He Kainga Oranga/**Housing and Health Research Programme**

Housing, Heating and Health Study: 2005/2006 Report One Aims and methods

Prof Philippa Howden-Chapman and Housing and Heating Research Team[1]

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[1] Professor Julian Crane, Michael Baker, Nevil Pierse, Sarah Nicholls, Helen Viggers, Jo-Ani Robinson, Julie Gillespie, Luca Quaglia, David Shields, Kristen Wickens,University of Otago (Wellington)
Associate Professor Ralph Chapman, School of Geography, Environment and Earth Sciences, VUW
Dr Malcolm Cunningham, BRANZ
Professor Alistair Woodward, Dr Chris Bullen, School of Population Health, University of Auckland
Professor Chris Cunningham, Dr Robyn Phipps, Pär Fjällström, Mikael Boulic, Massey University
Dr Bob Lloyd, University of Otago (Dunedin)

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ŪPOKO KI TE URU HAUORA

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Summary

Four hundred and sixteen households have been successfully enrolled in the Housing, Heating and Health Study in Porirua, the Hutt Valley, Christchurch, Dunedin and Bluff.

In winter 2005, baseline data were collected and have been double-entered into an extensive database. Descriptions of some of these are presented in this report.

Several meetings were held in each area to describe the heating options, which were available free of charge to the participants. Households were randomly assigned to either the intervention or control group. All uninsulated houses were insulated over the summer and heaters were installed in the intervention group houses.

Follow-up measures began in June 2006 and will continue until September, when face-to-face follow up interviews will be held.

The study is proceeding smoothly according to the protocols and preliminary results will be available at the beginning of 2007.

Introduction

Despite the fact that we spend about three-quarters of our lives inside, we still know surprisingly little about the specific health effects of the indoor environment (Howden-Chapman 2004; Sundell 2004). Indeed, the indoor environment has received much less attention that the outdoor environment. Yet the indoor environment has consistently higher concentrations of pollutants than the outdoor environment and some types of indoor heating can increase outdoor air pollution.

Our Housing, Insulation and Health Study, a community-based trial of retrofitting homes, found that the temperature in most New Zealand homes was about two degrees colder than recommended by the WHO, but that retrofitted insulation had a beneficial effect on the occupants' fuel bills, health and sense of well-being (Howden-Chapman, Crane et al. 2005; Howden-Chapman, Crane et al. 2006). A cost-benefit analysis of this study indicated that the tangible health and energy benefits of insulating a house outweighed the costs by a factor approaching two, when calculated in present value terms at a five percent real discount rate over 30 years (Chapman, Howden-Chapman et al. 2006). This is a conservative estimate, as the potential avoidable mortality from cold homes, which has been calculated in a British study to be a two percent increase for every degree below the WHO recommendation of 18^{o}C, has not been taken into account (Wilkinson, Landon et al. 2001), nor have rises in real fuel prices.

Yet most of the temperatures in houses with retrofitted insulation, were still below 18^{o}C. Indeed, the 2001 Census showed that three percent of New Zealand households were unheated. There have been a number of cross-sectional studies of home heating and morbidity which have shown that the type of heating indoor environment has an effect on health, particularly the respiratory symptoms in children (Bothwell, McManus et al. 2003) (See Appendix One for more detailed literature review).

Aim

The aim of this study is to see whether the absence of insulation and more sustainable home heating is a significant factor in occupants' morbidity and energy usage.

Subjects

Four hundred and sixteen children and their families were included in this study. The inclusion criteria were: a child, 6-12 years old with doctor diagnosed asthma living in a household where the main form of heating was a plug-in electric heater or unflued gas heater.

Table One: Flow of Participants in Study

Total Applications	899
Applications Rejected	378
Accepted for Baseline measurements	521
Moved in Year 1	35
Forms not returned*	39
Did not meet criteria+	13
Withdrawn by Community Worker no follow up	8
Person withdrew themselves	20
Completed Baseline	406
Moved	8
Withdrawn by Community Worker	7

* Unable to make contact after at least three phone-calls, two letters and community worker visits, it is probable that these households have moved, but we are unable to confirm this.

+ Did not meet entry criteria and were dropped when this finally became clear after cross-checking with building inspectors

Setting

The study is being carried out in five communities: Porirua, the Hutt Valley, Christchurch, Dunedin and Bluff.

Method

After obtaining multi-centre ethics approval, letters of invitation to participate in the study were initially sent out to local primary health organisations (PHOs) and asthma societies. Nine organisations agreed to participate and these organisations were kept in regular contact by the researchers through telephone calls and newsletters. [2] These community organisations identified

[2] Te Runaka o Awarua – Bluff
Otago Asthma Society – Dunedin
Pacific Trust Canterbury – Christchurch
Community and Public Health – Christchurch (replaced Te Amorangi Richmond in 2006)
Tu Kotahi Maori Asthma Trust – Hutt Valley
Community Planners – Mid Valley PHO – Hutt Valley
Waiwhetu Marae – Hutt Valley
Porirua Health Plus – Porirua
Te Ropu Awhina – Porirua (contracted in 2005 only)
Community organisation funding was provided by the HRC.

community coordinators, who were employed by the community organisations and trained by the researchers both centrally and locally in the details of the study. The community coordinators were employed to recruit families and then work with these families to ensure all measures are collected correctly and in a timely fashion.

