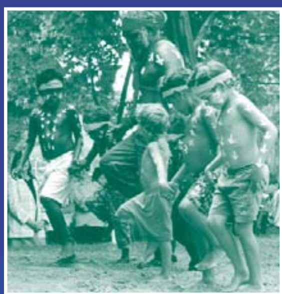
Environmental Health

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 encourage contributions from students

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

Guest Editorials

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

Research and Theory

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

Practice, Policy and Law

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

Reports and Reviews

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

Correspondence

Associate Professor Heather Gardner
Editor, *Environmental Health*
PO Box 68, Kangaroo Ground, Victoria, 3097, AUSTRALIA
Guidelines for Authors can be obtained from the Editor
Telephone: 61 3 9712 0550
Fax: 61 3 9712 0511
Mobile: 0417 580 507
Email: gardner@minerva.com.au

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Environmental Health

Special Issue
Climate Change and Health

Call for Papers

Papers are sought for the **Special Issue, Climate Change and Health,** *Environmental Health*, Volume One, Number Four, to be released in December 2001.

Details of the journal, and Guidelines for Authors, including the aims and sections under which articles can be published are in this issue, can be seen at www.aieh.org.au, and are available from the Editor, Associate Professor Heather Gardner.

Email: gardner@minerva.com.au,
Telephone: 61 3 9712 0550,
PO Box 68, Kangaroo Ground,
Victoria, 3097, Australia.

Papers, reports, commentaries, and reviews on all aspects of environmental health, national and international, are always welcome.

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EDITORIAL

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REPORTS AND REVIEWS

As the September issue of the *enHealth News* says, “Everything we do is associated with some degree of risk [and] there is a need to identify and assess the hazards and analyse the risks” (2001, p. 1). The enHealth Council has developed “Environmental Health Risk Assessment Guidelines” applicable to environmental health hazards found in air, water, food and land.

Consistent with the enHealth Council’s comments, this issue of *Environmental Health* has a number of papers on environmental health risk assessment. These range from pollutants in the air to microorganisms found in drinking water from tanks, from traditional hazards in a war torn country to a health promoting approach in the school community, from changes in environmental health practice to chemicals used for the control of microorganisms in swimming pools.

Simpson et al. describe a project to assess the impact of air pollution on daily mortality and morbidity in Australian cities. The project will develop a research protocol, using international benchmarking, to investigate the associations between air pollution and daily mortality and morbidity in Melbourne, Sydney, Perth and Brisbane. The National Environment Protection Council review of air quality standards in 2005 can then be conducted primarily on Australian results. The Journal then moves on to a paper by Khalili and Thomas on the application of a lung deposition model for calculating carcinogenic risk assessment of polyaromatic hydrocarbons.

Environmental health challenges are nowhere more widespread than in developing countries. They are exacerbated by war and its consequences for environmental health. Stoneham and Hauengue argue that environmental health is a major challenge facing Mozambican cities, and that environmental health in developing countries can be categorised as traditional. The environmental health issues for Mozambique, from the literature and the survey of residents and practitioners, included poor housing, lack of water, ineffective sanitation facilities, a lack of environmental policy, erosion, and unemployment. The paper describes a project to identify and prioritise environmental health needs to assist local government in planning services consistent with the development of an Environmental Health Action Plan.

Environmental health also ‘encompasses principles of risk communication and community consultation/participation’ (enHealth 2001, p. 1). These aspects are prominent in two papers and one report. In “Health and Wellbeing in the School Community Environment: Evidence for the Effectiveness of a Health Promoting Schools Approach”, Carlsson, Rowe and Stewart argue that, “changes in the conceptualisation of health and wellbeing have led to our understanding of the social-ecological view of health where the impact of the social, mental, physical and economic environments on health is recognised”. The health promoting schools approach, indicates that the more comprehensive the approach, the more effective the outcomes for youth. They review and analyse data from three research projects in Queensland. In “Environmental Health Practice: For Today and For the Future”, Nicholson, to gain insights into the changing roles of environmental health practice, conducted interviews with a wide range of informants. The research was guided by the principles of the National Environmental Health Strategy and throws light on the current status of community-based environmental health action and partnerships.

The theme of community participation in environmental health is taken up in the Report Section. Hay, Frew and Butterworth report on a project by the Victorian Department of Human Services to develop a new municipal public health planning framework, in partnership with local governments and other stakeholders. Based on extensive research and consultation, they argue that the new approach to MPHPs embraces consideration of factors impacting on health that originate in the built, social, economic, and natural environments. The new municipal public health planning framework draws on the strengths of approaches to public health planning, including strategic local area planning, a social model of health, health promotion, health outcomes, and participation and partnership.

Three papers are concerned with contamination of water, either drinking water from tanks or from water in swimming pools. Verrinder and Keleher researched whether tanks on farms are a health hazard to gain a better understanding of the relationship between drinking water quality, knowledge, and maintenance practices of private tank water supplies. Maintenance varied considerably, few of the households had published guidelines on water quality, and none of the households had their drinking water tested regularly. Assessing the microbial health risks of tank rainwater used for drinking water is also researched by Simmons, Heyworth and Rimajova. The paper provides a framework for considering the health impacts of rainwater with microbial contamination using an epidemiological approach but encompassing risk assessment as a central theme. Issues that need to be addressed in a microbial risk assessment can include the numbers of pathogens in tank rainwater, their ability to survive and multiply, the extent of individual exposure, and the measurement of health outcomes. The third paper, by McLaren, researches swimming pools and the presence and possible danger from the pool chemicals used to destroy microorganisms.

Probing the depths of wastewater in unsewered neighbourhoods is the concern of award-winning environmental wastewater planner, Callum Morrison. The huge potential of digital soil and septic tank system testing that Morrison has developed is reported. Wastewater management in areas without town sewerage is one of the most complicated and challenging aspects of environmental health, Morrison argues. His concern is with how to reverse the decay of existing systems and to reduce the "environmental footprint" of new wastewater systems. Morrison's innovation is his finding that a submersible probe and computer used for monitoring groundwater levels and temperatures is able to be adapted and used for charting wastewater levels underground. The Journal extends congratulations to Callum Morrison for receiving the Australian Institute of Environmental Health (Vic Div) inaugural award for innovation and excellence in research relevant to the area of environmental health.

Reference

enHealth Council 2001, *enHealth News*, vol. 2 No. 2, p. 1.

Heather Gardner
Editor

The Assessment of the Impact of Air Pollution on Daily Mortality and Morbidity in Australian Cities: Description of a Study

R. W. Simpson[1], G. William[2], A. Petroeschevsky[1], L. Denison[3], A. Hinwood[4], G. Morgan[5] and G. Neville[6]

Faculty of Science, University of the Sunshine Coast, Maroochydore[1], School of Population Health, University of Queensland[2], Environmental Protection Agency, Melbourne[3], Department of Environmental Protection of Western Australia, Perth[4], New South Wales Department of Health, Sydney[5], and Queensland Health, Brisbane[6]

The paper describes a project funded by the Australian Research Council for 2001-2002: The assessment of the impact of air pollution on daily mortality and morbidity in Australian cities using a protocol based on international benchmarking. Air quality health standards recently set by the National Environment Protection Council (NEPC) were based primarily on results from epidemiological studies from overseas as there were few results from Australian studies available at the time. The project will develop a research protocol, using international benchmarking with groups from the United States (US) and Europe, to investigate the associations between air pollution and daily mortality and morbidity in Melbourne, Sydney, Perth and Brisbane. The NEPC review of air quality standards in 2005 can then be conducted primarily on Australian results.

On the 26th June, 1998, the National Environmental Protection Council (NEPC) made a National Environment Protection Measure (NEPM) for ambient air quality which sets national air quality standards for the six major pollutants: nitrogen dioxide (NO_2), particles (as PM_{10}), carbon monoxide (CO), ozone (O_3), sulfur dioxide (SO_2), and lead (Pb). This is the first time that a consistent set of air quality standards has been in place across Austalia.

The NEPM (Ambient Air Quality) standards have been set to be protective of human health. These standards are based primarily on studies conducted overseas. Comprehensive reviews (Dockery & Pope, 1994; Pope, Dockery & Schwartz 1995) have described associations between air pollution and health outcomes such as daily mortality and daily morbidity across a range of climatic conditions and cities. Many of the initial studies were conducted in the United States (US), but other studies were undertaken in the United Kingdom (UK) and Europe (Anderson et al. 1996; Ponce de Leon et al. 1996) have also found significant associations. Whether these findings can be extrapolated to the Australian situation has been the subject of much debate. Recent work in Sydney (Morgan et al. 1998a, Morgan et al. 1998b) and Brisbane (Simpson et al. 1997) indicate that current levels of ambient air pollution in these cities are making significant contributions to variations in daily mortality and hospital admissions for cardiovascular and respiratory disease, and that the effects observed overseas may occur here as well. However, a number of questions remain about these studies regarding (a) the robustness of the statistical techniques used (would a different technique give a different result?); (b) whether all confounding effects were included; and (c) how applicable are these few studies to all the major Australian cities? There is a commitment in the NEPM to undertake a full review by 2005. An important part of this review will be the expansion of the local database relating to air quality and health issues. The study will provide essential information for this review as well as indicating a process for how international benchmarking can become an ongoing component of future reviews to be conducted.

Aim of the Study

The aim of the study is to examine the associations between ambient air pollution (specifically ozone, particles, nitrogen dioxide and carbon monoxide) and daily mortality and hospital admissions in Melbourne, Sydney, Perth and Brisbane, as defined by the respective statistical sub-divisions, using a standardised statistical approach. A range of cardiovascular and respiratory conditions will be investigated. Any regional differences in impacts will be examined further by pooling the data for a meta-analysis.

Methods

The study will develop a standardised time series protocol for Australian studies of the acute effects of air pollution on daily mortality and daily hospital admissions. This protocol will then be applied in Melbourne, Sydney, Brisbane and Perth. The research protocol developed will be subjected to international benchmarking by exchanging information and data with an international group of scientists from the APHEA project and the National Morbidity, Mortality and Air Pollution Studies (NMMAPS) study in the US conducted by the Health Effects Institute (HEI). The acronym APHEA refers to the project on the short-term effects of Air Pollution on Health - European Approach, which includes scientists from Greece, the UK, France, Germany, and the Netherlands.

As both pollutant levels and the daily health outcomes used might be sensitive to climate and weather, and other temporal factors such as season and long term trend, it is important to control for these confounding effects in the analysis. In this study, nonparametric smoothing using Generalised Additive Models (GAM) will be used to investigate the health effects of air pollution. Instead of assuming dependence on a sum of linear predictors, GAM fits a sum of smooth functions of the predictors and allows additional covariate effects on a linear scale (Schwartz 1994). The steps in analysis using GAM will be similar to those used by the APHEA project (Katsouyanni et al. 1996). The basic aim of this approach is to model temporal variations in the data in the initial step, and then add meteorological and other confounding variables in subsequent steps (e.g., see Hoek et al. 1997).

Data

Hospital admissions data

These data will be obtained from the government health departments in each state. Only emergency admissions will be considered: scheduled admissions, transfers from other hospitals or admissions arranged through a general practitioner will be excluded from the analysis to minimise the delay and level of uncertainty associated with the period between onset of symptoms and day of admission. A range of respiratory and cardiovascular conditions will be considered, including asthma, other chronic obstructive pulmonary disease (COPD), ischaemic heart disease, stroke, and heart attack.

Mortality data

Mortality data will be obtained from the Australian Bureau of Statistics. Cause of death groups will be aggregated into broad categories of respiratory mortality, cardiovascular mortality and total mortality.

Pollution data

The pollutants to be considered in the study include: particles at 24-hour, 1-hour maximum nephelometer/light scattering data – b_{sp} – and PM_{10} and $PM_{2.5}$ data, where available on a daily basis; ozone at 1-hour/4-hour/8-hour; nitrogen dioxide at 1-hour/24-hour; and carbon monoxide at 1-hour/8-hour.

Meteorological data

The confounding effects of meteorology will be modelled using various lags and transformations of temperature (minimum, maximum, average), dew point temperature, relative humidity, barometric pressure and rainfall.

Scope and Limitations

The research project is designed to assess the acute effects of short-term air pollution exposure, day to day, of a population. The research design cannot assess chronic effects over several months of such exposures; cross-sectional studies over a long period of time are needed for such assessments (see Ostro & Chestnut 1998). Therefore, as McMichael et al. (1998) point out, the mortality effects assessed here might only be 'harvesting' effects, or the shortening of the life of sick elderly people by only days or weeks, and therefore might not be useful in estimating increases in annual averages of daily mortality. However, even McMichael et al. (1998) agree that studies such as these are useful in assessing the acute short term air pollution impacts on illness using daily hospital admissions data.

Economic and Social Benefits for Australia

In June 1998, NEPC set National air quality standards for the first time. The standards, framed as a NEPM, were set to protect human health and were based on an assessment of the scientific and medical literature available at that time. Where possible NOAEL or LOAEL levels were identified and a safety factor applied. Where this was not possible, as was the case for particles and O_3, a standard was set which in the judgement of the NEPC, posed a minimal risk to the Australian population. Associated with the NEPM standards is a goal to be reached within a 10-year time frame. This goal has been set taking into account current air quality, technology readily available for controlling emissions and an assessment of what could be achieved nationally over the 10-year period of the NEPM. Prior to the setting of the NEPM air quality standards were set by individual states. Victoria was the first state to set air quality standards. These were set out in the State Environment Protection Policy (the Air Environment) in 1981. The standards for CO, NO_2, SO_2, lead and O_3 were set for the protection of human health. An 8-hour O_3 standard was also set to protect vegetation. There was no health-based standard for particles, however, a visibility standard, which is an indicator of fine particles, was included in the SEPP. Other states subsequently incorporated air quality standards into their state legislation.

The National Health and Medical Research Council (NHMRC) has provided guidelines for ambient air quality that are based on World Health Organization (WHO) standards. The NEPC (1998) report made a number of key points regarding air pollution impacts including the following:

(a) Ozone: the upper bounds of annual control costs is $250 million; health costs (excluding increased deaths) are in the range $95-285 million, with total health costs estimated in the order of $270-810 million; ozone reduction would also reduce other pollutants such as particles and nitrogen dioxide.

(b) Nitrogen dioxide: the proposed new standards would reduce health costs in the order of $5 million per year.

(c) Particles: the reductions proposed would save approximately $4 billion per year, mainly due to reduction in number of deaths.

Most of the cost-benefit estimates were based on the results of studies of the type proposed here, namely the impact of air pollution on daily mortality and hospital admissions, and used the results to estimate increases in daily deaths and hospital admissions. As McMichael et al. (1998) indicate, on one hand this approach is reasonable for hospital admissions, but may be problematical for daily mortality, and the study will examine this aspect (the "harvesting" effect) in conjunction with overseas groups. Ostro and Chestnut (1998) on the other hand point out that, because chronic health effects are not considered, the studies proposed give a lower limit to the estimates of health effects and use them as such in estimating the health benefits of meeting the new particle standards in the US. Ostro and Chestnut point out, for example, that the short term studies for acute effects indicate a 1% increase in daily mortality per 10 µg/m3 increase in PM_{10} levels, while the cross-sectional studies combining both chronic and acute effects indicate an increase of 3.5%. Ostro and Chestnut subsequently predict savings of $14 to $55 billion per year in health costs if the US particle standards for $PM_{2.5}$ are met.

Conclusion

The study proposed here will use data sets for daily mortality and daily hospital admissions, and air pollution data for ozone, nitrogen dioxide, particles, and carbon monoxide. Particular attention will be given to the use of fine particle data ($PM_{2.5}$) where available, given its importance in health impact studies overseas. The results will be useful in the evaluation of the NEPC air quality standards, as well as to identify any regional differences in impacts. The latter will be examined further by pooling the data for a meta-analysis and to carry out spatial analyses.

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Correspondence to:
Rod Simpson
Faculty of Science
University of the Sunshine Coast
Maroochydore, Queensland, 4558
Email: r.simpson@usc.edu.au

Application of Lung Deposition Model in Carcinogenic Risk Assessment of Polyaromatic Hydrocarbons

Nasrin R. Khalili and Salimol Thomas

Department of Chemical and Environmental Engineering, Illinois Institute of Technology Chicago

The inhalation risk for polyaromatic hydrocarbons (PAHs) classified as Group B2, probable human carcinogens, was evaluated using empirical equations driven for estimating particle deposition in human lung and ambient PAH data. The parametric study on the effect of various factors such as aerosol density, particle size distribution, PAH concentration, and tidal volume showed that higher particle density leads to higher particle deposition in the lung. The PAH deposition in the total lung is significant for semivolatile PAHs such as fluoranthene (FLT), pyrene (PYR), benso (a, h)anthracene (BAA) and chrysene (CHR) due to their predominance in the larger size particles. The largest carcinogenic risk was estimated for benso(a)pyrene (BAP). The estimated potential cancer cases reduced for all PAHs when the fraction deposited in the lung was incorporated into the risk calculations, that is, the potential cancer cases for BAP reduced to 0.19 from 1.22 per million. Although these results suggest the importance of inclusion of the deposition factor in the risk calculations, further developments might logically explore the ramifications of incorporating the lung clearance mechanisms into the fraction deposition calculations.

Key Words: *Polycyclic Aromatic Hydrocarbons, Lung Deposition, Risk Assessment*

Polycyclic aromatic hydrocarbons (PAHs) are formed mainly by anthropogenic processes and incomplete combustion of organic fuel. The adverse health effects of PAHs are mainly dependent on their concentration in ambient air and the size of particles with which they are associated. Recent studies have shown that PAHs are present in ultrafine, fine and coarse mode particles. Between 39-62% of PAHs originate in the ultrafine mode (0.01-0.1 µm) as they are formed during high temperature combustion. These can grow into larger particles (0.1-2 µm) by condensation, gas-to-particle conversion and ultimately the formation of bimodal ambient PAH size distribution (Allen et al., 1996; Venkataraman, Lynos & Friedlander 1994). The fine PAH particles have also a tendency to be deposited on coarse particles (like soil) and form coarse mode (2-10 µm) particles. The coarse mode particles settle out by sedimentation and therefore contribute to particulate pollution on a local scale, rather than on a regional or large scale.

Toxicity and ubiquity of PAHs are the main reasons for the study of these compounds (Allen et al. 1996, Harrison, Smith & Luhana 1996; Lohman, Northcott & Jones 2000; Venkataraman, Lynos & Friedlander 1994). Cancer is known to be the major concern from exposure to polycyclic organic matters. Epidemiological studies have reported an increase in lung cancer in humans exposed to coke oven, roofing tar, and cigarette smoke emissions that are heavily contaminated with PAH compounds.

Although there are no data available on the acute effects of PAHs in humans, animal studies have reported respiratory tract tumors, forestomach tumors, and leukemia from inhalation and oral exposure to benso (a) pyrene (Hanning et al. 1997; Tornqvist & Ehrenberg 1994; United States Environmental Protection Agency [USEPA] 1993). Chronic exposure to benso (a) pyrene (BAP) in humans has resulted in dermatitis, photosensitisation in sunlight, and irritation of the eyes and cataracts (USEPA 1993).

Over one hundred PAH compounds have been identified in the urban air. They are present both in particle and gas phases. Recent studies have shown that particle phase PAHs are more abundant and toxic to health (Coutant et al. 1988; Liang et al. 1997; Lyall, Hooper & Mainwaring 1988). Due to low vapor pressures, most PAHs have a tendency immediately to adsorb (condense) and form a thin film on the soot particles. PAHs also react rapidly with nitrogen dioxide (NO_2), nitric acid (HNO_3), sulfur dioxide (SO_2), and sulfur trioxide (SO_3). These reactions commonly yield carcinogens of increased potency. Pro-mutagens like BAP and direct mutagens like nitro and oxy PAHs have been found in the organic extracts of atmospheric fine particles (Liang et al. 1997, Kamens, Odum & Fan 1995).

Health risk assessment, risk analysis applied in a particular situation, plays an important role in health and environmental protection. Policy makers depend on health risk assessment and research while making regulatory decisions about which risks to tolerate and which to reduce. The evaluation and estimation of potential risks of human exposures to PAHs, is significant and can be used extensively in setting permissible levels of these compounds in the workplace and the environment (Chu & Chen 1989).

Risk is the measure of the probability of occurrence of an undesirable outcome (Kolluru et al. 1996) or introduction of an exotic disease, and the seriousness of such an outcome in the context of the importation of animals or animal products (Molak 1996). Risk analysis, however, is a methodology that evaluates and derives the probability of the adverse effect of an agent, chemical, process, technology or natural phenomena. Risk can be expressed quantitatively (probabilities ranging from zero to one) or qualitatively (low, medium, or high).

To perform health risk assessment that includes hazard identification, toxicity assessment, exposure assessment and risk characterisation, public health effects are classified as cancer effects from carcinogenic compounds such as PAHs and other non-cancer categories. The relative principal indices of toxicity for these groups are cancer potency slope factor (CSF) (or potency equivalency factors [PEF]) and reference dose (RfD), respectively (Kolluru et al. 1996; USEPA 1989).

Carcinogenic risk is a composite function of exposure and hazard potentials. Exposure parameters can be derived from the concentration and duration of exposure. This is then coupled with the ability of the chemical to induce the potential effect (i.e., CSF) to estimate the potential risk.

To define an accurate exposure parameter, many researchers (Beekman 1965; Soong et al. 1979; Yeh & Schum 1980) attempted to model the deposition of particles in the human lung as air enters the lung, traverses the nose and trachea and finally permeates the alveoli. Various mechanisms like impaction, sedimentation and diffusion are suggested for estimating the extent of particle deposition in the lung (Hatch & Gross 1964; Heyder et al. 1980, 1986; Hounam, Black & Walsh 1971; Ingham 1975; Stahlhofen, Rudolf & James 1989; Yeh 1974; Yu, Diu & Soong 1981). Soong et al. (1979) were among the first researchers to describe the lung in a statistical manner using an underlying average model to estimate probability distributions of particles for the lengths and diameters of airways and for the number and volume of alveoli. Later, Koblinger and Hofman (1985) described the stochastic model of the human tracheobronchial tree and asymmetry and randomness of the airway system as accurately as possible, using morphometric data. Most of these models are based on either a regular geometry of the respiratory system, which consists of straight cylindrical tubes (Venkataraman & Raymond 1998; Yeh & Schum 1980) or a variable cross-section channel (Soong et al. 1979).

In this study, the estimated fraction of PAH deposition in different lung regions was used in the risk equation to derive inhalation risk for nine PAHs including those that have been classified as Group B2, probable human carcinogen. Group B2 includes: benso(a)anthracene (BAA), benso(b)fluoranthene (BBF), benso(k) fluoranthene (BKF), benso(a)pyrene (BAP), chrysene (CHY), dibens[a, h]anthracene (DBA) and indeno [1,2,3-cd] pyrene (INP). This classification has been based on sufficient evidence for carcinogenicity in animals and limited evidence in humans.

The fraction of PAHs deposited at different lung regions was estimated from the PAH size distribution and the modeled particle deposition in the lung. The effect of particle density and tidal volume on the fraction deposited was evaluated in addition to assessing the excess lifetime carcinogenic risk associated with inhalation, the primary route of exposure to PAHs. Modifications to the risk equation are proposed according to the characteristics of the PAH deposition in the lung regions.

Mathematical Modeling of PAH Deposition in the Lung

The major factors affecting deposition of particles in the lung are aerosol (e.g., concentration, or particle size distribution), respiratory (e.g., volume of air inhaled, or tidal volume), and anatomical factors. The human respiratory system is primarily divided into three major regions: nasopharyngeal region (NPL), tracheobronchial region (TBL) and pulmonary region (PUL) (Hinds 1998; Hofman & Koblinger 1992; Hunan, Black & Walsh 1971). The NPL consists of the nasal cavity, pharynx and larynx. The TBL includes the trachea and the airways to the terminal bronchioles. The trachea has the shape of an inverted tree, subdividing into smaller branches called bronchioles (Hidy 1984).

Since the air entering the lung traverses the nose, trachea, and finally into the alveoli, it is logical to assume that PAH containing particles would also follow the air stream and deposit into the different regions of the lung by various mechanisms of impaction, sedimentation, and diffusion (Hinds 1998).

A ForTran code was generated to simulate the deposition characteristics of particulates in human lung. Simulation utilised the anatomical model “path lung model” of the airways proposed by Yeh and Schum (1980), assuming that lung is an ordered set of branching airways, consisting of the NPL, TBL and PUL regions.

The geometry of the lung listed in Table 1 corresponds to a lung inflated to its total capacity (TLC). Therefore, for practical applications, the airway dimensions were scaled down to normal lung volume, assuming functional residual capacity (FRC) is 0.6 TLC, conducting airway diameters expand as the square root of volume expansion, and both diameters and lengths in the respiratory region are proportional to the cube root of lung volume. See Appendix A for formulae used in simulating particle deposition in the lung.

