Developing methodologies for studying health impacts of wood smoke in small population centres in New Zealand

Consultancy Report

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1. Scope of the project

In general, New Zealand has very good air quality. However, there are certain times of the year when air quality in some of our communities is significantly degraded due to householders' reliance on solid-fuel burning for domestic heating. Emissions of fine particulate matter from wood burners become trapped in the breathing zone during cold, clear and calm conditions, leading to elevated surface level recordings of particulate matter (PM_{10} and $PM_{2.5}$). Thus, poor air quality can occur during the winter months in the smaller centres and towns across New Zealand, as well as in the cities.

A close association between adverse health impacts and long-term exposure to PM has been reported in overseas literature, but less is known about health impacts of seasonal exposure to high levels of wood smoke. This is because many of these studies have been carried out based on large dense populations where road traffic emissions dominate over wood smoke. The New Zealand town setting, therefore, represents a unique opportunity to investigate the health impacts of wood smoke largely in insolation from other sources.

The project's objective is to develop relevant methodologies for understanding the impacts of elevated wood smoke levels on the health of residents of small population centres (less than 50,000) in New Zealand. The deliverable consists of a **written report detailing appropriate study designs, including appropriate health metrics given the available air quality data, that could be used by regional councils to describe the health impacts of wood smoke on resident populations.** This report is the product of this work.

2. Acknowledgements

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3. Literature review of health effects of wood smoke

Introduction

This brief review investigates the international scientific literature in relation to the types of studies used to determine woods smoke and its health effects. Naeher *et al.* (2007) suggest that "Surprisingly relatively few studies examining the health impacts of wood smoke have been conducted in developed countries, partly due to the difficulty of disentangling risks due to wood smoke and those associated with other pollutants also present". In New Zealand, wood smoke from solid fuel burning for domestic space heating is a significant source of air pollution. Thus, its small towns are ideal for studies investigating the health impacts of wood smoke as they are largely free of industrial pollution and road traffic emissions, though they also tend to be much closer to areas used for agriculture with emissions from agricultural burn-offs contributing to the mix. The focus of this review is also on studies carried out in developed countries where woodburning is for the purpose of space home heating, rather than for cooking.

Meteorology

Wood smoke is largely a wintertime problem as it is at this time of year that home heating is needed to maintain thermal comfort for residents. Concentrations of wood smoke tend to be high when the nighttime temperature is low, when the air is stagnant and when a temperature inversion profile has formed, trapping air near the ground surface, limiting dispersion and facilitating the accumulation of pollutants.

Chemical constituents

Wood smoke contains a range of chemical toxins, including carbon monoxide (CO), oxides of nitrogen (NOx), as well as particulate matter ($PM_{2.5}$ and PM_{10}). Wood smoke also contains known carcinogens such as benzene and benzo-a-pyrene. If the wood that is being burned consists of construction timber offcuts, it is likely that it also contains copper chrome arsenate, a chemical used extensively in New Zealand as an anti-fungal treatment. When burnt, a large percentage of arsenic in chemically-treated timber becomes volatilised, allowing for easy and rapid ingestion into the human body, as with other atmospheric pollutants, through respiration. Despite the burning of treated timber being prohibited by regional plans, the practice still occurs.

Monitoring and wood smoke component

Air pollution is typically monitored at outdoor locations as part of urban air quality monitoring programmes for regulatory compliance. For this purpose, PM_{10} has been monitored at a number of locations around New Zealand, including in the South Island, both in urban centres such as in Christchurch and in Dunedin, but also in small towns including Alexandra and Oamaru. The monitoring of $PM_{2.5}$ is more limited, both in terms of the length of the historical record, but also with respect to the number of locations. For $PM_{2.5}$ specifically, the World Health Organisation suggest that there is

unlikely to be a 'safe threshold', with any exposure considered to be a risk to human health (Janssen *et al.*, 2011). Therefore, wood smoke remains a significant health concern for countries such as New Zealand that is highly reliant on wood for home heating.

Health Effects and Health Data

While the case for adverse health effects of wood smoke specifically on the circulatory system is not so convincing, and in need of further research, the case for effects on the respiratory system is much more robust. Significant effects are observed with increasing exposure, allowing for the construction of a pyramid of health effects (from rare and serious at the top to common and mild at the bottom) across a range of symptoms and events. Adverse health effects include a wide range of respiratory symptoms including wheeze, cough, congestion, lung function, and asthma symptoms. Information about these conditions can be collected through questionnaires, diagnosis by a health practitioner, or, by the participants themselves, using equipment provided for the purpose. Another option is to use information about prescribing – records of purchasing of relevant medication (e.g. steroids for managing asthma symptoms obtained from a chemist shop, for example). At the more severe end, measures include hospitalisation for asthma, visits to emergency clinics, and mortality from respiratory causes. Such data are accessible, by request, via anonymised databases for the purpose of scientific statistical analysis.