Participants were recruited through the PHO and asthma society databases of children with asthma and then through opportunistic attendances at local meetings. Press releases were made to local, national newspapers as well as school newsletters (See Appendix Two). Several members of the research team gave national and local television and radio interviews on public, commercial and ethnic radio stations, which gave a free-phone number for those interested.

All applicants were telephoned to thank them for their application and some of their details were checked. Applications that meet the criteria were sent to retrofit teams to audit whether the house had insulation and the type of heating used. In some cases community workers made home visits to get more information (e.g. to check whether household has **both** flued and unflued gas heater as stated).

Provisional acceptance or rejection letters were then sent out or in some cases where the family was on the case-load of the community worker, she took out provisional acceptance and 'rejection' letter to those who do/do not qualify. Wherever possible these households were offered a 'consolation prize', such as retroffited insulation. Tenants gained approval from landlords with the community worker's help if necessary. Approval for Housing New Zealand Council houses was obtained centrally.

Initially researchers trained the interviewers centrally. At the beginning of the follow-up period researchers visited each site to train the community workers at their organisation's offices or marae. The training included:

- a description of the seven different forms the participating households have been asked to fill out over this winter and mock interviews to familarise the community workers with them
- details on the i-buttons (temperature recorder), how they operate are where best to place them
- an explanation of the Palmes tubes (for measuring NO2) their placement and how to replace them
- standardising the technique used in the PIKO meters (measures lung function), and an explanation on how to download them and how to deal with common problems in there operation.

After training, the community workers visited each household to explain the study in person to the head of household, the type of heating was double-checked and each member of the household was asked to sign informed consent forms. The community workers coordinated arrangements with the local retrofit teams to insulate the houses if they were uninsulated. They also explained the child's peak flow meter (See Appendix Three), the daily recording sheets for the child identified with asthma and the rest of the family. All households had calibrated digital Thermocron iButtons that monitored temperature and Palmes tubes that monitored Nitrogen

Dioxide levels both in the in the living room and child's bedroom (See Appendix Three). At baseline community workers were supposed to visits family monthly with fortnightly phone call, but due to hitches in some communities there was less contact than planned.

In September/October 2005 community workers interviewed the head of the household and all members of the household to fill in self report questionnaires. In November the community workers arranged meetings/ *hui/fono* to which all participants were invited to discuss the study with the research team, answer any questions and get the information to decide on the heater of their choice. The main intervention was the installation of a sustainable heater that was capable of generating at least 6 KW (Westergard and Chapman 2005).

The pros and cons of the three heater types (heat pumps, wood pellet burners or flued gas heaters) were explained to the participants at community meetings, questions were answered and the full report was placed on open access in the research website [www.wnmeds.ac.nz/healthyhousing.html]. Homeowners and landlords were asked to choose their preferred heater. All uninsulated houses were insulated. [3]

Once all the measures were collected, the households were randomised to either the intervention or control group and sent a letter detailing which group they had been assigned to. In 2006, after a public tender to select the heater models, the heater of their householders' choice was installed in the autumn months before winter.[4]

After retraining all the community workers, at the end of May visits to all householders began. The iButtons and Palmes tubes were placed ready to begin recording in mid-June until mid-September.

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[3] Each house was insulated to current EECA insulation specifications (regional variations applied) and measure included: ceiling insulation; sissalation foil (under floors); draught stopping doors; and draught stopping windows. EECA provided part funding for the insulation through a EnergyWise Home Grants Strategic Partnership, the remainder was funded by the HVDHB, MOH and Contact Energy. Insulation was provided and installed by Energy Smart in the Hutt Valley and Porirua, CEA in Christchurch, Kati Huirapa Runanga Ki Puketeraki in Dunedin, Bluff.

[4] *Heater Choice.* Once householders and landlords had made their decisions about their preferred heater type, the following heater types were chosen after a competitive tender process (managed by Smart Power) and were as follows:
Flued Gas Heater, only 11 (6 in 2006 and 5 in 2007) were chosen so the WSM is managing this work independently. Heaters have been purchased from Hutt, Gas and Plumbing, so far 4 have been installed (with 2 waiting on further work) the type of heater installed is Rinnai.
Wood Pellet Burner , 30 have been installed in the first batch with approximately another 25 due to be installed at the end of the study. Solid Energy (Natures Flame) were the only NZ supplier and installer and the only organisation that was able to fulfil the contract. The model installed is the Classic (EF2) either insert or freestanding unit.
Heat Pumps, 159 have been installed in the first batch with approximately another 160 due to be installed at the end of the study. Air Con NZ were successful at winning the tender and the type used are either Mitusbishi or Fujitsu, various sized models have been used depending on the size of the space that needs to be heated. Model information for Mitsubishi can be found at http://www.bdt.co.nz/comfortmaster/group.asp?category=7008. Funding for the heaters has come from the Contact Energy, MOH, HVDHB, CCDHB, MFE.

In September/October, community worker checks with PHO whether child has had visits for asthma during winter (June, July, August). At the conclusion of the study in October 2007, researchers will check with local schools as to whether the children had had days off during the winter months (June, July, August, September) of 2005 and 2006.

At the end of the follow-up measures, the households in the control group will also have the heater of their choice installed.

