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The Journal of the Australian Institute of Environmental Health

...linking the science and practice of Environmental Health

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Environmental Health is a quarterly, international, peer-reviewed journal designed to publish articles on a range of issues influencing environmental health. The Journal aims to provide a link between the science and practice of environmental health, with a particular emphasis on Australia and the Asia-Pacific Region.

The Journal publishes articles on research and theory, policy reports and analyses, case studies of professional practice initiatives, changes in legislation and regulations and their implications, global influences in environmental health, and book reviews. Special Issues of Conference Proceedings or on themes of particular interest, and review articles will also be published.

The Journal recognises the diversity of issues addressed in the environmental health field, and seeks to provide a forum for scientists and practitioners from a range of disciplines. *Environmental Health* covers the interaction between the natural, built and social environment and human health, including ecosystem health and sustainable development, the identification, assessment and control of occupational hazards, communicable disease control and prevention, and the general risk assessment and management of environmental health hazards.

Environmental Health is indexed in Ulrich's Periodicals Directory, the Australasian Medical Index, PANDORA and APAIS

Aims

- To provide a link between the science and practice of environmental health, with a particular emphasis on Australia and the Asia-Pacific Region
- To promote the standing and visibility of environmental health
- To provide a forum for discussion and information exchange
- To support and inform critical discussion on environmental health in relation to Australia's diverse society
- To support and inform critical discussion on environmental health in relation to Australia's Aboriginal and Torres Strait Islander communities
- To promote quality improvement and best practice in all areas of environmental health
- To facilitate the continuing professional development of environmental health practitioners
- To encourage contributions from students

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Call for Papers

The Journal is seeking papers for publication.

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Papers can be published under any of the following content areas:

Guest Editorials

Guest Editorials address topics of current interest. These may include Reports on current research, policy or practice issues, or on Symposia or Conferences. Editorials should be approximately 700 words in length.

Research and Theory

Articles under Research and Theory should be 3000-5000 words in length and can include either quantitative or qualitative research and theoretical articles. Up to six key words should be included. Name/s and affiliation/s of author/s to be included at start of paper and contact details including email address at the end.

Practice, Policy and Law

Articles and reports should be approximately 3000 words in length and can include articles and reports on successful practice interventions, discussion of practice initiatives and applications, and case studies; changes in policy, analyses, and implications; changes in laws and regulations and their implications, and global influences in environmental health. Up to six key words should be included. Name/s and affiliation/s of author/s should be included at start of paper and contact details including email address at the end.

Reports and Reviews

Short reports of topical interest should be approximately 1500 words. Book reviews should be approximately 700 words and Review Articles should not exceed 3000 words in length.

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Welcome to the third issue of *Environmental Health* for 2005. Those of you who have recently downloaded the online Journal will have discovered our new website at http://journal.aieh.org.au. We hope you find the new format easy to use and an important resource for your environmental health information needs. We are particularly pleased with the searchable database of back-issues, which will be of great value for subscribers and members of the AIEH. The Journal is also now available via IP Access, which will make electronic access much easier for libraries and other institutions. If you are interested in upgrading your subscription to take advantage of this option please ensure you include a proxy server IP Address in your subscription renewals for 2006. If you would like more information on IP Access and its benefits, feel free to contact us.

Our thanks go to Bruce Morton for writing the Guest Editorial in issue two of *Environmental Health*. For those of you who missed out on the editorial last issue, Bruce covered the pressing issue of low retention rates in Environmental Health Officer Courses, and the increasing scarcity of qualified Environmental Health Officers (EHOs) available for employment. The editorial produced much discussion on education and workforce management in the field of environmental health. In response to Morton's editorial, Thomas Tenkate has contributed further commentary on educational issues in the environmental health profession. Tenkate uses the UK experience for comparison, as he reports on educational issues experienced by EHOs today.

On the topic of improving EHO education, it is useful to note the development of a new environmental health degree course in Tasmania. We will keep you posted on this new development as information arises.

If the issue of EHO education and employment is a cause for debate among you and your peers, why not write down your viewpoint in a Letter to the Editor? We would be pleased to receive feedback on the topics and subject matter published in *Environmental Health*, and look forward to receiving your views.

Once again, the issue of disaster management is fresh in our minds after the devastating effects of Hurricane Katrina in the United States, and another bombing in Bali. We can only imagine the impact such a disaster would have both on a personal and environmental level. Skills and knowledge in the management of the public health implications of disasters will be covered in the *Disaster Management Course*, to be held in Broome on the 6 - 11 November. The Journal is currently calling for papers on the environmental health aspects of disaster management. Any interested professionals with research, reports, fieldwork, reviews or comments on this issue please send your papers to the Journal for publication. We are aiming to collect enough manuscripts for a special issue on disaster management but require your help to see this aim brought to fruition.

Peng Bi provides us with a commentary on the most topical issue of climate change and she outlines the current research on climate change, and how this could affect population health in Australia. Peng Bi will also be presenting on this topic at the *AIEH National Conference in Adelaide 'Imagine Life without Us'* to be held from 7th to 9th November 2005. Also, Jacques Oosthuizen, who published in *Environmental Health*, vol. 5, no. 2, will be presenting his research on mobile phone use.

We would like to extend an invitation to other conference presenters to publish their conference papers and/or associated research on environmental health in an upcoming issue of the Journal. For all enquiries, please email Jaclyn at journal@aieh.org.au.

Noise pollution is also a topic of interest in our current issue. Hansen and Neller explore the use of the Short Form-36 Health Survey as a tool for measuring residents' health and wellbeing in relation to traffic related air and noise pollution. Watts, Schluter and Whiting also briefly touch on the issue of noise pollution in their survey of public opinion of a proposed wind farm in New Zealand. This interesting paper highlights the need for scientifically robust methods for determining community attitudes on contentious environmental issues, especially around issues of community representation and majority opinion.

Kowal et al. present a paper highlighting the challenges faced when undertaking research in remote Indigenous communities. The paper is based on fieldwork experiences from the Housing Improvement and Child Health Study, and contributes to the improvement of research practice and quality in Indigenous Environmental Health.

An interesting article on occupational hygiene is presented in Cross' research on the results of biological monitoring during a vanadium catalyst change-out at the Murrin Murrin Operations in Western Australia. Cross uncovers an unusually high urinary vanadium level of creatinine, which is carcinogenic to humans and can lead to a variety of conditions including acute respiratory irritation, nervous depression, and cardiac palpitations. Cross puts forward an interesting theory on how the levels were so high in this individual, even though the monitored dust levels were below the occupation exposure standard.

Jalba, Rizak and Hrudey delve into the interpretation of drinking water monitoring data for environmental health professionals. The authors explore the results from a questionnaire in Western Canada, identifying a need for more effective monitoring strategies and appropriate responses towards detected contamination.

Nanbakhsh, Hamzehzadeh and Golizadeh also explore water contamination in the Shar Chai River in Iran. They investigate the levels of heavy metals present in the water during different seasons due to agricultural, urban, and industrial wastewater draining into the river. The authors refer to measures that need to be taken to protect the drinking water especially during the winter months.

I trust you will enjoy the current issue of *Environmental Health*. Remember, don't leave your research to gather dust - publish in the Journal and receive recognition for your hard work. Your support is appreciated.

Jim Smith
Editor

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Environmental Health University Education in Australia: Market Forces, Threats and Opportunities

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In the previous issue of *Environmental Health*, Bruce Morton authored an editorial discussing issues faced by the environmental health officer (EHO) workforce. One of the issues identified was a reported decrease in the number of students choosing to undertake university courses leading to a career as an EHO. Following from this, I wish to discuss some of the issues currently faced by the higher education sector in Australia, how these impact on environmental health education, and ultimately on the environmental health workforce and profession.

The Current Higher Education Landscape

Australian universities are under increasing financial pressures that have been brought about by government policy and factors associated with globalisation. These have resulted in decreased government funding on a per-capita basis; substantial growth in demand for university courses; an increasing diversity and competitiveness in the higher education sector; increased demand for performance and quality in higher education; and students demanding higher standards of service and flexibility due to an increasing contribution by them to their own education (Coaldrake 1999). Some statistics that back this up include: in 1996, federal government grants made up 57% of universities revenue and by 2003 this had dropped to 41% (O'Keefe 2005); over the same time period student numbers have increased by more than 30% (Department of Education, Science and Training [DEST] 2005a, b); and currently there are 38 public universities, the Australian Catholic University, three private universities, and over 100 non-university providers authorised to deliver higher education awards (DEST 2005c).

Such dramatic changes can be viewed in both positive and negative terms. For example, Jarvis (2001, p. 2) states that "change creates space that enables innovation and experimentation, and for those universities that are able to respond, there are exciting and challenging times ahead". However, Jarvis goes on to say that "whether the outcome will be a recognisable university is another matter". This view is shared by Drucker, a highly influential economist and management 'guru', who has argued that universities in their current form, and in particular research-focused universities, will disappear within a few decades because they are no longer relevant in the current and ever expanding knowledge-based economy (Altbach 2004). Drucker asserts that the new information technologies are the drivers for the rethinking, restructuring and rearrangement of education (Drucker 1997). These technologies have not only had an enormous impact on the way educational materials are delivered, but also on what is delivered and the settings through which education is undertaken (i.e. the home and workplace versus the university campus). This has therefore resulted in a change in relationship between academics and students, and is driving significant changes in the role of academics and the role of the institutions for which they work.

Drucker argues that for universities to keep up with demand from both students and industry, they will have to embrace distance education as their main form of delivery (Drucker 1997). This concept gained prominence in Australia when in the lead-up to the 2001 federal election, the Australian Labor Party (ALP) announced their 'Knowledge Nation' policy, of which the 'University of Australia OnLine' (UAO) was a major initiative. The UAO was to create 100,000 new online undergraduate places by 2010 and would enable students to "study in their own home, at their own pace and at a time that suits them" (ALP 2001). This policy was strongly supported by 'The Group of Eight' (a coalition of Australia's 'leading' universities) who stated that they recognised the UAO "as a commitment to harnessing the opportunities provided by new communications technologies to expand the educational opportunities and the skills base of our citizenry" (Group of Eight 2001).

In an attempt to 'innovate' as a way of responding to change, many universities have followed a 'commercialisation' pathway. Not surprisingly, a range of publications has been highly critical of this response (Baldwin 1997; Biggs & Davis 2002; Coady 2000; Davis undated; Hayes & Wynyard 2002). For example, the Senate report 'Universities in Crisis' noted that:

> *Public universities in Australia have been pulling away from traditional academic orientations and pushing towards stronger market influences to become entrepreneurial universities. The advent of the entrepreneurial or enterprise university has created significant tensions and conflict within these universities, particularly between those who embrace the development and those who see it as undermining the traditional role and function of public universities and their unique contribution to society* (Parliament of Australia 2001, p. 17).

Following from this, a recent issues paper released by the Australian Department of Education, Science and Training sought to stimulate debate on the future diversity of the higher education sector. This paper noted that "the boundary between public and private institutions is blurring as financial challenges drive some public universities to behave in a more entrepreneurial way characteristic of the private sector" (DEST 2005c). As a result of such dramatic changes, much of the popular literature on this topic uses emotive language such as 'crisis', 'disaster', and 'McDonaldization' to describe current trends, with a recent documentary on this issue titled 'The Degree Factories' (ABC 2005).

Overall, there is no debate on the fact that universities need to change as the world changes, and that universities have to respond to current government and market influences. We should, therefore, not be surprised if the future role and structure of universities is different from what we have experienced in the past. However, the crucial aspect on how universities respond relates to the basis on which these changes are being made. Are they founded purely in economic rationalism or is the wider role of universities in society appropriately acknowledged and supported (Biggs 2002)?

Current Environmental Health Issues in Higher Education

Unfortunately, tertiary education in environmental health (focused on training environmental health officers) is extremely vulnerable to the market forces that now drive the higher education sector. Virtually all courses across Australia are finding it difficult to attract enough students to make their courses viable and staffing levels are dropping. For QUT, a trend in decreasing numbers of applicants to its bachelor's degree and high running costs (compared with other programs) resulted in the course being discontinued from 2004. However, as a replacement, a Graduate Diploma was offered for the first time in 2005. This new program was designed to meet the current demand for graduates and fill a previously unmet niche market - people who hold another degree and who want to become EHOs.

Interestingly, the environmental health education and employment situation in the

UK has been surprisingly similar to what we are experiencing in Australia. For example, in 2002 it was reported that in the previous seven years there had been an 80% reduction in applications to environmental health courses, and between 2000 and 2002, "three environmental health courses have closed and all the remaining courses are struggling for numbers in an attempt to remain viable" (Statham 2002, p.310).

You may see some similarities with what is/has happened here from Harvey's (2001a) description of the changes that have occurred in the UK higher education system and their influence on environmental health education. He noted that polytechnics, which hosted most of the environmental health courses, were turned into universities; new arrangements for quality assurance were introduced; twice as many students are in higher education now than 20 years ago but the unit funding per student is about 40% less; student to staff ratios have increased from 8.5:1 to 20:1; and research which was not a significant issue for polytechnics has become the key performance measure of university quality. Harvey asserts that environmental health programs are not well placed to absorb these changes because they are comparatively expensive to run, due to small class sizes, laboratory activities, field trips, work placements for students and professional accreditation demands. Due to the vocational orientation of the environmental health curriculum, it requires more staff contact with students thereby increasing staff costs and reducing opportunities for staff to engage in research, which is now the main measure of achievement. This means that "environmental health as a university subject is vulnerable and its future is not guaranteed" (Harvey 2001a).

As the UK has already faced some of the higher education issues that are now starting to become a reality for us, it might be timely to review the way in which environmental health in the UK has responded to these changes. For example, Harvey (2001a, b) advocated that for environmental health courses to survive and develop, scholarly activity in both teaching and research is necessary. He cited as an example, that of the 50 environmental health academic staff in the UK in 2001, only 6 were considered to be research active (Harvey 2001b). One response to this has been from the Chartered Institute of Environmental Health (CIEH) in the UK, which has changed its accreditation process and core environmental health curriculum. This is an attempt to produce a more diverse environmental health workforce which includes alternative pathways into the profession (i.e. similar to the QUT Graduate Diploma). In addition, they are supporting different methods for course delivery and broadening the types of courses they will consider accrediting (Robinson 2005). In regard to the UK curriculum, it is now focused on life-long learning skills and building generic competencies, with the view to producing environmental health practitioners instead of environmental health officers (Lewis 2005).

Conclusion and Possible Actions

There is no doubt that the higher education landscape is changing and 'the good old days' will soon only be a distant memory. Universities have to change in response to changes in society, however, successive government policies in Australia and other countries (e.g. in the UK and the USA) have forced universities to become more commercialised in order to survive. The drive for commercialisation has resulted in widespread changes in the role of universities, the role of academics and their relationship with students, the way materials are delivered, and the number and types of students now enrolled. It is obvious that environmental health programs are not well placed to weather these changes, despite the enormity of the global environmental health issues faced by society. As such, the viability of these courses is under threat unless major changes are made in the delivery and operation of these courses or in their role in training the next generation of environmental health professionals. It is also obvious that the issues faced by universities have major implications for the environmental health workforce and the profession at large. I therefore offer the following possible actions as a way to 'turn the threats into opportunities'.

- Flexibility - the rapid technological advances, changes in student expectations and increasing demand by students and employers for flexibility in course offerings, are combining to force universities to review the types of courses provided and the way these courses are delivered. For environmental health, this will mean more integration of new technologies into the teaching programs and development of more flexible delivery methods that are of a high quality.

- Research - a substantial increase in environmental health research is needed to raise its profile both within the university setting and within the public arena. One of the main disadvantages of a professionally orientated degree, such as those designed to train EHOs, is that the graduates in general do not consider research as a viable career pathway. Therefore, soon-to-be or recent graduates should be encouraged and supported to undertake research. This can initially be in either a full time capacity (e.g. as an honours student, leading to a PhD), or in a part-time capacity (e.g. completing a research Masters degree while working as an EHO). In addition, many of the projects conducted in the workplace need to be designed with more methodological rigor and with a view to publishing the results. Overall, more emphasis needs to be placed on the value of environmental health research within universities and within the workplace.

- Curriculum - the curriculum for environmental health courses needs to be responsive to both industry and university needs. The current AIEH Course Accreditation Policy has been in draft form for a number of years now and so it has had little influence on university courses while they have been facing many internal pressures. As such, the AIEH Course Accreditation policy needs to be finalised as a matter of urgency and this should recognise both undergraduate and post-graduate entry pathways into the profession. The policy should also be reviewed regularly and any revisions made promptly.

- Support - in the past there seems to have been a view that the issues faced by universities were their problem and the profession did not involve itself with these issues. There now seems to be a new realisation of the critical role played by universities in the shaping of the profession and of the workforce. As such, the environmental health profession needs to be more active in supporting their local environmental health courses through providing student work experience placements, involvement on course advisory panels, and through involvement in teaching that provides 'real world' perspectives. Such involvement then sends a strong message to university administrators that the course is valued and supported by industry, which is vital when mounting arguments for the viability of the courses.

- Marketing - probably the key limiting factor for enrolments is the low profile of the environmental health profession. For students to choose to enrol in an environmental health course, they have to know that it exists and that it provides a fulfilling career. If you survey environmental health students, most say that they either stumbled across the course when looking for another course or they knew someone who was an EHO and this person encouraged them to do the course. It is rare for an enrolling student to say that they knew what an EHO was and really wanted to be one. It is therefore obvious that to increase the enrolment numbers to viable and sustainable levels, more needs to be done in raising the profile of the profession - such a task requires collaboration between the profession and the universities.

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Climate Change and Population Health in Australia: What Do We Know and What Can We Do?

Peng Bi

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Although extreme events, such as Hurricane Katrina in the Gulf of Mexico in 2005 or the Tsunami in the Pacific in 2004, have a low probability in our daily life, global climate change is happening around the world, including in Australia.

Australia will face some degree of climate change over the next 30 to 50 years irrespective of global or local efforts to reduce greenhouse emissions. The CSIRO has identified possible outcomes in Australia, including: i) an increase in annual national average temperatures of 0.4°-2.0°C by 2030 and of 1.0°-6.0°C by 2070; ii) more heatwaves, fewer frosts and severe weather events; iii) possibly more frequent El Nino Southern Oscillation events; iv) possible reductions in average rainfall and run-off in Southern and much of Eastern Australia with rainfall increases across much of the Tropical North; v) more severe wind speeds in cyclones; and vi) a change in ocean currents, possibly affecting our coastal waters (CSIRO 2004).

Of these possible results, the most likely are for temperature change, including heatwaves and reductions in frosts, sea level rises, and increases in cyclonic wind intensity. Such changes have made and will continue to make a significant impact on population health. Therefore, it is important for Australian governments, industrial and scientific organisations, and local communities to discuss and decide adaptation and mitigation strategies to deal with global climate change.

Although the Australian government has not signed the Kyoto Protocol, the Australian Greenhouse Office does set up various working plans and strategies to deal with, adapt and mitigate the consequences of climate change in different areas, including on population health. On the 28 July 2005, Australia has agreed, together with the United States, China, India, Japan, South Korea, to form the Asia-Pacific Partnership on Clean Development and Climate. This could be a significant step to deal with the impact of climate change in the region.

In terms of research, Australian scientists have conducted many studies on the relationship between climate variability and population health. In addition to the systematic assessment in *Human Health and Climate Change in Oceania: A Risk Assessment 2002* (McMichael et al. 2003), researchers have also conducted many specific works including changes in the distribution of vector-borne diseases, increased enteric infections, and variations in mortality and hospitalisation rates due to changes in weather conditions. Major findings indicated that climate variations had impacted on the transmission of vector-borne diseases such as Ross River virus infections, Barmah Forest virus infections, or dengue fever (Bi et al. 2000; Bi et al. 2001; Bi & Parton 2003; Hu et al. 2004; Lindsay et al. 1993; Tong et al. 1998; Tong et al. 2002; Tong et al. 2004; Tong et al. 2005; Woodruff et al. 2002), salmonellosis (D'Souza et al. 2004) and campylobacteriosis (Kovats et al. 2005), as well as hepatitis A (Hu et al. 2004). There was an association between climate variation and daily mortality. Most of these are historical analyses, using existing disease surveillance data sets. The main aims of such studies were to quantify the relationship between climate variation and disease transmission and then to set up a predictive model in each ecological region.

The above historic studies provided important information to government agencies, the scientific community and local councils to set up relevant mechanisms to adapt and mitigate the possible consequence to population health from climate change. But most of these studies were conducted in one region of Australia. More work could be done in other locations, for example, having a systematic assessment of climate change on major vector and food-borne diseases in various ecological regions, and different population settings.

Studying the effect of climate change in Australian rural and remote regions is extremely important due to the residents' unequal access to the healthcare system. Moreover, most Indigenous Australians live in remote regions, and they could be more vulnerable to global warming.

To generate sophisticated model-based estimates of the future (at 2030 and 2050) of climatic conditions in Australia by region will help to forecast future changes in climate variability and its impact on population health, such as the consequence of heatwaves, and spatial and seasonal changes of vector-borne and food-borne diseases. These health issues are of public health significance. Identifying vulnerable subgroups and regions, estimating their health risks, and promising adaptive strategies to reduce the negative health impacts of climate change will provide important policy suggestions.

Obviously, the prospective studies need input from government and from the local community. More funding from both federal and state governments through such bodies as the Australian Greenhouse Office, the NHMRC, the ARC, the State Office of Sustainability, State health departments, and relevant NGOs, is imperative.

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Use of the SF36 Health Survey to Compare the Health and Wellbeing of Residents Living along Roads with Different Levels of Commercial and Non-commercial Traffic

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Significant health effects have been associated with traffic-related air and noise pollution in urban areas. The primary aim of this cross sectional study was to assess the use of the Short Form-36 Health Survey (SF36), within a larger health questionnaire, as a tool for measuring residents' health and wellbeing in relation to commercial traffic density in Brisbane. Three levels of exposure were compared: i) low overall traffic density - control site, ii) high overall traffic density - with a low proportion of commercial vehicles, iii) high overall traffic density - with a high proportion of commercial vehicles. A total of 368 roadside residential houses were approached with 148 adult residents completing the health survey. When compared to residents in the 'low' traffic site, residents in the 'high' commercial traffic site were approximately three times more likely to have SF36 scores below the Australian norms for the scales of mental health and bodily pain, and two and a half times more likely for the social functioning scale, after adjusting for age, gender, income and smoking. Despite the limitations of the present study, it provides sufficient evidence to warrant the inclusion of the SF36 in future studies attempting to elucidate the nature of the health effects associated with traffic related pollution.

