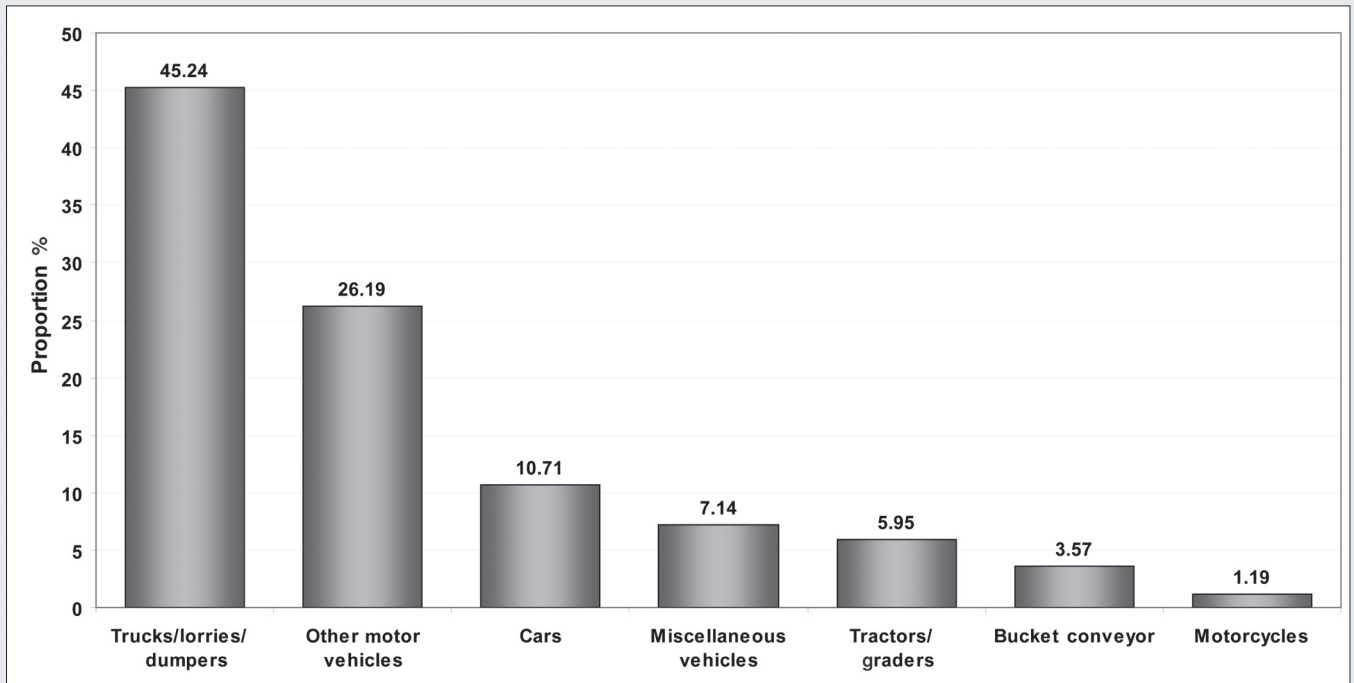


Figure 2. Eighty-five fatalities in the South African construction industry by type of MVA

*“The three leading causes of death were: motor vehicle accidents (MVAs), ‘struck by’ and ‘fall on to different levels’ ”*

are provided and worn by the workers”.<sup>19</sup> It is unclear whether these regulations are being adhered to, but the large numbers of MVA fatalities indicate that there may be lapses. Greater enforcement of these regulations may lead to a reduction of the fatalities in the MVA group. Further study of the underlying causes of individual incidents is needed to assess compliance with the Regulations and identify further areas for control.

### LIMITATIONS OF STUDY

Although the data presented in this paper cover a large proportion of employees in the South African construction industry, this proportion may not be representative of all employees. As the mutual assurance company caters mainly for large-scale employers, there is an inherent selection bias to the data. It is likely that a disproportionate number of smaller construction companies did not have a policy with mutual assurance company, and employees working for these smaller companies may be at higher risk. This could also be true of migrant or illegal workers, sub-contractors, or independent companies that do not submit their compensation claims via the mutual assurance company. Similarly, due to the nature of the data, it was not possible to calculate fatality rates per risk factor. Denominator information for variables such as age group, occupation group, and tenure would have

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assisted in determining vulnerable groups within the greater workforce. However, the data used for this study was the most coherent and recent data available for use in this type of analysis, and as such, provides us with the only benchmark of the fatality rate in the industry for South Africa at this time.

For comparison with previously published literature, the inclusion of other variables such as alcohol and drug use, time of accident, and size of employer would have been useful. Further analysis using a greater number of years would enable trends and risks to be identified. Furthermore, more details on each incident could enable an analysis that allows for the underlying causes of each incident to be understood. For example, not all deaths from MVAs would necessarily be workers being transported, or drivers, and this information would enable interventions to be better target the appropriate group.

## CONCLUSIONS AND RECOMMENDATIONS

In conclusion, our study showed high fatality rates in the South African construction industry, comparable to those of other middle-income countries. Motor vehicle accidents were the leading cause of death. Further analysis over more years would establish trends in rates and types of injuries, as well as focus health and safety efforts, such as on controlling motor vehicle accidents. The findings also corroborate those found in previously published international literature. The high fatality rate in the South African construction industry indicates that the focus now should be on the implementation and enforcement of

comprehensive policies in order to protect workers and allow them to work in a healthy and safe environment.

## ACKNOWLEDGEMENTS

We would like to thank Professor Sharon Fonn of the University of the Witwatersrand for facilitating access to the data. In addition we would like to extend our appreciation to Gys McIntosh, and the rest of FEM, for their cooperation and consenting to this research.

## LESSONS LEARNED

1. The three leading causes of death were MVAs, 'struck by' and 'fall on to different levels', with MVA and 'struck by' accounting for 65.2% of the fatalities and 'fall on to different levels' 18.0%.
2. The fatality data emphasise the need for more occupational health and safety protection for construction workers in South Africa.
3. Prevention efforts are needed in the industry, and the biggest improvement would occur in controlling MVAs.
4. It is unclear whether the Construction Regulations of South Africa's Occupational Health and Safety Act (1993)<sup>11</sup> are being adhered to, but the large numbers of MVA fatalities indicate that there may be lapses.
5. Greater enforcement of these regulations may lead to a reduction of the fatalities in the MVA group.

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# Low level exposure to nine volatile chemicals in research and testing laboratories at a South African university

## ABSTRACT

Universities have numerous research and testing laboratories where laboratory workers are exposed to various hazardous chemical substances on a regular basis with short periods of exposure possibly above the short-term exposure limits. Personal and general exposure to nine hazardous chemical substances in these laboratories was measured by using sorbent tubes and a direct reading instrument. Eight-hour time weighted average exposure to these chemicals was well below the occupational exposure limits. The simultaneous exposure to various chemicals adds to the total concentration which laboratory workers were exposed on a daily basis. Only half of the fume cupboards provided in the laboratories were functioning effectively; however those functioning fume cupboards were not used optimally. The continuous exposure to low levels of hazardous substances in laboratories reinforces the need for adequate control measures to be implemented and maintained in order to eliminate or reduce exposure, even though monitoring results does not exceed time weighted average occupational exposure limits.

**Key words:** university laboratory, hazardous chemical substances, long-term low level exposure, control

## INTRODUCTION

Worldwide, little has been written about the occupational health requirements of personnel working in research and testing facilities of universities, despite the risks involved.<sup>1</sup> The workforce is quite diverse, and employees at universities' research and testing laboratories include full-time and part-time laboratory workers and postgraduate students of different ages and both genders. Research and testing laboratories are characterised by a wide variety of high risk hazards usually present in low volumes. These hazards are chemical, physical, radiological or biological in nature, however the focus of this paper is on the chemical hazards.<sup>1,2</sup>

Laboratory workers can be regularly exposed to a wide range of chemical agents and many of the chemical agents may include carcinogens<sup>3</sup> such as dichloromethane and chloroform which are suspected human carcinogens.<sup>4,5</sup> Organic solvents are hypothesized to be a contributor to the increased risk to develop cancer.<sup>6</sup>

There is limited information available on the nature and level of risk laboratory workers are exposed to on a regular basis. The majority of exposure in laboratories includes a diversity of chemicals which may target a variety of organs.<sup>3</sup> A recent study in France indicated that exposure can be classified into two categories: (a) a number of chemicals used on a daily or weekly basis by the majority of workers, and (b) a large group of chemicals that are only occasionally used.<sup>3</sup>

There is also a general lack of information available on the cumulative effects of low levels of exposure to a variety

of chemicals over a long time.<sup>3</sup> This unknown potential risk reinforces the need for the implementation and maintenance of adequate control measures.

With the above in mind, a study was conducted, using personal air sampling and static sampling, in research and testing laboratories of a university to determine laboratory workers' exposure to nine chemical substances with the highest potential risk. Fume cupboards were the main measure to control exposure, therefore the effectiveness of these fume cupboards were determined to evaluate the existing control measures.

## METHODOLOGY

### Study design

The study used a cross sectional descriptive design.

### Sampling strategy

Monitoring was conducted in a faculty's laboratories with the highest potential risk regarding the exposure to hazardous chemical substances. A walkthrough survey was conducted where all chemicals used in the particular laboratory were listed, together with the frequency of use and the number of hours the workers spent in the laboratory. The laboratories posing the greatest risk with regard to the number and volume of chemicals used and the workers potentially exposed were selected for sampling. The selected laboratories included research laboratories as well as testing facilities. In view of their frequent use and the large volumes that were used, nine chemicals with the highest potential

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risk were selected for sampling from all the chemicals used in these laboratories for sampling.

Personal sampling was conducted on 14 of the 33 individuals working in the selected laboratories to determine their exposure to the selected nine volatile chemicals. Static sampling was conducted in 12 work areas in 7 laboratories to determine the general concentration of airborne chemicals in the laboratories.

### Data collection

#### Air sampling

Personal sampling was used to determine the concentrations of the nine chemicals that workers are exposed to, and static sampling was used to determine the general airborne concentration of the chemicals in the particular laboratories. This sampling was also used to determine if workers in a laboratory might be exposed to all the volatile chemicals used in the particular laboratory.

Personal air sampling was conducted in accordance with NIOSH 1500 and 1501 methods. The Gilair personal air sampler pumps were calibrated at a constant airflow of 200 ml/min. The sorbent tubes (coconut charcoal, SKC International No. 226-01) were placed in the breathing zone of the worker at the beginning of the workday. To limit the possibility of breakthrough, two sorbent tubes

were used per worker to sample 4 hours consecutively.

