UNIVERSITY OF AGDER

Indoor air pollution in rural China; associated with lung function?

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This Master's Thesis is carried out as a part of the education at the University of Agder and is therefore approved as a part of this education. However, this does not imply that the University answers for the methods that are used or the conclusions that are drawn.

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ABSTRACT

Introduction: Approximately, half of the world population depends on biomass fuels as primary energy source. Indoor air pollutants are recently studied and considered as to be responsible for health burden in rural China. Chronic exposure to biomass combustion has been claimed to be associated with increased prevalence of respiratory symptoms, reduced lung function and the development of chronic obstructive pulmonary disease (COPD) The present study focuses on two main indoor air pollutants produced by biomass combustion: CO (Carbon monoxide) and PM (Particulate matter). The aim of the current study is to consider the association between these two main indoor pollutants and women's lung function in chosen rural villages of Giuzhou Province of China.

Methods: A cross-sectional study was carried out on the present study. A cluster of household survey was randomly selected to perform measurement of indoor air pollution. Sample subjects were women in the age of 30 years old or older. Spirometry was performed in all subjects.

Results: There was no difference between participants with IAP measurement and those without IAP measurement. A significant association was found between CO concentration in living room and FEF50 (P=0.040). No statistically significant association was found between living-room CO concentration and FVC as well as FEV1. No significant association was found between PM2.5 concentration and lung function neither in kitchen nor in living room.

Conclusion: CO concentration was negatively associated with women's lung function, and there was no association between PM2.5 and women's lung function.

Key words: Indoor air pollution, lung function, biomass fuels, carbon monoxide (CO), particular matter (PM).

SAMMENDRAG

Introduksjon: Omtrent, halvparten av verdens befolkninger er avhengig av biobrensel som deres primære energikilde. Innendørs luftforurensning er nylig studert og regnes som å være ansvarlig for helse byrde på landsbygda i Kina. Kronisk eksponering for fyring med biobrensel har blitt hevdet å være assosiert med økt forekomst av luftveissymptomer, redusert lungefunksjon og utvikling av kronisk obstruktiv lungesykdom (KOLS). Denne studien fokuserer på to innendørs luftforurensninger produsert av biomasse forbrenninger: CO (karbonmonoksid) og PM (Svevestøv). Målet med denne studien er å vurdere sammenhengen mellom disse to viktigste innendørs forurensninger og kvinners lungefunksjon i utvalgte landsbyer i Giuzhou provinsen i Kina.

Metode: En tverrsnitts-studie ble utført på denne studien. Det ble tilfeldig utvalgt en gruppe av husholdningenes til å utføre måling av innendørs luftforurensning og lungefunksjon. Utvalgte var kvinner i alderen 30 år eller eldre. Spirometri ble utført i alle utvalgene.

Resultater: Det var ingen forskjell mellom deltakere med IAP måling og de uten IAP måling. Ingen signifikant sammenheng ble funnet mellom PM2.5 konsentrasjon og lungefunksjon verken på kjøkkenet eller i stua. Det ble funnet signifikant sammenheng mellom CO konsentrasjon i stue og FEF50 ($P = 0.040$). Ingen statistisk signifikant sammenheng ble funnet mellom stue CO konsentrasjon og FVC samt FEV1.

Konklusjon: CO konsentrasjonen var negativt assosiert med kvinners lungefunksjon. Det er ingen assosiasjon mellom PM2.5 konsentrasjon og kvinners lungefunksjon.

Nøkkelord: Innendørs luftforurensning, lungefunksjon, biobrensel, karbonmonoksid (CO), svevestøv (PM).

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My deepest gratitude is reserved to my dearest parents and my sisters who have prayed for me, supported and encouraged me.

"Cám ơn ba má và các em đã luôn tin tưởng và đồng hành với con".

"Unless the LORD builds the house, the builders labor in vain". (Psalm 127,1)

Thank You, Lord, for granting me the necessary graces to fulfill this study.

University of Agder, May 2013

Do, Stephanie Loan Vy

ABBREVIATION LIST

IAP	Indoor air pollution
PM	Particulate matter
CO	Carbon monoxide
FEV1	Forced expiratory flow-volume in one second
FVC	Forced expiratory capacity
FEF25-75%	Forced expiratory flow at 25%-75%
COPD	Chronic obstructive pulmonary disease
WHO	World health organization
GDP	Gross domestic product
ppm	parts per million
µg/m3	Micrograms per Cubic Meter
ID	Identity
Hb	Haemoglobin
COHb	Carboxyhaemoglobin
NO2	Nitrogen dioxide

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INTRODUCTION

Indoor air pollution (IAP) is a major concern of the public health all over the world, especially in development countries (1). In 2003 approximately 80% of the energy consumed by rural households was in the form of biomass and almost 10% as coal (2). China's rural habitants use mainly biomass and coal for cooking and household heating (3). The combustion of these biomass fuels produces various chemicals such as particles, carbon monoxide, nitrous oxides, sulphur oxide, formaldehyde, and polycyclic (4), are considered hazard to people health (5). Lung health such as acute respiratory infections in childhood, chronic obstructive pulmonary disease and lung cancer, are the risk for people who exposure to IAP (1). Consequently, there have been more and more epidemiologic studies, among which the studies on indoor air pollutants have been paid more and more attention (6, 7). According to Zhang and Smith, China is annually responsible for 420,000 premature deaths of indoor air pollution from biomass fuel use (2). In front of this situation, the impacts of indoor air pollutants from biomass fuel combustion were closely investigated. This master thesis aims at the following objectives: Are particulate matter 2.5 (PM2.5) and carbon monoxide CO associated with women's lung function in China?

THEORETICAL BACKGROUND

The Respiratory System

The respiratory systems which also consists the lungs are divided into two parts: the upper and lower respiratory airways. The upper respiratory tract consists of the nose, pharynx, larynx and trachea. The lower respiratory tract consists of the left and right bronchi, bronchial tree and lungs (Figure 1) (8, 9). The main function of the respiratory system is gaseous exchange – the transport of oxygen from the air to the blood and removal of carbon dioxide from the blood (10). External respiration refers to the exchange of gases between the lungs and blood, internal respiration refers to the exchange of gases between the blood and body cells and tissues, and the use of these gases during cellular metabolic processes. (9).