Key words: *SF36 Health Survey; Road Traffic; Health and Wellbeing; Annoyance*

Trends in the use of motor vehicles have continued to rise in the past decade along with the public health concerns related to increased road traffic density. The use of motor vehicles, particularly commercial vehicles, generates more air pollution than any other single human activity while noise from road traffic is responsible for an estimated 73% of environmental noise (Colls 1997; WHO 1999).

Studies that have compared the health of residents exposed to different levels of road traffic noise pollution have found that residents exposed to higher levels of traffic noise reported increased levels of depression, stress, anxiety, sleep disturbance, fatigue, headache, irritation, high blood pressure, annoyance, and cardiac reactivity (enHealth 2004; Hofman, Kumar & Tulen 1995; Ohrstrom 1991; Prasher 1998; Sato et al. 1999; Stansfeld et al. 1996; Yoshida et al. 1997). Research examining the health effects of road traffic air pollution has found increased prevalence of chronic respiratory symptoms (exacerbation of asthma symptoms, wheeze, bronchitis, allergic rhinitis) and decreased lung function among children living along roads with high traffic density and also within close proximity to main roads (Brunekreef et al. 1997; Ciccone et al. 1998; Oosterlee et al. 1996; Van Vliet et al. 1997; Venn et al. 2001; Weiland et al. 1994). Similar research has found that adults living near a main road have a higher risk of dyspnoea, cardiopulmonary mortality, and increased allergic sensitisation (Hoek et al. 2002; Oosterlee et al. 1996; Wyler et al. 2000).

The epidemiological studies cited above that have focused specifically on exposures to road traffic appear to consider the health effects of either air or noise pollution exposure alone without investigating their concomitant effects. Since air and noise pollution from traffic will always occur together and vary in levels according to a range of factors such as the proportion of commercial vehicles, it is likely that the health effects associated with exposure to traffic-related pollution are distinctive and should be examined using tools that can capture a broad range of health effects. Very few, if any, studies examining the health effects associated with road traffic density have employed a metric that incorporates the physical, mental and social dimensions of health.

The SF36 health-status questionnaire was developed as a generic psychometric measure of subjective health status that could be applied in a wide range of settings (Ware et al. 1993). The SF36 is a 36-item questionnaire that measures eight multi-item scales of health and wellbeing, namely - General health (GH), Physical functioning (PF), Role physical (RP), Bodily pain (BP), Vitality (VIT), Social functioning (SF), Role emotional (RE), and Mental health (MH). Administration and scoring of the SF36 produces a score between 0 - 100 for each of the eight scales in relation to the participant's self-reported health (a score closer to 100 indicates a better state of health and wellbeing). There are several methods of testing the reliability of health instruments such as the SF36 (e.g. test-restest, alternative forms and internal consistency reliability). These have been used to establish the reliability of the eight scales within the SF36 in numerous studies (Bensoussan et al. 2001; McCallum 1995; Sanson-Fisher & Perkins 1998; Scott et al. 1999).

Therefore, the primary aim of this study was to explore the utility of incorporating the SF36 Health Survey within a larger questionnaire to examine the health effects associated with exposure to traffic-related air and noise pollution.

Methods

Study design

Given the primary aim of this study, a cross-sectional survey was conducted in 2002 to compare the self-reported health status of people living along residential roads in Brisbane with differing levels of commercial and non-commercial traffic density. Three levels were compared: i) low overall traffic density - control site, ii) high overall traffic density - with a low proportion of commercial vehicles, iii) high overall traffic density - with a high proportion of commercial vehicles. Based on their relative proportions of commercial traffic, these sites will hereafter be referred to as 'low', 'medium', and 'high' commercial traffic sites respectively. Selection of the potential study sites was based on annual-average-daily-traffic (AADT) counts from the Queensland Department of Main Roads traffic census (Queensland Government 2002). Within each level, a number of roads with predominantly residential housing were selected as potential study sites. One road from each level was then chosen based on matching the three sites as closely as possible on demographic census data available. In order to maximise the sample size, all adult residents (sampling units) in every house along each of these three roads were considered a potential participant in the study.

Questionnaire design and administration

The questionnaire included the SF36 in its entirety, which was followed by questions related to several themes. These were self-reported respiratory symptoms, levels of annoyance towards air and noise pollution from road traffic, perceived health risks associated with air pollution, and general lifestyle and demographic attributes. These questions were derived from a variety of validated instruments (Asher et al. 1995; enHealth 2000; European Commission 1993). Piloting of the questionnaire was conducted with 62 residents living adjacent to a busy road outside the study area. Adult occupants of every residential home along the designated roads were approached and provided with information sheets, consent forms, and the appropriate number of questionnaires per household. While there were no explicit exclusion criteria, homes were not approached if aggressive pets prevented access to the residents. If residents were not at home two follow-up visits were made in an effort to maximise participation rates. Participants were asked to complete the questionnaires and leave them at their front door or in their letterbox for collection two days later.

In summary, the questionnaire used in this study incorporated a generic health status instrument (SF36) as well as a range of self-reported symptoms and a series of quantitative measures of impact on health and wellbeing. Ideally, in a larger, more holistic study, this cross-sectional survey approach would have been complemented by qualitative data, collected through focus groups or interviews, on the nature of the impacts of the traffic and potential mediating factors. However, time and resource constraints limited this study to addressing the primary research aim of exploring the utility of incorporating the SF36 Health Survey within a larger health questionnaire.

Data analysis

One of the aims of the analysis was to compare the health status of residents across the three study sites. As measures of self reported health status, the mean SF36 scale scores for residents in each study site were compared with the Australian norms (ABS 1995). Logistic regression was then used to calculate prevalence odds ratios for an outcome of having a 'below average' SF36 score (dichotomisation based on the Australian norms) in relation to living along roads of varying traffic density, particularly in relation to commercial vehicles. Self reported respiratory symptoms were also examined using logistic regression. The low traffic density site was used as the reference category and adjustments were made for age, gender, household income, smoking status, and length of residency. The Kruskal-Wallis test was used to examine differences in the annoyance levels across the three sites. Spearman rank correlation coefficients were calculated between the SF36 scores and levels of annoyance towards air and noise traffic related pollution. The Cronbach alpha coefficient was used to estimate the internal consistency reliability of the SF36 scales. All analyses were performed using SAS version 8.2 (SAS Institute Inc., Cary, NC, USA).

Results

Table 1 shows selected characteristics of the three study sites. A total of 368 roadside residential houses were approached along the three roads resulting in a total of 344 questionnaires handed out. Overall, 45% of the questionnaires handed out were returned with signed consent forms. The percentage of commercial vehicles for the 'high' and 'medium' sites were 47%, and 21.5%, respectively, while the 'low' site had too few commercial vehicles to report.

Residents from the 'high' commercial traffic site reported a slightly higher percentage of respiratory symptoms such as asthma, wheeze, allergies, shortness of breath and tightness in the chest than residents from the other two locations. However, the numbers of participants reporting these health symptoms were low overall and the odds ratios were not significant.

The Cronbach alpha values were between 0.81 and 0.87 for all eight SF36 scales. Inspection of the plots shown in Figure 1 shows that the mean and upper confidence limits of the MH, SF, BP, GH, and VIT scales were well below their corresponding Australian norms for residents in the 'high' commercial traffic site. As shown in Table 2, residents in the 'high' commercial traffic site were approximately three times more likely

Table 1: Selected characteristics of the three study sites

Selected Characteristics	High commercial traffic site n (%)	Medium commercial traffic site n (%)	Low overall traffic site n (%)	Total n (%)
Traffic Density/24hr (AADT)[a]				
Non commercial vehicles	18, 571 (53)	21, 019 (78.5)	1, 475	n/a
Commercial vehicles	16, 467 (47)	5, 756 (21.5)	n/a	
TOTAL	35, 038	26, 775	1, 475	
Houses approached	131	110	127	368
Questionnaires handed out	129	93	122	344
Questionnaires returned (With consent)	42	46	60	154
Net response rate (%)[b]	33	49	49	45
Total Participants	42	46	60	148
Gender				
Male	18 (43)	20 (43.5)	33 (55)	71 (48)
Female	24 (57)	26 (56.5)	27 (45)	77 (52)
Age				
18-24 years of age	4 (9)	8 (17)	9 (15)	21 (14)
25-34 years of age	7 (17)	14 (30)	5 (8)	26 (18)
35-44 years of age	12 (29)	7 (15)	11 (18)	30 (20)
45-54 years of age	5 (12)	8 (17)	11 (18)	24 (16)
55-64 years of age	8 (19)	5 (11)	11 (18)	24 (16)
65 years and over	6 (14)	4 (9)	13 (22)	23 (15)
Household income				
$0 - $20,000	15 (42)	8 (19)	17 (29)	40 (29)
$20,001 - $40,000	10 (28)	16 (37)	10 (17)	36 (26)
$40,001 - $60,000	10 (28)	10 (23)	11 (19)	31 (23)
$60,001 and over	1 (3)	9 (21)	20 (34)	30 (22)
(Note: there were missing data)				
Employment status				
Employed	21 (50)	31 (67)	29 (48)	81 (55)
Unemployed	14 (33)	10 (22)	15 (25)	39 (26)
Student/Retired/House person	7 (17)	5 (11)	16 (27)	28 (19)
Smoking status				
Yes	8 (19)	10 (22)	11(18)	29 (20)
No	34 (81)	36 (78)	49 (82)	119 (80)
Length of residency				
Up to 1 year	7 (17)	14 (30)	10 (17)	31 (21)
1 to 2 years	5 (12)	4 (9)	4 (7)	13 (9)
2 to 5 years	9 (21)	6 (13)	7 (12)	22 (15)
More than 5 years	21 (50)	22 (48)	39 (65)	82 (55)

a - AADT = Annual average daily traffic

b - Numerator = questionnaires handed out, denominator = questionnaires returned with consent

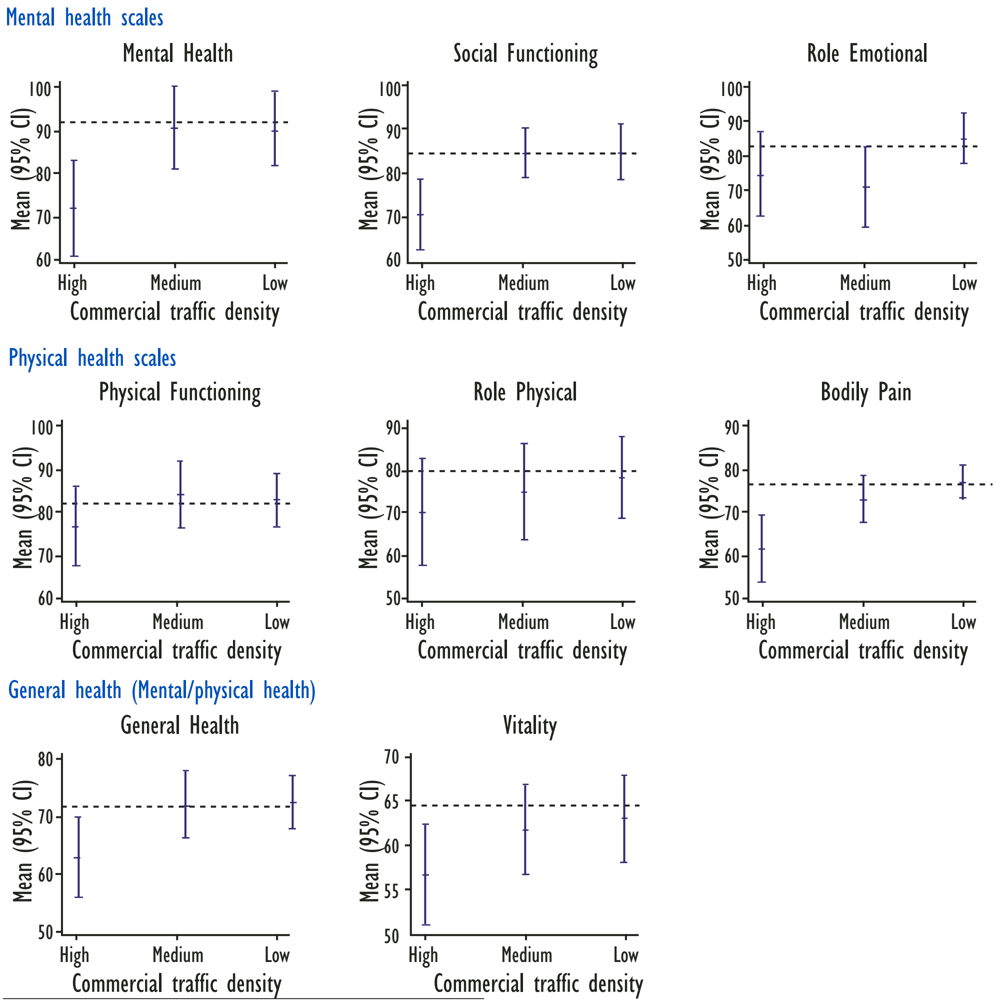
to have SF36 scores below the Australian norms for the scales of MH and BP (Odds ratio (OR) = 3.04, 95% CI 1.14 - 8.16; OR = 3.25, 95% CI 1.23 - 8.57 respectively), and two and a half times more likely for the SF scale (OR = 2.64, 95% CI 1.04 - 6.68) relative to residents in the 'low' traffic site, after adjusting for age, gender, income, smoking. After adjusting the model for length of residency, these results persisted for

Table 2: Odds ratios (95% CI) for SF36 scores below the Australian norm comparing the high and medium commercial traffic sites to the overall low traffic site (reference group)

	High commercial traffic site	Medium commercial traffic site	Low (overall) traffic site
Mental health			
Mental Health (MH)	**3.04 (1.14 - 8.16)***	0.68 (0.28 - 1.68)	1.00
Social Functioning (SF)	**2.64 (1.04 - 6.68)***	1.42 (0.59 - 3.41)	1.00
Role Emotional (RE)	1.01 (0.39 - 2.62)	1.31 (0.54 - 3.22)	1.00
Physical health			
Physical Functioning (PF)	1.75 (0.52 - 5.88)	1.20 (0.36 - 4.01)	1.00
Role Physical (RP)	1.70 (0.66 - 4.39)	1.33 (0.54 - 3.29)	1.00
Bodily Pain (BP)	**3.25 (1.23 - 8.57)***	1.64 (0.67 - 4.02)	1.00
Mental/Physical health			
General Health (GH)	1.72 (0.65 - 4.57)	0.73 (0.29 - 1.86)	1.00
Vitality (VIT)	1.58 (0.62 - 4.04)	1.05 (0.43 - 2.52)	1.00

Figures in bold indicate significant results p value < 0.05. Adjusted for Age, gender, income, and smoking.*

Figure 1: Mean (95% CI) scores for each SF36 scale across the three study sites with the Australian norm as a reference line (-----)



the MH and BP scales, whereas the result for the SF scale was not significant (OR = 2.59, 95% CI 0.96 - 6.99). The odds of having an SF36 below the Australian norms for residents in the 'medium' commercial traffic site compared to the residents in the 'low' traffic site were not significant for all SF36 scales.

Table 3: Spearman correlation coefficients between levels of annoyance and SF36 scales

Annoyance levels	Mental health scales			Physical health scales			Mental/Physical health scales	
	MH	SF	RE	PF	RP	BP	GH	VIT
Air pollution	- 0.236 **	- 0.244 **	- 0.159 *	- 0.164 *	- 0.075	- 0.268 **	- 0.155	- 0.136
Noise pollution	- 0.206 *	- 0.202 *	- 0.203 *	- 0.075	- 0.026	- 0.235 *	- 0.146	- 0.026

*Figures in bold indicate significant results * p value < 0.05. ** p value < 0.01..*

Figure 2: Level of annoyance towards traffic related air pollution across high, medium, low commercial traffic sites (1 = not annoyed; 10 = extremely annoyed)

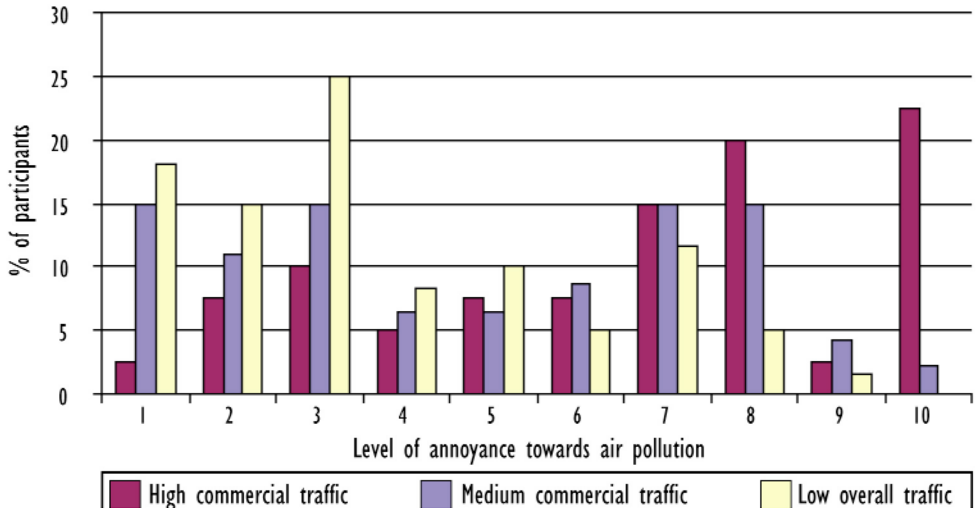
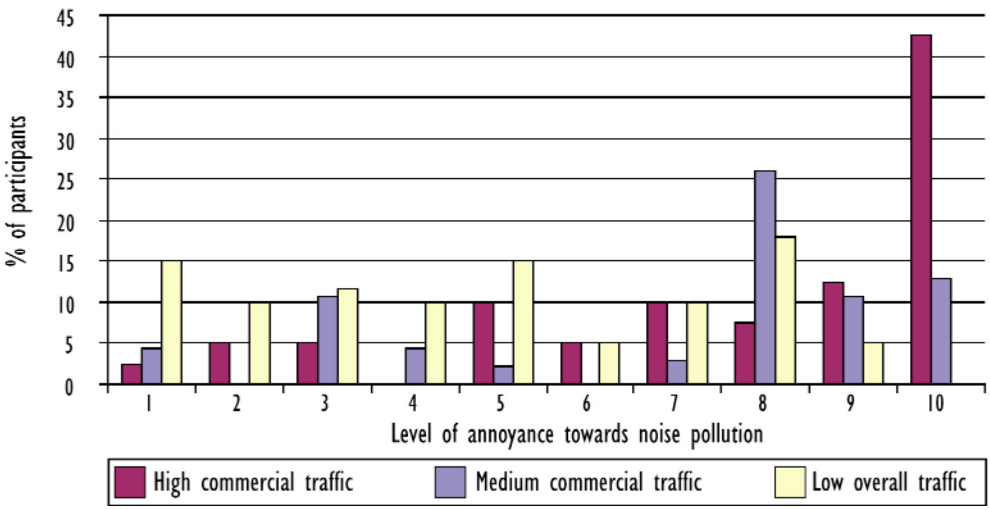


Figure 3: Level of annoyance towards traffic related noise pollution across high, medium, low commercial traffic sites. (1 = not annoyed; 10 = extremely annoyed)



Levels of annoyance were reported on a scale from 1-10 with 10 being extremely annoyed. Figures 2 and 3 show the annoyance levels towards traffic air and noise pollution within the three sites respectively. The annoyance levels towards both air and noise pollution were significantly different across the three sites. For air pollution the median annoyance levels were 3.0, 5.0, and 7.0 for the 'low', 'medium', and 'high' commercial traffic sites respectively; and 5.0, 7.5, and 9.0, respectively for noise pollution. Table 3 shows the correlation coefficients between the levels of annoyance towards air and noise pollution and the SF36 scores for each scale. There were significant but weak negative correlations between the annoyance levels and the MH, SF, BP and RE SF36 scales.

Discussion

The fundamental aim of this study was to compare the health and wellbeing of residents living along roads of different commercial traffic density. To the authors' knowledge, no published research has reported on the use of the SF36 to examine people's health and wellbeing in relation to residential exposure to traffic density.

Residents from the 'high' commercial traffic site were more likely to have an SF36 score below the Australian norm for the scales of MH, SF, and BP compared to residents from the 'low' traffic site. To place this in context, the lowest possible score for the three scales of the SF36 can be interpreted as having 'feelings of nervousness and depression all of the time', 'extreme and frequent interference with normal social activities due to physical or emotional problems', and 'very severe and limiting pain' respectively (Ware et al. 1993). Based on this interpretation, it could be argued that residents living along roads of high commercial traffic density have an increased risk of experiencing varying degrees of nervousness and depression, interference with social activities, and limiting pain, more so than residents living along roads of low traffic density.

These interpretations are consistent with several studies that found associations between exposure to chronic noise (including road traffic noise) and depression (Ohrstrom 1991), anxiety, increased stress (Stansfeld et al. 1996), sleep disturbance, fatigue, headache, irritation (Yoshida et al. 1997), and high blood pressure (Evans, Bullinger & Hygge 1998). Further, different levels of exposure to traffic density and traffic noise have also been linked to different forms of social behaviour. A study by Appleyard and Lintell (1972) found that there was more social interaction among people living along streets of low traffic density than high traffic density. It has also been reported that exposure to traffic noise can alter the physiological processes pertaining to the cardiovascular, endocrine, respiratory, and digestive systems within the human body and these physiological changes consist of responses typically associated with psychological stress reactions (Cohen & Weinstein 1981).

While no direct monitoring of noise levels at the three sites was possible within the present study (commercial traffic density was used a proxy measure), a commissioned government report indicated that the noise levels at two intersections within the 'high' commercial traffic site ranged between 69 and 75 dBA (Queensland Government 2003). Noise at these levels has been associated with interference in speech communication and intelligibility, increased annoyance, ischaemic heart disease, and hypertension (enHealth 2004; WHO 1999). Also reported were issues raised at community meetings by residents in the vicinity of the 'high' commercial traffic site and these included '...sleep deprivation, stress, tension, reduced social contact, and having to keep windows and doors shut' (Queensland Government 2003). Similarly, complaints in relation to traffic related air pollution were highlighted at the community meetings, specifically problems due to '...dust, soot, smoke, fumes, and particulates' (Queensland Government 2003). It is noteworthy that in the present study, residents across all sites were more annoyed with noise pollution from road traffic (median = 7.0) than with air pollution from road traffic (median = 5.0). Despite the large difference in the overall volume of traffic between the 'low' traffic site and the 'medium' commercial traffic site, the SF36 scores for residents from these sites were similar for most scales. This indicates that the type of road traffic (e.g. non-commercial or commercial) might be a stronger predictor of diminished health status than the overall volume of traffic.