The scaling factors, were computed for any given TLC, FRC and TV. The diameters of the conducting airway were then divided by ς for the distal airways. Lengths and diameters were divided by the scaling factor ξ. The particle deposition in the lung at NPL, TBL, and PUL regions were calculated based on diffusion, sedimentation and inertial impaction. The equations for diffusion, turbulent diffusion, sedimentation, and inertial impaction were adapted from Ingham (1975), Landhal

Table 1. Details of the Human Lung

N	No. of Bifurcation	D^c (cm)	L^d (cm)	θ^a (degs)	ϕ^b (degs)	$S(cm^2)^e$	$V(cm^3)^f$	$\Sigma V(cm^3)$
1	1	2.01	10	0	0	3.17	31.73	31.73
2	2	1.56	4.36	33	20	3.82	16.67	48.40
3	4	1.13	1.78	34	31	4.01	7.14	55.54
4	8	0.827	0.965	22	43	4.30	4.15	59.69
5	16	0.651	0.995	20	39	5.33	5.30	64.98
6	32	0.574	1.01	18	39	8.28	8.36	73.35
7	64	0.435	0.89	19	40	9.51	8.47	81.81
8	1.28x102	0.373	0.962	22	36	13.99	13.46	95.27
9	2.56x102	0.322	0.867	28	39	20.85	18.07	113.34
10	5.12x102	0.257	0.667	22	45	26.56	17.72	131.06
11	1.02x103	0.198	0.556	33	43	31.53	17.53	148.59
12	2.05x103	0.156	0.446	34	45	39.14	17.46	166.05
13	4.10x103	0.118	0.359	37	45	44.79	16.08	182.13
14	8.19x103	0.092	0.275	39	60	54.46	14.98	197.10
15	1.64x104	0.073	0.212	39	60	68.57	14.54	211.64
16	3.28x104	0.06	0.168	51	60	92.65	15.57	227.21
17	6.55x104	0.054	0.134	45	60	150.09	20.11	247.32
18	1.31x105	0.05	0.12	45	60	257.36	30.88	278.20
19	2.62x105	0.047	0.092	45	60	454.81	41.84	320.04
20	5.24x105	0.045	0.08	45	60	833.84	66.71	386.75
21	1.05x106	0.044	0.07	45	60	1594.39	111.61	498.36
22	2.10x106	0.044	0.063	45	60	3188.78	200.89	699.25
23	4.19x106	0.043	0.057	45	60	6090.97	347.19	1046.44
24	8.39x106	0.043	0.053	45	60	12181.90	654.64	1692.08
25	3.00x108	0.03	0.025	45	60		3871.80	5563.88

a = branching angle, b = gravity angle, c =diameter, d = length, e = area, f = volume

(1963), Beeckmans (1965), and Yeh (1974, 1980), respectively (Appendix B).

The fraction of aerosol deposited during inspiration at each generation (n), was computed as the product of the aerosol concentration in generation (n-1), the fraction of the tidal air penetrating to n, and the overall removal efficiency in that generation. The expiration phase of the calculations were similar to the inspiration, except that the direction of tidal air has been reversed, that is, “first in, last out”.

Nasopharyngeal deposition (mouth and nose) was calculated using Stahlhofen’s model (Stahlhofen, Rudolf & James 1989). See Appendix C.

The fraction deposited and concentration at each generation were computed for a specified particle size and density at a constant flow rate determined by the tidal volume and breathing frequency.

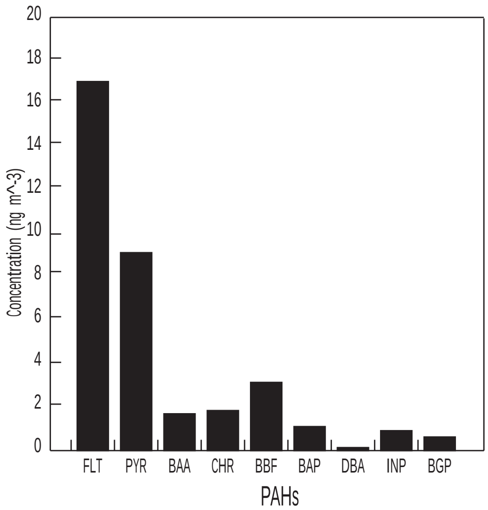
Results and Discussion

Ambient PAH size distribution

Determination of the particle size distribution is an important tool for studying atmospheric origins and fates of PAHs (Allen et al. 1996, 1997; Lohmann, Northcott & Jones 2000; Kleeman et al. 1999; Willeke & Whitby 1975). As presented in this study, the PAH size distribution can also be used in conjunction with the modeled particle deposition characteristics in lung to identify lung deposition characteristics and carcinogenic risks for these compounds.

The PAH size distribution was identified using ambient PAH data reported by Allen et al. (1996) and the bimodal log normal distribution model (Willeke & Whitby 1975). See Appendix D.

Figure 1: PAH Ambient Concentration (Allen et al., 1996)



The ambient data and calculated mass median diameters (MMD) and geometric standard deviations (GSD) of the PAHs used in this study are presented in Figure 1 and Table 2. As shown, MMDs range from 0.22 to 0.57 and 2.64 to 4.42 for the fine and coarse mode particles, respectively (note that corresponding GSD values range from 2.76 to 4.41 and 2.01 to 2.58). As indicated in Table 2, the MMD and GSD parameters are species dependent. The MMD of semi-volatile species (FLT, PYR, BAA, CHR) are higher than those calculated for the non-volatile PAHs (BBF, BAP, BGP, DBA, INP). The MMD and GSD values served as input parameters in simulation of particle deposition in the lung. Refer to Figure 1 and Table 2.

Table 2. Size Distribution Characteristics of Ambient PAHs

PAHs	MMD		GSD		Mass Fraction		Concentration ($gm\ cm^{-3}$)
	Fine Mode[a]	Coarse Mode[b]	Fine Mode	Coarse Mode	Fine Mode	Coarse Mode	
FLT	0.57	4.42	4.41	2.01	0.63	0.37	1.70E-14
PYR	0.54	4.28	4.42	2.06	0.66	0.34	9.14E-15
BAA	0.34	4.22	2.56	2.10	0.88	0.12	1.70E-15
CHR	0.32	4.00	2.50	2.01	0.85	0.15	1.85E-15
BBF	0.29	3.90	2.43	2.40	0.92	0.08	3.15E-15
BAP	0.29	3.53	2.46	2.50	0.95	0.05	1.11E-15
DBA	0.29	2.64	2.56	2.58	0.95	0.05	1.40E-16
INP	0.27	2.64	2.76	2.35	0.94	0.06	9.20E-16
BGP	0.22	2.64	3.00	2.50	0.94	0.06	6.30E-16

MMD = mass median diameter

GSD = geometric standard deviation

a = 0.01-1.9 μm

b = 1.9-19.2 μm

Modeling deposition efficiency versus particle size

The modeled deposition characteristics of the particles in the nasopharyngeal (NPL), tracheobronchial (TBL) and pulmonary (PUL) regions of the lung along with the calculated total deposition (TOT) are presented in Figure 2. A typical particle density for urban smog aerosols of 1.5 gm cm^{-3} was initially used to calculate the size dependent deposition efficiencies of the particles. As shown in Figure 2 particles less than 0.001 microns and those above 10 microns can be almost completely removed by the lung. The removal in the tracheobronchial part of the lung is most probably controlled by the diffusion mechanism. The larger particles are removed in the nasopharyngeal region, suggested by the literature due to the impaction mechanism. Particles in the 0.001 to 0.01 microns are estimated to be deposited mainly in the alveolar region.

Estimating deposition fractions of PAHs in the lung

The plots of PAH size distributions were combined with the deposition efficiency characteristics of the particles in the lung (Figure 2) in order to estimate the fraction of the PAHs deposited in different regions of the lung. The deposition fractions were calculated for a human lung under moderate exertion, assuming a breathing cycle of 15 breaths per minute (4s with 1.5s each of inspiration and expiration and with 0.5s pause in between), with a tidal volume of

1000 cm^3 (Koblinger & Hoffman 1990). This corresponds to a breathing rate of 21.6 m^3 day^{-1}.

Figure 2: Deposition Efficiency of Particles in Different Regions of the Lung

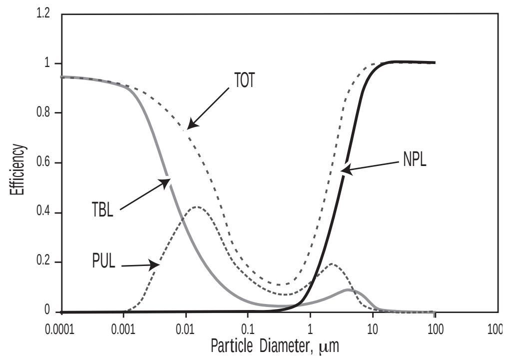
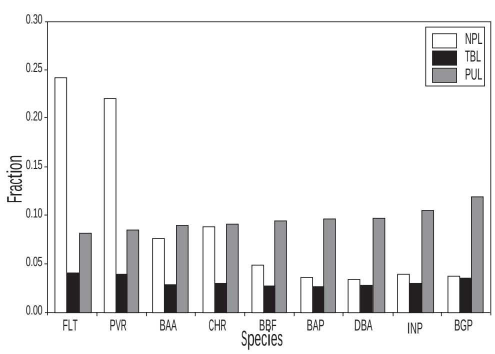


Figure 3 presents the estimated deposition fractions of the PAHs studied in different regions of the lung. As shown, the fraction deposited in the alveolar region increases with increasing mass in the fine mode (α_F) with the non-volatile PAHs dominating over the semi-volatile PAHs. Diffusional deposition increases with an increase in the fine fraction. Therefore, an increase of PAH mass in the fine mode corresponds to an increase in the pulmonary deposition with the tracheobronchial deposition remaining more or less constant. The nasopharyngeal deposition was found to be high for semivolatile PAHs like FLT, PYR, BAA and CHR, due to their predominance in large size particles.

Figure 3: Deposition Fraction of PAHs in the Different Region of the Lung

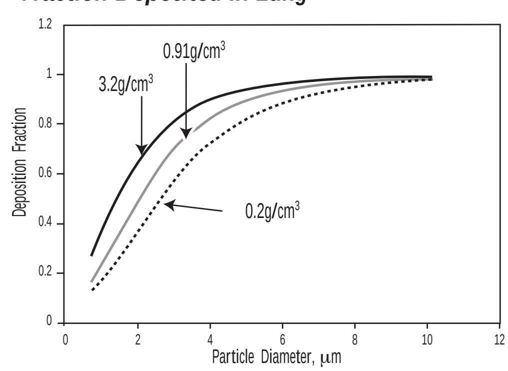


The modeled fraction deposited in the lung (Figure 3) suggests that for a typical urban PAH size distribution, the deposition is about 36% in the total lung, 24% in the NPL, 4% in the TBL and 8% in the PUL for FLT. The corresponding values are 34%, 22%, 4% and 8% for PYR; 19%, 8%, 3% and 9% for BAA; 21%, 9%, 3% and 9% for CHR; 17%, 5%, 3%, 9% for BBF; 16%, 4%, 3%, 10% for BAP; 16%, 3%, 3%, 10% for DBA; 17%, 4%, 3%, 10% for INP; 19%, 4%, 4% and 12% for BGP. The nasopharyngeal deposition is found to be high for FLT and PYR due to their predominance in the larger particles, which is conducive to deposition by impaction in the NPL region.

Effect of particle density on deposition

The effect of particle density on total deposition is shown in Figure 4 (a mean flow rate of 250 cm3 sec-1 and a breathing cycle of 4s were used to estimate the effect of particle density). For most particle sizes, total deposition increases with increasing density of the particles. However, for particles smaller than 0.01 µm and larger than 10 µm in diameter, deposition was found to be independent of density, suggesting that these particles are almost completely removed in the TBL and NPL regions by suggested mechanisms of diffusion and impaction.

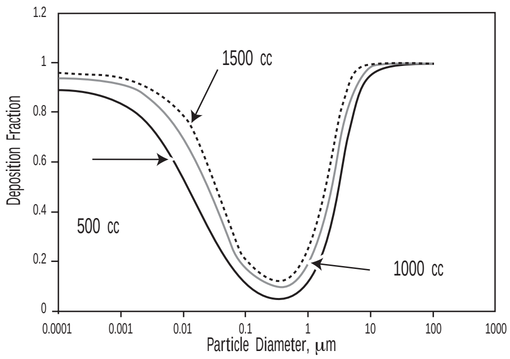
Figure 4: Effect of Particle Density on Fraction Deposited in Lung



Effect of tidal volume on deposition

Deposition efficiencies of particles were considered for three tidal volumes of 500, 1000 and 1500cc, representing “sitting”, “mild” and “heavy” exertion conditions of a human being. As shown in Figure 5, for all particle sizes, total deposition increased with increasing tidal volume, due to higher deposition fractions by impaction and sedimentation.

Figure 5: Effect of Tidal Volume on Modeled Particle Deposition



Comparison with experimental data

Experimentally determined total and regional deposition data presented by Heyder et al. (1986) for breathing monodisperse aerosols of a wide particle size range at various patterns through the mouth and nose was used for a comparison with the theoretical predictions in this study.

The deposition values reported by Heyder et al. (1986) represent mean values of deposition for three healthy subjects. Contrary to typical spontaneous breathing, a controlled breathing pattern was employed in the Heyder study. Constant inspiratory and expiratory flow rates and times without a pause was assumed and half the period of a breathing cycle was used for inspiration and half for expiration. The mean residence time of an aerosol in the respiratory tract was equal to the inspiration time or half the breathing cycle period.

Such a defined breathing pattern facilitated the comparison between theory and experiment, because the model developed in this study is also based on constant flow rates and the breath-hold period of 0.5s. In addition, the tidal volumes of the three test persons who volunteered for the Heyder study were 500cc, 1000cc, 1500cc, which are identical to the tidal volume assumed in our simulation.

Figure 6: Comparison of Experimental Data with Theoretical Prediction in the NPL Region

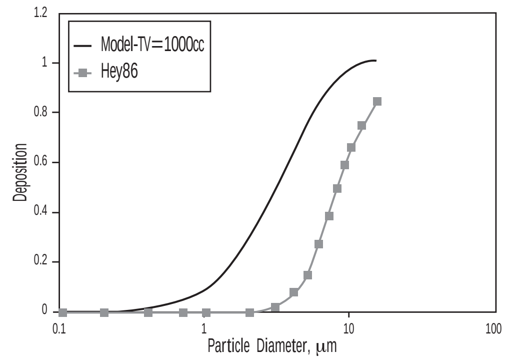


Figure 7: Comparison of Experimental Data with Theoretical Prediction in the TBL Region

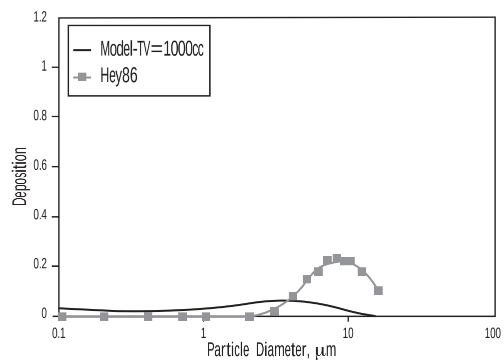


Figure 8: Comparison of Experimental Data with Theoretical Prediction in the PUL Region

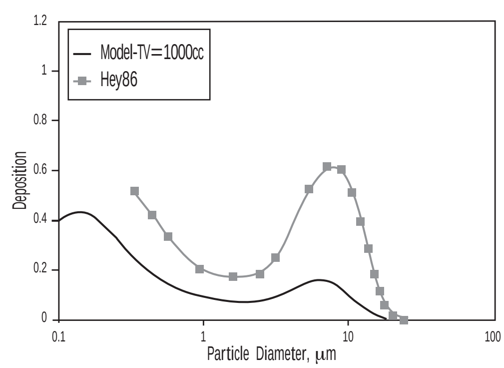
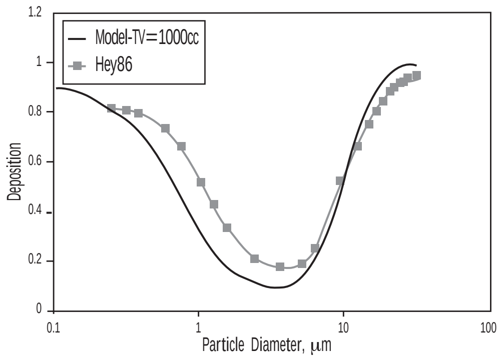


Figure 9: Comparison of Experimental Data with Theoretical Prediction in the Whole Lung



The total and regional deposition for experimental and theoretical predictions are illustrated in Figures 6 to 9. A comparison between the modeled and experimental data showed that: a) the shapes of the curves as functions of particle size are similar for the modeled and measured total deposition fractions, b) the model predicts a higher particle deposition for the NPL region, c) the model prediction is incongruent to the experimental deposition reported for the TBL region, although the general trend of deposition seems to be almost the same for the experimental and theoretical curves, and d) the maximum deposition efficiency in PUL region is observed for 0.08 and 5μm particles.

The impact of the particle density on the modeling results was also evaluated by

Figure 10: Comparison of Experimental Data with Theoretical Prediction for the Whole Lung where Particle Density is 0.91 g/cm³

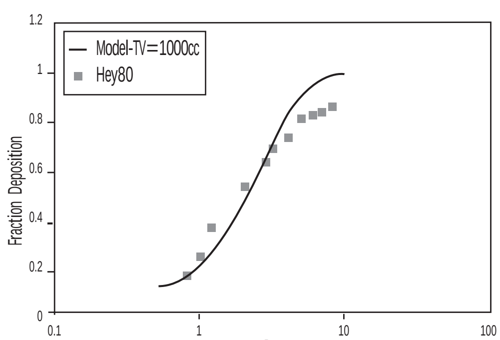
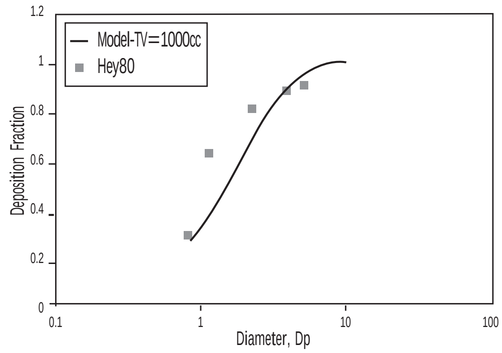


Figure 11: Comparison of Experimental Data with Theoretical Prediction for the Whole Lung where Particle Density is 3.2 g/cm³



providing a comparison between the experimental data (Heyder et al. 1980) and theoretical estimation of the deposition for the whole lung, assuming particle densities of 0.91 and 3.2 gm cm^{-3}. As shown in Figures 10 and 11, the modeling results are more consistent with the experimental data when smaller particle density is assumed for the calculations (the model starts over-predicting the deposition when particles become larger than 4 μm). For larger densities, modeling underestimates the deposition for particles larger than 1 and smaller than 8 μm.

Estimating Carcinogenic Risk due to PAH Exposure

To assess the actual exposure of humans to PAHs via inhalation, the risk model was modified by incorporating the estimated PAH fraction delivered to the lung into the risk calculations. The carcinogenic risk assessment utilised ambient PAH concentrations, actual PAH dose delivered to the lung (estimated from ambient PAH size distribution), characteristics of the particle deposition in different lung regions, and the unit risk and potency equivalency factors (PEF) of PAHs (Tables 3 and 4).

The Office of Health and Environmental Assessment (OHEA) reported unit risk factors of 1.1×10^{-3} $(\mu g/m^3)^{-1}$ for BAP, and 3.9×10^{-4} $(\mu g/m^3)^{-1}$ for DBA (USEPA 1989). Using the unit risk value of 1.1×10^{-3}, the potential cancer cases estimated to be 1.22 per million, and 36.69 in the total assumed population of 30 million residents of Massachusetts in the United States, where PAH sampling has been carried out.

Table 3. Risk per Million Based on Unit Risk Value and Fraction Deposited in the Lung

PAH	Unit Risk $(\mu g/m^3)^{-1}$	Concentrat'n of PAHs $(\mu g\ m^{-3})$	Risk per million[c]	Pop'n Risk[d]	Risk per million[a]	Pop'n Risk[b]
BAP	1.1E-3	1.11E-3	0.19	5.83	1.22	36.61
DBA	3.9E-4	1.38E-4	0.01	0.26	0.05	1.61

a,b excluding fraction deposited in the lung, c, d with fraction deposited in the lung

Table 4. Risk per Million Based on Potency Equivalency Factor

PAH	PEF	Concentrat'n of PAHs $(\mu g\ m^{-3})$	Risk per million[c]	Pop'n Risk[d]	Risk per million[a]	Pop'n Risk[b]
BAA	0.1	1.70E-03	0.04	1.08	0.19	5.61
CHR	0.01	1.85E-03	0.00	0.13	0.02	0.61
BBF	0.1	3.15E-03	0.06	1.77	0.35	10.40
INP	0.1	9.20E-04	0.02	0.52	0.10	3.04
DBA	0.4	1.40E-04	0.01	0.29	0.06	1.85

Note: a,b excluding fraction deposited in the lung, c,d with fraction deposited in the lung

As indicated in Table 3, when the fraction of PAHs deposited in the lung was incorporated into the risk calculations, the potential cancer cases reduced to 0.19 per million from 1.22 per million, and to 5.83 in the total population from 36.6 for BAP. A lower potential cancer case was estimated for DBA.

The Office of Health and Environmental Assessment has also developed potency equivalency factors (PEF) for other PAHs. The PEFs have been derived by comparing the cancer activity of the chemicals relative to BAP. Using potency equivalency factors of PAHs, it was found that there are 22 potential cancer cases from combined exposure to BAA, CHR, BBF, DBA and INP, as relative to BAP (Table 4). In comparison, inclusion of the fraction deposited in the carcinogenic risk estimates based on potency equivalency factors resulted in more excess cancer cases in the total population.

The results of this study emphasise the importance of the inclusion of the deposition factor in the risk calculations. The PAHs need to be deposited in the lung in order to cause cancer. Therefore, since only a fraction of the PAHs can be deposited in the lung, the actual risk for these compounds is lower than is assumed based on their ambient concentrations. These are the upper bound estimates of cancer risk and the actual incidences of cancer might be significantly lower.

Statistical evaluations such as Monte Carlo simulation that could examine variability in the PAH concentration-deposition relationship, and describe any uncertainties associated with the modeling results, was not possible since these types of analysis require availability of sufficient data (n≥12) for the measured PAH concentrations. The effect of particle density, and tidal volume on the modeling results was, however, evaluated.

Conclusion

The major routes of human exposure to PAHs are mainly oral or inhalation intakes. The PAH deposition fraction due to inhalation intake was estimated from the ambient PAH data (PAH size distribution) and characteristic and extent of particle deposition in human lung. The effect of particle density and tidal volume on the fraction deposited was evaluated in addition to assessing the excess lifetime carcinogenic risk associated with inhalation, the primary route of exposure to PAHs.

The results of this study showed that PAH deposition in the total lung is significant for semivolatile PAHs such as FLT, PYR, BAA and CHR. At higher particle density, deposition in the lung was higher, probably due to the increased impact of sedimentation. Increasing tidal volume led to an increase in particle deposition in the lung, manifesting a higher expected cancer risk for the PAHs.

The OHEA's value of unit risk factor, combined with the PAH concentrations and the portion deposited in the lung led to an accurate estimate of the potential cases of cancer due to exposure to PAHs. The estimated potential cancer cases reduced for all PAHs when the fraction deposited in the lung was incorporated into the risk calculations. This seems logical since PAHs need to be deposited in the lung in order to cause cancer.

Although, the results of this study emphasise the importance of inclusion of the deposition factor in the risk calculations, the lung deposition model needs to be further refined, taking into account the asymmetry and randomness of the airway system, variations in the diameters, lengths, branching and gravity angles, and finally the number of bifurcation, leading to the end of each bronchial pathway. Further developments might logically explore the ramifications of incorporating the lung clearance mechanisms into the fraction deposition calculations, as well as performing Monte Carlo simulation to incorporate uncertainties into the calculations and produce statistical distribution of the modeling results.