The airways consist of nasal cavities (nose and linked air passages), mouth, epiglottis (thin flap of tissue), larynx (voice box), trachea (windpipe), tubes (bronchial tubes or bronchi), and their branches (8, 9). The lungs enclose a branching network of airways, known as the bronchial tree (figure 1). When reaching the lungs, the windpipe divides into two airways, or bronchi. Once inside the lungs, these airways divide into smaller tubes, and continue to divide into thousands of smaller, thinner tubes called bronchioles. These tubes end in bunches of tiny round air sacs called alveoli which are covered by a mesh of tiny blood vessels called capillaries. These capillaries connect to a network of arteries and veins that carry blood through the body (8, 11).

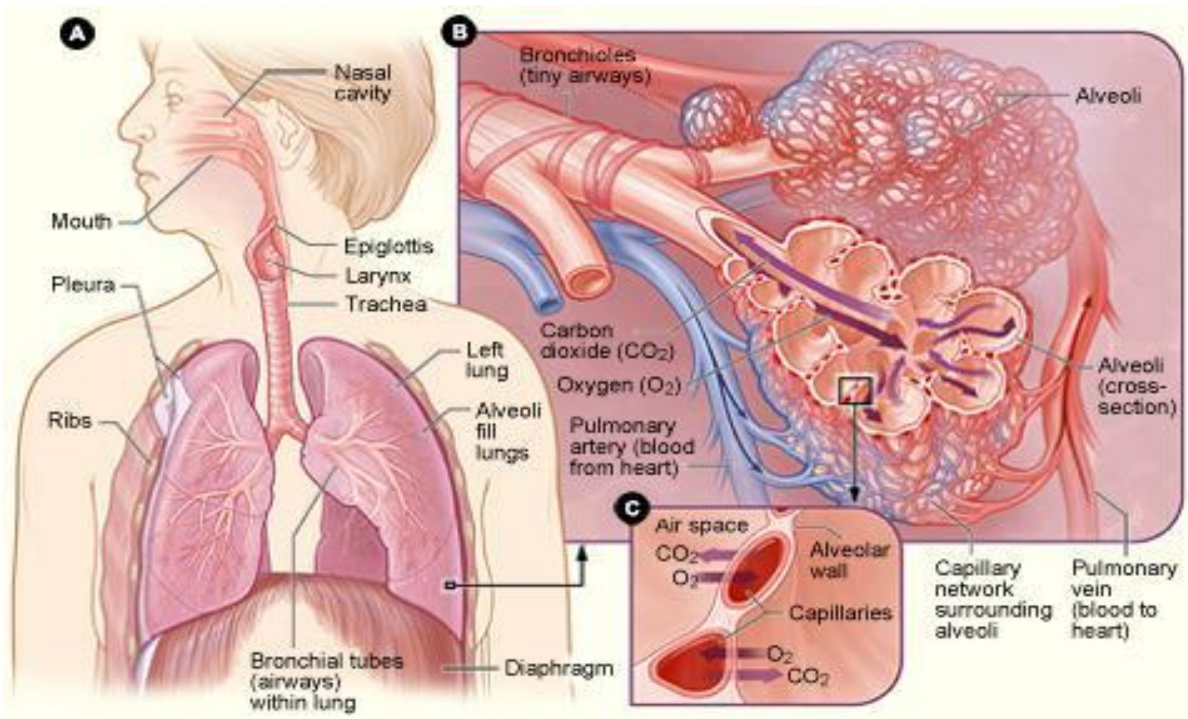

Figure 1. The location of the respiratory structures in the body, and how the airways, alveoli (air sacs), and capillaries (tiny blood vessels) work and exchange gas between the capillaries and alveoli (8).

Lung function

Lung function has been one of the most important assessment tools available to investigate the effect of air pollution on people health (12). Basic lung function parameters can be measured with spirometer, which is a medical test that measures various aspects of breathing and lung function (inspired and expired lung volumes) (13, 14). Spirometry is one of the simplest and the most effective tests available for the assessment of lung function. The spirometer is a special device that registers the amount of air which a subject inhales or exhales and the rate at which the air is exhaled. (13, 15-18).

During normal quiet breathing, about 500ml of air move in and out of the lungs with an average of 12 times per minute. The volume of air moving in with each breath is known as the tidal volume and can be measured with a spirometer (19). However, the lungs are capable of expanding far beyond this amount of air. The additional air that can be inspired during forced inspiration is referred as the inspiratory reserve volume. The volume of air that can be forcibly expired in a fixed period of time following full inspiration is known as the forced expiratory volume (FEV) (19).

Common lung function variables that can be measured by maximal forced expiratory flow-volume curves include forced expiratory volume in one second (FEV1), forced expiratory capacity (FVC) and forced expiratory flow at 25%-75% of FVC ($FEF_{25\text{-}75\%}$) (figure 2) (18). FEV1 is the volume of air that can be forcibly expired in one second, after full inspiration (16). Clinically, this measure is used to assess the severity of respiratory conditions. Reduced FEV_1 is the key feature of chronic obstructive pulmonary disease and tends to be associated with disease severity (20). FEV1 is also reduced in people with airflow obstruction (14, 15). The lungs are never completely empty of air. The air that remains in the lungs following maximum expiration is known as the residual volume.

FVC is the maximal volume of air exhaled with maximally forced effort from maximal inspiration, i.e. vital capacity performed with a maximally forced expiratory effort (16). The vital capacity is the maximum volume of air that can be expelled from the lungs following maximum inspiration. (20). The FVC is useful for detecting restrictive diseases. The FVC is reduced in people with obstructive and restrictive disorders (15).

The mean forced expiratory flow between 25% and 75% of the FVC (FEF25–75%) is known as the maximum mid-expiratory flow (15). This index is taken from the blow with the largest sum of FEV1 and FVC, it is highly dependent on the validity of the FVC measurement and the level of expiratory effort (15).