Static air sampling was conducted by using two methods, namely a direct reading instrument and sorbent tubes. The sorbent tubes were placed at a height of 1.5 m above floor level on the work surface. The sampling was done in the same manner as the personal air sampling. After sampling the sorbent tubes were transported on ice and stored at 4°C until analysis. Analysis was performed by an accredited laboratory. The direct reading photo-ionization detector (PID) (EntryRAE, RAE Systems Inc.) was placed at a height of 1.5 m above floor level in the same area on the work surface and at the same time as the sorbent tube. The EntryRAE sampled every 60 seconds for eight hours, and the results were given in ppm. The EntryRAE was calibrated with fresh air (VOC zeroing tube), and then by using isobutylene as prescribed by the manufacturer before use. The direct reading photo-ionization detector does not distinguish between different chemicals in a mixture of volatile organic compounds, it confirms the total number of volatile organic compounds present.

#### Fume cupboard effectiveness

The effectiveness of 36 fume cupboards was determined by using the University College London method for determining the average face velocity of the fume cupboard.<sup>7</sup>



Photograph: Annemie van Tonder, Paul Venter and Nadia Theron



Photograph: Annemie van Tonder, Paul Venter and Nadia Theron

**Table 1. The time weighted average personal exposure to hazardous chemical substances in 12 laboratories**

Hazardous chemical substances	TWA mean (mg/m <sup>3</sup> )	Standard deviation	Minimum (mg/m <sup>3</sup> )	Maximum (mg/m <sup>3</sup> )	OEL-TWA <sup>8</sup> (mg/m <sup>3</sup> )
Acetone <sup>#</sup>	3.59	7.34	0.23	35.15	1780
Chloroform	1.25	1.96	0.001	8.61	9.8
Cyclohexane	0.01	0.02	0.0003	0.10	340
Diethyl ether	0.49	1.66	0.001	8.40	1200
Dichloromethane*	2.66	7.82	0.001	38.43	350
Ethanol	13.10	12.62	0.0011	45.66	1900
Ethyl acetate	1.08	2.76	0.0016	12.77	1400
Hexane <sup>#</sup>	0.33	1.11	0.01	5.52	70
Tetrahydrofuran	0.08	0.27	0.001	1.15	590

<sup>#</sup> Listed in Table 3 of the Regulations for Hazardous Chemical Substances and requires biological exposure monitoring<sup>8</sup>

\* OEL-CL



Photograph: Janetta Reynecke and Christia Venter



Photograph: Janetta Reynecke and Christia Venter

**“Worldwide, little has been written about the occupational health requirements of personnel working in research and testing facilities of universities . . .”**

The fume cupboard was turned on for five minutes before measurements were taken. The opening of the fume cupboard was measured, and divided into rectangles of 200 mm x 300 mm. A calibrated vane anemometer (Pacer Industries, Serial No. 4200-07-07246) was used to record the airflow in the middle of each rectangle, and the measurements were repeated three times, after which the average face velocity was calculated. If the average was lower than the international recommended velocity, the opening was reduced by moving the sash down in order to establish an acceptable face velocity. Loose objects in the fume cupboard were removed where possible and if the objects could not be removed, their position was noted. Air current tubes (Dräger Air current tubes, CH 216) were also used to visually evaluate the airflow and turbulent flow in the fume cupboard.

**Ethics**

The study was approved by the Health and Safety Committee of the Faculty of Health Sciences. Biological monitoring was not conducted, personal air samples of workers performing their normal work activities were used and informed consent was obtained from all the participants.

**RESULTS**

Personal and static sampling of nine chemicals was conducted in twelve laboratories and in total 14 personal samples and 12 static samples were obtained.

Table 1 indicates that the average time weighted average (TWA) chemical exposure did not exceed South African occupational exposure limits, but the exposure had a wide range of variance. Exposure to ethanol was the highest level of chemical exposure, and also showed the largest variance of 45.66 mg/m<sup>3</sup> between exposures.

Dichloromethane showed a variance of 38.43 mg/m<sup>3</sup>, and acetone showed a variance of 34.92 mg/m<sup>3</sup>. This variation in exposure indicates the difference in possible exposures, depending on the activities performed in the laboratories, and chemicals used. Therefore workers’ exposure might vary on different days and at different times of the day.

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With statistical analysis there was a positive correlation between personal and static sampling exposure to dichloromethane (0.6781) and ethyl acetate (0.6854). There was no statistically significant difference between personal and static sampling exposure to any of the other chemicals.

During the 8 hours of sampling, different periods of peak exposure were observed by the direct reading PID as seen in Figure 1 and Table 2. In one laboratory there were 3 periods where high exposures were observed during one day of sampling.

Exposure to HCS in laboratories includes exposure to a mixture of different chemicals simultaneously, and these chemicals may have similar toxicological effects on the same target organ or system. Therefore the combined effect of the mixture of chemicals should be calculated and considered when determining exposure to HCS. The additive effect of mixed exposure to various hazardous chemical substances was calculated according to  $C_1/T_1 + C_2/T_2 + C_3/T_3$  where C is the observed concentration, and T is the corresponding threshold limit.<sup>8</sup> The calculated additive effect of the overall TWA of the nine chemicals did not exceed 1 (0.15). However, one static sample in a laboratory had an additive effect of 0.995, and a personal sample had an additive effect of 0.529. If the calculated additive effect exceeds 1, the threshold limit of the mixture should be considered as being exceeded and the mixture may have an additive effect.<sup>9</sup>

The efficiency of all fume cupboards in the particular laboratories were determined, and of the 36 fume cupboards measured, 18 were effective with a face velocity above

0.5 m/s. Eleven of the fume cupboards were effective if the sash was moved down, and seven of the fume cupboards were ineffective or not working.<sup>7</sup>

## DISCUSSION

The eight-hour TWA exposure to various HCSs were well below the occupational exposure limits (OELs), indicating that the laboratory workers were exposed to low levels of hazardous chemical substances over the long-term. Forty six percent of the laboratory workers had been working in laboratories for more than two years, and 76% worked in the laboratories more than 30 hours per week. As long-term exposure to hazardous chemicals such as dichloromethane, chloroform and acetone may lead to detrimental health effects on the liver, nervous system, kidneys and mucus membranes, exposure must be controlled to the lowest levels possible.<sup>4,5,10,11</sup> The maximum exposure level of chloroform for one subject exceeded the action level; therefore chloroform exposure must be actively controlled. According to the Regulations for Hazardous Chemical Substances, dichloromethane has a control limit ( $350 \text{ mg/m}^3$ ) with no short-term exposure limit (STEL), and therefore its exposure must be eliminated or controlled to the lowest reasonable practicable level.<sup>8</sup> Methylene chloride is a synonym for dichloromethane, and methylene chloride is listed in Table 2 with a recommended limit ( $350 \text{ mg/m}^3$ ) and a STEL limit of  $780 \text{ mg/m}^3$ .<sup>8</sup> This causes general confusion and can lead to double standards.

Exposure to hazardous chemical substances in these

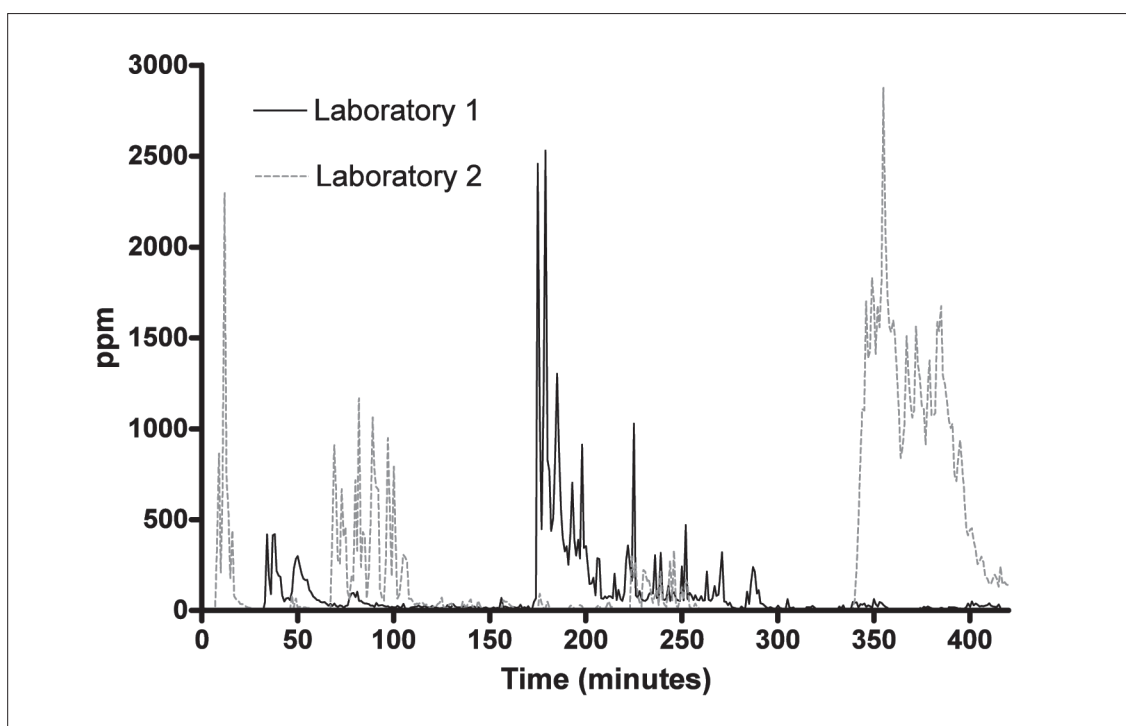


Figure 1. Static sampling exposure to volatile organic compounds in two of the laboratories with the highest risk according to the direct-reading PID

**Table 2. Average concentrations of exposure from Figure 1**

Graph	Time	Duration	Average concentration
Laboratory 1	174–290 minutes	116 minutes	259 ppm
Laboratory 2	7–16 minutes	9 minutes	693 ppm
Laboratory 2	67–107 minutes	40 minutes	409 ppm
Laboratory 2	339–468 minutes	129 minutes	626 ppm

*“Laboratory workers can be regularly exposed to a wide range of chemical agents and many . . . may include carcinogens . . .”*

laboratories varied between extremes because of the different processes and chemicals used at a certain time. This also leads to exposure to numerous chemicals at the same time and these chemicals can have synergistic or additive effects because they have a similar toxicological effect on the same target organ or system. Acetone acts in a synergistic manner; it increases liver toxicity of chloroform, carbon tetrachloride and other chemicals.<sup>11</sup> Acetone inhibits the metabolism and elimination of ethyl alcohol and thereby it potentially increases its toxicity.<sup>11</sup> In one laboratory, one sample of nine chemicals had an additive effective of 0.99. This significant additive effect could lead to serious toxic effects, especially where workers are exposed to acetone and ethanol on a daily basis.