With regard to assessing whether residents of the 'high' and 'medium' commercial traffic sites had SF36 scores below the Australian norms compared to residents of the 'low' traffic site, no significant results were found for the SF36 scales of PF, RP, RE, VIT, and GH. Several possible explanations for these results can be postulated. First, it is possible that these SF36 scales are simply not sensitive or specific enough to detect health effects associated with traffic related pollution. Second, higher differentials of exposure or a larger sample size might be required to obtain significant results for these scales.

By design, the differences in self-reported health status across the three sites are assumed to be associated with the combined effects of air and noise pollution generated by commercial traffic. However, a range of other factors could confound the observed differences in self-reported health status. These include, sensitivity to noise, actual levels of personal exposure, compensatory features of the dwellings (e.g. insulation, air conditioning), socio-economic status, and possible exaggeration of adverse health conditions. With regard to the latter, research has shown that once adverse health effects have been associated with high levels of exposure to traffic related noise pollution, residents do not always report improvements in their health status following significant reductions in exposure (Gomez-Jacinto & Moral-Toranzo 1999).

The main limitation of this study was the small sample size, which may have reduced the power of the study to detect real differences in relation to the respiratory symptoms and possibly, the SF36 physical health component scales. Due to limited resources, only two levels of higher road traffic exposure were assessed in relation to the low road traffic exposure.

Conclusion

Assessing the health effects associated with exposure to road traffic is a difficult task as both the exposure assessment and quantification of associated health effects are complex and often multi-factorial. This study showed that residents living along a road with high commercial traffic density had an increased risk of having a score below the Australian norm for the SF36 scales of MH, SF, and BP when compared to residents living along a low traffic density road. These differences were found despite the small sample size, demonstrating reasonable sensitivity of the SF36 as a measuring instrument for assessing the health impacts of traffic related pollution. Further, the results were consistent with previous research showing that exposure to road traffic noise is associated with various adverse mental and social health effects. It is not clear, however, to what extent this reflects the health effects of exposure to noise or air pollution or their combined effects.

For the aim of evaluating the utility of the SF36 in traffic-related health research, the different SF36 scales need to be calibrated against a range of specific disease/health outcomes associated with well defined environmental exposures. Further studies would also benefit from objective measures of air and noise pollution levels and objective measures of health status (e.g.

clinical assessments, biomarkers) to complement the self-reported and surrogate data. Also, several levels of exposure to overall traffic density and commercial traffic density, with replication, would provide more conclusive results. Qualitative methodologies could also be incorporated in a broader study examining the health impacts of traffic-related pollution. For example, it would be of interest to explore factors that may mediate the adverse effects found in this and other studies. Despite the limitations of the present study, it provides sufficient evidence to warrant the inclusion of the SF36 in future studies attempting to elucidate the nature of the health effects associated with traffic related pollution.

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Dust and Biological Monitoring During a Vanadium Catalyst Change-out: Is it the Dust Levels or the Hand to Mouth Contact?

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Biological monitoring was conducted on personnel performing the catalyst change-out task during a plant maintenance shutdown. One of the catalyst change-out crew returned a urinary vanadium level of 180 µg/g creatinine. Dust levels monitored over the duration of the catalyst change-out for this individual were below the occupational exposure standards. This individual was a smoker, which might indicate that his route of exposure was ingestion caused by hand to mouth contact. This would explain why his urine level was high while the dust levels monitored for him throughout the catalyst removal were below the occupation exposure standard. The catalyst contains a vanadium salt complex, crystalline silica and diamataceous earth (Monsanto Company MSDS 2002). The most likely initial health effects for this combination of materials if respiratory protection is not worn would be acute respiratory irritation that might lead to lead to bronchitis. Crystalline silica a component of the catalyst has been classified as 'carcinogenic to humans' (International Agency for Research on Cancer [IARC] 1997) and therefore prolonged exposure to excessive catalyst dust might cause lung cancer. The effects of vanadium include respiratory irritation, skin irritation, eye irritation, gastrointestinal discomfort, nausea, and vomiting, hepatotoxicity, fatty change, anaemia, nervous depression, cardiac palpitations, nephrotoxicity. The classic disorder from vanadium exposure is a greenish discolouration of the tongue, which was not observed in this case. To prevent permanent ill health it is imperative that compliance with good personal hygiene and washing the hands and face prior to eating, drinking and smoking is strictly adhered to.

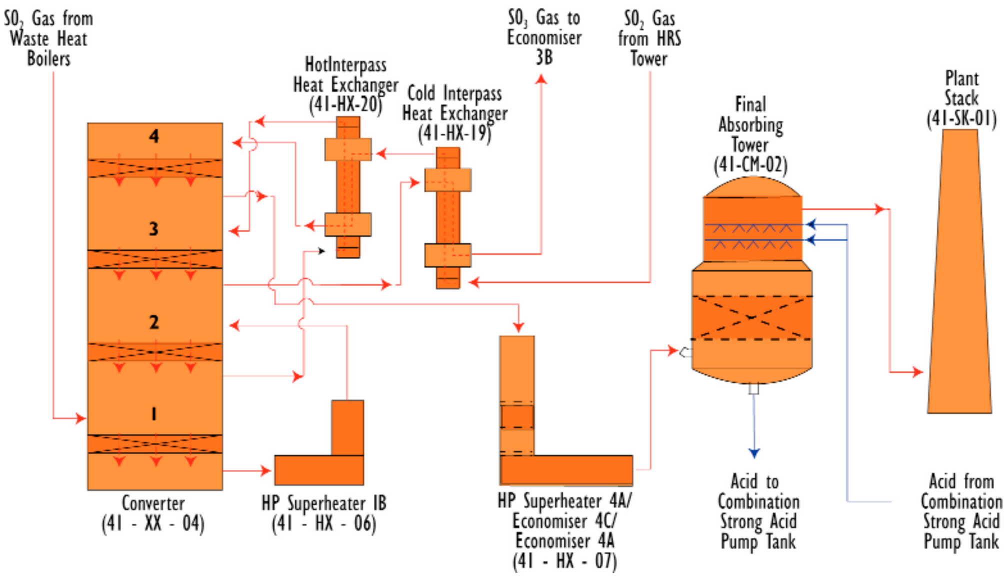
Key words: *Dust; Biological Monitoring; Vanadium; Mining; Catalyst Converter*

Biological monitoring was conducted on personnel performing the catalyst change-out task during a plant maintenance shutdown. One of the catalyst change-out crew returned a urinary vanadium level of 180 µg/g creatinine. Dust levels monitored over the duration of the catalyst change-out for this individual were below the occupational exposure standards. This individual was a smoker, which might indicate that his route of exposure was ingestion caused by hand to mouth contact. This would explain why his urine level was high while the dust levels monitored for him throughout the catalyst removal were below the occupation exposure standard. The catalyst contains a vanadium salt complex, crystalline silica and diatomaceous earth (Monsanto Company MSDS 2002). The most likely initial health effects for this combination of materials if respiratory protection is not worn would be acute respiratory irritation that might lead to bronchitis. Crystalline silica a component of the catalyst has been classified as 'carcinogenic to humans' (International Agency for Research on Cancer [IARC] 1997) and therefore prolonged exposure to excessive catalyst dust might cause lung cancer. The effects of vanadium include respiratory irritation, skin irritation, eye irritation, gastrointestinal discomfort, nausea, and vomiting, hepatotoxicity, fatty change, anaemia, nervous depression, cardiac palpitations, nephrotoxicity (Klaassen 2001; Rumack 2005; Sullivan & Krieger 1992). The classic disorder from vanadium exposure is a greenish discolouration of the tongue, which was not observed in this case. To prevent permanent ill health it is imperative that compliance with good personal hygiene and washing the hands and face prior to eating, drinking and smoking is strictly adhered to.

The Minara Resources, Murrin Murrin Operation, near Leonora in Western Australia utilises sulphuric acid in its high temperature, high pressure autoclave vessels to leach out nickel and cobalt from Lateritic ore. Sulphuric acid is produced by the Utilities Department at the Murrin Murrin Operation. Sulphuric acid catalyst is used to catalyse SO_2 into sulphuric acid (Process diagram, SO_2 Conversion to H_2SO_4, Figure 1). The sulphuric acid catalyst has a finite life and therefore was replenished during the regular planned process plant shutdown.

The task involved unloading, screening, handling, and reloading of the catalyst and quartz in the Acid Plant Converter, passes (beds) one and two. Specialists in catalyst handling were commissioned to undertake this work. The spent catalyst and quartz layers within the catalyst converter were sucked and removed through an enclosed vacuum system. A vacuum truck created the vacuum through twin cyclones that provided suction through a hose placed inside the converter which unloaded and screened the spent catalyst into twin silos and through a vibrating screening plant. The 20 000 CFM pneumatic dust collector was used for cleaning the catalyst as well as eliminating dust emission. The screened catalyst was collected in 'bulka' bags beneath the screening plant and waste dust into a collection drum for disposal. The screened catalyst in the 'bulka bags' was reloaded into a hopper using a two tonne forklift. A crane then slewed the reloading hopper to deposit screened catalyst on to the chute of a covered conveyor belt that transported it back into catalyst converter. The final stage for the operators inside the converter was to manually layer the quartz

Figure 1: SO_2 Conversions to H_2S0_4



stones and the catalyst at prescribed heights pre-marked on the converter walls. The potential occupational health issues studied during this process were:

- inhalation of the catalyst dust and crystalline silica
- ingestion of the catalyst, and
- heat stress

Methodology

Heat stress

The catalyst change-out was deliberately scheduled for a cooler period of the year for Western Australia to minimise the possibility of heat stress. By allowing sufficient cooling time, and monitoring with a 'QUESTemp 34 Thermal Environment Monitor' (Quest Technologies USA) heat stress was considered not to be an issue and the heat stress protocol was not required. Nonetheless personnel were constantly observed for heat stress symptoms on the first day.

Atmospheric monitoring for respirable dust

Atmospheric monitoring for respirable dust, vanadium salts and silica dust was conducted throughout the various stages of the whole catalyst change-out. Respirable Dust was sampled according to AS/NZS 2985-1987 - Workplace Atmospheres - Method for sampling and gravimetric determination of respirable dust (AS/NZ 2985 - 1987). The respirable dust collected on the filters from each individual sample was sent to MPL, a National Association of Testing Authorities Australia (NATA) approved laboratory, and analysed for vanadium. This was analysed in accordance with the microwave digest of filter for metal analysis: NIOSH 7300, USEPA 3051, MPL WILAB 6, 8, and 17. Quartz dust was determined in accordance with WILAB 17, Alpha 3120 Respirable dust: AS 2985 (2004) alpha Quartz by IR: NIOSH 7602, NIOSH 7603 (silica in coalmine dust), MPL WILAB 4 (MPL 2005)

Biological monitoring

Pre and post-task urine analysis for vanadium was carried out for the catalyst change-out personnel. Urine samples were provided prior to commencing any catalyst work and subsequently analysed. On the penultimate and the final day of the catalyst change-out personnel provided urine samples for vanadium analysis. Ensuring all personnel exited the working area removed their disposable coveralls and washed prior to providing a urine sample for analysis eliminated the chance of possible contamination.

Urine samples were sent to MPL for analysis in accordance with WILAB 8 Urine digest: MPL in house method: WILAB 8 Creatinine in urine by UV/Vis: metals by AAS/ICP and in-house method: WILAB 8 ICP general equipment (MPL 2005).

Results

Heat stress

The Wet Bulb Globe Temperature (WBGT) measure was 22.1°C on entry and a maximum of 23.1°C during a 5.5-hour monitoring period. The catalyst change-out crew was constantly observed for this initial period until it was determined that heat stress was not an issue.

Atmospheric monitoring

Respirable dust

There were 5 out of 55 dust samples that reached or exceeded the 8-hour Time Weighted Average (TWA) occupational exposure standard (OES) of 5mg/m^3 for respirable dust (National Occupational Health and Safety Commission [NOHSC] 1003 1995). (Figure 2).

Silica dust

On analysis of the respirable dust for silica there were 9 out of 55 samples that reached or exceeded the 8 hour TWA OES of 0.1 mg/m^3 (NOHSC 2004). (Figure 3).

Figure 2: Respirable Dust Results, Catalyst Change-out

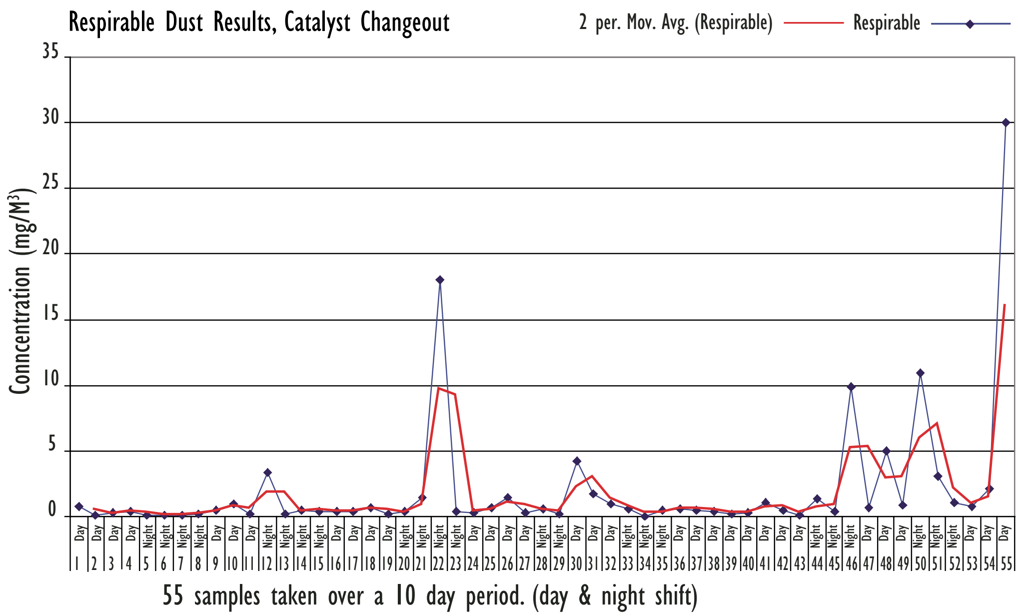
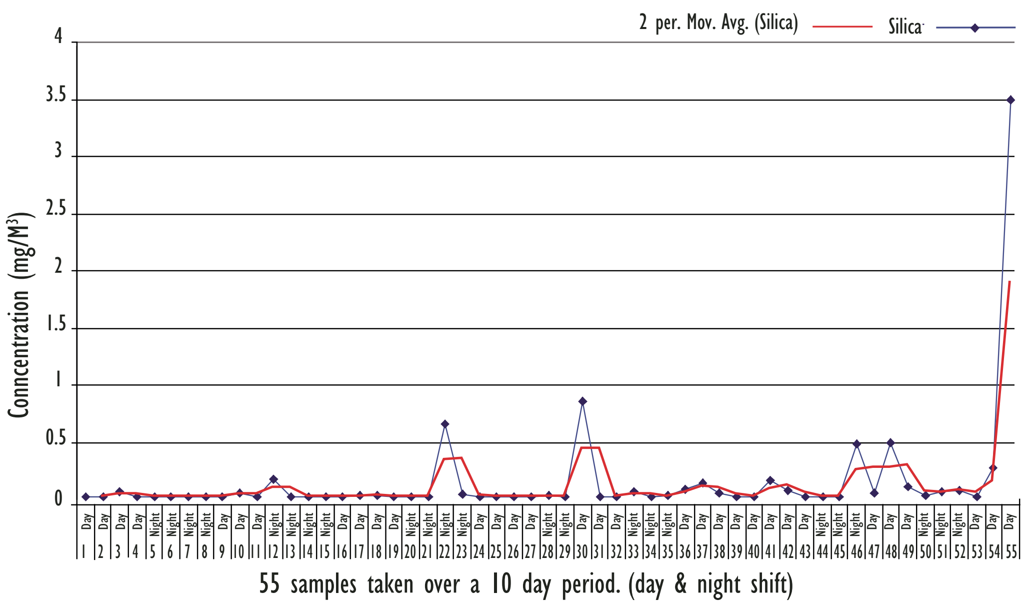


Figure 3: Silica (Si) Dust Results, Catalyst Change-out



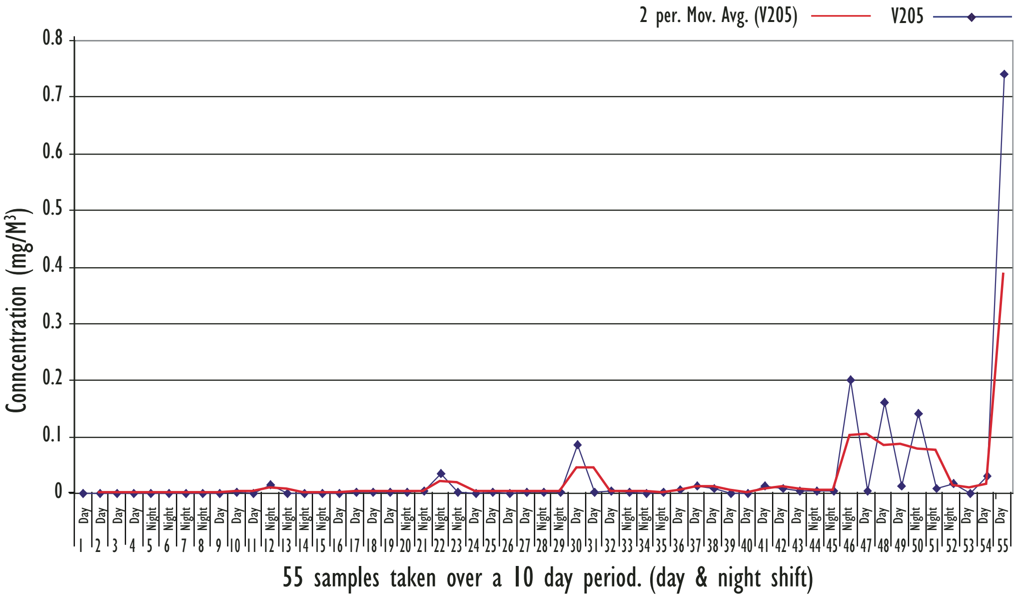
Vanadium

On analysis of the respirable dust for vanadium there were 5 out of 55 samples that reached or exceeded the 8-hour TWA OES of 0.05 mg/m^3 (NOHSC 1003 1995).(Figure 4).

Respirable, silica and vanadium dust in combination in a single sample

There were 4 out of 55 samples that reached or exceeded the 8-hour TWA OESs for all three parameters in an individual sample simultaneously.

Figure 4: Vanadium Pentoxide (V2O5) Dust Results Catalyst Change-sout



Elevated dust levels were associated with the catalyst screening process, and the final stage of the change-out process associated with the final loading of the catalyst in bed 2. Some manual screening was necessary as the screen became blocked at one stage due to oversized quartz stones. Potential exposures to dust were greatest at the later stage when the replenished catalyst is conveyed back into the converter bed where eventually the catalyst needed to be levelled out manually.

Biological monitoring (Vanadium Urine Analysis)

Vanadium urine analysis was conducted for 25 personnel prior to commencement of the catalyst change-out task. This workgroup had recently finished a catalyst change-out in a similar local industry, completed three days earlier. All levels were less than 1 µg/g creatinine.

At the end of the task the vanadium levels in urine samples of 20 personnel from the same workgroup, taken on the penultimate and final day of the change-out, ranged from less than 1 µg/g creatinine to180 µg/g creatinine (mean of less than 22.5µg/g creatinine). One person exceeded the biological exposure indices (BEI - ACGIH 2004) of 50 µg/g. The vanadium urine levels for the personnel with the elevated vanadium dust levels (shown in Figure 3 Appendix B) did not exceed the BEI.

Discussion

The task took 10 days to complete excluding set-up and demobilising, although the task was not limited to 10 days. Regular task observations were conducted over this period. Personal protective equipment compliance was good, the dust extraction system was excellent, and the documented work procedures were followed. The protocol required that contaminated coveralls were disposed of at the end of shift and at breaks. Wash-down facilities were available and appeared to be used by personnel throughout this task at break times and at the end of the shift.

The automated screening process was enclosed in a dust free vacuum system. The dust levels were lowest during the extraction of the spent catalyst using the suction of an enclosed vacuum system. The dust levels were elevated where the screened material was delivered from the automated process into the collection drums (data points 12, 22, and 30 on the graphs below). At one stage in this process some of the quartz (pebbles) were too large to fit through the screen and were removed from the enclosed system to be screened by hand. This manual task, screening of the quartz/vanadium powder combination, was limited to three people. They wore adequate personal protective equipment including coveralls, gloves, and a full-face respirator. The dust levels were high for this task, and they were covered from head to foot with vanadium dust (data points 46, 48, and 50 on the graphs below). Despite this their urinary levels did not exceed 50 µg/g creatinine. The person with the high urinary vanadium level did not conduct the screening task by hand.

The dust levels were also elevated during reloading of the screened catalyst inside the converter. At this final stage of replenishing bed 2 inside the converter fresh catalyst was reintroduced into the converter by conveyor and levelled out manually. The highest dust level was recorded during this procedure (data point 55 in the figures).

The vanadium urine levels for the personnel with the elevated dust levels during screening and the levelling out of the catalyst in bed 2 did not exceed the BEI. This would indicate that their respiratory protective equipment was effective and their decontamination was successful.

All personnel entering the confined space within the catalyst converter wore a full-face respirator with a combination ABEK1 and P3 filter (AS/NZS 1715 1994) consistently. The remainder wore a half face respirator within two meters of the screening process, and in the storage area of new and spent catalyst which was contained within a marquee close to the converter. The full-face respiratory protective equipment would have provided a protection factor of up to 100 (AS/NZS 1715 1994), which if worn correctly would have effectively reduced the respirable dust levels to acceptable levels.