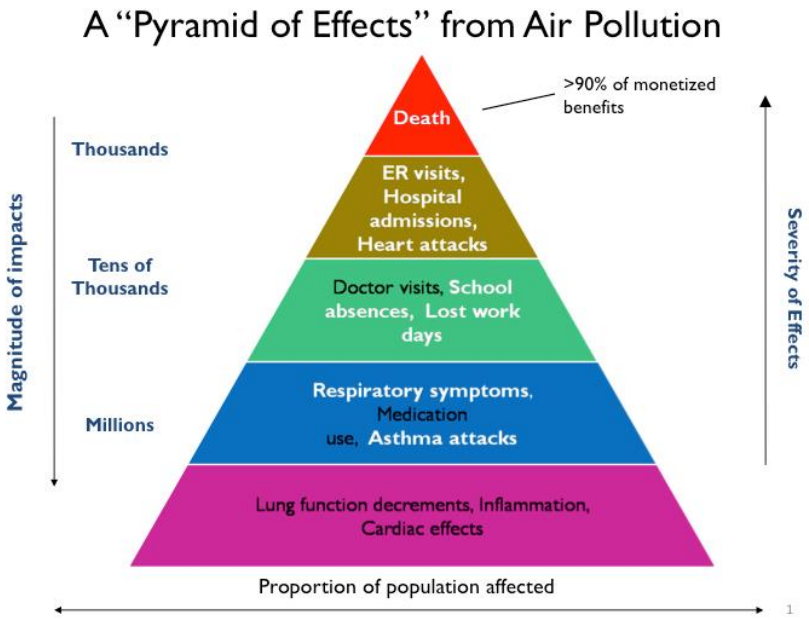

Figure 1: The pyramid of health effects associated with exposure to air pollution (Source: https://www.epa.gov/sites/production/files/2014-10/benmappyramid.png)

Epidemiological studies

Most of the studies found in the literature relating wood smoke to respiratory conditions are based on large epidemiological studies considering measures such as rates of hospitalisation, and visits to emergency departments. For example, Sheppard *et al.* (1999), investigated hospitalisations rates for asthma and Lipsett *et al*. (1997) investigated asthma emergency room visits. Most of these types of studies are focussed on children as they are a subset of the population most susceptible.

One example is the recent New Zealand study by Lai *et al*. (2017) investigating the rates of non-accidental presentations to hospital emergency departments (ED) before the age of three in relation to the density of household heating with wood or coal in the neighbourhood. Significant increases were found with increasing density of wood or coal-smoke producing households in the neighbourhood. The study was based on data from the ongoing Growing Up in New Zealand longitudinal study dataset consisting of 6822 pregnant women from the Auckland and Waikato regions.

Such studies require large populations to have sufficient statistical power for significant effects to be able to detected, if they exist. For small towns, populations are generally insufficient and alternative approaches are needed.

Smaller Studies

A number of studies based on much smaller sample sizes and thus more appropriate for small towns have been undertaken. One of the earliest studies was carried out prior to 1985 and compared the respiratory symptoms of 62 children, 31 of whom lived in areas with woodburners and 31 without (Honicky *et al.*, 1985). Despite the small sample size, significant effects were found with respect to 'severe' symptoms. A similar study was carried out by Butterfeld *et al.* (1989) looking at wheeze, cough and nocturnal awakening amongst 59 children. Browning *et al.* (1990) studied respiratory symptoms based on a sample of 600 homes experiencing low levels of smoke and 600 homes with high levels of smoke. They found significant difference for congestion and wheezing amongst 1-5 year olds. Thus, modest sample sizes are needed to detect significant symptoms when considering those located at the bottom of the health effects pyramid. Data of this type could be obtained based on observations from a health professional or could be obtained (more subjectively but more cheaply) from a community health questionnaire. Note that this type of study is generally cross-sectional in that all of the measures are taken at one time but could be administered more than once.

A somewhat more objective approach but none-the-less one that is suitable for studies involving small samples is respiratory function. As an example, Koenig *et al.* (1993) carried out a study investigating changes in respiratory function with levels of PM_{10} based on a sample consisting of 326 primary-school-aged children. Those who were asthmatic (26 of the 326) showed a deterioration in lung performance with increasing particulate levels, while those who were not, did not. This type of study is longitudinal in that the measure of health (respiratory function) is monitored over time and in this case, compared to air pollution, also tracked over time. It should be

noted that few of the studies found in the literature in relation to air pollution exposure are longitudinal in design.