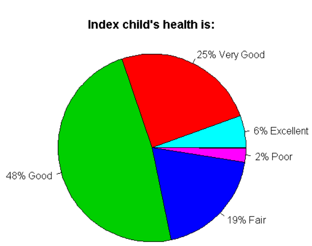
Intensive Monitoring

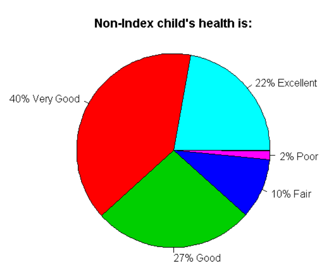
In the baseline year 2005, 33 households in the Hutt were intensively monitored for up to a week. Measures collected included nitrogen dioxide, formaldehyde, carbon monoxide and dioxide, fungi, moisture, temperature and heater usage. In 2006 40 houses are being monitored in the Hutt and 10 in Dunedin (see Appendix Four).

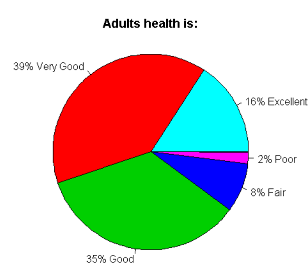
Results

The Index children, with doctor-diagnosed asthma, have poorer health than their siblings or the adults in the households, which were reflected in their greater number of sick days.

	Index Children	Non- Index Children	Adults
% Doctor Diagnosed Asthma	99%	48%	40%
% Had GP visit for Breathing problems during last winter	69%	45%	27%
Median number of GP visits (where not zero)	2	2	2
Mean number of GP visits (where not zero)	2.8	2.6	2
% With Sick Days off Work/School Last Winter	86%	78%	60%
Median number of Sick Days (where not zero)	6	5	4
Mean number Sick days (where not zero)	8.1	7	5.9
% Wheezing last winter	68%	37%	34%







Four a fuller presentation of the baseline results see Appendix Four.

Discussion

The study is more than half-way through and is progressing remarkably smoothly. It is a challenging study, which entails working with many different community agencies and private organisations; there are a total of 18 contracts, which add to the complexity of the research project.

Fund-raising has been time-consuming and more prolonged than we had envisaged, but we are pleased at the broad support we have received at this stage. The study has been funded by a number of public and private funders. The Health Research Council of New Zealand, Contact Energy, Ministry for the Environment, Hutt Valley District Health Board, Capital Coast District Health Board, EECA, LPG Association.

An aim of the study was to increase capacity for our community partners by providing additional funding and helping boost exposure; some organisations have increased PHO numbers by working with families that were recruited centrally. Feedback has been received both to the community organisations and to the research team praising both their work and the importance of the study. Anecdotal evidence has been provided on the improvements felt as a result of new insulation and new heaters, and when meeting with all community workers if has been great to hear that they feel energised by the positivity and interest of the families they are working with. PHOs particularly in the Hutt Valley have met to learn from each other and discuss difficulties and successes. The study has also provided positive spin offs for the communities. In Wainuiomata where there is not a local supplier of wood pellets (a necessary purchase to run their wood pellet burners) the families have got together and purchased wood pellets in bulk, not only giving them a chance to get together and discuss their participation in the study but also to save themselves money and time.

There is a considerable media interest in the study, but until it is completed we want as little publicity as possible in order not to contaminate our study design. We will be developing a communication strategy with our co-partners and funders in time for the release of results.

Appendix One
Health Effects of Poor Heating

Excess winter mortality has consistently been found to be more pronounced in temperate rather colder climates, suggesting that houses in these regions poorly protect occupants from the weather (Curwen 1990/91). There has been considerable uncertainty about why this phenomenon occurs; both behavioural factors and poor housing may be important (Keatinge, Coleshaw et al. 1989; Wilkinson, Landon et al. 2001). However, a British study of those 75 years and older, found little evidence for vulnerability to winter death being associated with any of the factors thought to lead to vulnerability (Wilkinson, Pattenden et al. 2004), a surprisingly consistent finding (Shah and Peacock 1999; Aylin, Morris et al. 2001; van Rossum, Shipley et al. 2001; Lawlor, Maxwell et al. 2002). One explanation may be that home-heating may be, at least in Britain and New Zealand, one luxury good that is *not* consumed disproportionately by those on higher incomes (Wilkinson, Landon et al. 2001; Isaacs, Amitrano et al. 2003). In Britain, the reason for this may be that housing association and local authority dwellings are often as well, or better, heated than owner occupied dwellings (Wilkinson, Landon et al. 2001). However in Ireland, the poorest individuals tend to spend three times more than those on average incomes on energy relative to their incomes (Clinch and Healy 1999).

One major review of the seasonality of mortality throughout the world speculated that the increasing use of central heating and been a principal cause of the general reduction in the magnitude of seasonal swings during the twentieth century, but without definite evidence (Sakamoto-Momiyama 1977). In a cross-country analysis of key risk factors related to excess winter mortality in Europe Healy noted that the strong positive relationship with environmental temperature and the strong negative relation with thermal efficiency indicated that housing standards in southern and western Europe play a strong explanatory role (Healy 2003).