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Nasrin R. Khalili and Salimol Thomas
Department of Chemical and Environmental Engineering
Illinois Institute of Technology
10 W. 33rd Street
Chicago, IL, 60616
United States of America
Email: khalili@iit.edu
Correspondence to Nasrin R. Khalili

Appendix A

The following formulae (Yeh & Schum 1980) were used in simulating particle deposition in lung:

$$LV = FRC + 0.5\ TV \tag{1}$$

$$V_{D,LV} = V_{D,FRC} + (LV-FRC)\alpha \tag{2}$$

$$V_{D,TLC} = V_{DFRC} + 0.6TLC\alpha \tag{3}$$

$$V_{D,0.6TLC} = V_{D,FRC} + 0.2TLC\alpha = V_{D,TLC}/(1.15)^2 \tag{4}$$

$$\alpha = \frac{0.2439V_{D,TLC}}{0.4TLC} \tag{5}$$

The expansion ratio for conducting airway diameters, was calculated as follows:

$$\varsigma = \sqrt{\frac{V_{D,TLC}}{V_{D,LV}}} \tag{6}$$

$$V_{R,TLC} = TLC-V_{D,TLC} \tag{7}$$

$$V_{R,LV}=LV-V_{D,LV} \tag{8}$$

The expansion ratio for the respiratory lengths and diameters was estimated from Eq. 9:

$$\xi = \sqrt[3]{\frac{V_{R,TLC}}{V_{R,LV}}} \tag{9}$$

Appendix B

Deposition by Brownian Diffusion was estimated as follows:

$$P_D = 1 - 0.819e^{-7.315X} - 0.0976e^{-44.61X} - 0.0325e^{-114X} - 0.0509X^{2/3} \quad (10)$$

For turbulent flow system, the following model was used:

$$P_D = \frac{2\sqrt{Dt}}{R}(1 - \frac{2\sqrt{Dt}}{9R} + ...) = 2.828x^{1/2}\left(1 - 0.314x^{1/2} + ...\right) \quad (11)$$

For a pause, Deposition by Brownian Diffusion was estimated from Eq. 12:

$$P_D^p = 1 - \exp\left(-5.784KTC_t / 6\pi\mu r_p R^2\right) \quad (12)$$

Probability of deposition by sedimentation (P_s) and impaction (P_I) was estimated using Eqs. 13 and 14:

$$P_S = 1 - \exp\ (-4gCr_p r^2_p L\cos\phi / 9\pi\mu Rv) \quad (13)$$

$$P_I = 1 - \frac{2}{\pi}\cos^{-1}(\theta.St) + \frac{1}{\pi}\sin[2\cos^{-1}(\theta.St)] \quad (14)$$

The combined effects of all these mechanisms on particle deposition via inspiration was estimated as follows:

$$P^i = P_d + P_s + P_i - P_d P_s - P_d P_i - P_s P_i + P_d P_s P_i \quad (15)$$

For expiration and pause, impaction effect was ignored. Thus, the total efficiency of particulate removal at each of these phases was estimated from the reduced form of Eq. 15:

$$P^e = P_d + P_s - P_d P_s \quad (16)$$

$$P^p = P_d + P_s - P_d P_s \quad (17)$$

Appendix C

$P_{mi} = 1\text{-}(3.5 \times 10^{-8}X^{1.7} + 1)^{-1}$ (18)

$P_{ni} = p_{ni}^* + (1\text{-}p_{ni}^*)p_{mi}$ (19)

where

$p_{ni}^* = 1\text{-}(3.0 \times 10^{-4}X + 1)^{-1}$ (20)

$X = d^2_{ae}Q$ (21)

for expiration:

$P_{ne} = P_{me} = 0$ (22)

Appendix D

$$M(D_p) = \frac{dM}{MdLogDp} = \frac{\alpha_F}{\sqrt{2\pi}\ln\sigma_{gF}}\exp\left[-(\ln D_p - \ln D_{pF})^2\right] + \frac{1-\alpha_F}{\sqrt{2\pi}\ln\sigma_{gC}}\exp\left[-\frac{(\ln D_p - \ln D_{pC})^2}{2\ln^2\sigma_{gC}}\right] \quad (23)$$

In this equation, $M(D_p)$ is the measured total particle mass concentration, D_{pF} and D_{pC} are the mass median diameters of the fine and coarse mode particles, respectively, and α_F is the fraction of particles in the particle size range between 0.0 and -1.9 µm.

Appendix E

Definition of Symbols

Symbol	*Definition*
LV	Desired lung volume
$V_{D,Y}$	Dead airspace at lung volume Y
α	Dead space expansion coefficient
$V_{R,Y}$	Volume of respiratory airways at lung volume Y
ς	The expansion ratio for conducting airway diameters
ξ	The expansion ratio for the respiratory lengths and diameters
P_D	Diffusion deposition probability
X	L.D./(2.R²v)
L	The length of tube
V	Mean flow velocity
T	Time for flow to pass through the tube or airway = L/v
R	Radius of tube (airway)
ν	Viscosity of fluid
C	Cunnigham Slip Correction Factor
D	Diffusion Coefficient of an Aerosol Particle ($Cm^2\ s^{-1}$).
T	Pause time
K	Boltsmann constant
T	Temperature, K
r_p	Radius of the particle
ρ_p	Density of the particle
ϕ	Inclination relative to gravity (ϕ= 0 for horizontal tube)
T	For a pause, L/v is replaced by the pause time, t.
P_I	Impaction deposition probability
θ	The bending angle
St	Stokes number ($C\rho_p r^2_p v/9uR$)
P_d, P_s , P_i	Probability that a particle will deposit by diffusion, sedimentation and by impaction
P^I	Conditional probability of the three exclusive mechanisms on inhalation
P^d, P^3 , P^p	Inspiration , expiration and pause effect
P_{ni} , P_{ne}	Probability of particle deposition in the nose, during inspiration, expiration
P_{mi} , P_{me}	Probability of particle deposition in the mouth, during inspiration, expiration.
Q	Mean Flow Rate (Cm^3s^{-1})
d_{ae}	Aerodynamic diameter of the particles

Appendix F

Polycyclic Aromatic Hydrocarbons (PAHs)

Compound Name	*Abbreviation*
Fluoranthene	FL
Pyrene	PYR
Benso(a)antracene	BAA
Chrysene	CHR
Benso(b)fluoranthene	BBF
Benso(a)pyrene	BAP
Dibens[a,h]anthracene	DBA
Indeno[1,2,3,-cd]pyrene	IND
Benso(g,h,i)pyrene	BGP

Environmental Health Challenges in a Developing Country: Mozambique - A Literature Review

Melissa Stoneham and Maria Hauengue

School of Public Health, Queensland University of Technology

Environmental health is a major challenge facing Mozambican cities today due primarily to the high incidence of natural disasters, high population density, and the civil war which raged across the country until the early 1980s. As a result, large numbers of people migrated to the cities, resulting in poor infrastructure, poor access to services and a weak economy. Mozambique is now considered one of the poorest countries in the world (Oxfam 1997). Many aspects that affect the health and lifestyle of the population, such as roads, drinking water quality and sanitation facilities, education, employment and housing conditions, need to be improved. However, with the lack of resources it is difficult to respond to all issues simultaneously, making it necessary to set priorities. This paper describes the first phase of a research project that aimed to identify and prioritise the perceived environmental health needs in Maputo City, with the intent to assist the local government in planning services for its citizens. The process followed was consistent with the development of an Environmental Health Action Plan as espoused by WHO (1990). Although this paper is predominantly a literature review, the research did evolve to identify the perceived environmental health needs of both the residents of Maputo and the Environmental health practitioners who worked in the City. Variations of the priority issues between the target groups were identified, however, the findings showed that, in general, the majority of environmental health issues perceived as concerns were related to urbanisation and its consequences. This finding was supported by the first phase of the research, being the evidence sought from literature. Environmental health issues in developing countries are widespread and could be categorised as traditional environmental health, which relate to poverty and insufficient development. Such issues may include sanitation, access to potable water and nutritious and safe food, inadequate waste disposal and access to services. The universal environmental health issues of concern specific to Mozambique, as sourced from both the literature and the survey of residents and practitioners, included poor housing, lack of water, ineffective sanitation facilities, a lack of environmental health policy, erosion and unemployment.

Key Words: *Environmental Health, Developing Countries, Environmental Health Action Plans*

The World Health Organization (WHO) has, since 1984, endorsed a common health policy for all Member States. Within this policy, it has been recognised that human health is dependent on a wide range of environmental factors. At the second European Conference on Environment and Health that was held in Helsinki (1994), the Ministers of Health and Environment adopted the Declaration on Action for Environment and Health in Europe and endorsed the Environmental Health Action Plan for Europe. Since this time, a number of environmental health action plans (EHAPs) have been developed throughout the world. Mozambique, an eastern African nation is currently developing an EHAP.

The WHO has developed guidelines for the framing of an environmental health action plan. This is a complex task that involves both political and technical issues (WHO 1999). The process has been divided into a seven step planning process including:

- Achieving government commitment to proceed with the EHAP
- Developing a framework for planning
- Conducting an environmental health assessment
- Developing government positions on priority actions
- Conducting public consultation
- Finalising and adopting the action plan, and
- Developing an implementation plan (WHO 1999).

The first steps of this process rely on political commitment and the collection of data to act as evidence for any issues of concern that are raised during the consultation period. During this process, it is imperative that a holistic view of environmental health is taken to ensure that health, environmental, economic and social issues are covered. This is necessary as such issues are complex subjects to address, are often interrelated and must be managed in a collaborative manner.

In 2000, an EHAP was proposed for the Mozambique Ministry of Health's consideration, having sought and received government approval to proceed in early 1999. The process of developing the EHAP followed the WHO planning framework and is still to be finalised. As the Ministry of Health completed the first two stages of the EHAP process with relative simplicity, this paper describes the third step of the EHAP process, which revolved around the collection of literature and evidence of environmental health problems in Maputo City, the capital of Mozambique. Maputo City is the political, industrial and economic capital of Mozambique and has the country's highest population density of 3223 inhabitants per square kilometre (National Institute of Statistics [NIS] 1998a).

Primary Causes for Concern: A Historical Perspective

Mozambique sits on the eastern coast of Africa and has a population of 16.3 million. It is considered to be the seventh poorest country in the world (Oxfam 1997). Environmental health problems is one of the major challenges that Mozambican cities are facing today. The primary causes for such problems include the prolonged drought, which commenced in the early 1980s, and the subsequent and annual floods. The 16 years of severe civil war that followed the colonial period destroyed the country's economy and contributed to the deterioration of politics and social stability (Finnegan 1992; Wigglesworth 1994).

Even though internal migration is recognised as a historical phenomenon of Mozambican evolution, the recent civil war induced specific migration movements influencing the process of urbanisation (Ministry of Health & NIS 1998; Patel & Gay 1997). By 1990, approximately one third of the total population was forced to move from residences into security zones around the cities and transport corridors, with a further 1.7 million people taking refuge in neighbouring countries (Finnegan 1992; United Nation Development Program 1996). The continuous migration of people to the cities caused a large growth of spontaneous or informal housing, which led to the development of slum settlements around the cities. In turn, this created difficulties in meeting basic services such as reticulated water, sanitation, schools, hospitals and communication systems to approximately 40% of the total population (NIS 1999; United Nations 1995).

The Scope of the Article

The article provides an overview of the

major environmental health concerns and issues for Mozambique as identified in the literature. It is important to state that an additional component of the environmental health assessment was the identification of community needs in relation to environmental and public health. Those findings are the topic of another journal article.

One of the issues with researching literature for Mozambique and other developing countries is the difficulty in accessing published data. As a result many of the references for this study are unpublished reports.

Although many environmental health issues are identified within the study, this article has not endeavoured to assess critically each of these, but has simply aimed to highlight the evidence that acted as indicators for such issues.

Environmental Health Concerns: The Specifics

Due to the diversity of issues raised through the literature, the authors have attempted to signpost these through the use of headings to enable a logical flow of information. The root of many of the environmental health problems in Mozambique stem directly from the proliferation of unplanned settlement. A large proportion of the city of Mozambique is comprised of these unplanned settlements. Such settlements can be described as makeshift houses or slums that have few or no services. Due to the development of these unplanned settlements, suitable space for constructing facilities such as schools, health centres, and shopping centres is unavailable. Water and electricity are not connected and deficient roads make it difficult to access any existing services (United Nations 1995).

Waste management

It is commonly cited that environment, health and economics are inextricably linked (Brundtland 1988; Milio 1987). These links are clearly evident in developing countries. Many quality of life problems relate to the lack of financial resources available in the country. For example, the City Council has not had adequate numbers of vehicles to collect refuse in the urban and peri-urban areas, resulting in refuse remaining in the streets or in public containers for days or months (Yassi et al. 1997). It is common for scavenging to occur amongst this refuse.

The inadequate disposal of domestic and industrial wastes and the insufficient storage and use of pesticides and other chemicals, contribute to the pollution of soil, groundwater, rivers and oceans, and food sources (Casadei 1986; Norway Agency of Development [NORAD] 1990). This has led to increasing patterns of diseases such as diarrhoea, cholera parasitoses and food poisoning, especially amongst children. According to the Mozambican Health Authorities, the infant mortality rate increased from 78 to 93 per thousand, from 1987 to 1992, with the major cause being acute respiratory infections, malaria and diarrhoeal disease (Ministry of Health & NIS 1998). Although this proportion reduced to 50% from 1992 to 1997, these diseases remain the major causes of mortality in Mozambique (Department of Environmental Hygiene 1999a; NIS 1998a).

The inadequate provision of services for collection and disposal of industrial solid waste, such as hazardous or toxic waste, represents a danger for the human and natural environments in Mozambican cities. Much of the industry is located in the urban and peri-urban areas, and pre-treatment of waste is not common. Others do not have filter systems to retain the dust. In some cases, the pollutant removal plants are not maintained due to inadequate technology, knowledge and resources (NORAD 1990). Consequently, untreated waste is discharged directly into the rivers and ocean, causing the death of water living organisms, destroying the ecosystem and increasing the organic matter that accelerates eutrofication of the water bodies (Silvana & Xavier 1999). Other industries dispose effluent directly to the ground, which, through filtration, pollutes the groundwater and creates dangers for those who access supplies from such sources (Casadei 1986).

Road and transport infrastructure

Urban roads in Mozambique have deteriorated in recent times. In 1996, from the total of 26 193 kilometres of roads in Mozambican cities, only 3528 kilometres were considered in good condition, 3822 kilometres were fair, and others were poor, bad or impassable (NIS 1998b). These conditions worsen during the wet season, as the majority of roads have no drainage system. The public transport system in Maputo is seriously overburdened, and this, combined with poor street conditions, results in frequent accidents, particularly on peri-urban roads and highways (United Nations 1995). For instance, in 1997 a total of 4798 road accident victims were registered, with 805 road deaths (NIS 1998a).

Directly related to transport use, is the mix and concentration of air pollutants in Mozambique. The current levels are already sufficient to cause illness and premature death in more susceptible individuals especially among the elderly and those with existing respiratory problems. Reported data from the Mozambican Ministry of Health suggest that respiratory diseases such as asthma are becoming increasingly common in the urban population (Ministry of Health & NIS 1998).

Water and sanitation

In Mozambique, the water companies do not have sufficient resources to extend water supplies to the newly created urban areas. As a result, in most of the peri-urban areas of Maputo, where approximately 40% of total Mozambican population live, drinking water is obtained from shallow-wells and boreholes. Sanitation facilities are commonly pit latrines (NIS 1998a; NIS 1999).

With inadequate water supplies, slum settlements tend to access any available water, including groundwater and water in drains or sewers. Due to the high reliance on such sources, the volume of useable groundwater has been reduced due to a substantial intrusion of salt water. This is clearly evident in the Mozambican coastal cities, where families can no longer drink water from wells due to the saline intrusion (Casadei 1986; United Nations Development Programme 1996).

Education and health care

Due to the war and insufficient public resources, education and health services have both deterioraed. In the 22 years from 1970 to 1992, the adult literacy rate has increased by only 12%. During this same period, approximately 68% of the primary school network was destroyed by war (United Nations Development Programme 1996). As the education sector does not have the resources to provide additional schools or teachers, the high demand for education has led to elevated numbers of students in each class, particularly in urban schools. The ratio between students and teachers at public education institutions in 1997 was estimated at 60:1 in primary schools and 35:1 at the secondary level (NIS 1998a).

Mozambique has one of the lowest literacy rates in the world, and faces acute shortages of skilled managerial and technical human resources, making it difficult for the government to conduct even the most basic policy analysis and planning activities (United Nations Development Programme 1996; World Bank 1992). Many professional people in Mozambique have studied overseas, and in many cases do not return to their homeland after graduation. A working example is the environmental health workforce, which predominantly consists of biologists. Postgraduate studies have been sought in countries such as Norway, Italy, Australia and America.

Similarly, standards of health care have deteriorated at all levels particularly in rural areas, where approximately 1100 rural health centres were destroyed by war and natural disasters before 1992 (United Nations 1995). As a consequence, the health service coverage has deteriorated from 9700 people per health centre in 1981, to 12 300 people per health centre in 1990. Further, the diversion of resources due to the war has led to a steady decrease in the Ministry of Health's share of total budget expenditure including recurrent investment from a peak of 6.7% in 1980 to 3.3% in 1993. In addition, the Ministry's share of the recurrent budget exhibited a similar trend, and fell from 10.5% in 1980 to 3.7% in 1993 (United Nations Development Programme 1996). However, when the war ended, the government policy for resource allocation emphasised a greater input to social sectors such as education and health. This led to a considerable increase in educational facilities, particularly primary and secondary schools, which have developed by 60 and 59% respectively between 1990 and 1997 (NIS 1998a). In the health sector, 1054 health units were available in 1997, compared with 946 in 1995 (NIS 1998a). Yet, despite this improvement in the health sector, additional health care needs remain. For example, most prescribed drugs are not available from pharmacies and professional medical care is extremely difficult to obtain due to scarcity (Ministry of Health & NIS 1998) and the difficulty in accessing transport to visit such services.

Population and employment trends

Migration to the cities has been occurring for many years, primarily due to war and poverty. The majority of people who have migrated to the cities tend to be male, young and single. This has caused changes in the population's gender distribution. According to the 1997 population census, 52.3% were female and 47.7% male (NIS 1999). The gender gap was considerably affected not only by migration itself, but also by the civil war that caused many deaths, particularly among males (United Nations 1995).

Large-scale agriculture and farm activities have traditionally occurred in the rural areas fringing Maputo. However, with migration, these activities have declined to subsistence models (World Bank 1992). Such demographic and economic changes have led to a reduction of food production in the rural areas, resulting in famine and fewer employment opportunities in the cities (United Nations 1995). Consequently, there has been an increase in the informal or less remunerative employment sectors, such as carpentry and furniture production, vehicle maintenance, shoe shining, fabrication of metal goods, food vendors and streetcar washing in all Mozambican cities. According to the NIS (1999) the informal sector in Mozambique employed almost 40% of the urban labour force. The informal activity included the selling and purchasing of products in open streets or in the backyards, often under poor and unhygienic conditions. As these markets are not regulated and do not pay taxes (United Nations 1995), the low price of products attracts large numbers of consumers contributing to the decline of more formal stores, and thus having a negative impact on the economy (United Nations Development Programme 1996).

Due to high unemployment levels, prostitution has become a popular avenue to enhance income. Mozambique has a considerable problem in relation to HIV/AIDS, and infection rates have increased from 64 cases per week reported in 1990 to 1300 per week in 1997 (NIS 1998a). The increasing level of prostitution is a concern as safe sex is not practiced universally and it is culturally acceptable to have more than one sexual partner.

Social Problems Related to Urbanisation

Such a concentration of people in the cities due to urbanisation has substantially increased the cost of goods and services. As the majority of the low-income sector is immigrant families, poverty is widespread.

Statistics indicate that between 40 to 50% of the urban population in Mozambique live in poverty and cannot obtain sufficient food, shelter or health care (NIS 1998a; NIS 1999). As a result, people from lower socio-economic groups, including young people, are often sighted in all Mozambican cities asking for help or begging, searching for food in public waste containers, and sleeping in the streets. This behaviour has been linked to an increase in violence, depression, and risk taking, such as smoking, alcohol, drugs, and prostitution (United Nations 1995; United Nations Development Programme 1996).

One important consequence of the socio-economic and cultural changes in Mozambican cities is the increase in violent crimes including murder or homicide, infanticide, assault, rape and sexual abuse, and domestic violence. Such crimes now comprise between 10 to 15% of the total deaths occurring in urban areas (NIS 1998a). The police forces are unable to protect residents against theft and violence (United Nations Development Programme 1996) due to inadequate numbers and resources.

Many Mozambican families are large with an average of four adults and ten children per household (Hauengue 2000). The combination of low family income and inadequate housing, causes exposure to extreme factors such as inadequate ventilation, cold or biomass combustion from cooking and heating, noise, dust, rain, insects, and rodents (Norway Agency of Development 1990). As a result, injuries and illnesses, such as burns, scalds and accidental fires, acute respiratory infections, pneumonia, tuberculosis, and food poisoning are increasing (Department of Hygiene 1999a; Ministry of Health & NIS 1998). These conditions also create optimum environments for the spread of infectious diseases such as cholera and conjunctivitis (Cliff & Noormahomed 1988; United Nations 1995).

Degradation of the Environment

Due to the concentrated demand for agricultural products from fertile land, substantial ecological changes have occurred to bodies of water and forests. Deforestation is a particular concern in Mozambique, and in urban areas there is evidence of accelerated erosion (Dijk 1997). In both rural and urban areas, soil is removed and trees lopped for construction of houses, resulting in the destruction of the natural environment. Such activity has been occurring both with and without government permission. Dependence on these raw materials is necessary to support regular activities, such as furniture manufacture, cooking, medication, and construction and are therefore critical to the survival of those living in poverty. Other changes to the natural ecology include the acquisition of native plants for natural medicine or drugs, and the taking of sand as an essential element in the construction of houses (Norway Agency of Development 1990; United Nations 1995).

The Economic Perspective

From an economic perspective, the government's war effort absorbed a huge component of available resources. From 1986 to 1992, an average 37.3% of government recurrent expenditure was allocated to defence and security (United Nations Development Programme 1996). Although this percentage is now much lower, many activities and industries continue to be affected, due to the lack of infrastructure, policy direction, and available funding that was accessible during the war period.

From Information to Action

All of the information and data described in this article contribute to public health problems that affect the environment, the society, and the economy (United Nations Centre for Human Settlements 1996; WHO 1992). The solutions for controlling and minimising these issues are complex and often conflicting. They cannot be addressed simultaneously due primarily to resource constraints. Each issue requires access to resources, supportive legislation, decentralisation of power, intersectoral collaboration and input into decisions from the community. Such community input needs to be comprehensive and to involve many actors, including public institutions, industries, farmers, and residents (WHO 1993). However, it is clear that if the current environmental health trends continue, together with an unclear definition of environmental health policy and lack of resources, there will be serious socio-economic implications for Mozambique.

The data collected for this step of the EHAP, have indicated that the improvement of environmental health services is required to enable the Government to respond effectively to the particular needs of all social partners. The investment made to develop the precis of key environmental health problems in Mozambique was the cornerstone for the EHAP to proceed. It directed the consultation and community participation phase, assisted in directing the economic sectors response in planning to mitigate for environmental health problems, identified areas in need of immediate financing, and recognised the need for a monitoring, reporting and evaluating program to ensure effective program planning and staffing levels.

Following the review of these data, the Ministry of Health developed an institutional framework that combined and redistributed responsibilities of Ministries. The cooperation between Ministries was considered imperative in order to ensure that issues were identified as agreed priorities and were implemented as part of national reform. The EHAP process in Mozambique continues to gain momentum and recognition in many government and non-government sectors of the country.

Conclusion

The paper has described the major environmental health issues and concerns relating to Mozambique, which is a country that has been ravaged by war, natural disasters, and poverty. These issues were identified during a literature review for the environmental health assessment that was conducted as one component of an Environmental Health Action Plan. Preceding this assessment, governmental support for the process was gained and the decision to use the existing WHO framework for developing an EHAP was taken. The issues identified included health effects from unplanned settlements, access to water, transport, education and health services, poor waste management services, and a change in population demographics that in turn caused the degradation of the environment and resulted in a new set of social issues.

The use of literature as one avenue of accessing such data is valid and will in turn provide an evidence base upon which to plan future actions and strategies.

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Melissa Stoneham and Maria Hauengue
School of Public Health
Queensland University of Technology
Locked Bag No. 2
Red Hill, Queensland, 4059
AUSTRALIA
Email m.stoneham@qut.edu.au
Correspondence to Melissa Stoneham

Health and Wellbeing in the School Community Environment: Evidence for the Effectiveness of a Health Promoting Schools Approach

Dru Carlsson, Fiona Rowe and Donald Stewart

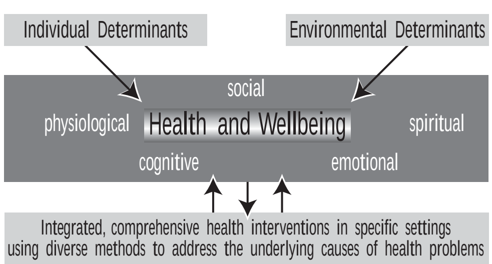
Centre for Public Health Research, School of Public Health, Queensland University of Technology, Brisbane

Changes in the conceptualisation of health and wellbeing have led to our understanding of the social-ecological view of health where the impact of the social, mental, physical and economic environments on health is recognised. Current evidence recommends the use of integrated, comprehensive approaches to address the underlying causes of health problems in specific settings. The health promoting schools approach, based on the application of the five action strategies of the Ottawa Charter to the school setting, is a process employed by whole school communities to enable them to address the identified social and health needs of their school and local community. International evidence indicates that school health interventions that recognise and work within such an approach have made a positive impact on the wellbeing of young people. A consistent pattern indicates that the more comprehensive the approach, the more effective the outcomes for youth wellness. This article reviews such evidence and examines data emerging from three related research projects in Queensland, Australia.