During the 8-hour working day there were periods (9, 40, 116 and 129 minutes) where laboratory workers were exposed to very high concentrations of volatile organic compounds as shown by the direct reading PID. These short-term exposures also pose a great risk to the health of the workers, though they are not always taken into account if TWA is calculated. Hence the TWA does not give an indication of the frequency or magnitude of short-term exposures to these hazardous chemical substances. As certain chemicals may have a dose-response pattern, it is of utmost importance to determine exposure to the peak levels during the short periods. In this study the direct reading apparatus was used to determine if there were periods during the 8-hour work shift where exposure was exceedingly high. However, this direct reading apparatus can also further be used to connect exposure to a particular task or process using certain chemicals, and this can be useful to control future exposure. The apparatus was not used in this manner for the study.

A positive correlation was found between static and personal sampling exposure, and this indicates that all workers in a certain laboratory may be exposed to all the chemicals used in that laboratory. This is as a result of various highly volatile chemicals used in the laboratory without adequate ventilation systems to extract the vapours. This

poses a great threat to workers who spend eight hours in the laboratories, or those who have office space situated inside a laboratory. Therefore control of exposure should be sufficient to ensure that the vapours do not extend beyond the point of activity. The control measures provided in these laboratories were fume cupboards; however the majority of workers said they never work in the fume cupboards because of discomfort or general lack of fume cupboards available. Only 18 fume cupboards were functioning correctly, and 11 fume cupboards had to be adjusted to ensure adequate airflow. Seven of the fume cupboards were non-functioning because the face velocity was below acceptable levels, or airflow through the fume cupboard was turbulent and had the potential to leak vapours. The functioning fume cupboards provided



*Photograph: Janetta Reynecke and Christia Venter*

were not used optimally and therefore provided little to no protection against exposure to these hazardous chemical substances. Workers were issued with laboratory coats and gloves and these only provide protection against spillages. The workers did not have any additional personal protection equipment and therefore were not protected against the vapours and inhalation exposure.

## CONCLUSION

This study showed that the laboratory workers were exposed to concentrations of nine volatile chemicals during the eight-hour shift which were below the TWA-OEL. During the work day, laboratory workers were exposed to high levels of hazardous chemical substances for short periods of time. Without appropriate ventilation, laboratory workers would be unnecessarily exposed to elevated levels of the chemicals used in that laboratory. Therefore the greatest risk to working in a university research and testing laboratory is the long-term exposure to low levels of chemicals with regular intervals of high exposure, and often without adequate ventilation.

It is extremely important to include full workday exposure monitoring as well as short-term exposure monitoring when planning or conducting occupational hygiene surveys. TWA levels can be misleading in laboratories as exposure depends on the process or activity performed in the laboratory, and peak exposures can be high without exceeding the eight-hour TWA. Therefore, short-term exposure monitoring should include worst case scenarios of highest exposure during specific activities in the laboratory.

The study reinforces the importance of adequate control measures in laboratories to protect workers against the various chemical vapours that may be produced from laboratory processes and activities even though exposure does not exceed TWA-OELs. A thorough investigation should be launched to determine short-term exposure to hazardous chemicals. General extraction ventilation should be installed in all laboratories, with a sufficient supply of fresh air to the laboratories. All windows and doors should be kept closed. Fume cupboards should be regularly checked and ineffective ones be repaired, and more fume cupboards supplied. All laboratory workers must be encouraged to maintain good working hygiene and work in fume cupboards. All technicians and visitors should be supplied with the appropriate laboratory coats, gloves and eye protection. The direct reading PID can be used to determine peak exposures during specific tasks or activities to improve control measures supplied in laboratories.

## LESSONS LEARNED

The greatest risk to working in a university research and testing laboratory could be the long-term exposure to low levels of chemicals with regular intervals of high exposure, often without adequate ventilation.

Long-term exposure to hazardous chemicals such as dichloromethane, chloroform and acetone may lead to detrimental health effects on the liver, nervous system, kidneys and mucus membranes, and exposure must be controlled to the lowest levels possible.

Exposure varied between extremes because of the different processes and chemicals used at a certain time leading to exposure to numerous chemicals at the same time and these chemicals can have synergistic or additive effects because they have a similar toxicological effect on the same target organ or system.

TWA levels can be misleading in laboratories because exposure depends on the process or activity performed in the laboratory, and peak exposures can be high without exceeding the 8-hour TWA. Therefore, short-term exposure monitoring should include worst case scenarios of highest exposure during specific activities in the laboratory.

All workers in a certain laboratory may be exposed to all the chemicals used in that laboratory. This is as a result of various highly volatile chemicals used in the laboratory without adequate ventilation systems to extract the vapours.

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# A preliminary investigation of the effects of exposure to multiple health stressors using the Physiological Strain Index

## ABSTRACT

**Miners are exposed to multiple health stressors simultaneously. Studies on the individual and combined physiological effects are needed. Therefore, the effect of heat, exercise and noise, individually and in combination on Physiological Strain Index scores in a laboratory controlled environment was evaluated.**

**Method: Eleven participants were exposed to individual and combinations of the stressors. Heart rate and core body temperature were used to calculate the Physiological Strain Index levels. Results: Exposure to noise alone significantly increased the scores. Simultaneous exposure increased but not statistically significantly. Male participants experienced more physiological strain during exposure to noise alone than females.**

**Conclusion: The results were inconclusive due to the small sample and limitation of severity of exposure for safety and ethical reasons. The index appears to be a potentially useful means of measuring physiological strain during exposure to multiple health stressors. Further research is warranted.**

**Key words:** Physiological Strain Index, multiple health stressors, heat, exercise, noise

## INTRODUCTION

Dust and noise are inherently associated with mining, as are hot, humid and confined working conditions in some forms of mining.<sup>1,2,3</sup> The assessment of the physiological responses to health stressors in a mining environment is confounded by the mineworkers' simultaneous exposure to combinations of stressors, such as exercise, heat/humidity, noise and dust.<sup>1,3</sup> Another confounding factor is the synergistic impact of the exposure to multiple health stressors. Therefore, the evaluation of the risks associated with exposure to combined health stressors requires information on the effects of both the individual stressors, as well as their combined effects. To obtain information applicable for the mining industry, controlled laboratory conditions that simulate the mining environmental are required. However, no South African mining environment studies on the individual, cumulative and combined effects of stressors have been identified.

Studies have demonstrated that simultaneous exposure to noise and exercise exacerbates the auditory effects of noise.<sup>4,5</sup> Similarly, exposure to noise

and chemical agents accelerates the development of NIHL.<sup>6,7</sup> Noise also has non-auditory effects on workers such as elevated skin temperature, increased pulse rate and blood pressure, constriction of blood vessels, abnormal secretion of hormones and tensing of muscles.<sup>8,9</sup> However, the measurement of the physiological impact of the non-auditory effects of noise individually and with other stressors has not been reported and if investigated, could enhance the understanding of the effect of individual and combined environmental stressors on workers.

Two valid and reliable measurements for monitoring miners' physiological status are heart rate (HR) and core body temperature ( $T_{cr}$ ).<sup>10,11</sup>  $T_{cr}$  indicates the increase in body heat storage during exercise or physical work resulting from an accumulation of heat produced by skeletal muscle contraction, while HR reflects demands placed on the circulatory system and is an immediate effector of vasomotor response to metabolic and environmental conditions.<sup>11</sup> HR is measured using a HR monitor strapped to the chest and can estimate the degree and duration of aerobic

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workload.<sup>10</sup>  $T_{cr}$  is more difficult to measure accurately in field assessments since probes for oesophageal temperature are difficult to insert and impractical to use,<sup>12,13</sup> while oral temperature measurement under field conditions is not always accurate.<sup>12</sup>

A Physiological Strain Index (PSI) based on  $T_{cr}$  and HR has been developed from studies in the military, on the physiological status of individuals performing exercise in heat under varying conditions (e.g. in different heat-related environments, with protective clothing, and varying hydration levels).<sup>11,13</sup> The two parameters adequately depict the combined strain reflected by the cardiovascular and thermoregulatory systems.<sup>7</sup> Furthermore, the PSI can rate and compare the strain imposed by various combinations of environmental and work rate conditions, with a reduced risk of error because it is based on these two easily measured parameters. It has a scale of 1 to 10, with a high value indicating a high risk of physiological stress<sup>13</sup> and also provides for five categories of physiological strain, ranging from “no/little strain” to “very high strain”.<sup>11</sup> Comparisons of the PSI based on gender, age, and level of exercise training and intensity have shown PSI to be a simple method for examining the impact of environmental temperatures and exercise on individuals to predict who might be at risk for heat stress.<sup>12,14-18</sup> Studies using the PSI for the measurement of non-auditory physiological effects of noise have not been identified.

Developments in biotelemetry have resulted in

the CorTemp™ physiological monitoring system that permits real-time measurement and logging of  $T_{cr}$  via an ingestible capsule transmitting data to a receiver worn on the belt. An evaluation of this system by the CSIR Occupational Health and Ergonomics Research Group during a pilot study in an underground mining environment showed that it was a viable measurement method for  $T_{cr}$ .<sup>19</sup> Participants agreed to swallow the capsule after being fully informed about it and wore the monitoring system whilst performing their usual work underground, and the system functioned correctly. The PSI was used in the study and found to be a useful tool to measure the physiological responses to environmental health stressors. However, because it was conducted in the field, the data reflected the combined effects of health stressors such as noise, heat and exercise which occur simultaneously in the actual mining environment. Therefore the individual and cumulative effects of different combinations of the stressors could not be evaluated in this setting, and would require controlled laboratory conditions that simulate the mining environment. This led to the research question: Can differences in PSI levels be demonstrated as a result of exposure to the individual health stressors of heat, exercise and noise in a laboratory setting, and if so, are those differences greater for exposure to the three health stressors in various combinations?

If the physiological effects of individual and combined exposures to health stressors could be reliably measured, the information would have practical importance and relevance. It could provide a scientifically sound basis to assess current occupational heat exposure limits, enhance the validity of current physical selection criteria, and contribute to design specifications to improve workplace ergonomics and prevention strategies for occupational health diseases. Despite most South African mineworkers being male, information on the physiological responses of females to occupational health stressors is required, since legislation requires increased numbers of females in the mining workforce.

Therefore, a preliminary study was conducted to:

1. evaluate the effect of heat, exercise and noise, individually and in combination, on PSI scores; and
2. investigate whether the responses of males and females to these stressors differed.

## METHODOLOGY

A controlled experimental design was used to compare



the PSI during exposure to noise, heat and exercise individually and in combinations to a resting PSI. Each participant's baseline PSI was determined at rest for comparison with his or her PSI score during exposure to individual and combined stressors.