The evidence suggests that there is a greater increase in winter mortality from respiratory rather than coronary disease (Collins 1983; Collins 1993; Collins 2000). But, the risk factors for cardiovascular conditions, such as blood pressure, cholesterol and the clotting factor fibrinogen, also vary seasonally (Khaw and Woodhouse 1995). Arterial blood pressure, particularly among older people, increases significantly after two hours exposure to temperatures below 12oC (Collins, Easton et al. 1985). Accidents in the home are also more common in winter. This appears to be related to the effects of lower body temperature on mental functioning or to cold-induced impairments of movement or sensation. Finger strength and manual dexterity have been shown to decrease progressively as indoor temperatures fall from 26ºC to 6ºC (Raw, Aizlewood et al. 2001).

Natural experiments like the introduction of central heating in the Netherlands in the 1970s has also been explored with inconclusive results (Sakamoto-Momiyama 1978; Keatinge, Coleshaw et al. 1989). A detailed study of the decline of excess winter mortality concluded that the strong reduction over time in excess winter mortality cannot be attributed to a single cause of death and that central heating central heating could have played only a small part as the decline had occurred previously and may have been related to better construction materials in the 1950s and 1960s (Kunst, Looman et al. 1991).

A further consideration is that the demand for space heating is one of the contributors to carbon emissions and housing, like the rest of the built environment, needs to be prepared for climate change, although much of the technical and policy-making community have been reluctant to address this problem in new or existing buildings (Lowe 2003).

New Zealand has lower space heating intensity than Europe, Australia or Canada (Schipper and et al 2001) despite having some of the cheapest electricity in the OECD (Ministry of Economic Development 2003). Most people only heat the living room and occasionally a bedroom (Isaacs, Amitrano et al. 2003). Poorly constructed and older houses are more difficult and expensive to heat. Inadequate household warmth can have health consequences for the occupants, particularly during winter (Boardman 1991; Wilkinson, Landon et al. 2001). Domestic energy efficiency is linked with health because money spent on energy cannot be spent on other necessities such as food (Healy 2004; Heyman, Harrington et al. 2005). Colder houses place more physiological stress on older people, babies and the sick, all of whom have less robust thermo-regulatory systems and are likely to spend more time inside (Curwen 1990/91). Houses that are cold are also likely to be damp and this can lead to mould growth, which can cause respiratory symptoms (Tobin, Baranowski et al. 1987; Institute of Medicine of the National Academies 2004). This link between inadequate heating, damp, cold and mouldy houses and poor health has been highlighted in a number of international reports (Acheson 1998; Department of Health 1998; Howden-Chapman and Tobias 2000; Bonnefoy, Braubach et al. 2003; Institute of Medicine of the National Academies 2004). Surprisingly, excess winter mortality has consistently been found to be more pronounced in temperate rather than colder climates, suggesting that houses in these regions poorly protect occupants from the weather (Curwen 1990/91; The Eurowinter Group 1997).

Appendix Two
Housing, Heating and Health Study Media and Related

Morning Report and Radio Live, Housing, Heating and Health Study, May 2006

NZPA, ODT, The Press, Bay of Plenty Times, Housing, Heating and Health Study, May 2006

TV1 News, Asthma and Insulation, 28 February 2006.

Morning Report, Housing, Heating and Health Study, 30 September 2005.

Linda Clark Nine-noon Unflued gas heaters Wednesday 29 June 2005

TV1, Close-Up, Housing, Heating and Health Study, June 2005

The Dominion Post, May 11 2005

Howden-Chapman, P, Judge ECCA Energywise Awards 2006

Howden-Chapman, P, Presentation *Healthy Buildings 2006* Portugal 4-8 June 2006

Chapman, R, Poster Presentation *Healthy Buildings 2006* Portugal 4-8 June 2006

Phipps, R, Poster Presentation *Healthy Buildings 2006* Portugal 4-8 June 2006

Baker, M Presentation *Australasian Housing Researchers Conference,* Australia 19 – 21 June 2006

Boulic, M Presentation *Environmental Toxicology Conference,* Australia 11-12 July 2006

Appendix Three
Equipment specifications and setting

Piko Meters

Pikometers are manufactured by Ferraris Respiratory. They are the world's first pocket sized electronic peak flow and FEV_1 meter, and are easy to use - just one operating button. There is electronic storage of the last 96 readings. The peak flow readings have a range of 15 - 999 l/min with 1l/min resolution, to an accuracy to ±5% or 20 l/min (whichever is greater). The FEV_1 readings have a range of 0.15 - 9.99 litres with 0.01 litre resolution, and to an accuracy of ±3% or 0.1 litre (whichever is greater). The sensor uses pressure/flow sensor technology (patented).

The designated child in each family should use the meter every morning just after they get up; and again at night just before they go to bed. Three to five readings should be taken and the piko meter will choose only the best measurement to record. In 2006 the children have also been asked to record the measurements in the symptom diaries provided.

How to use a piko meter

1) To turn the meter on, press the blue button once. You will see the results of the last reading on the screen
2) Your child should stand up, and press the blue button again. When the meter beeps twice it is ready to start
3) Your child should breathe in as much as he/she can
4) Then put the mouthpiece in his/her mouth. Making sure make sure their hand isn’t covering the vent-hole that the breath comes out of
5) Then your child should breathe out as hard and fast as he/she can, and keep on breathing out for as long as they can
6) If there is a long beep then it means that either the reading is very low or that there was some problem with it – maybe your child coughed when doing the reading, or didn’t blow for long enough (the piko meter needs a longer blow than some other meters), or the blow started slowly. Try again.
7) Return to step 2 to do repeated readings.
8) The Meter will turn itself off when you have finished.

iButtons

One of the parameters that will be monitored in the Heating and Asthma study is the temperature in the bedroom and in the living room over an extended period of time. Ideally the monitoring should be performed on a period of three weeks, at a rate of three or four measurements per hour and with an accuracy of 0.5°C. In order to accomplish this task, the device selected is the Thermocron iButton DS1921G manufactured by Dallas Semiconductor.