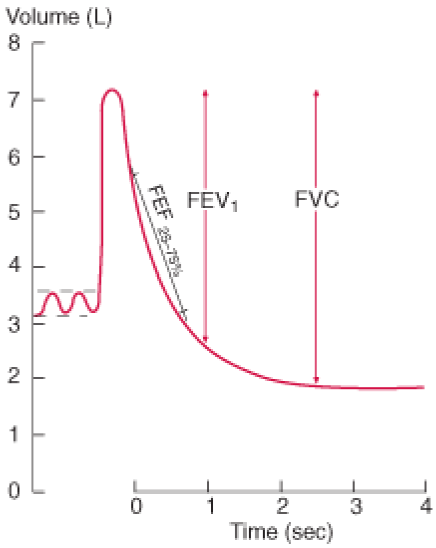

Figure 2. Tidal volume during a maximal forced expiratory maneuver with forced vital capacity (FVC), forced expiratory volume in the first second of forced (FEV1) and forced expiratory flow during expiration of 25 to 75% of the FVC ($FEF_{25–75\%}$); (21).

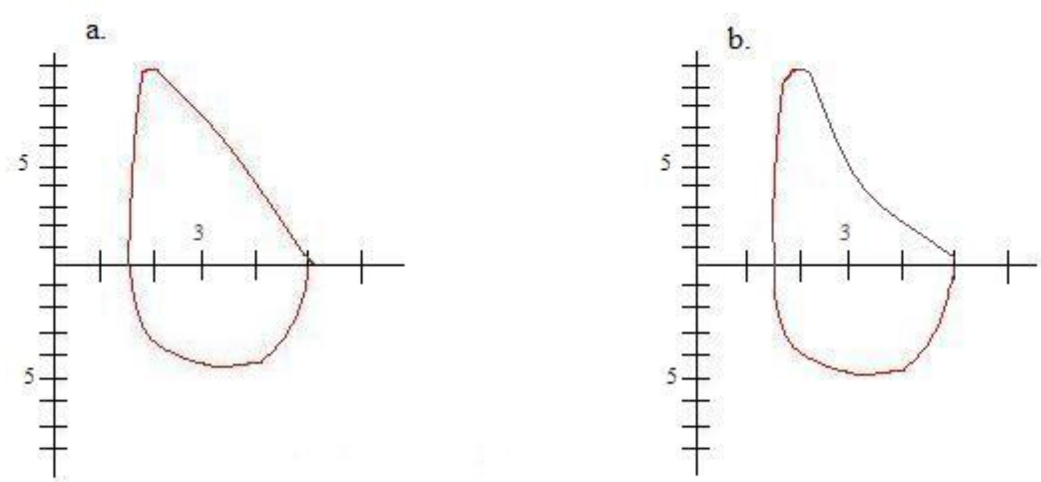

Figure 3a. Shows a normal flow-volume loop. Figure 3b. Shows an obstructive defect. X-axis is volume, Y-axis is flow.

Indoor Air Pollution

Biomass fuels refer to any recently living plant/animal-based material that is deliberately burned by human as fuels, including wood, crop residues, and animal dung (22, 23). These fuels are burned indoors in open fires and stoves that are not often ventilated (23). When biomass is burned, the combustion of organic matter occurs. At the same time, chemical reactions appear and produce smoke (24). Smoke is a complex mixture of several different chemicals such as carbon dioxide (CO_2), water vapor, carbon monoxide (CO), particulate matter (PM), hydrocarbons, nitrogen oxides (NO) and thousands of other compounds (25). Biomass fuels have higher emission factors for these chemicals. Especially, the incomplete combustion at the low temperatures generates indoor airborne particles at levels much higher than those for cleaner fuels (26-28) or outdoors (25), and well above levels in most polluted cities (29). Combustion under such conditions leads to high emission factors that can lead to extremely high pollutant concentrations in the vicinity of the stove. Pollutant concentrations are further exacerbated by the lack of ventilation that characterizes many kitchens in rural areas of developing countries (30, 31). Cooking and heating with biomass fuels in open fires or traditional stoves result in high indoor levels of health-damaging pollutants such as CO and PM. Indoor concentrations depend on indoor emission rate of pollutants, air exchange rate, and room volume. Indoor emission rate can be largely reduced if there is a well-functioning ventilation to vent smoke outdoors; however, flues are absent or poorly maintained in many Chinese households using biomass fuels for cooking (2). Most households use several fuels in different settings. However, there is relatively an association of socioeconomic factors with the main fuels used. Four factors appear to be more relevant in the household's choice of fuel type: (a) cost of fuels, stove type and accessibility to fuels; (b) technical characteristics of stoves and cooking practices; (c) cultural preferences; and lastly, if at all, (d) the potential health impacts (32).

Figure 4. An illustration of one of the stoves that participants used during the investigation.

According to a large survey, in 1993 about 70% of the population in rural China used coal for cooking (33). Domestic coal burning generates the same categories of pollutants as biomass burning, and the levels of these pollutants depend on the type of coal, stove type, combustion efficiency, housing characteristics, and ventilation (34).

Exposure refers to the concentration of pollution in the immediate breathing environment during a specified period of time (1). This can be measured either directly through personal monitoring or indirectly by combining information on pollutant concentrations in each micro environment where people spend time with information on activity patterns (35). People in developing countries are commonly exposed to very high levels of pollution for 3–7 hours daily over many years (36). In the highland areas with the temperate climate, people spend more time indoors to protect themselves from the cold. Such climate requires to extend heating periods and tighter house construction for space heating (37). The exposure may occur over a substantial portion of each 24-hour period (38), and would increase levels of pollution and exposure time (30). Because of their customary involvement in cooking, women's exposure is much higher than that of men during the cold winter in mountainous areas (39). In the present study, CO and PM2.5 are in focus and presented more in detail.

Particulate Matter (PM)

Particulate matter is a mixture of solid particles and liquid droplets suspended in the air (40). These particles originate from a variety of sources such as dust, dirt, soot, smoke, and liquid droplets, and they are formed in the atmosphere by transformation of gaseous emissions (41-43). Particles related to human activity include motor vehicle emissions, industrial processes (e.g. electricity generation and stone crushing), unpaved roads and biomass burning (30). Their chemical and physical compositions depend on location, time of year, and weather (43, 44).

