The "Study on Workplace Environment and Health": An Efficient and Productive Collaboration in Occupational Health and Safety between Industry (WMC Fertilizers) and University (James Cook University)

Reinhold Muller[1], Tony Carter[1], Michael Ridd[2] ,Tom Magee[3], Matthew Wicking[3]

[1] School of Public Health and Tropical Medicine (SPHTM),

[2] School of Pharmacy and Molecular Sciences, James Cook University (JCU)

[3] WMC Fertilizers Pty Ltd (WMC)

Abstract

In 2001, WMC Fertilizers Pty Ltd at Phosphate Hill commissioned the School of Public Health and Tropical Medicine (SPHTM) at James Cook University (JCU) in Townsville to develop, conduct and evaluate epidemiological research studies into the workplace environment and health as part of their pro-active approach to occupational health and safety. Over the last two years, this scientific project has been established as an efficient and productive collaboration.

The first part of this presentation discusses the key-features essential for the success and bilateral benefit of an occupational health research project in the specific collaborative setting between industry and university:

- Independence of Research
- Involvement of the Workforce
- Evidence-based Epidemiological Research
- The Objectives are Tangible Results Achieved in a Practically Relevant Time-Frame
- Cost-Effectiveness

In the context of the "Study on Workplace Environment and Health", a range of practice-oriented research studies in occupational health and safety have been undertaken. The main goal of the research project was to achieve tangible results within a practically effective time frame. This goal has been fully accomplished and a variety of practical solutions and resulting improvements at WMC Fertilizers at Phosphate Hill were achieved.

Some components and results of specific studies will be discussed to examplify the practical research approach. These project cover the general areas of

- Chemical environmental sampling and mapping,
- Biological monitoring (annual health checks) and
- Dehydration and fatigue management.

Introduction

In 2001, WMC Fertilizers at Phosphate Hill commissioned the School of Public Health and Tropical Medicine at James Cook University (Townsville) to develop, conduct and evaluate epidemiological research studies into the workplace environment and health of the workforce at their Phosphate Hill operation. Identified potential health issues before the start of the project mainly related to chemicals in the workplace environment where hydrogen fluoride, and sulphuric and phosphoric acids were stated as potentially hazardous chemicals at the Phosphate Hill site.

The WMC Fertilizers plant at Phosphate Hill is located 150 km south-west of Mount Isa. The plant is a fly-in/fly-out operation and employees predominantly work a "2 on / 1 off ratio" schedule of 12 hour shifts. The climatic conditions at Phosphate Hill are harsh, with hot to very hot temperatures and an often extremely low humidity.

Considering the specific characteristics of the Phosphate Hill workplace, JCU identified the following main research areas:

- Identification and quantification of occupational chemical exposure;
- Development and implementation of a chemical monitoring program;
- Research into the potential (long-term) health effects of the identified chemicals;
- Development and implementation of a biological monitoring program;
- Research into dehydration and fatigue management.

The key features necessary for this research collaboration between a university and the mining industry to be successful are discussed, together with some the results of specific projects that exemplify the bilaterally beneficial nature of the research project in obtaining evidence-based knowledge and tangible scientifically valid results during practically relevant time frames.
Examples of projects discussed cover the general areas of (1) chemical environmental sampling and mapping, (2) biological monitoring (annual Health checks) and (3) dehydration and fatigue management.

Key Features of the Research Project

The following key-features are deemed essential for the success and bilateral benefit of an occupational health research project in the specific collaborative setting between industry and university:

(1) Independence of Research

Studies carried out by university researchers are independent and consequently enjoy a higher credibility compared to consulting work carried out by agencies; this is also true with respect to the perceptions of the workforce. All content aspects of the "Study on Workplace Environment and Health" were developed by researchers at JCU. The role of WMC Fertilizers was restricted to logistical issues during the planning and conduct phase of the projects in contrast to many consultancy contracts where the employer often determines to a high degree the type, conduct and scope of the project. It should also be emphasised that full confidentiality of the information provided by individual workers is guaranteed as WMC Fertilizers only has access to summary (as presented in the respective reports), not individual data.

(2) Involvement of the Workforce

The importance of workforce involvement as a vital component of any epidemiological study cannot be overestimated. Above all, in this area of workplace health and safety, the employees can contribute indispensable information (it's their workplace after all!) and the quality of quantitatively collected general health information is directly related to the support of the workforce. The involvement of the workforce covers two main areas; active participation and regular feedback. The presented study incorporated from the outset a variety of different measures for ensuring involvement in both areas.