The iButton is a digital device able to measure temperature and to record the result in a permanent memory. It is formed by a self-sufficient microchip encased in a stainless steel case. Its external appearance is similar to a wrist clock battery. Every iButton has a unique digitally readable serial number for perfect traceability. The iButton can store up to 2048 readings at equidistant time intervals. The time of each measurement given by an internal clock is also store at the same time. This gives the knowledge of the whole time series of measurements. Setting the time interval equal to 15 minutes, the iButton can record data for slightly more than three weeks. Setting the time interval equal to 20 minutes, the recording time becomes a bit more than four weeks.

Data are exchange between the iButton and a computer by a special USB device. This device allows the setting of a starting date for the mission of the iButton, the setting of the sampling rate and the synchronisation of the internal clock. The same USB device allows the reading of the characteristics and of the result of a mission.

Temperature is measured in 0.5°C increments with a manufacturer guaranteed accuracy of 1°C. Nevertheless the accuracy can be increased to 0.5°C performing a calibration of the iButton in a laboratory. The calibration consists in putting the iButton in an environment at a known temperature and then comparing the reading of the iButton with the value of the known temperature. This comparison tells us if the iButton reads the temperature with an offset and, in that case, the amount of the offset. For practical reasons, we have chosen to perform the calibration at two temperatures which brackets the range of usual room temperatures: at 0°C and at 30°C. We have performed the measurements at 0°C putting the iButtons in a mixture of liquid water and melting ice. In order not to have a great difference in temperature between the mixture and the surrounding air, everything has been put in a fridge so that the ice can melt slowly. The measurements at 30°C have been performed using a water bath. Even if the water bath could work below the room temperature, we have chosen a higher temperature that is much easier to maintain for a prolonged period of time. Knowing these offsets (if they exist), we can thus correct the measurements taken by each iButton and attain an accuracy of 0.5°C.

Example of offset distribution for a particular set of 88 iButtons

OFFSET (in °C)	PERCENTAGE OF iButtons
-0.5	43%
0	42%
+0.5	15%

Palmes Tubes

We determined exposures to nitrogen dioxide with Palmes passive samplers (Palmes, Gunnison et al. 1976). Palmes tubes measure the average amount of oxides of nitrogen in the air. We think that the amount of oxides of nitrogen in the air may have an effect on children's asthma. In the winter of 2005 the study installed Palmes tubes into 285 of the study households.

This year the Palmes tubes will be installed during the months of June to September into all study homes. Both the living room and the bedroom of the index child will have tubes installed with the tubes being swapped every four weeks.

The Palmes tubes are attached to the wall with a bracket so that the tube is

*held vertically (and the grey cap will be on top),
*about 1.8m (a raised adult arm height above the floor),
*away from curtains
*somewhere air can circulate around it
*and out of reach of children
*(if possible it should be away from doors and windows).

There are two caps on each 71mm long acrylic tube, one of which is removed when the Palmes tube is installed, the other stays on the tube all the time. The cap-to-be-removed is white, and the cap-not-to-be-removed is grey. Contained under the grey lid there are two metal mesh grids, which are coated in a 20% Triethanolamine (TEA) and water solution, this acts as an absorbent for the oxides of nitrogen, in particular nitrogen dioxide. The nitrogen dioxide penetrates from below by diffusion in the tube according to Fick Laws and is absorbed by the TEA giving rise to the formation of the nitrosodiethanolamine (NDEA) and is then spectrophotometrically measured out as nitrite (lambda 540mm), according to the Griess-Saltzman reaction (Panella, Tommasini et al. 2000). The average concentration of nitrogen dioxide can then be derived from the quantity of nitrogen dioxide obtained from a standard curve, in relation to exposure time, to the nitrogen dioxide air diffusion coefficient and to the known dimensions of the passive samples.

Appendix Four

Paper in Conference Proceedings

Not Just Hot Air: Methods and Preliminary Results for the Intensive Monitoring of Emissions and By-Products from Two Types of Domestic Heaters.

Robyn Phipps[1], Malcolm Cunningham [2], Pär Fjällström[1], Mikael Boulic[1], Philippa Howden-Chapman [3], Julian Crane [3], Michael Baker[3], Helen Viggers[3], Jo-Ani Robinson[3], Sarah Nicholls[3], Bob Lloyd [4], Ralph Chapman [5]

[1] Massey University, Institute of Technology and Engineering 456, Palmerston North, New Zealand
email: R.A.Phipps@massey.ac.nz
[2] Building Research Association of New Zealand
[3] *He Kainga Oranga*/Housing and Health Research Programme, University of Otago (Wellington)
[s4] Department of Physics, University of Otago (Dunedin)
[5]Department of Environmental Studies, Victoria University

Summary: *Intensive air quality measurements were made for up to a week in a sample of 33 homes drawn from a 500 home Heating, Housing and Health interventional community trial. Measures include nitrogen dioxide, formaldehyde, carbon monoxide and dioxide, fungi, moisture, temperature and heater usage. Families with an asthmatic child and where their primary means of heating was a plug-in electric or unflued gas heater were enrolled in the trial. Baseline measures were completed in 2005 and in 2006 a randomly selected 250 households will be given a heat pump, flued gas heater or pellet wood fire. All environmental measures will be repeated in 2006.*

Keywords: *domestic heaters, indoor air, emissions, dampness, nitrogen dioxide, fungi, insulation*

1 Introduction

New Zealand houses are generally low density structures constructed from lightweight timber or more recently some steel framing. They often have lightweight wall and roof cladding of brick veneer, timber weather board, solid plaster, profiled metal sheet products or masonry tiles. Single glazing is the norm.