Bui *et al.* (2013) looked at asthma in adults in relation to exposure to wood smoke in the community based on longitudinal data from Tasmania and questionnaire data around asthma severity. They found an association between wood smoke and asthma severity based on a four–point scale (intermittent asthma, mild persistent asthma, moderate persistent asthma, severe persistent asthma) and a 1-10 scale on "How much is the area where you live subjected to wood smoke in winter". The sample size was about 1400 adults of whom 19% were current asthmatics (a sample size of 262 adult asthmatics).

Indoor/outdoor air quality

It is relevant to note that while air quality is generally assessed based on monitoring at outdoor locations, people tend to spend the majority of their time indoors, especially during the wintertime. In the case of wood smoke, indoor concentrations have been found to be highly correlated with outdoor concentrations, assuming no significant sources of indoor particles exists, such as the household's own woodburner, cooking, or candles, for example. This suggests that outdoor measures are useful for assessing individual exposure to wood smoke. It also suggests that, as well as individual household behaviour with respect to wood burner use, the behaviours of other households in the immediate neighbourhood also play an important role. This is significant when behaviour change strategies are introduced, aimed at reducing the amount of woodburning within the community.

Wood smoke as natural

There remains a perception in the community that wood smoke is natural and thus not toxic, though the extent of this misconception remains unclear. Naeher *et al.* (2007) suggest that these is little evidence to suggest that wood smoke is less harmful. However, it is still relatively sparse as most air pollution and health studies associated with urban air pollution tend to be based on data from cities in which road traffic emissions dominate over other sources of pollution, including wood smoke. It would be difficult based on small town data to add to the body of knowledge about the relative impacts of wood smoke and road traffic emissions. Nonetheless, it would contribute to the body of knowledge around the impact of wood smoke emissions in relative isolation from other sources.

New Zealand Context

It is worth noting that New Zealand has one of the highest rates of asthma in the world with about 70 dying from the disease each year. Useful information about asthma, its cases and statistics can be found in the Global Asthma Report 2014 (including a table of percentage of respondents who experience asthma symptoms for countries around the world). As such, the focus of many studies investigating the health impacts of wood smoke consider asthma symptoms as asthmatics have been found to be amongst those most affected by wood smoke. In this regard, New

Zealand is an ideal location for investigating the health impacts of wood smoke from the point of view of respiratory symptoms amongst asthmatics.

Even in cities where road traffic is a significant source of air pollution generally, wood smoke has been found to be a major component of the air pollution. For reference, 90% of Christchurch's wintertime PM_{10} is estimated to come from home heating using wood (McGowan *et al.*, 2002).

Key Points

- There are relatively few studies looking at health effects of wood smoke from domestic heating in developed countries, due at least in part by the challenge of isolating wood smoke from other sources such as road traffic. In this regard, small towns in New Zealand are ideal, though sources that are agricultural in origin also need to be accounted.

- Most studies have focussed on outdoor concentrations (in the community) rather than indoor. Outdoor contributions to indoor pollution can be expected to be high due to New Zealand homes being relatively leaky.

- Most studies investigating the health impacts of wood smoke have focussed on respiratory conditions rather than circulatory conditions. There is an increase in interest in circulatory conditions at the moment.

- Many studies rely on self-reported questionnaire data with respect to respiratory symptoms (including the severity of asthma), as well as the amount of wood smoke in the community, as measured by assessments of smell and a reduction in visibility due to wood smoke.

- Most studies focus on children rather than adults, especially when considering asthma symptoms as they are a susceptible subset of the population.

- New Zealand has the highest rate of asthma in the world so not only is it of interest from a health perspective but a relatively small sample size from the childhood population is needed in order to obtain a sufficient number of asthmatics in order to be able to detect effects.

- In New Zealand, we have the additional concern that some of the wood we burn is timber treated with compounds containing arsenic. This presents an added risk to wood burning, not only for the households doing the burning, but also the wider community.

- Any study carried out would need to exclude (or control for) those living in households where there are smokers.