On completion of the catalyst change-out task there were 14 of the 20 change-out personnel with detectable urinary vanadium levels; two below the level of detection, 13 below the BEI and one exceeding the BEI at 180 µg/g creatinine. This individual recorded respirable dust, vanadium and silica below their respective occupational exposure standards and the elevated dust levels were considered not to be directly associated with the increased vanadium urine. This person was a smoker. A follow up vanadium urine analysis was conducted and his level returned to normal (<1 µg/g creatinine). According to Kiviluoto (1981) most vanadium is excreted in the urine after one day, whilst Heinemann et al. (2003) reported 52% excretion in urine at 12 days after exposure had ended.

It was observed that these workers most often removed their (thick leather 'Riggers') gloves prior to removing their respirators and therefore would inadvertently contaminate their hands. The majority of personnel were seen to wash their hands before breaks, although a full compliance check was not conducted. Most of these workers remained in their coveralls at break times other than meal times. Several members of the workgroup smoked at break times, including the individual with the high urinary vanadium. If this person did not wash his hands at break times he might have ingested vanadium dust as he smoked or when he ate. This is considered the most likely scenario.

Another possibility is that he inadvertently contaminated his sample jar with vanadium dust, which is a possible limitation of the biological monitoring data. It cannot be ascertained that there was no contamination of the sample jar. It is possible that the individual had vanadium dust on his hands, and dust from his hands entered the sample jar. The author has evidence of this for similar sampling conducted for urinary nickel of Refinery personnel at this site.

As part of the protocol the catalyst removal workgroup were requested to ensure they removed contaminated clothing and washed their hands before providing a urine sample. It was suggested that they provided a sample on the final morning after returning to their accommodation and showering. The majority did this. A few including the individual with the high urinary vanadium provided a sample on the final day. To go to the toilet facilities close by he would have to have removed his personal protective clothing to exit the restricted work area, thus reducing the chance of contaminating the sample jar. However, he might not have washed his hands and dust from his hands might have entered the sample jar.

Conclusion

Biological monitoring was conducted on personnel performing the catalyst change-out task during a plant maintenance shutdown. One of the catalyst change-out crew returned a urinary vanadium level of 180 µg/g creatinine. Vanadium dust levels monitored over the duration of the catalyst change-out for this individual were below the occupational exposure standard. This individual was a smoker, which might indicate that his route of exposure was ingestion caused by hand to mouth contact. This would explain why his urine level was high whilst the dust levels monitored for him were below the occupation exposure standard.

The main target organ for vanadium and silica, the components of the catalyst, is the respiratory system. There are, however, a number of other toxicological effects which may be elicited through ingestion of vanadium due to hand to mouth contact.

The primary focus for protecting this group of catalyst change-out personnel was predominantly dust containment with respiratory protection as a back up. The vacuum system and dust collector linked to the vibrating screening process was efficient. However, exposure was possible at the collection point where the screened material was delivered into drums.

Certainly, manual screening by hand posed a significant risk, and so too did the levelling out of the catalyst beds inside the confined space inside the converter. Compliance with wearing respiratory protection was good. Compliance for decontamination of respirators was not checked as this was left to each individual. A formal check of washing down at breaks and at the end of shift was not undertaken although the majority appeared to conform.

The elevated urine vanadium would indicate the need for a formal education program to promote the need for proper decontamination and good personal hygiene throughout the catalyst change-out process. To prevent acute, and chronic health effects, such as neurobehavioural effects suggested by Barth et al. (2002), it is imperative that compliance with good personal hygiene and washing of hands and face at break times, and at completion of the shift prior to eating, drinking or smoking, is strictly adhered to.

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Interpretation of Drinking Water Monitoring Data for Environmental Health Professionals

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As part of a larger study investigating the role of public health agencies in assuring drinking water safety in Canada, a questionnaire survey of practicing Public Health Inspectors/Environmental Health Officers (PHI/EHO) in Western Canada was conducted. The results from a portion of this questionnaire dealing with the interpretation of water quality monitoring data are presented and analysed. These reflect, in common with other professional disciplines surveyed, evidence of an over confidence in the accuracy of monitoring data in cases, such as that found in effectively-treated drinking water, where the occurrence of target contaminants should be rare. A hypothetical monitoring scenario was presented with characteristics sufficient to estimate what level of confidence was warranted in a positive result. The respondents' stated requirements for a level of accuracy that should be provided by environmental monitoring to support making a risk management decision, implied a capability that will be difficult to achieve. The respondents' own estimates for confidence in the hypothetical scenario presented greatly exceeded the realistic, but poor level of confidence that was warranted for a positive result. More effective monitoring strategies and appropriate responses to detected contamination will inevitably depend upon better understanding of the practical quantitative limitations of treated water monitoring.

Key words: *Positive Predictive Value; Diagnostic Sensitivity; Diagnostic Specificity; False Positives*

Monitoring treated drinking water has developed as one means for verifying system performance and assessing compliance, ostensibly for the protection of public health. However, the interpretation of quality monitoring data for the purpose of making risk management decisions can be complex and we often have to judge monitoring data even with incomplete information and uncertainty. The waterborne disease threat in Sydney in 1998 in which high levels of protozoa *Cryptosporidium* and *Giardia* were detected in treated drinking water provided an effective illustration of the challenges of interpreting monitoring evidence to manage public health risks (McLellan 1998).

Because risk management decisions based on drinking water quality monitoring often carry significant social and economic consequences, the reliability of data from monitoring programs must be clearly understood by all those involved in the analysis and interpretation of monitoring data, and the design of monitoring programs. Some recognised limitations of reliance on treated water quality monitoring as the primary means of assuring the safety of drinking water include shortcomings in sampling and analytical techniques, limitations in our knowledge of the relationships between routine water quality parameters and public health outcomes, and the inherently reactive nature of treated water monitoring (Allen et al. 2000; Hrudey & Hrudey 2004; Hrudey & Rizak 2006; NHMRC 2004; Sinclair & Rizak 2004). However, there are also some important statistical limitations inherent in the use and interpretation of monitoring data, particularly when evaluating rare or infrequent hazards that are typical of treated drinking water in developed countries (Hrudey & Leiss 2003).

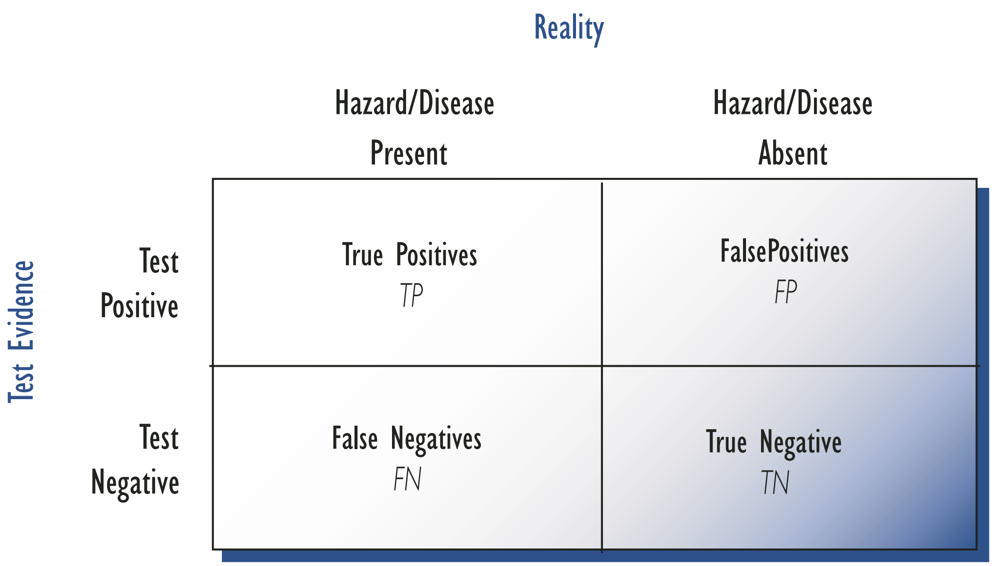
The research outlined in this paper was performed as part of a larger study to explore the role of public health professionals in assuring drinking water safety in Canada. Our study included a questionnaire survey of practicing Public Health Inspectors/Environmental Health Officers (PHI/EHO) in Western Canada, and a limited interview-based comparison with current public health practice in Australia (New South Wales and Victoria).

Conceptual Background

Applying a framework that is well established for medical diagnosis, Hrudey and Leiss (2003) highlight some practical quantitative limitations in data analysis and interpretation, and offer essential insights for environmental monitoring and risk management decision-making particularly as we move towards detecting more potential health hazards at increasingly lower concentrations. Utilising concepts of diagnostic sensitivity, diagnostic specificity, and positive predictive value, an important premise this framework demonstrates is that monitoring for a hazard that is relatively rare or infrequent will inevitably yield more false positive results than true positive results, regardless of the apparent capability of the screening or monitoring method used (short of perfection). This anomaly arises because the frequency of the hazard being monitored is the primary driver determining the ability correctly to identify its presence or absence.

These relationships are best understood through a simple 2 x 2 typology (Figure 1). The two rows of the figure relate to the

Figure 1: Relationships between test evidence and reality



$$DSe = \frac{TP}{TP + FN}$$

evidence obtained from a testing method considered to be either positive or negative (dichotomised, even when working with continuous data), and the columns of the table relate to the true condition of whether some condition or hazard is present or absent, that is, reality. The four cells of the table reflect the unique combinations of the true situation versus the test result: *TP*, true positives, refers to when the test result is positive and the condition is truly present; *FP*, false positives, refers to when the test result is positive but the condition is truly not present; *TN* refers to true negatives, and *FN* to false negatives (Black et al. 1999).

Diagnostic sensitivity (*DSe*) in this regard represents the conditional probability or chance that a test will correctly identify the disease or hazard, given the disease or hazard truly exists. *DSe* is calculated from the true positives and false negatives and is equal to the complement of the false negative rate (β) as shown in Eq 1:

$$Dse\ (true\ positive\ rate) = \frac{TP}{TP + FN} = 1 - \beta \qquad \text{(Eq 1)}$$

Diagnostic specificity, *DSp*, on the other hand, represents the conditional probability or chance that a test will correctly identify the disease or condition being absent, given the disease or condition is truly not present. *DSp* is calculated from the true negatives and the false positives and is equal to the complement of the false positive rate (α) as shown in Eq 2:

$$Dse\ (true\ negative\ rate) = \frac{TN}{TN + FP} = 1 - \alpha \qquad \text{(Eq 2)}$$

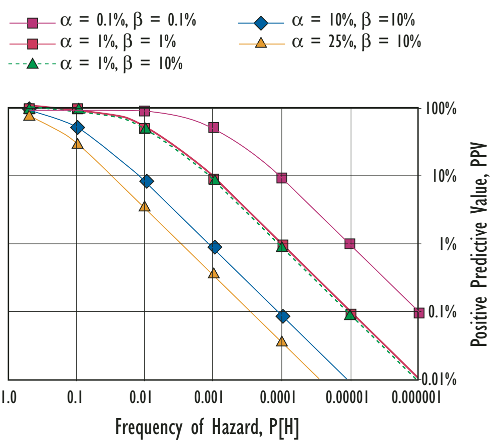
These two concepts reflect the performance characteristics of a test and inform us of the probabilities that a test will be positive or negative, respectively, given cases where a condition is known to be either present or absent. However, in practice the relevant question when interpreting the meaning of monitoring evidence is: what is the probability or chance of something being truly present given a positive test result? Or alternatively what is the probability or chance of something being truly not present given a negative test result? This information is provided by what is termed in medical diagnosis as the predictive value of a test.

The predictive value of a positive test result, or the positive predictive value, *PPV*, is the conditional probability or chance that there truly is a hazard given one has been identified by a positive test. It is the chance that a positive test detected will be a true positive and can be demonstrated horizontally on the 2 x 2 table by calculating the ratio of true positives to total positives (Eq 3):

$$PPV = \frac{TP}{TP + FP} \qquad \text{(Eq 3)}$$

A reality recognised in the medical sciences is that the prevalence or frequency of the condition that is being tested for has a dramatic effect on predictive value and is the dominant factor in determining the ability to interpret monitoring and correctly identify potential hazards. As Hrudey and Leiss (2003) demonstrate, *PPV* will be poor for conditions that are rare or low frequency (Figure 2). In such circumstances, false positive results will exceed the rare true

Figure 2: Quantitative dominance of Positive Predictive Value (PPV) by low frequency of hazard occurrence, P[H]



positive results; and the rarer the occurrence of the hazard the smaller is the *PPV*. In medicine, this insight has essentially meant that screening for some rare condition only yields useful results when testing is done in targeted populations with higher than average risk, rather than universal population screening. This is a valuable principle that has neither been explicitly recognised by environmental professionals nor has it been incorporated in environmental monitoring programs that typically screen for infrequent hazards (Hrudey & Rizak 2004, 2006).

Methods

A questionnaire survey was conducted among PHI/EHOs in Western Canada (British Columbia, Alberta and Saskatchewan) in order to understand to what extent the limitations of environmental health monitoring are either explicitly or intuitively recognised by public health professionals involved in the interpretation of drinking water quality monitoring data. The questionnaire aimed to assess the ability of these professionals to use evidence to guide their risk management decisions. This survey was part of a larger project aimed at understanding the current practices among public health professionals in Canada and Australia in assuring drinking water safety.

The questionnaire was approved by the Health Research Ethics Board (Panel B Health Research) of the University of Alberta and was mailed in August 2004 to all practising PHI/EHOs in British Columbia, Alberta and Saskatchewan. Response was voluntary and the responses were received and stored with a protocol that ensures the anonymity of any respondent. Of the 444 eligible, a total of 146 questionnaires were completed and returned (33% response rate).

Respondents were encouraged to provide their answers based on their first instinct and to not consult with colleagues or reference sources to guide their answers. They were also encouraged to answer all questions even if they would prefer the questions to have been worded differently and to include comments to elaborate on their responses or suggest improved wording for the questions. The comments received provided further insights into the respondents' choices and how they use positive water monitoring results in decision-making.

Among the survey questions, we included three questions directly relevant to the interpretation of analytical test results for rare drinking water hazards (Box 1). The first question addressed issues relating to an

Box 1: Selected survey questions

Q1. What is the lowest accuracy that you would accept from an analytical method, for a specific environmental contaminant, before you would be confident in taking a major risk management action (e.g. issuing a boil water advisory) based on this method indicating the presence of that environmental contaminant?

☐ 50% ☐ 70% ☐ 90% ☐ 95% ☐ 99%

Q2. *[A hypothetical scenario]* Evidence for a Canadian city has indicated that in treated drinking water, a pathogen, say '*Giardia*', is truly present above the recognized standard methods detection limit, about once in every 10,000 water samples from the treated water distribution system.

Assume the analytical test for the pathogen has the following characteristics:

- 99.9% of tests will be positive for detection when the agent is truly present above the detection limit, and
- 98% of tests will be negative for detection when the agent is truly not present above the detection limit.

With these characteristics, given a positive result (detection) on the analytical test for the specified pathogen in the Canadian city, how likely do you think this positive result is true? Provide either a probability estimate ______ or indicate your scale of agreement below:

☐ Almost certain (95 to 100%)

☐ Very likely (80 to 95%);

☐ More likely than not (50 to 80%);

☐ Less likely than not (20 to 50%);

☐ Very unlikely (5 to 20%);

☐ Extremely unlikely (0 to 5%);

☐ No idea.

Q3. For the circumstances of question 2, if you have any remaining concerns about this evidence, how would you improve certainty for this result?

acceptable accuracy of analytical methods for informing risk management decision-making. The second question presented a hypothetical *Giardia* monitoring scenario that required environmental health professionals to estimate the accuracy of a test result given excellent intrinsic performance characteristics but applied to a low frequency hazard situation. The third question explored how respondents would improve the certainty of the positive monitoring results in future.

Results

The responses to the hypothetical *Giardia* monitoring scenario are presented in Figure 4. This question was included to assess the understanding among environmental health professionals of the quantitative limitations of monitoring evidence and the appreciation of the effect of hazard frequency when interpreting monitoring results. The correct answer to the probability of the positive result being true (i.e. *PPV*) based on the characteristics provided by the scenario is actually 0.5% (Box 2). Only 5 respondents (3.4%) selected the correct confidence estimate of 0 to 5% (Figure 4).

Box 2: Answer to Hypothetical Monitoring Question

The answer can be illustrated following the logic of the 2 x 2 table (Figure 1). The characteristics of the analytical method described in the scenario provide a false negative rate of 0.1% (corresponds to a diagnostic sensitivity of 99.9%, i.e. 99.9% of water samples will report positive when the *Giardia* is truly present) and a false positive rate of 2% (corresponds to a diagnostic specificity of 98%, i.e. 98% of water samples will report negative when *Giardia* is truly not present or detected). However, in interpreting the meaning of a positive result, our best intelligence indicated that about 1 in 10 000 water samples truly does contain *Giardia* above the detection limit. This means that for every one true positive result there will be 9999 true negative results. Applying the false positive rate (when *Giardia* is truly absent) and false negative rate (when *Giardia* is truly present) to these values we obtain 199.98 false positive results (9999 x 0.02) for every 0.999 true positive result (1 x 0.999) giving a ratio of 0.005 (0.5%) true positive results to total positive results (i.e. the sum of true positives plus false positives). This ratio is what is termed the predictive value of a positive test result, or the positive predictive value, *PPV*, i.e. the chance that a positive test detected will be a true positive.

The qualitative comments for this question provided further insight into how environmental health professionals interpret laboratory evidence for decision-making and also support that there is not much appreciation of the link between rare or infrequent hazards and poor predictive value of a positive test result when interpreting monitoring results. Forty-five (45) respondents provided comments on this question.

The last question selected for this discussion was open-ended and required respondents to indicate how they would improve certainty for the result in the previous question if they have any remaining concerns about the monitoring evidence. A variety of comments were given by 89 respondents (61.0%) who provided one or more responses to this question (Table 1).

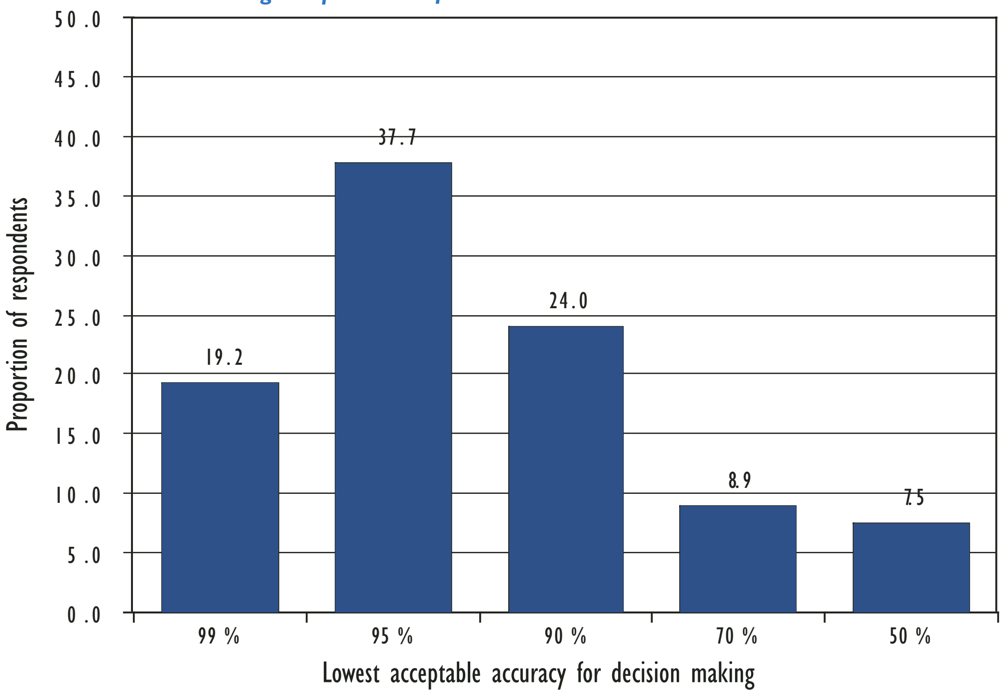
Discussion

The purpose of drinking water management and treatment is to eliminate environmental health hazards from drinking water. Thus, for any responsible water supplier (well operated systems) the presence of hazards in drinking water should be a rare occurrence. Further, no analytical method for water contaminants has 100% *DSp* ($\alpha = 0\%$), that is, even the best practicable sampling and analysis protocols cannot completely avoid false positive results. Therefore, when monitoring for rare or infrequent hazards in treated drinking water, common false positives are inevitable. This reality places a substantial burden of responsibility on public health decision-makers who cannot afford to ignore positive results. The challenge is to take sensible and responsible actions, including collaborating with water providers to develop more strategic monitoring programs that will provide supporting evidence which can be used to judge more effectively the meaning of any given positive result. This situation cannot be simply improved by better sampling or analytical techniques, as long as monitoring

Table 1: Responses for improving the certainty of a positive* Giardia *test result

Action [# of respondents]	Percent of respondents	Grouped Percent of respondents
Re-sample and/or re-analyse		
- re-sample and analyse [52]	35.6%	
- re-sample and find/use another analytical method [6]	4.1%	
- re-sample and use another lab [5]	3.4%	
- split samples [4]	2.7%	50.6%
- sequential analyses [4]	2.7%	
- re-analyse same sample, use quality control methods (spikes, blanks, etc.) [3]	2.1%	
Modify or review monitoring program		
- sample at other locations in the water system [14]	9.6%	
- increase sampling frequency [11]	7.5%	
- increase sample size [4]	2.7%	32.2%
- review analytical procedure [10]	6.9%%	
- review sampling procedure [8]	5.5%	
Gather additional evidence		
- corroborate with other analyses (e.g. turbidity, Crypto) and/or data (environmental, history, etc.) [13]	8.9%	
- further investigate water source and water treatment [8]	5.5%	23.9%
- sample and analyse raw water [5]	3.4%	
- look for *Giardia* cysts viability / infectivity [4]	2.7%	
- look for increase in GI disease trends in community [5]	3.4%	
Other response		
- consult a specialist [5]	3.4%	
- the test result as presented was conclusive (implies no further action required) [5]	3.4%	6.8%

Figure 3: Survey responses to the question: "What is the lowest accuracy that you would accept from an analytical method, for a specific environmental contaminant, before you would be confident in taking a major risk management action (e.g. issuing a boil water advisory) based on this method indicating the presence of that environmental contaminant?"