Homes constructed prior to 1978 were not required to have any insulation installed at the time of construction and if this has been retrofitted it most likely only found in the roof cavity. Although the New Zealand climate is relatively mild, houses are typically under heated with indoor winter temperatures falling frequently below the World Health Organisation recommended level of 18℃. Studies conducted during winter have found overnight indoor temperatures as low as 12-13℃ deg with a relative humidity above 75% (Isaacs et al, 2005). Consequently dampness and fungi frequently occur.

Central heating is only found in about 5% of New Zealand houses. Portable electric and portable gas heaters are used in over 70% and over 30% of homes respectively (Branz, 2006). Unflued gas heaters (UFGH) are the only heater type that is growing in prevalence, even though there is evidence that they emit directly into the indoor air moisture and combustion products (Pilotto et al ., 2003). Combustion products include nitrogen dioxide, carbon monoxide, carbon dioxide, and formaldehyde.

The Group's *Housing, Insulation and Health Study* found insulating homes gave improvements in dampness, warmth, energy use and health of the occupants', but raised the question if larger capacity and non emitting heaters could increase these gains and improve the indoor air quality.

2 Method

A 400 household interventional trial is underway where families whose primary means of heating is either a plug-in electric or unflued gas heater and who have an asthmatic child are enrolled in the *Housing, Heating and Health Stud*y. In the winter of 2005, uninsulated houses were insulated and baseline temperatures in the living room and index child's bedroom, 1 week averages of nitrogen dioxide and objective and subjective health measures were collected.

Intensive indoor air monitoring was conducted in a subsample of 33 homes drawn from the main trial group. These homes were all located in a semi coastal geographic region called Lower Hutt, which is a predominately residential area with some light industry located close to the Capital city of Wellington.

Measures included nitrogen dioxide (NO_2), formaldehyde (HCHO), carbon monoxide (CO), carbon dioxide (CO_2), temperature (T), relative humidity (RH), viable fungi and available moisture. Continuous measurements of the volatiles as well as temperature and relative humidity were made in the index child's bedroom and the living room for between 4-8 days.

One API Chemiluminescence analyser (Model 200E, Teledyne Instruments, USA) with a switching valve was used for monitoring both rooms interchangeably with 10 minutes intervals. These units were typically mounted in the cavity of the roof space with 15m Teflon sampling lines running to the test rooms with an inlet just under the ceiling.

One set of gas probes for monitoring CO, CO_2, RH, T (Gasprobe IAQ-4-DL, BW Technologies, Canada) and formaldehyde (Formaldemeter htV and AMS-2, PPM Technology, UK) was used for the index child's bedroom and the living room. Sampling height was 1.2 m above floor level.

Duplicate (and sometimes triplicate) airborne fungi samples were collected from the living area, child's bedroom and outdoors by means of samples onto two types of media using an SAS impactor air sampler. Floor dust samples were collected from 1sqm of floor adjacent to the index child's bed and in the centre of the living room. Two dilutions of sieved floor dust were cultured. Plates were cultured at 23 deg C and counted after 5 days incubation.

Heaters were also monitored for use with thermocouples and pulse loggers for the gas end electric heaters respectively. Gas consumption was recorded in the cases where the source was bottled LPG gas.

For 2006, the sample has been randomly assigned into two equal groups. The interventional group are being given new heaters which are more energy efficient, larger capacity, sustainable, and which emit no indoor gaseous emissions or water vapour. Households, or the home owner in the case of rental property, have a choice of a heat pump, wood pellet burner, or flued gas heater. Control households will receive their choice of new heater after winter 2006

Intensive environmental monitoring will be repeated in both the interventional and control group in during the winter of 2006.

This paper describes the methodology and preliminary results for the intensive air monitoring conducted during the first year of the trial. Final results will be available in 2007.

3 Results

The 33 homes selected were of mixed tenancy between owner-occupied (73%) private ownership and public ownership (6% and 21%) respectively. All homes were low rise detached dwellings with a variety of house sizes, house age and construction. All homes had one or more asthmatic children between the ages of 7 – 12 years old. Ten homes used exclusively UFGH, ten used UFGH and electric, four were solely portable electric and the remainder used other heater types.

The winter of 2005 was unseasonably warm and was the third warmest on record. Sunshine hours (and consequently solar heat gain) during the period studied were 26% higher than normal (NIWA, 2005). This could have had a substantial impact on solar heat gain in the homes as well as the length of time occupants elected to operate their heaters and the heater setting, compared to a colder winter.

Guidelines from the World Health Organization (WHO) state that the NO_2 levels should be below 23 ppb on a yearly average and below 110 ppb for peak values over an hour. Unfortunately a guideline value was not available for a weekly average making a direct comparison between the annual guideline and weekly measurements complicated. However, the yearly average was exceeded in two of the homes; one with of these homes was heated with an UFGH and the other had an UFGH and an open fireplace.