4. Research gaps

- Studies in which wood smoke is the main source of air pollution and not significantly influenced by road traffic emissions or other significant sources of industrial pollution, i.e. small towns

- Studies aimed at quantifying health improvements achieved through interventions - very few studies are longitudinal in design

- Exposure assessment studies to determine the relative contribution of indoor (own house) and outdoor wood smoke (others in the neighbourhood) to total exposure for people inside houses

- Toxicity of wood smoke relative to other sources of pollutants (e.g. road traffic) – many of the constituents are the same (CO, nitrogen oxides and benzene)

- Studies investigating the health impacts of exposure to wood smoke from the burning of treated timber. What is the relative risk of burning treated versus untreated wood?

- Very few wood smoke health studies have been carried out in New Zealand in general, especially those looking specifically at respiratory symptoms (at the bottom of the health pyramid) rather than epidemiological in nature (looking at the top).

5. Health metrics

There is existing evidence of adverse health effects from air pollution at all levels ranging from very serious to mild. Since New Zealand has a largely publicly funded healthcare system, much of the data relating to publicly funded treatments and procedures is available for research use. Diagnoses and procedures are available from public hospital admissions and the dispensing of subsidised medicines from Pharmac Mortality data are kept by the Ministry of Health. Regional Public Health has access to many notifiable communicable diseases. The beauty of these data sources is that individuals can be linked across them using a unique identifier (NHI).

National Databases:

Some relevant data are available through national databases. There are most suitable if populations are large. Usually these relate to hospital diagnoses, with hospitals only present in main relatively large towns or cities.

The coding for these data is standardised in codebooks available from the Ministry of Health (e.g. hospital diagnoses https://www.health.govt.nz/publication/national-minimum-dataset-hospital-events-data-dictionary). The data are held by the Ministry and usually available if ethical approval is granted to researchers. It usually costs about $500 for the time required to extract the relevant data requested.

Examples of data available include:

- Mortality
- Ischaemic heart disease
- Myocardial infarction
- Emergency room admissions/visits for asthma/respiratory issues
- Hospitalisations for asthma, bronchiolitis, pneumonia

Useful demographic, health and environmental data can also be found in the Stats New Zealand IDI database.

Relevant data available through GP clinics:

GPs are private entities, so access to the data is usually contingent on agreement with the practice management and ethical approval to do so, ensuring privacy and data security measures have been put in place before access is granted.

Relevant data that may be able to be sourced include:

- Respiratory infections
- Acute changes in lung function in children
- Otitis media or recurrent otitis media (4 or more in 1 year)
- Asthma diagnosis (and severity)

Relevant data available through database on prescription purchasing (Pharms Data Warehouse):

From the Pharms Data Warehouse, individual level data are available, and can be tracked to Census Area Unit (CAU) by linking with other databases. Geolocation can be estimated from residential addresses through matching. Data are considered to be complete from about 2006, with patchy implementation before that. Ethical approval is required to access the data, with constraints around secure storage. The data are usually presented as encrypted NHI to protect individual identity.

Relevant data that are able to be sourced include:

- Asthma medication/steroids for treating asthma symptoms

Data able to be collected by participants themselves with inexpensive equipment provided (and minimal training):

- Peak flow (inexpensive equipment (~$20)

Data able to be collected via questionnaire after identifying a suitable cohort and inviting people to participate:

In the Growing Up in New Zealand Study, demographic data were collected via questionnaire with health data individually linked to the Ministry of Health (MoH), District Health Board datasets and other health providers.

Other respiratory questionnaires that may be relevant include the St Georges Respiratory Questionnaire, and ones designed for specific child cohorts, including asthmatics.

Relevant questions could be ones related to:

- Demographics (Age, gender, ethnicity, etc)
- Occupation (to determine possible exposures outside of the home)
- Housing
- Smoker/non-smoker/smoker(s) in the household

- Asthma symptoms
- Cough, sore throat, chest tightness, phlegm
- Asthma aggravation
- Respiratory symptoms- mild moderate severe (wheeze, cough nocturnal awakenings – young children)

Expert input is required to ensure the most relevant questionnaire is used for the specific study of interest.

6. Air Pollution Metrics

- Air pollution data collected routinely by regional councils for compliance monitoring.
    - Such monitoring is only carried out at a limited number of places throughout the country.

- Estimates of wood smoke production based on the density of households who use wood or coal for space heating.
    - This would suit a study looking at health effects over an extended period of time such as admissions to hospital.
    - The limitation is that there is no temporal information

- Estimates of wood smoke based on a questionnaire asking participants about the presence of a smell of wood smoke in the air over the last week (or other time period) or presence of wood smoke due to reduced visibility
    - This is clearly a subjective method but can be asked of anybody anywhere irrespective of the presence or absence of any physical monitoring.