Key Words: *Health Promoting School, Evidence, Young People, Health and Wellbeing*

A positive and more holistic view of health, as wellness, was recognised in the World Health Organization (WHO) definition of health as "a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity" (WHO 1947). This reconceptualisation (Figure 1) has gradually permeated existing theories of health and medicine and influenced political commitment to health (McDowell & Newell 1996; Wilkin, Hallam & Doggett 1994).

Figure 1: Changes in conceptualisation of health and health interventions



Health interventions have changed in response to these developments. With the view that health is influenced by multiple individual and environmental determinants, it has been recognised that the physical, cognitive, social and emotional wellbeing of people and the environments in which they live, need to be considered when addressing health issues. Thus, to achieve positive health, health interventions that combine holistic and diverse yet integrated methods, and recognise the multiple dimensions of health and the inextricable relationship between the individual and the environment have been explored (Hawe 1998; Wenzel 1997). Current evidence recommends the use of integrated, comprehensive approaches to address the underlying causes of health problems in specific settings.

The School Setting

The health promoting school (HPS), as initiated and described by the World Health Organization (1996), is based on the application to the school setting of the five action strategies of the Ottawa Charter (1986) for health promotion. It thus revolves around the need to build public policies that support health, create supportive environments, strengthen community action, develop personal skills and reorient health services. A health promoting schools approach (HPS) involves a process employed by school communities to enable them to address the identified social and health needs of their school and local community. The approach involves the diverse members of the school community, including students, school staff, parents and carers and local community organisations and businesses. Such groups work collaboratively within a planned framework to promote the health of the school community (Downie, Tannahill & Tannahill 1997; Lister-Sharp et al. 1999; National Health and Medical Research Council [NHMRC] 1996; St Ledger 1999; WHO 1995a, 1995b, 1997).

The approach has been adequately described elsewhere (e.g., NHMRC 1996), but is broadly comprised of three essential and interrelated components:

- curriculum, teaching and learning;
- school organisation, ethos and environment; and
- partnerships and services.

Curriculum, teaching and learning

The curriculum, teaching and learning component of the framework is concerned with the implementation of an integrated, experientially-based curriculum, that encompasses a holistic view of health (Hancock & Perkins 1985, Kickbush 1989). The development of more generic life skills such as decision making, effective communication and negotiation skills are emphasised, as these are perceived as assisting school community members in making healthy choices in their everyday lives.

Evidence indicates that linking the classroom curricula to experiential or real life activities embeds learning and skill development in experiences that are relevant to students' everyday lives, and so helps to address the social and environmental influences on health and wellbeing (Lister-Sharp et al. 1999; NHMRC 1996; St Ledger 1999, WHO 1995b). This component of the approach also advocates student-centred learning that encourages student participation and decision making in the classroom and values their contributions as partners in the learning process (Holdsworth 1996).

School organisation, ethos and environment

The school organisation, ethos and environment component of the framework uses existing school structures, organisation, policies and planning to support and reinforce the health messages that are taught in the formal curriculum (Lister-Sharp et al. 1999; NHMRC 1996).

The social environment, termed "Ethos" in this framework, refers to the values, structures and functions of the school, which contribute to the relationships between staff, students and parents and the overall climate or atmosphere of the school. Also included is the physical environment, which refers to factors such as the playground layout and structures, building and classroom appearance, spaces for social interaction, special facilities such as healthy canteens and recycling of renewable resources (NHMRC 1996; St Ledger 1999;Young & Williams 1989; WHO 1996).

Partnerships and services

Central to the health promoting schools framework is the commitment and collaboration of the whole school community in developing a shared vision and creating strategies to address the health needs of the community. This is done through the framework of the school curriculum, school policies, ethos and environment. Partnerships fostered between parents and carers and the broader community increases the likelihood that health messages learnt at school will be reinforced by home life and the broader living context (NHMRC 1996).

In summary, these are the three components of the health promoting schools approach, which should ideally be used together within a school in an integrated manner. The approach is much more than including additional health education, for example, in the curriculum – a misperception which commonly is strongly resisted by teachers. Rather it can reformulate and link associated activities, curriculum and policies that help to improve opportunities for learning and health, and which can highlight additional occasions for both educational and health gains. Although teachers have sometimes viewed this new initiative with alarm, as yet another project that they are being asked to support, there is considerable evidence available to show that the health promoting schools approach actually enhances the chance that important educational goals are achieved. For those involved in health promotion, the approach allows for categorical health promotion projects to be integrated and supported in a much more educationally worthwhile manner, with increased chances of improved health outcomes.

The approach has strong support internationally and has received equally strong grassroots and government support in school communities in Australia (Australian Health Promoting Schools Association [AHPSA] 1997; NHMRC 1996). In practical terms, this support has been particularly apparent in the work of local Health Promoting School associations and their partners, such as universities and government departments, in running training programs, workshops, seminars and conferences, as well as investing in curriculum and other materials to support such educational and training efforts.

Within health promotion literature, schools have been identified as a setting, which provides an ideal opportunity for health practitioners to undertake preventative action and promote healthy lifestyles. The attraction of this approach has been seen in discussions about the cost/effectiveness of investments in categorical programs in the school setting. Thus programs to expand immunisation, to increase knowledge about family planning, nutrition and health care, to reduce the consumption of tobacco, alcohol and other drugs, and the prevention of HIV/AIDS and STDs (WHO 1995c) have typically been constructed with a view to this setting. A ‘settings’ approach to health promotion has, in a number of instances, provided a useful framework for developing initiatives and ensuring that all key decision makers and stakeholders are recognised and involved in efforts to promote health and wellbeing, such as the healthy cities projects, healthy hospitals, healthy workplaces and healthy market places. The settings approach has, however, been recognised as having limitations, for example it may well be the very groups who are most at risk, such as the homeless, or alienated youth, who are not represented in formal settings, such as schools or the workplace.

Schools, parents and governments at all levels have recognised the importance of the school and its community as a physical, social, psychological “learning” environment which has the potential to affect the health of all who are involved, in both a positive and a negative way. Substantial resources have been devoted to planning, developing, implementing and sustaining health promoting schools. The necessity for good evidence as to whether the health promoting schools approach actually encourages wellness has become increasingly clear.

Evidence on the Effectiveness of the Health Promoting Schools Approach

The health promoting schools approach has only been recognised and promoted over the last decade or so and within this relatively short period of time research data regarding effectiveness have only recently begun to emerge. Further, as illustrated above, there are multiple facets to the school as a setting and the components of the HPS approach and this increases the challenges relating to measurement. The strength of this approach is the extent to which there is supportive interaction across the curriculum, the environment and the community and health service partners. Thus, a range of research methodologies can be selected to suit the specific dimensions of the evaluation. As with much health promotion research, process and impact measures can be applied with a reasonable chance of success. Outcome measures, however, are difficult to obtain and this is particularly the case when a large proportion of the school community, the student body, is undergoing contemporaneous developmental change. Nevertheless, evidence is mounting in the international literature regarding the success of comprehensive approaches to the enhancement of the health and wellbeing of individuals and their communities.

There are some difficulties in demonstrating the evidence of the effectiveness of the HPS approach, as much of the current literature argues the potential benefits but provides little real evidence of the actual benefits (St Ledger 1999). However, this may well be because few studies have actually examined the effectiveness of school interventions that are using the HPS approach in its fullest sense. For example, a 1999 review found only four quasi-experimental studies that had met their criteria for using the HPS approach, where schools addressed health issues using a holistic, integrated approach (Lister-Sharp et al. 1999).

Most evidence comes from predominantly topic-based interventions that have only used one or two of the HPS components. Despite this, there is evidence that an intervention in a combination of areas is more successful than in any one area alone (Lister-Sharp et al. 1999). For example, the same authors note that there has been considerable success with school health interventions that combine curriculum teaching (the curriculum, teaching and learning HPS component) with involvement of parents and peers (the partnerships and services HPS component). While it might be overstating the case to suggest that the results for curriculum-based initiatives around health issues are all bad, there is evidence to show that insubstantial and even negative results have been found for purely curriculum-based models, particularly in the hard-to-change areas of drug use, sexual behaviour and eating disorders (St Ledger 1999).

***Figure 2:* Evidence for the health promoting schools approach**

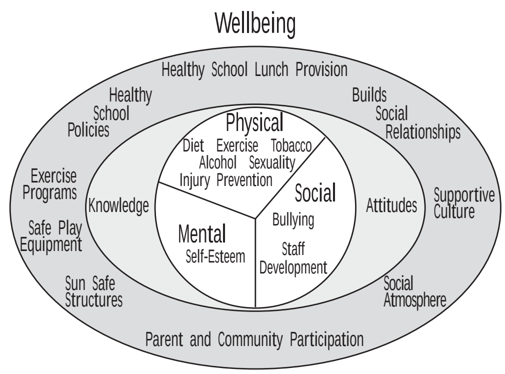


Figure 2 charts the growing evidence showing that where school health interventions recognise a health promoting schools approach, there has been a subsequent positive impact on the wellbeing of young people. It maps, as examples, some of the needs-based issues that have been considered within the three components of the HPS. It is recognised that for each issue, program planning and evaluation is required to incorporate and address the particular combination of elements needed to contribute to the desired outcomes.

For clarity of representation, evidence for specific health issues in the centre circle has been divided into three dimensions of health and wellbeing - mental, physical and social. Also included in the model, is evidence of the personal and the broader social and physical environmental factors that influence wellbeing. These are shown in the outer two circles

Starting in the centre under the physical wellbeing component, the health promoting schools approach has been shown to be effective, for example, in improving dietary behaviour and exercise habits and preventing injuries (Arbeit et al. 1992; Lister-Sharp et al. 1999; Luepker et al. 1996; Plotnikoff, Williams & Higginbottom 1996; Sobczyk et al. 1995). In this area it has also been shown to be effective in reducing tobacco (Moon et al. 1999, Jamison et al. 1998) and alcohol use (Jamison et al. 1998) and unsafe sexual practices (St Ledger 1999) which have typically been very difficult to influence. However, it must be noted here that results in these areas have only been found when a comprehensive approach that utilises the three components of the HPS framework was used.

Under the last two components, mental and social wellbeing, there is some evidence that suggests the health promoting schools approach enhances student self-esteem (Jamison et al. 1998) and improves social wellbeing by reducing bullying and supporting staff development (Jamison et al. 1998, McBride & Midford 1999, Lister-Sharp et al. 1999).

As shown in the middle circle, the approach has had favourable effects on skills, attitudes and knowledge. Specifically, this has been shown to include students' knowledge and attitudes about nutrition (Luepker et al. 1996; Sobczyk et al. 1995), food-selection skills (Luepker et al. 1996), and knowledge about safe sex, disease prevention and substance use (Jamison et al. 1998, Sobczyk et al. 1995).

In the broader school environment, the outer circle, the health promoting schools approach provides a framework which can assist in the implementation of health policies in schools (McBride & Midford 1999, Smith et al. 1992, Tudor-Smith et al. 1997). The approach has been shown to have an impact on the physical environment of the school, for example, through the provision of healthy school lunches, healthy tuckshops, exercise programs, together with the construction of safer playground equipment, comprehensive sun safety programs and sunshade structures. Although there has also been inconsistent evidence, with some studies identifying no change, for example, research on the Wessex Healthy Schools Award Schemes using a quasi-experimental evaluation found no change in level of physical activity or healthy food choices (Moon et al. 1999), there appear to be many promising benefits of the HPS approach.

Using the HPS approach can result in changes to the school's social environment and atmosphere which is thought to develop a more supportive culture for staff and students and to build social relationships (Turenen et al. 1999). It also increases parent and broad community support for promoting the health of young people (Jamison et al. 1998, McBride & Midford 1999, McIntyre et al. 1996).

Evidence from Queensland

Evidence emerging from research projects conducted by the Health Promoting Schools research group at the School of Public Health, Queensland University of Technology, supports and confirms the international trends noted above. Three research projects, each investigating use of the health promoting schools framework for evaluation purposes are currently under way. Each project revolves around a specifically articulated and planned HPS initiative and, while they will be reviewed in future articles in more detail when completed, the following vignettes provide early indications that the process of implementation and the impact of the HPS initiative are satisfying the stated objectives.

Community renewal and school connectedness

This project, located in the socio-economically disadvantaged western suburbs of Brisbane, Queensland, investigates the significance of the relationship between school and young people, and the extent to which young people feel that they belong to the school. The notion of 'school connectedness' has been shown to be a protective factor for emotional health, the reduction of violence and substance abuse and promotion of healthy sexuality for adolescents (Hawkins et al. 1999; Resnick et al. 1997).

Using a health promoting schools framework, 10 primary and secondary schools have been funded over a three-year period to plan and implement projects that aim to improve participation and connectedness between the various members of the school community, and thereby promote better health and wellbeing. The program is being evaluated using a qualitative multiple case study research design, examining the implementation of the health promoting schools approach and the impact on school connectedness in three schools: a secondary school, a primary school and a special school.

School connectedness in this study has been examined through the concept of social capital defined as 'social relations of mutual benefit, characterised by norms of trust and reciprocity' (Winter 2000). Aspects of social capital including trust, mutual reciprocity, tolerance of diversity, value of life, and participation (Onyx & Bullen 2000), as well as other ecological indicators, such as bullying and truancy, have been used as indicators of school connectedness.

Preliminary evidence from focus group and in-depth interviewing (Rowe 2000) indicates that school community members' perceptions and ecological indicators of school connectedness can be attributed to the key components of the HPS approach. In terms of the school ethos, for example, evidence from in-depth interviews with key stakeholders indicates that cultural awareness policies have been identified as having a positive impact on tolerance of diversity, which is a significant contributor to school connectedness. Other policies have been developed and implemented as a result of the project, such as the security and safety procedures implemented in the school. As indicators of school connectedness, the evidence indicates that such policies appear to have had a favourable effect on feelings of trust and safety. Peer support or tutoring programs have been introduced and positive results have been commented on in such areas as students helping other students; students intervening for others being bullied; and students from different grades being friends with each other. Such developments, as indicators, can contribute to evidence supportive of the notion of school connectedness as a key issue.

In formal health education curriculum terms, the schools have encouraged and facilitated experiential learning activities such as school excursions, food preparation activities and cultural activities. Evidence from a variety of stakeholders, including the students, indicates that this has contributed to students' feelings of being valued as well as enhancing their participation in school activities.

In terms of partnerships with the broader school community, experiences within the project where 'whole school' and 'whole class' HPS activities have taken place have been commented on as increasing the sense of belonging and being committed to the welfare of the school and those associated with it. For example, where students, school staff, parents, carers, and the broader community have worked together evidence indicates that this has provided opportunities where members of the school community are mutually supportive and do things for each other. In one case, a health promoting school activity has demonstrably developed friendships between students and improved tolerance of diversity among students of differing abilities.

Another important finding at this stage in the research relates to the size of the school. The smaller the school, the more people know each other and the more people trust each other.

The school-based youth health nurse (SBYHN) program

The school-based youth health nurse (SBYHN) program involves the evaluation of a statewide secondary school nurse program that has been developed within an HPS framework and is designed to address broad issues affecting the health and wellbeing of young people. Rather than take a more clinical orientation, the nurse's role is to address individual, group and community health issues to improve health outcomes for young people, through the implementation of a primary health and HPS framework. With training in the HPS approach, nurses within the SBYHN program are encouraged to increase the capacity of schools to develop structures and environments that enable and reinforce the young person's ability to maintain health and wellbeing throughout the lifespan. This is the first attempt in Queensland to provide a health service intervention that not only adopts a social view of health, but also consciously works in a collaborative manner within the school to address health holistically through the three HPS components.

After an in-service training program that develops the awareness and understanding of core HPS concepts, nurses are allocated to clusters of state secondary schools. The research project is designed to identify what these nurses have been doing which specifically reflects their training and understanding of the HPS approach. It also assesses the extent to which their activities have contributed to the development of a whole school approach to promoting health, broadly defined, and explores what has facilitated and what has inhibited the implementation of the HPS approach within their cluster of schools.

The research is comprised of three phases. Phase 1 involves selection and development of appropriate indicators and measures. Phase 2 involves comparing and contrasting baseline level differences in the current health status of school communities between school communities without a school nurse and schools who have had a nurse for one year. Finally, the use of the HPS approach within the SBYHN program is investigated within Phase 3 to identify the nurse's implementation of the HPS approach, barriers and enablers to implementation, and the difficulties associated with implementing the three components of the HPS approach.

Evidence is available from an initial survey administered to nurses who have been working in schools for varying lengths of time (ranging from a few months to two years), to establish their expectations with regard to the extent of their influence and to provide examples of how they are currently impacting on these areas. These data indicate that nurses feel that they can have an influence on many of the health issues encompassed within a holistic view of health and the three HPS components (Carlsson 2000).

Health knowledge, behaviour, attitudes and health-related skills (e.g., resiliency, coping, decision making, and problem solving) were unanimously considered by the nurses surveyed to be factors that they could influence and expect to change. Extensive agreement among nurses was also found regarding their perceptions of their ability to make positive changes to the physical and social school environment. The majority of school nurses believed that they had the ability to increase the number of partnerships, and for some, increase participation within the school community.

Not surprisingly, teaching practices and curriculum content were considered the most difficult to influence by these school-based health workers. However, a school's use of, and commitment to, the HPS approach was an area on which school nurses thought they could be expected to have an impact. This suggests that while teachers, principals, students, and their families are clearly critical in regard to decision making about the development and support of the HPS approach, school communities might also be amenable to the influence of opinion leaders. For example, health service practitioners using processes that follow the principles of the HPS approach, such as creating partnerships and addressing needs holistically, could be important.

Although the impact of nurses has not yet been measured and the sample size in this survey was limited, qualitative data from the sample indicate that nurses were able to provide example activities that they thought had made a change to the health of individuals and the school community. The nurses themselves felt that the settings-based health intervention and their role within the HPS framework can produce a change in health. These preliminary results indicate that a health service can successfully utilise the HPS approach and interact within the education sector to produce positive health results for individuals and the school community. Further research is planned to assess the extent to which the nurses continue to work within the HPS framework and the effectiveness of the HPS approach.

A health promoting schools approach to insect infestation

The burden on school communities as a result of head lice infestation is significant in social and emotional terms, through the stigma associated with head lice. It is also important in terms of finance, through the costs of purchasing products to eliminate lice, as well as lost school and work time when dealing with the issue. Typically, the problem of head lice infestation has been responded to within a victim-blaming perspective, which can include formal exclusion from the school, and in the informal classroom and playground situation by fairly insensitive and cruel negative stereotyping.

The project researches an alternative way of dealing with the problem by focusing on the capacity of a school community as a whole to control head lice; specifically using an HPS approach to plan and implement the intervention. It involves an investigation of the effectiveness of different components of a multi-faceted, comprehensive head lice control project introduced into over 40 primary schools in the southern suburbs of Brisbane. It involves an evaluation of the capacity of a school community as a whole to control head lice and which components contribute most significantly to this control.

The Head Lice in Schools Pilot Project was initiated in response to community concerns about head lice in the Brisbane South area. From this concern, a plan was developed to try and deal with the problem from a holistic perspective rather than relying solely on medicated head lice treatments or other categorical initiatives. Key individuals in the school and local communities were invited to have input into the development of the project and an HPS approach was adopted. Implementation of the project required groups in the school communities to collaborate and interact with each other and local community agencies and organisations, while the Queensland Health project team provided support through resources and training. The research project involved developing and implementing an evaluation with a sound theoretical base that reflected and accounted for the complexity of the project, and was sensitive to the different perspectives within and across the stakeholder groups.

A qualitative approach, consisting of a series of case studies involving key stakeholder groups in four school communities selected for their strong involvement in the project, was carried out. The data collection instruments, a series of semi-structured focus group and individual interviews, were designed on the basis of the objectives and strategies of the Head Lice in Schools Project. Data analysis was carried out through content analysis, which was achieved by identifying themes into which common and discrepant significant statements by the stakeholders were grouped. These were synthesised and analysed for final conclusions.

Preliminary evidence (Shuter 2001) evaluating the impact of the various components and strategies of the program indicates that the project has achieved a positive impact on the capacity of school communities involved in the project to control and self manage head lice. Some significant specific issues, which impacted on the project, such as training and participant involvement, were highlighted through this approach to evaluation.

Conclusion

Each of the projects described briefly above will be the subject of articles in their own right, but have been included here as preliminary results indicate broad support for international evidence. These three projects are concerned with a wide range of issues, from mental and emotional health (school connectedness), through the role of health service providers (school-based youth health nurses) as initiators and supporters of a holistic, primary health approach to school health promotion, to head lice infestation.

In summary, there is growing evidence that the HPS approach encourages youth wellness both in Australia and internationally. Research is consistently showing that the more comprehensive the approach, the more effective the outcomes for youth health and wellbeing. This paper provides an insight into how complex qualitative and quantitative evaluation underpinned by a sound theoretical framework is able to identify issues that impact on comprehensive and complex health promoting schools projects.

As schools implement the HPS approach more comprehensively by integrating all three of the HPS components, evaluation is needed to continue to demonstrate the effectiveness of the HPS approach. It is recommended that schools planning to utilise the HPS framework should ensure that health issues are addressed collaboratively and across all three, integrated components of the HPS approach in a socio-ecological manner to ensure the maximum benefits are received. Evaluating health promoting school projects is essential for ensuring successful outcomes and that efficient use of resources, but it is also difficult due to the multi-faceted and complex nature of such projects. This paper illustrates that there is good evidence to show that a whole school environment framework is effective for improving the health and wellbeing of young people and school communities in general.

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Dru Carlsson, Fiona Rowe and Donald Stewart
School of Public Health
Queensland University of Technology
Kelvin Grove Campus
Victoria Park Rd
Brisbane, Queensland, 4059
AUSTRALIA
Email de.stewart@qut.edu.au

Correspondence to Donald Stewart

Domestic Drinking Water in Rural Areas: Are Water Tanks on Farms a Health Hazard?

Glenda Verrinder[1] and Helen Keleher[2]

Department of Public Health, La Trobe University, Bendigo[1], and School of Health Sciences, Deakin University, Burwood[2]

The aim of the research was to gain a better understanding of the relationship between drinking water quality, householders' knowledge and maintenance practices of private water supplies and drinking water-related public health risk on farms. Samples of drinking water were taken from 100 farming households. The Colilert-18 method was used for the detection of total coliforms and Escherichia coli (E. coli) *as indicators of water quality. Each household completed a questionnaire about their knowledge and practices relating to a safe water supply. Coliforms were present in 52 water samples and* E. coli *was present in 38. Seven households reported minor illnesses in the previous three months and two households reported gastroenteritis. Some tank maintenance occurred in 86 households, but tank maintenance activities varied considerably. Four of the households had published guidelines on water quality. None of the participating households had their drinking water tested regularly. There was no obvious relationship between drinking water quality, householder knowledge, maintenance practices and drinking water-related health risk on farms.*

Key Words: *Public Health, Rural Health, Water Quality, Rainwater Tanks, Private Water Supplies*

Rainwater tanks are installed on farms across Australia as the primary source of drinking water for rural households. It is a common belief among people living in rural areas that tank water is superior to treated reticulated water supplies. Unlike reticulated supplies in urban areas, the maintenance of the tanks to ensure the quality of the water in privately owned supplies is totally dependent on the users of the supply.

The research study was undertaken to gain a better understanding of the relationship between drinking water quality, householders' knowledge and maintenance practices of private water supplies and drinking water-related public health risk on farms. There was anecdotal evidence to suggest that tank owners did not carry out tank maintenance routinely and also that private tank water supplies on farms were much less likely to be routinely tested than reticulated water supplies. We reasoned that an initial small study might provide some useful information about the quality of the drinking water and the tank management behaviours of the householders who drink that water, as a basis for further public health research and education. The study was conducted in the Shire of Loddon in Victoria.

Monitoring and improving microbiological standards of water has been used as an important means of preventing water-borne disease. The most frequent and extensive health risk associated with drinking water is contamination by certain microorganisms contained in either human or animal faeces (National Health and Medical Research Council [NHMRC] & Agriculture and Resource Management Council of Australia and New Zealand [ARMCANZ] 1996). Drinking or preparing food with water that has been contaminated with microorganisms associated with enteric diseases provide particular risk to subgroups of the population. The very young, the very old, those whose immune systems are suppressed and those who are already sick are the most vulnerable to this health risk (NHMRC & ARMCANZ 1996).

The major microorganisms detected in water supplies in Australia can be divided into three major groups: disease causing, water pollution indicators and harmless microorganisms (NHMRC & ARMCANZ 1996). Disease causing bacterial pathogens, which present the greatest risk of disease to humans, include *Salmonella* spp, *Shigella* spp, enterovirulent *Escherichia coli*, *Vibrio cholera*, *Yersinia enterocolitica*, *Campylobacter jejuni* and *Campylobacter coli* (NHMRC & ARMCANZ 1996). The major water pollution indicators used are coliforms, thermotolerant coliforms (including *Escherichia coli* [*E. coli*]), and regrowth bacteria. Colony counts may be used to assess the general bacterial content of the water. These indicator organisms do not pose a major health risk, but their presence indicates that disease-causing organisms may also be present (NHMRC and ARMCANZ 1996). Coliforms may be present when there is no faecal contamination of the water supply, however, the presence of thermotolerant coliforms indicates faecal contamination (NHMRC & ARMCANZ 1996). Further, the absence of thermotolerant coliforms does not necessarily guarantee the absence of faecal contamination. These indicator organisms provide the best available measure of faecal contamination. The regular absence of these indicator organisms has been shown to correlate highly with the safety of drinking water (NHMRC & ARMCANZ 1996).