The NO_2 hourly peak guideline value was exceeded at least once in 33% of the households, all with UFGH only or in combination with portable electric heaters or an open fireplace. One home recorded a peak NO_2 of 338 ppb, which is three times the WHO guideline; this home had two UFGH and one portable electric heater. This peak occurred simultaneously with the operation of one unflued natural gas heater operated on full. Another small semi-detached house (House 873) with one UFGH exceeded the NO_2 hourly peak guideline six times with peak concentrations between 200 – 319 ppb. Again these peaks occurred simultaneously with the operation of the UFGH.

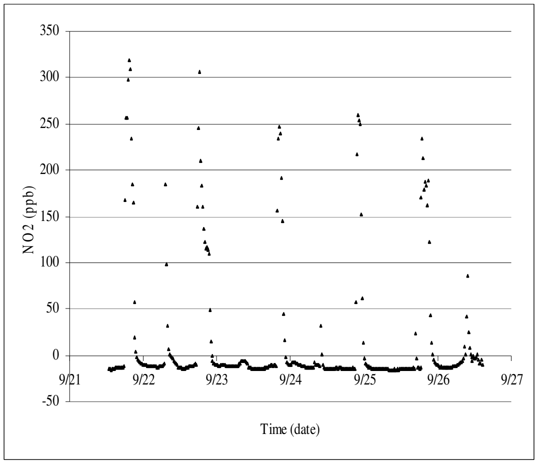


Fig 1. NO_2 concentrations in House 873.

Formaldehyde showed even higher values compared to WHO's recommendation of 0.08 ppm over 30 min average. In more than 84% of the homes this recommendation was exceeded at least once in either the living room or index child's bedroom. One home had a peak formaldehyde reading of 1.8 ppm and was heated with UFGH and an open fireplace. The highest average concentration measured was 0.10 ppm, which was recorded in a home that was heated with electric only but had undergone two lots of new construction two and five years prior to the measurements being taken. Since there are a number of possible sources for aldehyde emissions, further data processing and additional experiments are needed to draw any conclusions about the levels found so far in the study.

Average temperatures were found to be above the recommended 18°C in only 15% of the bedrooms and temperatures down to 7.5°C were observed. The average indoor temperatures were above the recommended 18°C in 36% of the households but it was not statistically higher in the living rooms than in the bedroom over the whole set of households. Even though the average temperature was in accordance with recommendations, there was in some cases considerable fluctuations with temperatures creeping down to 11-13°C. The temperatures were not significantly different between homes heated with portable gas or portable electric heaters.

The average relative humidity in all rooms ranged between 48-75%. There doesn't appear to be any correlation between either average RH or peak RH and heater type. Further analysis on absolute humidity will be undertaken.

CO2 levels were not found to exceed the recommended limit values. The highest weekly average was 1600 ppm and 1900 ppm in the bed and living room respectively. This was in a house heated with UFGH only. The second highest was 1200 ppm in both rooms and this was in a house with electric heating only. Further investigation of the data and modelling of other parameters is needed to draw any conclusions about the CO_2 concentrations found. The latter house had no high peaks of CO_2 which was the case with the former but was for example more well insulated which can explain the high average.

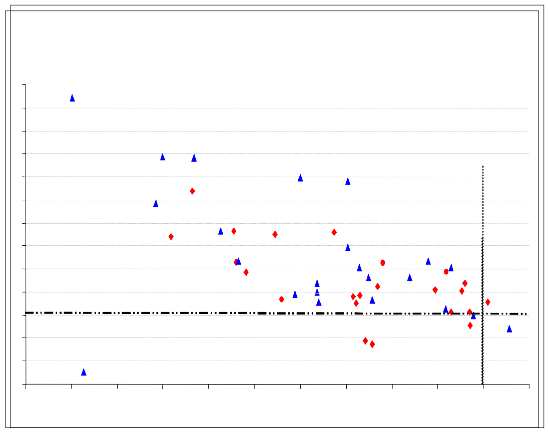
CO levels were also below recommended concentrations. The highest peak found was 19 ppm and the highest average was only 1.1 ppm. The highest values were found in houses with either UFGH or open fireplaces.

The median viable airborne fungal spore concentration in the living rooms was 350 Colony Forming Units per cubic meter (CFU/m3) with a range from 100 CFU/m3 to 1350 CFU/m3. In the index child's bedroom the median and the range were approximately the same (440 CFU/m3 for the median and a range between 60 CFU/m3 and 1130 CFU/m3.

A plot of the average temperature and relative humidity against CFU/m3 predictably showed that the RH decreased with increasing temperatures. However, the CFU/ m3 counted in each space did not appear to have any relationship to the temperatures nor relative humidity. It is possible that using the average temperature and average RH was masking the fluctuating

psychometric conditions that may have promoted or inhibited fungi growth. Further investigation of the data is required to attempt to explain the apparent random distribution of CFU compared to temperature and relative humidity..

Figure 2 also shows that only two homes had an indoor temperature above the WHO 18 deg C guideline for human health. Only one of these homes was below the 60% RH level.