- Asking about the presence or absence of a woodstove (and usage) during the period of observation.
    - This clearly only targets own woodburner usage.
    - Given there has been found to be a high correlation between indoor and outdoor air quality, it is clear that wider woodburner usage in the local community is an important additional contributor to the levels of wood smoke in the home so presence/absence of a woodburner may not be a sufficient metric.

7. Study design considerations

7.1 What would the best study design look like?

A good study is one where significant health effects are able to be identified, that the majority of people are able to relate to, are able to be identified in a study that consists of a modest number of participants, and able to be carried out in small town on a limited budget. It would also be helpful if the study was able to incorporate an intervention aimed at reducing woodburner emissions (such as only burning seasoned/dry wood) that would allow a reduction in adverse health effects to be observable and easily able to be communicated to the community. Ideally, this would involve:

- A survey about the type of wood used (if known), in addition to information about whether the wood used is construction offcuts or logs
- Extent to which the age of the wood and dryness are considerations before being used
- Woodburner usage (as measured in the home using iButton (or similar) technology)
- A measure of outdoor air quality (PM2.5 or black smoke)
- A measure of indoor/in-home air quality ($PM_{2.5}$ or black carbon)
- A measure of health effect from the bottom of the health pyramid
    - Focussed on a vulnerable subset of the population e.g. low socio-economic, Maori, Pacific, children, elderly, those with existing respiratory conditions, and
    - In the case of children, a measure such that participants are able to participate in the study themselves without adult assessment/intervention

7.2 Sample size/statistical power

The size of the sample is always an important consideration in any study involving sampling. In the context of air quality and health, if only a small change in air quality results in measurable health impacts in a large proportion of the population of interest, then only a small sample is required to be able to observe a significant impact. The sample size can be reduced by targeting a specific subset of the population most likely to be affected (such as asthmatics).

In contrast, when the health effects are rare, say those at the top of the health pyramid (the dependent variable), and/or the range in air quality is low (the independent variable), then a large sample size is needed. In the case of studies investigating changes in admissions to hospital, for example, a sample the size of a city is required.

The size of a study has cost and time implications so choosing an appropriate sample size is an important aspect of study design, particularly if data collection

is part of the study. If the size of the effect is known, or can be estimated (based on data from overseas), a power calculation can be carried out to give an estimate of the appropriate sample size. Other than in the case of a very simple study, a power calculation is something that is done routinely by statisticians involved in research projects of this nature.

The sample size will vary depending on the study design. For example, a smaller sample size will be required in a study that involves health measures from participants before and during/after an air pollution event (a paired test) compared with a sample that involves two separate cohorts, say a town with low levels of woodburners compared to one with a high level (an unpaired test). This is because some of the inter-subject variability is accounted for in the paired test. However, in the former, seasonal effects (or temperature and respiratory illness) may need to be taken into account.

7.3 Cohort (age groups, locations)

Health studies typically focus on a specific age group or stratify the data based on age groups. Some studies consider only adults. This group is larger, and is simpler regarding consent as adults are able to assess their own symptoms rather that replying on the assessment of another (such as a parent). There will also be an age limit below which spirometry/peak flow measurements, for example, are not able to be performed reliably.

There may be some groups that are more vulnerable than other groups. Children, for example, are more vulnerable to the harmful effects of air pollution than adults, in part because they breathe more pollutants in proportion to their body weight than adults, for a given exposure, and in part because their respiratory system is still developing. Groups of low socioeconomic status are more vulnerable, as are the elderly and Māori and Pacific people. It would be helpful if the study were designed so that a vulnerable group were able to be compared with the wider population so the extent of the difference on the effect is able to be quantified.

One important consideration is that respiratory symptoms and conditions may be more prevalent in some age groups than others or are different in some ways. Adult asthma is more complex than childhood asthma which tends to be more 'classic' allergic inflammation. Studies looking at the association between wood smoke and asthma in children tend be more consistent (with stronger associations) than studies focussed on adults alone. Children have also been more extensively studied than adults with respect to asthma and air pollution generally.

7.4 Ethical Approval

Any study involving human participants or data related to people requires ethical approval from a body able to grant it. If the study involves study participants providing data through a questionnaire, interview, or measurements made on themselves (e.g. spirometry), ethical approval may be granted by a University Ethics Committee providing there is university involvement on the project. If patient data are involved, ethical approval will need to be sought through a regional ethical approval granting board.