"When indicators provide evidence of faecal pollution in drinking water supply, this is a prima facie evidence of a health hazard" (NHMRC & ARMCANZ 1996, p. 2). Current practice for monitoring water quality usually relies on testing for total coliforms, faecal coliforms and total colony counts. *E. coli* is considered to be the best indicator of contamination partly because coliforms are easily injured through environmental factors such as heat, freezing, sunlight, and biological interactions, as well as ultraviolet radiation and disinfection (Lehloesa & Muyima 2000). Ideally, no coliforms and thermotolerant coliforms should be detected in a minimum 100mL sample of drinking water (NHMRC & ARMCANZ 1996). Monitoring for *E. coli* and coliforms is relatively easy and inexpensive whereas monitoring for specific pathogens such as *Giardia* and *Cryptosporidium* can be complex, expensive and time-consuming (Cowie & Corbett 1994; Lehloesa & Muyima 2000) and importantly, might fail to detect their presence.

The Australian Drinking Water Guidelines, and National Water Quality Management Strategy (NHMRC & ARMCANZ 1996) provide water authorities in Australia with the frameworks for practice and water quality standards. There are also regulations and guidelines within each state and territory. In addition, some water authorities have customer charters where the supply and standard of water to the customer is promised by that authority (Coliban Water undated).

Method

A small study was designed to assess whether there was any suggestion of a relationship between the quality of rainwater, householder knowledge, practices of water supply maintenance, and illness. There were two aspects to the study: (i) microbiological testing of water samples to ascertain levels of microorganisms in private rainwater tanks on farms, and (ii) an administered questionnaire to inquire about levels of illness, tank maintenance behaviours and householders' knowledge of safe water quality. Farms were selected from a particular geographical area over a three-week period in the spring of 1998. The weather pattern was relatively stable. Householders were selected, farm-to-farm and asked if they were willing to participate in the study.

One hundred-ml samples were taken from 100 farm households and were tested for the presence of coliforms and *E. coli*. The sample was taken from the point of use, that is, the tap used most commonly by the household for its drinking water. All care was taken to ensure that contamination of the sample did not occur after leaving the tap. The samples were transported to the laboratory in sterile containers within a thermally insulated container with an ice pack installed. The water samples were delivered for testing on a daily basis to the Centre for Biotechnology Research at La Trobe University, Bendigo. The Colilert-18 method was used because it is a reliable, quick and relatively inexpensive method for detecting these water pollution indicators (Eckner 1998). Following testing, 12 households were retested with samples taken from both the kitchen tap and directly from the tank supply because of considerable contamination in the samples. At the end of the three-week sampling period, householders were sent their results together with information about how to ensure safer drinking water in private supplies.

A questionnaire was administered during the water sampling phase to find out about the type and age of the tank, whether tanks were above or below ground, sources of the water, and also to assess each householder's knowledge and behaviours associated with tank maintenance and water quality monitoring. The questionnaire also inquired into common illnesses experienced in that household in the previous three months.

Results

Microbiological testing

Of the initial 100 tests, 52 showed the presence of coliforms and 38 showed the presence of *E. coli* as well. Table 1 demonstrates the range of coliforms and *E. coli* present in the tap water sample.

Table 1: range of coliforms and* E. coli *numbers in tanks

n = 100	<20	21-99	> 100	Total
Coliforms per 100ml.	32	15	5	52
E.coli per 100ml	32	5	1	38

Two samples had readings that exceeded the limits of the test score capabilities (200 coliforms/100ml). There was a considerable amount of contamination in twelve samples including the two with excessive readings. We decided to sample and test these 12 again to determine whether the contamination detected was present in the tank, or whether there were problems in the plumbing between the tank and the source tap. Eleven of the 12 households were available for a retest. Two of these drew their water directly from the tap on the tank. For the other nine, samples were taken from both the point of source tap and directly from the tank. Retesting was done within the three-week sampling period for the whole study. In two household supplies, water sampled directly from the tank was contaminated but the water from the household tap was not. At one test site water sampled from the household tap only was contaminated and in five household supplies there was contaminated water detected at both the tank and at the household tap. In three of the 12 supplies the second sample and test showed that the water was completely free of contamination including one of the direct-draw tanks, after showing levels of 62/13 (coliform/*E. coli*), 110/1 and 130/78 respectively.

Questionnaire Results

Illness

Householders were asked about any illnesses experienced by family or visitors in the previous three months. Seven individuals reported illness within this time including two who reported gastroenteritis. Other illnesses reported were rashes, ear and throat infections and viruses. One person reported a visitor who contracted gastroenteritis. Of the two reports of gastroenteritis there was one report of gastroenteritis where indicator counts were higher than acceptable standards. In this sample the coliforms were 70 per 100ml and the *E. coli* was 9 per 100 ml. A retest of this water supply revealed both coliform and *E. coli* from the tap and the tank. Coliforms and *E. coli* were also present in some samples taken from sites where other illnesses and disorders were present.

Tank management behaviours

Four householders reported having drinking water quality guidelines from brochures published by the state government. Ninety-two of the households had never had the water tested. Some maintenance activity was reported in 86 of the households. Of these households, most cleaned the spouting and filters on spouts or gutters; some "flushed" the system and kept inlets free of leaves. One person mentioned that they released the overflow valve if rain was on the way and another checked for birds' nests. Six of the 86 reported cleaning their tanks "occasionally". Fourteen householders reported performing maintenance tasks explicitly to ensure a clean water supply. The motivation of others was to "prevent blockages" and "stop leaves and other things" getting into the tank. The methods used to clean the tanks involved high pressure hoses, brooms and towels inside the tank, bucketing or scraping out of sediment, scrubbing and washing out. Two people mentioned that they cleaned the pump itself. Most owners performed these activities themselves, but two had employed commercial cleaners.

Water collection

In 90 households, water was collected purely from roof run-off. The remaining 10 reported a mixture of roof run-off and other supplies, including river, dam and bore water and water from a reticulated system. The water from the river, dam and bore was not treated. Six households had noticed an odour in their supply, but none were able to identify the odour. Thirteen noted the presence at times of an indefinable taste and fourteen noted some colour changes that occurred predominantly after rain. Ninety-eight of households had septic systems for waste disposal but none believed that there was a possible risk of contamination of the water supply from the septic system.

Some householders (27) agreed that chemicals might affect their water supply due to drift onto the roof and into the spouting from aerial spraying. Spray drift from neighbourhood activity was blamed as often as the householder's own chemical use.

Tank age and type

Less than half (48) of the tanks were installed within the last ten years, the two oldest tanks were installed in 1948 and the two newest were installed in 1998. Ninety-eight of the tanks for the main supply were above ground tanks and two were underground. Fifty-eight of the tanks were concrete, 36 were galvanized tanks and six were made of PVC. There was no relationship between the age of the tank and the presence of coliforms or *E. coli*.

Discussion

Due to the sample size it cannot be assumed that the results are representative of the community. However, the study revealed that there were few reports of illness that could be associated with the presence of high levels of contamination of indicator organisms found in the supplies. The levels of bacterial contamination reported in this study would not be tolerated in most public drinking water supplies in Victoria. Most water authorities would issue a notice-to-boil if regular monitoring of the supply revealed results that did not meet the standard set by NHMRC guidelines. Yet, it is not unusual to find indicator organisms in private water supplies (Appan 1997; Schwartz et al. 1998) and in reticulated supplies, particularly in rural areas (Cowie & Corbett 1994). Faecal coliform pollution is mostly of bird and animal origin (Appan 1997). Animal faeces might cause disease, for example, birds are frequent carriers of salmonella. Salmonella has been found in roof runoff (Appen 1997).

There are a number of variables to consider when examining the relationship between the quality of drinking water and the potential for disease. For example, most pathogenic microorganisms of faecal origin do not survive for long outside their human or animal hosts. Therefore, storing water is recommended as a way of reducing the number and virulence of the organisms. Storing water can reduce total coliforms and thermotolerant coliforms or *E. coli* considerably. This probably means that some of the samples in this study were recently contaminated. During the collection phase the weather was relatively stable, however, there were reports of isolated patches of rain in the district that could have affected some of the samples.

Roofing material, type and condition of gutters and type of containers have also been considered important factors affecting the quality of water (Appan 1997). A limitation of this study was that roofing material was not considered, however, variables such as the age and size of the tanks did not show a relationship with high levels of contamination.

As stated previously, the concentration of the pathogenic organism is one factor to consider. It would seem reasonable to consider individual immunity, the amount of water taken, the virulence of the particular organism, and other local conditions. The level of morbidity within a family who rely on rainwater stored in tanks might be negligible particularly for healthy adults despite the indicators of faecal contamination (NHMRC & ARMCANZ 1996). Still, water is a potential source of infection. The Australian Drinking Water Guidelines (NHMRC & ARMCANZ 1996) suggest that drinking water should not contain organisms capable of causing disease and recommend various strategies to protect water sources from both human and animal faeces contamination (NHMRC & ARMCANZ 1996).

The overriding concern of householders in this study was with supply of water rather than with the quality of water. No systematic pattern could be determined when cleaning was performed or what events might prompt householders to undertake a “clean-out” of their tanks. Concerns were expressed about a variety of potential contaminators including “chook-dust on the roof”, bird droppings, cats walking on the roof, possums in the tank and the build-up of slime in the tank. Yet the person who said their water was “200% better than town water” had a coliform reading of 50/100ml and another who said it “wouldn’t get much better, surprised if unhealthy” had a reading of 70/100ml coliforms and 9/100ml *E. coli*. Another whose retest showed 165/100ml coliforms in the tank was concerned about chemicals. And despite a reading >200/100ml coliforms and 145/100ml *E.coli*, one householder thought that the water was “pretty good”. These results are similar to other studies such as Schwartz et al. (1998) who found that while 82% of participants were satisfied with their water supply, 31% had coliforms. They also found that half the participants did not test their water. Householders in our study were positive about testing and were interested in the results. Ninety-six agreed to a follow-up test if they were offered one.

Exceeding the numerical guidelines for the microbiological content might not necessarily be a threat to the health of the public. Still, water-borne diseases remain a potential threat to public health. Four households in this study had a copy of drinking water guidelines. Better and wider distribution of these guidelines would seem reasonable.

Conclusion

Water stored in tanks from roof runoff does not necessarily provide householders with a safe drinking water supply by current standards. However, there seems to be no obvious relationship between drinking water quality, householder knowledge of private water supply maintenance practices, and drinking water-related health risk on farms. This does not mean that contaminated water is not a health hazard.

The consumption of rainwater is widespread, particularly in rural areas. There appears to be a relatively high level of self-assurance regarding the safety of private drinking water supplies despite the fact that many people do not actively protect their supply. Rainwater is popular because of its palatability and an immune response is possible. While better tank maintenance would seem to be a sensible measure and could improve water quality, there may be no benefit to the public's health.

Regular treatment and testing is required for all reticulated systems to make sure the quality of the water is safe for public consumption. This is a basic public health measure. Logically, the same needs to apply to private supplies, however, this is a moot point given the current evidence. Perhaps the development and introduction of simple, inexpensive testing methods for householders to test their own supply is needed.

Further research on a national basis taking into consideration rainfall patterns and the variation in indicator organisms over time seems warranted. Research into water storage, particularly after extracting water from the source of use may provide us with a better picture for health risk assessment.

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Glenda Verrinder
Department of Public Health
La Trobe University Bendigo
PO Box 199
Bendigo, Victoria, 3552
AUSTRALIA
Email g.verrinder@bendigo.latrobe.edu.au

Correspondence to Glenda Verrinder

Assessing the Microbial Health Risks of Tank Rainwater Used for Drinking Water

Greg Simmons[1], Jane Heyworth[2] and Miroslava Rimajova[2]

Public Health Protection, Auckland District Health Board[1], and Department of Public Health, The University of Western Australia[2]

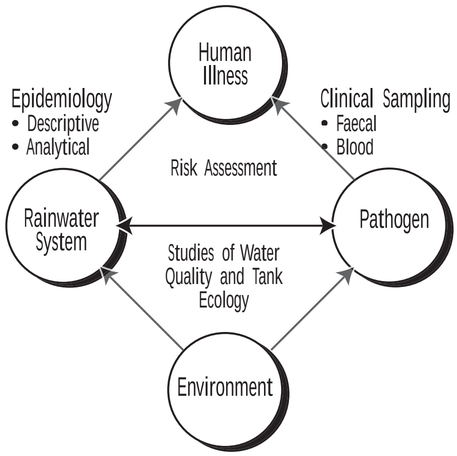
The health risks associated with tank rainwater consumption are not well defined. The paper provides a framework for considering the health impacts of rainwater with microbial contamination using an epidemiological approach but encompassing risk assessment as a central theme. The issues that need to be addressed in a microbial risk assessment (MRA) are identified. These include, for example, the numbers of pathogens in tank rainwater; their ability to survive and multiply; the extent of individual exposure; and the measurement of health outcomes. The usefulness of the various epidemiological study designs as tools to estimate the risk of illness from rainwater exposure are discussed. The MRA framework enables a systematic estimation of health risk as a consequence of consumption of contaminated potable tank rainwater and has important implications for the setting of microbial standards for potable rainwater.

Key Words: *Tank Rainwater, Microbial Contamination, Microbial Risk Assessment*

Rainwater collection systems in less developed countries might provide potable water of higher quality and less risk to health than alternative sources. However, in developed countries such as Australia and New Zealand, consumption of tank rainwater of potentially lower microbial quality than alternative mains supply, is often a matter of choice. In South Australia, for example, 42% of households use tank rainwater as their main potable source compared with 40% who use the public mains supply (Heyworth, Maynard & Cunliffe 1998). A number of pathogenic species have been identified in tank rainwater. Microbiological surveys have found *Clostridium perfringens*, *Salmonella* spp. (Fujioka, Inserra & Chinn 1991), *Salmonella typhimurium* (Simmons et al. 2001), *Cryptosporidium* spp. (Crabtree et al. 1996; Simmons et al. 2001), *Giardia* spp. (Crabtree et al. 1996), *Legionella* spp. (Broadhead et al. 1988), *Aeromonas* spp. (Simmons et al 2001), Hepatitis A virus (Luksamijarulkul, Pumsuwan & Pungchitton 1994), *Pseudomonas* spp. (Waller et al. 1984), and *Shigella* spp. (Canoy & Knudsen 1983), as contaminants of rainwater. Further, untreated rainwater may be a potential source of infection for pathogens such as *Campylobacter* spp. (Merritt, Miles & Bates 1999). However, the degree of contamination and the implications for health have not, to date, been quantified. Therefore, given the high level of consumption of tank rainwater, microbial contamination of this water source is a potentially important public health issue.

Figure 1 provides a framework for relating roof water consumption to the development of illness. Central to this framework is microbial risk assessment (MRA), which provides a systematic evidence-based approach to quantifying risk. The framework can be used at a number of levels, from individual cases to whole communities, and for different uses of collected rainwater, in assessing the importance of rainwater consumption in the

Figure 1: A Model for investigating microbial health impacts of rainwater



development of infectious disease. Referring to Figure 1, epidemiological analysis, either at a descriptive level or using an in-depth analytical study, can be used to assess an association or causal link between tank rainwater exposure and risk of illness. Clinical sampling of cases for blood or faeces can identify the pathogen causing illness. Site investigations of implicated rainwater systems can identify and enumerate the pathogen in the tank rainwater. These elements of the investigation can be interpreted in the light of pathogen prevalence surveys and existing data on infectious dose and level of exposure. MRA, involving clinical sampling, consideration of tank ecology and sanitary and water quality surveys, has a central role in estimating the nature and magnitude of the risk posed by the consumption of tank rainwater. In this paper the particular issues that need to be addressed in a risk assessment of tank rainwater are identified and the key role of epidemiology within this framework is outlined.

Microbial Risk Assessment

The purpose of the risk assessment approach is to determine the nature and magnitude of a risk caused by a hazard. This approach has been used widely to assess the public health implications of exposure to hazardous substances, in particular chemical hazards (De Rosa et al. 1998). The advantages of the risk assessment approach are that it provides a consistent and systematic approach to determining the magnitude of risk, and it is also a transparent approach to decision making.

There has been widespread agreement that a risk assessment approach is needed for assessing microbiological hazards (Advisory Committee on Dangerous Pathogens 1996; Haas, Rose & Gerba 1999; ILSI Risk Science Institute 1996; Jaykus 1996). The models for microbiological risk assessment (MRA) generally have been based upon the chemical risk assessment approach, but have been expanded or modified to address some of the unique features associated with microbiological contamination. For example, these include the potential for secondary transmission, the acquirement of short or long term immunity and the potential for rapid change in microbial population numbers (Gibson, Haas & Rose 1998; ILSI Risk Science Institute 1996).

The chemical risk assessment model as described by the National Research Council (1983) is used as a basis for a microbial risk assessment of tank rainwater. It comprises four steps: hazard identification; exposure assessment; dose-response estimation; and risk characterisation. The issues specifically related to a microbial risk assessment of tank rainwater are summarised in Table 1.

Step 1: Hazard identification

Hazard identification refers to the identification of the microbial contaminants likely to occur in tank rainwater, their sources and determining whether or not these microorganisms are causally linked to adverse health outcomes. Where water is gathered from a roof catchment, animals or birds that inhabit or traverse the roof might be the main sources of contamination (Lye 1992; Merritt, Miles & Bates 1999). If underground tanks are used, there is also the potential for microbial contamination from agricultural run-off or seepage from waste disposal systems. The question that follows is whether these organisms are pathogenic and to what extent they are able to survive and multiply within the tank environment. Pathogen prevalence surveys are limited by providing only a snapshot assessment in time and significant, but transient, contamination might go undetected. In addition to temporal differences in contamination, pathogens are likely to differ by region, depending on the occurrence of the contaminating source and the environmental influences affecting pathogen survival. The idiosyncratic nature of environmental influences on tank rainwater in any one geographical locality also limit the degree to which survey findings can be generalised to other regions. Moreover, valid techniques to identify viral pathogens have until recently, been lacking. Where methods for the detection of pathogens are available, poor sensitivity might underestimate the true level of contamination.

Case studies reporting the investigation of illness in individual cases have provided data linking adverse health effects to tank rainwater. Illnesses linked to contaminated rainwater supplies by case studies include campylobacteriosis (Brodribb Webster & Farrell 1995; Merritt, Miles & Bates 1999), legionellosis (Back, Schvarcz & Kallings 1983), yersiniosis (Cafferkey et al. 1993) and botulism (Murrell & Stewart 1983). However, individual case investigation by sampling implicated rainwater systems is problematic because there is usually a prolonged period between infection and sampling. The time period between exposure to contaminated water, the onset of illness and subsequent medical diagnosis, is likely to be a number of days. During this time pathogen die-off may have occurred and the rainwater system incorrectly vindicated as the source of infection. Another disadvantage of the individual case study is its limited ability to make inferences about causality. In order to do this, epidemiological data involving a number of linked cases need to be assessed. To this end, the investigation of outbreaks of illness involving a number of cases may support a link between illness and tank rainwater exposure (Merritt, Miles & Bates 1999). Evidence supporting tank water borne salmonellosis has come from the investigation of a 63-case outbreak in Trinidad in 1976 (Koplan et al. 1978) and a small outbreak in Auckland in 1996 (Simmons & Smith 1997). However, outbreaks are notoriously under-reported and sporadic illness involving a single case is precluded from such investigation. In Australia and New Zealand, while the use of tank rainwater is extensive, each rainwater system supplies only a few persons. A survey of 125 domestic tank rainwater supplies in Auckland in 1996-98 found the mean number of tank rainwater users to be only 2.9 persons per supply (Simmons, Hope & Lewis 1997). Given the possible immunity in a proportion of those exposed, coupled with asymptomatic infection in others, contaminated tank rainwater is more likely to manifest as a source of sporadic illness.

Step 2: Exposure assessment

Exposure assessment is a function of both the extent to which tank rainwater is contaminated, and the level and mode of exposure. The water, consumer and environment-related factors affecting exposure are outlined in Table 1. The degree of tank rainwater contamination will be influenced by determinants such as water pH, temperature, competing microflora and disinfection processes. Also, the distribution of microorganisms within rainwater tanks may be heterogeneous, adding to the difficulty of determining levels of exposure. Microorganisms may accumulate in sediment and be resuspended after rainfall. Consumption of tank rainwater may vary by age and level of activity. But while ingestion of tank rainwater is likely to be the main mode of exposure, inhalation may be a more effective route of infection by some pathogens such as *Legionella* spp.

***Table 1:* Key questions in the MRA of potable tank rainwater**

HAZARD IDENTIFICATION	
1.	Which birds and animals traverse roofs?
2.	What organisms are carried by these birds and animals?
3.	What is the potential for other contamination, such as agricultural run-off?
4.	To what extent can the organisms survive and grow on the roof, or in tank water and sediment?
5.	What factors affect this survival e.g. solar radiation, oxygen and nutrients?
6.	What is the effect of the tank environment on the pathogenic potential of contaminants?
7.	Are the organisms pathogenic to humans?
8.	What short and long term health outcomes are expected?
9.	Are there at-risk populations?
EXPOSURE ASSESSMENT	
WATER	
1.	What is the extent and distribution of contamination?
2.	Are tanks topped up with water from other sources such as bore or stream?
CONSUMER	
3.	What is the tank rainwater used for (e.g. drinking, toilet flushing, showering)?
4.	Who consumes tank rainwater?
5.	How much is consumed and how often?
6.	Does consumption vary by age or area of residence?
7.	For how long has tank rainwater been consumed?
8.	What are the important routes of exposure - inhalation, ingestion or skin contact?
ENVIRONMENT	
9.	Do animals and birds or the organisms carried by them vary by geographic region?
10.	Do local environmental conditions influence pathogen carriage (e.g. proximity to landfill sites)?
11.	How long do pathogens survive under different environmental conditions (e.g. summer versus winter)?
12.	What is the effect of rainfall and cleaning on level of contamination in tank rainwater?
13.	Do the design and maintenance of the catchment area and the tank rainwater affect levels of contamination?
14.	What factors lead to re-suspension of organisms from the sediment?
15.	Is the tank rainwater treated at any stage (e.g. by filtering or boiling)?
DOSE-RESPONSE	
1.	What is the infective dose, rate of infection and incubation period for each pathogen?
2.	What are the virulence factors associated with the pathogens of concern?
3.	Is there evidence of development of immune response with previous acute or chronic exposure?
4.	How does the response differ within high-risk groups?
RISK CHARACTERISATION	
1.	What is the absolute risk of illness (in a given period of time) or relative risk for tank rainwater compared to non-consumers?
2.	What is the precision of this estimate?
3.	Is a sensitivity analysis warranted given that a number of assumptions are likely to have been made?
4.	What alternative sources of water are available? What is the chemical, microbiological, aesthetic quality of these sources?
5.	Is the risk acceptable to the exposed community?

Step 3: Dose-response assessment

The dose-response step describes the relationship between the dose of the pathogen and the magnitude of the adverse health effect. There are three factors important in determining the response: the amount of infective agent or bacterial toxin consumed from tank rainwater; the infectivity and pathogenicity of the infectious agent; and the vulnerability of the host. The response within the host population will vary across a spectrum of infection without symptoms to severe illness or death and so, the health outcome of interest must be carefully defined.

Step 4: Risk characterisation

This step synthesises the first three to provide an estimate of the risk of the adverse health outcome. This is accompanied by an acknowledgment, and also a description, of the assumptions made, the uncertainty of this estimate and variability in the data on which it is based. When quantitative data are available, mathematical models, such as Monte Carlo simulation models (Eisenberg et al. 1996; Haas, Rose & Gerba 1999), are used to estimate the distribution of a derived risk estimate.

There are significant gaps in the data on which MRA is performed. These include uncertainty relating to the prevalence and survival of pathogens in tank rainwater and the absence of dose-response data for a number of pathogens. Nevertheless, the systematic application of MRA will assist to identify and target these gaps with future research.

Epidemiological Investigation

Epidemiology is the study of the distribution and determinants of disease in human populations (Last 1995) and is an essential tool to the risk assessment process. A number of epidemiological study designs can provide evidence for a causal link between exposure to potable rainwater and illness, and thus contribute to the assessment of microbial health impacts of rainwater consumption. A schema has been proposed for ranking the strength of association between exposure to water and outbreaks of illness (Tillett, De Louvois & Wall 1998). There are three main types of epidemiological study design that assist MRA: descriptive, analytical and experimental designs.

Descriptive or cross-sectional studies are useful in describing the distribution of disease within a population and factors associated with its presence or absence. They also can provide useful population data on levels and modes of tank rainwater use. A cross-sectional study usually takes the form of a sample, preferably random, from a population in which current consumption of rainwater and prevalence of illness are measured using standardised questions. These studies are useful as a first step in identifying whether rainwater consumption might be associated with illness. However, because exposure and outcome are measured concurrently, it is not possible to draw conclusions regarding causality.

