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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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Call for Papers

The Journal is seeking papers for publication.

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.

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

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

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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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EDITORIAL

In this issue continue some of the themes of previous issues, and are particularly fortunate to have another article by Doggett et al. on the recent resurgence of bed bugs in Australia. The authors are particularly keen that this information is disseminated as widely as possible to environmental health professionals. Risk management has become a key concept and practice in environmental health, and this is addressed in the paper by Panikkar et al. on the need to find alternate methods of treating domestic waste because of the cost of disposal and the health issues that originate from the mismanagement of waste. This paper focuses on comparative risk evaluation of domestic biowaste management, particularly that using vermicomposting. Two different risk evaluation techniques, risk evaluation matrix and risk score calculator from two sources are utilised. It is shown that vermicomposting is a viable and low risk option for waste management. Bushfires and forest fires are relatively common environmental phenomena in Australia leading to high ambient concentrations of particulate matter. In Sydney in 1994, there were major bushfires on the outskirts of the city with a haze of smoke over the entire city. This environmental disaster provided an opportunity for Jalaludin et al. to observe the effects of bushfire smoke, as measured by particulate matter less than 10 microns on the prevalence of evening respiratory symptoms and beta agonist use in children with a recent history of wheezing.

In the Practice, Policy and Law section of the Journal, we have two articles on understanding and knowledge of sustainable development at the local level. Lloyd-Smith looks at how to protect communities better from hazardous chemicals and how to support their involvement in the decision making processes that affect them. There are many obstacles to effective participation by the community, including limited access to information and expertise. This paper introduces community capacity building through the development of community based information systems to support informed environmental decision making in toxic disputes. Hardy-Holden and Dyer assessed the link between sustainable development and a Rates Rebate Scheme that fosters environmental health by rewarding retention and maintenance of valued habitat in Cooloola Shire, South East Queensland. It found that there was a dearth of understanding of the term 'sustainable development' among the general public. Remaining in Queensland, Adams and Langley examine two outbreaks of scombroid poisoning on the Sunshine Coast and discuss some of the problems and key issues to be considered when investigating outbreaks of this disease. Scombroid poisoning is a food-borne illness resulting from the consumption of certain species of spoiled fish. It is arguably the major cause of food-borne illness from fish consumption, but it is under-reported and misdiagnosed as fish allergy. Still in Queensland, Earl continues with his work on the influences on crowd behaviour at outdoor music festivals. Bi et al. are concerned that climate variations play a role in Ross River virus infection and attention should be paid to preventative measures, given the probable effects of global warming. The results show that temperature, rainfall and high tides are possible contributors to transmission of the virus. Moving from Queensland to South Australia, Fearnley et al. are concerned with water usage in a residential recycling initiative. They provide an example of an innovative wastewater reuse initiative. Storm water, grey water and sewage are collected and treated at an onsite, small package treatment plant, then recycled for irrigation and toilet flushing. Still on water but this time in Iran, Nanbakhsh looks at fluoride in drinking water and its health importance.

AIEH 31st National Conference in Melbourne: 18-20 October 2004

Environmental health leadership is the theme of the 31st National Conference, to be held in the Melbourne Park Function Centre. Leadership will be explored through a policy, planning and practice perspective. It will also incorporate the first meeting of the International Federation of Environmental Health Asia and Pacific Rim Group.

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Heather Gardner
Editor

Environmental Health Leadership
through
Policy, Planning and Practice

The Australian Institute of Environmental Health invites you to attend the 31st National Conference at Melbourne Park Function Centre, Melbourne, Victoria on the 18th — 20th October, 2004.

This 3 day conference will showcase the latest in environmental health policy, planning and practice, nationally and internationally.

Who should attend?

The work of the environmental health professional crossea many borders and this conference program will be aimed at a wide audience of environmental health and associated professions. Participants will include environmental health practitioners, managers, business and industry representatives, consultants, researchers, educators, regulators and finance and risk managers.

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Risk Management in Vermicomposting of Domestic Organic Waste

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There is a worldwide need to find alternate methods of treating domestic waste because of the cost of disposal and environmental and human health issues that primarily originate from the mismanagement of putrescible waste. Composting has been accepted as a productive and eco-friendly way to manage the waste materials, but there are environmental and human health risks. This paper focuses on comparative risk evaluation of domestic biowaste management, particularly that using vermicomposting, against direct reuse of putrescible and human wastes; and traditional treatment of human wastes, such as using septic tanks. The paper is based on a prototype vermicomposting unit developed as part of a whole-of-waste approach for domestic waste management in the developing and rural world. Two different risk evaluation techniques, namely, risk evaluation matrix and risk score calculator from two sources are utilised. It is shown that vermicomposting is a viable and low risk option for waste management that reduces costs compared to other systems, that it provides reusable products, and is capable of being used at a residential scale.

Key words: *Vermicomposting; Putrescible Waste; Blackwater; Pathogens; Human Health; Risk Evaluation.*

Composting is a waste management technique that is many centuries old (Haddon 1993; Haug 1993). Composting, the controlled biodegradation of organic wastes into a humus-like product (Bluestem 1997a), manipulates the processes of biodegradation in a controlled environment. It has a preferred position in the hierarchy of integrated solid waste management (ISWM) (Beukering & Gupta 2000; Bluestem 1997b). The by-products of composting contain nutrients and compost is well known as a fertiliser and soil conditioner.

This paper is concerned with the risks associated with the use of vermicomposting as a total waste management approach for individual residences and small communities in rural areas and in the developing world. The paper explores the risks associated with vermicomposting, compares the risks of different waste management techniques, and reviews the benefits of vermicomposting. A brief discussion on pathogen removal achieved in composting is also presented. Some preliminary results of tests conducted on a vermicomposting prototype were presented at ORBIT 2003 conference (Panikkar et al. 2003a) and will not be repeated in detail in this paper.

Microbial Composting and Pathogen Removal

The microorganisms that reside on organic material can mutate and adapt to treat a wide variety of organic and inorganic compounds and subsequently degrade them (Haug 1993). Microbial composting achieves pathogen reduction through an increase in temperature via the actions of composting microbes and competition between species. Composting using worms (vermicomposting) is faster and gives a

better end product (vermicastings) than composting that is solely microbial-based (Department of Natural Resources [DNR] 2001; Dominguez et al. 1997; Eastman 1999; Panikkar et al. 2003a).

An important aspect of biological waste treatment is the reduction of pathogens such as disease-causing bacteria, viruses, or protozoa. In microbial composting, pathogen destruction is a result of competition with composting microbes for the available nutrients, high temperatures encountered due to thermophilic stages and some of the intermediate metabolites secreted by microbial respiration (Farrell 1993; Sidhu et al. 2001; WaterWatch 1999).

Haug (1993) reported that approximately 14.65 kJ energy is released for every gram Chemical Oxygen Demand reduced in microbial composting. This release of energy causes the temperature build-up that in turn increases the rate of material conversion and thermal inactivation of pathogens. Excessively high temperatures inhibit bacterial growth (microbial suicide) with only a few species of thermophiles showing metabolic activity at temperatures above 70°C (*bacillus stearothermophilus*, *bacillus subtilis*, *clostridium sp*. and non-sporogenous gram negative aerobe of genus *thermus*). Optimum temperatures vary between 45-55°C (de Bertoldi et al. 1983). Other researchers claimed that 55°C for three days was enough for pathogen reduction to acceptable levels; reducing pathogens considerably even in the cooler regions in the composting mass (Stentiford 1986). Most species of microorganisms cannot survive at temperatures above 60-65°C (Trautmann & Richard 1995).

Vermicomposting and Pathogen Reduction

Certain species of earthworms (epigeic - litter dwelling) grow and consume organic waste more rapidly compared to other anecic (sub-surface) and endogeic (deep soil) earthworms (Aranda et al. 1999; Darwin 1945). Compared to microbial composting, vermicomposting is faster in decomposition of organic waste, as worms and microbes both take part in digesting the waste materials (DNR 2001; Edwards 1988).

Previous studies have shown that vermicomposting can achieve safe levels of pathogen removal, by the intestinal enzymes and actions of worms and the beneficial soil microbes that the worms leave behind, with which the pathogenic organisms have to compete for the limited resources (DNR 2001; Dominguez et al. 1997; Eastman 1999). The hazards caused by pathogenic content in the waste materials and composting itself, and the risks thereof have been the subject of many discussions on public health, and environmental safety and regulations. Risk analysis of vermicomposting is the focus of this paper.

Worms have been known to secrete certain fluids with antibacterial properties (Satchell 1983). Most human pathogens, including *E. coli* are killed by composting worms such as the most-widely used tiger worm (*Eisenia foetida*) and red worm (*Lumbricus terrestris*). More studies are required into this subject to shed light on the processes that attain pathogen reduction. Competition between pathogenic organisms and indigenous microflora in the worm castings for nutrients has been shown to cause pathogen removal (Allievi et al. 1986; Eastman 1999; Eastman et al. 2001; Ellery 2000; Morgan 1988; Rouelle 1983; Sidhu et al. 2001).

Risk management in domestic waste management

The Australia/New Zealand standard AS/NZS4360 defines risk as the chance of something happening that will have an impact on objectives. It relates to the probability or frequency of occurrence of a particular hazard or event, and some measure of the severity of its consequences. The acceptability of the consequence is relative and depends on the perception of the risk. A voluntary risk may become acceptable with increased confidence in the

operational safety of the system; given the positive consequences outweigh the negatives ones.

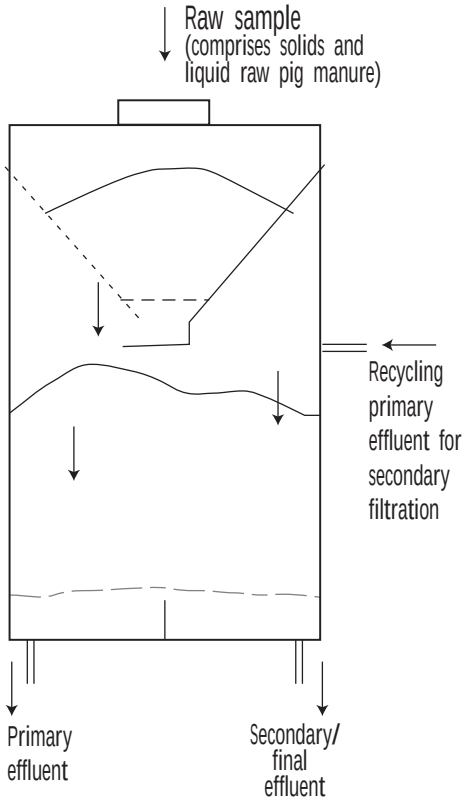
Although community acceptance might not be as important in the successful application of a domestic waste/wastewater treatment system, community perception and acceptance become critical for the uptake of the technology. The judgment of safety - or what is a tolerable risk in particular circumstances - is specific to the affected community for the particular event.

Waste management by any technology involves a variety of hazards, including those originating from mis-handling to the inherently pathogenic materials. Application of risk evaluation to biological waste management techniques, such as composting, should pay attention to the effect on the microbial life that could be both harmful (enteric pathogens) as well as eco-friendly (soil microbes) (Alcamo 2001). Risk calculation methods such as risk score matrices/tables and risk scale calculators need to be adapted for the particular application (AS/NZS4360 1995; Knief et al. 1991; National Safety Council of Australia [NSCA] 1998, 2002). In the present study, a risk matrix approach was used to assess risk in vermicomposting.

Experimental Methods

Following detailed tests on vermi-composting to validate results found in literature regarding the worm-stocking rate and feeding capacity, a prototype vermicomposting unit was designed and tested at the Sustainable Engineering and Technology (SET) research facility at the University of Western Sydney. The test results are presented elsewhere (Panikkar et al. 2003a; Panikkar & Riley 2003b; Panikkar & Riley 2003c). The vermicomposting unit is the primary treatment part of a design for a whole-of-waste management system that would apply to single residences and small communities in developing countries or remote areas. The effluent from the prototype treatment plant was initially expected to provide three-order of magnitude reduction in pathogen counts, against comparable secondary treatment in centralised wastewater management of one-order reduction (WHO 2003).

Figure 1: A schematic of the prototype with wastewater flow directions.



The prototype incorporated three chambers for vermicomposting, all with solid materials at different stages of decomposition (Figure 1). The conceptual design of the treatment system is provided in Riley et al. (2003). The prototype was tested by feeding a fixed amount of pig manure and organic material each day into the collection chamber. The quantity and composition of material fed into the reactor was based on an assumption of the quantity and quality of waste produced by a household, but scaled down for the size of the reactor. Details of the experimental design are given in

Panikkar et al. (2003b). The liquid waste (pig manure initially), which was used as the most closely comparable substitute for sewage, flows through different chambers with a designed hydraulic retention time (HRT) of 1 day based on calculations of waste material quantities. The final effluent is collected at the end of a composting cycle and tested for faecal coliform, *E. coli*, several chemical and physical water quality parameters including turbidity, ammonium, nitrate and solids content. For quality control, occasional paired, spiked and blind samples were tested at a NATA accredited professional water-testing laboratory. Microbiological analysis was undertaken at the Australian Government Analytical Laboratory. The results of the prototype test were used in assessing the risk levels of associated events identified as of particular significance.

Before testing began on the prototype vermicomposting unit, and during the design stage, a detailed risk assessment was conducted on the hazards of the project. Risk reduction measures were undertaken for the hazards identified (Panikkar et al. 2003a). Different risk assessment tools were used for detailed risk evaluation of the project and the results were compared to other blackwater recycling options currently in practice around the world, including septic tanks and direct agricultural and aquaculture use of sewage (Aalbers 1999; Agriculture Technology Notes [ATN] 1997; Pescod 1992).

A risk comparison was made between direct application of nightsoil and vermicomposting for different impacts such as infection and groundwater pollution. Both the direct application of nightsoil and vermicomposting treatment are aimed at nutrient recycling and resource utilisation. The cases of direct application in agri-aquaculture and treatment in septic tanks are used here due to widespread instances in the developing world. Direct application of nightsoil is practised in many parts of the world by farmers who are not educated on the safety and health aspects. The different hazard identification tables resulting from the risk analysis were compared. Qualitative measures were adopted, as prescribed by the standard AS/NZS 4360, 1995 (revised 1999). The NSCA risk calculator scale was used to calculate the risk score. The scale incorporates the probability and exposure level of the affected populated along with impact level (NSCA 1998, 2002).

Risk Analysis

The risk evaluation matrix (Table 1) is applied to a selected set of events arising from possible hazards, with reference to the effects of pathogen content and public health. Most hazards could be avoided by proper maintenance of the system and basic personal safety such as use of personal protective equipment (gloves, dust mask and proper footwear). The result of the risk analysis of the vermicomposting system was compared against risk analysis of the direct blackwater application in agriculture and aquaculture. As expected, the direct application of nightsoil/blackwater to crops and fishponds poses an impact on human health (high risk of disease) in most of the identified events compared to medium to acceptable/low levels for the vermicompost.

Table 1: Qualitative risk evaluation matrix for the vermicomposting system

	Consequences or impacts				
Likelihood	Insignificant	Minor	Moderate	Major	Catastrophic
Almost certain	S	S	H	H	V
Likely	M	S	S	H	V
Moderate	M	M	S	S	H
Unlikely but possible	L	L	M	S	H
Rare	L	L	M	M	S
Very rare	L	L	L	M	S

Risk level: V - very high; H - high; S - serious; M - medium; L - low / acceptable.

Source: from AS/NZS 4360:1995

On the one hand, the risk matrix table approach to risk assessment takes into account certain set levels of risk for the identified hazards and is not very flexible.

Figure 2: NSCA Risk score calculator for pollution from effluents

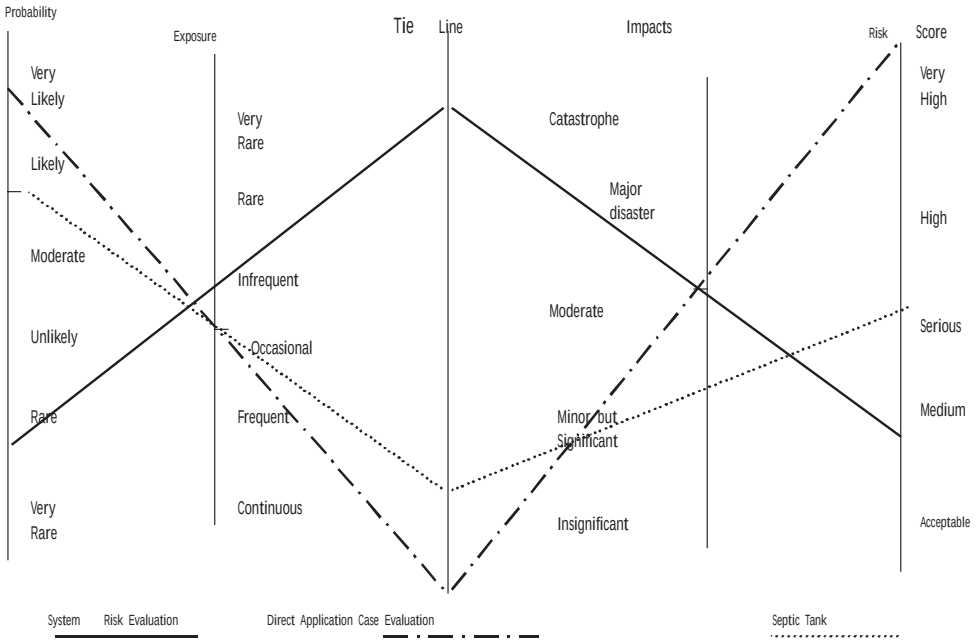
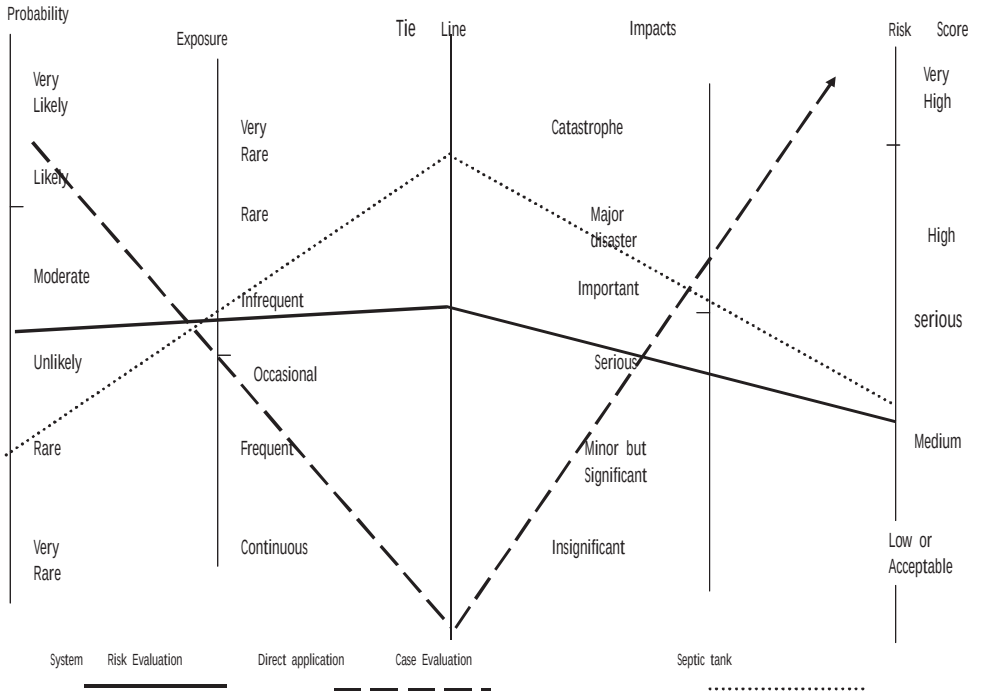


Figure 3: Risk score calculator for disease caused by contact with blackwater/nightsoil



Different scenarios need to be analysed separately. On the other hand, the NSCA risk score calculator allows for intermediate risk levels to be calculated. It also includes several scenarios in the same graph. In the calculator nomograph (Figure 2 and 3), vertical lines are drawn for the probability of the hazard to occur and the level of exposure expected with different values assigned to different points on the lines. For a particular hazard, values for probability and exposure are estimated from a preliminary analysis; the points are then joined by a straight line, which is then extended to the tie line. This point on the tie line is joined with the estimated value of possible consequence on another vertical line on the right of the tie line and then extended to calculate the risk score on a graded scale.

Results and Discussion

The results of laboratory analysis on different physical, chemical and microbiological parameters as well as behaviour of the composting organisms were utilised in the risk evaluation study. It was noted that reduction in the different physical parameters such as turbidity and solids conformed to expected trends and gave safe levels in the effluent. Reduction in pathogen level (as CFU/100ml of faecal coliform) was seen to fluctuate between 1 and 3.5 order of magnitude reduction. Given that the effluent could be further treated, these indicate effective primary treatment.

The analysis of risk for domestic vermicomposting of blackwater and biowaste identified certain hazards and associated risk, in comparison to the risks in direct reuse of nightsoil in agriculture and aquaculture (Table 2). The likelihood of each hazard occurring and the expected consequences of the same give the risk level from Table 1. Possible risk management options are specified in Table 3 for some hazards.

Many comparable hazards were identified between the vermicomposting system and the direct application of nightsoil. Most of the hazards in the vermicomposting system are managed to acceptable risk levels with proper treatment received and personal safety measures. However, the same hazards are seen to pose high-risk levels in the direct agriculture/aquaculture reuse option.

The technology used in blackwater treatment in most developing countries and rural areas, that of septic tanks, is also compared against the vermicomposting system and direct application in agriculture and aquaculture. The risk scores given by both techniques, those of risk matrix (Table 2) and the risk calculator (Figure 2 & 3) are similar. Only two Figures of the risk score calculators are shown in this paper as examples, although others were also prepared for the analysis.

In Figure 2, the hazard of ground water pollution for the vermicomposting of blackwater, direct nightsoil application to fields and septic tanks is compared. Only a worst case of leakage from the vermicomposting unit will cause groundwater seepage and contamination and this will be rare if the system is maintained properly, as mentioned in Table 3. The exposure of the environment to the hazard of release of liquid from the vermicomposting system is quite infrequent due to the contained nature of the system, with impact level between moderate to minor due to the efficiency of the treatment in removing major pollutants. This gives a risk score of less than medium for the vermicomposting system. Direct reuse of blackwater/nightsoil in fields or fish-ponds can have a probability estimated as 'very likely', as the waste material is frequently applied to ground without any treatment, giving an impact level of between moderate to major, with a risk level of 'very high'. Septic tanks, as currently in use, occasionally seep with minor impact, but ageing systems give a risk score close to 'serious'.

The risk scores for disease caused by contact with blackwater are evaluated in Figure 3. Risk scores range from 'medium' to 'serious' for the vermicomposting system and

Table 2: Risk Assessment comparison between blackwater vermicomposting system and direct reuse in agri-aquaculture

	Vermicomposting system			Direct reuse of nightsoil		
Hazard/risk source (and risk management)	Likelihood	Impact	Risk	Likelihood	Impact	Risk
Cuts and injuries from sharps in the solid waste	Moderate	Major	Serious	Moderate	Major	Serious
Start of disease from contact with blackwater	Unlikely	Major	Serious	Almost certain	Major	High
Spread of disease after one householder is infected	Likely	Major	High	Likely	Major	High
Raw blackwater leakage affecting groundwater	Rare	Moderate	Medium	Almost certain	Major	High
Raw blackwater leakage affecting waterways	Rare	Moderate	Medium	Almost certain	Catastrophic	Very high
Treated effluent leakage from the system	Rare	Minor	Low	-	-	-
Disease caused from contact with compost	Very rare	Minor	Low	-	-	-
Disease caused from contact with affected plants/fish	-	-	-	Moderate	Major	Serious
Children getting infected	Very rare	Major	Medium	Likely	Major	High
Waste spreading by weather -wind/storm	Very rare	Moderate	Low	Likely	Catastrophic	Very high
Spread of waste material by pets or other vectors	Unlikely	Minor	Low	Almost certain	Catastrophic	Very high
Plant diseases	Very rare	Moderate	Low	Likely	Moderate	Serious
Adverse effects of pathogens on edible crops	Very rare	Minor	Low	Likely	Major	High
Adverse health effects from ingestion of affected crops/fish	-	-	-	Likely	Catastrophic	Very high
Adverse effects on other flora/fauna	Very rare	Minor	Low	Likely	Major	High
Soil degradation from use of compost	Very rare	Minor	Low	Moderate	Minor	Medium
Foul odours from the system	Unlikely	Moderate	Medium	Almost certain	Moderate	High
Worm casualty from overstocking of waste or flooding with blackwater	Rare	Minor	Low	-	-	-
System failure due to weather patterns	Rare	Moderate	Medium	-	-	-

septic tanks, while the risk for direct application is very high due to the probability of constant contact and frequent exposure (both environment and human).