PM is one of the six criteria pollutants (43). The size distribution of total suspended particles (TSPs) in the ambient air is tri-modal, including coarse particles, fine particles, and ultrafine particles. Size-selective sampling of PM refers to collecting particles below, above, or within a specified aerodynamic size range usually selected to have special relevance to inhalation and deposition, sources, or toxicity (45). The size of particles refers to their aerodynamic diameter. The aerodynamic diameter of a particle is the diameter of one unit density sphere having the same settling velocity as the particle in question, whatever its size, shape or density (43). ‘Ultrafine particles’ are less than 0.1 µm in aerodynamic diameter, called PM0.1. ‘Fine’ particles are those which are less than 2.5 µm in aerodynamic diameter are identified as PM2.5. The ‘coarse particles’ are between 2.5 µm and 10 µm in aerodynamic diameter which had been classified as PM10. The largest particles are greater than 10 micrometers in diameter (42). Some particles are large enough or dark enough to be seen such as soot or smoke, while others are so tiny that they can be only be detected individually with a microscope. Particles from smoke tend to be very small – less than one micrometer in diameter. In comparison, a human hair is 70 micrometers in diameter (41, 46).

Fine particles (PM2.5) are formed from gas and condensation of high-temperature vapors during the combustion. They are composed of various combinations of sulfate compounds; nitrate compounds, carbon compounds etc. and particle bound water. (42) The major sources of PM2.5 are fossil fuel combustion, the vegetation burning, and the smelting and processing of metals (45). Their lifetime is from days to weeks and travel distance ranges from 100s to >1000s km (43).

Carbon monoxide (CO)

Carbon monoxide (CO) is a colorless, odorless, and tasteless toxic gas produced by a variety of combustion sources and in the infiltration or ventilation air from outdoors (46-49). The resulting indoor concentration, both average and peak, is dependent on a complex interaction of several interrelated factors affecting the introduction, dispersion and removal of CO (50). These factors include, for example, such variables as 1) the type, nature (factors affecting the generation rate of CO) and number of sources, 2) source use characteristics, 3) building characteristics, 4) infiltration or ventilation rates, 5) air mixing between and within compartments in an indoor space, 6) removal rates and potential remission or generation by indoor surfaces and chemical transformations, 7) existence and effectiveness of air contaminant removal systems and 8) outdoor concentrations. Source emissions from indoor combustion are usually characterized in terms of emission rates, defined as the mass of pollutant emitted per unit of fuel input (micrograms per kilojoule) (51).

CO is one of the most dangerous indoor air pollutants, which can be lethal at high doses (52, 53). In urban areas, CO exposure occurs near the roadways, in the smoke-filled rooms and in the poorly ventilated areas impacted by combustion appliances (54). Domestic cooking and heating by using biomass fuels of wood, crop residues, dried animal dung or charcoal and coal may produce substantial indoor concentrations of CO (55). Wood stoves, even when vented to the outside, emit high concentrations of CO, especially during the winter (56). Another major source of inhaled CO is cigarette smoke.(57).

Indoor air pollution and health

The use of biomass fuels mainly wood has been associated with lung function impairment (58). In cross-sectional studies, the reductions of FEV1 ,FVC PEF and FEF50 have been associated with the exposure to indoor biomass burning (59). The smoke emitted from biomass burning is known hazards to human health (60). The health effect is determined not only by the pollution level but also by the period of time people spend breathing polluted air, i.e. the exposure level (1). Similar to burning biomass, burning coal in households has been associated with several harmful long-term health consequences, including increased incidence of chronic obstructive pulmonary disease (2, 61) and lung cancer (2, 62-64). Indoor coal smoke exposure has also been associated to various respiratory illnesses and reduction of lung function (2). The adverse effect of coal use on these respiratory symptoms and diseases may be inherently linked to impaired lung function. In fact, there have been some studies that reported the effects of indoor coal use on lung function magnitudes (2). Subjects with chronic lung conditions are particularly susceptible to the adverse effects of ambient PM (65). One condition of such particular importance - chronic obstructive pulmonary disease (COPD) - is a progressive inflammatory condition of the airways, pulmonary vessels, and lung parenchyma caused predominantly by inhalation of noxious gasses and PM (66-69). COPD is characterized by chronic airways inflammation and remodeling, lung parenchymal inflammation, and destruction resulting in expiratory airflow obstruction, hyperinflation of the lung with loss of elastic recoil and, ultimately, disturbance of gas exchange (67).

PM2.5 , CO and lung health

Acute effects on health are the consequences of smoke inhalation and poisoning CO, which threatens people's life and cause rapid death if sufficient concentrations occur in the respired air (37). Sub-acute effects are the consequences of the irritant or inflammatory action of the pollutants on the conjunctiva and the mucous linings of the respiratory tract from the nose to the bronchi (37). Several pollutants produced by biomass fuels emissions such as aldehyde, phenols and toluene are among the important hydrocarbons that causes the irritant actions (37). Numerous studies have reported the association between the exposure to biomass smoke and chronic bronchitis or COPD and lung cancer (2, 38, 52, 70-72). Some studies also reported the effect of IAP such as coal smoke exposure on lung function (2, 12). In rural Mexico, the use of biomass was associated with a decrease of 4% in FEV1/FVC, while an increase in the kitchen particle concentration of $1000 \mu g/m^3$ was associated with a reduction of 2% in FEV1 (73). In India, patients using biomass had lower FVC than those using kerosene, gas and mixed fuels (74). Pandey et al. reported an exposure-response relationship with FEV1 and FVC which decreased as the reported hours of exposure increased; it was not statistically significant in non-smokers (75).

How particulate matter affects human health depends on its deposition in the respiratory tract. The deposition rates depend on the particle size, shape, and density of which the most important elements are its size and aerodynamic properties (43). Inhalation is the route of exposure that concerns the direct effects of suspended PM on human health (42). Particles indicated as PM2.5 can be breathed more deeply into the lungs. They remain suspended for longer periods of time, penetrate more readily into indoor environments, and are transported over much longer distances (76). The United States Environmental Protection Agency concluded that PM2.5 had the greater association with mortality and morbidity rates than PM10 (40). There is an evidence for a robust association between continuous PM2.5 exposure and early mortality (77). Thick smoke from biomass burning does not necessarily cause health problems for all people who are exposed to it. Most healthy people recover quickly from the exposure to smoke and do not suffer long-term effects (24). However, the very fine particles in smoke can go deep into the lungs. Fine particles, by themselves or in combination with other air pollutants, can make pre-existing diseases of the heart and lungs worse. Where there is a short-term exposure to smoke, the particles are the most significant threat to public health (24). There are a number of factors that determine whether exposure to smoke results in health problems or not: the concentrations of the air pollutants, the length of the exposure, age, individual susceptibility and health status of the pre-existing lung or heart disease (24, 25).