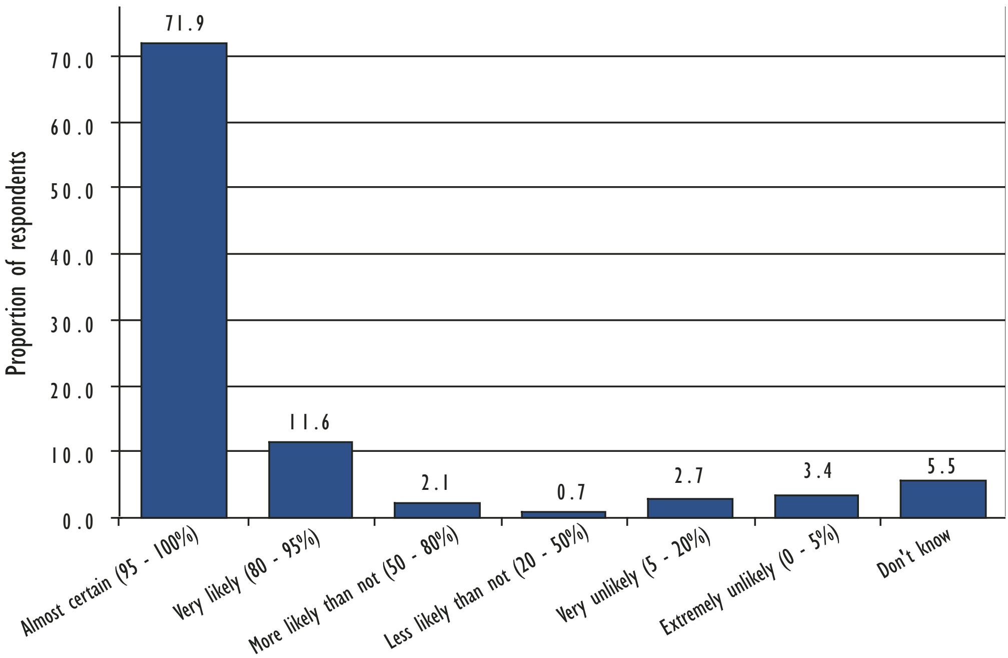
is only performed on treated water where we should expect contaminant occurrence to be infrequent.

Unfortunately, most questionnaire respondents failed to recognise this limitation of monitoring for rare hazards. In this regard our respondents are in good company. Hoffrage et al. (2000) reported similar results for hypothetical medical diagnostic questions given to faculty, staff, and students at the Harvard Medical School. In the case of the second question described from our survey, the likelihood that the *Giardia* test provided a true positive result was only 0.5%. Yet, 83.5% of respondents (Figure 4) believed this result was "very likely" or "almost certain" (i.e. confidence greater than 80% that the result is true).

For 80.9% of respondents to our survey (Figure 3), at least a 90% level of accuracy from an analytical method was required by these professionals before feeling confident in taking action based on results of an environmental contaminant test. The difficulty, however, is in not understanding what the accuracy of the test method means for the purposes of interpreting the meaning of a positive result. This arises from confusing the *DSe* (an intrinsic characteristic of the method) with the *PPV* (the likelihood that context-specific results using the method will provide a true answer). Test methods are evaluated by using them on samples known to be either positive or negative. The *DSe* or *DSp* of any method is a statement of how well the test performs on these spiked or known samples.

Figure 4: Survey responses about confidence in a positive result being a true result for a hypothetical scenario for 'Giardia', given that it is truly present above the recognized standard methods detection limit, about once in every 10,000 water samples from the treated water distribution system and the analytical test for the pathogen has the following characteristics:

- **99.9% of tests will be positive for detection when the agent is truly present above the detection limit, and**
- **98% of tests will be negative for detection when the agent is truly not present above the detection limit.**



However, unless the *DSp* is 100%, meaning that the false positive rate α is zero, the rare hazard problem will arise. Large numbers of negative samples will be analysed by a method that, even with a low false positive rate, will generate numerous false positive results (Box 1). Only if the false positive rate is as low or lower than the frequency of rare hazard being sought, will the *PPV* be greater than 50%, a level necessary to make a positive value more likely than not to be a true positive (Hrudey & Leiss 2003).

In our questionnaire respondents did not appreciate even intuitively the impact that the low *Giardia* prevalence in the respective media would have on the *PPV* of the *Giardia* test. As with other professionals who have been surveyed in this manner, the high levels of *DSe* and DSp for this test were enough to assure a high level of confidence in the validity of a given positive result.

The most common response to improve the certainty of the test result was re-sampling the treated water and analysing it using the same analytical method (35.6% of respondents). If water quality were constant, this would be an effective strategy. Retesting an individual for a medical condition that persists after an initial positive result will face a much more favourable chance of yielding a true positive because the test method is applied to a subset of positive results among which the frequency of true positives will be much higher than in the general population. Unfortunately, water quality does not remain constant, so retesting will only be effective for persistent contamination, but will be ineffective for intermittent contamination. Split sampling (2.7%), sequential analysis (2.7%), and reanalysis of the same sample (2.1%), were provided as response actions from a few respondents. These are methods commonly employed in drug testing of athletic competitions, but these are more difficult to implement for water quality monitoring, particularly for microbiological samples. Finding ways to perform such tests in a meaningful way, however, suggests an important research need.

About one third of respondents (32.2%) would modify or review the monitoring program. This would be helpful for detecting future incidents, improving prevention programs and verifying persistent contamination scenarios. Other recurrent responses included gathering more evidence, including investigation of the source water and treatment (23.9%). A strategic water quality monitoring program would ensure that adequate monitoring resources are dedicated to monitoring elements of the system with a higher probability of encountering contamination (e.g. raw water) to provide corroboration if a contaminant episode is suspected.

Of some concern is that five respondents specifically indicated that (in their opinion) the *Giardia* result presented was conclusively positive and no further action to confirm the result is necessary. This response is a serious misinterpretation of the capabilities of the hypothetical (but realistic) monitoring protocol. This small minority response is likely to lead to misguided risk management actions.

While it is an oversimplification to treat the Sydney Water Crisis of 1998 as only an exaggerated reaction in response to several false positive results, the Sydney Water Inquiry revealed that the lack of informed professional collaboration between water and health authorities, combined with a monitoring program that was not strategically designed to accurately characterise the Sydney drinking water system from raw water source to the water reticulation system, produced a traumatic and expensive experience for all involved (Clancy 2000; Cox et al. 2003; McLellan 1998). Fortunately, no drinking waterborne illness occurred in the community.

Conclusion

As with other professions that have been surveyed, PHI/EHOs have shown a misunderstanding of the challenge of monitoring for rare environmental hazards, specifically, compliance monitoring for contamination of effectively treated drinking water. Since public health professionals must err on the side of caution in responding to potential threats to public health, they face a substantial dilemma because of this challenge with interpreting monitoring evidence.

This challenge requires developing the means to obtain corroborative evidence for a positive result for a drinking water contaminant before taking drastic response actions. A single positive result for a contaminant, which should be rare, in the absence of any other supporting evidence for its presence, provides an insecure basis for taking drastic action. However, complete inaction, leading to public health consequences would be disastrous. Experiences such as the Sydney Water Crisis where boil water advisories were called at substantial costs when they were likely not required, contrasted with the Canadian Walkerton disaster where simple actions were not taken and seven people died (Hrudey & Walker 2005), suggest that health authorities and water providers must work together to develop sensible, effective and strategic monitoring programs to support public health risk decision-making.

Acknowledgments

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Notation

α the false positive rate

β the false negative rate

DSe Diagnostic Sensitivity is the conditional probability of finding a positive analytical result for detection of a hazard given that it is truly present at a defined hazard level (Eqn 1)

DSp Diagnostic Specificity is the conditional probability of finding a negative analytical result for a hazard given that it is truly not present at a defined hazard level (Eqn 2)

EHO environmental health officer

FN False negative, a test result indicating the absence of the hazard when it is truly present

FP False positive, a test result indicating the presence of the hazard when it is truly absent

PPV Positive predictive value is the conditional probability that the hazardous contaminant is truly present at a defined hazard level, given a positive analytical result (Eqn 3)

PHI public health inspector

TN True negative, a test result indicating the absence of the hazard when it is truly absent

TP True positive, a test result indicating the presence of the hazard when it is truly present

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Study of Heavy Metals in the Shar Chi River (Urmia Iran)

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Heavy metals are significant pollutants in the rivers due to their toxicity and potential to accumulate in the environment. Shar Chai River is the biggest river in the Urmia North West of Iran. The aim of this study was to assess heavy metal contamination (As, Zn, Pb, Cr) at various times over one year and compare with WHO drinking water guidelines. Along the Shar Chai, agricultural, urban and industries drain their wastewater into the river. Samples were collected from six stations along the river, from April 2002 up to March 2003. Heavy metals concentrations were measured by graphite furnace atomic absorption spectrometry. Results showed that the annual minimal, maximal, mean and standard deviation concentration of lead in site1 and 6 were 0.009, 0.17, 0.05, 0.079 mg/l and 0.012, 0.2, 0.07, 0.081 mg/l respectively. The seasonal mean concentration of lead in summer and autumn was 0.11, 0.12 mg/l respectively. In comparison, all remaining heavy metal results are relatively low and well below international standards. Analysis of the relationship between pH and concentration of metals in the river water (As, Zn, Cr, Pb) showed that lead displays a slightly higher correlation with pH. Findings also showed that the concentration of lead displayed greater seasonal variation than the other metals investigated. It is concluded that it would be an advantage to store water in a reservoir during winter in order to reduce lead concentrations in the drinking water.

Key words: *Shar Chai River; Agriculture Runoff; Domestic Wastewater; Heavy Metal*

Rivers are important, they provide water for economic development and human consumption; they provide recreational facilities - fishing, boating and so on. They support a large variety of wildlife and they are part of our natural scenic heritage. During recent years, the pollution of river basins by heavy metals has attracted attention by the scientific community. Unlike organic pollutants, natural biochemical processes of decomposition do not remove heavy metals. On the contrary, metals might be enriched by organisms; a process that might lead to the metals being converted to organic complexes that might enhance their toxicity. Metals are introduced into the aquatic system as a result of weathering of soil and rock, from volcanic eruptions and from a variety of human activities involving the mining, and processing industries, and the use of metals and/or substances containing metal contaminants, such as petrol (Jain 2004; Scholz 2004). In natural media, trace metals undergo numerous changes during their transport and sorption phenomena. Trace element concentrations of river basins depend on not only industrial and household waste inputs, but also on the geochemical composition of the area (Akcay et al. 2003).

The potential for pollution of aquatic ecosystems by heavy metals is a significant issue due to their toxicity and accumulative behaviour (e.g. lead). The toxicity and fate of the waterborne metal is dependent on its chemical forms, and therefore quantification of the different forms of metals (speciation) is more meaningful than the estimation of their corresponding total concentrations

(Jain 2004; Scholz et al. 2002).

Heavy metals such as lead, cadmium, copper and zinc are found in domestic waste. Based on mass flow studies, the runoff from roofs and streets contribute between 50% and 80% of these metals to the total mass flow in domestic sewage (Boller 1997). Lead in particular is associated with a degradation of the nervous system of children and older adults (Oller & Bates 2004).

Depending on the sewerage concept, heavy metals accumulate in different environmental compartments. Most systems result in metals being bound to the sludge during sewage treatment. If the sludge is used in agriculture as a fertiliser (bio-solids), the metals are enriched slowly in the topsoils. However, for systems involving only preliminary or primary treatment, metals may be discharged directly into receiving waters. This might lead to the accumulation of metals in the sediments (Boller 1997; Scholz et al. 2004).

Industrialisation leads to the pollution of ecosystems. Metal contaminants are often discharged into rivers and lakes, and subsequently leach into the soil and groundwater, or are emitted into the air (e.g. waste incineration and fumes from exhausts of vehicles) as particulate matter (Abernathy 1984). Heavy metal contamination is critical because of their easy uptake into the food chain and subsequent bioaccumulation processes (Beijer & Jernelov 1986).

Shar Chai River is the longest river in West Azerbyjan, Iran, and many urban, agricultural and industries drain their wastewater into the river. A preliminary study by Parsa (1985) measured the concentrations of Hg, Mg, Fe, Cu, Cd, Ag, Mn and Ni. Results showed that the concentrations of these metals were less than the World Health Organization (WHO) guidelines. Because of pollution from increasing industrial and agricultural activities in this region and pollution of the river from their wastewater, the authors decided to assess heavy metals such as AS, Zn, Pb and Cr in the Shar-Chai River. This river provides not only supply water for the majority of villages and Urmia City but also supplies water for irrigation in agricultural activities. The main aim of this study was to determine the concentration of heavy metals (As, Zn, Pb, Cr) at six different sampling stations from the main source (up stream) to down stream by the reservoir under construction and make a comparison with WHO guidelines.

Materials and Methods

Iran and West Azerbyjan

The research has been carried out in the City of Urmia, which is the centre of the province of West Azerbyjan, which is located in the North West of Iran. Figure 1 shows the river Shar Chai case study area. A salt lake (Lake Urmia) is located between West and East Azerbyjan. There is a mountainous region that is approximately 140 km long (North to South direction) and 50 km wide to the west of the Lake. The Shar Chai River has its source in these mountains.

The salt concentration in Lake Urmia is so high that there is virtually no fish life, and swimmers can float without movement. Lake Urmia is the largest lake in the country. The lake is about 130 km long (North to South) and 60 km wide (West to East). This brine lake has an adverse impact on the majority of agricultural land and groundwater resources in the province.

In West Azerbyjan, there are six major rivers draining into Lake Urmia. Some streams (tributaries to the major rivers) are dry during summer. The Shar Chai River flows through Urmia, which has a current population of approximately 450,000 (census in 1996) and is the political and cultural centre of West Azarbyjan (Nanbakhsh 2004a).

Regional climate and hydrology

The climate of the Urmia region is characterised by hot and dry summers, and cold and damp winters and early springs. The minimum and maximum temperatures in winter and summer are -15°C and 30°C, respectively. The average rainfall is almost 450 mm a^{-1}. Most of the region is subject to heavy continental rainfall in spring, resulting in soil with a relatively high moisture content.

There are three main catchments in West Azerbyjan. However, most land of this region drains ultimately into the basin of the Shar Chai River. Approximately 860 Mm^3 a^{-1} groundwater is currently withdrawn from the River Shar Chai catchment via quanats (aqueducts below ground) and wells, and to a lesser extent from springs (Nanbakhsh 2004b). River water is used for watering gardens, plantations, agricultural fields, and for animal husbandry. During some summers, the River Shar Chai dries out at downstream stretches (downstream of Site 6).

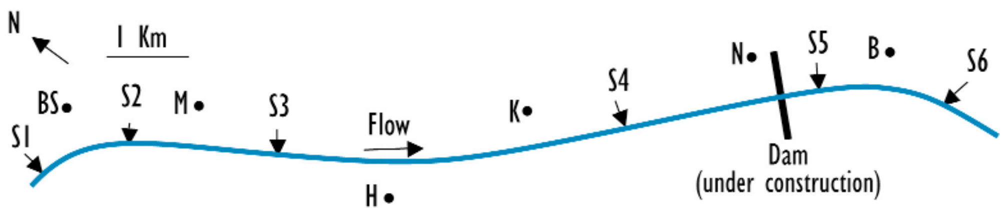
The catchment basin of the Shar Chai River is bordered in the North by the Rosaeh Chi basin, in the South by the Barandoze Chi basin, in the West by mountains (border region between Iran and Turkey), and in the East by Lake Urmia. The catchment size of the Shar Chai River is approximately 740 km^2. The Shar Chai River is the most important source of water in West Azerbyjan, but suffers from agricultural runoff and domestic wastewater pollution.

Sampling sites

Preliminary studies regarding the identification of sampling sites at Shar Chai River were carried out. Information on the hydrology and morphology of the river was assessed, and sources of likely pollution along the river were determined. Six sampling sites (Site 1 to Site 6) were subsequently selected (Figure 1). The characteristics of the sampling sites are as follows:

- Site 1 (Bardeh Sou) is located upstream of the village Bardeh Sou in the Bardeh Sou Mountains. The majority of villagers take their domestic animals to pastures near the river. It follows that there are animal droppings near the riverbanks.
- Site 2 (Mirabad) can be found downstream of Baredh Sou and upstream of Mirabad villages. The drains of these villages discharge into the river.
- Site 3 (Helori) is located upstream of Helori and just downstream of the confluence between Shar Chai River and several small streams (tributaries).
- Site 4 (Khovi) is situated upstream of a dam (under construction) and downstream of Khovi. Several small streams confluence upstream of the river in this area.
- Site 5 (Noshan) is located downstream of Nosham and a nearby dam (under construction). Samples should give an indication of the river contamination due to the construction effort.
- Site 6 (Band) can be found downstream of Band in a heavily populated area approximately 4 km North-west from the City of Urmia. The urban drains discharge into the river in this area, which is also used by the local and nearby urban

Figure 1: Sampling stations (S1-S6) at the River Shar Chai (Urmia Iran) Settlements: Bardeh Sou (BS); Mirabad (M); Helori (H); Khovi (K); Noshan (N); Band (B)



population for recreational purposes. Further, most of the current drinking water supply for Urmia is supplied via abstraction points just upstream of Site 6.

Sampling method

The sampling strategy was designed to cover a wide range of water quality heavy metals variables at key sampling sites that accurately represent the local and seasonal changes within the water quality of the Shar Chai River influenced also by tributary inputs. Six representative sampling sites were selected and sampled between April 2002 and March 2003. Each station was sampled four times per year, in mid-season, and at the same time. All analytical methods were performed according to American standard methods (APHA-AWWA-WPCF 1994).

River water samples were taken at a depth of 10cms to examine the heavy metal concentration. For the analysis of heavy metals, samples were collected at each site using a 1l polyethylene container. The sampling containers were rinsed with 5% nitric acid and subsequently with distilled water. River water was used for a final rinse just before sampling at the corresponding site. Samples were acidified with 1.5 ml of concentrated nitric acid (pH < 2). All samples were stored in a refrigerator at 4°C before analysis. Heavy metal (As, Cr, Zn and Pb) concentrations were determined by graphite furnace atomic absorption spectrometry (SHIMADSO AA 680). Distilled water was used for the dilution of samples.

Results and Discussion

The mean annual heavy metals characteristics of the Shar Chai River at all sampling stations are outlined in Table 1. Moreover, Table 2 indicates the mean seasonal variations of trace metals for all sampling sites. As Table 1 shows the annual minimal, maximal, mean and standard deviation concentration of lead in sites1 and 6 were 0.009, 0.17, 0.05, 0.079 mg/l and 0.012, 0.2, 0.07, 0.081 respectively. Moreover, the seasonal concentration of lead in summer and autumn was 0.11, 0.12 mg/l respectively. This represents a ten-fold exceedance of the WHO guideline value for lead (Table 2). The most likely source for

Table 1: Annual mean concentration of heavy metals of River Shar Chai (Urmia Iran) at sampling sites 1 to 6 (four samples per variable taken mid -seasonally between April 2002 to March 2003

Variable	Unit	Min	Max	Mean	Stdv[a]	WHO[b]
Site 1 (Bardeh Sou mountains)						
Arsenic	mg/l	0.004	0.01	0.01	0.004	0.01
Zinc	mg/l	0.000	0.004	0.003	0.002	0.3
Chromium	mg/l	0.000	0.005	0.001	0.002	0.05
Lead	mg/l	0.009	0.17	0.05	0.079	0.01
pH	---	7.6	8.2	7.9	0.27	6.5 - 8.5
Site 2 (Near the town of Mirabad)						
Arsenic	mg/l	0.002	0.01	0.01	0.006	0.01
Zinc	mg/l	0.003	0.003	0.003	0.003	0.3
Chromium	mg/l	0.000	0.005	0.001	0.001	0.05
Lead	mg/l	0.009	0.13	0.06	0.062	0.01
pH	---	7.8	8.2	7.9	0.15	6.5- 8.5
Site 3 (near the town of Helovi)						
Arsenic	mg/l	0.002	0.012	0.04	0.005	0.01
Zinc	mg/l	0.000	0.002	0.001	0.001	0.3
Chromium	mg/l	0.000	0.028	0.008	0.014	0.05
Lead	mg/l	0.012	0.15	0.07	0.060	0.01
pH	---	7.6	8.3	8.0	0.20	6.5- 8.5
Site 4 (near the village of Khovi and upstream of the drinking water reservoir currently under construction)						
Arsenic	mg/l	0.004	0.012	0.01	0.005	0.01
Zinc	mg/l	0.000	0.004	0.003	0.002	0.3
Chromium	mg/l	0.000	0.01	0.001	0.002	0.05
Lead	mg/l	0.009	0.15	0.07	0.079	0.01
pH	---	7.6	8.2	8.0	0.13	6.5 - 8.65
Site 5 (near the village of Noshan)						
Arsenic	mg/l	0.002	0.02	0.01	0.007	0.01
Zinc	mg/l	0.000	0.001	0.000	0.000	0.3
Chromium	mg/l	0.000	0.01	0.001	0.001	0.05
Lead	mg/l	0.009	0.134	0.07	0.062	0.01
pH	---	7.6	8.3	8.1	0.18	6.5 - 8.65
Site 6 (Downdtream of Band near the City of Urmia)						
Arsenic	mg/l	0.004	0.012	0.01	0.005	0.01
Zinc	mg/l	0.000	0.01	0.01	0.003	0.3
Chromium	mg/l	0.000	0.01	0.008	0.006	0.05
Lead	mg/l	0.012	0.20	0.07	0.081	0.01
pH	---	7.8	8.2	8.1	0.16	6.5 - 8.65

a Standard deviation
b WHO Guideline

Table 2: Seasonal concentration of heavy metals comparison (mean of six sampling sites sampled mid-seasonally between April 2002 and March 2003 for the River Sharchai (Urmia, Iran)

Variable	Unit	Spring	Summer	Autumn	Winter	WHO
Arsenic	mg/l	0.01	0.00	0.01	0.01	0.01
Zinc	mg/l	0.00	0.00	0.00	0.00	0.3
Chromium	mg/l	0.00	0.00	0.01	0.00	0.05
Lead	mg/l	0.01	0.11	0.12	0.01	0.01
pH	------	8.0	8.0	8.2	7.2	6.5-8.5

lead input is the underlying rock that is relatively rich in lead in the Bardeh Sou Mountains. Suspension of sediments (due to shear forces) into the water body could lead to increased lead concentrations. This rather natural contamination is in contrast to observations at other rivers in Iran where heavy metal pollution is due to industrial activities (Moussavi & Saber 1999). Further, the wash-off of lead from roads and the presence of old lead pipe work in urban areas may also be responsible for elevated concentrations. According to Table 1 and 2, in comparison, all remaining heavy metal pollution indicators are relatively low and well below international thresholds (WHO 1996).