Table 3; Risk Management for certain hazards identified with vermicomposting unit

Identified hazard	Risk management
Cuts and injuries due to sharp items	Use of suitable PPE (gloves, goggles, proper clothing and footwear)
Start of disease from contact with blackwater/nightsoil	Use of PPE (gloves, goggles, dust mask, proper clothing and footwear)
Spread of disease within the family	Immediate medical attention
Leakage of raw blackwater from vermicomposting unit	Regular monitoring and maintenance of raw sewage container & plumbing
Treated effluent leakage from vermicomposting unit	Regular monitoring and maintenance
Children and visitors getting infection	Containment of the system, fencing
Spread of waste by vectors, effect to fauna	Suitable location, fencing
System overload (solid waste or liquid waste)	Regular monitoring

Benefits of the Vermicomposting Treatment

A safe waste treatment system such as vermicomposting of blackwater and biodegradable waste could be of use in places where centralised or other waste management facilities are unavailable. This comparative risk study shows that direct application of human waste in agriculture and aquaculture should be avoided and better treatment options sought. In vermicomposting, the waste materials are safely converted into soil amendment material with reduced levels of pathogens. Harvesting of worms as a protein source in fish culture has been in practice in many places, and this could be an application of vermicomposting in aquaculture. The liquid effluent from the vermicomposting unit could be further treated and utilised in irrigation or elsewhere. Proper treatment of effluent along with greywater from the

household would offer a source of recycled water for different uses at the household, without adverse health implications.

Conclusion

Different risk evaluation techniques were applied to compare the risks associated with environmental and human health in treating household organic waste and blackwater through a process of vermicomposting. A vermicomposting/wet composting technology is a relatively safe means of primary treatment of blackwater and conversion of putrescible household waste into products that are useful in agriculture and aquaculture. Vermicomposting technology is safer in terms of risks to human and environmental health, compared to direct application of human waste in fields or fishponds, as practised in many places. Further studies and risk evaluation is required to validate the results for particular applications and regions, where the nature of wastes could differ.

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Acute Effects of Bushfires on Respiratory Symptoms and Medication Use in Children with Wheeze in Sydney, Australia

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The objective of the research was to determine the effects of the January 1994 Sydney bushfire smoke, as measured by particulate matter less than 10 microns (PM_{10}), on evening symptoms and beta agonist use in children with a history of recent wheezing. The study design used was a prospective panel study. Thirty-two children with a history of wheeze completed a daily asthma diary for a four-week period. We obtained daily air pollution, meteorological, pollen and Alternaria data. Ambient PM_{10} concentrations were categorised into bushfire and non-bushfire associated fractions. We then used logistic regression to determine associations between the bushfire PM_{10} concentration and prevalence of respiratory symptoms and beta agonist use. The results showed that the daily mean total PM_{10} levels peaked at 130 µg/m^3. There was a significant association between the bushfire PM_{10} fraction and prevalence of evening wet cough (odds ratio=1.23, 95% confidence interval=1.10-1.37 for a 10 µg/m^3 increase in PM_{10} concentration) after adjusting for the non-bushfire fraction of the PM_{10}. Controlling for sex, presence of airway hyperresponsiveness or house dust mite sensitisation did not appreciably alter the association. We found a significant association between bushfire associated PM_{10} concentration and prevalence of evening wet cough but not with the prevalence of evening dry cough, wheeze or beta agonist use. The clinical and public health implications of these results are unclear at present.

Key words: *Children; Bushfires; PM_{10}; Symptoms; Panel Study; Asthma*

Bushfires and forest fires are relatively common environmental phenomena especially in Australia, the United States of America, and South-east Asia, leading to very high ambient concentrations of particulate matter. The health effects attributable to bushfires and forest fires are now increasingly recognised as an important public health issue and reported in the scientific literature (Duclos, Sanderson & Lipsett 1990; Emmanuel 2000; Jalaludin et al. 2000; Johnston et al. 2002; Kunii et al. 2002; Mazrura et al. 2001; Mott et al. 2002; Smith et al. 1996). Understandably, most of these reported studies have been conducted retrospectively using quasi-experimental or ecologic study designs and there are few reported prospective studies that have

investigated the impact of bushfire or forest fire particulate pollution on individual level health outcomes.

In Sydney, Australia in January 1994, there were major bushfires on the outskirts of the city with a haze of smoke over the entire city for about one week. A few days prior to the bushfires we had commenced recruiting children for a panel study to prospectively examine the relationship between air pollution and daily respiratory morbidity in children with a history of recent wheeze. This environmental disaster provided an opportunity to observe, prospectively, the effects, if any, of bushfire smoke, as measured by particulate matter less than 10 microns (PM_{10}), on the prevalence of evening respiratory symptoms and beta agonist use in children with a recent history of wheezing. We have previously reported on the association between bushfire PM_{10} concentrations and peak expiratory flow rate in this same group of children (Jalaludin et al. 2000).

Methods

We obtained ethics approval from all relevant institutional ethics committees prior to commencement of the study. In August 1993, we conducted a cross-sectional study of children in school years three to five in six primary schools in western and southwestern Sydney. The cross-sectional study included a parent-completed asthma questionnaire, skin prick test to commercial allergens and measurement of children's airway responsiveness by histamine challenge.

From January 1994, 148 children with a reported history of wheezing in the previous 12 months were progressively enrolled in a panel study. Each child completed an asthma diary twice a day (on waking and before bed). Information recorded in the asthma diary included peak expiratory flow, symptoms (wet cough, dry cough and wheezing), asthma medications and time spent outdoors in the previous 12 hours. Children and parents were instructed in the use of the asthma diary and parents were asked to supervise their children's diary keeping. They were also asked to leave the diary entry blank on the occasions they forgot to complete the diary.

Air pollution, meteorological and pollen data

We obtained daily air pollution and meteorological data for 1994 from air quality monitoring stations in western and southwestern Sydney. The monitoring stations continuously measured ambient ozone (Monitor Lab Ozone Analyzer Model 8810), PM_{10} (TEOM Series 1400A, Rupprecht & Pataschnick Co. Inc. USA) and nitrogen dioxide (Monitor Lab Nitrogen Oxides Analyzer Model 8840). Air pollution and meteorological data were provided as daily maximum, daily maximum for daytime period (between 0600 hours to 2100 hours), daily arithmetic average and daily arithmetic average for daytime period. We averaged total pollen and *Alternaria* counts across two sites in the study area.

Statistical methods

Our analysis period was from 6 January 1994 to 31 January 1994 that included the bushfire period (7 January to 14 January 1994). Only children recruited by the 12 January 1994 were eligible for this analysis. We used the evening recorded symptoms (wheeze, dry cough and wet cough recorded just before bedtime) and beta agonist use as outcome variables. We excluded diary records when children were out of metropolitan Sydney.

We used the daytime mean values for air pollution and meteorological variables (only calculated if 80% or more of hourly values were present) in our analyses to preserve the temporal relationship between air pollution levels and evening symptoms. Each child's air pollution and meteorological exposures were derived from the monitoring station closest to that child's school. Data from two ambient air monitoring stations were used for children from the three schools involved in this analysis. One school was within two kilometres of a monitoring station (n=11

children) whilst the other two schools (*n*=21 children) were within 20 kilometres of the second monitoring station. Although all subjects lived some distance from the bushfires (about 10 to 20 kilometres away), there was visible haze throughout metropolitan Sydney at the time of the bushfires.

In this study, we wanted to examine the additional effects of the bushfire particulates on morbidity over and above any effects due to the usual urban PM_{10} concentration. We therefore created a new measure for particulates to represent the bushfire fraction ($BFPM_{10}$) of the total PM_{10} concentration. This daily bushfire fraction was calculated as the daily total PM_{10} concentration minus the average PM_{10} concentration for January excluding the bushfire period (non-bushfire fraction [non-$BFPM_{10}$]).

We used generalised estimating equations (GEE) logistic regression models (Liang & Zeger 1993) to determine associations between PM_{10} concentrations ($BFPM_{10}$ and non-$BFPM_{10}$) and prevalence of evening respiratory symptoms and beta agonist use. PM_{10} levels were also lagged for up to three days and averaged over two and five days to examine the delayed and cumulative effects. All GEE models included a first order autoregression correlation structure, mean temperature, mean humidity, number of hours spent outdoors, log transformed total pollen and Alternaria counts and inhaled corticosteroid use. Results are presented as odds ratios (OR) and ninety five percent confidence intervals (95%CI) for a 10 $\mu g/m^3$ increase in PM_{10} concentration. We conducted all analyses using SAS statistical software (SAS Institute Inc. Cary, USA).

Results

We commenced recruiting children for the panel study on 6 January 1994. By 12 January 1994 we had recruited 32 children from three primary schools whose data form the basis for these analyses. Of the total 1676 days of diary records, children were in metropolitan Sydney for 93% of the recordings. One child withdrew from the study before the end of the study period. There was a mean of 21 diary recordings per child (range: 11 to 25 recordings) and a mean of 25 recordings per day (range: 2 to 32 recordings).

Mean age of subjects was 9.2 years (standard deviation=0.78 years), 60% (*n*=19) were boys, 38% (*n*=12) had four or more attacks of wheezing in the past 12 months, 38% (*n*=12) had airway hyperresponsiveness on histamine challenge and 78% (*n*=25) had a doctor diagnosis of asthma.

Table 1: Daily daytime[1] mean air pollution and meteorological concentrations, and daily pollen and Alternaria concentrations, 6 January 1994 to 31 January 1994

	Mean daytime values	
	Mean (SD)2	Median (IQR)3
PM_{10} (µg/m3) *n*=26	33.6 (27.9)	23.2 (28.2)
BF PM_{10} fraction ($\mu g/m^3$) *n*=26	14.0 (27.4)	0 (24.6)
BF PM_{10} fraction ($\mu g/m^3$) *n*=84	45.5 (32.2)	35.7 35.0)
Non-BF PM_{10} fraction ($\mu g/m^3$) *n*=26	19.6 (4.3)	20.0 (4.3)
Ozone (pphm)5*n*=26	1.8 (0.9)	1.7 (0.5)
NO_2 (pphm) *n*=26	0.9 (0.5)	0.8 (0.3)
Temperature (°C) *n*=26	24.6 (3.3)	24.4 (2.8)
Relative humidity (%) *n*=26	66.1 (18.1)	67.6 (16.7)
	Daily values	
Total pollen ($grains/m^3$) *n*=26	31.3 (34.8)	18 (20)
Total Alternaria ($spores/m^3$) *n*=26	90.3 (85.6)	64 (93)

1. Daytime readings between 6am and 9pm
2. Standard deviation
3. Interquartile range
4. Bushfire fraction for the eight bushfire days
5. Parts per hundred million

The daily total PM_{10} level increased on 7 January 1994, peaked on 13 January 1994, and was down to baseline levels by 15 January 1994 (Figure 1). The maximum daytime mean PM_{10} concentration (130 $\mu g/m^3$) was nearly seven times that for the rest of January. Summary statistics and correlation coefficients for air pollutants and meteorological variables are presented in Tables 1 and 2. The mean daytime PM_{10} concentration during the bushfire period was 65.5 $\mu g/m^3$ compared to 19.4 $\mu g/m^3$

Table 2: Correlation between daytime[1] air pollutant and meteorological variables, 6 January 1994 to 31 January 1994

	Total PM_{10} ($\mu g/m^3$)	$BFPM_{10}$ ($\mu g/m^3$)	Non-$BFPM_{10}$ ($\mu g/m^3$)	Ozone (pphm)	NO_2 (pphm)	Temperature (°C)	Relative humidity (%)
Total PM_{10}	1.0						
$BFPM_{10}$	0.99**	1.0					
Non-$BFPM_{10}$	0.20	0.05	1.0				
Ozone	0.64**	0.58*	0.43*	1.0			
NO_2	0.61*	0.60*	0.11	0.67**	1.0		
Temperature	0.39*	0.33	0.48*	0.50*	0.15	1.0	
Relative humidity	-0.18	-0.14	-0.26	-0.03	0.42*	-0.62**	1.0

*1. Daytime readings between 6am and 9pm *p<0.05 **p<0.001*

during the non-bushfire period. During the bushfire period, mean daytime PM_{10} concentration exceeded 50 $\mu g/m^3$ on five of the eight days and the highest concentration was 130.3 $\mu g/m^3$. Both mean daytime ozone and nitrogen dioxide concentrations were also higher in the bushfire period compared to the non-bushfire period but not significantly so (ozone: 2.3 pphm vs 1.7 pphm; nitrogen dioxide: 1.0 pphm vs 0.9 pphm). PM_{10} concentrations between the two monitoring stations used in this analysis were highly correlated (r=0.94).

There were positive correlations between mean daytime PM_{10} concentration and mean daytime ozone concentration (r=0.64), mean daytime nitrogen dioxide concentration (r=0.61) and mean daytime temperature (r=0.40). Mean daytime PM_{10} concentration and mean daytime humidity were negatively correlated (r=-0.18).

Prevalence of evening dry cough was positively correlated with prevalence of evening wheeze and use of beta-agonists (r=0.48 and r=0.58 respectively) and negatively correlated with prevalence of evening wet cough (r=-0.35). Prevalence of evening wheeze was also correlated with beta agonist use (r=0.62). Evening wet cough was uncorrelated with the prevalence of evening wheeze (r=-0.07) and beta agonist use (r=0.04).

Compared to the non-bushfire period, there was a significantly higher prevalence of evening wet cough and inhaled steroid use during the bushfire period (wet cough: 17.0% versus 5.5%, p=0.001; dry cough: 16.9% versus 17.2%, p=0.94; wheeze: 10.6% versus 10.5%, p=0.98; inhaled β-agonist use: 13.2% versus 9.2%; p=0.15; inhaled corticosteroid use: 20.8% versus 13.8%, p=0.04).

Table 3 shows results for the association between various metrics for bushfire particulate pollution (total PM_{10}, bushfire period represented by an indicator variable, and total PM_{10} partitioned into $BFPM_{10}$ and non-$BFPM_{10}$) and evening prevalence of wet cough. Models 1, 2, 4 and 5 are single

Table 3: Models[1,2] to investigate effects of bushfire associated particles on evening wet cough, 6 January 1994 to 31 January 1994

	OR	95%CI
Model 1		
Total PM_{10}	1.247	1.111-1.400
Model 2		
Indicator variable for bushfire period	2.950	1.236-7.042
Model 3		
Total PM_{10}	1.220	1.037-1.436
Indicator variable for bushfire period	1.417	0.352-5.711
Model 4		
$BFPM_{10}$	1.246	1.095-1.418
Model 5		
Non-$BFPM_{10}$	1.933	1.219-3.064
Model 6		
$BFPM_{10}$	1.234	1.093-1.393
Non-$BFPM_{10}$	2.111	1.270-3.507
Model 7		
Indicator variable for bushfire period	2.872	1.175-7.018
Non-$BFPM_{10}$	1.912	1.142-3.201

1. For 10 mg/m³ increases in total PM_{10}, BPM_{10} and non-$BFPM_{10}$

2. Mean daytime temperature, mean daytime humidity, daily log total pollen, daily log Alternaria and inhaled corticosteroid included in all GEE models

pollutant models whereas Models 3, 6, and 7 are two pollutant models. The $BFPM_{10}$ concentration was significantly associated with evening wet cough with or without the non-$BFPM_{10}$ fraction in the model (models 4 and 6 in Table 3). Similar associations were seen when the bushfire period was represented as the total PM_{10} or as an indicator variable in the model (models 1, 2 and 7 in Table 3). In the rest of the analysis, we used $BFPM_{10}$ and non-$BFPM_{10}$ concentrations (the bushfire and non-bushfire fractions respectively) to represent exposure to particulates.

In single fraction models (either $BFPM_{10}$ or non-$BFPM_{10}$ in models) investigating the effects of lag periods, the greatest effects for wet cough were seen with lag 0 for $BFPM_{10}$ (OR=1.231, 95%CI=1.099-1.379) and lag 2 for non-$BFPM_{10}$ (OR=2.004, 95%CI=1.294-3.102) (Table 4). For dry cough, wheeze and beta agonist use, the effects for $BFPM_{10}$ were non-significant. In the case of non-$BFPM_{10}$, significant positive associations were found with dry cough (lag 0 and five day average) and wheeze (two and five day averages) (Table 4). In a sub-group analysis of only those children with bronchial hyperresponsiveness, the associations between lag 0 $BFPM_{10}$ and wet cough, dry cough and beta-agonist use were essentially unchanged (OR of 1.19 [95%CI: 1.04-1.37], 0.97 [95%CI: 0.81-1.15] and 1.01 [95%CI: 0.89-1.15] respectively) (OR was not calculable for wheeze).

We also investigated lag and cumulative effects of the bushfire fraction of particulate matter in two fraction models (both $BFPM_{10}$ and non-$BFPM_{10}$ fractions in the models). The associations between $BFPM_{10}$ and evening symptoms and beta agonist use were essentially unchanged from models where only the $BFPM_{10}$ was included in the models (Table 5).

Results from models that included both the $BFPM_{10}$ and non-$BFPM_{10}$ fractions as

Table 4: Associations[1] between $BFPM_{10}$ and non-$BFPM_{10}$ fractions and prevalence of evening respiratory symptoms and beta agonist use in single fraction models[2], 6 January 1994 to 31 January 1994

	Wet cough		Dry cough		Wheeze		Beta agonist use	
	OR	95%CI	OR	95%CI	OR	95%CI	OR	95%CI)
$BFPM_{10}$ fraction								
Lag 0[3]	1.231	1.099-1.379	0.90	0.865-1.044	0.976	0.828-1.151	0.961	0.825-1.119
Lag 1	1.105	1.012-1.207	1.040	0.978-1.105	1.048	0.977-1.125	1.031	0.956-1.113
Lag 2	1.231	1.032-1.469	0.959	0.834-1.102	0.917	0.751-1.120	0.983	0.886-1.091
Lag 3	1.083	1.009-1.162	0.976	0.899-1.060	1.088	0.998-1.186	1.048	0.982-1.118
D 2[4]	1.181	1.029-1.354	1.036	0.952-1.127	1.035	0.955-1.121	1.026	0.938-1.123
D 5[5]	1.165	0.884-1.536	0.951	0.764-1.185	0.787	0.582-1.064	1.110	0.900-1.369
Non-$BFPM_{10}$ fraction								
Lag 0	1.933	1.219-3.064	1.845	1.122-3.037	1.781	0.976-3.250	0.861	0.549-1.348
Lag 1	1.062	0.536-2.104	0.901	0.640-1.270	1.154	0.837-1.591	1.091	0.920-1.294
Lag 2	2.004	1.294-3.102	1.196	0.670-2.136	1.313	0.736-2.340	1.058	0.761-1.470
Lag 3	1.343	0.813-2.218	1.449	0.983-2.136	1.320	0.761-2.290	0.909	0.746-1.108
D 2	1.779	0.906-3.491	1.745	0.958-3.180	3.149	1.495-6.631	0.893	0.484-1.650
D 5	6.679	1.836-24.304	7.185	2.365-21.831	12.692	3.334-48.314	0.918	0.185-4.542

1. For increases in $BFPM_{10}$ and non-$BFPM_{10}$ of 10 mg/m^3

2. Mean daytime temperature, mean daytime humidity, daily log total pollen, daily log Alternaria and inhaled corticosteroid use included in all GEE models

3. Lag 0=same day value

4. Average of lag 0 and lag 1

5. Average of lag 0, lag 1, lag 2, lag 3 and lag 4

Table 5: Associations[1] between $BFPM_{10}$ and prevalence of evening respiratory symptoms and beta agonist use with non-$BFPM_{10}$ fraction[2] also included in the models[3], 6 January 1994 to 31 January 1994

	Wet cough		Dry cough		Wheeze		Beta agonist use	
	OR	95%CI	OR	95%CI	OR	95%CI	OR	95%CI)
BFPM10 fraction								
Lag 0[4]	1.226	1.095-1.374	0.943	0.855-1.040	0.971	0.821-1.150	0.983	0.879-1.099
Lag 1	1.274	1.051-1.544	1.030	0.972-1.093	1.044	0.969-1.125	1.029	0.954-1.111
Lag 2	1.294	1.104-1.517	0.918	0.795-1.059	0.880	0.726-1.066	0.994	0.891-1.109
Lag 3	1.067	0.991-1.150	0.983	0.895-1.080	1.094	0.998-1.200	1.053	0.970-1.144
D 2[5]	1.235	1.025-1.488	1.021	0.935-1.115	1.027	0.937-1.127	1.023	0.935-1.120
D 5[6]-	1.225	0.942-1.593	0.984	0.784-1.235	0.808	0.594-1.099	1.123	0.916-1.277

1. For increase in PM_{10} of 10 $\mu g/m^3$
2. For non-$BFPM_{10}$ – lag 0 for dry cough and wheeze, lag 2 for wet cough and lag 1 for beta agonist use included in the two fraction models
*3. Mean daytime temperature, mean daytime humidity, daily log total pollen, daily log **Alternaria** and inhaled corticosteroid use included in all GEE models*
4. Lag 0=same day value
5. Average of lag 0 and lag 1
6. Average of lag 0, lag 1, lag 2, lag 3 and lag 4

well as ozone or nitrogen dioxide are presented in Table 6. In these models, lags with the greatest effects from single pollutant models were included. The association between $BFPM_{10}$ and evening wet cough remained unchanged when mean daytime ozone was added to the model. However, with nitrogen dioxide in the model, the association between $BFPM_{10}$ and evening wet cough was now non-significant. With ozone in the model, there was now also a significant association between $BFPM_{10}$ (lag 3) and evening wheeze (OR=1.164, 95%CI=1.013-1.338). There were no significant associations between ozone or nitrogen dioxide and evening symptoms or beta agonist use (Table 6).

In sensitivity analyses, addition of a history of airway hyperrsponsiveness, house dust mite sensitisation, sex of the child and whether there were smokers in the household did not appreciably change the associations between $BFPM_{10}$ (lag 0) and evening wet cough. However, there was a

Table 6: Multi-pollutant models[1,2] with PM_{10} fractions and with ozone or nitrogen dioxide, 6 January 1994 to 31 January 1994

	Models with ozone			Models with nitrogen dioxide	
	OR	95%CI		OR	95%CI
Wet cough			Wet cough		
$BFPM_{10}$–Lag 03	1.224	1.071-1.398	$BFPM_{10}$- Lag 0	1.154	0.941-1.415
Non-$BFPM_{10}$–Lag 2	2.052	1.365-3.085	Non-$BFPM_{10}$– Lag 2	1.868	1.226-2.847
Ozone–Lag 0	1.015	0.624-1.652	Nitrogen dioxide– Lag 0	1.401	0.569-3.450
Dry cough			Dry cough		
$BFPM_{10}$- Lag 1	1.054	0.979-1.136	$BFPM_{10}$- Lag 1	1.005	0.887-1.139
Non-$BFPM_{10}$- Lag 0	1.874	1.126-3.119	Non-$BFPM_{10}$- Lag 0	1.752	1.042-2.946
Ozone- Lag 1	0.891	0.694-1.146	Nitrogen dioxide- Lag 1	1.149	0.590-2.240
Wheeze			Wheeze		
$BFPM_{10}$- Lag 3	1.164	1.013-1.338	$BFPM_{10}$- Lag 3	1.085	0.986-1.195
Non-$BFPM_{10}$- Lag 0	1.868	0.937-3.724	Non-$BFPM_{10}$- Lag 0	1.732	0.843-3.555
Ozone- Lag 3	0.728	0.479-1.106	Nitrogen dioxide- Lag 1	1.348	0.981-1.853
Beta agonist use			Beta agonist use		
$BFPM_{10}$- Lag 3	1.038	0.959-1.122	$BFPM_{10}$- Lag 3	1.038	0.959-1.122
Non-$BFPM_{10}$- Lag 1	1.362	1.037-1.789	Non-$BFPM_{10}$- Lag 1	1.155	0.949-1.405
Ozone- Lag 1	0.782	0.629-0.973	Nitrogen dioxide- Lag 3	1.196	0.897-1.596

1. For increases in $BFPM_{10}$ and non-$BFPM_{10}$ of 10 $\mu g/m^3$, and for ozone and nitrogen dioxide of 1 part per hundred million
2. Mean daytime temperature, mean daytime humidity, daily log total pollen, daily log Alternaria *and inhaled corticosteroid use included in all GEE models*
3. Lag 0=same day value

significant association between dust mite atopy and evening wet cough (OR=7.6, 95%CI=2.0-28.4).

Discussion

The 1994 Sydney bushfires afforded us the unique opportunity to study prospectively the acute effects of particulate pollution due to bushfires on respiratory morbidity in a panel of children with a history of wheezing. In this study, we partitioned the daily total PM_{10} concentration into two fractions – a bushfire associated fraction ($BFPM_{10}$) and a non-bushfire associated fraction (non-$BFPM_{10}$). For the bushfire period, the substantial difference in the total PM_{10} concentration and the average PM_{10} concentration for the non-bushfire period was primarily attributed to the bushfires. This allowed us to uniquely investigate the additional effects of bushfire associated PM_{10} over and above the effects of motor vehicle derived urban PM_{10}.

We found a significant association only between same day $BFPM_{10}$ concentration and the prevalence of evening wet cough. During the bushfires, we estimate that the prevalence of wet cough would have doubled (interquartile range for $BFPM_{10}$=35 $\mu g/m^3$; OR=2.04, 95%CI=1.37-3.04). There were no significant associations between $BFPM_{10}$ and evening dry cough, evening wheeze and evening beta agonist use. The non-$BFPM_{10}$ fraction was associated with evening wet and dry cough but generally not with evening wheeze or beta agonist use. Interestingly, the associations between the non-$BFPM_{10}$ fraction and evening symptoms are much stronger when non-$BFPM_{10}$ concentrations are averaged over five days suggesting that cumulative effects are important.