### *Sampling strategy*

Eight male and three female unemployed volunteers, aged between 18 and 30 years participated in the study. The sample size of the study was limited by time constraints, the size of the climatic chamber and the cost of equipment such as the thermo-sensor pills.

contains a telemetry system, a micro battery and quartz crystal temperature sensor. While inside the gastrointestinal tract, the crystal sensor vibrates at a frequency that is proportional to the temperature of its surroundings (the body), producing a magnetic flux and a radio signal that is transmitted from the body to the recorder. The sensor continuously monitors body temperature as it travels through the digestive system, passing through the intestinal tract in 24 to 30 hours, according to the individual's rate of motility. The recorder receives, displays, and stores the data in the non-volatile solid-state memory. Data from both

***“Noise . . . has non-auditory effects . . . such as elevated skin temperature, increased pulse rate and blood pressure, constriction of blood vessels, abnormal secretion of hormones and tensing of muscles.”***

The attrition of the volunteers resulted in very few females being included and so providing insufficient data for statistical comparisons. Since this was a preliminary investigation the results of female participants' responses are reported despite the acknowledged methodological limitations.

Participants' age was limited to reflect that of new mining workforce recruits to facilitate future comparisons with the responses of miners. A medical examination of each participant checked the safety for them to use the thermosensor, as stipulated by the manufacturers.

Hydration status may have affected participants' HR when exercising in heat.<sup>17</sup> However, since it would be unfeasible to control this variable in the mining environment during further research, it was not controlled in this preliminary investigation. Participants' body mass was used in the calculation of the required stepping height for a light work rate for each participant.

### *Data collection*

The CorTemp™ Physiological Monitoring and Polar™ Heart Rate Monitoring systems were used to determine PSI scores. The CorTemp® system comprises an ingestible thermo-sensor, a POLAR® HR transmitter (worn as a chest strap) and a miniature ambulatory data recorder (worn on a belt) to capture data transmitted by the thermo- and HR sensors. The “thermometer-pill”, a standard medicine sized capsule

systems were downloaded after each experimental condition using the CorTemp® and POLAR® proprietary software, then captured in a database, using a secure participant-numbering system.

### *Climatic chamber*

The study was conducted in a climatic chamber to ensure precise control of temperature, humidity, and air velocity. Test conditions requiring exercise made use of graded stepping blocks. Loudspeakers produced white noise for test conditions requiring exposure to noise. Noise levels were measured with a calibrated Class 1 sound level meter.<sup>20</sup> During rest periods participants sat in a temperature-controlled room adjacent to the chamber. Adherence to the relevant occupational exposure limits (OELs) during exposure simulation prevented risk for participants.<sup>20-24</sup>

### *Noise*

A time weighted average ( $TWA_{8h}$ ) of 85 dBA is the OEL for safe exposure of the unprotected human ear.<sup>20-23</sup> To provide a margin of safety, the study limited the noise level to 87 dBA for a period of two hours, after which a two-hour rest and recovery period was applied.

### *Heat and humidity*

The difference between the temperature of the air in which physical work is performed and the worker's

body temperature determines the environment's capacity for removing metabolic heat produced by muscular contraction. Similarly, the humidity of the surrounding air determines the amount of perspired water that can evaporate from the skin surface to cool the skin and blood flowing to it, thereby limiting increases in body core temperature.<sup>13</sup>

Air velocity or wind speed also affects the environment's capacity to remove metabolic heat from the skin: a higher air velocity results in a greater volume of air flowing over the skin, causing more evaporation of perspired water and, hence, more cooling. In accordance with mining industry regulations for ensuring adequate ventilation in underground work environments,<sup>23</sup> the wet- and dry-bulb temperatures considered together provide an adequate indication of the environment's capacity to remove metabolic heat and limit heat stress. Therefore, a wet-bulb temperature (WBGT) of 30.0°C and a dry-bulb temperature of 31.5°C was applied for exposure to heat and humidity. Air velocity was regulated to 0.4 m·sec<sup>-1</sup>, which is 60% greater than the stipulated minimum for air velocity.<sup>23</sup> The use of heat, humidity and air velocity

below the recommended exposure limits ensured that participants were not at risk yet still exposed to environmental conditions approximating those in an underground mine.

#### Exercise

Participants performed two hours of intermittent light exercise (10 minutes exercise/15 minutes rest), and then rested for two hours. The environmental temperatures as described above equated to a WBGT of 30.8°C. The WBGT OEL is 31.4°C for 50% light exercise and 50% rest each hour.<sup>23</sup> Since participants performed light exercise for only 40% of the time, the combination of environmental conditions and exercise rate were regarded as conservatively safe for participants.

The exercise consisted of two hours of block-stepping. Stepping was at a rate of 12 steps per minute, with each participant's stepping height adjusted according to their body mass to yield an external workload of 35 Watts, positive component. This equated to a light workload, which, together with a 15-minute rest interval after every ten minutes of stepping, was regarded as conservatively safe.

**Table 1. Description of experimental procedure**

Test day, stressor and duration of exposure	Procedure
<b>DAY 1</b> Baseline recordings: two hours  Noise: two hours	Sit quietly at room temperature (18,0°C wet-bulb/25,0°C dry-bulb) for baseline recordings.  Sit at room temperature (18,0°C wet-bulb/25,0°C dry-bulb), with 87 dBA white noise.
<b>DAY 2</b> Heat/humidity: two hours  Physical work: two hours	Sit at 30°C wet-bulb/31.5°C dry-bulb. Rest at room temperature (18,0°C wet-bulb/25,0°C dry-bulb). Block-stepping at 12 steps per minute (35 watts) at room temperature (18,0°C wet-bulb/25,0°C dry-bulb) for 10-minute intervals, each followed by a 15-minute rest interval.
<b>DAY 3</b> Heat and physical work: two hours  Heat and noise: two hours	Block-stepping at 12 steps per minute (35 watts) at 30°C wet-bulb/31.5°C dry-bulb for 10-minute intervals, each followed by a 15-minute rest interval. Rest at room temperature (18,0°C wet-bulb/25,0°C dry-bulb) for 2 hours. Sit at 30°C wet-bulb/31,5°C dry-bulb, with 87 dBA of continuous white noise.
<b>DAY 4</b> Physical work and noise: two hours  Heat, physical work and noise: two hours	Block-stepping at 12 steps per minute (35 watts) at 18°C wet-bulb/25,0°C dry-bulb for 10-minute intervals, each followed by a 15-minute rest interval, with 87 dBA of continuous white noise. Rest at room temperature (18,0° wet-bulb/25,0°C dry-bulb) for 2 hours. Block-stepping at 12 steps per minute (35 watts) at 30°C wet-bulb/31,5°C dry-bulb for 2 hours 10-minute intervals, each followed by a 15-minute rest interval, with 87 dBA of continuous white noise.

**Procedure**

The researchers followed the experimental protocol as summarised in Table 1.

A two-hour rest period was applied between test conditions, to eliminate the effects of the first exposure and avoid confounding the results. Participants were asked not to eat during the exposure periods, in order to limit changes in metabolism and thermo-genesis. Water was available in 250 ml quantities at 15-minute intervals during the course of the exercise and at 30-minute intervals during heat exposure.

**Data analysis**

T<sub>cr</sub> and HR data were used to calculate PSI scores using an Excel spreadsheet with calculations from Moran.<sup>7</sup> PSI averages were calculated for 10-minute intervals. The averages of the results for the two-hour periods of exposure were calculated for each participant and for each exposure condition, and the results were statistically analysed to evaluate the significance of the differences in participants' responses.

A paired t-test was performed on the PSI baseline

measurements and those recorded after exposure to exercise; heat; heat combined with exercise; noise; noise combined with exercise; noise combined with heat; and noise combined with heat and exercise. An analysis of variance (ANOVA) test was performed to evaluate differences between responses to the various experimental conditions.

**Ethical considerations**

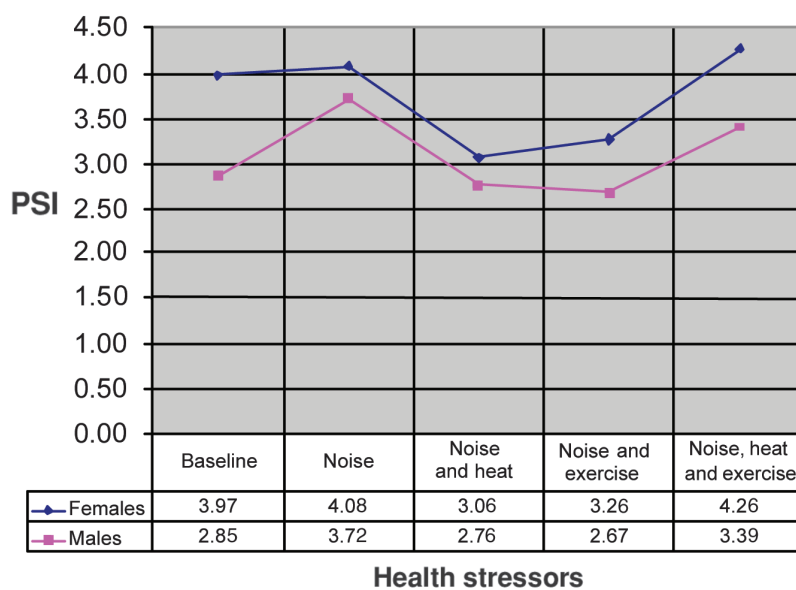
Participants' health, safety, privacy and dignity were upheld throughout the experiment. A paramedic was present during all exposure procedures. Ethical clearance was confirmed by the University of the Witwatersrand Human Ethics Committee.

**RESULTS**

The averaged PSI results of the participants for the baseline, individual and combined exposures are presented in Figures 1 to 3.

Exposure to noise alone increased the average PSI in males, but had little effect in females (Figure 1). The difference between the baseline and noise exposure

***“The two parameters adequately depict the combined strain reflected by the cardiovascular and thermoregulatory systems.”***



**Figure 1. The impact of noise and additional stressors on average PSI for females and males**

alone average PSIs was statistically significant. The averaged PSI decreased below the baseline values for noise combined with either heat or exercise, an unexplained result. PSI was greater following exposure to all three stressors than for a combination of two, but was still near baseline levels. Statistical analysis confirmed that the differences were only significantly different for exposure to noise alone. With the confidence level of  $p < 0,05$  and a small sample size, the significance of this difference is not very robust, and a larger sample size may have provided more definitive results. An ANOVA analysis indicated no significant differences for any of the exposure conditions.

Heat alone decreased PSI from baseline levels (Figure 2) – an unexpected finding. Heat exposure combined with exercise had the greatest effect, especially on female participants, but the increase from the baseline was not statistically significant.

Males showed very little change in PSI for any combinations of exercise with the other stressors (Figure 3). Females experienced a relatively large increase for exercise and even greater increases for exercise and heat combined. Noise combined with exercise

reduced the PSI, but when all three were applied, the females' PSI increased. These differences were not statistically significant.

All the averaged PSI results shown in Figures 1 to 3 were within the range of "little strain" to "moderate strain" and none of the individual PSI levels exceeded the "moderate strain" level. The PSI level of seven is unacceptable for human health.<sup>13</sup>

Figure 4 presents the PSI values for a male when exposed to heat alone and exercise alone.