Active participation: Annual qualitative focus group research is carried out in many segments of the workforce (usually 6 different groups) for the employees to have their say. Here the participants discuss with JCU researchers their perceptions of workplace and safety issues (including suggestions for improvement) and the performance of the management and the safety department in their working area. Additional questions also refer to their view of recent projects.

Feedback: Regular feedback to the workforce is achieved by publishing each JCU report uncensored and in full length on the WMC Fertilizers intranet (this accessibility to the full information gained is also a hallmark of independent research!). For specific aspects of the study, special "information flyers" summarizing the findings in plain language are also provided. Moreover, JCU features prominently during a "safety day out" at least once per year providing presentations followed by discussions on every individual project carried out on site. Additionally, the workforce and their families are kept up-to-date by regular contributions to the "Fertilizer Facts", the monthly site magazine.

(3) Evidence-based Epidemiological Research

The independence of the research also guarantees that JCU researchers can follow stringent scientific methodology, with the consequence that the results of the studies and the developed policies and procedures are strictly evidence-based and therefore valid. It is important that the beneficiaries of any type of study and research in the area of occupational health and safety are people, in this case, the employees. JCU has therefore implemented as much epidemiological studies (i.e. studies refering to actual people) as is possible.

(4) The Objectives are Tangible Results Achieved in a Practically Relevant Time-Frame

In contrast to some pure academic research, it is imperative that the main focus of an industry-university collaboration is on achieving practical solutions. JCU adopted this principle and the components of this study discussed below will exemplify the achievements in this area in more detail. In general it can be stated that the study has been running for two years and had to "start from scratch" in terms of epidemiological data. Considering this, the practical outcomes, also for previously unknown issues, seem impressive.

(5) Cost-Effectiveness

University research not only offers the previously discussed advantages of independent and credible scientific research, but is also highly cost-effective. The "Study on Workplace Environment and Health" enrolled several doctorate students from the School of Public Health, while a smaller research study into the hydration knowledge and behaviour of the workforce was conducted with the help of undergraduate students as part of one of their research methodology subjects.

The involvement of doctorate, graduate and undergraduate students, if carried out under strict supervision of a senior experienced person, is not only cost-effective but in this particular case also beneficial to all parties involved (the industry partner, the university and the students) in the following way: The students learn practical skills through their early exposure to "real-life" epidemiological research and are led to the field of occupational health and safety in the mining industry, an identified area of personnel shortage where employment opportunities for future graduates seem quite promising.

The "Study on Workplace Environment and Health"
Examples of Components and Results

Having considered the key features of the "Study on Workplace Environmental and Health", some examples of components and results achieved in different areas of occupational Health and safety by the project are presented in the following.
In the order of their discussion, these components exemplify practical research studies and their results in the areas of

(1) chemical environmental sampling and mapping,
(2) biological monitoring (annual Health check-ups) and
(3) fatigue and dehydration management.

(1) Environmental Chemical Sampling and Mapping

Environmental chemical sampling of the atmosphere was undertaken as part of the JCU study. The air was sampled for a range of chemicals of potential concern. Sampling has so far been conducted in two phases: (1) predominantly "uniform sampling" in 2001 and (2) primarily "targeted sampling" in 2002.

The objective of the first sampling operations was to provide a 'snapshot' of what might typically be observed in the atmosphere at the WMC Fertilizer site under routine operating conditions. During this first sampling phase the majority of the sampling points were equally spread in a regular grid over the whole site, while only the smaller part of the sampling points was concentrated in finer grids around the suspected sources.
The second phase of sampling was deliberately and highly "biased" towards detailed sampling at and around the identified sources of the first survey but nevertheless kept a wider grid over most of the rest of the site to confirm (or otherwise) the general pattern of distribution of the chemicals observed at the site during the initial sampling program.

The main chemicals sampled and measured were

- Hydrogen Fluoride (HF),
- Sulphuric Acid (H_2SO_4) and
- Phosphoric Acid (H_3PO_4).

The sampling methodology was designed to ensure that the detection limits for these chemicals were at least a factor of 10, and for HF close to a factor of 100 below the National Occupational Health and Safety Commission (NOHSC) Time Weighted Average (TWA) values.

Detection limits and NOHSC TWA for the main analytes were 0.03 (mg/m^3) and 2.6 (mg/m^3) for HF, 0.1 (mg/m^3) and 1.0 (mg/m^3) for H_2SO_4 and 0.03 (mg/m^3) and 1.0 (mg/m^3) for H_3PO_4 respectively.
Approximately 200 samples (6 hour time weighted average) were obtained for the main analytes during the two sampling programs. The initial sampling phase demonstrated that detectable HF concentrations were localized in and around the Phosphoric Acid plant and on the Gypsum Stack. These locations were consequently the main focus for the second sampling operation and detailed concentration maps were obtained for these areas, such as the filter floor of the phosphoric acid plant where a grid of 25 measurements was taken.