Few studies have investigated the health effects of bushfires or forest fires and the results are conflicting. In Singapore, there were increases in primary health care (for respiratory diseases) and emergency department visits due to forest fires but not increases in hospitalisations or mortality (Chew et al. 1995; Emmanuel 2000). Similarly, during the 1997 forest fires, there were no significant associations between PM_{10} levels and mortality in Malaysia (Mazrura et al. 2001). Duclos, Sanderson and Lipsett (1990) also reported increases in emergency department visits for respiratory conditions, including asthma, due to forest fires in California, USA. In Sydney, there were no increases in emergency department visits for asthma following the 1994 bushfires (Cooper et al. 1994; Smith et al. 1996). However, a recent study from Darwin, Australia, reported increases in emergency department presentation rates for asthma due to bushfire particle pollution (Johnston et al. 2002). Reports of symptoms in firefighters have also been mixed with some reporting no association with firefighting (Betchley et al. 1997) whereas others have reported increases in the prevalence of respiratory symptoms (Rothman et al. 1991).

It was surprising that we did not find associations between $BFPM_{10}$ concentration and prevalence of dry cough and wheeze as the most consistent associations between air pollution and respiratory morbidity appear to be between PM_{10} and lower respiratory symptoms (Schwartz et al. 1994; Vedal et al. 1998; Yu et al. 2000). In this study, the association between $BFPM_{10}$ concentration and wet cough may simply be due to the irritative effects of larger haze particles on the upper airways. Further, given the large number of comparisons that were made in this study, it is quite possible the association between $BFPM_{10}$ concentration and wet cough could have arisen simply by chance.

Interestingly, in this same panel of children, we also did not find any association between PM_{10} concentration and evening peak expiratory flow rate (Jalaludin et al. 2000). Many children may have stayed indoors during the bushfire period and reduced their exposure to fine particles. However, as indoor particulate concentration is about 50% to 70% of outdoor particulate concentration (Li 1994; Monn et al. 1997), staying indoors is

unlikely to bias our findings. It is also possible that we did not find associations between $BFPM_{10}$ and symptoms of dry cough and wheeze because bushfire derived PM_{10} may have different airway irritant characteristics to PM_{10} derived from urban sources.

There were a number of other limitations in this study. We used air pollution data from fixed site monitors to characterise individual exposures to air pollutants. While personal monitoring is preferable, it is generally impractical in these types of studies, and any misclassification of exposure would bias the results towards the null (Romieu et al. 1996). Similarly, any misreporting of symptoms or missing data in asthma diaries would also be non-differential as parents/children would normally not be aware of high pollution days at the time of diary completion and hence any subsequent bias would be towards the null (Neas et al. 1995; Romieu et al. 1996). However, as the bushfires were readily apparent, there remains the possibility that there may have been some systematic over-reporting of wet cough during the bushfires. The similar prevalence of reported wheeze and dry cough between the bushfire and non-bushfire periods suggest that any differential measurement error may be minimal.

The association between same day $BFPM_{10}$ and evening wet cough remained significant when ozone was added to the model but became non-significant when nitrogen dioxide was entered into the model. Further, in the model with ozone, $BFPM_{10}$ (lag 3) was significantly associated with evening wheeze. As $BFPM_{10}$ was moderately correlated with both ozone and nitrogen dioxide it is difficult to disentangle the independent effects of air pollutants (Schwartz et al. 1996).

Bushfires and forest fires are generally unpredictable events of relatively short duration, and when severe, as in the 1997 South-east Asian forest fires, tens of millions of people can be exposed to particulate pollution and other combustion by-products. The unpredictable nature and short duration make it impractical to conduct prospective studies to examine the acute and chronic effects of biomass combustion on human health. However, if these fires occur frequently enough, then it may be possible to use time series analytical methods to study the acute effects of air pollution due to bushfire and forest fires. Determining the chronic effects of biomass combustion is more problematic. As prospective studies are an impractical option, the only feasible method is to compare health outcomes in areas with and without bushfires but such study designs are prone to confounding. Nonetheless, as bushfire and forest fires expose large populations to extremely high levels of particulate pollution, it is imperative that we continue to study the impact of these events on populations, imperfect as the study methods might be, as further research is needed to determine the relative toxicity of particulate matter from bushfires and forest fires compared with particulate matter from other sources.

In summary, we investigated the association between particulate pollution due to bushfires and respiratory symptoms and beta agonist use in children with a history of wheezing. We found a highly significant association only between same day $BFPM_{10}$ concentration and prevalence of evening wet cough but, importantly, not between $BFPM_{10}$ concentration and prevalence of evening dry cough, wheeze or beta agonist use. The clinical and public health importance and implications of these findings are unclear at present. However, as exposures to such combustion particles will continue to occur, more detailed research is warranted.

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The Resurgence of Bed Bugs in Australia: With Notes on Their Ecology and Control

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During the first three years of the 21st century, bed bug numbers in Australia have undergone a dramatic rise. The Department of Medical Entomology, Institute of Clinical Pathology and Medical Research (ICPMR), Westmead Hospital, Sydney, has recorded an increase of over 400% in the number of bed bug samples submitted to its pathology service, since the beginning of 2001. Over the last four years, the pest control industry has noted a major resurgence in the number of bed bug treatments, with one company reporting an increase of almost 700%. The Australian Quarantine and Inspection Service has also recorded a similar trend, with a large increase in interceptions over recent years, and the majority of interceptions have been from the luggage of travellers. The resurgence of bed bugs is part of a worldwide trend, although the reasons for the increase have not been scientifically resolved. Many factors are probably contributing to the upsurge, with increasing world travel being suggested as the main cause as the insects are transferred through the movements of travellers. The trade in second-hand furniture, changes in pest management practices, the lack of awareness of bed bugs among pest controllers and health professionals, and other phenomena may all have contributed to the spread and increase in bed bug numbers. A review of this public health pest is provided.

Key words: *Bed bugs; Resurgence; Cimex; Interceptions; Australia*

Bed bugs are blood-sucking insects belonging to the family Cimicidae (Order: Hemiptera). Of the 89 species within the family, there are two that mainly bite humans, the common bed bug, *Cimex lectularius* Linnaeus, and the tropical bed bug, *Cimex hemipterus* Fabricius. Bed bugs were once a common public health pest worldwide, with estimates of up to 75% of homes in Britain infested (*Professional Pest Controller*, 2003, vol. 32, pp.16-7). In developed nations, they declined in incidence and, through improvements in sanitation and with increasing use of residual insecticides, infestations became a rare event. However, this downward trend is now starting to reverse and globally there have been recent reports of an increase in bed bug numbers (Boase 2001; Krueger 2000; Paul & Bates 2000). Some areas in Britain (*Professional Pest Controller*, 2003, vol. 32, pp.16-7) and the United States (Baumann 2002; Krueger 2000) have reported a tenfold increase since 1999. Australia has not been excluded and a dramatic rise has also been observed here. Unfortunately, evidence for the trend locally is anecdotal, as data on bed bug incidence are not collected systematically. Compounding this is the dearth of scientific reports relating to bed bugs in Australia, which means that there has been a notable lack of accurate and up-to-date information available to health professionals and pest managers. This article provides documented evidence for the recent rise in bed bug

numbers and attempts, for the first time anywhere in the world, to examine how they may have been introduced. Finally, as public health and environmental health workers will be called upon to provide advice on the management of bed bugs, and as there is limited information in Australia, a brief review of bed bugs is provided with notes on their identification, clinical significance, ecology and control.

Methods

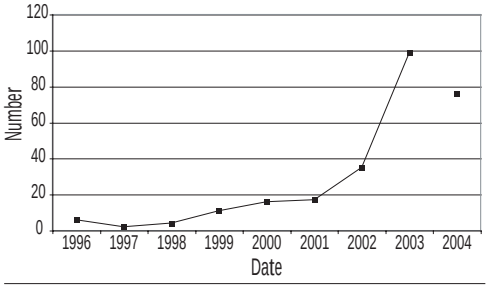
Evidence was sought to substantiate the anecdotal reports of the increase in bed bug infestations. The number of specimens submitted to the pathology service of the Department of Medical Entomology was tallied over time and information on when each was submitted, along with the species identity, was recorded. Three large local pest control firms were contacted and information on the number of bed bug treatments and the type of premises treated was requested. Health workers across the country were also contacted regarding the apparent increase. To determine how the bed bugs may have been introduced, a list of the interceptions by the Australian Quarantine and Inspection Service (AQIS) was requested from the Pest and Disease Information Database (PDID), Market Access and Biosecurity, Department of Agriculture, Fisheries and Forestry, and the AQIS Incidents database, covering the period 1 January 1986 to 31 January 2004. This also provided a time line of the interceptions, which could contribute evidence for the alleged upward trend in bed bug infestations.

Results

The Department of Medical Entomology, ICPMR, is the only NATA accredited pathology service in Australia for the identification of arthropods of medical importance and, as such, is possibly the main government health body receiving arthropod specimens of medical and public health importance. From the beginning of January 2001 to May 2004, the Department received 37 samples of bed bugs, representing an increase of over 400% upon the four-year period of 1997 to 2000 (nine samples submitted). A total of only 16 bed bug samples was received through the years 1988 to the end of 2000. Around 80% of the bed bugs were submitted during summer and autumn, and all were from within Australia. The common bed bug was the most frequent species (46/53), while all ten records of the tropical bed bug came from Queensland. Three of the samples contained both species.

One pest control company (Jones, G. Eagle Pest Control, 2004, *pers. comm.*) has recently observed almost an exponential increase in the number of treatments; a rise of approximately 700% for 2001-2004 (figures up to the end of April), compared with the four years 1997-2000 (Figure 1). One highly experienced pest controller estimated that he had been involved in some 50 treatments of bed bugs from late 2000 compared with some five in the preceding 25 years (Lamond, P. Field Biologist, Pest Control Division, Rentokil Initial, 2004 *pers. comm.*). The majority of treatments have been in budget style accommodation and backpacker hostels, which have high visitation from overseas guests (Jones, G. Eagle Pest Control, 2004, *pers. comm.*). However, recent sites have included private homes, 'up-market' hotels, interstate trains, charter boats, and even ocean going cruise ships.

Figure 1: Number of bed bug treatments undertaken annually by Eagle Pest Control, 1996 to 2003, and for 2004 up to and including April only.



Other agencies also have observed the increase; the South Eastern Sydney Public Health Unit, NSW Health, started receiving a dramatic increase in complaints about bed bugs in November 2002 and has investigated 15 such infestations since that time. The majority of these were in shared accommodation in the beachside suburbs of eastern Sydney (Cains, T. Environmental Health Officer, South Eastern Sydney Public Health Unit, 2004, *pers. comm.*). The Pesticide Safety Branch, Western Australia Department of Health, has noticed a marked increase in bed bug enquiries over the last six months (Gregory, K. Scientific Officer, 2004, *pers. comm.*). No other state health department contacted by us has documented an increase.

AQIS reported some 23 interceptions of bed bugs since 1986 when the database was established (Table 1). Some 74% (17/23)of the detections has occurred since 1999 and at least 74% (17/23) has come through personal baggage, with most (15/23) via air travel. The country of origin of the bed bug importations is difficult to determine as the database records the 'last port of call', namely the last country visited. Despite this, the majority where known (13/19) recorded the Asia/Pacific region as being the last port of call. The bed bugs were detected in a variety of goods, with woven materials being most frequent (5 of the 22 known). The common bed bug, when identity was known, was the most frequently detected species (13/17).

Table 1: Bed bug interceptions by the Australian Quarantine and Inspection Service, from 1 January 1986 to 31 January 2004[1]

Interception Date	Country of Origin[2]	Method of Import	Goods	Species[3]
23-Nov-90	Fiji	Sea baggage	Dried curry powder	*Cimex lectularius*
16-Oct-92	Unknown	Post	Packing Boxes	*Cimex lectularius*
21-Dec-96	Papua New Guinea	Air baggage	Carvings	*Cimex lectularius*
22-Jul-97	Kenya	Air cargo	Fresh Roses	*Cimex lectularius*
06-Feb-98	India	Air cargo	Fresh Roses	*Cimex lectularius*
19-Nov-98	Fiji	Air baggage	Baggage, personal effects	*Cimex lectularius*
02-Feb-99	Unknown	Other methods	Cabin bedding	*Cimex hemipterus*
21-May-99	India	Air cargo	Wooden Musical Instrument	*Cimex* sp.
12-Jul-99	Indonesia	Air baggage	Packing paper	*Cimex hemipterus*
22-Sep-99	Unknown	Other methods	Airport inspection bench	*Cimex lectularius*
22-Sep-99	Unknown	Air baggage	Airport arrivals hall	*Cimex lectularius*
28-Sep-99	Fiji	Air baggage	Woven straw fans	*Cimex* sp.
21-Aug-00	East Timor	Air baggage	Mosquito net	*Cimex lectularius*
19-Nov-01	Papua New Guinea	Air baggage	Woven cane baskets	Not determined
11-Feb-02	New Zealand	Sea baggage	Baggage, personal effects	*Cimex lectularius*
20-Feb-02	Asia?	Air baggage	Airline blanket	*Cimex hemipterus*
26-Apr-02	Papua New Guinea	Air baggage	Woven straw bag	*Cimex* sp.
25-Jun-02	East Timor	Air baggage	Woven straw mats	*Cimex lectularius*
20-Aug-02	Yugoslavia	Air baggage	Suitcase lining	*Cimex lectularius*
25-Oct-02	Italy	Air baggage	Baggage	*Cimex hemipterus*
14-Dec-02	Papua New Guinea	Air baggage	Woven cane baskets	*Cimex lectularius*
27-Mar-03	Tonga	Air baggage	Dried Grass	Not determined
12-Nov-03	Turkey	Air baggage	Unknown	Not determined

Notes

1 From the Pest and Disease Information Database (Market Access and Biosecurity, Department of Agriculture, Fisheries and Forestry), and the Incidents database (Australian Quarantine and Inspection Service).

2 This represents the last port of call and may not necessarily be from where the bed bugs were acquired.

3 Identifications were mostly undertaken by Australian Quarantine and Inspection Service Entomologists, where marked 'not determined' the insects were identified as Cimicidae.

Discussion

Clearly, there is currently a major upsurge in bed bug infestations within Australia. The data presented here probably only represent the 'tip of the iceberg' and the Department of Medical Entomology increasingly is receiving calls from hotel owners, hostels and backpacking associations, private residents, as well as other pest controllers reporting an increase in bed bug infestations.

It would appear that most of the bed bug infestations probably have been brought into the country as indicated by the accommodation type most frequently treated. Despite this, some of the infestations have been acquired locally, as the Department does have documented cases of incidences in private homes where the owners have had neither a recent history of overseas travel nor any visitors from other countries.

The interception of bed bugs will always be very difficult as they are a small insect (1-6mm, depending on the stage) and are very elusive in nature. In the event of bed bug detection by AQIS, the goods are treated, re-exported or destroyed (Halling, L. AQIS Entomologist, 2004, *pers. comm.*). There has been much speculation on how bed bugs are spread from country to country (Boase 2001; Krueger 2000), and it would appear from the PDID that most are transported via the baggage of air travellers. This, we believe, is the first attempt to document how bed bugs are spread around the world. It is likely that several of the interceptions where the method of import was not known (such as those on 2 February 1999 and 22 September 1999, Table 1), were from the nature of the interception, probably also through baggage, giving a total of over 82% carried by luggage. The type of goods in which the bed bugs were found varied quite substantially and probably reflects the diversity of items carried by travellers. Woven materials, being of plant origin, are always closely examined by AQIS inspectors and, as they contain many crevices, are likely materials for bed bugs. It is also not surprising that most of the places of origin (despite these being recorded as the last port of call) were in poorer nations, as these countries did not experience the earlier downturn in bed bug numbers to the extent in more developed nations (Lindsay et al. 1989; Newberry, Mchunu & Cebekhulu 1991; Tonn et al. 1982).

The resurgence in bed bugs is happening in many developed nations. To highlight the increasing global concern regarding bed bugs even further, the Department of Medical Entomology has received email enquiries from around the world. Over the three-year period from 1998 to 2000, 16 bed bug enquiries were received, while from the start of 2001 to May 2004 there were 179. It is also worth noting that on the Department's web site (www.medent.usyd.edu.au) the Bed Bugs Fact Sheet is the most commonly accessed page globally.

There are many explanations for the recent increase in bed bug numbers, although none has been scientifically substantiated (Boase 2001). The rise in international travel is suggested as the main reason, with travellers being more likely to encounter the pest (*Professional Pest Controller*, 2003, vol. 32, pp.16-7). Air conditioning in modern buildings, which has eliminated extreme variations in temperatures, is thought to have allowed bed bugs to become established in some countries (Abul-Hab et al. 1989). There are indications that the trade in second-hand furniture, especially beds, has facilitated the transfer of bed bugs locally, and probably around the world (King 1990). However, no infested furniture has been detected by AQIS since 1986 (the start of the PDID), although as stated, bed bugs are notoriously difficult to detect.

There have been many recent changes in management practices within the pest control industry, benefiting bed bugs. For example, insecticidal treatments of bedrooms are no longer commonly undertaken (Garrards Technical Advisory

2002). Insect management now targets the control of specific pests, which means that bed bugs are unlikely to be affected incidentally by treatments. For example, cockroach control now relies heavily on toxic baits, rather than broadly acting surface insecticides, and thus bed bugs are no longer exposed to the toxins. When insecticdes are used against bug beds, it is the synthetic pyrethroids (SPs) that are mainly employed. It appears that these have a repellent effect and bed bugs can therefore avoid lethal contact. The SPs do not have as long a residual activity as previous chemicals, which means that reinfestations are more likely to occur. Many pest controllers have had little experience in the control of bed bugs and treatment failure is common, largely due to harbourages not being identified during the control process. Compounding this is the omission of bed bugs from the curriculum of many pest control courses in Australia, meaning that knowledge of basic ecology of this pest is often lacking among pest managers. Often the cause of the mysterious bites within a premise is not linked to bed bugs, and misidentification of these pests is known to occur (Falco 1998). Also, control technologies for bed bugs have remained virtually unchanged during the last 30 years (Krueger 2000).

Another possible reason for the recent rise in the incidence of bed bugs is the stigma attached to the reporting of bed bugs by the hospitality industry. If an infestation is reported, the perception is that business might be threatened, and so minor infestations are often ignored or treated in an *ad hoc* manner (King 1990). Ignoring infestations, however, does come with a great risk, notably the possibility of litigation as a result of visitors being bitten. This has now happened; in a landmark case, a motel chain in the United States was successfully sued for $US382,000 after guests were bitten by bed bugs (*Matthias vs Accor* [Accor Economy Lodging] 2003). Other court cases have followed (Bowles 2003) and the first author has been involved in local rental disputes over similar incidences. It is only a matter of time before litigation over bed bugs occurs in Australia.

The introduction of the tropical bed bug to Australia (Doggett, Geary & Russell 2003) has probably contributed to the general increase in bed bug infestations. This species prefers a warmer climatic zone than that of the common bed bug, and thus a greater geographical area is at risk of developing an infestation. Currently, the distribution of this species is not known and to date all identified specimens have come from Queensland.

Resistance to insecticides has long been recognised in bed bugs but only recently has this extended to the synthetic pyrethroids (Myamba et al. 2002). This was reported in the tropical bed bug overseas and so treatment failures might well occur here in the future, especially as this group of insecticides is often the preferred choice by pest controllers in Australia. As there have been no local studies of insecticide susceptibility, any resistance might not be recognised for some time and control failure would probably be attributed to other causes.

For the compilation of this report, most state health departments across the country were contacted regarding the apparent rise and, interestingly, very few receive enquiries about bed bugs. This might explain why the dramatic increase has escaped the notice of many health workers and why health authorities have largely not actively responded to the rise of this public health nuisance. With the increase in bed bug numbers, it would be expected that health workers would be called on for advice in the near future.

Finally, with the combination of reduced control pressures and the factors encouraging bed bug dispersal and establishment described above, an exponential increase in this pest might have been expected. This appears to be the situation currently in Australia and other countries around the world.

In light of the dramatic resurgence in bed bugs and the need for health workers to be provided with up to date information, a brief review follows encompassing identification, biology, clinical association and control.

Bed bug biology

Bed bugs are wingless insects, roughly oval in shape, 5-6mm long when fully grown, and are fast runners (Service 1980). They are pale cream in the juvenile stages becoming rust brown as an adult and change to a deeper red brown following a blood meal (see the Department's web site for photographs of live bed bugs: www.medent.usyd.edu.au). Bed bugs are dorsoventrally flattened and can hide in narrow cracks and crevices, making detection often very difficult.

Of the two species, the common bed bug has long been known in Australia, whereas the tropical bed bug was only recently recognised in the country (Doggett, Geary & Russell 2003). The two species are differentiated on the basis of an upturned lateral flange on the thorax of the common bed bug, which is absent in the tropical (Ghauri 1973).

There are five juvenile stages known as nymphs, that are miniature versions of the adults in general appearance. Each nymphal stage requires at least one blood meal to moult to the next stage and it takes 3-5 minutes for complete engorgement to occur. The length of the lifecycle is extremely variable and is dependent on temperature. For example, in cold conditions, they can live for almost two years, even without a blood meal. However, in average conditions of around 23°C, the lifecycle takes around two months to complete and the adult can live for almost 4.5 months (Busvine 1980). All nymphal stages and adults of both sexes require blood for nutrition and development. After mating, each female lays 2-3 eggs a day throughout her lifespan. The cream coloured eggs (1mm in length) are cemented on rough surfaces of hiding places and will hatch within approximately nine days at a room temperature of around 23°C, but take longer in cooler conditions.

The mouthparts of bed bugs are especially adapted for piercing skin and sucking blood. Like most blood sucking arthropods, they inject saliva during feeding, which has anticoagulant properties. Bed bugs respond to the body warmth of a host and quickly locate a suitable feeding site. They tend not to live on humans and the only contact is for a blood meal. Being a cryptic species, blood feeding typically occurs at night, and they tend to seek shelter during the day and become inactive while digesting the blood meal. However, bed bugs are opportunistic and will bite in the day, especially if starved for some time. While their preferred host is human, they will feed on wide variety of other warm-blooded animals including rodents, rabbits, bats and even birds.

Bed bugs shelter in a variety of dark locations, mostly close to where people sleep. These include under mattresses, floorboards, paintings and carpets, behind skirting, in various cracks and crevices of walls, within bed frames and other furniture, and behind loose wallpaper. Bed bugs stay in close contact with each other and heavy infestations are accompanied by a distinctive sweet, sickly smell, akin to that of 'stink bugs' that commonly infest citrus trees. Blood spotting on mattresses, bed linen, nearby furnishings and walls is often a telltale sign of an infestation.

Clinical association

Bed bugs are public health pests largely because of their nuisance biting, and often the most serious health aspect for many individuals is the mental trauma of knowing that there is an infestation. Skin reactions, which are commonly associated with bed bugs, result from the saliva injected during feeding. Some individuals do not react to their bite, whereas others can experience a great deal of discomfort and loss of sleep from the persistent biting. The most commonly affected areas of the body are the arms and shoulders. Reactions to the bites may be delayed; with up to nine days before lesions

appear (Sansom, Reynolds & Peachey 2003). Common allergic reactions include the development of large wheals, often >1cm, which are accompanied by itching and inflammation. The wheals usually subside to red spots and can last for several days. Bullous eruptions have been reported in association with multiple bed bug bites (Fletcher, Ardern-Jones & Hay 2002) and anaphylaxis may occur in patients with severe allergies (*Professional Pest Controller*, 2003, vol. 32, pp.16-7). In India, iron deficiency in infants has been associated with severe infestations (Baumann 2002). It has been suggested that allergens from bed bugs may be associated with asthmatic reactions (Abou et al. 1991; WanZhen & KaiShong 1995), although such studies are limited and require further investigations.

Bed bugs have been suggested for the transmission of a wide variety of infectious agents, although their status as vectors is uncertain (Kruegar 2000). It has been proposed that they might play a role in the spread of hepatitis B (Ogston et al. 1979), but this is not supported by epidemiological evidence (Vall Mayans et al. 1994) and attempts to transmit the virus to chimpanzees have been unsuccessful (Jupp et al. 1991). However, hepatitis B DNA can be detected in the faeces of bed bugs for up to six weeks post-feeding on a viraemic blood meal (Silverman et al. 2001) and so the possibility of transmission through contact with contaminated faeces or crushing live bed bugs cannot be excluded (Ogston & London 1980). Despite this, there has never been a single proven case of an infectious agent passed on to humans by bed bugs (Goddard 2003).

Bed Bug Control

To control bed bugs, a careful inspection must be undertaken and all possible hiding places within infested and adjoining rooms examined. Once all likely sources have been identified, an approved insecticide, which has some residual activity, should be applied to all harbourages. The synthetic pyrethroids are the main chemicals of choice for control in Australia because of their low mammalian toxicity, although the efficacy of different chemicals from this group was found to be highly variable when tested against a laboratory colony of the common bed bug (Fletcher & Axtell 1993). Non-chemical approaches to control involve the use of hot air and/or wrapping up infested articles and furniture in black plastic and placing the articles in the sun, thereby killing the bed bugs with the heat generated, although the latter method may not be effective on larger items such as mattresses. Generally, pesticides will need to be applied in conjunction with any non-chemical means of control. Good housekeeping practices, especially improvements in hygiene standards, and the reduction in possible harbourages such as cracks and crevices will discourage repeat infestations. Metal bed frames provide fewer hiding places than wooden beds and may help to prevent an infestation in a mattress from spreading to other areas of a room. As bed bugs are cryptic in their habits, complete control is often difficult to achieve with one treatment. This is especially so with heavy infestations and thus a post control treatment evaluation is always required.

Conclusion

The global rise of bed bugs early into the 21st century seems to be the culmination of numerous phenomena. Perhaps the most telling of these is the lack of understanding of the ecology and biology of the pest, which is essential for control. This lack of knowledge is probably not surprising; bed bugs had virtually disappeared as a significant pest in the western world for many decades. However, this appears to have now changed and unless the accommodation industry openly acknowledges the extent of the problem, and pest control operators and health professionals gain expertise in recognising infestations and provide the most appropriate management advice, then bed bugs will continue to prosper.