## DISCUSSION

The study objective was to evaluate participants' physiological responses to heat, exercise, and noise when exposed to them individually and in combinations. PSI scores varied, some increased and others decreased. The unexpected results may be due to small sample size, indicating the need for further investigation using larger sample sizes. None of the results for exposure to heat alone, exercise alone, or combinations of two or three stressors showed a statistically significant increase in PSI. The lack of control for hydration may have affected the HR and therefore influenced the PSI, however, the regular intake of water during exercise in heat during this experiment closely resembles underground conditions and could be regarded as similar to responses expected from underground workers.

However, exposure to noise alone caused a statistically significant increase in PSI scores possibly indicating that reported non-auditory effects of noise have greater influence than expected.<sup>4,5,7</sup> Attention to the non-auditory effects of noise should be an important motivation for noise control measures and further investigation of the non-auditory effects of noise is required. The sequence of the introduction of the stressors may have influenced the effects noted from noise exposure alone since once other stressors were introduced the physiological effects of noise seemed to be mediated. To exclude this, further investigation with major variation in the exposure sequence is necessary.

Although males experienced more physiological strain during exposure to noise alone than females (statistically significant) and females experienced more strain from heat and exercise than males (not statistically significant), the small number of females prevented the production of meaningful, statistically significant results. Therefore, the gender differences



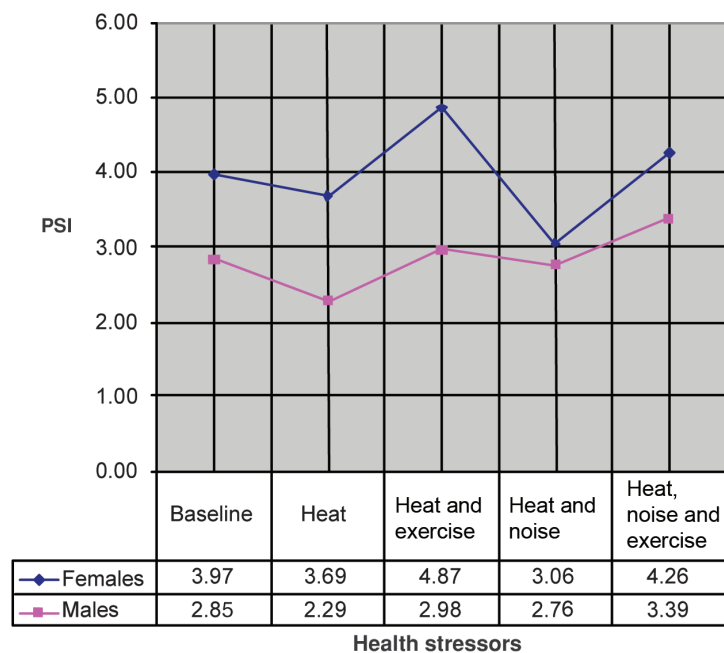


Figure 2. The impact of heat and additional stressors on average PSI for females and males

*“ . . . the individual and cumulative effects of . . . the stressors . . . could not be evaluated . . . and would require controlled laboratory conditions that simulate the mining environment.”*

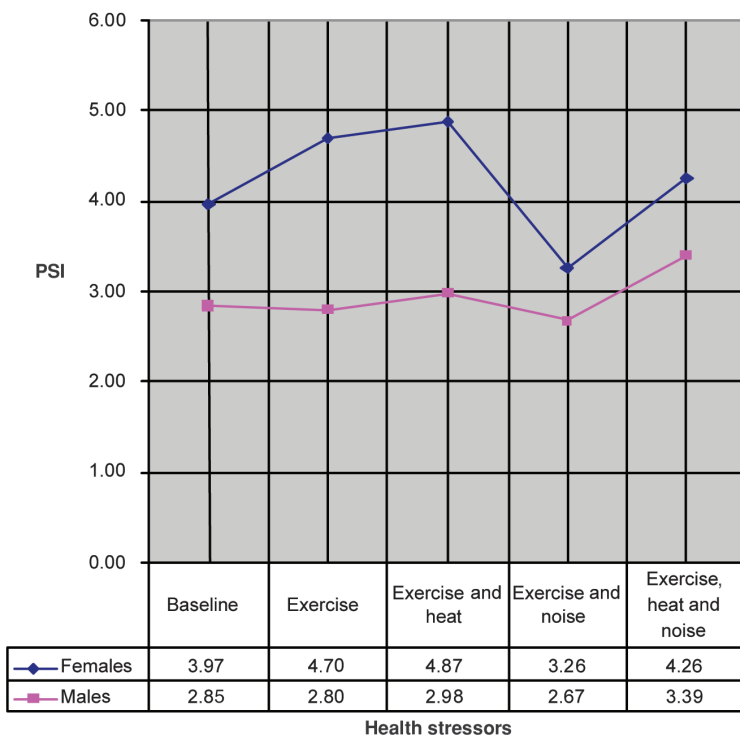


Figure 3. The impact of exercise and additional stressors on average PSI for females and males

require further investigation. If confirmed they may imply that women are less suited to occupations where heat and/or exercise occurs, and males less suited to jobs where noise occurs in isolation.

The results may also imply that when exposure levels are below the OELs, the physiological strain imposed on the worker is acceptable. However, if it had been ethically possible to expose participants to higher levels of the stressors, the results may have been different. Therefore, although the differences in this preliminary study were small and largely inconclusive, the effect may be different in the real setting.

Figure 4 is included as an example of the ability of the PSI to provide comparative information for a worker being exposed to varying environmental factors. Use of the CoreTemp™ system in a real-time mining situation appears to have potential for quantifying physiological strain for various work tasks and for selecting well-suited individuals to perform these tasks. The comparison of resting PSI with post-exposure results can provide useful information for job category placement in mining and other industries. The tool could also be used for pre- and post-intervention measures when comparing

the effectiveness of different intervention strategies to reduced physiological strain.

## CONCLUSION

This preliminary study simulated a mining environment to measure individual, cumulative and combined effects of stressors. The results were inconclusive since the sample was small and the severity of exposure was limited for safety and ethical reasons. The higher levels and longer periods of exposure that occur in the mining industry could produce more conclusive results. The only significant result was an increase in PSI scores in response to noise exposure, which warrants further investigation since the physiological effects of noise exposure have not been measured in this way before and may provide useful information relating to stress experienced by miners. The CoreTemp™ Physiological Monitoring system is a feasible method of determining core body temperature and the PSI and could prove a valuable tool for assessing the relevance of current occupational exposure limits, risk assessment and job selection criteria in terms of physiological strain and gender in the mining industry as well as other industries.

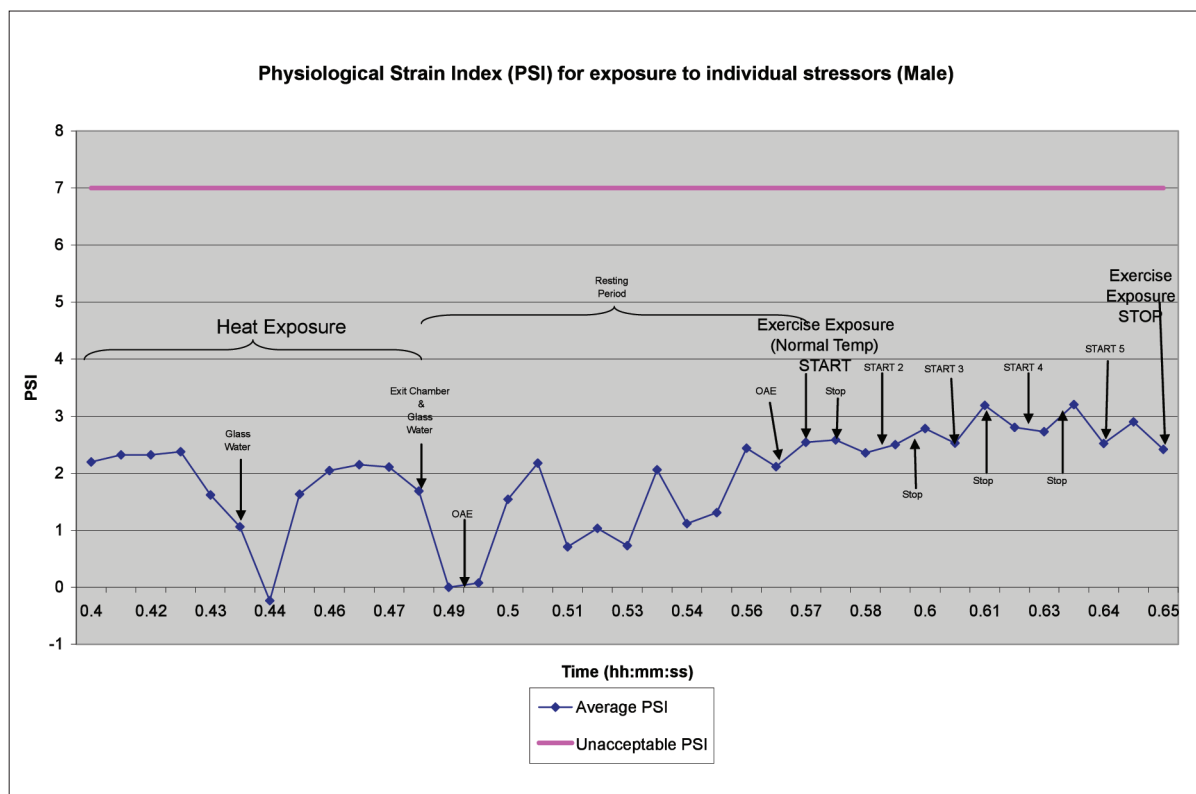


Figure 4. Example of PSI values for a male when exposed to heat alone and exercise alone



*“Exposure to noise alone increased the average PSI in males,*

*but had little effect in females.”*

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## The dynamic of chemical/drug absorption, distribution and elimination and the impact it has on the monitoring of exposure to (hazardous) chemicals

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### INTRODUCTION

As with occupational and clinical medicine, to produce a characteristic effect a drug or chemical must be present in appropriate concentrations at the site of the action. Nevertheless, the amount of exposure or administration, the concentration of active, unbound (free) drug/chemical attained, also depends upon the extent and rate of its absorption, distribution (which mainly reflects relative binding to plasma and tissue proteins), metabolism (metabolic rate, biotransformation) and excretion. Many of the chemicals that we as occupational health/medicine practitioners encounter in industry, follow pathways similar to those of therapeutic drugs and are responsible for similar effects/symptoms. The disposition factors for drugs/chemicals are depicted in Figure 1.

### A. PHYSICO-CHEMICAL FACTORS IN THE TRANSFER OF CHEMICALS/DRUGS ACROSS MEMBRANES

Regarding the chemicals that we find in the workplace, as with drugs, the physicochemical properties of the molecules and the bodily systems/membranes that influence this transfer are very important. The determining characteristic of the drug or chemical is the molecular size and shape, degree of ionisation, relative lipid solubility of its ionised and non-ionised forms and the binding to the tissue proteins.