7.5 Participant recruitment

Participant recruitment can only commence after ethical approval is granted. Participants can be recruited via GP clinics if specific cohorts are needed (e.g. those with an asthma diagnosis). For recruitment from the general public, recruitment can be done via printed flyers placed in public places (community notice boards, etc.), or via social media. Anyone under the age of 16 will require consent from a parent or guardian in order to participate. All participants will be required to sign a participant consent form after being provided with information about the study and being given the opportunity to ask questions about the study. They also have the right to withdraw from the study at any time without having to give a reason.

7.6 Methods and Recruiting in schools/children

Targeting schools to participate is one option. However, consent will need to be obtained from the school board, the school principal, the teacher as well as the parents of the children.

7.7 Linking health data to air quality exposure data

Focussing on areas where high-quality air quality data are available would help to minimise the costs associated with the study and ensure that exposure estimates are robust. It would also be helpful to choose two locations (where air quality is measured) where there is contrasting levels of wood smoke as the differences in health outcomes between two regions could be expected to be at their highest, providing there is adequate control for socio-economic status and health status which can be expected to be significant factors. It would also be useful to compare individuals from the same community who live in houses that are heated with wood and those who have an alternative (clean) source of heating.

Individual health and socio-economic information may be able to be obtained from a short questionnaire. The area-wide socio-economic information can be obtained from the NZ Census (Stats NZ). A challenge may be in identifying two towns such towns – perhaps it could be one that is well ventilated and one that

is poorly ventilated. Another option is to track short-term health impacts over time as air pollution levels rise and fall. Controlling for temperature will be important so that cold clean days are compared with cold polluted days.

If no air quality data are available, it may be possible to use information from the NZ Census (Stats NZ) about home heating to estimate woodburner use. This would result in a more indirect measure of air pollution but may be sufficient for the purpose. Another option is to base the quality of air on the 'sniff test' whereby people record whether or not (or maybe a three-point scale of 'no' a 'little' or 'a lot') they smelled wood smoke the night before, either from their own fireplace or from those in their community. A simple home weather station would also be useful to determine whether the conditions are stagnant or not and whether the temperature is sufficiently low that people start to use their fireplaces. 'Professional' weather data can also be sourced through MetService or NIWA's Clifo climate database. Woodburner usage can be tracked using an iButton (temperature sensing logger) place in the immediate vicinity of the fireplace.

7.8 Community engagement

Community engagement could involve the following stakeholders:

- Wood merchants
- Schools
- Local iwi
- Sport clubs

For any study involving community engagement, it is helpful to have a social scientist on the team. It is recommended that results are fed back to communities via community hui.

8. Sample study designs

8.1 Study 1: Respiratory Peak Flow in Relation to the Presence of Wood smoke in the Community

Aim: To determine the impact of winter wood smoke on respiratory peak flow and/or medication use in asthmatics

Health measures:

Peak flow: A reduction in peak flow indicates impaired lung performance (the degree of obstruction in the airways). Peak flow can be measured and recorded by the individual and simply involves the participant blowing into a device and recording the number provided by the device. Peak flow measurements need to be taken at the same time each day as there is diurnal variation. Measurements could be taken weekly for a season extending from before the woodburning season and beyond its peak. Note that peak flow is much cheaper to measure than FEV_1, for example, which requires the use of a spirometer which can cost thousands of dollars.

Medication usage: Medication usage could be tracked over the period of the study and compared between groups and in relation to air pollution levels. This be done using a paper-based or phone App based diary.

Air quality Measure:

Health measures could be compared with data from air quality monitoring stations (preferably PM2.5 or black carbon), from information from census data on the use of woodburners (woodburner density) or based on questionnaire data about the extent of wood smoke smell in the community. Asking participants about their household practices would also be helpful.

Participants:

Participants could be drawn from any age group but asthma is more common in children (about one in twelve school-aged children). Ideally, participants will be old enough that they understand the test and be able to participate effectively.

Study participants could be recruited directly through GP clinic databases of patients with an asthma diagnosis and a minimum level of asthma medication usage.

Those living in households with smokers should be excluded so that woodsmoke effects are better able to be isolated from other sources.

Methodology and Data Analysis:

Two groups could be invited to participate: a group living in a community with a high density of woodburners (or poor air quality) and another group living in an area with a low density of woodburners (or good air quality).

Data analysis:

Analysis could consist of estimating the difference in the mean peak flow of those living in areas of high woodburner density and those living in areas of low woodburner density during the winter months.

This could involve a time series analysis of daily measures of peak flow (at the same time of the day) over the winter season with nearby particulate matter concentrations (preferably PM2.5 measurements). The lag between PM2.5 and measures of peak flow will need to be considered. Modelling can be done to investigate the within and between changes in individuals symptoms, and compare communities using standard statistical models.