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Community Empowerment to Support Cooperative Environmentally Sound Management

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One way to protect communities better from hazardous chemicals is to support their involvement in the decision making processes that affect them. However, there are many obstacles to effective participation by the community, including limited access to information and expertise. This paper introduces the work of the National Toxics Network and its role in community capacity building through the development of community based information systems to support informed environmental decision making in toxic disputes. It reviews some situations where communities have found themselves at the centre of toxic disputes. It examines capacity building initiatives that inform and empower in order to facilitate the effective participation of civil society in the chemical management decision processes that affect them, their families, and their immediate environment.

Key words: *Pollution; Toxic Residues; Environmental Health; Policy; Emissions; Hazardous Waste Management*

One way to protect communities better from hazardous chemicals is to support their involvement in the decision making processes that affect them; a right enshrined in the Bahia Declaration on Chemical Safety (Intergovernmental Forum on Chemical Safety 2000). However, there are many obstacles to effective participation by the community, including limited access to information and expertise. This paper introduces the work of the National Toxics Network and its role in community capacity building through the development of community based information systems to support informed environmental decision making in toxic disputes. The term toxic dispute can be used to describe the political process of redress for victims of chemical contamination or residents affected by the siting of hazardous waste facilities. In this paper, it is used in the widest sense and encompasses the chemical conflicts between stakeholders concerned with pollution, toxic residues, environmental health and chemical policy (Reich 1991) over emissions and hazardous waste management. It reviews some real world situations where communities have found themselves at the centre of toxic disputes. It examines capacity building initiatives that inform and empower in order to facilitate the effective participation of civil society in the chemical management decision processes that affect them, their families, and their immediate environment.

The National Toxics Network (NTN) was first formed in 1993 and since then has grown as a national network to support community and environmental organisations across Australia, New Zealand and the South Pacific. NTN provides the many non-government organisations (NGOs) with a national and international voice on chemical and toxics issues. As the Australian focal point for the International POPs Elimination Network, NTN is currently working towards the implementation of the *Stockholm Convention*

on Persistent Organic Pollutants (POPs) (2001) and other relevant chemical conventions such as the *Basel Convention on the control of Transbourndary Movements of Hazardous Waste and their Disposal* (1989), the *Waigani Convention to Ban the Importation into Forum Countries of Hazardous and Radioactive Wastes and to Control the Transboundary Movement and Management of Hazardous Wastes within the South Pacific Region* (1995), and the *Rotterdam Convention on Proir Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade* (1998). Through the development of practical tools, such as the CD-based *Waigani Convention Handbook* for the South Pacific Regional Environment Program, NTN has provided capacity building resources for Pacific Island national regulators to aid them in the implementation of the four chemical treaties.

Internationally, NTN has represented both Australian and global NGOs at the OECD Chemical Joint Meetings, where it had a particular focus on the assessment and phaseout of persistent bioaccumulative toxic substances such as the perfluorochemicals, for example, perfluorooctanyl sulfonate (PFOS), perfluorooctanoic acids (PFOA) and the brominated flame retardants (BFRs) as well as the growing dependence on the protection of commercial business information (CBI). NTN is actively involved in the Intergovernmental Forum on Chemical Safety (IFCS) providing an Australian focal point for its INFOCAP information and capacity building program.

In Australia, NTNs focus is on community capacity building initiatives. It supports communities involved in hazardous waste management, for example; in the destruction of the world's largest stockpile of hexachlorobenzene (HCB) stored in the Sydney suburb of Botany and in the management and remediation of the DDT (1,1,1-trichloro-2,2-bis(4-chlorophenyl) ethane) contaminated dipsites in northern New South Wales and Queensland.

NTN is a member of a range of national advisory bodies including the Hazardous Waste Reference Group, the Dioxin Consultative Group, the National Industrial Chemicals Notification Assessment Scheme (NICNAS) and Australian Pesticides and Veterinary Medicines Authority committees as well as participating in their related technical advisory panels.

Capacity Building in Toxic Disputes

> *Unless the community has the capacity to receive the information, to interpret it, and to incorporate it into the decision making process, the amount and quality of information provided is irrelevant* (UN Earthwatch 1998).

In all toxic disputes there is considerable disparity of informational resources and expertise among the different stakeholders. Experience also shows that it is very difficult to manage or mitigate the impacts of pollution and hazardous waste without the ability to communicate effectively and equitably technical information with all those concerned with the issue. Across the globe, citizens face every day the challenges of participating in multiparty disputes over chemical policy, industrial pollution or the siting of hazardous facilities. This is often referred to as 'participatory technology' (Carrol 1971, p. 647). Yet, without knowledge and skills based 'capacity building', lay participants involved in these toxic disputes are easily disenfranchised. As one community member of the Botany Community Participation and Review Committee (CPRC) commented when reviewing the proposal for on-site destruction of hazardous POPs waste; "the real problem is that we don't even know the questions to ask" (Hillier, N., President, Botany Environmental Watch, 1998, *pers. comm*. June).

If they don t know why not simply trust us?

Faced with such a dilemma, why doesn't the affected community simply trust the word of

the regulators and industry? We enter the new century in a climate of growing public concern regarding new scientific developments, technical innovation and the role of experts. Consideration of these concerns formed part of international discussions regarding the public's involvement in science (Collier & Toomey 1997; Irwin & Wynne 1996). In 2000, the UK House of Lord's Committee on Science and Technology (UK House of Lords Select Committee on Science and Technology 2000) carried out an in-depth review of the perceived crisis of public confidence in science and technology. It dismissed the widely held assumption that the community's mistrust of science and technology was due simply to its ignorance and misunderstanding of science. Instead, it concluded that it was impacted on by a range of power disparities, commercial considerations and resource inequities. Differing considerations and experience of risks and related environmental justice issues were all integral to the acceptance of technical information.

Most important, the House of Lord's Committee stressed "democratic citizenship in a modern society depends, among other things, on the ability of citizens to comprehend, criticise and use scientific ideas and claims" (UK House of Lords Select Committee on Science and Technology 2000, para 1.11).

However, this ability depends on ready access to scientific and technical information. While it is usually accepted that environmentally sound decision making requires reliable, comprehensive, and accessible information, in the context of toxic disputes, there is rarely frank or open exchange of information. The issue of participants' rights to information remains fundamental to the resolution of chemical conflicts. Often the concentration of information, and thereby power, resides with select industry and government groups. The extensive protection for commercial business information (CBI) is provided with little consideration for the interests of affected communities. Nor can the reliance on freedom of information (FOI) legislation be warranted, as all Australian FOI Acts protect the confidentiality of a wide range of undefined commercial data (Lloyd-Smith 2002).

The incorporation of expertise is another contentious issue in most toxic disputes. However, reassuring the notion of a 'neutral, unaligned objective scientific expert', this is not borne out by the experience of the community. So often, the community's views of experts are coloured by the increased commercialisation and secrecy surrounding waste technologies and the close relationship and institutional ties between regulators, industry, and the risk assessor also compounds this mistrust (Grinter 1998).

While acknowledging that simply addressing the problems of information access and expertise within a dispute will not guarantee mutually acceptable or environmentally sustainable outcomes, failure to address these crucial issues carries its own risks. It significantly increases the chance that the dispute will not be resolved to the mutual satisfaction of stakeholders, and that the underlying conflict will remain unresolved, the power imbalances perpetuated and the dispute either continued or recommenced in another forum.

One response to this focuses on cooperative capacity building initiatives. They can take the form of cooperative information consolidation and the provision of community information system repositories. The collaborative model of information management (Allen et al. 1998) is a learning-based approach that can help communities access, develop, manage and refine technical information. Building on the 'joint fact-finding' (Susskind, McKearnon & Thomas-Larmer 1999) processes of conflict resolution, stakeholder dialogue is used to structure the information to provide the required decision support.

The participatory nature of this form of cooperative information consolidation (CIC) emphasises processes that in themselves can reduce the level of conflict surrounding environmental disputes.

To illustrate this, two case studies are presented. The first case study highlights what not to do and illustrates why there is so little confidence by the general public in the expertise and technical information provided by interested parties and government. The second case study provides recommendations for activities to address this.

Case Study One: The Tasmania TEST Incinerator

In November 2000, Total Energy Services Tasmania Pty Ltd (TEST) made an application to build and operate a Waste to Energy (WTE) incinerator at Bridgewater in the Brighton Industrial Estate, Tasmania. Estimated to cost $100-120 million, it proposed to burn 180,000 tonnes per annum of municipal solid waste ('MSW') and generate at least 20MW of energy. The Development Proposal and Environmental Management Plan ('DPEMP') was advertised on 3rd December 2000 and the public consultation closed on 5th January 2001.

In response, the Environmental Management and Pollution Control Board of the Department of Primary Industries, Water and Environment (DPIWE) published the Environmental Assessment Report in April 2001. It recommended that Brighton Council approve the application and in response to appeals, an amended list of environmental conditions was released in July 2001.

The TEST incinerator would use technology from Seghers Better Technology, a Belgian engineering company, which previously designed and operated WTE plants in Europe. The company was declared bankrupt in 2002 (Media Release 19 November 2002).

With the assistance of international NGO networks, it quickly became apparent that Seghers incinerators in Belgium and the USA had experienced serious emission problems, which had resulted in some closures. The Seghers incinerator in USA was reported to have failed stack emission tests for dioxin for five consecutive years and had been fined over a million US dollars for breach of environmental permits causing air pollution (Rogers 2001; Snyder 2001). Similarly, a 'state-of-the-art' Seghers incinerator in Belgium was involved in a furore over its breaching of dioxin emission standards and is now reported to have been closed. A study by the two Belgian scientists (de Fre & Wevers 1998) who were involved in the reassessment of the dioxin emissions from the Belgian incinerator had demonstrated how single point sampling for dioxins, rather than continuous sampling, could significantly underestimate dioxin emissions to the atmosphere (30-50 times).

The proposed site for the TEST incinerator also had problems. There were residential areas less than 2 kilometres from the site and in 1999, a 17 lot residential subdivision approximately 1 kilometre south east of the site had been approved. There were also at least three schools and a shopping centre situated within a 2-kilometre radius. Arguments raged over the predominant wind direction, but it was clear that at least on some occasions the wind would be likely to carry the incinerator plume towards residences, schools, parks and recreational facilities.

TEST health risk assessment

The TEST application was supported by a Health Impact Assessment, which was heavily reliant on a health risk assessment of air emissions (Stevenson 2000) prepared for an entirely different and unrelated incinerator proposal (GOWA) based in Kwinana, Western Australia. While the GOWA risk assessment was not available to either the community or NGOs, many of the assumptions, on which it was based, had already been challenged in the ongoing

conflict over the WA incinerator proposal. As well, it had only considered a handful of the hundreds of substances known to be emitted to air from incinerators. A 1995 study, published in Chemosphere (Jay & Steiglitz 1995), had identified over 250 substances emitted from incinerators, many of which were volatile organic compounds ('VOCs') with concentrations ranging from 0.05 to 100 µg/m^3. They included highly toxic and carcinogenic compounds such as benzene and phenols as well as phthalates.

Surprisingly, the GOWA risk assessment claimed that for both PCBs and PAHs, the results of the full health risk assessment were not presented because the risks arising from estimated exposures to these compounds were extremely small. The production of PCB byproducts by incinerators had been clearly identified in the Stockholm Convention on Persistent Organic Pollutants (2001). Neither of the risk assessments considered the growing concerns over brominated chemicals (first identified in incinerator emissions more than a decade ago) or acknowledged the widespread use of brominated flame retardants in commercial products such as carpets, textiles and plastics, many of which would end up in the incinerator feedstock. The generation of brominated compounds and in particular, brominated dioxins had recently been widely publicised in the European Commission Scientific Committee on Toxicity, Ecotoxicity and the Environment (CSTEE) warning about the risks of human and environmental exposure to brominated dioxins and furans created by incinerating brominated plastics (ENDS *Environment Daily* 18 November 2002).

In using the WA risk assessment, many of the significant differences between the two proposals and their siting were not addressed, including the type and size of the incinerator, the waste stream and a range of local meteorological and topographic conditions.

Disputes over the TEST byproducts

There were also many other disagreements over the assumptions underpinning the assessment of the TEST incinerator, including the quantity of ash that would be generated. The incineration industry's 'International Ash Working Group' estimated that a typical mass burn incinerator would produce approximately 342 kg of ash per metric tonne of municipal waste (Chandler 1997). This would consist of: 300kg of grate ash, 5kg of grate siftings, 5kg of boiler ash, 20kg of fly ash, and 12kg of air pollution control residue. Yet, it had been claimed that the Brighton incinerator would generate only approximately 18 tonnes of contaminated fly-ash and residues per annum that would need to be disposed of as hazardous waste. However, using the industry figures, burning 180,000 tonnes per annum of municipal waste would generate 6,660 tonnes of boiler, fly and air pollution control residues together with 54,900 tonnes of grate ash and siftings.

There were similar disputes over comparisons with dioxin emissions generated by residential 'wood stove' equivalents. The total dioxin emissions from the TEST stack had been estimated to be 180 mg/year (Department of Primary Industries; based on compliance with the emission limit of 0.1 ng/m3). This, it was claimed, would be less dioxins than 50 wood fires, that is, 49 wood fires burning 20 kg/day (Total Energy Services Tasmania Pty Ltd 2000). A simple recalculation made it clear that the figure was closer to 49,000 woodfires. Despite, all the ongoing disputes over data assumptions, calculations and the proponent's failure to acknowledge the increasing epidemiological evidence demonstrating the associations between municipal waste incineration and health impacts for workers and the public, the Environmental Assessment Report reached the conclusion that: "Health impacts at the nearest industrial and residential areas are likely to be negligible".

This form of assessment does nothing to improve the public's confidence in environmental planners, government agencies or technologies in general. Perhaps no process of assessment for the TEST incinerator would have resulted in its acceptance, in light of the Australian government's 1992 decision to abandon its proposal to build a centralised high-temperature incinerator (HTI) to destroy hazardous waste.

Nevertheless, a different model of participation and information consolidation and dissemination would have addressed the assumptions, calculations and datagaps much earlier in the process. This would have allowed the residents, the council and state government department's to tackle the issues in a more cooperative and positive framework, which could have contributed to building a relationship and trust that would benefit all stakeholders as well as any future development proposals.

Case Study Two: A Preferred Model

Such a relationship was established between local resident groups and the Botany City Council when they considered a proposal by the company Orica (formerly ICI Australia) to destroy the POPs stockpile of HCB (hexachlorobenzene) stored in the Sydney suburb of Botany. In that case, there was informed consideration of onsite destruction of the hazardous waste. However, the secrecy surrounding the assessments of risks to the local community plus the decision to reject a well tried and accepted non-incineration technology in preference to a semi-incineration vitrification process all conspired to undermine community tolerance of the project.

Nevertheless, what did result from this dispute, is a well informed, knowledgeable and astutely critical local community with sound and ongoing relationships with the local council. This was despite the fact that in the industrial and residential suburb of Botany, more than 45% of local residents had been born overseas, with most having English as a second language and with the majority having a low-income and only a moderate level of education.

From 1964 to 1991, the chemical company Orica produced hexachloro-benzene (HCB) as an unwanted byproduct from its manufacture of chlorinated solvents, carbon tetrachloride, and perchlorethylene. Approximately, 105,000 tonnes of HCB waste is stored at the Botany Industrial Park awaiting destruction. Australia's ratification of the Basel Convention removed the option of exporting the HCB waste to any overseas destruction facility (except in exceptional circumstances). In 1994, HCB was included in the National Strategy for the Management of Scheduled Waste, and a stakeholder body, the National Advisory Body on Scheduled Wastes (NAB) was given the task of consulting with the local community and negotiating a national management plan for the HCB stockpile.

In 1996, the federal and state ministers adopted the HCB Management Plan (Australian and New Zealand Environment and Conservation Council 1996), which was given effect through a chemical control order (CCO) under state legislation. However, a final decision on whether the waste would be destroyed on site or moved elsewhere was left to further consultations with the local community.

In early 2001, Orica released the proposal to build a facility at the Botany Industrial Park (BIP) to treat the HCB stockpile. The BIP was a large petrochemical manufacturing complex covering 73 ha and situated 11 kms south of the Sydney CBD. It already housed a chloralkali plant producing chlorine, a surfactant plant and a range of other chemical and plastic manufacturers.

A mix of commerce, industry and residential neighbourhoods surrounds the BIP. This included a large shopping complex near the site and a number of schools and hospitals in close proximity, as well as Sydney's international airport and Port Botany, through which almost all of

Sydney's commercial shipping passes.

Orica chose, based on costs and flexibility, the GeoMelt Vitrification Process, which destroys waste by reacting it with silica and alumina in steel crucibles. The waste is shredded and mixed with soil and loaded into crucibles, where it is melted by lowering electrodes progressively into the crucible. Once the melt cools it forms a vitrified glassy rock. However, as the HCB waste is decomposed at high temperatures, it also produces hydrogen chloride and other combustion off-gases, which would need to be collected and passed through a series of pollution-control devices.

The treatment technology had a history of adverse incidents, including an explosion at Maralinga, South Australia, where the waste had been treated in situ, that is, in the ground without the use of crucibles. The technology was seen by community and Botany City Council as being experimental, without sufficient scientific evidence to demonstrate safety, but with the potential to cause significant damage to human health and the environment. As the process depended on a thermal oxidizer (an incineration phase) for destruction of contaminants that survived the melt, it was viewed by many in the NGO community as an inappropriate incineration technology for the destruction of POPs.

The facility, operating 24 hours a day, seven days a week, for four years, would produce approximately 20,000 tonnes of vitrified rock needing storage or disposal. At the end of the destruction process, the HCB Management Plan required that the facility be dismantled and removed.

The HCB management plan had established the Community Participation and Review Committee (CPRC) in April 1997. Its role was to consider any matters that were within the scope of the plan that could affect the community's health or the environment including consideration of information about destruction technologies, its preferred siting, emergency planning, monitoring, compliance and public awareness campaigns.

The CPRC community participants faced significant challenges. The impacts of information and resource disparities, so typical of toxic disputes involving local residents, were clearly evident, as were the inevitable arguments over expertise, risk and conflict of interest. While government institutions viewed the HCB dispute as a national problem of hazardous waste management, the Botany community saw it as a local environmental issue concerned with human health and social equity. Much of their concern was linked to their experience of the waste holder, Orica, and its history of offsite pollution. While Orica claimed that the technology was safe and any risks acceptable, residents' experiential knowledge gave testimony to a range of spills, fires, and leaks and a well-publicised contaminated groundwater plume originating from poor management of toxic chemicals.

HCB Community Information System

A fundamental lack of access to information and expertise was clearly identified. Repeatedly at CPRC meetings, community participants expressed their dismay over the lack of access to full information regarding the company's ability to respond adequately to adverse incidents, and to the information and expertise they needed to assess all the risks involved.

The community members wanted an independent technical expert to provide them with an impartial assessment of Orica's technical data. They argued that the CPRC process had been set in train as a form of legitimisation for government initiated processes and, therefore, there was a clear responsibility for government to address this need. They were well aware of their right to information as set out in Agenda 21, and as described in the Bahia Declaration on Chemical Safety, that is, to participate meaningfully in chemical decisions that affected them (Intergovernmental Forum on Chemical Safety 2000).

In response, Orica provided a modest amount of funding ($5,000) for an external independent expert. However, in the adversarial nature of the dispute, clear separation between the expert and the funding was not achieved and the inevitable issue of a conflict of interest was raised. The concerns were due in part to the inability to provide a perception of an 'arm's length' between the independent expert and the waste holder, but also to other factors; not the least being the appearance of familiarity with Orica's technical staff, with whom the expert shared similar language and attitudes to risk.

Community participants argued repeatedly for an independent expertise based on the model used in the United States Environmental Protection Agency's (U.S.EPA) Superfund Program, where Technical Assistance Grants are provided directly to resident groups to employ their own experts. In an attempt to address the inequities of information and expertise, the development and trailing of the HCB Community Information System (HCB CIS) was initiated, utilising a cooperative information-consolidation process.

Its aim was to increase the residents' capacity by ensuring credible and undisputed information about all aspects of HCB, its management and destruction was provided to CPRC community members, matched with the capacity to use and disseminate it. Based on this objective, an information system design and development cycle was initiated. The development process was inclusive of all stakeholders including the proponent and industry. It was reiterative and incorporated changes reflecting the constant feedback from the CPRC participants and other users.

The criteria for the HCB CIS repository included being:

- designed in response to specific users' needs;
- developed from clearly established aims and objectives;
- prototyped to test acceptance of the data structure, content, layout, retrieval navigation and menu functionality;
- capable of storing large amounts of data with flexibility to incorporate changes in information requirements;
- built from a data collection plan with all data sets jointly accepted through a cooperative process;
- inclusive of different levels of complexity of information;
- easy to retrieve data by key word search, menu links and cross referencing;
- housed in one clearly identifiable and easily accessible system incorporating all relevant data and reference material;
- reviewed regularly with ongoing modifications, where appropriate; and
- attention given to resources and time allocation for maintenance and upgrades.

The final HCB CIS was provided as a CD for the residents and CPRC participants, a website for the wider community and printouts at the local library for those without computer skills. While the HCB Community Information System could not address the inequity of financial resources and expertise, it did provide an information resource, which both informed and empowered while removing conflict over basic information.

Most significantly, it was seen as an independent body of information on which residents, NGOs and Orica could agree. At the workshops held throughout the assessment stage, all stakeholders including ORICA directed the wider community to

consult the HCB CIS for independent information.

The HCB CIS provided information on:

- general issues of hazardous waste focusing on HCB;
- stakeholders and those agencies responsible for the HCB issue;
- the site, its history and surrounds including maps and aerial photos;
- options for waste destruction including detailed reports on the destruction technologies reviewed by Orica;
- the planning process and related legislation which was expanded to include the Commission of Inquiry;
- the minutes of the CPRC meetings, ORICA reports to NSWEPA, stakeholder submission on the Environmental Impact Statement;
- plus an electronic library of background papers, reports and overseas experience.

The HCB CIS also highlighted the limitations of the chemical risk assessment and the failure to supply the complete risk assessment to the CPRC. Many in the affected community viewed the company's risk assessment simply as a powerful tool to legitimise predetermined actions. They considered that it ignored many of the anecdotal and documented exposure incidences and pathways when it concluded that there was minimal risk. Residents continued to point out that the cocktail of chemicals and their synergistic reactions were simply being ignored, as was the community's experiential knowledge of the company's past record.

What was learnt?

The Botany research helped to identify the crucial elements common to toxic disputes (see Lloyd-Smith & Bell 2003). These are the aspects that must be addressed in order to move towards equitable and environmentally just resolution. They include:

- Dialogue (consultation process)
- Capacity building
- Right to know/information access
- Evaluation of risk/hazards
- Experts and expertise

The first two elements, dialogue and capacity building, are clearly concerned with process and focus on a course of action to promote effective communication within the dispute. Through capacity building, communities develop the skills to effectively participate in negotiating environmentally sound and just resolutions. The other three elements represent value themes that permeate all aspects and stages of the toxic dispute. It is these elements on which the process of dialogue and capacity building must focus. The competing forces of resources, commercial and institutional power, environmental justice, and sustainability influence all five elements. The order in which they are addressed may vary with individual disputes. However, it is evident that unless the community has a viable process for dialogue and capacity building (financial, geographic, technical) in order to participate, then the important issues of information access, the incorporation of expert advice, and evaluation of risk have no possibility of being addressed.

Conclusion

The case studies suggest that unless the evaluation of waste proposals are based on comprehensive, accessible, mutually agreed upon information, then toxic disputes will continue wasting all of our valuable time. They suggest that cooperative information consolidation early in a process can save

time, money and effort, as well as building positive relationships for the future. While there is no guarantee that access to information and expertise will ensure a proposal is accepted by the local communities and NGOs, they clearly demonstrate that in high profile proposals, failure to address these issues will result in rejection by the community. In the face of growing industrial, technological and chemical risks, community participation and empowerment provides a key to the resolution of toxics disputes and the achievement of environmental protection and justice, as well as a healthy pollution free future for us all.

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Scombroid Poisoning on the Sunshine Coast

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Scombroid poisoning is a food-borne illness resulting from the consumption of certain species of spoiled fish. It is arguably the major cause of food-borne illness from fish consumption worldwide. However, it is reasonably unknown in Australia and is likely to be under-reported and misdiagnosed as fish allergy. This paper examines two outbreaks of scombroid poisoning on the Sunshine Coast and discusses some of the problems and key issues to be considered when investigating outbreaks of this disease.

Key words: *Scombroid, Histamine, Public Health Unit*

Scombroid poisoning, also known as histamine fish poisoning, is an unusual illness resulting from the consumption of scombroid and scombroid-like fish species that have begun to spoil with the growth of particular types of bacteria. These bacteria produce the enzyme histidine decarboxylase, which converts histidine to histamine when fish are maintained at temperatures above 4°C. Scombroid poisoning is arguably the principal cause of morbidity from toxic fish consumption worldwide (Becker et al. 2001). Fish species associated with scombroid poisoning are harmless when fresh and after they have become toxic they may still have a normal appearance and odour although a bitter, sharp or peppery taste has been reported (Dickenson 1982 in Poisindex 2004; Kerr & Parke 1998). Histamine can accumulate to toxic levels and cause a rash, headache, vomiting and diarrhoea, and oral burning between 10 minutes and two hours after consumption of contaminated fish (Scoging 1998). Symptoms are generally mild, but severe reactions and deaths have been reported (Eitenmiller et al. 1981). Because scombroid poisoning is caused by bacterial spoilage, the disease is entirely preventable. However, once the toxin has formed, no available method of fish preparation, including cooking, freezing, canning and smoking, will render the fish toxin-free. The most important preventive measure is to ensure that fish are rapidly chilled, then refrigerated adequately and continuously from the time of catch to preparation (Gellert et al. 1992).