PM2.5 corresponds to the respirable particle fraction capable to penetrate the alveolar region of the lung. Inhaled particles come in contact with surface of the respiratory system. These particles pass the proximal airway (throat and larynx) of the respiratory tract, and deposit in the tracheobronchial conductive airway of the lungs (bronchial and bronchiolar airway) or in the gas exchange region (respiratory bronchioles, alveolar ducts, and alveoli of the lung parenchyma) (43). Lungs are the organs that are most directly affected by particulate air pollution. PM2.5, which may carry toxic chemicals of carcinogenic potential (78), can reach lung alveoli where the clearance is slow (79) and induce durable pulmonary and systemic inflammation (80). PM2.5 can also aggravate lung diseases such as asthma and bronchitis. If patients with lung disease are exposed to PM2.5, symptoms as coughing, phlegm, chest discomfort, wheezing and shortness of breath may occur. PM2.5 can also increase the susceptibility to respiratory infections (81, 82).

In some epidemiological studies, PM2.5 exposure from 18 µg/m³ to 30 µg/m³ was found to increase daily mortality due to cardiorespiratory mortality in the elderly people with cardiovascular and respiratory disease (83, 84). In addition, other studies demonstrated a relationship between 45µg/m³ and increased hospital admission and chronic bronchitis (84, 85). PM2.5 was associated with an increase of 36% in death of lung cancer and an increase of 26% in cardiopulmonary deaths. These risks have been higher for people of the age above 65 years old (43). The estimated association between PM2.5 and all-cause mortality implies that a decrease of 1 µg/m3 in population-average to PM2.5 would result in approximately 34,000 fewer deaths per year (77).

Carbon monoxide (CO) is one of many ubiquitous contaminants of our environment that requires prevention and control in order to insure the adequate protection of public health (86). In fact, CO may be responsible for more than one-half of all fatal poisonings that are reported worldwide each year (87). The frequency of health problems associated with sub lethal levels of CO is difficult to quantify (86). Low-dose chronic exposure to CO has somehow both short-term and long-term impacts on health, and is associated with fatigue, headaches, dizziness, weakness, sleepiness, nausea, vomiting, confusion and disorientation (55). At lower levels of exposure, CO causes mild effects that are often mistaken for the flu. The moderate level of CO exposure may cause disturbance of consciousness. The severe level of CO exposure may cause deep unconscious state, pulmonary edema, respiratory failure and focal brain damage (47). The effects of CO exposure can vary greatly from person to person depending on age, overall health and the concentration and the length of the exposure. The occurrence of CO poisoning events spikes during colder months when furnaces and space heaters are used (88). When inhaled, CO is readily absorbed from the lungs into the bloodstream (23). Its toxic properties are attributed to its high affinity for oxygen-carrying protein haemoglobin (Hb). The binding of CO to Hb produces carboxyhaemoglobin (COHb) (89). The presence of COHb in the blood decreases the oxygen carrying capacity, reducing the availability of oxygen to body tissues and resulting in tissue hypoxia. A reduction in oxygen delivery, caused by the elevated COHb level and exacerbated by impaired perfusion resulting from hypoxic cardiac dysfunction, will potentially impair cellular oxidative metabolism (90). And increasing air carbon monoxide concentration would decreasing FEV1(91). At high CO concentrations, excessive increases in hemoglobin and hematocrit may impose an additional workload on the heart and compromise blood flow to the tissues. It is unlikely that CO has any direct effects on lung tissue except for extremely high concentrations associated with carbon monoxide poisoning (92).

METHODOLOGICAL DISCUSSION

In order to perform the present study, a quantitative method was used. This is a survey which provides a quantitative of the population-the sample-through the data collection process of asking questions of people (26). This data collection enables a researcher to generalize the findings from sample of responses to a population (93).

Study Design

The purpose of the present study was to investigate whether PM2.5 or CO were associated with women's lung function in Guizhou province. Therefore, a cross-sectional epidemiological survey was carried out. The cross-sectional study design is a survey which is given at one point in time and only once to a particular sample of respondents (94). There will always be some advantages and disadvantages with each study design. The advantages with the present study design are standardized questions, less costly to reach larger samples, less labor intensive to collect data or train researchers, suitable for probability sampling and more accurate generalizability (95). In order to collect data, two home visits were conducted. At the first visit, we informed the participants about the study, and confirmed participant identity (ID). Obtain consent form for indoor air pollution monitoring was given to participants. All the participants had to provide informed consent for all aspects of the study, as approved by the ethics committee. Those who were unwilling to provide informed consent were ineligible to participate in the study. The CO tubes were also placed on participants clothing at this visit and we also informed that they must wear it on at all times and placed next to bed when sleeping. For a subsample of households, the UCB particle monitor and CO tubes were placed on the wall in both living room and kitchen. The IAP instruments were placed approximately 100cm from the edge of the combustion zone of the main cooking stove and at a height of 145 cm above the floor (Figure 5). Before we left, we also informed participants that upon next visit they would be ask about activities the last 48 hours, so that they would remember these activities when asked later. At the second visit, the CO tube for personal monitoring was collected, the measurement of weight, height and spirometry were conducted. For households with IAP monitoring equipment, the equipment's also be collected.

Since all the data collection and measurements refers to the same point in time. These information were just a basically snapshots of the population status with respect to disease or exposure variables, or both, at a specific point of time (96). This study design did not measure disease incidence, because risk or rate calculations require information across a time period. Another disadvantage of this study is that this study design are not ideal for uncovering causal relationships that require demonstration of a time sequence for the independent and dependent variables (95). Nevertheless, cross-sectional studies can assess disease prevalence and sometimes, cross-sectional information is used because it is considered a good proxy for longitudinal data (96).

Figure 5. Illustration of indoor air pollution instrument placement in homes. The horizontal measurement (100 cm) is made from the closest edge of the combustion zone and that the height is measured from the floor, not the top of the stove (145 cm).