The concentration of lead is lower during spring (0.01 mg/l) in comparison to summer (0.11) due to higher dilutions and lower temperatures. It would, therefore, be an advantage to store river water in reservoirs during winter in order to reduce lead concentrations in the drinking water. The concentration of lead would increase if the pH would decrease (Scholz 2004). This could be the case if alkaline agricultural runoff could be reduced. On the other hand, organic pollution associated with agricultural runoff has a much greater detrimental effect on the river ecosystem than elevated lead concentrations.

The lead levels are 10 times the WHO guideline values for at least six months of the year. The implications for children using the river for a source of drinking water and recreational or commercial fishing activities that might be impacted. Lead rarely occurs naturally in drinking water. It is more common for lead contamination to occur at some point in the water delivery system. Adverse effects caused by environmental pollution are well recognised. Too much lead in the human body can cause serious damage to the brain, kidneys, nervous system and red blood cells. Young children, infants and foetuses are especially vulnerable to lead poisoning. An amount of lead, which would have little effect on an adult, can greatly affect a child. Also, growing children more rapidly absorb any lead consumed. A child's mental and physical development can be irreversibly stunted by lead (Paoliello & de Capitani 2005). Blood lead levels as low as 0.01 mg /l may lead to decrements in measures of cognitive ability and academic performance. However, no data on children and older adults are currently available from the Shar Chai River basin (Spencer & Green 1981). There are several treatment methods suitable for removing lead from drinking water, including reverse osmosis, distillation and carbon filters specially designed to remove lead. Typically, these methods are used to treat water at only one faucet.

A comparison of the present study results to those of the other rivers reveals that the average metal load of lead is very slightly higher in the Shar Chai River. This implication is supported by research in Salinas River (California USA). Anderson et al.'s (2003) findings showed that the mean total metal concentrations (AS, Cr, Cu, Pb and Zn) in the river samples for each individual metal were less than 0.003 mg/l.

Concentration of Arsenic in surface water bodies is usually low. Rather high concentrations have been reported in some drinking water supplies in Latin America (0.6-0.8 mg/litre) and the western Pacific (0.24-0.96 mg/litre), and are associated with endemic arsenic poisoning and so called 'Blackfoot' diseases. Arsenic can occur as a contaminant if employed as a pesticide (WHO 1972). The most common sources of elevated As concentrations in the Australian environment are attributable to anthropogenic activities. Mining activities have contributed to the contamination of soil and water primarily in Western Australia and Victoria. However, other anthropogenic activities such as agriculture, forestry and industry have also contaminated soil and water on a localised scale (Smith et al. 2003). Recently, arsenic contamination of ground water has been recognised as a public health problem in Nepal (Shrestha et al. 2003). The latest statistics indicate that 80% of Bangladesh and an estimated 40 million people are at risk of arsenic poisoning-related diseases because the groundwater in these wells is contaminated with arsenic (Alam et al. 2002). In our study As levels were at the WHO guideline level in spring, autumn and winter. It seems that the main source of As pollution in the Shar Chai River is agricultural wastewater.

The major sources of pollution in agricultural wastewater are fertilisers containing heavy metals such as Cd, Pb, Cr, Zn, Cu and Ni. (Spencer & Green 1981). A study was done by Akcay et al. (2003) in Buyak Menderes and the Gediz River and sediment in Ankara, Turkey, and heavy metals, such as Pb, Zn, Cr, Ni, were examined. Results showed that the pollution levels were significant, especially for Pb, Cr, and Zn in the Gediz River. Pollution in these Rivers has probably originated from industrial, agricultural and domestic waste discharges. Although, these results are contradicted in some other studies, they are similar to our study. Our findings indicated that the main sources of pollution of the Shar Chai River are urban, agricultural and domestic wastewater of villagers and animals upstream and also from industrial wastewater downstream (site 6).

A study investigating heavy metals was carried out by Diagomanolin et al. in 2004 in the Karon waterway Havaz River in Iran (Ni, Cr, Cu). The results revealed higher concentrations of all heavy metals (Cr, Ni, and Cu) at downstream stations and all concentrations of pollutants were higher in winter than in spring. Results showed that the mean concentration of chromium at each station was significantly different from the respective down station of paired stations. Moreover, the main source of pollution of the Karon River is urban, agricultural and industrial wastewater. Our findings showed that the annual and seasonal mean concentration of Chromium is 0.01 mg/l at site 3 in autumn. However, its concentration is low when compared to the other rivers of the world (Sakai et al. 1986). The correlation analysis between pH and elements of heavy metals showed that lead displayed a slightly high correlation with pH. The maximum correlation coefficient was with pb ($r = 0.69$). But the correlation coefficient for other metals (As, Zn and Cr) was less than 0.5 ($r < 0.5$).

The impact of the reservoir on water resources

Construction work on the dam under construction (Figure 2) had started in 1998 and is likely to finish in 2006. The proposed dam will give the City of Urmia greater independence from groundwater and river water resources. Groundwater sources have a relatively high hardness (approximately 500 mg/l $CaCO_3$), and in some areas are polluted by nitrate-nitrogen (up to approximately 57 mg/l). Moreover, the volume available for abstraction has decreased continuously since 1990 (Nanbakhsh 2004b).

The reservoir will allow excess water to be stored during the wet seasons (spring and winter) and to be used during the dry seasons (summer and autumn). Moreover, groundwater will be recharged near Noshan and Band by the expected seepage of the reservoir (Figure 1).

Conclusion

The Shar Chai River exceeded selected international water quality standards for a few sampling sites during some seasons. The upstream stretches are subject to agricultural runoff pollution and the downstream stretches are contaminated due to discharge from urban development and dam construction work. Surveys in March 2002 - April 2003 showed that the Shar Chai River is less polluted with heavy metals in comparison to others in developing and under-developed countries, but concentrations of lead higher than the other metals, especially in the first and 6th station, is considerable.

Recommendations

The following suggestions are recommended:

- further research should be conducted into investigating the source of lead contamination, particularly at station 1
- the blood levels of children using the Shar-Chai River as a source of drinking water should be examined
- further research should be carried out into heavy metals in the sediments of the river
- treatment of drinking water to aid the removal of Pb
- consideration should be given to the monitoring and control of Pb
- consideration needs to be given to the monitoring and control of As.

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AIR FORCE

Dust, Distance and Discussion: Fieldwork Experiences from the Housing Improvement and Child Health Study

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The poor state of Indigenous health is in part attributable to poor housing and household environments. The Housing Improvements and Child Health study is a large research project that aims to improve understanding of the relationship between the household environment and child health in remote Indigenous communities, particularly the impact of improved housing stock. The collection of remote community household data for research purposes presents a number of challenges. This paper relates our experiences in this area. We discuss issues of survey design, including language, pilot testing, and innovations in the assessment of household function and condition. We then consider the processes of engaging remote communities in the study and administration of the surveys, including informed consent, the effect of researcher characteristics on data collection, confidentiality and the process of feeding back survey findings to community stakeholders. We conclude with a discussion of the critical lessons from our fieldwork experience. In discussing these issues, we aim to promote discussion of the challenges of working in remote Indigenous communities, and ultimately to improve fieldwork practice and the quality and use of research data in improving living conditions in remote communities.

Key words: *Indigenous; Aboriginal; Housing; Data Collection; Child Health; Environmental Health*

The inadequacy of housing in Indigenous communities has been noted for some time, with the problem being particularly acute in remote regions of the Northern Territory (Australian Bureau of Statistics 1996; Jones 1994). In recent years, the role of the environment as a determinant of Indigenous health has received increasing attention (Pholeros, Rainow & Torzillo 1993; Pormpuraaw Community Council et al. 1997). Research on the built and social environment is slowly advancing our understanding of how the environment contributes to ill health, and importantly, how it can promote health for Aboriginal and Torres Strait Islander Australians. However, collecting data on environmental health issues from Indigenous communities is a difficult process requiring much cultural sensitivity (Moran 1997; Trudgen 2000). Recent work has emphasised the need to collaborate with Indigenous people and organisations at all stages of the research process (Australian Institute of Aboriginal and Torres Strait Islander Studies [AIATSIS] 2000; Humphery 2001; NHMRC 2003). This growing body of work has come to be known as the *Indigenous Research Reform Agenda* (Rigney 1999). Issues identified by this agenda include the need for Indigenous participation in the formulation of research and in designing data collection tools, and the provision of timely feedback to communities (Henry et al. 2002). Housing surveys in particular have raised questions of immediate and longer-term benefits to those surveyed (Miller & Rainow 1997).

While those conducting environmental health research in Indigenous communities have many issues to tackle, the experience of dealing with these issues is seldom reported in the literature[1]. Fieldwork experiences are not often considered legitimate research findings, and hence are not published. We think that the practical and ethical challenges of this work will be assisted by the discussion of fieldwork experiences, including sharing information on critical success factors. This paper presents the experiences of researchers in a major study of remote community housing.

The Project

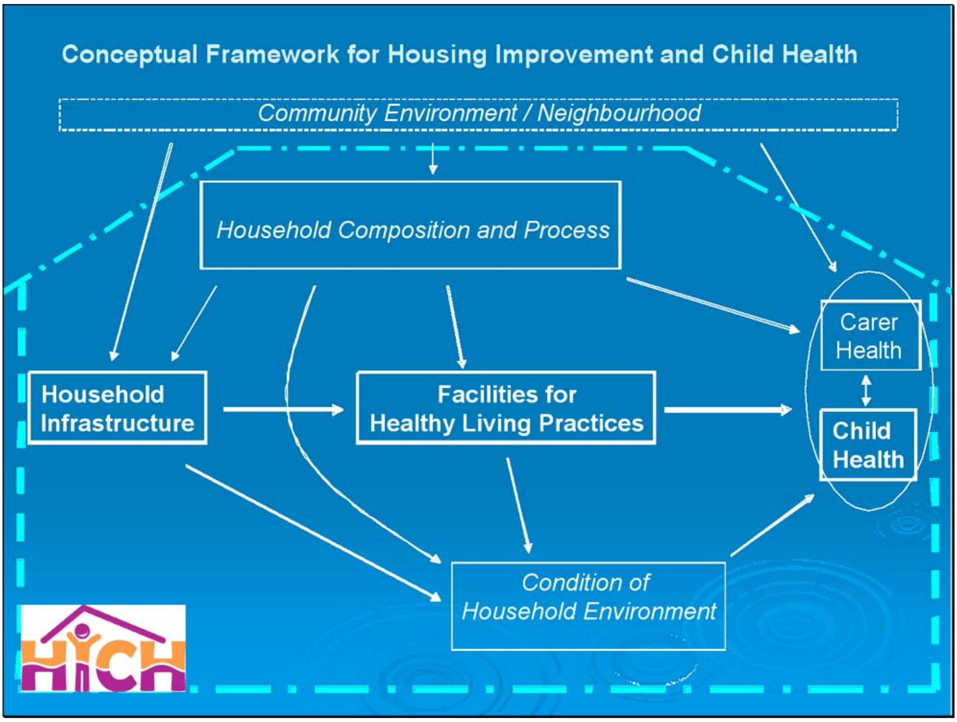
Project aims

The Housing Improvement and Child Health study (HICH) was funded in 2002 by the National Health and Medical Research Council, with additional funding provided by the Northern Territory Department of Community Development, Sport and Cultural Affairs, and the Department of Health and Community Services. The project is a partnership between the Menzies School of Health Research, the Indigenous Housing Authority of the Northern Territory (IHANT) and the participating Indigenous communities. The general aim of the study is to assess the impact of improved housing stock on the health of young children, and to understand the factors that may mediate this relationship. The HICH study builds on previous studies which have indicated that improvements in infrastructure can result in better health outcomes, but which have not been able to provide conclusive evidence (Guthridge et al. 2000; Hardy 1998; Pholeros, Rainow & Torzillo1993).

The HICH study is being conducted in 11 communities in the Northern Territory where there has been a significant injection of new housing stock through the National Aboriginal Health Strategy - Environmental Health Program, and other large infrastructure programs. Improvements in child health will be assessed through a comprehensive household survey in the year before and the year after the injection of new housing stock in the community, and through an audit of children's medical records over the same time period. The comments made in this paper are based largely on the experience of the first round of data collection, as the second round (conducted in the year after new housing stock was built) is still in progress.

The survey design was based on the conceptual framework of the study (see Figure 1). This framework builds on the work of Pholeros and colleagues that identified nine Healthy Living Practices (henceforth HLPs) as an environmental health basis for assessing household infrastructure, or 'health hardware' (Pholeros, Rainow & Torzillo 1993). At the heart of the model, it is recognised that the presence and quality of *Household Infrastructure* determines the ability of residents to carry out HLPs, which in turn determines the health of children living in the household environment. In addition, the framework acknowledges *Household Composition and Process* factors (such as the social and economic circumstances of residents, the number of young children and carers in a household, and the number of people who smoke inside the house), and *Community Environment/Neighbourhood* factors (such as the condition of the general community environment and staffing of key community organisations) as elements influencing the core pathway from household infrastructure to child health. The framework also recognises the *Condition of the Household Environment and Carer Health*, both physical and mental, as important determinants of child health.

Figure 1: Conceptual Framework for the Housing Improvement and Child Health Study



Source: Bailie 2004

Survey design

In order to address all aspects of the conceptual framework, six distinct mechanisms for data collection were designed. The community environment was assessed using a *Community Survey*, which involved direct observation of the community environment and an interview with council staff in the presence of Indigenous councillors. This survey was based on sections of the Community Housing and Infrastructure Needs Survey (Australian Bureau of Statistics 2002a). The household infrastructure, facilities for HLPs and the condition of the household environment were assessed with a detailed *Housing Survey* that incorporated a number of innovative components (see discussion below). Household composition and process were assessed with the *Householder Interview* conducted with the person self-identified as the head of the household, and a *Carer Interview* conducted with those who self-identified as the primary or secondary carer of children under seven years of age. Child health was assessed using the Child Health Interview, conducted with carers, and an *Audit of Medical Records* held in the local community clinic. Figure 2 provides an overview of the variables collected within each of the six elements of data collection.

The Housing Survey

The Housing Survey was based largely on the IHANT Environmental Health Survey and the National Indigenous Housing Guide (Department of Family and Community Services 2003; Runcie & Bailie 2000). It also incorporated a number of innovative elements, in addition to the assessment of whether health hardware could adequately support the HLPs. The aim of these innovations as a whole was to obtain a more functional, contextualised and holistic picture of household infrastructure than most previous housing survey methodologies have allowed, and to control for potential

Figure 2: Overview of Variables collected

Carer Interview
- Children in their care
- Relationship to Householder
- Travel to traditional lands
- Household relocation
- Self-assessed health
- Smoking
- Social support
- Social stress
- Financial stress
- Education
- Employment & income
- Affect & depression risk

Child health Interview
- Houses lived in
- Childcare
- Breastfeeding
- Non-acute health problems
- Episodes of illness

Householders Interview
- Overcrowding
- Travel to traditional lands
- Household members with community positions
- Household relocation
- House maintenance
- Smoking
- Social stress
- Financial stress
- Phone and electricity
- Education
- Employment & income
- Home ownership & rent
- Self-efficacy

Child health record audit
- Presentations with acute illness
- Growth parameters

Housing survey
Detailed assessment of health hardware and software – aimed at determining the extent to which they enabled the conduct of healthy living practices (HLPs)

Community survey
- Community access
- Housing
- Infrastructure
- Staffing
- Public ablution facilities
- Support centres – education, health.

confounding (see Thomson, Petticrew & Morrison 2001).

a) Condition and Function separated

In keeping with the conceptual framework, the hygienic condition of household infrastructure was assessed separately from its function. A focus purely on function might be misleading with regard to the effect of housing on health. A well-functioning house can be hazardous to health if in a poor hygienic condition. Conversely, a poorly-functioning house will have a different effect on the health of householders depending on the state of hygiene (EHP et al. 2004; World Health Organization 2002). Thus the presence of organic contaminants both inside and outside the house was recorded.

b) Health software

The concern of the study with a more holistic approach to household function led to the inclusion of 'health software' items on the Housing Survey. The presence of washing detergent and soap, toilet paper, mops and buckets, and other cleaning products was assessed observationally.

c) Assessment of Infrastructure to support HLPs

The conventional approach to Indigenous housing assessment involves a structured assessment of each component of household infrastructure. Another innovation in the HICH survey was the inclusion, in addition to this structured assessment (Runcie & Bailie 2000), of *overall* assessments of household function and condition. After completing the structured assessment, the researcher would assign an overall score to the household function and the household condition as they relate to the ability of householders to conduct HLPs. The use of both types of assessment in the HICH study will allow the study to explore the potential role of an overall assessment of house function and condition by an experienced surveyor.

d) Focus on function

The more holistic approach to function was also reflected in the scale used to assess each aspect of household infrastructure. Rather than using a dichotomous scale (working; not working), a five-point scale was used: fully functional; minor maintenance needed; major maintenance needed; broken, not working; not present. This approach leads to a more accurate assessment of function than a binary scale. For example, if a nut is missing from a tap handle, a binary scale may record this tap as not functioning, while the HICH Housing Survey would give this a score of 2 (minor maintenance required). This score reflects the fact that householders could still use the tap effectively (and carry out related HLPs) at the time of the survey, but recognises that without minor maintenance, the tap may break in the future.

Householder and Carer interviews

The Householder and Carer interviews used many standard questions from previous surveys of Indigenous people conducted by the Australian Bureau of Statistics, including the National Health Survey (Aboriginal and Torres Strait Islander Results) 2001 and the National Aboriginal and Torres Strait Islander Social Survey 2002 (Australian Bureau of Statistics 2001, 2002b). Below we discuss additional elements that were incorporated into these Interviews, along with related issues of language, pilot testing and ethical review.

Additional elements that were incorporated into the Householder and Carer Interviews included a *Community Position* question. This variable was included in recognition that conventional measures of socioeconomic position might not be appropriate for Indigenous populations (for example, Hunter 1999). This novel question asked whether someone in the household held a position of power in the community (e.g. town councillor, housing committee, or health board member). The Indigenous researcher (HU) suggested this might be a more valid way to assess social status within a community. It might also be a potentially important factor in housing allocation and prioritisation for maintenance work. Other questions aimed at capturing culturally relevant aspects of household composition and process asked whether householders lived on their traditional lands, and if not, how often they visited these lands.

Language

In the 11 communities participating in the study, dozens of Indigenous languages are spoken. It was not technically or financially feasible to translate the Householder and Carer Interviews into all of these Indigenous languages. Instead, plain English was selected as the most appropriate method of communicating with a diverse population of Indigenous people.

Where it was anticipated that questions might be ambiguous or confusing, *alternative equivalent wording* was included on the Interview form. This was particularly useful with psychosocial scales, where it was important to ensure the question was clear, but for methodological reasons the wording could not be significantly changed. Rather than the researchers spontaneously providing alternative wording where they perceived that the meaning was not clear, the team discussed acceptable alternative wording and included this on the form. For instance, under the statement "It is easy for me to stick to my aims and achieve my goals", the plain English word "reach" was suggested as an alternative to "achieve". This approach protected the quality of the data by recognising the need for researchers to use alternative wording when working in a cross-cultural context.

Pilot testing

Developmental versions of the instruments were pilot tested in three communities not included in the main study. Subsequent versions of the instruments, incorporating additional cultural elements discussed above, were piloted at an educational setting in Darwin with Indigenous people from remote communities. This important phase in the development of the data collection process ensured the length of interview was acceptable, enabled the ideal ordering of the questions to be established, and identified areas where ambiguity still remained in the questions. After the first field visit to the first community, further minor changes were made to the survey forms.

Ethical review

Ethical approval was obtained from two Human Research Ethics Committees (HRECs) in the Northern Territory, as the study involves communities in both the Central Australia and Top End regions. Both of these ethics committees had sub-committees comprised wholly of Indigenous people, ensuring that the proposal was satisfactory from an Indigenous as well as a Western ethical perspective. The engagement with the two ethics committees led to some changes in the survey tools used. There was concern about the length of the surveys, and further pilot testing was done to ensure that the Householder and Carer Interviews could be completed in 30 minutes.

The broader issue of benefit to communities was also raised through the HREC process. One aspect of benefit raised was the ability of the project team to ensure that damaged infrastructure was repaired. Unlike some housing projects, this research project was not designed to bring in external maintenance providers. Rather, the project integrates into existing maintenance services in the community. In the long-term, the HICH study aims to contribute to the development of sustainable solutions and capacity building, through the engagement of communities in the survey process and feedback of data in a form desired by community councils and other agencies. In the short-term, the immediate provision of information on requirements for urgent housing repair to the Housing Office (see below) benefited many in the community by facilitating a long-neglected repair. The HRECs also questioned whether the project team was aware of the potential policy implications of the project, and the subsequent need to report findings with sensitivity to ensure communities benefited in the long-term. The resolution of these issues was assisted by face-to-face discussion between the Principal Investigator (RB) and the HRECs, which clarified their concerns and allowed appropriate solutions to be determined. While the process of obtaining ethical clearance was frustrating at times, we believe it led to some improvements in the study design.

Engaging Communities in the Study

Simultaneously with the process of survey design, the research team worked at engaging communities in the study. As mentioned above, community selection was influenced by the degree of housing infrastructure development due to take place over the study period. Communities with more housing construction relative to population size were a priority for inclusion in order to maximise the number of children exposed to improved household infrastructure. Other considerations included architectural diversity, geographic spread, construction timeframes, and a history of previous environmental health upgrades.

Communities identified as potential participants were initially telephoned advising them of the project, with all of those contacted expressing a high level of interest in the research. The telephone calls were then followed up with letters and project information sheets, and the option of a site visit for further consultation. The project team personally knew many of the community council staff that they telephoned, as they had met them or worked with them before in their previous positions (as Environmental Health Officer and Housing Officer). These existing relationships were important to facilitating good communication and thereby establishing trust in the project. In fact, the only instance where a community requested that the project team visit the community to explain the project in person was where a preexisting relationship did not exist. The project was discussed at a meeting of each Community Council before it formally agreed to participate.

Through this consultation process, councils made some suggestions concerning the length of the surveys. They also raised concerns about councils being exposed to criticism in the reporting of results which could potentially lead to reduced funding. Discussions between the research team and council staff were able to establish a common understanding of the issues at stake, and the trust built during these discussions was beneficial to the project as a whole. Continuing engagement of community organisations through discussion of study progress and feedback of findings has also been important in maintaining good relationships.