Traditionally, scombroid poisoning was thought to occur in fish with dark flesh, particularly the family Scombroidae (mackerel, tuna, skipjack) and Scomberosocidae (bonito, saury), but it has also been documented in numerous 'non-scrombroid' fish, such as mahi mahi, sardines, pilchards, anchovies and herring. These species are characterised by having relatively high levels of histidine in their flesh, although the fresh fish contain negligible quantities of histamine (Lehane & Olley 2000).

Scombroid poisoning is associated with high levels of histamine in the spoiled fish. Histamine is a naturally occurring substance in humans and its effects are usually only seen when it is released in large amounts as in allergic and other reactions. Many incidents of scombroid poisoning go unreported because of the mildness of the disease, lack of reporting and misdiagnosis (Lehane & Olley 2000).

In early 2003, the Sunshine Coast Public Health Unit investigated two reported outbreaks of scombroid poisoning concerning five cases in total. This paper describes these outbreaks and discusses some

of the important considerations when investigating and managing this type of food-borne illness.

Case Reports

Cases 1, 2 and 3

Four staff members from a medical centre consumed a lunch of fish, chips and salad at a restaurant. Within 30 minutes, two of these people became ill, reporting symptoms of erythematous rash affecting the face and arms (x2), diarrhoea (x1), itching (x1) and severe headache (x2). All four people had consumed mahi mahi (also known as dolphin fish). The two cases were treated with antihistamines and had largely recovered by the following day.

An interesting point to note was that following receipt of initial notification of the alleged illness, the chef/owner of the implicated restaurant also tried a small amount of fish from the same fillet. Within a short period, he too experienced a mild headache and a slight, transient rash on the neck. His symptoms were consistent with scombroid poisoning.

Cases 4 and 5

The Sunshine Coast Public Health Unit received notification from the Nambour General Hospital Emergency Department of two possible cases of scombroid poisoning following the consumption of tuna patties. The two cases experienced symptoms of diarrhoea, a red itchy rash, which was spreading over their bodies, headache, and numbness of the tongue and mouth, within 20 minutes of consuming tuna patties.

Results

Cases 1 and 2 were employed in a medical setting, prompting them immediately to notify the Sunshine Coast Public Health Unit of the illness. The Public Health Physician then made a clinical diagnosis of scombroid poisoning. An Environmental Health Officer from the Unit was able to obtain a sample of the remaining fish and forwarded it to Queensland Health Scientific Services for analysis. Others who ate portions of the larger fillet did not become ill suggesting that spoilage, and hence histamine, was localised in the fillet. The fish had been defrosted in the refrigerator and it would appear the temperature-related spoilage most probably occurred at an earlier stage.

The Analyst reported that this sample contained histamine levels of 2000 mg/kg. Normal fish has levels of less than 1 mg/kg (Smart 1992). The *Australia New Zealand Food Standards Code* states that the level of histamine in fish is not to exceed 200 mg/kg (Food Standards Australia and New Zealand [FSANZ] 2000). A level of 500 mg/kg histamine is considered hazardous to health (Kirk & Sawyer 1991).

The follow up with the supplier of this fish revealed that it was part of a four tonne batch of mahi mahi which had been sold over a number of months. No other complaints of illness were received in relation to this fish.

Cases 4 and 5 reported experiencing diarrhoea and itching within 30 minutes of consuming tuna patties purchased from a local seafood retailer. The two cases attributed the symptoms to a bottle of red wine, which was also consumed at the time. The following day, the two cases consumed another larger meal of tuna patties from the same batch and suffered more severe symptoms of poisoning, which were then attributed to the patties. These two cases presented to the Nambour General Hospital Emergency Department where they received treatment for their symptoms before they were later released.

The Emergency Department notified the Sunshine Coast Public Health Unit and supplied a sample of the tuna patties brought to the hospital by the patients. This sample was forwarded to Queensland Health Scientific Services for analysis, together with a control sample of tuna kebabs, which was obtained from the supplier from the same batch of tuna. The Analyst reported

that the complaint sample contained histamine levels of >250 mg/kg, which exceeds the prescribed limit under the Australia New Zealand Food Standards Code. The control sample contained 10 mg/kg of histamine, indicating some type of mishandling and/or spoilage in the original sample. It appears that violation of storage and temperature controls is more likely with tuna used for patties or burgers, because pieces are generally stored over a longer period than fillets. The grinding process used to make tuna patties might also contaminate the fish by either mixing histamine-forming bacteria into previously uncontaminated material, or by increasing the temperature of the tuna through mechanical friction (Becker et al. 2001). This hypothesis is supported by evidence that the prepared tuna patties contained higher histamine levels than the control sample of unground fish (tuna kebabs) from the same batch.

Discussion

The highest morbidity worldwide from fish poisoning results from consuming spoiled scombroid fish (Bagnis et al. 1970). The resulting acute illness is called scombroid poisoning. Scombroid poisoning is a chemical poisoning with a short incubation period, usually ranging from minutes to a few hours after ingestion. Symptoms include tingling and burning sensations around the mouth, headache, facial flushing and sweating, rash and itching on the upper body, abdominal cramps, nausea, vomiting, diarrhoea, and heart palpitations (Chin 2000). In most people, symptoms are self-limiting and generally will resolve within 12 hours without treatment (Chin 2000), although histamine poisoning can be life threatening in persons with conditions such as asthma and heart disease. Antihistamine medication (H1 and H2 [cimetidine]) can often relieve symptoms, but severe cases of toxicity can require the same aggressive management as acute anaphylaxis (Becker et al. 2001; Poisindex 2004).

High histamine levels are formed by bacterial proliferation on the surface of fish that has been inadequately refrigerated (Becker et al. 2001). It is produced in fish tissue by the decarboxylation of free histidine by bacteria containing the enzyme histidine decarboxylase. In tuna and other scombroid fish, the level of free histidine is typically quite high compared to other species (Kerr et al. 2002). Therefore, there is an increased risk that toxic levels of histamine can be formed, especially where the fish is mishandled or stored incorrectly during processing (Ababouch et al. 1985; Silva et al. 1998). Storage of fish under refrigerated conditions from the time it is caught until when it is consumed has been found to be very important in reducing outbreaks of histamine poisoning (Kerr et al. 2002).

Incidence rates of scombroid poisoning are likely to be considerably underestimated as the illness is generally mild, passes rapidly with no after-effects, and therefore is not usually reported to health authorities (Gellert et al. 1992). Recording of scombroid poisoning has been inconsistent because of a vague case definition and insufficient knowledge about it in the medical community (Becker et al. 2001). When medical attention is sought, physicians may misdiagnose cases as 'seafood allergy' or confuse symptoms with those of other types of seafood toxins (Becker et al. 2001). Diagnosis is often clinical, though the fish specimen can be analysed for histamine levels.

A history of a sharp, bitter or peppery taste in contaminated fish appears in some case reports and in the literature on scombroid poisoning (Kerr & Parke 1998). This indicator may be important in alerting the practitioner of potential scombroid poisoning. Diagnosis also requires recognition of the time course, signs and symptoms of the illness and is made more obvious in the setting of multiple presenters (Hall 2003). The availability of suspect fish for histamine analysis will be useful in supporting the diagnosis.

Histamine concentrations within a spoiled fish are extremely variable, as is the threshold toxic dose. The level of histamine permitted in fish under the *Australia New Zealand Food Standards Code* is 200 mg/kg. Histamine levels detected in samples consumed by all cases were found to be in excess of this permitted level. The implicated fillet consumed by cases 1, 2 and 3 had 10 times the permitted level of histamine which would account for the intensity and rapid onset of symptoms experienced by the cases.

One of the constraints on Public Health Officers when investigating a scombroid poisoning outbreak is that there are currently only a few laboratories in Australia that conduct histamine analysis in fish using either capillary zone electrophoresis or an ELISA (Enzyme Linked Immuno-sandwich Assay) test method. This analysis can be done within 10 days but can take up to a month if test kits are not immediately available. Each ELISA test kit can do a maximum of 32 samples, but costs about $1000 per kit.

Another important consideration when investigating this type of illness, as demonstrated in the first incident detailed above, is that elevated levels of histamine may be associated with only one fish in a batch and possibly be quite variable within a single fillet. This presents problems when attempting to determine what public health measures to implement when investigating a potential outbreak. In the first incident, for example, where the implicated fillet was from a four tonne shipment of mahi mahi, would it be acceptable to recall the entire four tonnes after one reported outbreak, even when the histamine levels appeared to vary within a single fillet? A detailed risk assessment would have to be undertaken on a case by case basis before these types of questions can be answered.

Conclusion

Scombroid poisoning is a complex condition. This is illustrated by cases 1 and 2 where only two people out of four became ill after consuming a meal from the same fillet, suggesting an uneven distribution of histamine in the contaminated fish. Case 3 also suffered symptoms after 'testing' some of the remaining fillet. Cases 4 and 5 actually received an extra dose of poisoning on two consecutive days before they realised that it was the fish that caused the symptoms. In both incidents a dose-response relationship was observed with increased symptoms associated with greater consumption.

In all cases, the prompt liaison between the treating physician and the Public Health Unit assisted in verifying a correct diagnosis of scombroid poisoning and enabled a quick response to prevent further poisoning from occurring. In addition, a rapid response enabled samples to be obtained and analysed, which supported the diagnosis.

Although scombroid poisoning is not documented as a major source of food-borne illness in Australia, under-reporting and misdiagnosis might lead to the problem being understated. However, it is an important diagnosis to consider if there is a rapid onset of symptoms following consumption of a fish meal, especially if gastrointestinal symptoms are accompanied by facial flushing, headaches, or itching.

From an investigation perspective, it is important to note that elevated levels of histamine may be associated with many fish, a few fish or only one fish in a batch, or even part of that one fish. This may make it difficult to assess what public health interventions to implement following an outbreak and any intervention should be carried out following risk assessment approach involving consultation with relevant experts.

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Influences on crowd behaviour at Outdoor Music Festivals

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*The results of some crowd behaviour at outdoor music festivals (OMFs) are injuries and sometimes death. The following study has identified a number of factors that are highly likely to have an influence on crowd behaviour and safety at OMFs. The participants in the study (*N=*44) were specialised security professionals recruited from a single organisation providing security at music based events. These study participants considered problems resulting from intoxication, crowd crushes, the style of live performances and the overall crowd composition as being responsible for the majority of the behavioural concerns they encountered at OMFs. These behavioural factors could form a basic criterion to identify higher risk to patrons at OMFs. Additionally, the study participants considered the overcrowding of venues, a lack of emergency planning and insufficient security staff at events being highly likely to impact on safety at these events. These behavioural and safety factors should be highlighted in pre-event discussions and within the approval processes for OMFs. Highlighting these factors will contribute to the provision of appropriate services and infrastructure based on the specific risk characteristics of each OMF.*

Key words: *Outdoor Music Festivals; Crowd Behaviour; Crowd Safety, Planning*

Outdoor music festivals (OMFs) are increasingly common events on the summer entertainment calendar for youth in Australia. Attending these OMFs is associated with a risk of injury and in extreme cases, death (Arbon 2003). A considerable proportion of the risks to the patrons at these events can be attributed to high-risk behaviour in the general admission or standing room only areas in front of the stages or 'mosh pits'. High-risk behaviour at OMFs is a form of free expression for the patrons and includes intense crowd activities such as crowd surfing, 'moshing', stage diving, crowd surges and a phenomenon that is becoming more popular in recent times called 'swirling' (Ministry of Culture 2000).

There have been a number of recent health related incidents at OMFs that include:

a) The deaths of nine and injuries to 26 patrons from a crowd crush at the Roskilde Festival 2000 in Denmark (Crowd Management Strategies [CMS] 2003)

b) The death of a young girl from a crowd crush at the Big Day Out in Australia 2001 (CMS 2003), and

c) Overcrowding at the Glastonbury Festival 2000 in England caused by a large number of gatecrashers (Avon & Somerset Constabulary 2000).

These incidents have contributed to an increase in public concern and the recognition that improvements in public safety and service provision for OMFs are required. The authors of the *Planning Guide for Event Managers* (Liquor Licensing

Division [Qld] 1999) consider that the best chance to conduct a safe and successful event is through comprehensive planning and the development of event management plans.

Currently, there are considerable variations in planning approaches for OMFs, which is having an impact on public safety at OMFs (Emergency Management Australia 1999). Therefore minimising the variations in the planning processes is a critical step in improving public health outcomes at OMFs (EMA 1999; LLD 1999). One way to have a positive impact on these processes is through the approval processes undertaken by environmental health practitioners (EHPs) working within the various government agencies. These EHPs need to have an adequate level of knowledge or at least access to information and tools to assist them. Continued research into crowd behaviour and safety can assist these approval processes and contribute to the overall body of knowledge for the management of public health impacts at OMFs.

The following study focuses on the factors influencing high-risk behaviour within crowds at OMFs held in Australia. The study participants were well trained; specialist security guards experienced at OMFs and provide observations into the emergency and public health management. The security guards had been selected for this study based on their proximity to the patrons and involvement in crowd management.

Background

Many EHPs are likely to be more familiar with the requirements for food premises and environmental activities than OMFs. There are well-tested management tools and regulatory frameworks to guide the establishment and operation of these other activities. This is not necessarily the case for OMFs, especially in terms of crowd management, and the approval processes are made more difficult by the variations in planning undertaken for each event (EMA 1999).

In terms of event planning, an example of the issues facing EHPs involved in the approval process can be demonstrated in terms of safety requirements in mosh pits at OMFs. Currently, there are limited requirements beyond employing adequate numbers of security staff and a single barrier at the front of the stage (Department of Health, Western Australia 1995).

Recent incidents have shown a need to increase these basic requirements (Weir 2002) which has resulted in event managers trying different methods of improving public safety including variations in crowd safety barrier designs. There are a number of recognised designs such as 'finger' barriers or multiple barrier systems (e.g. double or triple barrier systems) suitable for OMFs (Health & Safety Executive [HSE] 1999). All of these barrier options can be successful and depend on a number of supporting factors, such as the number, training and experience of the security staff and first aiders working at the event (HSE 1999).

It is important for management of OMFs, especially mosh pits, to be based on risk management principles (EMA 1999; EnHealth 2002 & Tatrai 2001). The risks to public safety are identified and assessed, then appropriate strategies are designed, implemented and monitored. It is possible to reduce the impact of these risks, however, Commons, Baldwin and Dunsire (1999) warn that patrons should still able to express themselves. Commons et al. (1999) recommend that harm minimisation strategies such as the introduction of structural changes and education campaigns are the best options to consider.

Structural changes could include: soft fall materials to minimise injuries; a variety of safety barrier configurations; dress (e.g. studded belts) and age restrictions; and limiting patron numbers (Commons et al. 1999; Earl 2001; EMA 1999; HSE 1999; Wertheimer 2000). Integral to these strategies are well-trained and experienced security guards who are responsible to maintain order during the event (EMA 1999; HSE 1999).

There are many factors to consider when determining appropriate harm minimisation strategies for events which include the size of crowds; the use of alcohol and drugs; high temperatures; the humidity and event characteristics (De Lorenzo et al. 1989; Spaite et al. 1990; Bowdish 1992; Edwards 1991; Michael & Barbera 1997; Milston 2002; Zeitz et al. 2002). The event characteristics include event duration, event type, age, crowd mood and density (Milsten 2002).

Commons et al. (1999) suggest that the current trend to prohibit crowd surfing and stage diving is suppressing youthful expression. These behaviours are the most common and prohibition has had positive impacts. The prohibition involves warning signs and announcements and the removal of repeat offenders from the mosh pit by security staff. For repeat offenders, a 'sin bin' system has been introduced and in extreme cases they are ejected from the event.

It is highly likely that the prevention of crowd surfing has caused the latest phenomenon called 'swirling' - where a crowd run in a circular motion drawing more patrons in and is similar to a whirlpool. This activity is difficult to control, as security guards must enter the crowd to break up the swirl.

The Study

A cross sectional design was used for this study (Morton, Hebel & McCarter 1990; Protney & Watkins 1993) involving a survey methodology for the collection of self-report data from the study participants. The study was conceptualised as an exploratory study so no formal hypothesis testing was conducted. The results are presented in a descriptive form only in tables showing counts and percentages.

Sample

The participants in this study came from a single organisation based in a Sydney, NSW. The organisation was chosen because it specialises in crowd management at OMFs. The study participants were employed at a large OMF and were recruited at the end of their shift. Only management, and senior and regular personnel were targeted for the study with a total of 44 staff members agreeing to participate in the study. The collection of data involved the use of a convenience sampling methodology (Portney & Watkins 1993; Streiner, Norman & Munroe-Blum 1989).

Survey questionnaire

This survey instrument was developed to collect data on public health concerns, the factors influencing crowd behaviour, and safety and personal reflections. First, the study participants were asked to identify the main public health issues they have encountered and their level of training and experience. The second section included a number of risks and issues and the study participants were asked to comment on the influence these factors have on crowd behaviour and safety. Finally, the study participants were asked to comment on their most recent experiences with crowd behaviour at OMFs.

The survey instrument had been piloted and modified prior to the study. The questionnaire was designed for completion in 10 to 15 minutes and contained a combination of closed and open questions.

Statistical methods

The associations between variables are summarised in tables showing counts and percentages. As this was an exploratory and descriptive study, little statistical testing was employed. Differences of 10% or greater between the categories were considered of interest.

Results

The study participants

A total of forty-four (N=44) security employees agreed to participate in the study. The only demographic data collected were length of experience in the security industry

and amount of training undertaken. All of the study participants reported receiving training to work as security guards and over 45.0% (*n*=20) of the study participants were considered very experienced (Table 1).

Table 1: Experience of study participants

Years of Experience	Nos and % of participants
0 to 1 year	7 (16.0%)
2 to 5 years	17 (39.0%)
6 to 9 years	7 (16.0%)
10 years plus	13 (29.0%)
TOTALS	44 (100.0%)

Major public safety concerns at OMFs

Most of the study participants (76.0%; *n*=34) considered that working at OMFs was different from other security work due to increased public safety concerns at these events. All the study participants identified public safety, with the most common being intoxication, crowd crushes, the impacts of inappropriate or failed event infrastructures and poor behaviour from the patrons (Table 2).

Table 2: Common issues related to public safety at OMFs

Issues	Responses
Intoxication	20 (20.6%)
Crowd crushes	14 (14.5%)
Infrastructure failure (e.g. collapse of temporary structures)	13 (11.5%)
Poor behaviour of the patrons	11 (11.5%)
Side effects of taking drugs	9 (9.5%)
Dehydration	7 (7.3%)
Overcrowding	7 (7.3%)
Heat exhaustion	5 (5.3%)
Crowd control	5 (5.3%)
Weapons and terrorism	3 (3.1%)
Hearing damage	2 (2.1%)
TOTAL	95 (100.0%)

Note: Study participants could provide more than one issue

Reflections and crowd behaviour

The type of performance and group mentality were considered by the study participants to be the most common motivators behind bad crowd behaviour at OMFs (Table 3). Hardcore punk rock and heavy metal performances were most likely to instigate negative behaviour in crowds. Common management strategies used included an appropriate security presence, safety barriers and alcohol management strategies.

Table 3: Behaviour influencing factors identified

Influencing factor	No. of responses
The performance (including the tempo, rhythm, favourite songs and recognition)	36 (59.0%)
Group mentality	19 (31.6%)
Alcohol	3 (4.5%)
Media	2 (3.3%)
The young age of patrons	1 (1.6%)
TOTAL	61 (100%)

Note: Study participants could provide more than one factor

Factors impacting on crowd behaviour and safety at OMFs

All the factors included in this study have been identified from the literature as having the potential to influence crowd behaviour and safety. However, one aim of this study was to have the study participants identify the factors considered most likely to have major impacts on crowd behaviour and safety at OMFs.

The following series of tables present data on the themes of crowd composition, venue configuration, drugs and alcohol, and security staff. The study participants were asked to reflect on their own experiences and to indicate the likelihood of these factors having an impact on crowd safety at OMFs. For this section of the questionnaire a five point Likert scale was utilised. As only highly influential factors were of particular interest the five-point scale was then collapsed into two categories (Minichiello et al. 1999). Differences of 10% or greater between the categories were considered of interest.

These two categories represent the following responses:

Highly likely = highly likely to influence crowd behaviour or safety at OMFs

Less likely = less likely to influence crowd behaviour or safety at OMFs.

Crowd behaviour

1. Crowd composition

The study participants considered that high numbers of males or patrons who are of extreme appearance, such as punks, and predominantly under twenty-five year old audiences were the factors under this theme to be most likely to have an impact on crowd safety at OMFs (Table 4).

Table 4: Crowd composition

Issue	Highly likely	Less likely
A crowd made up of mostly males	77.5% (*n*=34)	22.5% (*n*=10)
A crowd of mostly extreme appearance (e.g. punks)	64.0% (*n*=28)	36.0% (*n*=16)
A crowd made up of only 25s and under	62.0% (*n*=27)	38.0% (*n*=17)
A crowd made up of a wide variety of ages	25.0% (*n*=11)	75.0% (*n*=33)

2. Drugs and Alcohol

All the factors associated with drugs and alcohol were considered likely to impact on crowd behaviour at OMFs. However, the consumption of excessive amounts of alcohol was the most likely factor under this theme to influence crowd safety at OMFs (Table 5).

Table 5: Influences of drugs and alcohol

Issue	Highly likely	Less likely
Patrons consuming excessive amounts of alcohol at the event	82.0% (*n*=37)	18.0% (*n*=6)
Use of various drugs (e.g. speed)	76.0% (*n*=34)	24.0% (*n*=8)
Licensed events	69.0% (*n*=31)	31.0% (*n*=14)

3. Type of performance

The study participants considered that heavy metal, hardcore punk and rap performances were considered most likely to have an influence on crowd behaviour at OMFs (Table 6).

Table 6: The influences of the performances

Issue	Highly likely	Less likely
Patrons consuming excessive amounts	82.0% (*n*=37)	18.0% (*n*=6)
Metal	80.0% (*n*=35)	20.0% (*n*=9)
Hardcore / Punk	77.0% (*n*=34)	23.0% (*n*=10)
Rap	57.0% (*n*=25)	43.0% (*n*=19)
Power pop	48.0% (*n*=21)	52.0% (*n*=23)
Dance	25.0% (*n*=8)	75.0% (*n*=24)
Contemporary Pop	13.0% (*n*=6)	87.0% (*n*=38)
Country & Western	9.0% (*n*=4)	91.0% (*n*=44)
Classical	8.0% (*n*=1)	98.0% (*n*=11)

Crowd safety

1. Venue configuration

The study participants indicated that a majority of the venue factors were likely to influence crowd behaviour. The study participants did, however, report that overcrowding, inadequate emergency planning, hot humid air temperature, and use of general admission areas, were clearly identified as highly likely to have an influence on crowd safety at OMFs (Table 7).

Table 7: Influences of the venue configuration

Issue	Highly likely	Less likely
Overcrowding of venues	77.0% (*n*=34)	23.0% (*n*=10)
Inadequate emergency planning	77.0% (*n*=34)	23.0% (*n*=10)
Hot humid air temperature	70.0% (*n*=23)	30.0% (*n*=10)
General admission areas (standing room only areas)	64.0% (*n*=28)	36.0% (*n*=16)
Pinch points that restrict movement	57.0% (*n*=25)	43.0% (*n*=19)
Unavailability of water for patrons	56.0% (*n*=18)	44.0% (*n*=14)
barriers to control crowds (not enough)	50.0% (*n*=16)	50.0% (*n*=16)
barriers to control crowds (too many)	48.0% (*n*=21)	52.0% (*n*=23)

2. Security Staff

The study participants considered the majority of the factors related to security staff identified in the study were likely to have an impact on crowd behaviour. However, numbers and experience of the security guards and poor communication and managed entry/exits were the factors considered highly likely to have an influence on crowd safety at OMFs (Table 8).

Table 8: Influences of the security staff

Issue	Highly likely	Less likely
Overcrowding of venues	77.0% (*n*=34)	23.0% (*n*=10)
Security guards (not enough)	80.0% (*n*=35)	20.0% (*n*=9)
Security guards (poorly trained/inexperienced)	75.0% (*n*=33)	25.0% (*n*=11)
Poor communication (security & other key staff)	69.0% (*n*=31)	31.0% (*n*=14)
Poorly managed entry/exit areas	64.0% (*n*=29)	36.0% (*n*=16)
Poorly managed ticketing areas	51.0% (*n*=23)	49.0% (*n*=22)
Security guards (too forceful/ not forceful enough)	46.0% (*n*=21)	54.0% (*n*=24)

Discussion

The study participants considered problems encountered at OMFs resulting from intoxication, crowd crushes, the composition of crowds, and the types of performances, as some of the main concerns. Heavy metal, hardcore punk and rap performances were considered likely to affect crowd behaviour. Crowds composed of mostly males, or of extreme appearance, or patrons under the age of 25 years, the consumption of alcohol and drugs, were all identified as being highly likely to influence crowd behaviour at OMFs. The overcrowding of venues, a lack of appropriate emergency management planning, high humid temperatures, and inadequate numbers of trained and experienced security guards, were most likely to impact on public safety. Knowledge of these factors can assist EHPs better to understand the hazard identification component of the risk assessment process being undertaken for mosh pits at OMFs (enHealth 2002).