Population and Sample selection

A clustered household survey was conducted among 1796 women ≥30 years in 3 counties in Guizhou Province: Xiuwen, Congjiang, and Danzhai. The clusters were selected based on main cooking fuel: raw coal, biomass, or a mix of biomass and biogas, respectively. A village functionary assisted with recruiting eligible participants. All women ≥30 years living in the study villages were invited to participate in the main study. Of all the participants, only 3% of women were excluded from the study because they had lost the tube or had forgotten to wear the CO tube for the entire measurement duration and less than 1% was also excluded from the study because they were smoker. The exclusion of the participants in the study did not affect the study or other participants since the excluded paricipants were just a small number. All villages were in rural areas, and the women who participated in the study are among the marginalized groups in Guizhou. Illiteracy rate among the participants was 73%. For comparison, 20% of the adult female population in Guizhou is illiterate. 36% of the participants were Han Chinese, and the remaining 64% belonged to different ethnic minority groups (97). Finally, 10% of participants in the aim study for IAP were randomly selected to measure IAP at their households. This subsample was limited to 10% because we did not have opportunity and capacity to measure everyone. This subsample was also wished to be representative for the entire study population, since they reflected the characteristics of the population (93). Before beginning second visit, it was critical that all data for a given participant be labeled using the same participant ID, and that any given participant ID was assigned to one and only one participant. It was important that fieldworker checked the participant ID to make sure that the correct ID was being used.

Methods and procedures

The interviewers conducted the questionnaire by asking the participants item by item in the questionnaire; and the participants answered the questions face to face at their home (95). Home interviews made the participants feel comfortable. The interviewers were competent staffs who were well trained for this domain. The questions were asked to the participants as clearly as possible. Non-verbal clues were not given. This was to ensure reliability of the questionnaire and the interviewer's behaviors. Besides the advantages described above, there are in the mean time the disadvantages while performing this research. First, the questionnaire was long, which made the participants distracted. Second, the personalities of the interviewers such as gender, race, sex, age may influence the answers of the respondents (95). These factors may more or less affect the accuracy of the respondents' answers.

Validity testing is the process in which accuracy of measurement using instrument is checked against a reference method, i.e. measurements of the same phenomenon made using an existing instrument of known accuracy. In questionnaire research, it involves testing whether the questions elicit answers that describe the intended phenomenon (98). The measurement instrument was measured in a standardized way in all women by the same highly experienced and trained staff. All individual flow-volume curves were also reviewed for technical acceptability and checked for reproducibility according to European Respiratory Society (ERS) (99). However, there would still be some factors that effect on spirometry quality; a subject may not take as deep a breath as possible or exhale as forcefully as possible at the start of the maneuver. Several possibilities which prevent a maneuver from being acceptable: an involuntary epiglottis closure, temporarily cutting off the flow of air; an early termination of the maneuver, preventing the achievement of a plateau; or a variable effort. Coughing during the maneuver or a leakage due to the participant's inability to keep a tight seal also prevent from obtaining a good maneuver. To address this source of error, it was important that field workers trained to watch the participant closely during the performance and accurately review the displayed flow-volume curves on the computer monitor. The field worker thus guided and explained the source of error to the participant. Leaks in the system, differences in temperature, and poor calibration were all factors that affect the quality of the test results. When analysis; a combination of all factors might affect the quality of the results. Results from the calibration factors, field worker's impression of test session quality, and the quality control supervisor's impression of test session quality are all integrated to obtain the final FEV_1 and FVC results used in the study.

The measurement of IAP to place in three phases, February-May 2009, September 2009 and November 2009-January 2010. November-March was defined as winter and April-October as summer based on measured nighttime minimum kitchen temperature, which was usually well below 16 ^{o}C in winter. Both kitchen and living room concentrations were measured, with the exception of September 2009 when only kitchen was included. Coal using households were not measured during summertime. Seven villages in Danzhai, four villages in Congjiang, and two villages in Xiuwen county were selected for IAP monitoring to represent biogas, biomass and coal households. In all, 179 homes were included in winter and 122 in summer. Indoor particulate pollution (PM2.5) was monitored by the UCB-PATS photoelectric real time particle and temperature monitors developed at UC Berkeley (Berkeley Air, CA, USA). CO tubes were co-located with the USB-PATS monitors, and were done in parallel with particle monitoring. CO concentration was measured with Gastec 1D passive diffusion tubes (Gastec Corp., Kanagawa, Japan). Stationary PM2.5 and CO was monitored for an average of 48 ± 1.2 hours. Monitors were placed one meter from the stove, 145 cm above ground, and at least on meter away from any doors and windows. To avoid investigator variability, the investigator read all tubes under standard conditions at the field office. For quality control purposes, at least one reading was performed independently by another investigator. There was good agreement between repeated readings. The average difference between the first and second reading was 0.01mm, and the largest discrepancy was 2.5 mm. Cumulative exposure was converted to mean exposure by dividing by the measurement duration.

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INDOOR AIR POLLUTION IN RURAL CHINA; ASSOCIATED WITH LUNG FUNCTION?

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ABSTRACT

Introduction: Approximately, half of the world population depends on biomass fuels as primary energy source. Indoor air pollutants are recently studied and considered as to be responsible for health burden in rural China. Chronic exposure to biomass combustion has been claimed to be associated with increased prevalence of respiratory symptoms, reduced lung function and the development of chronic obstructive pulmonary disease (COPD) The present study focuses on two main indoor air pollutants produced by biomass combustion: CO (Carbon monoxide) and PM (Particulate matter). The aim of the current study is to consider the association between these two main indoor pollutants and women's lung function in chosen rural villages of Giuzhou Province of China.

Methods: A cross-sectional study was carried out on the present study. A cluster of household survey was randomly selected to perform measurement of indoor air pollution. Sample subjects were women in the age of 30 years old or older. Spirometry was performed in all subjects.

Results: There was no difference between participants with IAP measurement and those without IAP measurement. A significant association was found between CO concentration in living room and FEF50 (P=0.040). No statistically significant association was found between living-room CO concentration and FVC as well as FEV1No significant association was found between PM2.5 concentration and lung function neither in kitchen nor in living room.

Conclusion: CO concentration was negatively associated with women's lung function, and there was no association between PM2.5 and women's lung function.

Key words: Indoor air pollution, lung function, biomass fuels, carbon monoxide (CO), particular matter (PM).