Remote Indigenous communities are dynamic places, and conditions relevant to the conduct of research can change quickly. Researchers need to maintain frequent contact with communities prior to field visits, and be prepared to change their plans at short notice. Even with the most meticulous planning, unanticipated community events can affect data collection. In one community, although a homicide had occurred in the community the previous week, the council indicated that the community was still happy for the researchers to visit and collect data. During that visit, when research participants were asked as part of the interview, "Has someone dying been a worry for you in the last year?" all respondents answered that it had, illustrating that a single death affects the whole community.

At another community, a death occurred during the field visit. The researcher present suspended data collection and was able to offer to drive community members to the funeral in his vehicle; a gesture that was much appreciated as transport options in remote communities are always limited. This use of project resources for this purpose is an illustration of the Aboriginal and Torres Strait Islander ethical principles of *reciprocity* and *spirit and integrity*, which encompass the need to ensure that communities perceive that they are benefiting from the project, a preparedness to modify the research in light of community needs and aspirations, and the need to show respect for the richness and integrity of Indigenous cultures (NHMRC 2003). An unexpected outcome was that during the next field visit, the researcher was recognised by more community members, assisting with the smooth conduct of fieldwork when it resumed.

Conduct of fieldwork in the communities

Interviews were conducted face-to-face by trained researchers, including an Indigenous man with extensive experience working in the housing sector in many parts of the territory (HU), and a non-Indigenous man with extensive experience working with NT Indigenous communities as an Environmental Health Officer (PD). The first round and part of the second round of data collection was carried out by this team. In late 2004, the non-Indigenous researcher left the project, and a non-Indigenous woman with experience in housing policy in the NT (KL) joined the team.

Engaging community agencies

Prior to the planned visit, researchers would re-send information about the study to the council chairman, and maintain frequent contact with the council to ensure that nothing had occurred in the community (such as a death) that could make the timing of the visit inappropriate. When the researchers arrived at the community, they would first visit the council, and meet with Indigenous councillors, the housing officer, and often the town clerk. Permission would be sought again to conduct fieldwork.

Council workers and representatives would then assist the team in identifying an appropriate community member to work with the team during their field visit. As the study involves approaching people in their homes, this measure was important to ensure that the researchers acted in a culturally appropriate way and community members felt their privacy was being respected. In some cases the person would also act as an interpreter. Often, a Community Development Employment Program (CDEP) worker would be recruited for casual work with the research team. In other communities, an Environmental Health Worker or Aboriginal Health Worker would be identified as the most appropriate person.

Often the casual worker initially identified would not work with the study for the duration of the visit (approximately two weeks), due to conflicting family and cultural commitments, and alternative workers were identified. At times where assistance from a local community member could not be accessed, permission was sought from council representatives to visit houses without a local person accompanying the researchers. Generally, this was acceptable after the team had been in the community for some days.

Approaching potential research participants

All houses in the community were identified using the Serviced Land Availability Plan (SLAP) held in the community housing office. Houses occupied by non-Indigenous people were excluded. The remaining houses were systematically visited and occupants were asked whether children under seven resided in the house. These households were given information about the study and invited to participate. If they consented to participate in the study, the interviews were generally conducted at that time. Most householders preferred to have the Housing Survey done at the same time, while others opted for it to be done a few days later.

As this population has a high rate of mobility, 7.8% of households approached by the researchers in the first round of data collection were not home throughout the field visit (typically a two-week period), and had to be excluded from the study. The rate of refusal to participate among eligible households was low (3.5%). Of those who participated, 5.7% declined access to the inside of the house for the Housing Survey, reflecting the sensitivity of this aspect of data collection.

Informed consent

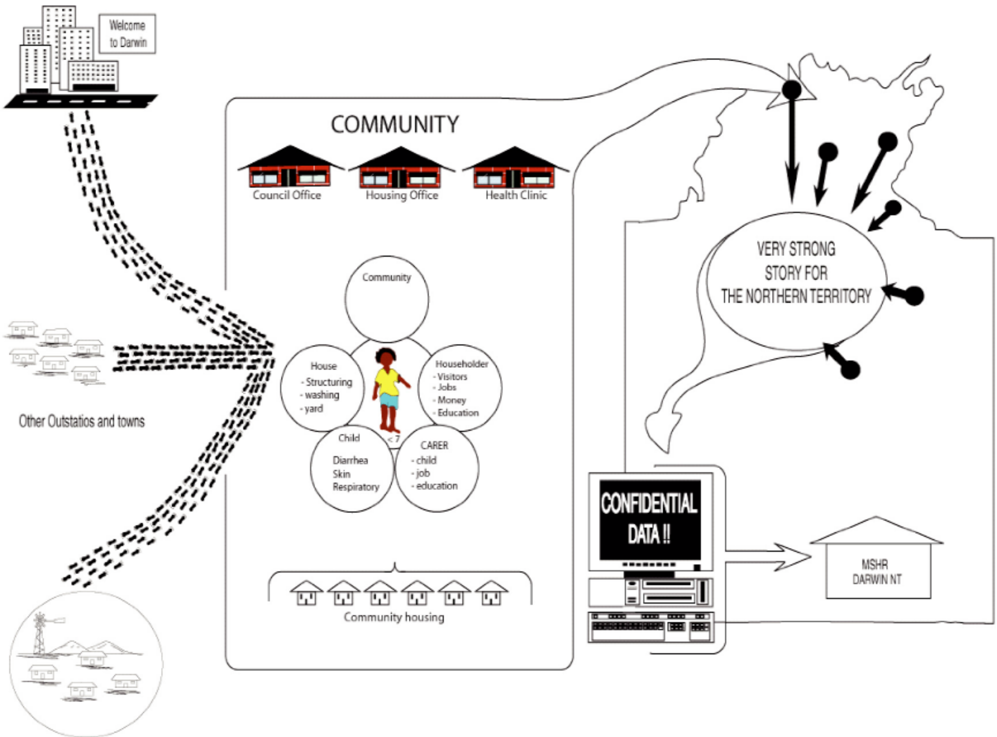
The team is committed to informed consent as a legal and ethical requirement to ensure that participation in the research is voluntary. An important element of this was the provision of a plain English Information Sheet. However, to ensure that participants were appropriately informed of the study, a visual resource was also designed by the Indigenous researcher to enable 'The HICH Story' to be told in a culturally-appropriate way (see Figure 3). A plain English script was devised for either researcher to use in explaining the study. In practice, the script acted as a prompt rather than being followed precisely, but the process of devising the script was important for the team in developing ways to explain the study. The consent process was considered to be an opportunity to engage people in the study as well as an ethical requirement.

The consent form included a checklist of information required to be covered in the consent process. This checklist was useful in reinforcing the information received in the HICH Story and the form was generally read out by the researcher prior to the participant signing it.

Effect of researcher characteristics

The gender and Indigeneity of the researchers had an effect on their ability to carry out the data collection, particularly for the Indigenous researcher. Cultural norms meant it was usually inappropriate for the Indigenous researcher to interview women

Figure 3: Visual resource for telling the HICH story



younger than him, while this was not the case for the non-Indigenous researchers. The ability of the two researchers to work in a team was thus essential.

The Indigenous researcher had family connections in a number of study communities, which assisted with community members being comfortable with the presence of the researchers in the community. The male non-Indigenous researcher had been adopted previously into the East Arnhemland kinship system. Within that region, those kinship connections made both the community members and the researchers more comfortable with the process of approaching potential research participants. The male non-Indigenous researcher would also go to some lengths to indicate his trustworthiness and legitimacy through his actions. For instance, when approaching a house, rather than shy away from any barking household dogs, he would approach the dog, sit down and pat it. This simple action could generate a sense of trust and legitimacy among household members.

The language skills of researchers were also useful in some places. The Indigenous researcher spoke the Indigenous languages in communities in his home region, and the male non-Indigenous researcher had conversational language skills in another region where he had spent some time.

As mentioned above, part way through data collection, the male non-Indigenous researcher left the team and was replaced by a female researcher. Orientation to study instruments and processes, including cross-cultural interviewing techniques and protocols for working in communities was provided by experienced members of the team. This process inevitably impacted on study timelines and budgets as it took some time and required hands-on training and mentoring in the field. However, this attention to the development of cultural competence was considered crucial. Without guidance and mentoring for inexperienced researchers, the research is likely to be more difficult, more time-consuming (and thus expensive), and involve more risks to the project, such as poor participation rates, inaccurate questionnaire data or inconsistent recording of data between researchers, and offending research participants. If it is possible to engage an Indigenous researcher or a non-Indigenous researcher with experience working in Indigenous communities, the enhanced cultural competency of the project team is likely to be rewarded (Kearns & Dyck 2005).

As the above discussion illustrates, recruitment is of the utmost importance for projects such as this one. The researchers must be culturally competent and ideally have experienced both the setting and the subject matter. A team of an Indigenous and a non-Indigenous researcher was ideal, as both Indigeneity and non-indigeneity have advantages in particular circumstances. Within that team, the non-Indigenous researcher must be mindful of the cultural protocols that must be followed and also the particular effects of these protocols on the Indigenous researcher. A well functioning team of an Indigenous and a non-Indigenous researcher can assist in facilitating the trust required for research participants to feel comfortable with potentially sensitive research projects such as this one. Decision support from a principal investigator familiar with the challenges of this research (RB) was also important at times.

Confidentiality

In telling the HICH story, it was important to stress that all the information provided to the researchers would remain confidential. However, within the family group, there was usually no desire for information to be kept from other family members. People preferred to be interviewed in family groups, invariably sitting under a tree outside their house with the senior family members present, and younger members coming and going as interest and responsibility dictated. The family often operated collectively in answering questions posed to one family member. For example, when asked how many cigarettes a person smoked in a usual day, up to five people would all count, confer and agree before a final answer was given to the researcher. Sometimes, discussion within the group was necessary as family members interpreted the questions into the local language, usually younger people translating for older people.

This approach does pose some ethical and methodological issues. Ethically, it was important to stress to the person being interviewed that they could talk to the researchers alone if they wanted to, thus ensuring that the group interview setting was voluntary. One way this was achieved in a culturally appropriate way was to ask the participant if they preferred to be interviewed where they were (sitting in their family group), or if they would prefer to move to a spot nearby.

Methodologically, for most questions it was not a concern if the family group answered collectively, but for some questions such as the psychosocial scales, this was problematic. For these sections of the interview, researchers had to ensure that only the answer of the interviewee was recorded.

Reliability surveys

An important assessment of the reliability of a survey is the stability of results over time. This is assessed using the 'test-retest' method (Streiner & Norman 1995). Ideally, a smaller representative sample of research participants should be asked to complete the interview again, some time (two days to two weeks) after the initial interview was completed. While the answers to some questions may have changed in that time, most of the answers should remain the same if the survey instrument is reliable in a statistical sense.

In practice, this proved difficult to implement. It was challenging to explain why we were asking the same questions again to those approached to complete the reliability surveys. People felt they, rather than the survey instrument, were being tested, and some were resentful. It was also difficult to obtain a representative sample, as finding research participants randomly chosen for reliability surveys was resource-intensive and they would commonly decline to answer the questions again.

Several compromise solutions were devised by the research team. The reliability survey was shortened so that some questions from each section of the interview remained, but fewer questions were asked overall. The researcher would explain that the reliability surveys were to check whether the *researcher* had collected the correct information, rather than whether the participant had answered correctly. The research team also resorted to an opportunistic sample for the re-test data, as achieving a representative sample was not feasible for the reasons discussed above.

These compromises meant that the validity of the test-retest data is less than optimal. This is a good example, however, of the compromises between feasibility and methodological rigour that are inherent to research in this setting. Timely, open and honest discussion within the research team of problems such as these is essential to finding solutions early in the data collection process.

Providing Feedback to Communities

It is important that communities both perceive and receive benefits from health research projects in which they participate (Kimberley Aboriginal Health Workers 1992; NHMRC 2003). There are many forms that these benefits can take, and different stakeholders have different perspectives (Bailie & Paradies 2005). In this project, councils were particularly interested in timely feedback regarding the state of household infrastructure, as they perceived this would be useful in lobbying for funding for additional housing stock. Health centre staff are particularly interested in the Child Health Audit data as a means of assessing their performance and for planning purposes. The research team saw the feedback process as an opportunity to promote environmental health as an essential health development strategy for the whole community. The broader benefits of the study - a better understanding of the relationships between child health and the household - will have a delayed effect on communities, for example, through the development of maintenance, 'homemaker' support and housing allocation processes that maximise health benefits for the community.

As part of the research team's concern that communities both perceived and received benefits from the study, five levels of feedback were planned and budgeted for from the outset (see Table 1).

Table 1: Five levels of community feedback

Timing of feedback report	Audience	Content of report
1 At the end of data collection visits	Housing Office	All repairs required, with urgent repairs highlighted
2 After first round of data collection in community	Council (including Housing Office), health clinic	Aspects of household infrastructure, centred on the ability of householders to perform Healthy Living Practices
3 After second round of data collection in community	Council, health clinic	Changes in aspects of household infrastructure between the two rounds of data collection, centred around HLPs
4 After Child Health Audit in community	Council, health clinic	All community results including changes across study period; comparative data on community infrastructure.
5 After data collection in all communities completed	Council, health clinic, other agencies (e.g. school), whole community	Results for entire study (centering on aspects of concern to each community)

All feedback reports were designed to present a manageable amount of information, to be meaningful to the audience and to be useful for their purposes. An important issue was the comparison of results between communities within the study, and the comparison of study communities to non-Indigenous household data. It is often said that remote Indigenous communities do not like being compared to other communities, and particularly resent being compared to mainstream communities. This relates to communities being inundated with negative stories that can be detrimental to community esteem (Brough 1999). Thus sensitivity and consultation were required to balance the need to provide useful and accurate information and the need to present results in an acceptable and constructive manner.

One solution to this is to concentrate on the change in results over the study period within a community. As new houses have been built in all study communities, all communities that have received the third round of feedback to date (five communities) have experienced improvements in household infrastructure over the study period. Thus the feedback reports can include a positive story, and positive validation can be provided to the housing office and council. This facilitates the communication of more confronting findings in a constructive way.

Another strategy has been to use the concept of ranking study communities, rather than comparing them to non-Indigenous data. Communities are ranked for selected data items, and communities are informed of where in the ranking their community was positioned. The community can thus be informed in a sensitive and constructive way of whether an issue is a particular problem, or whether they are doing relatively well. The issue of what to feed back and what form this should take clearly requires ongoing consultation with all study communities, as communities have different interests and preferences.

Conclusion

Our experience of conducting research in remote Indigenous communities has been rewarding, but not without significant methodological, ethical and personal challenges. Methodological decisions regarding the language and length of surveys must balance data quality and acceptability with data quantity and detail. Although these decisions must be initially made at the stage of project design, they will inevitably be revised in response to ethical review, community consultation and pilot testing.

In the conduct of data collection, the context of remote Indigenous communities raises particular issues for engaging local research assistance, approaching potential research participants, gaining informed consent, confidentiality, and assessing survey reliability. We consider the two single most important factors for addressing these issues are careful recruitment of the research team, and the need for flexibility in responding to changing community conditions.

Ongoing research and evaluation have an essential role in addressing the poor state of environmental health in remote Indigenous communities. However, as we have demonstrated, research in this setting poses numerous challenges. Building the body of research literature that discusses these challenges will contribute to developing research and evaluation knowledge and skills in this critical area.

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Endnotes

1 Fieldwork experiences in other areas of Indigenous health have been described, however. See Donavon & Spark 1997; Holmes et al. 2002; Eades & Read 1999; Henderson et al. 2002.

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Public Opinion of a Proposed Wind Farm Situated Close to a Populated Area in New Zealand: Results from a Cross-sectional Study

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In accordance with New Zealand's Resource Management Act 1991, in 2003, electricity generating company Genesis Energy made public its intention to apply for consent to build the Awhitu wind farm. Several community groups claiming to represent the majority opposed this application and in September 2004 consent was declined. The aim was to investigate the attitudes of local community members to the proposed wind farm. A survey was mailed to 500 Franklin residents, systematically selected from the local 2004/2005 telephone directory. Forty questionnaires were returned undelivered. Of the remaining 460, completed questionnaires were returned from 46% (211). Most, 70% (145), residents supported a wind farm being built in their area, with 17% (35) neutral, and only 13% (28) against the farm. There was no statistical difference in respondents' attitudes between sex, age, or residential proximity to the farm. Respondents listed renewable resource (83%), suitability (78%), and environmental friendliness (76%) as main advantages. Visual unsightliness (24%) and noise pollution (21%) were listed as main perceived disadvantages. Contrary to the assertions of several lobby groups, the majority of local residents support the construction of the Awhitu wind farm. Scientifically robust methods are essential to measure appropriately community attitudes, particularly on contentious issues.

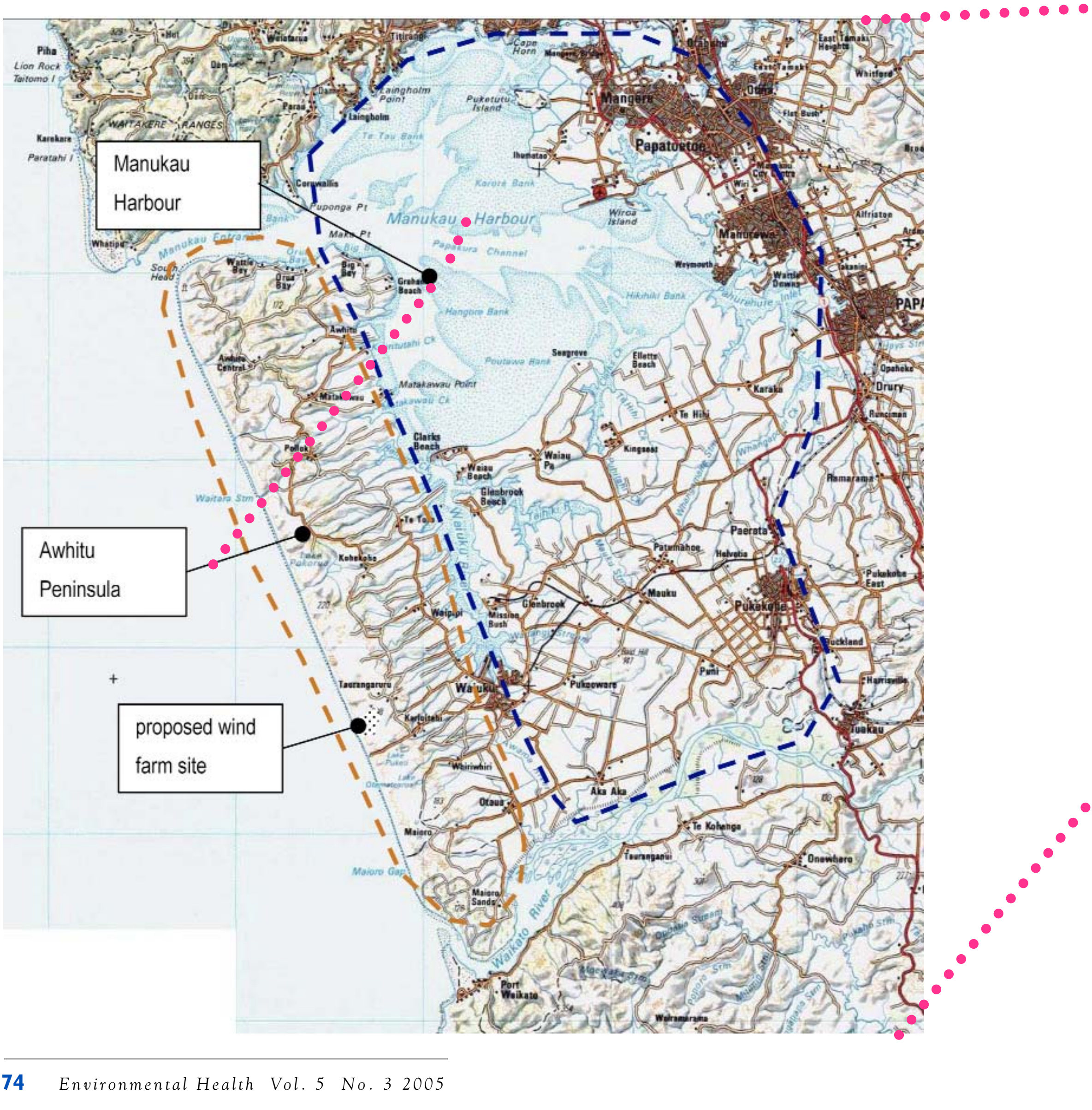
Key words: *Wind Farm; Community Attitudes; Cross-sectional Study; Noise Pollution; Perception*

The demand for electricity in New Zealand has steadily increased since 1974, particularly in the North Island north of Lake Taupo (Leyland 2004). Since the commissioning of the Clyde hydroelectric power station in 1993, thermal plants have provided the bulk of the increase in the required electricity generation (Ministry of Economic Development 2005a). In order to meet the current and predicted demand growth in electricity demand rates, it is estimated that 320 megawatts (MW) of new electricity will be required by 2025 (Leyland 2004). Advances in energy demand efficiencies and savings through better electricity utilisation are included in this estimate.