♦ living room
▲ index child's bedroom
---------- minimum WHO no adverse health temperature
………. maximum ASHRAE relative humidity standard
Groupings of CFU/m3 A = 0-99, B = 100-199, C = 200-299, D = 300-399, E = 400-499, F = 500-599, G = 600-699, H = 700-799, I = 800-899, J = 900-999, K = 1000-1099, L = 1100-1199, M = 1200+

Figure 2 Relative Humidity (RH) vs Temperature (T) linked to the groups of CFU counting per m3 in the living room and the Index child's bedroom

In both the living room and index child's bedroom *Cladosporium* was the most common genus with a level up to 85% of fungi part. *Penicillium* was the second most common genus present with a level around 10%. In addition, the genera *Aspergillus* (2%), *Mucor* (1%), *Botrytis* (1%) and *Alternaria* (1%) were relatively common. Some genera like *Paecilomyces, Gliocadium, Phialophora, Epicoccum*, *Fusarium*, *Ulocladium* and *Geotrichum* were also found in very small quantities. The nonsporing fungi were involved in only 0.6% of fungi part.

The median viable fungal spore concentration in the outdoor air was close to the indoor air environment with 350 CF/m3 but the range was greater between 70 CFU/m3 and 2360 CFU/m3. The genera observed were roughly similar in quality and quantity to the indoor airborne with the genus *Cladosporium* first with around 90% of the fungi part and *Penicillium* in the second rank colony type with 5% of the fungi part.

In both indoor and outdoor airborne the yeast count was approximately 10 % of the total fungi counting.

Further analysis required to determine any differences in airborne fungi levels found in the homes and the heater type. More detailed analysis of the data is also required to investigate the multivariate effect of other variables.

4 Conclusions

The operation of the UFGH appears to have contributed to the higher concentrations of nitrogen dioxide and carbon dioxide in the homes with an unflued gas heater. Levels of NO2 were found to exceed the WHO guidelines in 33% of homes, all of which were heated with an unflued gas heater. The relationship between relative humidity and temperature and heater type is not significant.

The effects of the warmer than average outdoor temperatures during the sampling period most probably influenced the participants operation of heaters and the environmental parameters measured in the homes. Only one homes had an average temperature above 18 degC and RH below 60%. Higher indoor concentrations of pollutants may have been found in a colder winter.

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NIWA 2005 National Institute of Water and Air annual climate report
http://www.niwascience.co.nz/ncc/cs/sclimsum_05_3_winter

Appendix Five

Does improving insulation and heating improve health?

Presented by: Nevil Pierse[1] on Behalf of the Housing Heating and Health Research Team

[1] University of Otago, Wellington School of Medicine, He Kainga Oranga/ Housing and Health Research Programme.

Introduction

New Zealand houses are relatively poorly constructed and maintained for the temperate climate and most homes are heated to less than the WHO recommended minimum winter temperature of 18°C. Excess winter mortality is comparable to the levels in Portugal and Scotland. The Group's previous *Housing, Insulation and Health Study* has shown that insulating existing homes leads to a small but significant improvement in health and energy consumption, but raised the question as to whether installing more sustainable heating could increase these gains .

Study Households

•416 Households were enrolled in the study and returned baseline data.

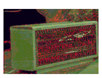
•Each household had at least one child age between 6 and 12 with doctor diagnosed asthma

•Each Household used "non-optimal heating" mainly no heating, unflued gas or plug in electrical heating. Our intervention is the installation of modern sustainable heaters – Heat pumps, wood pellet burners and flued gas heaters.

Baseline Data

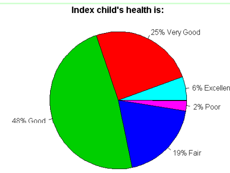
The Baseline data consists of 416 household questionnaires, 816 child questionnaires, 804 adult questionnaires. Lung Function Data on 219 children, NO_2 recorded in 285 homes and temperature reading for 311 homes, 318 symptom diary records from the index children.

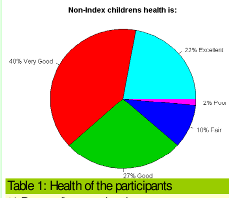
Old Heaters



New Heaters

Baseline Results





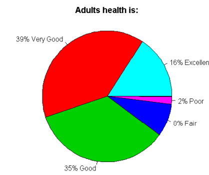


Table 1: Health of the participants	Index Children	Non- Index Children	Adults
% Doctor diagnosed asthma	99%	48%	40%
% Had GP visit for breathing problems during last winter	69%	45%	27%
Median number of GP visits (where not zero)	2	2	2
Mean number of GP visits (where not zero)	2.8	2.6	2
% With sick days off work/school Last Winter	86%	78%	60%
Median number of sick days (where not zero)	6	5	4
Mean number sick days (where not zero)	8.1	7	5.9
% Wheezing last winter	68%	37%	34%

Table 2: Household data			
Own home	60%	Smoking inside the house	20%
Home built before 1977	81%	Smoking in childs bedroom	2%
Condensation	65%	Income >$38,000 (where stated)	49%
House is cold	95%	Mean number of people in house	4.3

- Study is well placed to examine the effect of heating and insulation this winter
- The index children are less healthy than their siblings and the adults
- A significant amount of time is taken off work and school to deal with asthma problems
- 95% of homes were cold last winter and 65% had condensation
- Smoking in asthmatic children's bedrooms is rare 2%.

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Contact details: nevil.pierse@otago.ac.nz

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