Ethical Considerations:

Confidentiality with respect to peak flow data (medical data). Participant data will need to be kept in anonymous form. Ethical approval will need to be obtained via regional ethical approval granting board.

Study Limitations:

As participants will be providing data, there will no doubt be periods of missing data (people will forget to take measurements).

There may be missing data with respect to asthma medication usage.

There may be participants who withdraw from the study during the period of data collection.

Peak flow will be variable within the study population. A sufficient sample size will need to be obtained in order for effects to be able to be detected. Note that participants could be drawn from any age group but asthma is more common in children (about one in twelve school-aged children). An early study suggests that asthma prevalence is 26% to 30% of the rural adolescent population with higher prevalence in Māori compared with European (Shaw *et al.*, 1990).

Budget:

Peak flow devices are readily available and cost about $20-$40 depending on where they are sourced and the quality.

- Peak flow meters 20 participants x 2 groups = $800 - $1600
- Amateur Meteorological station x2 = $400 (if needed)
- Incentive to encourage participation by GPs (~$200 would be considered as appropriate)

Staff time to write ethics application, recruit GP clinics into the project (provide patient contact information) and maintain relationships, invite patients to participate, collate health data, analyse data and report. The cost of such a study would depend on the size but it is unlikely such a study is able to be done for less than about $200,000.

Comments:

Peak flow in relation to asthma is a health outcome that most people can relate to. Asthma is well known as a condition and everyone knows people who are asthmatic. Also, the proportion of people in the community who are asthmatic is high so even with a small population, it should be possible to recruit sufficient participants. By providing each participant with a peak flow meter to keep, there is a 'reward' for participating in the study and participants will be provided with something that will help them to monitor their health. It will also mean there will not be any issues of hygiene (as would be the case if using shared equipment) and specialist training in how to use the peak flow meter is not required (Some simple instructions would suffice). The time commitment required for participation is low but the risk of people forgetting to take a measurement is high so a reminder system (e.g. a phone text) might be helpful for minimising missing data.

** See Koenig et al (1993) for a relevant study investigating pulmonary function in relation to fine particulate matter exposure.

8.2 Study 2: Steroid Prescription Dispensing in Relation to the Presence of Wood smoke in the Community

Aim: To determine the impact of winter wood smoke on steroid prescription dispensing in asthmatics.

Health Measures:

Patients experiencing impaired breathing as a result of asthma are more likely to visit the chemist for medication to help treat their condition. Data on dispensing of steroids for the purpose of treating the symptoms of asthma can be obtained from the Pharms Data Warehouse with information about the location of the dispensing and patient demographic information. The health measure could be dispensing rates within a period of time following an air pollution event (say, a daily average exceedance in PM2.5 concentration) or treat air pollution concentration as a continuous variable and estimate the strength of the association between air pollution concentration and the rate of dispensing.

For these patients, information on admission to hospital for asthma (or death from asthma) would also be helpful.

Participants:

Participants would be any person who has been dispensed steroids for the treatment of asthma and who lives in a particular area or had the medication dispensed from specific pharmacies.

Methodology:

Data analysis would consist of assessing the strength of the association between air pollution and medication dispensing (with a suitable time lag). The outcome variable would be the rate of dispensing (the count per 1000 people per month). If several seasons of data were available, seasonality would need to be accounted for in the analysis.

It will be important to be mindful of the time lags between dispensing, usage and air pollution levels.

Ethical Considerations:

Ethical approval will need be sought through the regional ethical approval granting board in order to access the database.

Study Limitations:

A limitation of this study is that it will not be possible to know if the medication was actually used, just that it was purchased.

Several years of data would likely be needed.

Budget:

Most of the cost of this project would be in data management, data cleaning and in analysis. As no participant recruitment or equipment is required, a study of this kind could perhaps be done for about $100,000.

Comments:

This study is weak if community engagement is lacking. However, it would work with the introduction of an intervention to reduce the burning of wood as dispensing rates could be compared before and after the introduction of the intervention. In this case, it would be important to control for differences in wood burning behaviours during cold and mild winters. In this case, the association between temperature, air pollution and rates of dispensing would need to be assessed.

8.3 Study 3: Respiratory Symptoms in Response to Wood smoke Based on a Community questionnaire

Aim: To determine the impact of wood smoke on respiratory symptoms in adults based on a community questionnaire

Health Measures:

Question can be posed about wheeze, breathing difficulties, asthma medication usage requirements, runny nose, stuffiness, quality of sleep, etc. Data will be cross-sectional (collected at one point in time) though a follow-up survey could be carried out. Useful additional data could he a questionnaire asking about changes in behaviour (exercise levels) in response to any respiratory symptoms or perceptions of air quality (smell and/or reduced visibility due to wood smoke).