Potentially, there are two uses by EHPs for the findings from this study. First, the factors identified to be highly likely to influence crowd behaviour and safety should be highlighted in early discussions with the event organisers. This will increase the likelihood of strategies being considered that reflect the appropriate level of risk for that particular event. Second, these same factors should also be highlighted during the review process of the event planning documents. In this way, EHPs can confirm that an appropriate level of consideration has been given to the relative risks within the event planning process.

It is also likely that many of the factors that influence crowd behaviour and safety will appear concurrently at OMFs. Issues such as alcohol consumption, overcrowding, higher ambient temperatures and the level of security staffing, become more significant when the critical performances and crowd demographic characteristics are all present. A key finding from this study is that attracting a broader crowd demographic at an OMF will potentially have a positive influence on crowd behaviour and safety.

Identifying the factors highly likely to affect crowd behaviour and safety is one issue, but being able to determine the appropriate level of management required is another. The risks associated with mosh pits at OMFs can be reduced and there are resources available for EHPs to utilise. One resource available is the Emergency Management Australia (EMA) manual titled *Safe and Healthy Mass Gatherings* (1999), which is available electronically from the EMA website. This resource includes a number of checklists that can assist both the EHPs and event managers, and discusses a variety of strategies that can be used. Also there is an international resource published by the Health and Safety Executive (1999) in England titled *The Event Safety Guide* (also referred to as the "purple" book).

The following are examples of the different strategies and controls that may be encountered by EHPs during the approval processes to manage venue overcrowding, emergency management, alcohol and drug management, and security staffing issues.

Overcrowding can be limited by controlling patron numbers at the OMF, especially in the mosh pit area. To determine appropriate numbers of patrons can be determined using the findings from research undertaken by Fruin (EMA 1999). Fruin (in EMA 1999) has indicated that optimal crowd densities be considered at no less than 0.46 square metres per patron.

Emergency management planning is considered important for any mass gathering and should be undertaken to meet the risks at OMFs as documented in the national and international event guidelines (EMA1999; HSE 1999).

The alcohol and drug management strategies, such as designated drinking areas, highly visible security staff, provision of appropriate medical treatment facilities and services, incorporate the use of trained, peer support groups such as 'Rave Safe' teams, and prompt defusing of intoxication related behaviour, are recommended strategies.

The provision of adequate numbers of appropriately trained and experienced security staff is very important to crowd management. The standard expectation for security is one guard per 150 patrons (Department of Health Western Australia 1995). However, the numbers of security guards should be closely linked to the type of performance and crowd demographics, as well as to advice from expert security consultants. It is important to note that the integration of strategies is recommended for the best results.

Limitations of the study

A limitation of the study is the small sample size (N=44) and that the participants have been recruited from a single organisation. All the security staff targeted, participated in the study.

Conclusion

The results of inappropriate crowd behaviour compounded by poor service provision can be injuries, and sometimes even death and it is, therefore, important to minimise these effects. This study has identified a number of factors that are highly influential in crowd behaviours and safety for mosh pits at OMFs. The study participants considered possible problems at OMFs, which could result in such dangerous effects, and the main concerns encountered were from intoxicated people, crowd crushes, some types of performances, and the composition of the crowds. These and other key factors were considered to form basic criteria for recognition of individual risk characteristics for OMFs.

Additionally, these factors could be highlighted in pre-event discussions on crowd behaviour and safety between regulators and events' organisers and then again within the assessment processes to finalise the approvals of OMFs. This is to encourage the provision of appropriate levels of service and infrastructure to maximise crowd safety for patrons for each individual OMF.

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Sustainable Development: A Term yet to Penetrate Public Consciousness

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The enHealth Council (2000) supports those practices that incorporate a system of rewards for achieving integration between sustainable development and environmental health practice. This study assessed the link between sustainable development and a Rates Rebate Scheme that fosters environmental health by rewarding retention and maintenance of valued habitat in Cooloola Shire, South East Queensland. It found that there was a dearth of understanding of the term 'sustainable development' among the general public; a concern for those responsible for implementation of sustainable development policies and environmental health. Those who were eligible to participate in the Rates Rebate Scheme had a better understanding of sustainability than the general public.

Key words: *Sustainable Development; Environmental Health; General Public; Rates Rebates; Local Government*

Local government is widely seen as one of the important facilitators of sustainable development policy. Burritt (1999) points out that local, state, and national governments in Australia are legally required to adopt the concept of ecologically sustainable development. The term 'sustainable development' is open to many interpretations, ambiguities and complexities (Carruthers 2001; Esty 2001; Floyd, Vonhof & Seyfang 2001; George 2000; Lim 2001; Mercer & Jotkowitz 2000). Bruff and Wood (2000) maintain the first broad objective for sustainable development is high, stable economic growth and employment, whereas Eichler (1999) notes three imperatives: remaining within bio-physical limits; ensuring an adequate standard of living; and providing social structures that develop and sustain values that maximise human welfare. Lowe (2001) maintains that economic development has exposed the present generation to soil and water degradation, the greenhouse effect, global warming and other serious systemic problems. These have become serious issues impacting both on human health and healthy environments. The definition of 'sustainable development' underpinning this project is an amalgamation of the World Commission of Environment and Development ([WCED] 1987) definition with its emphasis on the need for equity for present and future generations and Eichler's (1999) definition with its emphasis on bio-physical limits, adequate living standards for all, and social structures that maximise human welfare. The sustainable development component of the Guiding Principles of the Australian Charter for Environmental Health also endorses the WCED definition (enHealth Council 2000, p. 5). The enHealth Council definition of environmental health is: "those aspects of human health determined by physical, chemical, biological and social factors in the environment" (enHealth Council 1999, p. 3), and it covers a "wide ranging, multidisciplinary field" (enHealth Council 1999, p. 2). The concept of integrated sustainable development and environmental health was canvassed in this research

through the exploration of sustainable development and rates rebates in a local government setting.

Designing programs to encourage people to take a more sustainable approach to development has exercised the ingenuity of a number of people since the WCED in 1987. Rebates of various types have been nominated, among many other ideas, as tools suitable for achieving sustainable development outcomes (Berwick 1997; Global Ideas Bank 2002; Kirkby, O'Keefe & Timberlake 1995; Natural Heritage Trust 1999; Stockwell 1996; von Weizsaker, Lovins & Lovins 1995). The Cooloola Shire Council in South East Queensland, Australia, was the first local government in Australia to implement a Rates Rebate Scheme that attempted to achieve nature conservation on private rural properties encompassing high quality ecological values (Stockwell 1996). In the mid-1990s, planners within the Cooloola Shire Council responded to the perceived shortcomings of the Environmental Impact Assessment (EIA) model by considering that early in the planning process endeavours should be made to develop 'trust relationships' to resolve differences between parties (Stockwell 1996). Out of this lengthy process of community consultation and the building of 'trust relationships' came several initiatives to address local ecological issues, one of which was the Rates Rebate Scheme for Nature Conservation.

The Rates Rebate Scheme addressed the need for property owners to be encouraged to engage in conservation practices that enhance, restore or remediate the natural values of their properties. To be eligible for consideration for the Scheme the nominated property must include some of the following features:

- remnant or ecotonal rainforest;
- riparian ecosystem;
- melaleuca wetlands;
- wildlife habitat or corridor;
- rare or endangered species;
- old growth forest;
- scenic landscape; and
- other relevant features (Bouma 2000).

The properties are then subsequently assessed on the following criteria:

- vegetation type values;
- ecological linkage values;
- ecosystem status values;
- wildlife habitat values;
- catchment management values;
- scenic qualities values; and
- the intention to maintain or enhance ecosystem value (Bouma 2000).

Each criterion has three possible indicator ratings that score ten, five, or one. The highest possible rating for a property is 60. The original requirements for a successful application for the Scheme were less stringent than current requirements. Originally, a qualifying score of 25 was considered adequate, but deliberations in 2001 set the minimum score at 40 to increase the value of ecological outcomes (Bouma 2000).

This research project considered the Rebate Scheme six years after its initial implementation, by which time the number of participants in the scheme had reached 30. The rebate rates had been adjusted recently as shown in Table 1.

The initial point of interest in the research was whether people who had an understanding of sustainable development were more likely to take up the offer of a

Table 1: A comparison of original and current rebate rates

Area	Up to 2001	2001 Onwards			
		Score 25-30	Score 30-40	Score 40-50	>50
<5ha	50% general rate or $300 pa max	20% general rate or $100 pa max	30% general rate or $150 pa max	40% general rate or $175 pa max	50% general rate or $200 pa max.
5-10 ha	50% general rate or $500 pa max	20% general rate or $150 pa max	30% general rate or $200 pa max	40% general rate or $250 pa max	50% general rate or $300 pa max
10-20 ha	50% general rate or $750 pa max	20% general rate or $200 pa max	30% general rate or $300 pa max	40% general rate or $400 pa max	50% general rate or $500 pa max
>20 ha	50% general rate or $1000 pa max	20% general rate or $300 pa max	30% general rate or $400 pa max	40% general rate or $500 pa max	50% general rate or $600 pa max

Source: Bouma, 2000, p. 18

rates rebate than people who had little understanding of the often used concept that might or might not have wide currency among the general population.

Methods

Two methodologies were deemed necessary to ascertain, first, the level of understanding of sustainable development among three populations. These populations were: i) members of the general public; ii) those who were currently rebate participants (participants); and iii) those whose properties were identified by Council as containing the appropriate ecological values to be eligible for inclusion in the scheme, but who had not applied for inclusion in the scheme at the time of the research (non-participants).

Second, a focused interview with the participants and the non-participants, was considered appropriate to ascertain what influenced people's participation in the rebate scheme. Further, the research investigated whether or not an understanding of the sustainability concept influenced respondents' accessing reimbursement of rates for conservation of private property that has ecological value.

A questionnaire pertaining to an understanding of sustainable development was administered to all three groups: general public, participants, and non-participants. The questionnaire consisted of a mix of closed and open-ended questions. It was administered to 150 members of the public at a large shopping centre in Gympie, using a systematic sampling process of approaching every fifth person. The Cooloola Shire Council invited the 30 participants and 75 eligible, but non-participating property owners, in the Rates Rebate Scheme to take part in this research project. Eighteen participants and 10 non-participants agreed to be involved in the project. The questionnaire yielded quantitative data that was processed mainly through Pearson's Chi-square (χ^2) tests. Cross-tabulations were examined to compare frequencies in order to interpret the χ^2 results. Qualitative responses were reviewed in order to explain the quantitative results.

Results

All results were tested for statistical significance of association using the Chi-square test at the generally accepted limit of significance for such studies ($p<0.05$).

There was a significantly lower level of recognition of the meaning of the term 'sustainable development' among members of the general public than among both participants and non-participants. All participants in the Rates Rebate Scheme had frequently heard of sustainable development, and all but one among the non-participants had heard frequently of sustainable development (n=178).

The three populations were tested against the meaning of the term 'sustainable development' and again there were

significant differences among the three populations. Those with land that Cooloola Shire Council had identified as eligible for inclusion in the Rates Rebate Scheme, both participants and non-participants, showed a better understanding of the meaning of sustainable development than members of the general public, of whom 45.3% indicated that they had no idea what 'sustainable development' meant.

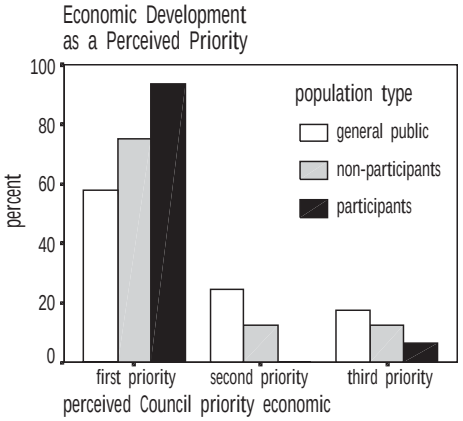
Contrary to expectations, 93.8% of participants and 75.0% of non-participants in the Rebate Scheme identified economic matters as the primary focus of sustainable development.

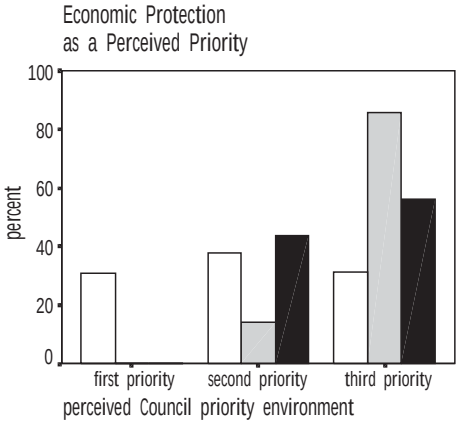
When considering the general public results, the oldest age cohort was found to interpret sustainable development as having a predominantly environmental focus (*n*=150), whereas the 30-49 year olds were inclined to identify the environment or the economic focus as predominant. Of concern is the fact that more than two thirds of the under 30 year old respondents had no idea of the meaning of sustainable development.

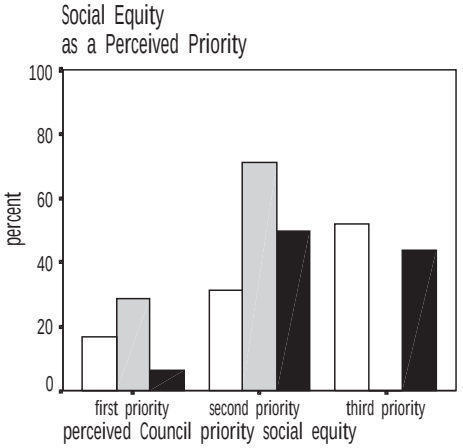
Females (52.6% of females) in the general public sample were less likely to have "heard about sustainable development" than males (30.6% of males). There were further differences based on gender, for general public responses, to the question about what sustainable development "means". Males (36.1% of males) were more inclined than females (16.7% of females) to identify the environment as the central focus of sustainable development. Similar proportions of females (approximately 16.0% of females) considered one of environmental, social or economic matters as the predominant focus of sustainable development.

Only 1.3% of females from the general public recognised the combined foci as central to sustainable development whereas 11.1% of general public males did so. These findings have implications for environmental health in Australia as sustainable development is the third principle of the Australian Charter of Environmental Health (enHealth Council 2000).

Figure 1: Cooloola Shire Council priorities as perceived by the three populations: general public, non-participants, and participants in the Rebate Scheme







There was no difference between groups in their perception of Cooloola Shire Council's principle focus when choosing from three priorities, namely environmental protection, social equity, and economic development. All groups, 57.9% of the general public, 75.0% of non-participants, and 93.8% of participants, agreed that economic development enjoyed the highest priority (Figure 1).

There were differences in perception among groups when considering environmental protection and social equity. No participants or non-participants perceived environmental protection as the highest priority of Council whereas 30.7% of the general public did so.

The perception among all three groups was that the Cooloola Shire Council favoured economic development. However, among the general public, some respondents expressed an ambivalent attitude to the worth of economic development as a major priority shown in comments such as:

> *They only care about business around town or the farmers, they don't care what happens to the bush.*

> *The Council takes good care of business, and that is pretty important.*

It is noteworthy that those with the greatest understanding of sustainable development, that is, the participants in the Rates Rebate Scheme, did not consider environmental protection as the highest Council priority. For some among the general public a certain naivety or annoyance towards environmental protection as the highest priority is shown in such comments as:

> *The Council won't even let you cut down a tree any more, so obviously they think environmental protection is the most important thing.*

> *The Council is very interested in tree planting and other environmental issues, so environmental protection must be their main focus.*

Equally, among those members of the general public who thought that social equity was Council's first priority, naivety and misunderstanding showed in such comments as:

> *Obviously it's social equity. They are always up there in the Council having their photos taken for the paper.*

After the questionnaire had been administered to the three populations, a focused interview was conducted with the two populations of the participants and non-participants in the Rates Rebate Scheme. A focused interview was considered appropriate for this part of the study as it is not so wide-ranging as an unstructured interview but concentrated on the issue of the Rates Rebate Scheme (Merton 1956 in Bryman 2001).

It is from the focused interview that the further two issues of pertinence to environmental health were raised. It is apposite to note at this point that the method, derived by the researcher and the Cooloola Shire Council, of inviting non-participants to engage in the research, resulted in a very small return (10 respondents from 75 invitations). This may have led to the situation where people who had a positive attitude to involvement with environmental issues self-selected for participation in the interview.

The first question of the focused interview rated the level of interest in the Scheme by participants and non-participants in the Rates Rebate Scheme and the reason for that level of interest. All respondents agreed that the Scheme was 'interesting' or 'very interesting'. Table 2 shows the categorised responses that individuals gave as reasons for their level of interest.

Table 2: Reasons given for interest in the rates rebate scheme

Categorised response	Participants	Non-participants
Nature, conservation, natural areas, environment	72.2% (n = 18)	60% (n = 10)
Financial returns	33.3% (n= 18)	50% (n = 10)
Rewards/incentives	27.8% (n = 18)	
Other responses	16.7% (n = 18)	10% (n = 10)

Some of the responses to the first question regarding interest in the Scheme include:

> *a chance to be rewarded financially.*
>
> *an incentive, reward, encouragement - to compensate* [effort] *and rectify* [damage].
>
> *encourage next owner to leave alone - the rebate is an incentive* [for this to happen].

The second question asked in what ways the Rates Rebate Scheme was important to the individual. Table 3 shows in what ways the Rates Rebate Scheme was important to the respondents.

Table 3: The reasons given for the importance of the rates rebate scheme

Categorised response	Participants	Non-participants
Incentives	22.2% (*n* = 18)	20.0% (*n* = 10)
Money	50.0% (*n* = 18)	70.0% (*n* = 10)
Politics, local government, authority, bureaucracy	38.9% (*n* = 18)	
Other	27.8% (*n* = 18)	10.0% (*n* = 10)
Conservation		20.0% (*n* = 10)

Responses to the second question about the ways in which the Scheme was important to the individual include:

> *Rates Rebate Scheme provides for equality between ratepayers…provides a form of differential rating for differences in land use.*
>
> *important politically because Council supports the Rates Rebate Scheme…it makes conservation more mainstream.*
>
> *it means someone in local government put a value on land that isn't suitable for farming…not necessarily a money value but an intrinsic value.*

When asked if they could identify whether land management practices on their property affected anyone off-site in terms of social, economic or environmental matters, responses revealed some environmental health values of such a program (Table 4).

Several respondents identified visual amenity and educative capacity as social outcomes, while two recognised the value of these, in terms of mental health and community building. Environmental health outcomes were recognised in terms of water, wildlife corridors, and bio-diversity values. These environmental health phenomena were also recognised as having favourable economic outcomes in terms of land value and eco-tourism.

Table 4: Perceptions of individual land management practices on social, environmental and economic outcomes

Social outcomes	Participants	Non-participants	Total
Educative role	6	5	11
Visual amenity for others	4	1	5
Appreciative visitors	4	0	4
Effect on neighbours	2	1	3
Mental health	1	1	2
Community building	1	1	2
Other	4	0	4
Total	22	9	31
Environmental outcomes	**Participants**	**Non-participants**	**Total**
Water issues	5	5	10
Wildlife corridors	5	1	6
Biodiversity	4	0	4
Habitat	3	1	4
Erosion control	2	1	3
Example to others	2	0	2
Others	5	3	8
Total	26	11	37
Economic outcomes	**Participants**	**Non-participants**	**Total**
Timbered blocks more saleable	3	3	6
Ecotourism	3	0	3
Timber income	2	1	3
On-property costs paid into community	0	2	2
Others	6	3	9
Total	14	9	23

Discussion

Discussion of, or education in, sustainable development is not reaching females in the general community. As women have an important role to play in family health outcomes, strategies to ensure their appreciation of the need for sustainable development outcomes should take a high priority. The enHealth Council (2000) notes the need for integration of sustainable

development principles and environmental health practice along with promotion of potential outcomes from both programs. The enHealth Council (2000) supports those practices that incorporate a system of rewards for achieving such integration. With a low level of recognition of sustainable development in the general public, education programs and information dissemination are needed to foster this initiative of public awareness.

Not only had many members of the general public not heard of sustainable development, but also those who had, did not understand the concept. Further, they did not understand the individual components, let alone the importance of the linkages between those components. However, those participating or eligible for the Rates Rebate had a clearer understanding of the concept and its components. While some did not understand the linkages between the components to any substantial degree, they showed some insightful perceptions by suggesting that, although the Council espoused sustainable development, its primary focus was probably growth and economic development. When people are actively engaged in environmental issues, recognition of sustainable development is high with no comparable gender anomalies as in the general public, in either recognition or understanding of sustainability. It would appear that education and/or life experience with environmental values and activities lead to a greater understanding of the sustainability concept. This is the level of understanding that is necessary for integration of the two concepts of sustainable development and environmental health.

Rather than supporting the initial contention that a recognition and understanding of sustainable development influenced people's decision to participate in the Rates Rebate Scheme, this research has shown a correlation between participation and a knowledge of sustainability.

Conclusion

Without a balance between social equity, economic development and environmental protection, further erosion of social amenity, with all the inherent problems associated with declining environmental health, may be inevitable (enHealth Council 2000). This study has shown that the term 'sustainable development' is not well known among the general public, and hence the likelihood of achieving high levels of sustainable development is limited. The need for extensive education of the general public, including specifically women and young people, regarding sustainable development and its actionable outcomes, through agencies such as environmental groups and local, state and commonwealth governments, is obvious.

The term 'sustainable development' has been in use since 1987, and has achieved a very shallow penetration into public consciousness. This disturbing result should be of concern for those who rely on community engagement to implement sustainable development policies. If the term 'environmental health', officially used when the National Environmental Health Strategy was inaugurated as policy in 1999, is not to suffer the same fate there needs to be extensive work done on introducing and explaining it to people in order for them to support it and to benefit from it. A strong point can be made that esoteric terms do not necessarily indicate the reality of implementation; only understanding, and actions growing out of understanding, will achieve quantifiable results pertaining to both sustainable development and environmental health.

Because eligible but non-participants in the scheme showed a higher level of recognition and understanding of sustainable development than the general public, it could be that a prior respect for environmental matters is aligned with, but not a determinant of, participation in the Scheme. It appears then, that those who are environmentally committed as evidenced by

their ownership of properties that comply with the criteria of the Rates Rebate Scheme are aware of the sustainability concept. Some, however, may prefer not to formally acknowledge their commitment through such schemes that could be seen to limit proprietary independence.

There are significant insights drawn from this preliminary study regarding the evident misunderstanding of the terminology and components of sustainability. These insights expose gaps to be filled before the terms 'sustainable development', and conceivably, 'environmental health', can achieve a satisfactory level of integration. Specialists and practitioners could become so familiar with specialist terminology that they assume a penetration and understanding of these terms that simply do not exist among a majority of the general public. Further studies are required to investigate the implications of this phenomenon.

Acknowledgments

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Determination of Water Usage Rates and Water Usage Patterns in a Residential Recycling Initiative in South Australia

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Larger populations and changing patterns of water usage globally have resulted in the investigation and implementation of more sustainable uses of recycled water. New Haven Village on the Le Fevre Peninsula, South Australia, provides an example of an innovative wastewater reuse initiative. Storm water, grey water and sewage are collected and treated at an onsite, small package treatment plant, then recycled for irrigation and toilet flushing. This research describes a case study, which investigated the amount of water (both recycled and potable) used within a sample of eight individual houses. Through the monitoring of meters at these eight individual dwellings on nine residential blocks, patterns of water flow throughout the village were also examined at comparable intervals over a three-year period. The total water consumption in these sample homes at New Haven Village was below state, interstate and international averages on a per capita basis. This study identified a 30% reduction in total water usage compared to the state average, and a 61% reduction in potable mains water usage per person. On average, almost half (50%) of the water used in each household was recycled water. The patterns of water flow throughout the village identified a correlation between the inflow to the treatment plant and the outflow to the village for irrigation and toilet flushing, and to the adjacent oval for irrigation. Differing trends emerged for weekday and weekend water usage.

Key words: *Wastewater; Reuse; Recycling; Water Quality; Water Quantity; Sustainability*

The existing pressures on water as a resource have prompted the development of strategies for reuse of wastewater throughout the world. Population growth, coupled with increasing urbanisation in Australia, contributes to the forces limiting the availability of water as a resource (Anderson 1996; NWQMS 2000). Adelaide has relatively low average annual rainfall of 585 mm compared to 1200 mm in Sydney (Engineering and Water Services [E & WS] 1993), and South Australia also has a relatively low run-off rate. Therefore, water sources outside of the State must be relied upon to provide enough water to meet South Australia's needs (E&WS 1993; Law 1997). Unlike rainfall, wastewater is generated in urban areas in relatively constant amounts, even in times of drought, providing a reliable water source where rainfall is deficient (Hermanowicz & Asano 1999). Consequently, wastewater reuse should be considered to help alleviate water shortages, particularly in regions of low rainfall.

Using water as a method of waste disposal is becoming more of a concern to the community, as awareness increases of the environmental damage that disposal into natural waterways can cause (Simpson 1999). This, and the concept of a sustainable environment, are reported influences for considering wastewater reuse (Simpson 1999; Terpstra 1999). There has also been a subsequent change in attitude towards regarding wastewater as a resource

rather than a waste to be discharged (Anderson 1996; Asano & Kayaalp 1997; Levine 1996).