The main results for the Phosphate Hill site referring to around 200 (6 hour averaged) samples (taken as above described) can be summarized as follows:

(1) Only one single sample of **phosphoric acid** exceeded the detection limit of 0.03 mg/m^3 with a result of less than 6% of the NOHSC TWA.
(2) Twenty-three samples of **sulphuric acid** mist exceeded the detection limit of 0.1 mg/m^3 during the first sampling phase and only one single sample during the second sampling program despite the above described deliberately biased sampling procedure. All quantities above detection limit were below 15% of the NOHSC TWA with the exception of four samples collected at the filter floor of the phosphoric acid plant where levels up to 75% of the NOHSC TWA were seen. The sole sample above detection limit of the second sampling phase reached approximately 10% of the NOHSC TWA.
(3) **Hydrogen fluoride** was detected in 40% and 60% of samples during the first and second round of the sampling program respectively. The typical concentrations of detectable hydrogen fluoride around the site were below 4% of the NOHSC TWA with two marked exceptions; the phosphoric acid plant and its immediate surrounds and the gypsum stack where three samples (2.6, 2.7 and 2.8 mg/m^3) revealed concentrations at or above the NOHSC TWA of 2.6 mg/m^3.

The interpretation of the results from the two sampling programs can be summarized by stating that, under routine operating conditions, the sampled chemicals do not appear to imply a significant risk to human health at the Phosphate Hill site. It seems worth noting in this context that the only three samples revealing values at or above NOHSC TWA were obtained at locations where the use of PPE is compulsory.
The general agreement of the results for all analytes between the two sampling operations indicates that the two surveys provide a valid overview of the spatial distribution of the sampled chemicals around the Phosphate Hill site. The only observed differences between the sampling operations disappear when the relative frequency of the samples at the respective sites is taken into account. For instance, the observed increase of detectable amounts of hydrogen fluoride between the two

sampling programs is explained by taking the deliberately biased sampling strategy for the second sampling phase into account.

The only exception is the filter floor of the phosphoric acid plant where the observed decrease in detectable amounts of sulphuric acid between the two sampling programs is attributable to engineering solutions. The significant decrease in samples containing a detectable amount of sulphuric acid mist (despite the increased sampling frequency around the phosphoric acid plant) therefore demonstrates the effectivity of the implemented structural solution.

(2) Biological Monitoring

As part of the biological monitoring process of the JCU study at Phosphate Hill, a quantitative Health Survey has been conducted annually since 2001. All employees of WMC Fertilizers, as well as all contractors at Phosphate Hill, are invited to participate.

The main aims of this annual Health Survey are to:

1.) determine the general health status of the workforce;
2.) create a baseline of the general health status as reference data for future monitoring and/or surveillance projects and for quasi-experimental intervention studies;
3.) identify attributable fractions of relevant risk factors (occupational history, diet, smoking, alcohol etc);
4.) identify specific priorities for intervention strategies; and
5.) contribute generally to a safer working environment.

The main components of the Health Survey comprise:

a) a full blood count, a liver function test and an ACR urine test;
b) a full respirometry (including changes after the use of dilators);
c) a basic physical examination (including visual acuity, joint laxity, blood pressure); and
d) a detailed health questionnaire covering basic demographics, medical and occupational history, individual risk conditions and behaviour, current medications, smoking, alcohol consumption and detailed symptoms pertinent to potential exposure to hydrogen fluorides and other relevant chemicals.

Personal confidential letters are delivered to each participant detailing their results of the Health Survey.

The Health surveys are well received by the workforce and this is reflected in a high participation rate (around half to two thirds) of the overall workforce. Taking into account that a substantial percentage of this "overall workforce" are contractors who are not necessarily on-site on a regular or permanent basis, the overall participation rates may even exceed the above estimates.

The main aim of this series of health surveys is the biological long-term monitoring of the workforce and to obtain baseline information for future quasi-experimental intervention studies. Therefore, the general results do generally not lend themselves to stand-alone interpretation. However, some findings can be directly used to develop specific recommendations towards health improvements of the workforce and are discussed in the following.

More than one-quarter of all staff (compared to less than 20.0% of the Australian population[1]) have a Body Mass Index (BMI) that is in a high-risk category for hypertension, cardiovascular disease and diabetes. Every third participant has a high-risk waist-to-hip ratio and close to half of the participating workforce is hypertensive, which both impose a substantial health risk with respect to a variety of cardiovascular diseases and seem worth addressing. Similar statements hold true for the observed high prevalence of (and likely synergisms with) smoking (35% compared to 24% for the Australian population) and significant levels of alcohol intake.