#### Weak electrolytes and the influence of pH

Most drugs and chemicals found in the industry are weak acids of bases that are present in solution as both the non-ionised and

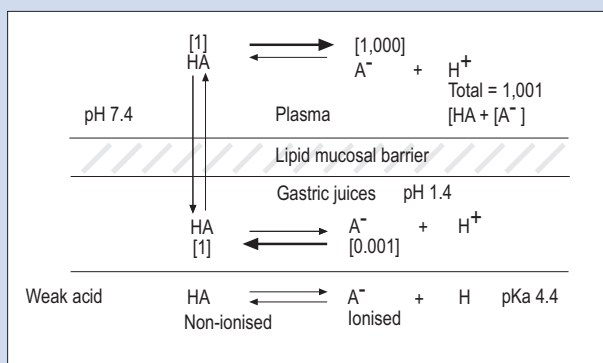


Figure 2. Effect of pH and pKa of the membrane and molecules absorbed

ionised species. The non-ionised molecules are normally lipid-soluble and can diffuse across the cell membrane.

Therefore, the trans membrane distribution of a weak electrolyte is usually determined by its pKa and the pH gradient across the membrane. Figure 2 illustrates the effect of pH and pKa of the membrane and molecules absorbed.

### B. METABOLISM OF CHEMICALS/DRUGS

The lipophobic characteristics of chemicals/drugs promote the passage through the biological membrane and subsequently access to their site of action and excretion from the body. Renal excretion of the unchanged drug plays only a modest role in the overall elimination of most therapeutic agents, since lipophilic compounds filtered through the glomeruli are largely reabsorbed back into the systemic circulation during passage through the renal tubules. Thus before excretion is optimal, the drug or chemical has to undergo hydroxylation to make the substance more water-soluble. In many cases metabolites with more potent activity or toxic properties are formed through this process. Figures 3, 4 and 5 actually illustrate the effect of metabolism within the body and are an indication of the process involved in converting a substance to the more soluble non-ionised substrate.

The major reactions involved in drug metabolism are illustrated in Table 1. Many components have to undergo multiple steps of metabolism before being excreted in the urine.

Although a number of other organs, including the adrenal glands, kidneys, lungs, placenta and gut, are capable of chemical/drug metabolism, the liver is the primary organ involved in the biotransformation of endogenous and exogenous substances and

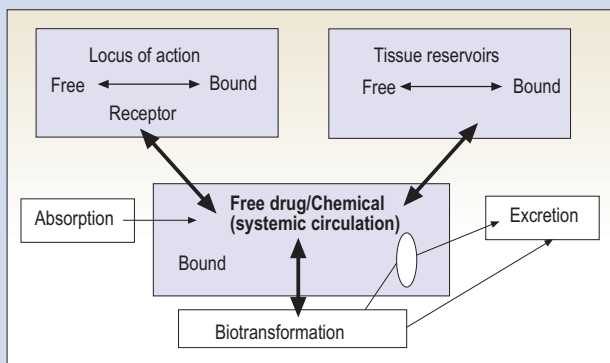
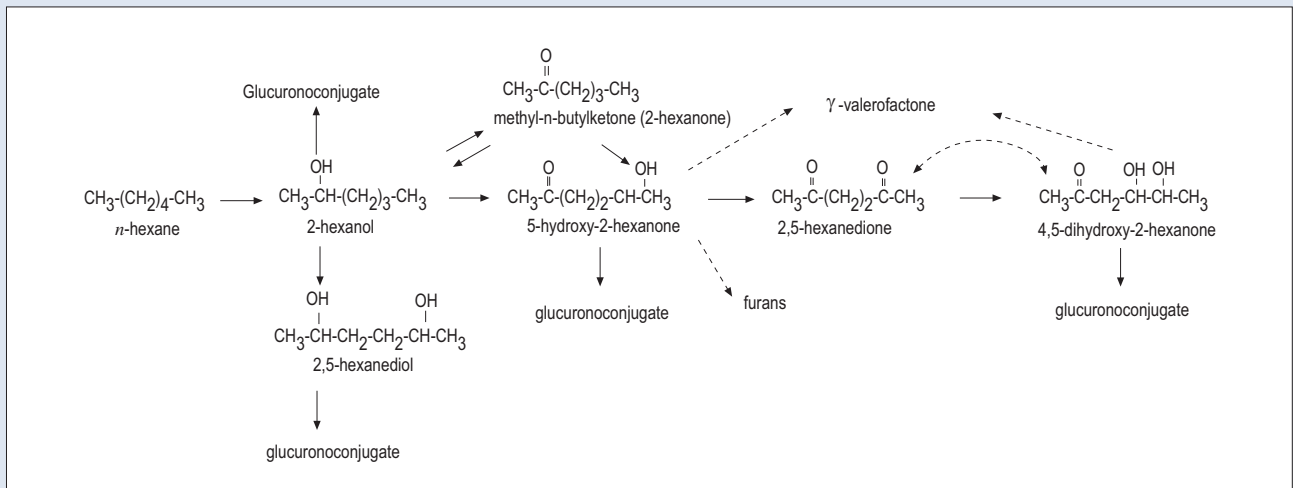
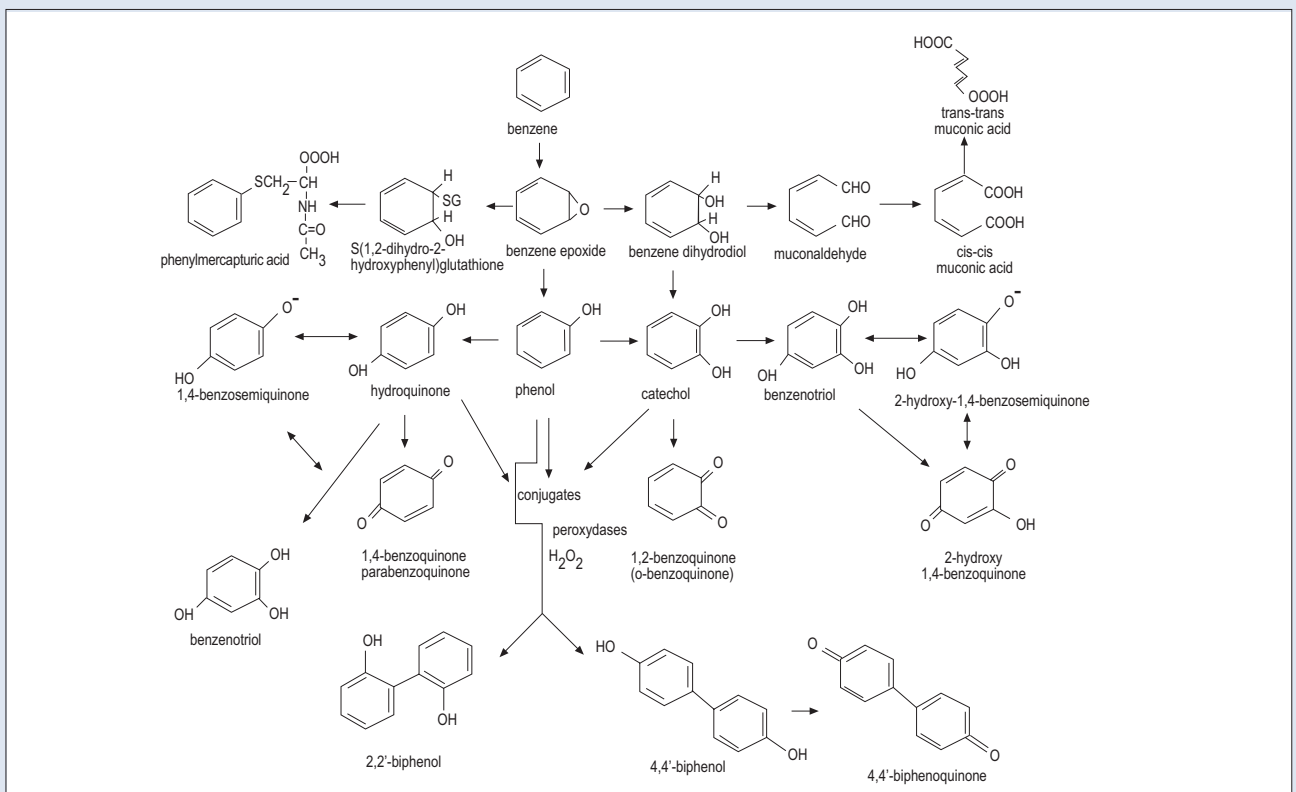


Figure 1. Illustration of the inter-relationship of absorption, distribution, binding, metabolism and excretion and its concentration at the locus of action



**Figure 3. Effect of metabolism on the hexane molecule and the different metabolic compounds formed through this process within the body**



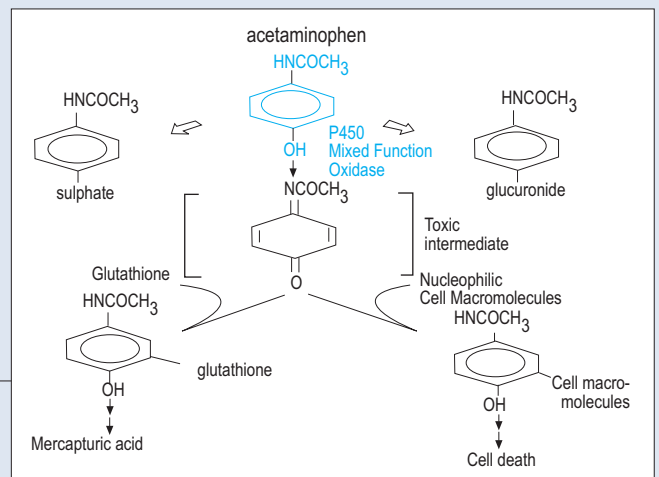
**Figure 4. Effect of metabolism on the benzene molecule and the different metabolic compounds formed through this process within the body<sup>13</sup>**

most substances are hepatically biotransformed by the mixed function oxidase (cytochrome P-450) system.