Treatment of wastewater is necessary before reuse because of the threat to public health from potential pathogens including bacteria, viruses, protozoa and helminths (Asano & Levine 1996; Rynne & Dart 1998). These pathogens are known to cause diseases such as typhoid, cholera, shigellosis, dysentery, anaemia and diarrhoea (Rynne & Dart 1998). In order to reduce the presence of pathogens and subsequent diseases that they may cause, advanced treatment processes such as disinfection, membrane filtration and lagooning are utilised. The level of treatment required is dependent upon the end use of the wastewater (Rynne & Dart 1998). State and National reuse guidelines have been implemented to protect public health and have criteria based on the end use of the water (Department of Human Services and Environment Protection Agency 1999; Rynne & Dart 1998). *Guidelines for South Australia*, released in 1999, are similar in many respects to the *National Water Quality Management Strategy Guidelines* (2000), which in turn are based on the *Californian Title 22* wastewater reclamation criteria (State of California 1978).

Domestic water usage patterns will vary between countries, cities and households depending upon the number, age and habits of household occupants, the type of property, the season, and the type of water appliances within the household (E & WS 1993). This uncertainty is reflected in the various estimates of domestic water usage in Adelaide that ranged from 486 L/person/day in 1990 to 348 L/person/day in 1993 (E & WS 1993). International water usage rates also vary with 145 L/person/day recorded in a Netherlands study, with only 5% of that being used for garden watering and rinse water (Terpstra 1999), 450 L/person/day in Zurich and 250 L/person/day in Copenhagen (Dixon, Butler & Fewkes 1999). It is, however, unclear whether these last two figures include garden irrigation water.

Water usage patterns in Adelaide identify garden irrigation as the major use of water, representing 182 L/person/day or 52% of total daily use, followed by showering (60 L/person/day or 17%) and toilet flushing (50 L/person/day or 9.1%) (E & WS 1993). Potable use is minimal, representing 8 L/person/day or 2% of total daily per capita consumption (E & WS 1993). Understanding patterns of water usage can assist in directing wastewater reuse to where it will create the most effective reductions in potable domestic water usage, while minimising potential health risks to communities.

New Haven Village is located in a heavily industrialised suburb on the Le Fevre Peninsula approximately 20 kilometres from central Adelaide, in South Australia. The village is a functional example of domestic wastewater reuse using a dual reticulation system. The housing development comprises some 65 residences, whose wastewater is treated by an onsite aerobic package system. The treated effluent is recycled for non-potable uses such as toilet flushing and sub-surface irrigation of gardens and an adjacent oval (Kayaalp 1997). Domestic wastewater (including both grey and black water) enters the treatment system from the village, combined with stormwater from an on-site storage facility. This water is pumped to the treatment system at a rate of approximately 8000 litres per day. Overflow from the stormwater tank flows into a soakage trench, and ultimately infiltrates the oval, which has been set-down by 500 mm to act as a retention system. The processes of intermittent aeration, settlement, sand filtration and UV disinfection treat the sewage and stormwater. Treated water is then stored in two tanks, for use on demand for oval and village garden irrigation, and toilet flushing. Mains water provides an essential back up facility if the treatment system needs to be

taken off-line for maintenance or is unable to meet the demand for recycled water within the village.

The dual water system in the village was originally designed to reduce household potable water consumption by 30-40%, and to reduce the amount of stormwater entering and polluting Adelaide's waterways. This paper discusses the actual measured changes in water consumption compared to the state and international averages, and the determined patterns of flow of potable and recycled water within the village.

Methods

Household meter readings

Residents within New Haven Village were invited to attend a community meeting at which time they were encouraged to take part in the study. Eight of the eleven households present agreed to participate. Given the intrusive nature of the request, which included digging up driveways and gardens to allow meters to be fitted to the reticulation system, the participation rate was seen as very encouraging. The absolute numbers participating do, however, mean that the findings are qualitative in the main rather than statistically verifiable.

Individual meters were placed in the gardens of the participating residences to measure mains water usage and usage of recycled water for garden irrigation and toilet flushing. The sites were numbered and meters positioned as outlined in Table 1.

Table 1: Location of meters on eight household sites (note 2 irrigation meters at site 3 as it was a double block)

Site Number	Mains Supply Meter	Irrigation Supply Meter	Toilet Supply Meter
1, 4, 6 & 7	✓	✓	✓
2	✓	Combined with toilet	
3	✓	✓ (2 meters)	✓
5	✓	✗	✓
8	✓	✗	✗

Readings were collected from the 21 meters at the test sites from March to August 2000 and March to July 2001. All of the sites had mains water meters. Site 3 had two meters for irrigation as the house was built on a double block. Site 5 did not have a separate irrigation meter as it used mains water for irrigation. Site 8 only had a mains water meter, and did not use recycled water so it was initially proposed as a control site for this study. Meter readings were taken at differing intervals, from daily to monthly and by two different researchers over the 2-year period. The numbers of residents at each site were used to calculate water usage per person within the village. Averages and standard deviations were calculated from the readings using Microsoft Excel (Excel 2000 for Windows, Microsoft Corporation USA).

Treatment plant flow meter readings

Mag-Flo® meters (ABB Kent Taylor, Adelaide) were used to monitor the flow rates (L/min) for stormwater, sewage, reclaimed water for irrigation of homes and toilet flushing, oval irrigation, and additional mains water requirements. These five meters measured all water flow into (sewage and stormwater) and out (additional mains, oval irrigation, and reclaimed supply to village) of the water treatment plant, to and from New Haven Village. Over a period of three years, flow rate information was recorded for a series of different time periods ranging from weeks to months using a Datalogger (DT 500, Datataker Pty Ltd, Rowville, Australia) which read every 5 minutes and averaged to hourly readings. Information was downloaded from the Datalogger onto a laptop computer and analysed in Excel (Excel 2000 for Windows, Microsoft Corporation, USA).

Results

Household meter readings

Readings obtained from meters located at individual homes allowed calculations to be made for daily consumption of potable mains water along with recycled water for

Table 2: Daily figures for mean and median water usage for mains, irrigation and toilet flushing per household for all sites (– 1 standard deviation)

	Mains Water	Irrigation Water	Toilet Flushing Water
Daily Mean (L)	409.2 ± 144.5	391.4 ± 317.2	76.6 ± 43.9
Daily Median (L)	369.3	283.9	57.6

Table 3: Daily household water usage per person. Total water usage includes mains, toilet flushing and garden irrigation consumption (note Site 4 and 8 not included as the number of persons was unknown)

Site Number	Number of Persons in Household	Litres /person/day	Percentage of total usage
1	2 Adults		
Mains		184.6	45.6%
Toilet		28.5	7.0%
Irrigation		192.0	47.4%
TOTAL		405.1	
2	2 Adults		
Mains		121.8	55%
Toilet/Irrigation		99.5	45%
TOTAL		221.3	
3	2 Adults		
Mains	6 Children	72.0	49.8%
Toilet		18.9	13.1%
Irrigation		53.7	37.1%
TOTAL		144.7	
5	2 Adults		
Mains inc. Irrigation		120.8	80.6%
Toilet		29.1	19.4%
TOTAL		149.9	
6	2 Adults		
Mains	2 Children	129.9	58.9%
Toilet		27.0	12.2%
Irrigation		63.6	28.8%
TOTAL		220.5	
7	2 Adults		
Mains		174.5	53.5%
Toilet		19.4	6.0%
Irrigation		132.1	40.5%
TOTAL		326.0	
AVERAGES			
Mains		136.6	50.3%
Toilet		24.6	9.1%
Irrigation		110.4	40.6%
TOTAL		271.6	

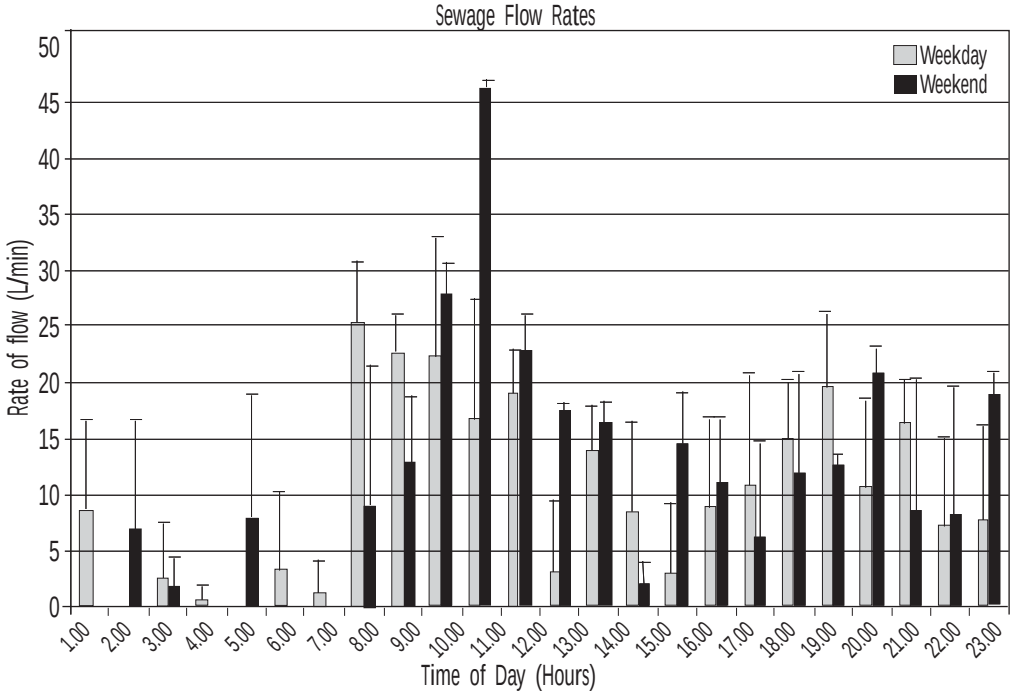
irrigation usage and toilet flushing on a per household basis, as summarised in Table 2. Per capita water usage rates were determined for 6 sites where information was available on the numbers of residents per household (Table 3). The average total amount of water consumed (± standard deviation) was 244.6 ± 102.4 L/person/day. Of this consumption, mains water comprised 136.6 ± 45.2 L/person/day or 52.6%. The remainder (49.7%) of water usage was recycled water. Of this recycled water component, 24.6 ± 5.0 L/person/day (11.5%) was used for toilet flushing and 110.4 ± 64.6 L/person/day (38.5%) was used for irrigation. There was not a consistent relationship between property size and water consumption. The smallest site used the least irrigation water (171m^2 using 254.5 L/day), but the largest volume of irrigation water (1015.8 L/day) was used on a site of 190m^2, while the largest site (330m^2) used only 424 L/day. The site that used 1015.8 L/day could be viewed as anomalous since the result had a standard deviation of 668.6 L/day, which was higher than the average (391.4 L/day) or median (283.9 L/day) daily household use for all sites measured.

Treatment plant flow meter readings

Examination of the Mag-Flo® meter data generated over a three-year period highlighted that on average, approximately 20 ± 5 ML/day was input from sewage and stormwater combined (ratio about 4:1), and the remaining contribution made by mains water was averaged at 20 ± 11 ML/day. Thus mains water represented on average 47% (±17%) of the total volume used, which was about 40 ± 10 ML/day. Recycled water thus made up the majority (53%) of the water flow on the site.

Incoming stormwater and outgoing oval irrigation were set as pre-programmed flow rates to the treatment system. Available stormwater was treated at the plant in aliquots of 8000 litres per day and was therefore not directly related to rainfall. Oval irrigation was related to season, with increased programmed watering in summer compared to winter. In summer, four programmed periods each of two hours duration were pre-set over a 24 hour period, compared to four periods each of one hour

Figure 1: Flow rates of sewage to the treatment plant from New Haven Village averaged over 5 weekdays and 2 weekend days in September 2000



duration in winter. These pre-set flow rates were reflected in the results obtained from the flowmeters (data not shown). Figure 1 illustrates a typical example of the different patterns of sewage flow entering the treatment plant, which were identified on weekdays in contrast to weekends. The flow rates shown were collected in September 2000, but are a representation of typical patterns seen throughout the 3-year period analysed. Typically, the peak flow on a weekend started at a later time (around 9am) compared to the weekday flow where the peak was less pronounced and stretched from 7am-12 noon.

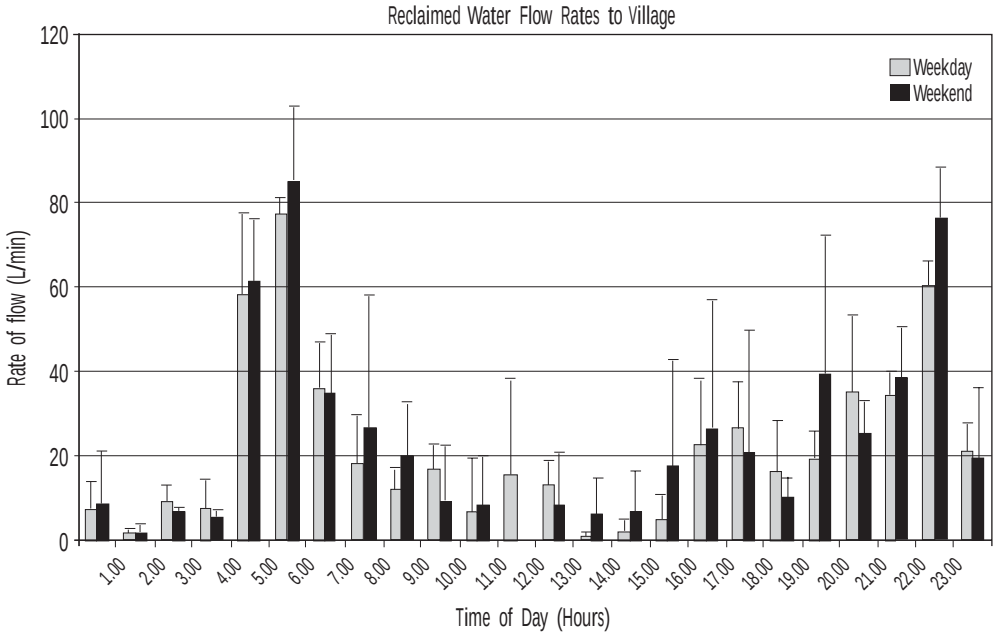
Recycled water for village irrigation and toilet flushing generally had two flow peaks, one in the morning (from 4-7am) and one in the evening (from 8-10pm). Figure 2, collected in November 1999, but representative of typical patterns seen throughout the study, illustrates this 'twin peak' pattern of village water flow on both weekdays and weekends. The height of the peaks varied between months according to the season, with higher flows in summer months compared to winter months. February and March usually had small midday peaks (data not shown).

A significant proportion of the recycled flow (38.5% of total flow or 77% of reclaimed water flow) is associated with garden irrigation (see Table 3) and much of this irrigation occurs at time intervals pre-programmed by residents in their homes.

Discussion

The wastewater reuse system at New Haven Village has the capacity to reduce markedly potable water requirements for irrigation and toilet flushing. These are identified areas of significant domestic water usage (E & WS 1993). This finding supports the opinion of Hermanowicz and Asano (1999) that application of wastewater reuse should be linked directly to the existing major water usage patterns. The average total amount of water used in the village was

Figure 2: Flow rates of reclaimed water from the sewage treatment plant to New Haven Village averaged over 5 weekdays and 2 weekend days in November 1999



271.6 L/person/day, compared to the State average in South Australia of 348 L/person/day (E & WS 1993). This represents a saving of 30% per day, which is a significant reduction in total usage rates, without factoring the recycled component into the equation. It also compares favourably to an international comparison of 250 L/person/day in Copenhagen (Dixon, Butler & Fewkes 1999) and is considerably lower than the interstate value of 448 L/person/day recorded in Perth, Western Australia (Pigram 1986).

Comparing the usage rates for specific purposes between the village with the State averages (E & WS data 1993), showed that considerably less water was used at New Haven for irrigation, with 110.4L or 38.5% of total consumption compared to 182 L/person/day, or 50% for the rest of the State. A similar trend was noted for toilet flushing with 24.6L (11.5%) usage in the village compared to 50 L/person/day or 14% of the State average. This may in part be explained by the presence of dual flush toilets and water efficient showerheads that were installed in most homes in the village as standard. Meeuwissen (Meeuwissen, B.A.J. 2002, *pers. comm.*) cites water usage for toilet flushing in the Netherlands at 36.2 L/person/day, and suggests that within domestic households (not including irrigation) 50% of the water requirements, for toilet flushing and washing machine usage, could be obtained from 'low' quality water, such as recycled water.

Taking into consideration both savings made in total water usage and combining this with the additional saving of potable water (when recycled water is used for the relevant application) it is apparent that total potable usage of these village residents is considerably less. A saving of almost 61% of total potable mains water was achieved at New Haven Village (136.6 L/person/day at New Haven Village compared to 348 L/person/day). The proposed control site (at site 8) could not be evaluated as the house was used for a child day-care facility. The subsequent variable occupation rate did not allow calculation of water usage per person.

Daily water usage rates between individual households were subject to a large degree of variation. Suggested factors responsible for this variation include the number and age of people in the household, personal habits, the size and nature of the property, the number and type of water appliances present and the season (E & WS 1993). Garden irrigation is known to be highly variable for all residences due to different garden sizes, the nature of the garden flora, and the amount of rainfall, which is generally related to the season (E & WS 1993).

At New Haven Village, the residential allotment sizes range from 123 m^2 to 348 m^2 (averaging 196m^2), while the allotment sizes used to determine the average water usage rate in Adelaide were not detailed by the E & WS. They are, however, expected to be larger than those at New Haven on average. As an illustration, New Haven Village is situated in the Port Adelaide Enfield Council, which has several different residential zones; with residential allotment size averages ranging from 300-350m^2 to 700-800m^2 in older zones closer to the CBD (City of Port Adelaide Enfield Council 2001). For new developments the minimum allotment size ranges from 150m^2 to 450m^2, but generally is around 250m^2 (City of Port Adelaide Enfield Council 2001). The average allotment sizes and minimum size requirements for new developments in the surrounding suburbs are significantly larger than those at New Haven Village, thus, it might be reasonable to conclude that this factor alone could contribute to the amount of water being saved within the village, since garden size is a pertinent variable in water consumption data, utilising up to 50% of a household's daily water.

A relationship between increasing allotment size and increasing water consumption is supported by the smallest allotment with an irrigation meter at New Haven Village (171m^2) having the lowest water use per person (254.5 L/day). However, a direct relationship between these parameters could not be identified due to the small size of the data set from participating households and variation within those households being measured. The very high irrigation use of site 5 (1015.8 L/day), significantly higher than the average (391.4 L/day) and median (283.9 L/day) for the village with a large standard deviation (668.6 L/day), seems anomalous and would warrant further investigation, since such high usage was atypical of the village irrigation use.

A limitation of this research that will impact on the findings was the timing of the research program. Sampling was carried out between March and August each year, to coincide with the academic calendar, which meant that no meter readings were obtained for the summer period from September to April. As these summer months typically have lower rainfall and higher temperatures, water consumption would be expected to increase at these times, thus making the water savings at New Haven look even more environmentally sustainable. A future planned program of sampling will attempt to address the lack of available data for a consecutive 12-month period, which would adequately account for seasonal variations.

Recycled water used for sub-surface irrigation of the oval at New Haven Village was pre-programmed at different levels in relation to the season. Generally, the flow was set for early morning and late at night in accordance with public health minimisation strategies (Rynne & Dart 1998). Sub-surface irrigation is the method of choice for reducing the risk of microbial infection, as pathogens have less chance of surviving in soil compared to surface application (Jeppesen 1996). It is important to note that subsurface irrigation (which is used by 50% of the New Haven Village residents) is also 60% more efficient in terms of water use compared to surface irrigation (Jeppesen 1996). This factor must be considered when comparing New Haven Village 'irrigation' water consumption per person with the State averages.

The general trend for recycled water being supplied to the village included peaks in the morning and evening. The patterns for

sewage flow correlated with recycled water supply to the village. This was expected because the reclaimed flow to the village measures water used in the village for toilet flushing as well as individual garden irrigation. The changes in the peak rates of reclaimed flow to the village could be related to the seasonal changes in rainfall and subsequent requirements of garden irrigation. High rates of rainfall were seen in winter months, and also in the spring months of September and October (up to 57.6 mm in October), and very low rates in summer months (as low as 2.0 mm in January) (Bureau of Meteorology 2001). This correlated with the patterns of oval irrigation for the village, with an average of 330 L/day in October, and 619 L/day in January, indicating that low levels of rainfall require greater levels of irrigation and vice versa. Water flow to the village also displayed a similar pattern of lower morning and evening peaks in October (60 L/hour morning peak and 30 L/hour evening peak) compared to January (120 L/hour morning peak and 110 L/hour evening peak).

Water entering the treatment plant from the mains supply as backup for system downtime or to supplement the supply, had no set pattern for the three-year duration of available data. This was an expected outcome due to the nature of the mains water use in the treatment plant. In general, the stormwater flow was low if there had been prolonged periods of low rainfall causing a depletion of storage tank volume. Consequently, less stormwater resulted in an increase in mains water flow to ensure adequate amounts of water are supplied to the village and oval. If rainfall was low, irrigation needs would increase, further increasing the need for mains supplement water. The early morning period of water flow from the stormwater tank to the treatment plant was chosen to ensure sufficient recycled water was available for the village's morning peak usage.

The amount of water entering the treatment plant from the village sewage had the general pattern of peak flow in the morning and evening. There was also a difference in weekday compared to weekend flow. Weekday flow was more regulated to the morning and evening use, whereas weekend flow often had a similar pattern, but at a later starting time, and/or more flow during the middle of the day. This difference between weekday and weekend use of domestic sewage is supported by Friedler et al. (1996) who discussed a similar pattern of later and more frequent use of the toilet throughout the day on weekends compared to weekdays. This was attributed to the increased likelihood of people being at home on weekends compared to weekdays, and the later rising of people on non-working days (Friedler, Butler & Brown 1996). However, the difference between weekdays and weekend flow was not always prominent at New Haven Village, as the population had a large component of retirees at the time of the study, and thus work influences may be less important.

Conclusion

New Haven Village has achieved significant reductions in water consumption through recycling stormwater, black water and grey water. The initial aims of the village regarding sustainability included a 30-40% reduction in average household water consumption, which would consequently reduce the amount of stormwater runoff entering St Vincent's gulf. This study has identified a 30% reduction in total water usage per person compared to the state average, and a 61% reduction in potable mains water usage per person. An average of 50% of the total water consumed at New Haven Village was recycled water.

The substantial reductions achieved, coupled with the linking of a recycled water supply to areas of most effective saving and health risk minimisation, that is irrigation and toilet flushing, indicate that schemes such as this have the potential to become successful wastewater reuse options. There

have been some ongoing issues with continuity of supply at the village, which need to be addressed urgently so that the full potential of this project can be realised. New Haven Village wastewater reuse project, when functioning optimally, is a viable and environmentally worthwhile approach to addressing water shortages.

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Determination of Fluoride in Drinking Water in URMIA City (West Azarbyjan) and Its Health Importance

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Fluoride is one of the constituents naturally present in water sources, and the main source of fluoride is drinking water. Deficiency of fluoride in drinking water is associated with dental caries and an excess with dental fluorosis. The World Health Organization (WHO recommends fluoride in a concentration of 0.5 to 1 mg/1 as the optimum concentration in drinking water). The main purpose of this study was the determination of fluoride in the drinking water supplies of Urmia City, comparison with the optimum level, and its health importance. In this research, 30 samples of water were collected from deep wells and one sample from Shahrchaie River, which are the main sources of drinking water. The amount of fluoride in the water samples was determined by the Megrian-Meyer method, with the spectrophotometer apparatus and red Alizarine indicator. The results showed that the average level of fluoride concentration was 0.12 mg/1, in comparison with the optimum level which is negligible

Key words: *Drinking water; Fluoride; Health*

Owing to the universal presence of fluorides in the earth's crust, all waters contain fluorides in varying concentrations. The bulk of water normally available to humans is involved in the hydrological cycle, which means that it originates in the seas. Seawater itself contains significant quantities of fluoride, at a level of 0.8-1.4 mg/kg. The fluoride content of water obtained from lakes, rivers, or artesian wells is for the most part below 0.5 mg/kg even though concentrations as high as 95 mg/kg have been recorded in some areas (World Health Organization [WHO] 1994).

There is an obvious abundance of fluoride in water, but it should be remembered that most of it is firmly bound to minerals and other chemical compounds and is, therefore, not biologically available in its usual form. The availability of free fluoride ions in the soil is governed by the natural solubility of the fluoride compound in question, the acidity of the soil, the presence of other minerals or chemical compounds, and the amount of water present. Fluoride concentrations in soil increase with depth (WHO 1994). The rate of ground water content of fluoride associated with fluoride layers in several depths is different, and it is related to the geological characteristics of the area. Study in Cuba showed that all the localities with high fluoride concentrations in the water were associated with wells (Luna & Melian 2003). Another study was carried out in Mexico and indicated that variation in fluoride concentration was found at all well depth intervals considered (Siegal & Degnan 1985).