Analytical studies using case-control and longitudinal cohort methods provide stronger evidence for causality. In the case-control study, cases with a defined illness are assessed regarding past exposures relevant to their illness, with the same information recorded for controls, that is individuals similar to the cases but without illness. The risk of illness (odds ratio) can then be calculated for rainwater consumption. The New Zealand MAGIC study (Eberhart-Phillips et al. 1997) is an example of a case-control study in which consumption of tank rainwater was associated with a three-fold greater risk of campylobacteriosis than that of non-consumers. An estimated 2% of campylobacteriosis in New Zealand was likely to be explained by the consumption of rainwater.

Case-control studies have the advantages of being able to investigate rare illnesses, and are relatively cheap and rapid. One disadvantage is that this study type is prone to recall bias. Cases might have thought more about possible exposures and be more likely to remember having consumed rainwater than members of the control group.

Prospective cohort studies have the important advantage of establishing the correct time relationship of events. A group of well people chosen on the basis of their exposure to tank rainwater, are followed for a period of time, with the purpose of documenting the onset of illness. Such a cohort study of 1000 children aged 4-5 years has been undertaken in South Australia and the analysis of these data are near completion (Heyworth pers. comm. August 2001). Serial sampling of rainwater systems can also be related to the degree of illness. In a group followed closely during a cohort study, it should be possible in many cases to confirm the presence of a pathogen by clinical sampling at the time of illness and to correlate this with the findings of concurrent rainwater system sampling. The main difficulties with this approach are that such studies are of long duration and are expensive. Their advantage is that they provide stronger evidence of a causative link between tank rainwater exposure and illness.

In experimental studies using randomised controlled trials, persons or households are randomised to some form of intervention and the incidence of illness is compared with those allocated for no intervention. This type of study has been used to assess the impact of public supply water on gastrointestinal illness (Hellard et al. 2001; Payment et al. 1991). It would be possible, though expensive, to undertake a similar study of tank rainwater.

The key issues to be addressed in any epidemiological study are the assessment of disease, the assessment of exposure, control of confounding or bias and random error. An appropriate sample size will reduce the impact of random error. While randomised controlled trials allow better control of confounding, there are many important risk factors for gastroenteritis. Teasing out the particular effect of tank rainwater is made more difficult by the potential for confounding. This is particularly so in rural areas where tank rainwater exposure is associated with farming and animal contact where there is potential for direct or indirect zoonotic transmission of disease. Also it is important to be able to assess the spectrum of gastrointestinal illness from mild and self-limiting to severe illness requiring hospitalisation. One approach is to rely on self-reporting of gastrointestinal illness but this is then dependent upon the subjective interpretation of gastrointestinal symptoms by respondents. On the other hand, case-control studies that rely on laboratory or medical practitioner-based notification for the selection of cases may limit the study to more severe cases only. Exposure assessment is again reliant on self-reporting of tank rainwater consumption. Because individuals may have several sources of potable water, it might be very difficult to classify accurately their exposure to potable water. In addition, measures of exposure may not take into account differences in the individual level of consumption.

Conclusion

This paper has identified a number of issues relevant to the MRA of tank rainwater. Although there are still significant gaps, data are becoming available to allow risk assessment of increasing complexity. In Table 1 we have identified the breadth of data required to undertake a MRA of tank rainwater. Many of these data are available and MRA provides a systematic approach to drawing it together in order to provide an estimate of risk associated with tank rainwater exposure. Ultimately, MRA will enable evidence-based decision making to develop microbiological standards for tank water quality and for the accurate communication of risk to consumers of potable tank water. As the World Health Organization intends to include guidance on the quality and storage of collected rainwater as a source of drinking water in the update of the Drinking Water Quality Guidelines scheduled for 2003 (Heijnen 2001), a MRA of tank rainwater would be timely.

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Correspondence to:
Jane Heyworth
Department of Public Health
The University of Western Australia
35 Stirling Highway
Crawley, 6009, Western Australia
AUSTRALIA
Email heyworth@dph.uwa.edu.au

The Potential Health Effects of Pool Chemicals and Disinfection By-products

Stuart J. McLaren[1], Jacques Rousseau[1], Michael Coleman[1], Philip Weinstein[2] and David Harding[3]

Institute of Food, Nutrition and Human Health, Massey University, Wellington Campus[1], Department of Public Health, Wellington School of Medicine, University of Otago[2] and Institute of Fundamental Sciences, Massey University, Palmerston North[3]

Concern has been developing over the chemical determinants of health significance associated with chlorination of pools, such as chloramines and trihalomethanes (THMs). Dermal absorption has been identified as a significant exposure pathway for THMs as well as inhalation and ingestion. Competitive swimming and training are examples of THM uptakes as high as seven times those that occur during rest periods in pool environments. Two of the four THM species are classified as possible carcinogens and numerous studies have been conducted to investigate possible associations to THM exposure from chlorinated drinking water and cancers of various sites. Such information on THM exposure from chlorinated swimming pool water is limited. An association has been suggested between an increased risk of first trimester miscarriages and consumption of drinking water with elevated levels of THM. Volatile components have been implicated as trigger agents for exercise-induced asthma (EIA). Cancers associated with exposure to chlorinated swimming pool water have been discussed. In 1995, 329 deaths in New Zealand were estimated as potentially attributable to exposure to chlorinated water with 108 deaths possibly due to chlorinated bathing water.

Key Words: *Trihalomethanes (THMs), Disinfection By-products (DBPs), Swimming Pools, Exposure, Treatment.*

Malcolm, Weinstein and Woodward (1999) outlined the potential health impact of chlorination disinfection by-products (DBPs) in drinking water. They indicated that we pay a price for increased microbiological safety from the addition of chemicals to drinking water, swimming pools and public bathing facilities. It is this aspect of water safety that we explore here in a New Zealand context.

Health-related conditions of swimming pools and public bathing facilities have been of major concern to public health authorities for a number of years. The 1988 epidemic of the pathogen, Cryptosporidium in the Wellington Region (Baker et al. 1998), which was attributed largely to local swimming facilities, heightened the lack of desirable hygienic practices by users of these facilities.

Microbiological determinants of health significance present the greatest public health risk. Increasing concern has been developing over the chemical determinants of health significance associated with pools (Nokes 1997; Wallace 1997). Improper handling of chemicals or inadequate maintenance and control of chemical pool parameters can lead not only to ineffective disinfection, but also to conditions such as acid or alkaline burns to the skin or mucous membranes, damage to teeth, explosion or toxic fume production and exposure to potential carcinogens. Centerwall et al. (1986) outline a case of acid erosion of dental enamel among regular swimmers at a private pool in the United States (US). This was due to improper chemical control and lack of monitoring resulting in high acidity levels in the pool water.

Following considerable work carried out nationally and internationally on undesirable DBPs in public water supplies, attention is now turning to swimming facilities, which have been shown to be important sources of disinfection by-products due to repeated chlorination and precursors introduced by bathers (Wallace 1997). Swimmers and pool staff are exposed to a greater degree than are householders. The highest level of exposure for swimmers occurs under intensive training and competition.

There are two major groups of chlorination by-products of relevance to human health.

The first of these is the chloramine compounds formed by reaction of chlorine compounds with ammonia and related species. The most common are: Monochloramine (NH2Cl), Dichloramine (NHCl2), Trichloramine or nitrogen trichloride (NCl3) (Nokes 1995). These compounds are responsible for the characteristic chlorine smell associated with pools. They give rise to irritation of eyes and other mucous membranes as well as reducing disinfection ability.

The second group is the halogenated organics, which include the trihalomethanes as the predominant species, haloalkanes, haloacetic acids, haloacids, haloacetonitriles, haloketones, haloaldehyedes and chlorinated hydrates. These by-products are formed by the reaction of halogenated disinfection agents (usually chlorine) with organic compounds, predominantly humic substances (Malcolm, Weinstein & Woodward 1999; Wallace 1997). The trihalomethanes (THMs) have received the most attention and are listed as Priority Two Determinands in the Drinking Water Standards for New Zealand 1995. The four species of THM are: Chloroform ($CHCl_3$), Bromoform ($CHBr_3$), Bromodichloromethane BDCM ($CHCl_2Br$), Dibromochloromethane DBCM ($CHClBr_2$).

Chloroform appears to be the most prominent of the THMs. Where bromine is used as a disinfectant, the brominated THMs can exist in greater concentrations than chloroform (Nokes 1997). The mechanisms by which such disinfection by-products are formed in water supplies are not fully understood. Nokes (1993) has indicated that pathways used in THM production are complex and has suggested several reaction pathways including detectable chlorinated intermediates.

In this paper, we review the theoretical risk to swimmers, and estimate the likely number of New Zealanders affected.

Theoretical Risk to Swimmers

(i) Exposure studies

Exposure occurs from dermal absorption by physical contact from swimming, from inhalation of air above the pool and accidental ingestion of pool water. Dermal absorption is a significant exposure route from direct contact with water disinfected by chlorine (Lindstrom, Pleil & Berkoff 1997; Wallace 1997). Wallace (1997) summarised experiments which have been conducted with subjects showering in the normal way (inhalation and dermal absorption exposure routes) and subjects showering wearing raincoats and boots (inhalation route only). Dermal exposure has been estimated as approximately equivalent to inhalation during showering (Wallace 1997). Other studies reported by Wallace (1997) corroborate inhalation as being a significant exposure pathway at indoor but not at outdoor pools. It seems that enclosed indoor pools may allow a build up of airborne THMs that would not occur at outdoor pools.

A number of studies (Aggazzotti et al. 1998; Cammann & Hubner 1995;

Lindstrom, Pleil & Berkoff 1997) examined THM exposures during competitive swimming training. The Lindstrom study (1997), using male and female subjects, investigated the body burden of THMs before, during, and after a two-hour competitive training session. Of the trihalomethane species, little chloroform and no bromodichloromethane body burden was shown before the session commenced. The uptake of the male subject was rapid during training with breath samples from the subject exceeding long-term indoor air levels within eight minutes of the session commencing. The uptake of the female subject was slower but ultimately reached a similar level to the male subject, which exceeded twice the long-term indoor air levels of the pool environment. This suggests dermal uptake is very rapid and of greater importance than inhalation alone, with dermal absorption estimated at approximately 80% of the total absorption in these studies. Monitoring of the three-hour post-exposure burden revealed levels still five times higher than pre-exposure levels (Lindstrom, Pleil & Berkoff 1997). Cammann and Hubner (1995) confirmed a similar trend of higher levels of physical activity in swimmers being correlated with higher concentrations of trihalomethanes in alveolar air, blood and urine.

Aggazzotti et al. (1998) carried out a study with male and female competitive swimmers. Air and alveolar samples were measured at a centre away from the pool, at the poolside while resting and immediately after one hour of intensive training. The subjects returned to the centre away from the pool where air and alveolar samples were rechecked at one hour and one and a half hour intervals after the training session had finished.

The following observations can be made (Aggazzotti et al. 1998):

1. Uptake is rapid once exercising begins from increased pulmonary ventilation. Overall THM uptake was found to be approximately seven times greater after one hour of swimming than at rest.

2. Ambient air concentrations increase with agitation and churning of the water, enhancing diffusion into the air space above the pool.

3. Alveolar air levels can be higher than that of the ambient air. When subjects are at the poolside, trihalomethanes can only be introduced by inhalation. When swimming, oral, respiratory and dermal exposure routes can introduce trihalomethanes.

Uptake is slower in female subjects possibly due to different pulmonary ventilation rates.

(ii) Spontaneous abortion

Spontaneous abortion (SAB) has been associated with DBPs. A major study by the Californian Department of Health Services (Betts 1998; Waller 1998) showed an increased risk of first trimester miscarriages among women who drank five or more glasses of cold tap water/day which contained an average of $\geq$ 75 µg L^{-1} total trihalomethanes (TTHMs). No information was given as to the likely range of volumes of glasses used. Consumption of water at levels lower than 75 µg L^{-1} TTHM or by drinking less than five glasses per day showed little increase in risk. Of women consuming more than five glasses of cold water containing $\geq$ 75 µg L^{-1} TTHM, 16% had miscarriages compared to 9.5% of women exposed to lower levels than this amount. Factors that decrease concentrations of trihalomethanes such as the use of in-line water filters and allowing water to stand before consumption (allowing volatile trihalomethanes to dissipate) were examined. In-line filter users had an SAB (14.3% of 28) versus those drinking unfiltered tap water users (16.1% of 93). Women who drank straight from the tap had a higher SAB rate (17.6% of 74) versus those who let tap water sit before drinking (13% of 46). Showering and swimming were accounted for in the study and were claimed to have little additional effect.

The primary limitation for this study was the potential for misclassification of exposure. Trihalomethane levels can change rapidly over short periods of time but levels for most subjects were based on a single day's testing (Waller 1998). However, the authors thought that the degree of misclassification between SABs and non-SABs was not likely to differ. Exposure to trihalomethanes via routes other than ingestion such as washing dishes, washing clothes and bathing/swimming would tend to augment existing exposure as the same drinking water is usually used for these activities (Waller 1998).

(iii) Respiratory and other irritant effects

Fjelbirkeland, Gulsvik and Walloe (1995) found swimming to have low asthmogenicity especially relative to other forms of physical activity. The high relative humidity is thought to provide a level of protection against asthma.

Chloramines are well-known respiratory irritants and triggers for asthma and other breathing problems. A case of chloramine production in a water bed mattress due to improper chemical addition for conditioning and removal of odour set up a reaction very similar to chloramine production in swimming pools and water supplies. The asthmatic victim suffered acute respiratory distress requiring hospitalisation (Ministry of Health 1999). Chloramines are an occupational sensitiser, which can produce bronchial asthma (Blasco et al. 1992).

Studies on swimming athletes who developed exercise-induced asthma (EIA) after prolonged periods of training have been reported (Fjelbirkeland, Gulsvik & Walloe 1995). Indoor heated swimming complexes seem to present the greatest potential to develop EIA when compared to outdoor pools or other forms of activity. Volatile components were suspected as possible trigger agents (Fjelbirkeland, Gulsvik & Walloe 1995).

A study by Erdinger et al. (1998) specifically examined disinfection by-products for irritating potential to mucous membranes. Previous evidence indicated that typical concentrations of free and combined chlorine residuals were not sufficient to explain the degree of eye irritation associated with swimming pool water. They suggested that halogenated intermediates such as halogenated carboxyl compounds, which act as THM precursors, might be responsible for eye irritation. Some of the compounds tested were found to have significantly increased irritating effects when compared to chlorine/chloramine mixture of the same concentration. Mixtures of halogenated carboxyl compounds were found to have strong synergetic effects with mixtures of several compounds. They suggested that the irritating potential of swimming pool water was a result of synergistic action of a combination of disinfection by-product species in the presence of chlorine. Although this study concentrated on eye irritation it provides considerable evidence that such compounds may be an important trigger for asthma and similar respiratory complaints (Erdinger et al. 1998).

(iv) Cancer

The International Agency for Research on Cancer (IARC) (1991) has listed chloroform ($CHCl_3$) and bromodichloromethane ($CHCl_2Br$) as possible carcinogens to humans (Group 2B). Drinking-water guideline values for chloroform of 0.2 μg L^{-1} and 0.6 μg L^{-1} for bromodichloromethane were recommended based on a lifetime excess cancer risk of 1 x 10^{-5}. Guideline values for bromoform ($CHBr_3$) and dibromochloromethane ($CHClBr_2$) of 0.1 μg L^{-1} each was also recommended. These values were adopted as maximum acceptable values for the Drinking-Water Standards for New Zealand 1995 (Ministry of Health 1995).

Numerous studies have been carried out to investigate the possible associations between exposure to disinfection by-products from chlorination of water and cancers. According to Morales et al. (1994), cancer of the stomach and bladder have been the most frequently studied. Rectal cancer has been associated with the consumption of chlorinated water (Morris 1992). The data collected supported a significant association between bladder cancer and exposure to chlorination DBPs in drinking water. A dose-response relationship appeared to follow which did not diminish when factors such as gender, smoking, residence urban living, and occupational risk were considered (Morris et al. 1992). The association of rectal cancer followed a similar pattern to bladder cancer.

Attias et al. (1995) report an integrated carcinogenic risk assessment procedure based on accepted methods. Animal experimentation and epidemiological databased assessment derived by using the multi-stage model and unit risk procedures were found to be reasonably close. The assessments did not appear to indicate a risk level of concern in light of local cancer mortality standard statistics.

(v) Likely numbers of New Zealanders affected

Swimming is a popular physical activity in New Zealand. According to the Hillary Commission (1997), it is estimated that approximately 36% of New Zealand adults swim. The proportion that solely uses non-chlorinated facilities such as the sea is not indicated in this study. The Life in New Zealand Survey (Cusham et al. 1991) states that approximately 19% of the population over 15 years of age use swimming pools with 4% using home pools. A figure of 18% of the population using chlorinated pools is a reasonable and conservative estimate for 1991-1996. The percentage of the population using public swimming pools is likely to have steadily increased through the 1990s with the opening of many new facilities.

The two most common sources of THMs are drinking water and swimming pool waters for those who swim in chlorinated facilities. There is also exposure from using hypochlorite bleaches in the home or work environment. Malcolm, Weinstein and Woodward (1999) collected data from the morbidity and mortality from cancers of the bladder, colon and rectum in New Zealand during 1994-1996. An estimation of the likely numbers of cancer related deaths attributed to exposure to chlorinated water was determined. Using a same relative risk (RR) of 1.5 as Malcolm, Weinstein and Woodward (1999), the population attributable risk percentage (PAR%) can be calculated by using the formula:

PAR%=[P_e (RR-1)/1+P_e (RR-1)] x 100, where P_e is the proportion of population exposed (Malcolm, Weinstein & Woodward 1999).

If all of the population who engage in swimming used chlorinated swimming facilities (36%) (P_e = 0.36), the PAR% would be approximately 15%. Applying this figure to New Zealand cancer deaths of 1315 in 1995, approximately 197 deaths would be potentially attributable to DBP exposure as a result of swimming (Malcolm, Weinstein & Woodward 1999).

Malcolm, Weinstein and Woodward (1999) estimated the PAR% from exposure to chlorinated drinking water as 25% from the estimation of 66% of the population exposed (P_e = 0.66). From these figures Malcolm, Weinstein and Woodward (1999) suggest that 329 deaths were potentially attributable to exposure to chlorinated water. It is certain that a significant percentage of those exposed to chlorinated swimming pool water would also be exposed to chlorinated drinking water as source waters for a large number of swimming facilities are chlorinated water supplies.

Thirty four percent of the population is estimated not to drink chlorinated water (Malcolm, Weinstein & Woodward 1999). Many of these will be those using private non-disinfected supplies or those using alternative methods of disinfection or none at all. It is reasonable to assume that of the total 329 deaths estimated by Malcolm, Weinstein and Woodward (1999) as potentially attributable to exposure to chlorinated water, a sizeable portion of these could be in part be due to chlorinated bathing water. We estimate 197 deaths based on a 36% exposure to chlorinated swimming pool water (if all those engaged in swimming were exposed to chlorinated pool water). If 18% of the adult swimming population are exposed to chlorinated swimming pool water, this represents a P_e of 0.18 and a PAR of 8%. Based on this scenario we estimate that 108 of the 329 deaths attributed to chlorinated water exposure were potentially due in part to chlorinated swimming pool exposure.

It is not possible to reliably estimate the portion of cancers attributable to exposure to chlorinated drinking-water versus exposure to chlorinated swimming pool water or other sources such as bleaches without further studies. It is worth noting that in 1999, just over 8000 competitive swimmers were registered with the New Zealand Swimming Federation. (Annual report 1999). These athletes compete at national level and train an average of 4-6 hours per day with 90% of training in the swimming pool. The majority of pools used by these persons will be chlorinated and indoor heated pools. In terms of exposure, this group is likely to be in one of the highest risk categories. There are also swimmers at club level competition training on average 2 hours per day and those at provincial level competition training at 2-3 hours per day.

Malcolm, Weinstein and Woodward (1999) estimated the number of birth defects associated with chlorinated water (DBPs) as 94 annually based on the PAR value of 25%. Similarly, a significant number of these cases might be attributable in part to swimming and bathing facilities. Indoor heated facilities are promoted among pregnant mothers for exercise and in some cases to relieve pain. Hospitals have chlorinated indoor heated hydrotherapy pools, which are used by pregnant mothers.

Discussion

Even with the limited information presently available, there is a strong suggestion that a significant level of fatal cancers, birth defects and other health effects are potentially due in part to chlorinated swimming pool water.

Malcolm, Weinstein and Woodward (1999) raised the question as to why we should undertake research into DBPs rather than relying on overseas information and risk estimates. They refer to the complex chemistry involved and the nature and quantity of DBP formed, which depends upon factors such as the quantity and nature of precursors, water temperature, pH, bromide ion concentration, chloride dose and nature and timing of the disinfection process. While THM levels in feed water are thought not to contribute significantly to the overall levels of THM in pools, a great many factors which might be peculiar to New Zealand could significantly influence the type and levels of chlorinated by-products. These include the indoor environments for indoor pools. Bather habits and hygiene might also be significant. Personal hygiene habits of many New Zealand communal pool users is by observation, poor, with few washing or showering properly before bathing. This has the potential to introduce an increased amount of organic contaminant precursors to the pool from body dirt, skin, hair, sweat, urine and lotions shed from skin and hair.

Other factors, which might differ from overseas practice, might include indoor ventilation in indoor pool enclosures, climatic conditions, operation practices, the characteristics of plant used, bather loads and the disinfection chemicals used.

Conclusion

The wide variety of swimming pools and bathing facilities in New Zealand provides a good basis to undertake research on the formation of DBPs and human exposure. A range of disinfected and non-disinfected geothermal pools, outdoor summer pools, fresh-water and salt-water pools, and a good range of indoor heating facilities are available for study in New Zealand. In addition, a number of disinfection regimes are used ranging from no disinfection, disinfection by chlorine gas, liquid or solid hypochlorite, chlorine/ozone combination, and bromination for spa pools. Such a range of pool types and disinfection regimes gives an opportunity to investigate the effects of such unique factors on DBP formation. Studies are critical to the development of appropriate intervention strategies to limit production or to remove these undesirable by-products from swimming pools environments, thereby protecting the health of New Zealand swimmers.

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Correspondence to:
Stuart J McLaren
Institute of Food, Nutrition and Human Health
Massey University
Wellington Campus
Private Box 756
Wellington
NEW ZEALAND
Email S.J.McLaren@massey.ac.nz

Environmental Health Practice: For Today and For the Future

Rosemary Nicholson

Regional Integrated Monitoring Centre, University of Western Sydney

In order to gain an insight into the changing role of the environmental health workforce, 40 in-depth, structured interviews were undertaken between July and September 2000. Key informants in environmental health whose interests spanned the broad spectrum of environmental management and human health were interviewed. The thoughtful responses of this specially selected group threw light on the current status of community-based environmental health action. The key informants selected for this study worked either in a specialised area of environmental health, had a strategic planning role in government, represented a community group with a specific environmental health concern, or worked to integrate activities across the other three groups. Interviewees were asked first to identify their priority issues and then to list actions which they believed should be taken to address these issues. Analysis of their responses provides insights into the range of practice in the rapidly changing arena of environmental health.

Key Words: *Change, Partnerships, Issues, Actions, Workforce, Environmental Health*

The Changing Nature of Environmental Health

Contemporary environmental health practice is characteristically complex, seeking to address the impacts of societal changes on human health and environmental sustainability. Many of these changes are associated with globalisation, increased travel, and the transboundary movement of goods and substances, together with the ever-increasing pace of urbanisation, rural decline and socio-economic inequity (Chartered Institute of Environmental Health [CIEH] & World Health Organization 1999; National Research Council 1999).

The changing nature and increasing complexity of environmental health both nationally and internationally have been well documented over recent years (Brown 2001; Brown, Powis & Ireland 1997; CIEH 1997; Commonwealth Department of Health and Aged Care 1999; MacArthur 2000). One of the unchanging features of environmental health, however, is that it is predominantly place-based, that is, it is concerned with a specific area of the biophysical environment and the people who live there. Thus environmental health improvements, both locally and globally, depend increasingly on action at the local level (MacArthur 2000).

The National Environmental Health Strategy variously describes environmental health as “the cornerstone of public health” and as “a highly intersectoral discipline, embracing a broad range of subject areas and involving a wide variety of stakeholders” (Commonwealth Department of Health and Aged Care 1999). Similarly, Soskolne and Bertollini (1998) refer to global ecological integrity and “sustainable development” as cornerstones of public health. Humans are thus acknowledged as an integral part of nature’s processes and the environment as integral to human health.

Definitions

For the purposes of this paper the following definitions are used, based on the widespread recognition of the importance of community involvement and interdisciplinary partnerships in addressing contemporary environmental health issues (Chartered Institute of Environmental Health 1997; Commonwealth Department of Health and Aged Care 1999; Soskolne & Bertollini 1998).

Environmental health role: Form of individual contribution towards addressing environmental health issues.

Environmental health workforce: The diverse range of stakeholders working (paid or unpaid) to prevent and mitigate the effects of human impacts on public health and environmental sustainability.