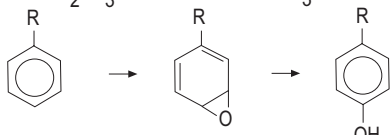
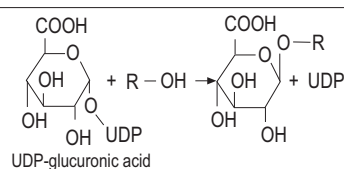
Drug and industrial chemicals are known to be potent and predictable inducers of hepatic cytochrome P-450 activity. It is important to know that drugs/chemicals like ethanol, environmental pollutants, including tobacco smoke, organochlorinated pesticides, polychlorinated phenol, hydrocarbons (cyclic and aliphatic), and foods such as brussels sprouts and cabbage

*Continued on page 35*

**Figure 5. Effect of metabolism on the acetaminophen molecule and the different metabolic compounds formed through this process within the body**



**Table 1. Major reactions involved in drug and chemical metabolism**

	Reaction	Examples
<b>1. OXIDATIVE REACTIONS</b>		
N-Dealkylation	$RNHCH_3 \rightarrow RNH_2 + CH_2O$	Imipramine, diazepam, codeine, erythromycin, morphine, tamoxifen, theophylline, caffeine
O-Dealkylation	$ROCH_3 \rightarrow ROH + CH_2O$	Codeine, indomethacin, dextromethorphan
Aliphatic hydroxylation	$RCH_2CH_3 \rightarrow RCH(OH)CH_3$	Tolbutamide, ibuprofen, pentobarbital, meprobamate, cyclosporine, midazolam
Aromatic hydroxylation		Phenytoin, phenobarbital, propranolol, phenylbutazone, ethinylestradiol, amphetamine, warfarin
N-Oxidation	$RNH_2 \rightarrow RNHOH$ $R_1-NH-R_2 \rightarrow R_1-N(OH)-R_2$	Chlorpheniramine, dapsone, meperidine Quinidine, acetaminophen
S-Oxidation	$R_1-S-R_2 \rightarrow R_1-S(=O)-R_2$	Cimetidine, chlorpromazine, thioridazine, omeprazole
Deamination	$RCH_2CH_2NH_2 \rightarrow RCH(OH)CH_2NH_2 \rightarrow R-C(=O)-CH_3 + NH_3$	Diazepam, amphetamine
<b>II. HYDROLYSIS REACTIONS</b>		
	$R_1COOR_2 \rightarrow R_1COOH + R_2OH$	Procaine, aspirin, clofibrate, meperidine, enalapril, cocaine
	$R_1CONR_2 \rightarrow R_1COOH + R_2NH_2$	Lidocaine, procainamide, indomethacin
<b>III. CONJUGATION REACTIONS</b>		
Glucuronidation		Acetaminophen, morphine, oxazepam, lorazepam
Sulfation	$ROH + \text{3'-phosphoadenosine-5'-phosphosulphate (PAPS)} \rightarrow R-O-S(=O)_2-OH + \text{3'-phosphoadenosine-5'-phosphate}$	Acetaminophen, steroids, methyl dopa
Acetylation	$CoAS-CH_3 + RNH_2 \rightarrow RNH-C(=O)-CH_3 + CoA-SH$ acetyl-coenzyme A	Sulfonamides, isoniazid, dapsone, clonazepam

**Table 2. Clinical important interaction of drug and chemical elimination due to alteration in renal excretion**

	Compound affected	Effect on excretion
Probenecid	$\beta$ -lactam antibiotics indomethacin sulfonpyrazone	Secretion Secretion Secretion
Urinary alkalinization (sodium bicarbonate)	salicylate phenobarbital	Reabsorption Reabsorption
Urinary acidification (ammonium chloride)	amphetamine chloroquine lidocaine	Reabsorption Reabsorption Reabsorption

Continued from page 33

can all stimulate the hepatic metabolism with enhanced metabolism of other chemicals/drugs when exposed at the same time.

### C. ELIMINATION

The most common route of elimination of drugs and chemicals in the body is via the kidneys. Interactions that influence renal clearance of a compound primarily involve the physiological processes of glomerular filtration, tubular reabsorption or active tubular secretion. Recently, the non steroidal anti-inflammatory drugs (NSAIDs) – aspirin, fenoprofen, ibuprofen, indomethacin, naproxen and many others, have all been shown to reversibly depress renal function in certain patients. The mechanism of decreased renal function is most likely the result of NSAIDs' inhibition of renal prostaglandin synthesis. In clinical practice, interactions that influence renal tubular function are observed frequently and can result in serious consequences. Renal function in occupational medicine is of critical importance as all the exposure (BEI) values measured in urine are based on "normal kidney function" as reflected in normal creatinine values. Renal clearance is sensitive to change in urine pH, acid and basic drugs or chemicals must have pKa values that range between 3.0-7.5 and 7.0-11.0 respectively, to not influence kidney excretion. Table 2 illustrates the effect of excretion through the acidification and alkalinisation of urine.

### D. DRUG – NUTRIENT INTERACTION

Nutritional habits, the quantity of food consumed as well as the overall nutritional status of the employee/patient may directly or indirectly alter the drug chemical disposition characteristics. It is a known fact that malnutrition and nutrient – drug effect may result from single cofactor (eg. vitamin trace metal/humeral) deprivation leading to inhibition of specific enzymatic reactions to modifying renal function and/or the quantity and functional activity of the hepatic mixed function oxidase system. Obviously the impact of these effects is often difficult to prove. Moreover, certain drugs/chemicals may directly alter or impair a patient's underlying nutritional status (Table 3).

### CONCLUSION

Drugs (medical, over-the-counter and illicit) and chemical exposure interaction in the workplace remain an important consideration when assessing an employee's response to workplace chemical exposures. It is imperative that the

**Table 3. Influences of food on bioavailability of selected drugs**

TOTAL AMOUNT OF DRUG ABSORBED	
Increased	Decreased
spironolactone	isoniazid
hydralazine	rifampin
hydrochlorothiazide	tetracyclines
griseofulvin (↑ fat)	erythromycin stearate
diazepam	levodopa
cefuroxime axetil, erythromycin	methyl dopa
erythromycin ethylsuccinate, and estolate	

potential interactions are understood and taken into account when assessing biological monitoring (BM) results. Clearly this means that we need to have information on all exposures (drugs, medical, over-the-counter and illicit, as well as workplace) when embarking on BM programmes.

Abnormal or outlier results from BM programmes may indicate the need for reviewing such interactions. Workplaces and countries with a high burden of infectious or chronic diseases, HIV/AIDS, TB, hypertension, diabetes and others, will need special attention. In this regard integration of patient medical information with workplace exposure profiles becomes a major challenge with legal, practical and ethical considerations.

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# SASOHN gives back . . .

In February 2009 SASOHN included 'Social responsibility' as a national objective for the year. The SASOHN Executive Committee represents the 10 regional branches of SASOHN in South Africa, and all objectives set at their meetings are implemented from the regions. So, the challenge was set for each region to initiate or become involved in a social responsibility project for the year. The overwhelming response has resulted in a variety of organisations benefitting from this initiative. Whilst each region rose to the challenge, the reports below illustrate some of their responses.

## WEST RAND

ES le Grange, a Potchefstroom school for physically and mentally challenged children has approximately 252 pupils, ranging in ages from 3 to 21 years. About 75% are boarders and many others are dependent on the home. Residents often come from broken homes and so this is the only real home they know. SASOHN West Rand members collected items, ranging from toiletries to clothes and magazines, and found additional sponsors to assist with much needed donations. For example, Pieman's Pantry has donated hundreds of pies and pledged to keep the school on their donation list, and Transfarm cc donated boxes of first aid supplies and hand cleaner that will be utilised in their clinic.

## PORT NATAL

The Jes Foord Foundation was formed by 'multiple-rape' survivor Jes Foord. This dynamic young woman developed a drive to establish the 'Protect Our Woman Against Rape' (POWAR) centres. The centres work to reduce the debilitating effects of rape on survivors and their families through counselling, education and awareness. Port Natal selected this as a worthy initiative as OHNPs often assist employees who have suffered a rape attack or suffered vicariously when a family member has been raped. The Palm Tree Care Centre was another easy choice. Ros Visagie had a vision which she is living – to care for abused children by providing a safe, secure and stable home for children from broken backgrounds, and to develop them into fully functioning members of society. This is achieved through the provision of love, support, discipline, comfort and carefully structured tuition, which includes Christian teaching. The Centre supports 18 children on a tight budget, and 'special needs' children necessitates ongoing renovation and maintenance of the accommodation. Twelve children attend the local Christian school, three participated in the KZN Gymnastics team, and they have an ARV programme for the HIV positive children. SASOHN Port Natal admires these women and is proud to partner with them to assist them to achieve their visions. We know they have benefited from us, but we don't think they know how much we have benefited from being involved with them!

## VAAL

Kanana, a home for approximately 50 mentally retarded adults in the Vaal triangle area, is totally dependent on donations of food,



**Table decorations at the SASOHN 2009 conference provided through a social responsibility initiative**

clothing, money, toiletries and domestic cleaning products. The residents perform their own domestic chores and cooking. SASOHN Vaal supported the Rotary Anne's and ATKV to assist Kanana with necessary donations, including furniture from one of their members. Through this joint venture, Vaal has managed to receive monthly donations of crockery, groceries, clothes, non-perishable items for the home. SASOHN Vaal is very proud of its members who have generously opened their hearts and hands to this project.

## PRETORIA

SASOHN Pretoria has generously supported Jacaranda Kinder Huis in Eastlynn Pretoria (see page 33 of the September/October 2009 issue).

## EASTERN CAPE

The Eastern Cape Branch adopted the Thandusana Home for abandoned babies for the year. 'Tea money' collected at each meeting was donated at the end of the year, in addition to baby products, clothes and cleaning products, which have been greatly appreciated by the home. In November 2009, the Region hosted the National SASOHN conference, and showed us all the meaning of social responsibility by using local community projects instead of corporate companies and organised businesses to provide services. Table decorations and every gift for speakers, delegates and exhibitors was purchased from a local informal entrepreneur, and these gifts were stunning – proving what immense talent we have in this country. Transport for delegates to and from the airport was 'outsourced' to homes as a mean of raising money, rather than given to a transport / tour business. Every effort was made by this region to give back to the community during this conference – right down to the specially made cup-cakes (bearing the SASOHN logo) for the formal banquet! SASOHN congratulates the Eastern Cape on not only organising an exceptional conference, but on their outstanding efforts in upholding the social responsibility initiative.

I am sure that each region will continue with their social responsibility projects into 2010 and we will see more people benefiting from this.

*Jenny Meaker, SASOHN National Secretary*

## Report-back on the 12th Annual Congress – Part 2



DB de Villiers, VG Govender, T Pieterse

In this issue, the report on the proceedings of 12th Annual Congress, held at Glenburn Lodge between 2 and 4 October 2009, is continued.

After the introductions of the previous session and some serious reality checks regarding problems facing our industry, the Saturday session made way for some teaching and hope for the way forward. Dr Theunis Pieterse was the early bird to chair the Saturday morning marathon session.

Ms Daleen Schoombee speaking on assessment of physical and functional work capacity – a practical approach to managing fatigue demonstrated that it should be an integral part of the fitness to work assessment. She noted that normal work rates should be suitable to candidates, or else recovery is slow and fatigue sets in, posing dangers in the workplace. Body mass index (BMI) correlates strongly with work capacity – low BMI is a problem often found in novices.

Dr Mary Ross gave an update on pandemic influenza, a business challenge but not a high exposure problem for health care workers. Free information for employers to draft an action plan is available at [www.facocmed.ac.uk](http://www.facocmed.ac.uk), the Centers for Disease Control and Prevention (<http://www.cdc.gov/H1N1FLU/>) and NICD websites.