The most important source providing fluoride to the body is drinking water. Studies have shown that fluoride enters the body when absorbed completely through drinking water, but fluoride entrance through foods is absorbed at only 25% (Newbrun 1968). The fluoride intake from water will depend upon (1) the fluoride concentration of the water, (2) the age of the person, (3) climatic conditions, and (4)

dietary habits (Park & Park 1989; WHO 1994). Fluoride has played a key role in caries prevention for 50 years (Whelton et al. 2004). Its efficacy is mainly due to a topical effect (Vivien & Baehni 2003). The public health use fluoride in community water supplies for the prevention of dental caries is accepted worldwide, and the safety and efficacy of its use in trace concentrations in this manner have been repeatedly documented (Dunipace 1993). Several studies have clearly established a causal relationship between the use of fluoridated water and the prevention of dental cavities. Fluoridate drinking water normally contains 0.7 to 1.2 parts per million (ppm) of fluoride (Kirpal et al 2002). In addition, studies in Great Britain, Hungary, Austria, Spain, and the United States show a decrease in caries is experienced with the increasing fluoride content of the water supply of up to about 2 ppm (Newbrun 1968). These kinds of reports are used when it is planned to add fluoride to drinking water and the effects this has in different communities. Today, fluoridation of water programs has been introduced in 39 countries and reach 170 million people, while an additional 40 million are served by water that is naturally fluoridated at a concentration of 0.7 mg/l or higher (Moller 1965; Newbrun 1968; WHO 1994). Different studies conducted in these communities showed that water fluoridation in the optimum level could reduce forty to seventy percent of caries (Moller 1965).

Much evidence suggesting that the inclusion of fluoride in drinking water has beneficial as well as adverse effects on human health was obtained (Kono 1994). The optimum fluoride concentration will normally be within the range 0.5-1 ppm (WHO 1994). When the concentration is within optimal limits, no adverse health effects are observed, and the rate of dental caries (destruction of teeth) in children is at least 65 percent below the rate in communities with little or no fluoride in their water supplies.

Excessive amounts of fluoride in drinking water supplies produce adverse health effects and unsightly dental fluorosis (brownish discolouration of teeth), which increase with fluoride concentration (Okun 1986; Whelton et al. 2004). In addition, mottling of the teeth began to be noticeable when the fluoride concentration increased above 1.5 ppm (Moller 1965). Dental fluorosis occurs during tooth formation and becomes visible eruption of the teeth. Mild dental fluorosis is characterised by whitish areas on teeth, while the severe form of the condition is characterised by pitting of the enamel and brownish discoloration (Kirpal et al. 2002). Further more, acute fluoride poisoning produces a clinical syndrome characterised by nausea, vomiting, diarrhoea, abdominal pain and paresthesia. In May 1992, excess fluoride in one of two public water system serving a village in Alska caused an outbreak of acute fluoride poisoning (Gessner et al. 1994).

The main purpose of this study was to determine the rate of fluoride in drinking water sources of URMIA City and compare that with the optimum level and with its health importance.

Materials and Methods

This research has been carried out in URMIA City, which is the centre of West Azarbyjan province. This region includes the whole of Azerbyjan and it divided into two parts, East and West Azerbyjan. West Azerbyjan is located in the North west of Iran. A salt lake is located between them known as Lake Urmia. On the west of the Lake there is a range of mountains which is nearby 140 km long from the South and average of 50 km wide. The salt concentration in the Lake is so high that no fish can live there and swimmers can not sink. Urmia Lake is the largest Lake in the country; it is about 130 kms long and 60 kms wide (Khosravi 1987). This brine lake has significant adverse impact on the majority of lands and ground water sources around the Lake. The population of the URMIA City

based on the census in 1996 was nearly 450,000. The basin of URMIA is an example of an active densely populated region.

The climate of the URMIA region is basically one of hot and dry summers and cold, damp winters with snow fall occurring mainly during the winter and early spring. The maximum and minimum temperature in summer and winter are 38 °C and -15 °C respectively. The average rainfall is almost 450 mm per year. Hence, the major part of areas is subject to heavy continental rains in spring and is relatively well watered. This aspect has a positive beneficial impact on increasing ground and surface water sources for the purpose of water supply for rural areas and cities. There are three main rivers and many small streams of which some are dried in summer. The Urmia basin, mainly depends on underground water resources and nearly 853 million cubic meters are withdrawn annually, 42.3% from qanats, 37.3% from wells and 20.4% from springs (Honari 1979).

The drinking water of URMIA City is provided by mainly ground waters (31 deep wells, 80%) and (Shahrchaie River 20%). The method of study was descriptive and cross-sectional. Thirty-one samples were collected from all drinking water sources in plastic containers during summer in 1999. The fluoride content of the water samples was determined by the Megrian-Meyer method, the spectrophotometer apparatus Model (Perkin Elmer - Coieman 548) and Red Alizarine indicator in the wavelength 528 (American Public Health Association [APHA], American Water Works Association [AWWA], Water Environment Federation [WEF] 1998).

Results

The results obtained from measuring the amount of fluoride in drinking water (deep wells and river) in URMIA City are shown in Table 1. The data obtained for Table 1 indicated that the maximum and minimum level of fluoride content among deep wells were 0.58 ppm and 0.04 ppm respectively. Further more, the range level of fluoride was (0.58 - 0.04 = 0.54) ppm. But the rate of fluoride content in river water was 0.00 ppm. Among the deep wells, only two wells (6.4%) were equal to the standard level of fluoride (0.5ppm.), and of the remaining wells (93.6%) were less than the standard level. The average and standard deviation of fluoride content of wells were (0.12 ppm) and (0.14 ppm) respectively.

Table 1: Rate of fluoride in drinking water sources in URMIA city

No. sample	Characteristics of water sources	Aquifer lit/sec	Rate of fluoride ppm
1	Well No1. Pool goyon	40	0.1
2	Well No2. Pool goyon	40	0.07
3	Well No3. Pool goyon	40	0.1
4	Well No4. Pool goyon	40	0.07
5	Well No5. Behshty ave	40	0.17
6	Well No7. Behshty Ave	40	0.0
7	Well No8.Fazay sabz	30	0.58
8	Well No9. Fazay sabz	40	0.04
9	Well No11. Standary	40	0.07
10	Well No12. Barg Ave	40	0.08
11	Well No13. Takhty stadium	40	0.04
12	Well No14. Behshty Ave	40	0.14
13	Well No15. Behshty Ave	40	0.14
14	Well No16. Behshty Ave	40	0.04
15	Well No18. Bazar bash	32	0.10
16	Well No19. Park bazar	40	0.14
17	Well No20. Barg Ave	40	0.14
18	Well No21. Barg Ave	42	0.54
19	Well No22. Barg Ave	45	0.04
20	Well No23. Barg Ave	45	0.18
21	Well No24. Upper poll goyon	45	0.07
22	Well No25. Upper poll goyon	45	0.10
23	Well No1. Rehan abad Road	42	0.04
24	Well No2. Rehan abad Road	17	0.04
25	Well No3. Rehan abad Road	40	0.07
26	Well No4. Rehan abad Road	40	0.1
27	Well No5. Rehan abad Road	40	0.1
28	Well No6. Rehan abad Road	40	0.14
29	Well No7. DeDe sagi village	45	0.1
30	Well No8. Tolatapeh village	50	0.17
31	River water	332	0.00

Discussion

The wide range of fluoride in water is probably due to the contact of water with soils and rocks having a range of fluoride content. The rate of fluoride in Shahrchaie River (the surface water source) was zero (0.00 ppm), but the rate of fluoride in deep wells varied from 0.04 to 0.58 ppm. Almost 93.6% of samples containing fluoride were less than the optimum level, and 6.4% of samples equalled the recommended level. The average level of fluoride in samples was 0.12 ppm and it was less than the standard level (Table1).

Further studies have been conducted about the rate of fluoride in drinking waters. According to Grobler, et al. (1991) the fluoride concentration in the drinking water of 67 villages in the Cape Province in Africa was determined. Results showed that boreholes contained more fluoride in the drinking water than fountains, dams or canals. Five out of 41 boreholes have less than or equal to 0.10 parts per million (ppm) in the drinking water, while 17 out of 26 dams, 4 out of 13 rivers and 3 out of 5 fountains and canals contained less than or qual to 0.10 ppm fluoride. Another study was carried out in South Africa; it was found that, fluoride levels in drinking water changed for 93% of the cities and villages studied during the period 1983-1985. Furthermore, boreholes showed significantly higher fluoride levels (p less than 0.01) than rivers or dams (Grobler & Dreyer 1988). The same research was conducted in smaller towns (500 or more inhabitants) in the Transvaal, Orange Free State and Natal in South Africa. Drinking water was collected in polypropylene containers and fluoride content determined potentiometrically. Results showed that the fluoride content in boreholes was more than fountains and rivers. A pilot study was undertaken in Vorarlberg in Austria to determine the concentration of fluoride ions in drinking water. The results showed that 91.3% of the population was supplied by drinking water containing under 0.3 ppm fluoride and the remaining 8.7% by drinking water containing 0.3-0.6 fluoride. Hence, the fluoride concentration was too low to prevent caries in all areas of Vorarberg. Exogenous fluoridation of the drinking water or table salt in all districts of Vorarlberg was recommended (Nell et al.1993). The results of our study indicated that the fluoride content in deep wells was more than Sharchaei River and confirms the above studies (Table 1).

A research study was carried out in the United States in Houston Texas in 1993, results showed that there were significant fluctuations in fluoride content of tap water from 1988 to 1991. This inconsistency in water fluoride content makes it very difficult for health care providers to prescribe and maintain an optimal fluoride supplementation to children. Based on results from this study, more rigorous surveillance and monitoring of water fluoridation in Houston is recommended (Chan et al.1993).

Several scientific and health organisations, such as the Federation Dentaine International (FDIL), the International Association for Dental Research (IADR), and WHO, have confirmed the positive impacts of water fluoridation with appropriate concentrations in the reduction of dental caries (WHO 1994). A study was carried out on dental disease in Urmia (West Azarbyjan) in 1989 showed that dental caries, with decay, missing and filling (DMF) equalled 2.66 in the age group 16 years and 12.8 in the age group 40 years was very high.

Conclusion

The results of measuring the fluoride in the drinking water sources of Urmia City showed that the average rate of fluoride is 0.12 ppm which when compared with the optimum level is low, so the prevalence of caries would be increased. Therefore, due to the importance of fluoride in drinking water to dental health, it is recommended that:

- more studies on increasing the amount of fluoride to the drinking water sources of Urmia City should be done, and
- a study regarding the installation of fluoridation equipment in schools and/or using bottled water containing fluoride should be carried out.

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Climate Variability and the Transmission of Ross River Virus in Coastal Regions of Queensland, Australia

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To determine the impact of climate on the transmission of Ross River (RR) virus, an historical data analysis was conducted in the coastal regions of Queensland over the period 1985-96. The results show that temperatures, rainfall and high tides are possible contributors to the transmission of RR virus in these regions, with a lagged effect of zero to three months. This suggested that climate variations might play a certain role in RR virus infection and attention should be paid to preventative measures, given probable effects of global warming.

Key words: *Climate; Ross River Virus Infection; Australia*

Ross River (RR) virus infection, or epidemic polyarthritis, is a mosquito-borne disease caused by an alphavirus, Ross River virus. It is a debilitating and frequently persistent disease characterised by arthritis, fever, rash, and fatigue, and is the most prevalent vector-borne disease in Australia, with thousands of cases reported annually (Curran et al. 1997; Mackenzie et al. 1994). A total of 53,347 laboratory confirmed cases were reported to the Department of Health and Ageing over the period 1991-2000 (Department of Health and Ageing 2003). The economic cost of RR virus infection was approximately $2,500 per case, so that at a minimum tens of millions of dollars are spent annually in direct and indirect health costs nationally (Boughton 1994; Russell 2002).

The virus has been isolated from 38 species of mosquito belonging to six genera, and all of them are vectors of RR virus (Russell 2002). On the northern coasts of Australia, it is *Aedes vigilax*. On the south and southwest coasts of Australia, *Aedes camptorhynchus* is thought to be the main vector. Both breeds of mosquito are tidal-dependent. *Culex annulirostris*, which breeds in vegetated semi-permanent and permanent fresh water, is the major vector in the inland tropics and temperate inland regions of New South Wales and Queensland that are subject to flooding or irrigating during summer (Lindsay et al. 1993). *Aedes notoscriptus* may be important in semi-rural and urban areas. The search for reservoir hosts of RR virus does not link infections in vertebrates with human disease (Harley et al. 2001).

The disease is recorded as geographically scattered cases throughout the year, but with the preponderance of cases in the period January to May, particularly in the tropics. This distinctive seasonal pattern is largely dependent upon the life cycle and habits of the mosquitoes. Occasional severe outbreaks have also been recorded in temperate Australia following extensive summer rainfall (Lindsay et al. 1993).

The transmission of many vector-borne diseases has been linked to climatic variables, particular rainfall, temperature and high tide (Bi & Parton 2003; Lindsay et al. 1993; Tong et al. 2002; Woodruff et al. 2002). Global warming might lead to a rise in temperature and sea level and bring changes to future precipitation, which may impact on the development of the mosquito and the virus, and could possibly lead to

epidemics of vector-borne diseases including RR virus infection. Therefore, the implications of climate change for virus transmission in this study is explored in the coastal region of Queensland, where most of the State's cases occur (Tong et al. 2001). The purpose is to estimate the quantitative relationship between climate variation and the transmission of the disease in the coastal region of Queensland, to set up a statistical model on the basis of the empirical data, and to provide suggestions for future health policy.

Materials and Methods

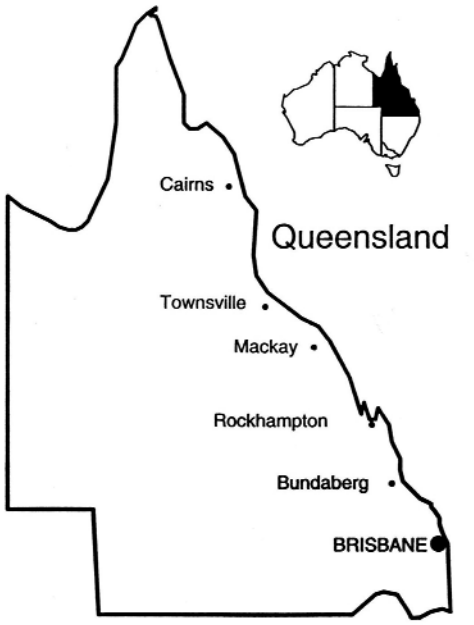
Study sites and population

Queensland is the second largest state, but has the largest habitable area in Australia. Of the cases notified from all states and territories each year, more than 60% of RR virus infections in the past decade have been in Queensland (Curran et al. 1997; Russell 2002). It is located in the northeast of Australia and covers about 1,727,000 km^2, with 7,400 km mainland coastline. Lying generally between 100 and 290 south of the equator, it ranges from the temperate and densely populated southeast to the tropical, sparsely populated Cape York Peninsula in the north. Queensland's population on the 30 June 2000 was 3,566,357 (Queensland Government 2004).

Based on weather forecast districts in Queensland from the Australian Bureau of Meteorology, six cities were selected as study sites. Cairns and Townsville were from the northern region of Queensland, Mackay and Rockhampton from central Queensland, and Bundaberg and Brisbane from the southeast region (Figure 1). Their residents over the period 1985-96 were treated as the study population.

Data collection

Notified cases of RR virus infection were provided by the Queensland Department of Health. Population data for the six selected towns were provided by the Australian Bureau of Statistics. Climate data were retrieved from the Australian Bureau of Meteorology.



In Australia, notifications are made to the state or territory health authority under the provisions of the public health legislation in each jurisdiction. Notifications may be required from treating clinicians, diagnostic laboratories or hospitals. Computerised, de-identified unit records of notifications are supplied to the Department of Health and Ageing for collation, analysis and publication. It is assumed that the quality of the disease data is good and notified cases can fairly represent real incidence of the diseases.

Data analysis

Data analysis was conducted with the Statistical Package for the Social Sciences (SPSS) (SPSS Inc. 2001). The monthly incidence of RR virus infection in each coastal city was treated as a dependent variable, and the climatic variables such as monthly mean maximum and minimum temperatures, relative humidity, monthly total amount of precipitation and monthly mean high tide were independent variables. Spearman's correlation and regression analyses were conducted between these

variables. Since there might be auto-correlation among both dependent and independent variables over time, the AutoRegressive Integrated Moving Average (ARIMA) and Generalised Least Square (GLS) regression analyses were preformed. A model was developed after the effect of auto-correlation had been removed by the ARIMA procedures, and GLS regression analysis was conducted to assess the independent effects of each climatic variable (Box & Jenkins 1976).

Results

1. Seasonal changes of RR virus infections in the coastal region of Queensland over the study period.

Monthly variations of RR virus infection in six coastal cities of Queensland, 1985-96 were examined, with most of the cases occurred in autumn over the study period. The peak month was in March in most of the study locations.

2. Correlation analyses between climatic variables and RR virus infections.

Correlations between monthly incidence of RR virus infection and climatic variables were conducted in the coastal region of Queensland, 1985-96. Table 1 shows that there were significant correlations between the monthly incidence of RR virus infection and climatic variables in the coastal region of Queensland, with a lagged effect of zero to three months. The correlation coefficient between the incidence of disease and monthly mean minimum temperatures was the largest.

3. Cross-correlation examination among climatic variables (Table 2)

Cross-correlations among the climatic variables in the coastal region of Queensland were estimated. Table 2 shows that there were strong correlations between monthly mean maximum and minimum temperatures, and between relative humidity in the morning and in the afternoon. To avoid multi-collinearity these pairs of variables were separated in the regression analyses.

Table 1: Correlation between climatic variables and monthly incidence of RR virus infection in the coastal region of Queensland, 1985-96

	Coefficient	P<
MaxT	0.42 (3)	0.000
MinT	0.47 (3)	0.000
Rain	0.22 (3)	0.000
3pmRH	0.33 (1)	0.000
9amRH	0.30 (0)	0.000
HT	0.34 (0)	0.000

MaxT=maximum temperature; MinT=minimum temperature; 3pmRH=relative humidity in the afternoon; 9amRH=relative humidity in the morning; HT=high tide

The number in the bracket is the number of lagged months

Table 2: Inter-correlations among the independent variables in the coastal districts of Queensland, 1985-96

	MaxT	MinT	3pmRH	9amRH	Rain	HT
MaxT	1.00					
MinT	0.88	1.00				
3pmRH	0.14	0.46	1.00			
9amRH	-0.06	0.23	0.77	1.00		
Rain	0.21	0.37	0.49	0.47	1.00	
HT	0.001	0.14	0.38	0.23	0.04	1.00

4. Regression analyses between climatic variables and RR virus infections (Table 3).

The relationships between the climatic variables and the monthly incidence of RR virus infection in the coastal region of Queensland, 1985-96 were examined, using regression analyses. Table 3 shows that temperatures, rainfall and high tides could be possible contributors to the transmission of RR virus infection in the coastal region of Queensland. It seems that minimum temperature played a more important role than maximum temperature. An increase of minimum temperature, and a rise in sea level could influence the development of the mosquitoes and the virus within the mosquitoes.

Table 3: The relationship between climatic variables and monthly incidence of RR virus infection in the coastal districts of Queensland, 1985-96

Explanatory variables	B	SE	P<
Model 1			
MinT (3)** (°C)	0.0514	0.0083	0.000
HT (cm)	0.0093	0.0005	0.038
LograinP3*(mm)	0.0003	0.0002	0.050
Constant	-5.8267	0.2134	0.000
		R^2=0.38	
Model 2			
MaxT (3) (°C)	0.0465	0.0088	0.000
HT (cm)	0.0011	0.0005	0.012
LograinP3 (mm)	0.0005	0.0002	0.001
Constant	-6.3597	.2824	0.000
		R^2=0.36	

* *Log transformation of rainfall, with a three month lagged effect*

** *Number in the bracket is the amount of lagged months which was the largest correlation coefficient*

Discussion

Arboviral diseases including RR virus infection are among the most sensitive of all diseases to climate and the environment (Lindsay & Mackenzie 1996). Changes in climate, including an increase in its variability, may alter the ecology of these viruses, leading to an increase in the activity of vectors and impacting on the incidence and distribution of mosquito-borne diseases.

Correlation analyses in this study showed that monthly mean maximum and minimum temperature, relative humidity, high tide and monthly total amount of precipitation were significantly correlated with monthly incidences of RR virus infections in the coastal region of Queensland, with a zero to three-month lag effect.

The lagged effect of climatic variables on the incidence of RR virus infection is very important. Such delays are consistent with the development of mosquitoes and the external period of incubation of RR virus within mosquitoes and the incubation period of the virus in the host. Hence, the delay is biologically plausible. Both monthly mean maximum temperature and monthly mean minimum temperature are positively correlated with monthly incidences of RR virus infection. It seems that minimum temperature plays a more important role than maximum temperature in the transmission of the disease. The increase in minimum temperature might be helpful in maintaining the survival of mosquito larvae during the winter period, with persistence into late spring and summer. It might also maintain the epidemic foci of the disease, which is now recognised as one of the predisposing factors to outbreaks of RR virus infection in southwest Western Australia (Lindsay & Mackenzie 1996).

For mosquitoes that reach maturity, low humidity and too high daily temperatures (e.g., over 35°C) would ensure a high rate of attrition. Under these conditions, fewer adult females survive to take two or more blood meals, decreasing the possibility of infection with and subsequent transmission of the virus. Also the very high temperatures would restrict dispersal of vector species, and reduce their ability to find vertebrate hosts. Outbreaks of RR virus infection in arid regions of Western Australia rarely occurred during the hottest months of the year (Lindsay & Mackenzie 1996).

Total monthly precipitation was also positively correlated with the monthly incidence of RR virus infection in Queensland over the study period, generally with a two-month lagged effect. Quantity, timing and pattern of rainfall would affect the breeding of mosquitoes, especially fresh water mosquitoes, then the incidence of the disease could be affected in turn.

Relative humidity had a significant impact on the transmission of RR virus infection in Queensland. High relative humidity had a positive impact on the breeding of mosquitoes, and therefore could be considered as a contributing factor to the occurrence of RR virus infection (Lindsay & Mackenzie 1996).

Monthly mean high tides were positively correlated with the incidence of RR virus infection along the coastal region of Queensland over the study period. Higher tidal levels result in inundation of large areas of salt marsh and provide ideal

breeding sites for tidal-breeding mosquitoes in summer. As a result, the population of adult *Aedes vigilax* may have increased, as soon as eight days after a series of spring tides (Lindsay et al. 1993), and more RR virus infections could have occurred. For example, in an RR virus outbreak in south-western Australia during the summer of 1988-89, a rise in sea-level of 5.5 cm, led to more frequent and widespread inundation of coastal saltmarshes in the region than is normally recorded, which may increase the populations of *Aedes camptorhynchus* (Lindsay & Mackenzie 1996).

The characteristics that were observed from the regression analysis follow: (a) climatic variables acted on RR virus infection through a 0-3 month lagged effect; (b) minimum temperature seemed to play a more important role in the transmission of the disease than maximum temperature; and (c) monthly mean high tides seemed to play an important role in the transmission of the disease.

It should be pointed out that there are fresh and salt water breeding species involved in the transmission of RR virus in Queensland. In this study, however, they were not treated separately because data were not available. But it should be remembered that they are from different ecosystems and climatic variables and tidal differences might impact on them in different ways. This is a limitation of the study.

It is clear that climatic variables are only one set of contributors to the transmission cycle of RR virus infection. The natural cycle of the transmission of vector-borne diseases, including RR virus infection, is complicated and poorly understood. The abundance of mosquitoes, biting habits and vector competence are important factors for transmission. Social factors, such as economic status, housing conditions, mosquito control measures, population health education and health promotion, population immunity and migration, urbanisation and increased travel could all affect transmission. Other environmental factors could also contribute to and interact with transmission. The low explanatory ability of the regression analysis completed within the current study tends to confirm that there are other factors excluded from the analysis that are important to RR virus transmission. These data are not available and this is also a limitation of the study.

Another possible limitation of the study is that there could be issues of 'underreporting' and 'over reporting' associated with clinical familiarity, which could vary between regions and larger cities and small towns. As reported cases probably account for a relatively small percentage of the total cases of Ross River virus infection and the clinical/subclinical ratio could be anything between 1:2 and 1:30, reported infections in humans provide limited data (Harley et al. 2001). This study only focused on reported cases. Clearly a much more effective way of monitoring the infection is necessary.

This study suggests that climate effects might have contributed to RR virus infection. According to the meteorological record, Australian annual mean maximum temperatures have risen 0.5°C and mean minimum temperatures have risen 0.9°C since 1900, and Australian annual mean rainfall has increased by about 1% since 1890 (Torok & Nicholls 1996). By the year 2030, climate change will be expected to be observed as an increase in Australia's mean temperature of 0.3-1.0°C along the north coast, 0.3-1.4°C along the south coast, and 0.4-1.4°C inland. Average precipitation is also likely to increase (CSIRO 1996). If climate scenarios predicted by current models do eventuate, it seems likely that transmission of vector-borne disease, including RR virus infection, will increase due to the several reasons discussed above. However, it is not yet possible to predict with any precision the extent and magnitude of the alteration in the disease pattern (Lindsay & Mackenzie 1996; McMichael 1996). The results of the current study are supportive of the view that RR

virus infection rates will be higher with an increase in temperature and high tides in coastal Queensland. An effective and well coordinated surveillance and monitoring system is very important, because it will provide not only forewarning of outbreaks of disease but also valuable information on which to base public health decision making. Computer models need to be developed on the basis of in-depth research to predict possible epidemic activity under different environmental conditions, and as a means of predicting future consequences of environmental change (McMichael 1996; Sutherst 1998). Choi et al. developed a computer model in Southwestern Australia and similar work needs to be done in the eastern coast of Australia (Choi et al. 2002). Mosquito control and health education are essential for the prevention of RR virus infection.

Conclusion

Climate variations might play a certain role in RR virus infection in the coastal region of Queensland and attention should be paid to preventative measures, given probable effects of global warming. However, the transmission of mosquito-borne diseases is complicated and many factors need to be taken into account in disease prediction and prevention.

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