Environmental health practice: The wide range of strategies and actions taken in order to address environmental health issues.

Environmental health practitioner: Any member of the environmental health workforce.

Environmental health professional: A member of the environmental health workforce with formal tertiary qualifications and peer recognition in the field.

Study Rationale

Environmental health practice, as illustrated in Figure 1, comprises the combined actions of professional and community practitioners in the context of policies and strategies for the management of priority issues. Professional services are delivered within one of the three possible frameworks illustrated in Figure 2 and across the three domains shown in Table 1.

Table 1: Domains of environmental health action

Environmental Health Justice	Environmental Health Systems	The Human-Environment Interface
Indigenous environmental health	Economic analysis	Air
Sustainable development	Health impact assessment	Built environment
	Health risk assessment	Vector borne diseases
	Information	Water
	Research	• Drinking water
	Standards and guidelines	• Recreational water
	Workforce	

Source: National Environmental Health Strategy Implementation Plan (enHealth Council 2000).

The National Environmental Health Strategy acknowledges that: "No single organisation has the capacity to manage environmental health in isolation. Improving environmental health in Australia requires a well-planned and sustained effort from all partners", (Commonwealth Department of Health and Aged Care 1999, p. i). Similarly, the enHealth Council notes that the success of the National Environmental Health Strategy rests on each of the "diverse range of stakeholders influencing environmental health…recognising their role and embracing new and actively collaborative approaches to environmental health management" (enHealth Council 2000, p. 1). Australian examples of local partnerships for environmental health include initiatives such as Local Agenda 21, Cities for Climate Protection, Regional Waste Management Strategies and the Healthy Cities movement (Addison 2000; Brennan 2000; Chu, 1994). These are just some of the emerging environmental health initiatives addressing global and local environmental pressures. Two key questions to arise from our knowledge of these emerging initiatives are: what are the priority issues of environmental health practitioners today? and what actions do they undertake?

Table 2: The top twelve perceived community environmental health risks in descending order of priority

Perceived health risk to the public	Perceived health risk to respondent's family
Cigarette smoking	Misuse of chemicals and poisons
Illegal drugs	Food poisoning
Suntanning	Chemicals in drinking water
Nuclear waste	Germs in drinking water
Crime and violence	Mercury in fillings
Stress	Chemical termite treatments
Chemical pollution overall	Food additives
Motor vehicle accidents	Loud noise from traffic or industry
AIDS or HIV	Drinking alcohol
Ozone depletion	Mobile phones
Insecticide and weedkiller residues in food	Smoke from wood heaters
Treated sewage pumped into rivers and sea	Indoor air quality

Adapted from Starr, Langley & Taylor 2001

Policies and strategies are clearly

detailed in the National Environmental Health Strategy and Implementation Plan (Commonwealth Department of Health and Aged Care 1999; enHealth Council 2000). The implementation plan details action plans for 13 separate issues within the three domains of environmental health justice, environmental health systems, and the human-environment interface (Table 1).

In an extensive study of Australian community perceptions of environmental health risk Starr, Langley and Taylor (2001) analysed community priorities and expectations. The researchers reported high levels of community concern about a range of environmental health issues as listed in descending order of risk perception in Table 2.

The focus of the inquiry

In the light of the above it is clear that extensive work has been undertaken in two of the three major dimensions of environmental health in Australia (Figure 1). This paper focuses on the largely unexplored dimension of practitioner priorities, services and actions. The qualitative study discussed here does not purport to be a workforce survey but rather an in-depth exploration of the experiences and views of a broad range of practitioners, 36 from within Australia, seven of whom work with Indigenous communities, and four overseas respondents. The data were collected in July-September 2000 as the first stage of a more extensive consultation strategy to inform the design of a national handbook for community-based environmental health action (Brown et al. 2001, Nicholson, Brown & Mitchell 2001).

Figure 1: The three overlapping components of environmental health practice

Method

The method of choice for this study was one of in-depth, structured interviews. This allowed for a detailed exploration of a broad range of environmental health roles.

Rationale for selection of the study sample

Of an initial list of over 100 key informants with overlapping environment and health interests and who were on record as supporting community contribution, 50 were identified as having already worked successfully on, in, or with community environmental health. The 40 key informants selected for in-depth interviews were evenly distributed between environment and health organisations and representative of a wide range of stakeholder groups. Table 3 summarises the geographical spread of the key informants, the range of organisations represented, and the primary areas of interest and responsibility of each key informant within those organisations. Respondents working with Indigenous communities were deliberately sought in order to reflect the high priority needs in this area (Commonwealth Department of Health and Aged Care 1999, Stephenson 2001).

It is important to understand that some respondents worked for more than one organisation, for example local government and a professional body, and some had multiple roles; as when academics might at different times teach, research, or consult in their discipline area. Hence the numbers in columns 2 and 3 total more than 40.

Survey respondents were asked to place

Table 3: Profile of survey respondents (n=40)

Geographical location		Nature of organisation		Role and/or primary interest		Focus	
ACT	6	Academic	5	Community development	4	EH	17
New South Wales	10	Community group	6	Coordination	7	EM	7
Northern Territory	1	Consultancy	9	Philanthropic	1	OH and E	1
Queensland	9	Government		Indigenous EH	7	EH and EM	1
South Australia	2	• local	4	Policy and planning	10	EM and PH	2
		• state or territory	9				
Tasmania	1	• national	3	EHO	7	PH	12
Victoria	5	Industry	1	Research	11		
Western Australia	2	NGO	4	Teaching	4		
Overseas	4	Professional body	2				

Key: EH = Environmental health EM = Environmental management OH and E = Occupational health and environment PH = Public health

themselves according to their primary environmental health interests along the five major fields of action of environmental health as described by Brown et al. (2001):

- Environmental protection/conserv-ation
- Individual health/population health
- Health/environment
- Spatial scale (global vs local interests), and
- Time scale (short-term vs longer-term priorities).

For each of these fields of action respondents were asked to identify the single most important issue of direct concern to them, and then to suggest two actions that their organisation could take, and two actions that the wider community could take to address their stated issues.

Results: Issues

Although respondents were asked to list one issue for each of the five dimensions described above, responses to the different dimensions in the survey were found to overlap and to form just three distinct patterns of response over the wide range of issues. The three main environmental health domains to emerge from analysis of the results were:

- environmental quality and security
- human health and wellbeing, and
- health-sustaining environments

Further issues were expressed by respondents as concerns relating to equity (environmental health justice), time (short-term vs long-term priorities), and spatial scale (local vs global foci). Some respondents cited more than the five issues requested, while others cited fewer. Hence there are different numbers of issues in Tables 4 to 6, and to aggregate at variance with the 200 (40x5) issues requested, although the variation was not wide.

Domain 1 Environmental quality and security

A total of 30 of the 40 respondents included in their five priority issues matters relating to environmental degradation and conservation. These were both in general and in relation to specified environments, namely forest, marine and coastal areas, and riparian zones.

Pressures brought about by rapid urbanisation, intensive farming practices, unsustainable levels of use of natural resources and inappropriate waste management and disposal practices were all identified as contributing to environmental degradation as evidenced by:

- loss of biodiversity
- the presence of acid sulphate soils
- poor water quality

- global warming and changing climate patterns
- greenhouse emissions
- atmospheric pollution, and
- salinity

Table 4 summarises respondents' issues within the domain of environmental quality and security. Particular population sub-groups identified by respondents as best placed to take action to address an issue are listed in the right hand column. Where no sub-group was specified the word 'All' is used to indicate a whole of community responsibility. Numbers in brackets both here and subsequently in this paper indicate the number of respondents who included the issue in their list of priorities.

Table 4: Issues of environmental quality and security

Issues cited	Community Sub-sections most commonly implicated
Pollution/Toxic chemicals in the environment (18)	
air (5)	Industry
water (8)	Industry
soil (2)	Industry
unspecified (3)	Industry
Environmental degradation (14)	
forests (5)	All
oceans and the marine environment (3)	All
coastal areas (2)	All
riparian zones (2)	All
unspecified (2)	All
Loss of biodiversity (6)	All
Air quality (5)	Industry, motorists
Ecosystem health and sustainability(5)	All
Unsustainable waste disposal/waste management practices (5)	Industry
Energy use and depletion of natural resources (4)	All
Greenhouse emissions (4)	All
Climate change (3)	All
Environmental effects of rapid urbanisation (2)	Developers
Global environmental issues (1)	All
Maintenance of habitat (1)	All
Salinity (1)	All
Unsustainable farming practices (1) (agroforestry, monocultures, pesticide use, tillage of soils)	Farmers

Table 5: Human health and wellbeing: issues and associated at-risk groups

Issues cited	At risk population sub-groups
Mental health and wellbeing (3)	Rural people, unemployed
Communicable diseases (2)	Indigenous communities
Coronary heart disease (2)	Indigenous communities
Drug and alcohol abuse (2)	Indigenous communities, youth
Allergies (1)	Children
Arbovirus infection (1)	All
Asthma (1)	Children
Cancers (1)	All
Diabetes (1)	Indigenous communities
Food poisoning (1)	All
Health of individuals (1)	All
Health service provision (1)	All
Immunisation (1)	Children
Lead exposure (1)	Children
Parasitic infections (1)	All
Safety (1)	All
Stress (1)	Workforce employees
Tobacco use (1)	All
Toxic chemical sensitivity (1)	The unborn foetus, children

Domain 2 Human health and wellbeing

A total of 11 respondents expressed concerns specifically related to issues of human health and wellbeing. While these can be linked clearly to social and physical environmental causes, such linkages were not expressly acknowledged in these responses. Respondents' priority concerns in relation to human health issues are listed in Table 5. Where a population sub-group was identified by respondents as being most at risk, this is listed in the right hand column against the associated health issue. As in Table 4 'All' denotes whole of population with no particular sub-group specified.

Domain 3 Health-sustaining environments

> *We need to cut through the complexity to increase people's understanding of the basic linkages – no little birds means no pollination means no food supply* (Community integrator - NGO).

Table 6: Issues of environmental risk to human health and wellbeing

Issues cited	Most at-risk population sub-groups
SUBSTANTIVE ISSUES	
Toxic chemicals in the environment (21)	
unspecified (8)	
lead/heavy metals (4)	
herbicides (2)	
toxic waste (2)	Children
contaminated sites (1)	
endocrine disrupters (1)	
persistent organic pesticides (POPS) (1)	
products of toxic waste incineration (1)	
solvents (1)	
Physical environments: (5)	
housing quality (1)	Indigenous communities
inadequate infrastructure (1)	Indigenous communities
rapid change (1)	Indigenous communities
unhealthy workplaces (2)	Low socio-economic groups
Food contaminants (chemical and microbiological) (4)	All
Contaminated drinking water (1)	Indigenous communities
Environmental degradation (1)	All
Global warming (1)	All
Salinity – impacting on socio-economic wellness (1)	Rural communities
The genome project (1)	All
ACTIONS AS ISSUES	
Conservation & environmental protection (8)	
Planning (7)	
integrated planning development (4)	
ESD (2)	
strategic goal setting and policy development (1)	
Indigenous environmental health management (9)	
in general (5)	
community involvement (4)	
People's connections with and respect for the natural environment (5)	
Peoples' lack of understanding and awareness of the linkages (between the environment and human health) (4)	Not applicable. These issues are all general to Environmental Health practice
The dependence of human health on health of the environment (4)	
Local government & local agenda 21 (3)	
Catchment management (2)	
Inadequate regulatory regimes (2)	
for the control of emissions and the use of toxic chemicals (1)	
to disallow the destruction of environments fundamental to health (1)	
Identifying issues & resources for action (1)	
Mutual impacts between people and the environment (1)	
Peoples' (mis)use of their democratic voting right (1)	
The environmental/health divide (in local government) (1)	

Of the 32 respondents with issues of concern in this dimension, 20 identified specific issues as their concerns and 12 identified processes relating to environmental health systems. Table 6 lists respondents' substantive issues together with their associated at-risk population sub-groups. Actions cited as issues are listed as a separate sub-set. Each sub-set of issues is presented in descending order of frequency of response.

> *Aboriginal communities have different priorities. It's a mess out there* (Community advocate).

Indigenous respondents expressed particular concern for service coordination and the promotion of environmental health issues within their communities. One respondent described the current approach to issues in Aboriginal and Torres Strait Islander (ATSI) communities as "sectoral and narrow". Others believed that local and state governments could work more effectively with ATSI communities and that state health departments should elevate indigenous environmental health from the level of "special projects" to that of "core business". Community involvement was cited specifically in relation to Indigenous communities with respondents stressing the need to include community in the management of the environment ("not locking it out"), and to ensure local ownership of environmental health issues. Table 7 summarises the three environmental health domains.

Overarching the three domains are the separate contexts of environmental health justice, time scale, and spatial scale. These are discussed below.

Environmental health justice

> *You can't have social justice without environmental justice, and vice-versa* (Environmental planning consultant).

Respondents' concerns in relation to environmental health justice are summarised in Table 8. Specific equity issues were cited by respondents regarding access

Table 7: Summary of the three domains of environmental health

Domains	Focus	Aims/priorities	Action/practice
Environmental quality and security	Ecocentric	Environmental wellbeing	Environmental management
Human health and wellbeing	Anthropocentric	Human health and wellbeing	Public/community health
Health-sustaining environments	Systemic	Strengthening mutual support; Acknowledging environment and human interconnectedness; Acknowledging the place of humans within and not outside of natural ecosystems.	Emphasis on environmental health systems and process

to adequate food, clean water, data and information pertaining to environmental health risks, resources and transport.

Time scale

> *People have difficulty envisioning a good healthy future. There's a 'no hope' aspect* (Community advocate).

Eleven respondents indicated their concerns in relation to long-term sustainable behaviour and the need to reverse short-term thinking. These were articulated in terms of concern for the future and security of the environment, families, human society, and planetary health. Substantive issues cited here related specifically to environmental pollutants and toxic chemicals, particularly the effects of air pollution both in the short term and in relation to the long-term cumulative effects of a POPS (persistent organic pesticide) body burden.

The need for a greater emphasis on long-term planning was emphasised by five of the eleven respondents who identified time as an issue. These respondents expressed their concern that current decision making processes fail to take into account long-term futures. One respondent specifically prioritised the need to determine the role of local government in the longer term.

Spatial scale: Global vs local thinking and action

> *I theorise at a global level, but work at a local level* (Public Health Academic).

Somewhat surprisingly given the recent emphasis on environmental risks from climate change and increased UV radiation, only a small minority of respondents (4/40) expressly prioritised concerns relating to global environmental health issues. Those who did listed the need to increase people's awareness and capacity to consider the global effects of local actions and the need to preserve our environment both individually and at a local level and collectively through global policy.

Table 8: Environmental health justice

Population sub-group	Associated equity issue
Australian poor	Health status and quality of life
Children	Their future (intergenerational equity)
Indigenous Australians	Base health levels significantly lower than non-Indigenous Australians
Populations of developing countries	Health opportunities and quality of life
Rural populations	Insecurity and sense of frustration
Youth	Unemployment

Results: Actions

Analysis of responses

Actions which respondents suggested might be taken by their organisation and by the community were sorted and grouped according to the themes listed in Table 9. The Table shows the number of respondents who listed each category of action, first for their organisation, and then for the community. Figures in brackets indicate the total numbers of actions cited by respondents in relation to that particular theme.

Respondents' ideas for action in each of the categories listed in Table 9 are detailed below.

Table 9: Actions for organisations and for communities

Action	Organisation	Community
Take direct action on specific issues	28 (74)	37 (144)
Educate/raise awareness	33 (82)	29 (72)
Research and improve access to information	26 (80)	14 (25)
Change attitudes/values	7 (7)	24 (41)
Form networks and partnerships	21 (14)	6 (29)
Plan for sustainable futures	11 (17)	11 (16)
Regulate	14 (30)	6 (11)
Develop policy	13 (26)	3 (6)
Resource	6 (10)	6 (8)
Provide social support	7 (11)	1 (1)

Direct action on specific issues

> *I am one of many, and many many's has a global impact* (Public health academic speaking on action by individuals in the community).

Organisations can provide a healthy working environment for employees, manage by example, consider the strategic supply and use of essential raw materials, encourage the use of public transport, decrease the need for executive travel by an increased use of e-business, stop land clearance, commit to energy reduction targets, reduce environmental health risks from their operation, and ensure public safety. Actions specific to government include the provision of immunisation programs and the banning of leaded petrol.

Community members should "care enough to take it on". This means committing to local environmental health activities, attending or coordinating activities and meetings and helping identify problems. Community members and networks can act as whistleblowers, complain to the Human Rights Commission, lobby and embarrass government, agitate, call for initiatives, talk loudly, "make a hell of a noise", and lobby for change. Individuals should make strategic use of their democratic voting power and their consumer choices.

Organisations and community should both look after their own immediate environment, reducing energy consumption and decreasing their use of natural resources. They can also advocate for equity and the reduction of environmental health risks, model alternatives, work across sectors to network with other stakeholders, and work together to prepare community indicators.

Education and awareness raising

> *Education and understanding contribute to change – contribute to better decision making* (NGO Advocate for youth).

Organisations. Respondents employed in the field of tertiary education discussed the potential for the expansion of environmental health across the tertiary curriculum in order to raise the awareness of the environmental health role of key professional groups such as doctors, engineers, planners, and regulators. Universities were identified as being ideally placed to teach the links between environment and health across a range of academic and professional disciplines.

Community members need to believe in the power of their own influence on the environment and have a dual responsibility to become better informed themselves, through actively seeking information and by listening to the concerns of others, and to raise the environmental health awareness of others by publicising issues. Suggested actions included working with local schools, publicising issues of concern through the media, educating newly-elected councillors, taking responsibility for leadership in order to increase the sense of community responsibility for environmental health issues, speaking out and "having a say" at community meetings, and taking an interest beyond their own region.

Research and access to (specialist) advice and information

> *There is no evidence to show what is really going on* (Community representative). *Information is power* (Indigenous EHO).

Organisations such as government departments and research institutions have a role to play in adding to new knowledge through research, data collection, the provision of risk assessment tools and information and providing access to information in a way that is meaningful to people. Actions identified here include monitoring and auditing, mapping, State of the Environment (SoE) reporting, and the submission of papers to national and international conferences,

Community members have been long undervalued in western society for their local knowledge and personal and family experience of environmental health impacts.

The community has a valuable, but generally unacknowledged, role to play in observing and recording local environmental changes and health impacts on themselves and on close family members. When this information is passed on it adds to the body of knowledge and research on the linkages between human health and the health of the environment.

Changing attitudes and values

> *It all comes down to ethics, spirituality and the things we have lost* (Community integrator – NGO).

Organisations need to show a real commitment to reduction targets, acknowledge the link between the environment and human health and adopt a broader, more holistic, approach to problem solving.

Community members must acknowledge that problems exist and that actions are necessary. They need to develop a sense of place and a sense of responsibility for issues, acknowledge the bigger issues outside their own region, commit to a broader view of health, and develop a positive view of the legislation. There is also a need to value health above property ("realise that buying and selling is not the only way to view land"), conservation, and species protection.

The formation of networks and partnerships

> *Community (members) don't realise how much power they have collectively* (NGO community integrator).

Organisations should link with community groups and coordinate their involvement, collaborate with other stakeholders (this includes a "whole of council" approach to projects), and think in a holistic way by taking an integrated approach to issues, connecting whole packages, and linking environment and health.

Community members can develop formal structures, strengthen their networks and pull together through forming and integrating community interest groups and working parties.

Future planning

> *Sustainability is difficult. People are usually dealing with the immediate issues of every day life* (Public health academic).

Organisations should develop common planning templates and vision statements, include communities in planning decisions, work collaboratively; budget for 5-20 year projections and incorporate Ecologically Sustainable Development (ESD) principles into development applications.

Community members need to reverse their short-term thinking, forego luxuries, and "not accept the unacceptable". They could also become less inward looking, take an interest, participate in local planning and development decisions, and support long-term improvements.

Regulation

> *We need regulatory regimes that don't allow people to destroy things fundamental to their health* (Environmental planning consultant).

Organisations have an obligation to comply with licensing conditions, enforce legislation and prosecute for non-compliance. They should set appropriate standards, support and develop regulatory reform, introduce harsher penalties and end the dichotomy between regulatory frameworks for environment and health. Local government can set an example though local regulation and by-laws and state government should devolve certain responsibilities to the local level.

Community members, in turn, should comply with regulatory requirements, and lobby for and support regulatory reform.

Major response category: policy development

> *We need better connections between professionals, planning frameworks and policy* (Government policy adviser).

Organisations should adopt ESD principles into organisational policy and function, set best practice guidelines, sign international agreements to reduce environmental risks to health and move towards land use planning policies which favour access over mobility.

Community members have an obligation not to accept risks to human health or environmental sustainability.

Resourcing

> *In the longer term there won't be enough people to work to provide the taxes to support these people* [who have been incapacitated through toxic chemical exposure] (Community advocate).

Organisations can provide and develop expertise, donate land, subsidise "green" initiatives, and fund community projects. Government should tax carbon emissions, offer financial incentives on emission standards and eliminate third world debt.

Community members can work collectively to raise funds, offer expertise, actively participate, and provide infrastructure.

Provision of social support

> *Disease and housing problems are very much about broader social conditions* (Indigenous EHO).

Organisations can work towards redressing inequities by working with, developing and assisting local communities. Similarly, industry should provide support for families of employees through good industrial relations policy and prioritise the securing of future employment.

Community actions suggested here include participation in social reform, sponsoring children, and advocating for change.

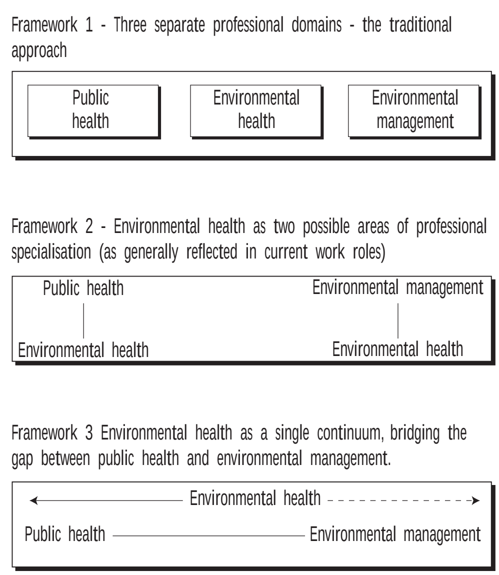
Discussion

The results of this study highlight and further identify the breadth and complexity of environmental health, the diversity of associated issues and actions, and the richness and diversity of the environmental health workforce across a wide range of professions, disciplines, and community interests. The results also provide some insights into the complexity of environmental health practice both now and for the future.

Issues

The issues prioritised by respondents fell into three distinctly separate environmental health domains: environmental quality and security, human health and wellbeing, and health sustaining environments. Together they indicate a potential for division within

Figure 2: Frameworks of environmental health service delivery



the workforce with three subsets of foci, aims and actions (Table 7) and confirm the existence of the three different frameworks illustrated in Figure 2. The findings on the third, systemic, grouping, with its emphasis on environmental health systems and process, are the most noteworthy since, while recommended in the National Environmental Health Strategy, this approach does not appear to be documented elsewhere in the literature. If this third way is the future for us all as stakeholders in environmental health, then it provides a foundation for current action and a basis for the way forward.

Actions

Respondents favoured direct action on specific issues together with education and awareness raising to raise the profile of key issues on community, corporate and government agendas. The need for research was also given high priority, together with improved and equitable access to information. The call for changes in attitudes and values of community members in particular, and, to a lesser degree, of respondents' organisations would appear to reflect some of the frustrations commonly expressed by stakeholders working for change within the community setting. Similarly, the need for organisations to work in partnership with others was widely acknowledged. The comparatively low emphasis on community networks reflects both the relatively low representation by community respondents (6/40) and the lack of recognition on the part of professional and government groups of the value of community partners. This, however, is arguably countered by respondents' acknowledgment of the role of community members in planning, regulation, policy development and in the resourcing of environmental health action.

Partnerships

Linquist (1991) discusses the concept of organisational networks or "policy communities" as organic learning systems and posits that public managers are uniquely positioned to facilitate such collaborative partnerships between governments and non-government sectors. In order for such partnerships to be effective, however, there is a need to address potential barriers of distrust and differing values through nurturing dialogue, managing conflict, tapping into the range of sources of expertise and wisdom, and encouraging learning across all sectors.

Conclusion

The breadth of environmental health issues and actions, the range of stakeholders working in the field, and the inadequacy of a solely regulatory approach to environmental health issues have clear implications for the ongoing role and professional development of the environmental health workforce. Clearly, it is now time to move forward through the development of collaborative, cooperative and inclusive partnerships and approaches across and beyond the range of disciplines and stakeholder groups represented by the survey respondents in this study.