It was most positive to get the involvement of the statutory bodies as recent communications were perceived as a bit problematic. Dr Mokoboto was willing to address the congress at very short notice and touched on South African Medical Occupational Disease Database (SAMODD) requirements and new requirements in the Mine Health and Safety Amendment Act, No 74 of 2008.

Dr Dzingwa from the Medical Bureau for Occupational Disease (MBOD) urged colleagues to supply comprehensive case histories, such as a detailed labour history, address of the health unit for reports and beneficiary details for autopsy cases. Possibilities of fraud and corruption were mooted as problems. Due to several action plans for service improvement being considered and limited funding, a digital chest X-ray system at MBOD is not currently regarded a priority.

Dr Deodat Kritzinger gave an overview of the activities of the Rand Mutual Assurance Company, which is 115 years old. Costs have increased, the leading drivers being fatalities and spinal cases, also 20% hand in injuries, 10% foot injuries, and 7,5% NIHL.

Mr Henry Moorcroft in reminding us of the importance of linking medical surveillance to hygiene, pointed out the legal requirements to get improved communication systems and presented a management model for this integration.

Dr Don Emby delivered an interesting talk called "Don't die by mistake", covering leading natural- and unnatural causes, the latter including preventable / treatable infections! He quoted interesting statistics, such as similar daily fatalities as in Iraq due to violence, road accidents and domestic incidents, e.g. dog bites (often the family pet), falling due to preventable causes and alcoholic beverages, drowning in the family swimming pool, etc.

Prof. Jan Verschoor from Pretoria University described research on tuberculosis diagnostics, which has become an absolute necessity

due to the increased prevalence of *Mycobacterium avium* in HIV patients, the challenges with diagnostics in children, and HIV cases with less reaction in the older skin tests and on chest X-rays. Sputum and blood samples are still the most reliable and research continues in an effort to increase sensitivity and specificity.

Dr Kritzinger chaired the graveyard shift after lunch, presenting the speakers with a very thought-provoking session. Dr Hansia in discussing the use of hearing protective devices, stated that NIHL is still the most prevalent occupational disease worldwide. Usage rates vary from reasonable (79% compliance in Brazil) to extremely poor (5%) and all should assist with training since 23% of workers value training by medical staff. Dr Mbekeni dealt with clinical governance in OH and how we conduct our practice. Dr Jim Murphy talked on ethics, mentioning that a Code of Ethics is available on the ICOH website (<http://www.icohweb.org/>). As participants were by now doing some serious introspection, the scene was set for a hard hitting talk by Prof. Tony Davies (Ex Director NIOH) outlining how serious the situation is regarding the industry's disease profiles and continued work. He made a serious plea to move beyond the abundance of research papers into some real action by medical professionals moving out of their "silos".

Dr DB de Villiers chaired the "light at the end of the tunnel" session. Dr Vanessa Govender presented the way forward in the form of the MOSH (Mines Occupational Safety and Health) adoption perspectives, an initiative steered by the Chamber of Mines involving expert industry members and consultants. She described the phases, noting that the most powerful influences on adoption are leadership and behavioural communication.

Dr Murray Coombs presented a paper on "Manganism, the ongoing saga", cautioning that although disease symptoms are uncommon, brain deposits of manganese could be shown in a large number of welders and employees in smelter plants etc. Brain deposit T½ is estimated at 2½ years. Despite the low incidence of disease, science must prevail. Dr Emby gave the last talk on silicosis and lung disease, and showed some X-rays on the laptop – the power failure at the time provided for a real old-fashioned teaching get-together!

Dr DB de Villiers made closing remarks commenting on the uniqueness of this congress, fulfilling the need to present topics of interest wider than just those of the occupational health practitioners in order to attract a wider membership base. There were 61 attendees (a record attendance!) from various disciplines, and 26 presentations. Special thanks went out to the participation of statutory bodies, the DMR and MBOD. A heartfelt appreciation was expressed to the organisers, mainly our Senior Committee Secretary Ms Shirli Geere and our President, Dr Vanessa Govender. The 2009 MMPA congress was truly a memorable one, creating new relations, forging old ones and providing ample food (literally!) for thought and direction to go out there and answer the calling of our mission, especially promoting best practice in mine medicine and promoting the health and productivity of the workforce.



## SASOM in 2010

The five-year period granted by the Health Professions Council of South Africa (HPCSA) in Article 12 of Government Notice R1457 of 13 December 2004 has now expired. Article 12 allowed for HPCSA recognition without formal training as a registrar at a Medical Faculty in South Africa. SASOM was given a mandate to appoint a peer review committee of occupational medical specialists to review each application and where substantial compliance with the criteria in Article 12 was found, recommend a letter of support for the application from SASOM.

SASOM has undertaken to step up a gear in its efforts to enhance professional and personal development of occupational health practitioners in 2010. To this end the National Office will host two one-day conferences in March, the annual two-day congress at the end of July and an academic day in November.

Dr Murray Coombs will revive monthly Ramazzini Club meetings and the National Office will undertake the administration. The SASOM Chapters will continue with their regular meetings, which include presentations and an

opportunity to network. Contact the Chapter Chairpersons for programme details:

Cape: Dr Greg Kew (Greg.Kew@synergiee.co.za)

Inland: Dr Marina Botha

(Marina.Botha@lifehealthcare.co.za)

KwaZulu-Natal: Dr Kevin Rainier

(Kevin.Rainier@sappi.com)

The first two SASOM conferences will have the same programme and take place at Kirstenbosch Gardens in Cape Town on 5 March and at The Ranch Hotel near Polokwane on 12 March 2010. The programme follows below.

Contact Jenny Acutt in the SASOM National Office for more information and note the contact details which have changed in the last year:

Tel: +27 (0)12 803 7418 or 086 111 4417

Fax: +27 (0)11 507 5085 or +27 (0)12 803 7418

Email: info@sasom.org

Postal address: PO Box 32, Silverton, 0127

All previous numbers, e-mail and postal addresses have been discontinued.

### ASPECTS OF TRAVEL, BIOLOGICAL HAZARDS, DRIVING AND SLEEP IN OCCUPATIONAL MEDICINE PRACTICE

#### PROGRAMME

07:30 – 08:00	Registration	Viewing of Exhibitions
08:00	Welcome by the SASOM Chairman, Prof. Daan Kocks <i>Chairperson: Dr Greg Kew or Dr Frank Fox</i>	
08:30 – 10:00	Travel Medicine within South Africa and abroad (includes immunisations, psychological aspects and topical issues)	Dr Pete Vincent Dr Salim Parker Prof Gboyega Ogunbanjo Dr David Hyams
10:00	Refreshments	Exhibitions <i>Chairperson: Dr Hanli de Wet or Dr Elton Dorkin</i>
10:30 – 12:30	Hazardous Biological Agents – All types are included in an unusual practical demonstration	Prof. Anton Stolz
12:30 – 13:30	Lunch – very special! <i>Chairperson: Dr Anita van der Walt or Dr Lettie La Grange</i>	
13:30 – 14:30	Shift work	Dr Elton Dorkin
14:30 – 15:30	Rest, sleep disorders, narcolepsy, sleep apnoea and more	Dr Alison Bentley
15:30 – 16:00	Vehicle drivers' health – Newly revised SASOM Guideline	Dr Greg Kew
16:00 – 16:15	Closing of the Conference	Prof. Daan Kocks

# Dear Colleagues

It's 2010! Many people are looking forward to the FIFA Soccer World Cup. The SAIOH Council is also looking forward to this year with lots of challenges and opportunities within the field of occupational hygiene. One of the opportunities is the pilot of the OHTA module: Health effects of hazardous substances being presented from the 1st to the 5th of February 2010. These modules are aimed at technologists and are intended to provide practical, hands-on training. The training materials are not available to individuals but only to IOHA member organisations that have signed a memorandum of understanding with OHTA. More information is shown below.

Another opportunity is Safeconex 2010, to be held at the Indaba Hotel on the 17th and 18th of March 2010. The SAIOH Annual General Meeting will be held during this time. The date and time will be confirmed and circulated to all members.

I represented SAIOH at the AIOH (Australian Institute of Occupational Hygienists) Annual Conference during December in Canberra, Australia. The following associations were invited and shared successes, challenges and opportunities with education and training being a major activity: Hong Kong Institute of Occupational and Environmental Hygiene, Korean Society of Occupational and Environmental Hygiene, Malaysian Industrial Hygiene

Association, Southern African Institute for Occupational Hygiene, President IOHA, BOHS, ACGIH, AIOH.

I would like to convey the following message at the start of this year.

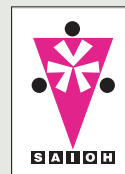
### *Success is determined on the drawing board*

According to Max Steingart it isn't enough to just want to be successful. You've got to ask yourself: "What are you going to do to get the things in life you want?"

Your problem is to bridge the distance which exists between where you are now and the goal you intend to reach. Planning brings your future into the present so you can do something about it now. Somewhere there is a map of how it can be done. All you need is a good plan, and the courage to press on to your destination. A well built house is started with a definite purpose and a set of blueprints. Your plan should provide the pattern for the actions you'll take. Take time each day to study, think and plan. Plan your steps, then implement your plan, then review your results. Do this frequently and make the appropriate alterations to your plan, and you'll develop the power that will bring you to success. No one was ever lost on a straight road.

Let's all plan and succeed in our goals for 2010.

*Melinda Venter, SAIOH President,  
E-mail: melindav@iantic.net*



## Southern African Institute for Occupational Hygiene Occupational Hygiene Professionals Council

### PILOT: International Occupational Hygiene Training Module HEALTH EFFECTS OF HAZARDOUS SUBSTANCES

In association with:



The Occupational Hygiene Training Association (OHTA) have agreed to pilot the latest IOHA recognised international training module "Health Effects of Hazardous Substances" at the National Institute for Occupational Health here in Johannesburg from the 1st till the 5th of February 2010.

The author of this module, Phil Johns of Gully Howard Technical Ltd, and Kate Jones, the British Occupational Hygiene Society's ambassador to South Africa, will present the module.

Phil Johns, a chartered chemist and occupational hygienist, has over 30 years work experience in private industry and local government, and five years as a senior lecturer at the University of Portsmouth. He is

now Course Director at Gully Howard Technical Ltd – a leading UK occupational hygiene training provider. He has been extensively involved with the development of the modules, including authoring this module and the asbestos module.

Kate Jones, an analytical chemist, is a principal scientist in HSL's Biological Monitoring Section. With over 15 years experience in biological monitoring of organic compounds, her skills include the use of specialist analytical techniques; method development; toxicology; and undertaking human volunteer studies. Currently Secretary to the Royal Society of Chemistry's Toxicology Group and Chair of the BOHS Annual Conference Scientific Committee, she has been the BOHS Ambassador to South Africa since 2008.

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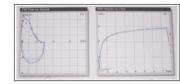
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