Consequently, the roles of Eurest in providing nutritional information and low-fat food options and Trench Sportz in facilitating physical activity on-site seem justified. In this context, it seems worth noting that employees are significantly more likely to engage in physical activity on-site (median 5 days) than off-site (median 3 days).
The main focus of the overall study, however, is on workplace environment and occupational health and therefore specific intervention programs to change the general life-style seem beyond the scope of this project.

Almost every fifth participant of the first survey would have failed the Queensland Transport heavy vehicle visual acuity test. This is disquieting, despite the fact that the visual acuity test (using only an eye-chart) cannot be regarded as a final diagnosis, and may actually overestimate the proportion of subjects with compromised visual acuity.
A potentially compromised visual acuity was of course mentioned in the confidential personal letters and the apparently high percentage of such findings intensively discussed in the respective health reports and JCU presentations on site. The respective percentage observed during the second health survey was 5% with a coinciding increase in the use of a corrective lens. However, whether this improvement was attributable to the described "interventions" remains unclear since the illumination of the eye chart seems to have been unfavourable during the first health survey.

An interesting finding with respect to respiratory parameters was the observation that some employees had been previously diagnosed with and were currently suffering from asthma. This constitutes a major workplace health risk as it is known that exposure to inorganic gas mist and dust – above all in combination with physical activity – vastly increases the risk for asthma attacks and potentially serious consequences[2]. The result also indicated that the screening for asthma performed during routine entry examinations prior to employment was sub-optimal.
As a consequence, a detailed proposal for a more effective pre-employment medical has been developed by the JCU team and the logistics for the amalgamation of this proposal with new corporate guidelines are currently under development. Additionally, those employees identified with a history of asthma or breathing obstruction were encouraged to develop an asthma management plan with their General Practitioner to control and reduce the severity of their symptoms[3].

While participants in this study have only marginally less usual hours of sleep per night on- than off-site (median of 7 compared to 8 hours), more than twice as many have less than 4 hours sleep on at least one night on-site (45%) than off-site (18.0%). Sleepiness, in combination with low blood alcohol concentrations and dehydration may influence injury risk and productivity and currently implementations of random tests (such as simple reaction time, dual task Mackworth clock vigilance and symbol digit coding) are considered as assessments[4] of fatigue.

The biochemical blood analyses, self-reported symptoms and the observed colour of the collected urine samples indicated considerable levels of dehydration in the workforce which led to the dehydration studies which are discussed in the following.

(3) Dehydration Study

The series of dehydration studies illustrate the dynamics of the research process. Dehydration was identified as an important issue during the standard components of the project and led to a variety of interesting specific research projects.

The first observation leading to this process was that approximately 16.0% of the workforce exhibited elevated serum albumin levels and 10.0% of the workforce had elevated serum albumin and potassium levels in combination. Both are biochemical markers for dehydration[5]. Additionally it was observed that the most frequent self-reported symptoms in the health surveys were all discussed in the literature as closely associated with dehydration[6]; over 40% reported tired or strained eyes, and close to 40% stated unusual fatigue and headaches during the last 4 weeks while

working on-site. A further indication for dehydration as a workplace issue came from the qualitative focus groups where people again complained about symptoms consistent with dehydration.

Consequently, a study of the hydration status and hydration needs of the workforce was conducted and is reported in detail in an additional contribution to these proceedings. The main aim was to determine the hydration status and hydration needs by measuring urine specific gravity (portable refractometer), fluid intake (questionnaire) and fluid loss (difference in weight and specific questionnaire items).

This study found that two thirds of the workforce maintain or improve their hydration status during their shift but those working predominantly in direct sunlight need to improve their hydration behaviour. Data collected for this study also allowed the development of detailed weight and task specific fluid input targets. The most surprising result, however, was that a majority of the workforce *arrived* dehydrated for their shifts.