Participants:

A questionnaire is most easily able to be completed by an adult in the household. For this purpose, a community organisation such as a sports club may be able to be targeted. If the activity involved training a night, they may show more symptoms than those who remain largely indoors in the evening.

Printed surveys may be posted but is it usually cheaper to deliver them by hand, especially in densely-populated neighbourhoods.

An on-line survey may also be able to be carried out, although targeting the population of interest will be more difficult than identifying addresses of houses that are in a specific area and distributing printed questionnaires based on this. The advantage of an on-line survey is that it can more easily be administered at a specific time depending on that the weather/air quality is at the time (hand delivery of printed questionnaires takes time and coordination). It is also important that they don't get wet (and many post boxes leak) – nobody will fill in a soggy questionnaire!

Methodology:

Either:

Identify two areas of contrasting levels of wood smoke based on air pollution levels or other measure of wood smoke level. This could be two areas with similar levels of emissions from woodburners but contrasting dispersion (town in a valley versus a will ventilated coastal town). Administer a questionnaire about respiratory symptoms during the winter to groups in both communities and compare the outcomes. If asking about respiratory symptoms, a time frame of 'over the past 3 days' might be appropriate. A time limited would need to be placed for the completion of the questionnaire to ensure they are able to be compared.

or:

Identify an area that is affected regularly by wood smoke. Administer a questionnaire at a time during winter when air pollution levels are low (and forecast to be low, due to wind, etc), and repeat again during or near the end of a high pollution period. For this design, it would be helpful for the two sets to linked. For this purpose, an online survey would be better. Again, if asking about respiratory symptoms, a time frame of 'over the past 3 days' might be appropriate. A time limit would need to be placed for the completion of the questionnaire to ensure they are able to be compared due to changing weather and air pollution conditions.

Some interesting social data could also be collected by asking about people's perception of wood smoke being a health risk and how they think it compares to similar levels from road vehicle emissions. It would also be interesting to ask if participants change their behaviour in response to air quality perceptions (smell/reduced visibility as a result of wood smoke). This could be in response to their own woodburner use or the activities in which they engage (e.g. outdoor sport).

Ethical Considerations:

Ethical approval will need to be obtained but considerations are minor as completed questionnaires are often returned anonymously.

Study Limitations:

Questionnaire data are subjective measures of health.

If participants are aware of the reason or the study, this may bias their responses. Questions need to be worded carefully in order for this to be minimised.

Budget:

Most of the cost is associated with the time required to deliver the questionnaire and enter and process the questionnaire data when it is received. Thus, the budget will depend almost exclusively on the size of the study and the amount of 'in house' help that may be able to be obtained.

Comments:

Questionnaire data, by their nature, are subjective. However, they are easy to collect so large samples can be obtained at low cost (some printing, delivery and data input is required). They also involve limited disruption and time from study participants (they don't need to travel anywhere, they are not being subjected to any test, it takes only a short amount to complete, etc). Participants do need to be literate and be relatively fluent in English.

Asthma Incidence Information

- The impact of respiratory disease in New Zealand: 2016 update
- Asthma and Respiratory Foundation Infographic

List of Research some organisations in New Zealand with an Interest in Air Pollution and Health (wood smoke)

- University of Canterbury (GeoHealth Lab) – Focus on Health Geography

  https://www.canterbury.ac.nz/science/research/geohealth/

- University of Otago (Wellington) – Focus on healthy housing and public health more generally

  https://www.otago.ac.nz/wellington/departments/publichealth/staff/#hod

- University of Auckland (School of Population Health, School of Environment) – Focus on air pollution exposure

  https://unidirectory.auckland.ac.nz/profile/k-dirks
  https://unidirectory.auckland.ac.nz/profile/j-salmond

- NIWA (Crown Research Institute) – air pollution generally

  https://www.niwa.co.nz/atmosphere/programme-overview

- Emission Impossible (Consultancy) – focus on air quality and greenhouse gas emissions management with work in health

  https://emissionimpossible.co.nz/

Biostatistical Units

- University of Otago Biostatistical Unit

  https://www.otago.ac.nz/healthsciences/research/biostatistics.html

- University of Auckland Biostatistical Unit

  https://www.fmhs.auckland.ac.nz/en/soph/about/our-departments/epidemiology-and-biostatistics/biostatistics.html

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