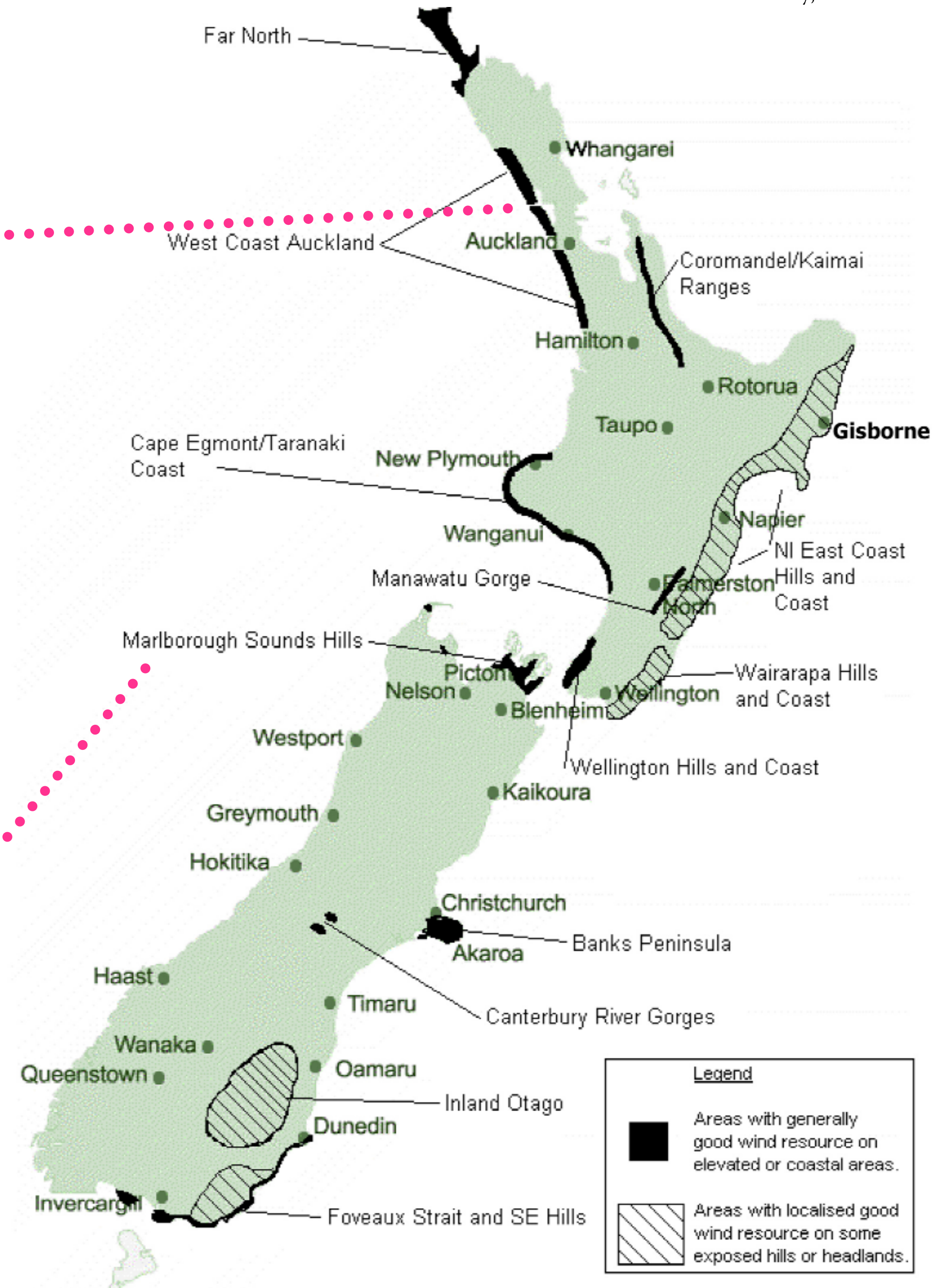
The increase in predicted demand has prompted efforts throughout New Zealand to seek new and alternative generation options. These efforts include new wind farms in the Tararua Ranges, possible re-commissioning of the oil fired Marsden Power Station and various other projects (Ministry of Economic Development 2005b). In 2004, Meridian Energy, New Zealand's largest electricity generator (Meridian Energy 2005a), abandoned its plans to develop a hydro generation scheme in the South Island (Project Aqua). Project Aqua had been considered New Zealand's largest new renewable generation option (Meridian Energy 2003). Instead, Meridian Energy focused on developing two wind farms, one in each of the North and South Islands of New Zealand, with a total capacity of approximately 280 MW (Meridian Energy 2005b). This choice was made because New Zealand has a significant wind energy resource with relatively strong winds throughout the year and is considered well suited to wind energy development (Figure 1) (Energy Efficiency Conservation Association 2001).

Wind farms are a relatively new phenomenon in New Zealand and there is little statistical information on public opinion to these farms, and even less on public opinion to the proposed development of such farms. To date there are two studies which have explored the public opinion of New Zealanders to wind energy and the existing Tararua wind farm (Berg 2003;

Figure 1: Locations in New Zealand believed to be most suitable for wind energy development (Energy Efficiency Conservation Association (EECA), 2001) with the proposed Awhitu wind farm location inset



Energy Efficiency Conservation Association 2004). The Omnibus Wind Survey conducted in 2004 found that wind power is the public's preferred generation option to meet New Zealand's future electricity needs, with 60% of respondents expressing some level of support for building a wind farm in their local area (Energy Efficiency Conservation Association 2004). The main reason cited for favouring the building of a local wind farm was the perceived benefit for the environment. Conversely, the main



reason cited for opposing the building of a local wind farm was the perceived visual and auditory impact. Common arguments used to oppose the Tararua Wind Farm included anticipated adverse effects such as a noise, electro-magnetic interference (EMI), visual intrusion and land devaluation (Berg 2003).

The New Zealand findings are comparable with those garnered overseas. One of the most commonly cited and contentious issues surrounding wind farms is their visual impact on the landscape (Braunholtz 2003; RBA Research 2002). However, in Scotland, twice as many people think that their local wind farm has had a positive impact on the landscape as think it has had a negative impact (Braunholtz 2003). In a United Kingdom community, three quarters of local residents support their wind farm (RBA Research 2002). The most frequently mentioned benefits of this wind farm is that it is both good for the environment and non-polluting (RBA Research 2002). A United States study of a yet to be developed wind farm in the Appalachian Mountains found that Western North Carolinians were favourably disposed towards the development of a wind energy industry. For those who oppose wind energy development, the overwhelming problem noted was aesthetics (O'Grady 2002).

The Awhitu Peninsula situated within the Franklin district, West Coast Auckland, New Zealand, has been identified as having significant wind energy generation potential (Energy Efficiency Conservation Association 2001). This area is also considered ideally located, being proximal to Auckland, and a heavy electricity using centre (Figure 1). A site within this area was identified by Genesis Energy for the development of a wind farm (known as the Awhitu wind farm). Its proposed location was on a privately owned farm, approximately 6km west of the township of Waiuku. The proposed 19 wind turbine structures had a maximum overall height (including the rotor) of 90 metres from the base of the structure and a maximum hub height (excluding the rotor) of 62 metres from the base of the structure. The turbines were to have a nominal capacity of between 600 and 1500 kilowatts each, while the total installed capacity for the new development was expected to be within the range of 15 to 25 MW.

An assessment of environmental effects from the Awhitu wind farm was submitted by Genesis Energy at the resource and subsequent environment court hearings (Genesis Energy Ltd 2004). The assessment was wide-ranging and examined the natural character, traffic, noise, archaeological aspects, radio service, property values, birds, turbine safety, public health, and effects on animals (Genesis Energy Ltd 2004). Individuals and groups opposing the wind farm, also made submissions on these and other environmental effects, which included cultural effects (tangata whenua), bird kill, erosion, shadow flicker, traffic, radio services, decommissioning, health, noise, and emissions (Genesis Energy Ltd and Franklin District Council 2004). One key element of the opposing submissions was the claim that a significant majority of the local population opposed the construction of the wind farm (Waiuku Wind Farm Information Group 2004b). As a consequence of these opposing submissions, the application for consent was declined in September 2004.

Upon closer scrutiny, the surveys purporting to be statistical studies reflecting public opinion on wind farms (Environment Court 2004; Hobbs 2004; Waiuku Wind Farm Information Group 2004a) appeared to be seriously methodologically flawed and likely to produce biased findings. Several of these studies were conducted by partisan interviewers, using non-probability convenience sampling methods with a verbal unstructured survey instrument and no follow-up strategy. Target populations were commonly undefined, sample sizes were small, information about the number of residents approached was lacking, and the practice of reporting important demographic information (such as sex and age) was ignored. It is widely recognised that elicited data from verbally conducted convenience samples invariably lacks objectivity, validity, reliability, and data quality despite any good intentions of an interviewer (Kish 1965). Moreover, without information about the target population, the numbers refusing the survey, or the participants' demographic information, it is impossible to determine whether the survey results are representative or generalisable (Rothman & Greenland 1998). Evidence from the Omnibus Wind Survey suggested that the pattern of response was likely to be substantially different from that tabled at the resource and Environment Court hearing (Energy Efficiency Conservation Association 2004). In an effort to understand fully public opinion on the matter, this study was instigated. Using robust statistical methods and sound epidemiological principles, this study sought to measure public opinion on the proposed Awhitu wind farm from residents living in close proximity to the site.

Methods

Study population

The study population is Franklin district residents listed in the Franklin 2004/2005 local telephone directory.

Study design

A cross-sectional survey of 500 sampled residents was undertaken; the logistic maximum possible. Residents were selected using a randomised systematic approach. Specifically, the directory contains approximately 16 000 phone and address listings. A starting point page number was randomly selected using random number tables, and then every 30th residential listing was selected for the survey. A covering letter describing the survey (and a $50 dollar lottery incentive for the return of a completed questionnaire), the questionnaire, and the self-addressed prepaid envelopes were mailed to the 500 selected residents. Two articles appeared in the local free Franklin County News informing and prompting selected participants to return completed questionnaires, one timed when the questionnaires were initially mailed, and the second two weeks later. As the questionnaires could be returned anonymously, no formal reminder strategy could be used to target individual non-responders. Any household resident over the age of 18 years was invited to complete the questionnaire.

Survey instrument

The questionnaire contained seven groups of questions relating to wind farm attitudes and perceptions, in addition to sex and age range (elicited in five age-bands), over two pages. Participants were asked, if they had visited a wind farm with more than one turbine (Yes/No), and how they felt about a wind farm being built in the Waiuku area (responses on a 5-point Likert scale from strongly against to strongly in favour). They were asked what the perceived main advantages of the wind farm were: environmental friendliness; low cost; renewable resource; employment opportunities; and well-suited to New Zealand (each option having a No/Yes/Not sure option and room for additional comments). What were the perceived main disadvantages of the wind farm: unsightly; requires too much space; noise pollution; disadvantage to wildlife; and bad location (each option having a No/Yes/Not sure option and room for additional comments). Participants were asked to comment on their feelings about the Awhitu wind farm under the following conditions (with responses on a 5-point Likert scale from strongly against to strongly in favour): if you can't see or hear the wind turbines from your property; if you can't hear the wind turbines but can see them as distinct features from your property; if you can't hear the wind turbines but can see them as an obvious feature from your property. Lastly, respondents were asked "which of the following factors has most influenced your views about the proposed Awhitu wind farm?" Response options were: environmental friendliness; low cost; renewable resource; employment opportunities; well-suited to New Zealand; unsightly; requires too much space; noise pollution; disadvantage to wildlife; bad location; other.

Statistical analyses

Frequencies and percentages were reported for all categorical variables. To accommodate small expected cell count sizes, comparisons of categorical variables between groups was made using Fisher's exact test. A significance level of P-value ≤0.05 was used to define statistical significance. All data were analysed using statistical software package MINITAB Release 14.

Ethics

The local AUT Research Ethics Committee provided clearance for this study (clearance number: 04-153).

Results

Overall, 500 household residents were posted questionnaires, but 8% (40) were returned by New Zealand Post with the message return to sender. Of the remaining 460, completed questionnaires were returned from 46% (211). Responder demographics included 49% (98) females. The age distribution of 18-25 years was 3% (7); 26-39 years, 14% (29); 40-55 years, 38% (76); 55-70 years, 30% (60); and 70+ years, 14% (29). Demographics determined from the 2001 Census for the Waiuku region revealed that 51% were female, and of those aged 15 years and over, 84% were aged under 65 years and 16% were 65+ years of age (Statistics New Zealand 2003). Only 24% (50) had ever visited a wind farm with more than one turbine in the past.

Where possible, the data were partitioned by whether respondents resided outside or inside the Waiuku region, the vicinity of the proposed farm. Sufficient contact details were available from 149 survey forms to allocate their geographical location, 107 outside the Waiuku region and 42 from inside Waiuku.

Attitudes to a wind farm being built in the Waiuku area

The distribution of Franklin residents' attitudes towards the proposed wind farm being built in the Waiuku area appears in Table 1. Overall, 70% (145) Franklin residents support a wind farm being built with the majority 56% (116) declaring strong support. A further 17% (35) of Franklin residents were neutral (neither for nor against), and only 13% (28) residents were against the building of the proposed farm.

Table 1: Distribution of responses to the question "How do you feel about a wind farm being built in the Waiuku area?" and partitioned by whether respondents lived inside or outside the Waiuku region

	Overall (N=208)		Resident outside Waiuku region (N=105)		Resident within Waiuku region (N=42)	
Response	n	(%)	n	(%)	n	(%)
Strongly against	20	(10)	8	(8)	6	(14)
Weakly against	8	(4)	4	(4)	2	(5)
Neutral	35	(17)	16	(15)	5	(12)
Weakly in favour	29	(14)	18	(17)	5	(12)
Strongly in favour	116	(56)	59	(56)	24	(57)

There was no statistically significance difference in the distribution of attitude between responders across sex or age groups. Moreover, no statistically significant differences emerged in the pattern of response from those participants residing inside or outside the Waiuku area (Table 1). While not statistically significant, 78% (39) of those who had ever visited a wind farm with more than one turbine in the past were in favour of the proposed farm compared to 68% (109) of those who has never visited such a farm.

Attitudes to seeing and hearing wind turbines from respondents' properties

Participants were next asked to respond to a series of scenarios pertaining to their attitude about seeing and hearing wind turbines from their property. Table 2 summarises the pattern of responses to these questions.

Table 2: Pattern of responses for attitudes to a wind farm being built in the Waiuku area under three auditory and visual scenarios

	Cannot see or hear wind turbines from your property (N=205)		Cannot hear but see in the distance wind turbines from your property (N=204)		Cannot hear but see as an obvious feature wind turbines from your property (N=203	
Response	n	(%)	n	(%)	n	(%)
Strongly against	16	(8)	21	(10)	25	(12)
Weakly against	6	(3)	7	(3)	15	(7)
Neutral	35	(17)	34	(17)	37	(18)
Weakly in favour	21	(10)	27	(13)	35	(17)
Strongly in favour	127	(62)	115	(56)	91	(45)

The majority, 62% (126), of Franklin residents declared that they supported a wind farm in the Waiuku area, even as an obvious feature from their property, with many, 45% (91), declaring strong support. A further 18% (37) of Franklin residents were neutral (neither for nor against) a wind farm as an obvious feature and only 20% (40) of respondents were against. Again, there were no statistically significant differences in the pattern of response for any of these three scenarios across sex, age, or place of residence. Of those who had ever visited a wind farm with more than one turbine in the past, 88% (42) responded in favour of the scenario of having a wind farm built that cannot be heard or seen from their property, 74% (35) responded in favour of the scenario of having a wind farm built that cannot be heard but seen in the distance from their property, and 76% (36) responded in favour of the scenario of having a wind farm built that cannot be heard but seen as an obvious feature from their property. This compared with 68% (107), and 57% (89), respectively, of respondents who had never visited such a farm in the past; a difference that was statistically significant for the first and third scenario.

Respondents perceived advantages and advantages of the proposed wind farm

Table 3 houses the pattern of response to a list of perceived advantages and disadvantages associated with the Awhitu wind farm.

Table 3: Pattern of responses to participants perceived main advantages and disadvantages of the proposed Awhitu wind farm

	No		Yes		Not sure		No response	
	n	(%)	n	(%)	n	(%)	n	(%)
Perceived main advantages								
Environmental friendliness	18	(9)	161	(76)	16	(8)	16	(8)
Low cost (comparable to coal/oil/gas)	16	(8)	137	(65)	43	(20)	15	(7)
Renewable resource	6	(3)	173	(82)	15	(7)	17	(8)
Increased employment opportunities	43	(20)	83	(39)	57	(27)	28	(13)
Well suited to New Zealand	10	(5)	164	(78)	20	(9)	17	(8)
Perceived main disadvantages								
Unsightly	108	(51)	51	(24)	31	(15)	21	(10)
Requires too much space	121	(57)	24	(11)	36	(17)	30	(14)
Noise pollution	91	(43)	44	(21)	55	(26)	21	(10)
Disadvantages to wildlife	118	(56)	32	(15)	38	(18)	23	(11)
Bad location	117	(55)	26	(12)	36	(17)	32	(15)

Respondents ranked the renewable resource advantages of the proposed wind farm the highest, 83% (173), closely followed by the suitability of such farms to New Zealand, 78% (164), and the perceived environmental friendliness, 76% (161). Unsightliness was the highest ranked main perceived disadvantage of the proposed wind farm for nearly a quarter of respondents, 24% (51), followed by noise pollution, 21% (44). Only 12% (26) of residents thought the location of an Awhitu wind farm was a main disadvantage. Again, there were no statistically significant differences in the pattern of response across sex, age, or location of residence in relation to the Waiuku area. There was no statistical difference between the distribution of response for perceived main advantages of the proposed Awhitu wind farm between those who had visited a wind farm with more than one turbine in the past and those who had not. Specifically, 74% versus 78% of respondents considered environmental friendliness a main advantage, 62% versus 67% of respondents considered low cost, 92% versus 79% of respondents considered renewable resource, 40% versus 38% of respondents perceived employment opportunities, and 82% versus 76% of respondents considered the suitability of New Zealand as main advantages, respectively. Similarly, there was no statistical difference between the distribution of response for perceived main disadvantages of the proposed Awhitu wind farm between those who had visited a wind farm with more than one turbine in the past and those who had not. However, those ever visiting a farm generally tended to have fewer perceived disadvantages of the proposed Awhitu wind farm than those never visiting such a farm, with: 20% versus 26% of respondents concerned about unsightliness; 6% versus 13% of respondents concerned about space; 18% versus 22% of respondents concerned about noise; 12% versus 16% of respondents concerned about wildlife; and 16% versus 11% of respondents concerned about location, respectively.

Discussion

A clear majority (70%) of Franklin residents supported the proposed wind farm in the Waiuku area. Indeed, only 13% of residents were opposed to the proposal. These results are consistent with the recent Energy Efficiency Conservation Association (EECA) nation-wide omnibus survey (Energy Efficiency Conservation Association 2004) which found that 60% of respondents were in favour of having a wind farm built in their local area. Sub-group analysis revealed no statistically significant or important differences in the pattern of support for the wind farm across sex, age categorisation, or whether respondents lived in the Waiuku area (close in proximity to the proposed farm) or outside this area. The sub-group analyses are important in determining whether the wind farm support is general or sex, age, or proximity specific.

More than half (62%) of the Franklin residents reported that they supported a wind farm in the Waiuku area even if it was an obvious feature from their properties. Leventhall's 2004 report on low frequency noise from wind turbines asserted that the anticipated noise from the proposed Awhitu wind farm would be negligible (Genesis Energy Ltd 2004). Thus, a specific question about noise being heard from residents' properties was not included in the scenarios determining attitudes to seeing and hearing wind turbines. However, nearly a quarter of respondents considered noise pollution to be a perceived problem. It might be anticipated that if the wind farm is granted resource consent and the turbine noise is indeed negligible then the proportion of respondents who consider noise pollution an associated problem with wind turbines would decrease.

On the basis of the survey respondents concerns, Genesis Energy has subsequently proposed a number of mitigation measures. These include screening measures, such as the planting of trees, and moving of turbines to less visible and topologically sensitive (rather than linear or grid-like) positions. Public relations and education measures focusing on individuals rather than group delivery is also to be conducted. However, the specifics of these latter exercises are the subject of further research.

The main advantage of an Awhitu wind farm identified by 82% of Franklin residents was that it is a renewable resource. Franklin residents also thought an Awhitu wind farm was well suited to New Zealand, along with environmental friendliness being identified as main advantages with 78% and 76%, respectively. Groups opposing wind farms often ascribe the attributes of unsightliness, noise pollution and disadvantages to wild life. However, in this study the majority of Franklin residents did not associate this with the Awhitu wind farm. Visual unsightliness was a concern for 24% of respondents, while 21% considered noise pollution as main perceived disadvantages. In addition, Franklin residents did not consider the space required or the location to be issues.

Those respondents who had visited a wind farm with more than one turbine in the past appeared more receptive to the construction of the Awhitu wind farm than their counterparts who had never visited such a farm. These respondents had significantly more favourable attitudes to the building of this farm under two auditory and visual scenarios, and although not statistically significant, appear to be more predisposed to the wind farm, its perceived advantages, and had fewer perceived disadvantages. While it is difficult to argue that wind farm visits change people's perceptions as those to visit such farms are likely to be more predisposed to this form of energy generation than those who do not visit wind farms, the experience clearly did not impact negatively on respondents' attitudes and perceptions. Wind farms are a relatively new phenomenon in New Zealand, and most people have little if any long-term experience of them. It could be argued that with experience, residents' naturally suspicious attitudes and potentially negative preconceptions of wind farms might be found to be baseless and thus alleviated.

Strengths of this study include the methodological rigour in design, using robust probability sampling methods and the relatively large yet targeted sample size. However, the study also suffers from weaknesses including a moderate response rate (46%). It may be argued that this response rate implies that the findings lack representation and cannot be generalised across the population. We assert that this is not the case. The age and sex distributions of the respondents have good representation and are similar to the demographics determined from the 2001 Census for this region (Statistics New Zealand 2003). Moreover, individuals with stronger opinions, either negative or positive, tend to be more motivated to respond to surveys and thus it can be assumed that non-responders are likely to be more neutral (Kish 1965). The positive pattern of response was emphatically demonstrated from our findings and consistent with those previously determined (Energy Efficiency Conservation Association 2004). Thus, we argue that these results have both utility and can be generalised across the population (Rothman & Greenland 1998) and are important in describing the public's perception of wind farms. The response rate might have been improved if non-responders could have been individually targeted with timely reminders. However, this could only be achieved if questionnaires were not returned anonymously. Given the heightened level of agitation and disparate opinions within the local community on this issue, the option of returning questionnaires anonymously was considered vital so that responders could respond honestly and without fear of identification or the threat of reprisal.

Conclusion

Further research will examine the changes in attitudes of the Franklin residents should the proposed wind farm gain resource consent and be constructed. We intend to investigate changes in the public's perception over time to determine whether the strong support elicited in this survey is maintained or whether it fluctuates in some way.

In conclusion, the results of this survey indicate that the majority of residents support the construction of the wind farm in the area even when it is an obvious feature from their property. The majority of Franklin residents think that the advantages of a wind farm are its status as a renewable resource, environmental friendliness, low cost, and its suitability to New Zealand. The majority of Franklin residents do not believe that the proposed Awhitu wind farm would be unsightly, requires too much space, produces noise pollution, would disadvantage wildlife, or that it is in a bad location. The difference between the results of this survey and those of a convenience sample presented to the resource hearing and the Environment Court emphasises the need for rigorous statistical conduct and review before statements about a community's 'majority view' can be appropriately declared.

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