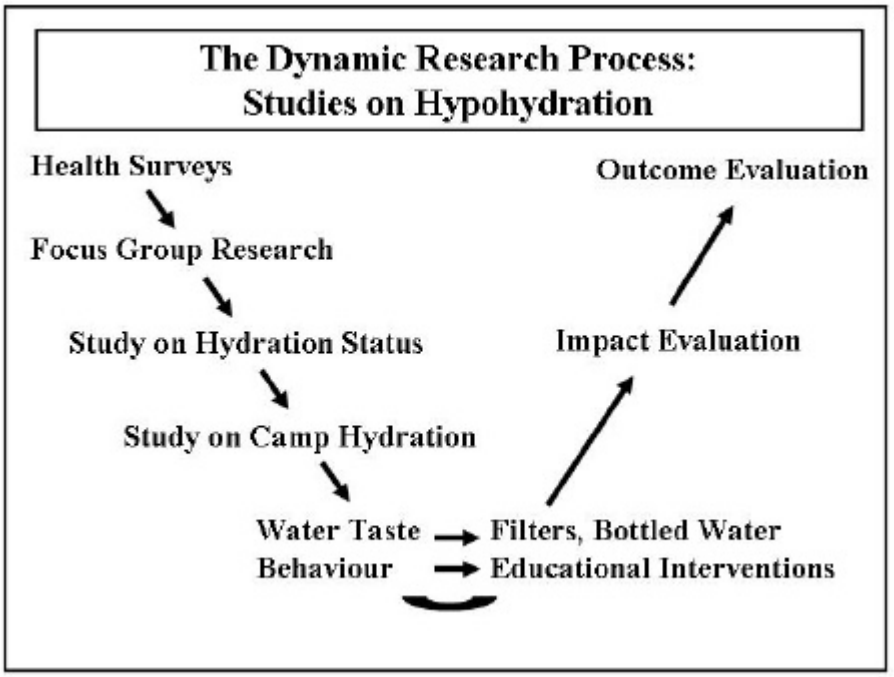
The prime target for improving the hydration status of the workforce consequently shifted from the workplace to the camp, and an additional study was carried out on the hydration knowledge of the workforce and their hydration behaviour at camp. Third-year Occupational Therapy students were involved in this project (as part of their research studies) and developed, piloted, adjusted and then administered a questionnaire to the workforce in April / May this year.

At the time of writing, some data were still being analysed in detail. However, the main results clearly demonstrate that while the general hydration knowledge (risk factors for dehydration, what type of drinks are actually dehydrating etc.) of the workforce is adequate, people simply don't seem to drink enough non-alcoholic beverages at camp. The stated averages of one "cup"-equivalent of soft drink and 2 "cups" of water are by far not sufficient to keep a person adequately hydrated.
Why is there a discrepancy between knowledge and behaviour? One answer was found in the perceived obstacles to re-hydration in the questionnaires: Half of the comments stated referred to the perceived poor taste of the tap water at camp and a similar proportion of comments relate to access to alternatives to tap water such as bottled water.
A number of possible practical solutions on how to most effectively address this critical issue are currently being investigated. These include possible "engineering" solutions (such as implementing additional water filters, increasing the number of water fountains at camp, etc.) but will also have to bridge the gap between hydration knowledge and the respective behaviour by means of information campaigns and other educational interventions.

The research process in the area of dehydration at Phosphate Hill is still in progress but the series of the above described projects clearly demonstrates the dynamics and often multi-stage character of a practical research process.

Starting with the biochemical findings of the Health surveys indicating a dehydration problem and the confirmation of the identified issue by results from the qualitative focus group research, a specific study on the hydration status (and hydration needs) of the workforce was developed and conducted. The results of this third stage of the research process demonstrated that the main problem lies at camp. Digging even deeper, an additional survey of the hydration knowledge and hydration behaviour at camp was undertaken to identify the "ultimate" causes. Preliminary results of this survey point to the taste of the tap water and an understimation by the employees of their susceptibility to and the consequences of dehydration.

Figure 1:



Once these results are confirmed and effective interventions have been developed and implemented the research process can be "reversed". The next stages will then be the process, impact and outcome evaluations of the interventions employing another series of studies (Figure 1).

References

[1] Australian Bureau of Statistics. How Australians measured up. ABS Cat No. 4359.0. Canberra, Australian Capital Territory: ABS, 1998.

[2] Sciences International Incorporated. Toxicological profile for sulfur dioxide. Atlanta: Agency for Toxic Substances and Disease Registry, 1998.

[3] National Asthma Council of Australia. Asthma Management Handbook 2002. 20 March 2002. [online] http://www.nationalasthma.org.au/publications/amh/amhcont.htm

[4] Williamson A.M., Feyer A.M., Mattick R.P., Friswell R., Finlay-Brown S. Developing measures of fatigue using alcohol comparisons to validate the effects of fatigue on performance. Accid Anal Prev, 2001; 33(3):313-26.

[5] Tietz N.W., ed. Clinical guide to laboratory tests. 2nd ed. Philadelphia: W.B. Saunders, 1990:26-7,456-7.

[6] American College of Emergency Physicians. Emergency physicians stress dangers of heat illness: education key to saving lives. [online] http://www.acep.org/1,51,0.html