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Rosemary Nicholson
Regional Integrated Monitoring Centre
School of Environment and Agriculture
University of Western Sydney
Hawkesbury Campus
Locked Bag 1797
Penrith South DC, New South Wales, 1797
AUSTRALIA
Email r.nicholson@uws.edu.au

Environments for Health: Municipal Public Health Planning

Andrea Hay, Ron Frew and Iain Butterworth

Local Government Partnerships Team, Public Health Division, Department of Human Services, Melbourne

Local governments in Victoria are mandated to prepare municipal public health plans (MPHP) to improve health status. This article reports on a project initiated by the Victorian Department of Human Services (DHS) to develop a new municipal public health planning framework, in partnership with local governments and other stakeholders. Based on extensive research and consultation conducted in 2000-2001, the new systems approach to MPHPs embraces consideration of factors impacting on health and wellbeing that originate in the built, social, economic, and natural environments. The new municipal public health planning framework draws on the strengths of a number of approaches to public health planning, including strategic local area planning, a social model of health, health promotion, health outcomes, and participation and partnership.

Key Words: *Municipal Public Health Planning, Local Government, Environmental Health, Participation, Ecological Planning*

A New Policy Framework for Municipal Public Health Planning

The Municipal Public Health Plan (MPHP) program provides a holistic framework for public health planning by Victorian local governments to help communities achieve maximum health and wellbeing. A new framework for municipal public health planning has been developed through a partnership between the Public Health Division of the Department of Human Services (DHS), the Municipal Association of Victoria (MAV), the Victorian Local Governance Association, local governments, and other stakeholders. An extensive consultation process, including forums across the state and written submissions, has informed its development.

The new framework, "Environments for Health", aims to take the MPHP program into a new phase, building on past achievements and revisiting the principles that established the program. It offers a balance between the practical and the theoretical, drawing on international and national research, policy, and best practice. By placing explicit emphasis on the social, economic, natural and built environments, the framework makes public health a central focus for local government in its governance role that includes strategic planning, advocacy, coordination, and facilitation of community participation.

Local governments have a traditional geographical concern with people and place, which includes the local context of health, disease and social process. Recognition that place influences health might help to balance an individual focus, by redirecting attention to interventions at the environmental level.

MPHPs are integral to any comprehensive strategic planning process undertaken by local governments (McBride, Hulme & Butler 1999). The new framework promotes a renewed effort in local area planning and should ensure that MPHPs can inform other planning processes effectively and prevent duplication of planning effort at a local level.

Research

Ten years of development of MPHPs across Victoria has provided the basis for a strategic and integrated approach to public health planning at a municipal level. In 1990, 11 councils participated in a pilot program to put into practice the new section of the Health Act relating to MPHPs. By 1994, 76% of the then 210 councils had an MPHP and others were in the process of developing plans (Frew 1993; Garrard & Schofield 1991; McBride, Stubbings & Legge 1999; Smith 1995).

Development of the new municipal public health planning framework was initiated, first, by the appreciation of the need to support greater planning consistency amongst councils. Second, there was a realisation that MPHPs needed to be informed by an ecological, holistic consideration of the impact on health and wellbeing of factors originating across and between the four environmental dimensions.

In August 2000, a questionnaire was sent to all Victorian local governments. The questionnaire sought information about the status and content of current MPHPs, and to uncover issues requiring consideration in the development of the new planning framework. Data were received for 63 of the 78 local governments in Victoria. Additional data were received from DHS regional offices, and from a regional local government workshop to explore the development of a consistent planning approach to MPHPs and primary care.

The 2000 survey found that over 52% of the 78 new councils were implementing a plan, 18% were developing a new plan, and 15% were under review. Numerous positive features of MPHPs were identified, including:

- providing a strategic planning focus,
- promoting useful partnerships and networks throughout the municipality,
- highlighting local health issues and providing a vehicle by which to address them,
- involving all divisions of council,
- promoting community involvement and ownership,
- enabling councils to integrate a social model of health into public health planning, and
- linking regional, state and national priorities.

The research also showed a number of areas for consideration when developing the new framework. There was extensive acknowledgment about the role of MPHPs in promoting useful networks and partnerships throughout the municipality. In addition to the appreciation of the value of external partnerships was the recognition that to have maximum impact, MPHPs needed to embrace – and be embraced by – all sections of council operations. A new perspective to enable local governments to integrate social dimensions of health was required to provide the new framework with a sound theoretical base. There was a need to develop a clearer model to underpin population based health planning and to gain greater consistency in municipal health planning across local governments, while retaining local issues and flavour. Community involvement and a sense of ownership were seen as key components to the new approach for local area planning. Community input will translate, it is hoped, into overall commitment from the community for the plan.

The survey provided a rich, diverse range of themes and issues, which gave significant insight and impetus for the development of the new municipal public health planning framework. As part of the partnership approach to development of the new framework, the findings were provided back to the field in the form of a summary (Department of Human Services 2000).

Process for development

The partnership approach used to develop the new framework has been advanced with the assistance of a skilled reference group, representing stakeholders from the field and from policy development areas. Reference group members helped shape the conceptual framework, facilitated links to key research and practice, provided material for inclusion, and commented on drafts. Development has been further enhanced by an extensive consultation process including written submissions and forums held throughout Victoria.

Consultation Findings

In April 2001, the Municipal Public Health Planning Framework: Draft Document for Consultation was released (Department of Human Services 2001). The consultation process provided an opportunity to contribute to the future direction of planning for health on a municipal wide basis.

Five consultation forums were held across Victoria in April and May 2001, allowing over 200 participants from all regions to attend. Representatives from 62 of the 78 local governments in Victoria attended the forums. At each forum, DHS presented an overview of the municipal public health planning framework that explained the rationale, process for development, and features of the document. This was followed by a brief comment by a representative from the MAV about the partnership approach needed to develop it between state and local government. With the assistance of facilitators from DHS, participants discussed in small groups the strengths and limitations of the framework, and how it might contribute to integrated planning including internally within council and with external stakeholders.

In addition to the data gathered during the consultation forums, feedback was received from written responses. Further to the questions posed at the consultation respondents were invited to:

- comment on how the framework would be used at a local level, and

- make suggestions for future directions for municipal public health planning.

Thirty-two written submissions were received, representing the input of over 70 people. A wide range of organisations responded, including commonwealth and state government agencies, local governments, statewide and local non-government organisations, and the primary care sector. Some of the respondents had also attended the forums.

There was a strong positive response to the framework document itself and its potential to improve municipal public health planning. There was a great deal of interest in the next steps to be taken to implement the new framework once finalised. Analysis of the extensive feedback generated by forums and written comments was used to strengthen the new direction in municipal public health planning. The revised document was discussed by the reference group and finalised. Comments on the next steps to be taken will be used to develop the implementation phase of the new framework.

Environments for Health

The new municipal public health planning framework is titled "Environments for Health: Promoting Health and Wellbeing through Built, Social, Economic and Natural Environments". The Victorian Burden of Disease Study shows that

Table 1: Environmental Dimensions and Corresponding Council Action Areas

Environmental Dimensions	Components	Characteristics	Council Action Areas – Examples
Built/Physical	• Provision of infrastructure • Amenities: parks, street lighting, roads, footpaths	• Liveable	• Land use planning • Transport and traffic management • Recreation facilities
Social	• Sense of community • Participation • Perceptions of safety	• Equitable • Convivial	• Community support • Art and cultural development • Library services
Economic	• Economic policy • Industrial development • Employment	• Sustainable	• Community economic development • Access and equity
Natural	• Geography • Air & water quality • Native vegetation	• Viable	• Water quality • Waste management • Energy consumption

although the overall health status of Victorians has improved over the past 20 years, it varies according to where people live (Magnus, Vos & Begg 2001). Many of the factors influencing health lie in the social, economic and physical environments in which people live. We cannot continue simply to deal with illness after it appears, or keep exhorting individuals to change their attitudes and lifestyles, when the environments in which they live and work give them little or no choice or support.

The framework emphasises the need to make environments supportive, rather than damaging, to health. This can be advanced by considering the impact on health and wellbeing of factors originating across any or all of four environmental dimensions: built, social, economic and natural.

Politicians, planners, government officials and citizens need to appreciate the reasoning and implications behind policy decisions across all four environmental dimensions. The benefits of involving these areas of council core business in addressing health issues is demonstrated in the following examples:

- Action on the built environment can include better lighting and maintenance of public spaces. Together with social programs to promote community participation such as walking groups, this action can promote physical activity, reduce injuries and crime, encourage use of public spaces, change perceptions of safety, and manage risk more effectively.

- Creating opportunities for community participation can enhance mental and physical wellbeing of specific groups, such as older people, while building local economy and community infrastructure. This might involve liaising with adult learning centres, working with libraries and local employment agencies, encouraging local commerce and services, and maintaining parks, playing fields and footpaths

- Effective action to ensure food safety and promote healthy eating might focus on local business innovation, cultural diversity and social needs for access to nutritious food, which can then contribute to both economic viability and community vitality.

Everyone has a role to play in creating supportive environments for health. Municipal public health planning offers a collaborative approach to creating supportive environments that can be used by local policy makers, decision makers and community members.

For further information

To obtain copies of the Municipal Public Health Planning Framework, and for further information, visit the Department of Human Services' website: www.dhs.vic.gov.au/phd/localgov/mphpf/index.htm

Contact

Andrea Hay, Team Leader, Local Government Partnerships, in the Public Health Division of Department of Human Services, Telephone: 61 3 9637 4755 andrea.hay@dhs.vic.gov.au

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Andrea Hay, Ron Frew and Iain Butterworth
Local Government Partnerships Team
Public Health Division
Department of Human Services
L18, 120 Spencer Street,
Melbourne, 3000, Victoria
AUSTRALIA
Email andrea.hay@dhs.vic.gov.au

Correspondence to Andrea Hay

Probing the Depths of Wastewater in Unsewered Neighbourhoods: The Theoretical Potential of Digital Soil and Septic Tank System Testing

Callum Morrison

Environmental Wastewater Planner
South Gippsland Shire Council

Wastewater management in neighbourhoods without town sewerage is one of the most complicated and challenging aspects of environmental health work. The concern now is not only how to reverse the decay of existing systems but also to reduce the "environmental footprint" of new wastewater systems, and other aspects of the built environment. Soil testing methods for designing septic tank systems have gradually improved over time, more realistically to meet rising environmental and public health expectations. The information age has recently produced a submersible computer for monitoring groundwater levels and temperatures. This same computer is perfect for accurately charting the rise and fall of wastewater levels underground.

Key Words: *Digital Septic Testing, Soil Percolation, Town Sewerage*

Rising public health and environmental expectations suggest we should be taking more care about how we manage wastewater in neighbourhoods without town sewerage. The key to this is being able to measure accurately what is going on underground. Traditionally, this would have been a very boring and smelly process, however, the development of digital testing equipment for monitoring ground water turns out to be perfect for charting the ups and downs of wastewater.

Often septic tank system failures occur when they are not being observed and usually outside of office hours for the responsible authorities. It is generally only the really obvious discharges with a lingering or invasive presence, which are noticed and sometimes reported to authorities when neighbourly relations have disintegrated. Unless authorities catch a washing machine in action, substantiating the extent of the problem can be difficult. Generally, expensive works and garden disturbance are needed to correct these problems.

The new technique involves the modified use of a narrow metal probe containing a water pressure sensor, a thermometer, a data-logging computer and batteries. Detailed readings can be taken every half-second or left recording on site for up to six years. Water levels are recorded to within millimetres and can either be studied in the field or downloaded later to a personal computer making it perfect for testing septic tank trenches.

Water level rise is proportional to wastewater flush production and fall is proportional to wastewater discharge rates. The equipment enables the plotting of system storage, recovery, and sometimes system failure. This is the sort of evaluation needed to establish simple and clear wastewater system performance and management standards. All decisions involving the spending of money on wastewater management depend largely on the confidence and understanding governments and householders have in the advice and analysis they receive. Evidence in the past has depended on the detection of microorganisms and contaminants that are largely "out of sight and out of mind". The advent of digital water level monitoring now gives the opportunity to present "water tight arguments" for satisfactory systems. Shortfalls in land capability or system condition should indicate clearly when and where wastewater could be released hazardously. These data might also aid in better targeting and timing of water sampling.

Equipment

The MiniTroll in the photograph is used to record water level and temperature readings. The probe is set and activated with a computer then disconnected and positioned in the test bore hole of the soil being tested or the distribution pit of the trench being monitored. The data are then uploaded from the probe to a computer in the field or back in the office where the wastewater discharge profile is observed. Where wastewater is entering the system from flushes there is also a record of wastewater production profile. If the wastewater production profile over time exceeds the disposal profile then water levels rise. Once the storage capacity is exceeded then wastewater might spill to the adjacent trench or burst out to the ground surface.

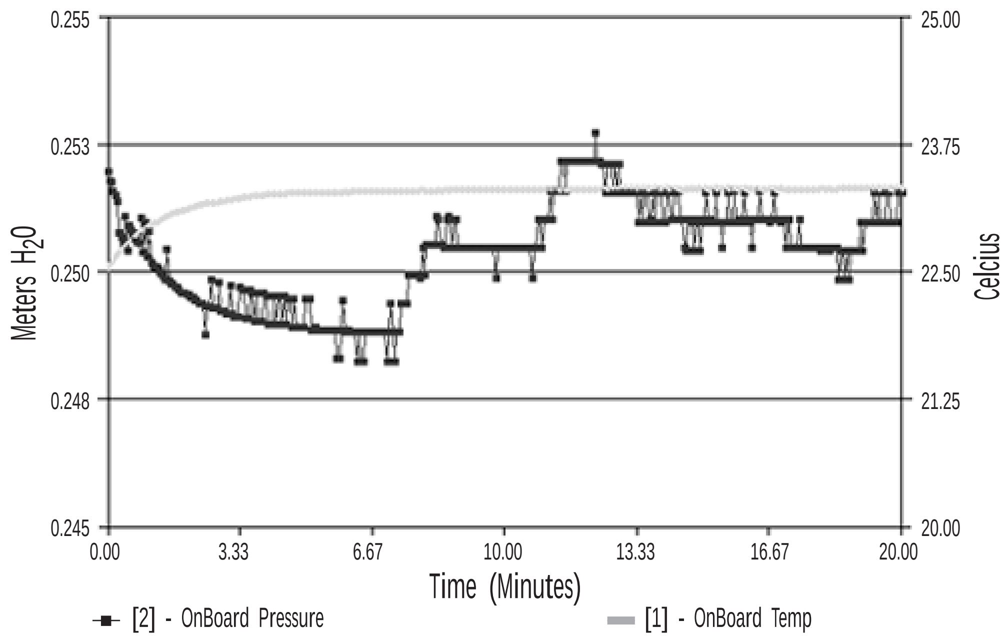
Figure 1 (opposite) shows a short plot with the discharge rate from an earlier flush which lifted the temperature of the water in the base of the distribution pit to around 23 degrees. (The septic tank water must be warmer that the trench water temperature - it was a cold wet day.) The blips in the water pressure/depth graph were caused by raindrops. Water levels rose with subsequent wastewater flushes entering.

Method

Testing methods need to be improved to communicate clearly the risks and ensure that works are accurately defined and justified. These need to determine performance standards for correction of individual system failures and sometimes extend to justifying the installation of sewer to a whole township. The use of digital water level testing data has the potential to reduce appropriately the risks to public health and the environment by more accurately measuring performance at the design, construction, and ongoing maintenance opportunities. It is possible to measure wastewater disposal trench recovery rates when known volumes of water are added to systems. Alternatively, diagnosis will involve matching discharge plots with soils of known performance.

Calibration is based on known water consumption ability and repeatedly plotting over long periods of time under a variety of operational conditions. Where system failure has been diagnosed then expansion into new soil often has to be considered for construction of an additional system. Soil profile can be tested according to the falling head method in small diameter test holes. These measurements are the sum of all the disposal, evaporation and transpiration processes corresponding to a rating for system performance rather than a rating for the soil percolation. This is exactly the information needed for more accurate computer models and databases needed for better wastewater management.

Figure 1: Korumburra septic tank



Conventional soil percolation testing has become very theoretical and does not seem to reflect adequately all of the other variables that impact on system performance. Technically, it would be possible to set up digital testing equipment that operated in a constant head environment, however, this does not accurately reflect the operational environment of trenches in which water levels fluctuate. It is important to recognise that soil percolation rates vary enormously in the walls and base of trenches. Rather than trying to calculate accurately soil percolation rates and making all sorts of assumptions, it is thought that just identifying various types of test hole and trench discharge profiles, might be more realistic. Each test hole and trench could generate its own performance fingerprint and matching this with known reference standards should enable quick and accurate performance predictions.. These reference standards might be repeatedly monitored over long periods of time and in a variety of conditions also enabling models of system decay to be devised.

Soil testing

Presoaking small diameter bore test holes for 24 hours then running a digital falling head test will identify the soil discharge profile.

Disposal trench testing

Trenches are usually presoaked regularly by daily use. The probe can be left in the trench until an accurate picture of the discharge profile is clear providing consistent discharge patterns. Sometimes the best plots will be recorded through the night when the system is not in use.

Benefits of the Technology

The benefits of this technology could apply in many areas and be useful to a number of different practitioners and stakeholders. Some of these are discussed below.

Councils and Environmental Health Officers

Unfortunately land capability assessment and soil percolation testing is currently a very expensive and time consuming process carried out by consultants using complicated and subjective testing processes. Large variations in test results occur across sites and some consultants might be repeating tests until they record the desired test result.

Digital testing will give Councils the opportunity to undertake their own assessments, or ask for a second independent test after a system has been constructed to validate the original site assessment. This will mean that no matter what site assessment criterion is used, whether it is a green stick water diviner or the latest proposed digital soil testing, a true measure of whole systems constructed performance can be tested at any point in the operational life of the system.

Complaint resolution should be easily resolved by running clear and simple tests that everyone can understand. There will be a choice of clearly proscribed solutions that can be confidently implemented to resolve the problem. Local conditions will be measurable and new installations could be better adapted.

Environment protection authorities and state health departments

Digital testing allows more stringent testing and measurement of individual system design performance. Testing of old systems might clearly identify risks and problems in need of correction. Threats to ground water quality and water supply catchments will clearly be quantifiable.

The current Land Capability Assessment criteria suggest that conventional septic tank systems do not work effectively in areas with high average annual rainfalls. Digital analysis is likely to assist with development of system designs capable of withstanding certain rainfall events. There is evidence that certain soils and system designs such as mounding of systems might be able to withstand longer or higher periods of rainfall. The effects of dilution of wastewater in run-off could be checked more effectively when more is known about underground wastewater levels.

The manufacturers of components with "Certificates of Approval" from authorities will be able to have their claims tested accurately. An example of this might be the claim that some treated wastewater systems can be safely discharged into smaller trench systems.

Householders

Householders will be given far more reliable information about the performance of the systems that they choose to construct. Choices of plants from lawn type to tree type will be provided with attributes such as wastewater uptake, wastewater filtration ability, maintenance aspects such as frequency of mowing, ease of mowing, and any negative aspects such as root blockage of void space.

During the life of a building in a neighbourhood without town sewerage the wastewater production volumes generated can vary enormously with the stage of life and lifestyle of the occupants. It is important to make sure there is adequate provision of space for the highest volume of wastewater likely to be generated, and that this space is reserved for this use if ever required. This new technology will enable the forecasting of system performance as we learn more about the rates of system decay and the importance of system maintenance.

Land developers

Accurately knowing land capability and system design performance could greatly aid in the design of subdivisions providing better integration of individual site uses and better compatibility between neighbouring allotments. Sustainable wastewater systems take up enormous areas and there might have to be arrangements made between neighbouring land holders to ensure the passage of wastewater through the soil is not disturbed or disrupted. Accurately knowing how systems will perform and being able to monitor system performance will enable a reduction in the massive safety margins and reserve areas likely to be required by responsible authorities in the future. It is also likely that some lower cost and lower maintenance blocks with known limited capacity could be approved with clear constraints and management plans to limit wastewater production.

Land capability assessors

Land capability assessment should be demystified in most circumstances and better developed because of the rigorous testing of systems that will follow to validate the capability assessment methods. Digital soil testing should enable more accurate land capability assessment and validation of assessments could easily be carried out.

System component designers

Manufacturers of commercial wastewater system components will be able to chart more accurately the disposal performance of their units, and provide more accurate performance data on how their system performs in relation to other units. It will be possible to monitor the negative or positive effects of clogging depending on the situation. The introduction of various synthetic fabrics to aid distribution, filtration and soil protection will be able to be measured. The positive attributes of naturally heating wastewater in irrigated composting systems (worm farms) will be able to be monitored along with the benefits if infusion with composting bacteria and liquid compost. The effects of encouraged earthworm activity in the surrounding soil structure will be able to be measured.

System installers

The skills of installers will clearly be able to be measured with each trench that is dug being tested for disposal rating and storage capacity. The skills involved with surveying sites, preserving ground structure, and choice of materials will show up in these tests.

Integration of systems into confined spaces with competing uses and threats has to be undertaken with a great deal of care. Digital testing should take out some of the guesswork to utilise space more effectively, and maximise the beneficial uses of wastewater for growing vegetation.

Smart wastewater management systems are likely to result from digital analysis and design of system performance. Systems, which sense the capacity of the site to take water, are probably not that far away. This technology will sense when capacity is going to be exceeded and hold back flow in storage until the sun comes out and disposal or reuse capacity returns.

Wastewater system maintainers

The importance of good maintenance programs will become clear thus encouraging the servicing of components, desludging and protecting systems from contamination damage. More systems are likely to be placed on programmed maintenance.

Wastewater system repairers

Plumbers will be able to test accurately the capacity of systems requiring repair, measure the capacity of soil, and then test the system once it has been constructed.

Water authorities

Many townships have wastewater systems in a poor condition and the current range of technical solutions might be far more expensive than town sewerage in some situations. Digital testing should make the right choices clear and satisfy authorities that investment is well directed.

Authorities responsible for wastewater management in areas without town sewerage

Calculations with system performance data and town water meter readings will provide useful information to predict reasonable times to justify desludging, servicing and upgrading of wastewater systems. Well-founded checks to determine the condition of systems will give the database the information it needs to minimise risk of system failure and keep wastewater under control. This will minimise expense and inconvenience as well as provide a valuable planning tool for any larger infrastructure that may be required.

Conclusion

The thought of throwing computers into septic tank systems would probably appeal to those who find computers frustrating. Surprisingly, it appears that training computers to work in some of the most inhospitable and hazardous human environments might radically and positively change the way we view and manage wastewater.

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Callum Morrison
Environmental Wastewater Planner
South Gippsland Shire Council
9 Smith Street
Leongatha, 3953, Victoria
AUSTRALIA
Email callumm@sgsc.vic.gov.au

Epidemiology: An Introduction

Graham Moon, Myles Gould and Colleagues

Open University Press, Allen & Unwin, 2000, 190 pp. $49.95, paperback

Epidemiology: An Introduction is a book in the Open University Press series "Social Science for Nurses and the Caring Professions". The series editor's preface states that the book will "enable nurses to understand epidemiology, become aware of the major findings from epidemiological research and critically evaluate research papers" and also that it will provide a basic guide for those wishing to carry out epidemiological research. The first chapter is titled "What is epidemiology?", chapters two to six form the first major section of the book on design and analysis of studies, and chapters seven to ten a second section on assessing studies and applying epidemiology.

The book suffers from a shallow, often poorly argued and presented discussion of the basics of epidemiological study design and analysis. On the positive side, it encourages critical thought, for example, the bias in epidemiological work on smoking and occupation towards explaining disease on the basis of individual behaviours rather than occupational exposures, is discussed. Readers will gain some insight into why modern epidemiology has been criticised on the grounds that an obsession with methods has led to a loss of focus on the social causes of health and disease (Krieger 1994). Placing epidemiology in a broader social context is one of the book's strengths, however, the book is not well written or edited. A dearth of commas makes it difficult to read. Tenses are mixed. At times the language used is bizarre, for example a systematic review is described as "vigorous and trustworthy" (p. 135). There are many examples of loose, ambiguous statements that are likely to confuse epidemiological neophytes. For example, when discussing standardisation the authors state: "To make comparisons between sets of continuous data, the researcher has to ensure that the measurements are defined in exactly the same way. This may involve standardising to refer to a common base or denominator or may involve ensuring that the definition used in the numerator is consistent" (p. 38). This is all very well, but one is left wondering what is really being discussed.

In summary, this book provides a broad introduction to epidemiology and its context. Given its broad coverage it gives adequate depth to the areas covered, however, it is marred by a lack of clarity. Consequently, readers are unlikely to gain an adequate introduction to epidemiological methods, and the book certainly would not suffice as a basic guide for those wishing to undertake epidemiological research. Anyone with a blossoming interest in epidemiology would do better to buy one of the established textbooks (for example, Beaglehole, Bonita & Kjellstrom 1993; Hennekens & Buring 1987), which while they do not provide much coverage of the social context of epidemiology, give a far better introduction to epidemiological methods.

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Dave Harley
Tropical Public Health Unit
Queensland Health
PO Box 1103
Cairns, Queensland, 4870
AUSTRALIA
Email Dave_Harley@health.qld.gov.au

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Australian Institute of Environmental Health

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I wish to apply for: ☐ Admission to *OR* ☐ Advancement within the AIEH.

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☐ Indigenous Health
☐ Environmental Management
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PO Box 2222
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