INTRODUCTION

Indoor air pollution (IAP) is associated with increased morbidity and mortality worldwide (1-4). IAP affects a large proportion of the world's population (1), especially women in developing countries who often assume cooking activities (5-7). IAP comes from the combustion of biomass fuels such as coal, wood and animal dung. The indoor use of biomass fuels is a major contributor to indoor air pollution (8-11). Indeed, the chronic exposure to biomass combustion has been claimed to be associated with increased prevalence of respiratory symptoms, reduced lung function and the development of chronic obstructive pulmonary disease (COPD) (2, 3, 12, 13). Approximately, half of the world's population depends on biomass fuels as primary energy source (14, 15). Up to 90% of rural households use unprocessed biomass such as dung, crop residues, wood and coal for cooking and heating (5). According to the World Health Organization (WHO), the smoke from biomass fuels burned in households is one of the health risks to people in developing countries (16).

The Chinese population suffers a high health burden from lung diseases (17) and one of the explanations of lung diseases could be the combustion of biomass fuels (13). The use of biomass fuels counts about 80% of domestic energy (13,18, 19), and the combustion of biomass fuels causes severe indoor air pollution (13). Several researches had reported about indoor air pollution from biomass fuels (13, 20-23). Recently, China has conducted more IAP measurements focused on household combustion than any other developing countries (24). In the early 1990s, the results of more than 100 published studies conducted by the China were combined into a WHO database (25). In particular, over 25 years a wide-ranging set of studies has been conducted on coal smoke exposures, toxicology, and health effects in one rural area-Xuanwei in Yunnan Province-with several impacts (24).

More than 60% of the population in China lives in rural areas (26) and Guizhou province is one of the rural areas in China which is located in southwest of China. This is the poorest province in China measured by gross domestic product (GDP) per capita, and is home to 35 million inhabitants (26). Guizhou is a mountainous region ranging in altitude between 150-1700 m with a humid sub-tropical climate. The annual average temperature is 15^{o}C, ranging from 22-25^{o}C in July to 4-6^{o}C in January, usually necessitating heating in wintertime. According to survey data in 2000, 91% of households in the province used solid fuels for cooking, with 57% and 34%, respectively, using coal or biomass (wood logs, twigs, or charcoal) as their main fuel (27). Gas or electricity (clean household fuels) had been slow to penetrate in the province. Unprocessed coal is cheap and abundant, and is used by many families in rural areas. In addition, crop residues and wood are collected and used as fuels in large amounts. Even in the urban parts of Guizhou, only about 30% of the population uses gas or electricity.

There have been several studies about the measurements of indoor air pollution in rural China and other developing countries, and recently in China, the indoor air pollution has been studied in 4 provinces; one of the provinces was Guizhou. Four provinces in China had been studied for IAP. By using stationary monitors at the household level, the researchers have measured the amount of carbon monoxide [CO], sulfur dioxide [SO2], and respirable particles [RPM; PM with a median aero-dynamic diameter ≤4 μm (PM4)]. The result shows that: The highest PM4 concentrations have been found in two provinces which use biomass as the primary fuel. The amount of PM4 in Guizhou province using biomass fuel and traditional stove is higher than in Shaanxi province using coal and improved stove (28). Large cultural and climatic differences between populations lead to large differences in indoor air pollution, and measurements from one area are not necessarily representative of the situation in other areas. The aim of the present study was to investigate whether CO and PM were associated with women's lung function in Guizhou Province.

MATERIALS AND METHODS

Study design

A cross-sectional epidemiological survey was carried out in rural Guizhou Province. A clustered household survey was carried out on 1796 women ≥30 years old. The monitoring process took place in three periods: February-May 2009, September 2009 and November 2009-January 2010. Based on the measured nighttime minimum kitchen temperature which was usually well below 16ºC in winter, November-March was defined as winter and April-October as summer.

A home visit to the participants was conducted twice. The purpose of the first visit was to obtain informed consent, and to place the equipment for indoor air measurements of CO and PM2.5. The purpose of the second visit was to administer the full study questionnaire, measure height and weight, conduct spirometry before and at least 20 minutes after the administration of an inhaled bronchodilator (Salbutamol), and collect equipment for indoor air measurements of CO and PM.

The present study is based on Indoor PM and CO measurement and lung function in rural Guizhou. The study subjects signed an informed consent form after being given oral and written information about the study objectives and methods. The study was approved by the Regional Committees for Medical and Health Research Ethics and the Bureau of Health of Guizhou Province.

Study sample

In total, 179 homes were measured for IAP, PM2.5 and CO, in winter and 122 homes in summer. A clustered household survey for personal CO measurements was conducted among 1796 women ≥ 30 years in 3 counties in Guizhou Province: Xuiwen, Congjiang, and Danhai. The clusters were chosen based on main cooking fuels: biomass. The following women were among the more marginalized groups in the Province. Illiteracy rate was measured 73% and they are original from different groups: 1- Han Chinese accounts for 36%; 2- The rest of 64% belong to different ethnic minority groups (50% Miao, 13% Dong, 1% other minorities) (26).

Out of 1796 fifty-nine participants were excluded for following reasons: 1) they had forgotten to wear the CO tube during the entire measurement process; 2) they had lost their CO tubes. Another 10 participants were excluded because they were smokers. The total number of personal CO measurements which were available for analysis was 1727.

All women ≥ 30 years living in the study villages were invited to participate in the main study, of which about 10% were randomly selected as sub-sample subjects for indoor air pollution monitoring and these 157 sub-sample subjects were included in the present study. All sub-sample subjects participated in the measurement of their lung function.

Methods

Indoor particulate pollution (PM2.5) was monitored by the UCB-PATS photoelectric real time particle and temperature monitors developed at UC Berkeley (Berkeley Air, CA, USA). The UCB-PATS - small, portable, battery-operated (9 volt) data logging monitor used for indoor environments - measured and logged PM every minute (in units of milligrams PM per cubic meter of air, mg/m) (29). Stationary PM2.5 was measured during 48 ± 1.2 hours on average in both living room and kitchen. Based on the photoelectric (light-scattering) detector set up, it is capable to measure PM2.5 down to 50µg/m3 and even PM0.1. Monitors were placed at an approximately 100 cm from the edge of the combustion zone of the main cooking stove, and at a height of 145 cm above the floor of each household, and at least 150 cm away (horizontally) from doors and windows, where possible. Light-scattering devices require calibration for each pollutant source because different particles carry different light-scattering behavior. The monitors were calibrated to coal using co-location tests which showed good inter-correlation between the UCB-PATS both for biomass and coal with a standard deviation 39 µg/m3 for biomass. All devices were co-located with a few centimeters of space between them to ensure that their inlets were not blocked. The lower signal-to-noise ratio in coal measurements implies that these measurements must be interpreted with care.

Integrated CO measurements were done in parallel with particle monitoring in all households. CO tubes were co-located with the USB-PATS monitors. CO concentration was measured with Gastec 1D passive diffusion tubes (Gastec Corp., Kanagawa, Japan). The tubes change color when they are exposed to CO, and the length of the stain is determined by CO concentration and measurement duration. The length of the discoloration was measured to the nearest millimeter with a metric ruler.

Lung function was measured by maximum forced expiratory flow-volume curves (29) according to American Thoracic and European Respiratory Society (30) using SpiroUSB (Micro Medical LTD, Rochester, Kent, UK). The following variables were included in the present study: Forced expiratory volume in 1 second (FEV_1), Forced vital capacity (FVC) and Forced expiratory flow at 50% (FEF50). Reversibility after administration of 0.4 mg Ventoline (GlaxoSmithKline, Brentford, Middlesex, TW8 9GS, UK), salbutamol 0.1mg per puff inhaled using an AeroChamber Plus (GlaxoSmithKline, Brentford, Middlesex, TW8 9GS, UK.) to the participant were carried out. Lung function was measured before and 20 min after inhalation of salbutamol.

Statistical analysis

Demographics data were given as mean values and standard deviation (SD) unless otherwise stated and results as coefficients with 95% confidence intervals (CI). Chi-square tests and independent t-test with Tukey-post hoc tests were used to analyse differences between groups.

Multivariate linear regression models were applied with FEV1, FVC or FEF50 as dependent variables. The following covariates (independent variables) were included based on associations with lung function demonstrated in previous studies: age, socioeconomic status, COPD, height (core set variables), in addition to CO and PM 2.5. Only winter measurement was chosen to analyze; therefore, the accuracy of the results is reliable. Since the participants spend more time inside during winter, and the cold weather in winter requires them to heat. Statistical significance level was set to 5%. Statistical analyses were performed with Statistical Package for Social Sciences (SPSS) v. 19.0.

RESULTS

The descriptive data of the participants in the present study are presented in Table 1. There were no statistically differences between participants with and without IAP measurement in age and height. There were significantly differences in age ($P = 0.037$) ethnicity (P-values <0.001), socioeconomic status (P-values 0.025), used of stove type (P-values <0.001), and type of fuels (P-values 0.034 (Table 1).

Mean lung function values and PM2.5 and CO concentration are presented in Table 2. According to the guideline of Occupational Safety and Health Administration (OSHA) (31), standard for CO is 50 parts of CO per million parts of air (ppm) averaged over an 8-hour. The National Institute for Occupational Safety and Health (NIOSH) (32) has then recommended that the allowed exposure limit be reduced to 35 ppm averaged up to 10-hours per day. However, the mean CO concentration in the present study which had been measured for 48-hours, were lower than the allowed exposure both in kitchen and living room (Table 2). The PM2.5 concentrations were higher and not usually within guidelines (33). Both PM2.5 concentration in kitchen and living room exceeded WHOs 24-hour guideline value of 25 μg/m^3 mean (33).

No significant association was found between PM2.5 and lung function neither in kitchen nor in living room. CO in the living room was negatively associated (P=0.040) with FEF50. An increase in CO of 1ppm decreased FEF50 with 0.029 l/s when adjusted for core set variables. CO concentration in the kitchen was negatively associated (P=0.049) with FVC. An increase of 1ppm decreased FVC with 0.017l when adjusted for core set variables. CO in the kitchen was negatively associated (P=0.045) with FEV1. An increase of 1ppm CO decreased FEV1 with 0.015l when adjusted for core set variables. There were no significant association between CO concentration in the kitchen and FEF_{50} and there was no statistically significant association was found between living-room CO concentration and FVC as well as FEV1 (Table 3).

DISCUSSION

In the present study we found a significant negatively association between CO concentration and lung function in women in living room and in kitchen. No significant association was found between PM2.5 and women's lung function.

Our finding showed a negatively association between CO and lung function. Not all the available evidence from a number of studies supports the presence of such an effect, but our results agree with those reported in several investigations (34, 35). A case-control study of 20-to 39-yr-old female participants in the Tecumseh Community Health Study compared use of cooking fuels and other factors in women from the highest and lowest quartiles of the lung function distribution. FEV1 was used as the index of ventilatory lung function. The use of a kitchen exhaust fan was significantly associated with low lung function (35). Another cross sectional study of a population based sample of 2868 adults aged 20 to 74 years in Singapore reported that domestic exposure to cigarette smoke and gas cooking is associated with increased risks of respiratory symptoms and impairment of lung function in non-smoking women (36).

Moreover, a Chinese study reported the harmful effects of CO levels on lung function in adults. CO and PM10 exposure indices in the bedroom were negatively associated with FVC and FEV1 ($P<0.01$) to the (37). In Singapore nonsmoking females who frequently used gas for cooking had more respiratory symptoms and worse lung function than females who used gas infrequently or not at all (36). Another study on lung function carried out on 213 women aged 50-70 years, including 167 women using coal for cooking, and 46 women using gas for cooking in Shanghai, showed a statistically significant decrease in forced expiratory flow in the first second and FEV1/FVC ratio among women using coal for cooking (38).

Indoor concentrations depend on indoor emission rate of air pollutants, air change rate, and room volume. This indoor emission rate may be reduced by a good flue/chimney, ventilators and, by using clean fuels for cooking and in heating (39). There might be a speculation of our findings with respect to CO. Lack of ventilating system or chimney/flue may increase indoor CO concentrations. Furthermore, the traditional open-fire pits and rudimental method of food heating increase CO emission inside the house. The subjects who have the most frequent exposure to indoor CO concentrations are women because they spend most their time at home cooking, heating, doing housework and drying food (40). The cold climate at Guizhou, makes it necessary to dry food using a drying agent. The traditional solution is to equip the stoves with a chimney that releases flue gasses to the attic where the food hangs for drying. The attic is separated from the living areas by a porous ceiling, thus the pollutants readily disperse back downstairs.

All the factors like foo drying, fuel types, stoves, chimney etc., contributed to intensify the indoor CO concentrations. As mentioned previously, CO is a poisoning chemical which have caused many adverse effects on human being health. Conflicting results may be due to for example, CO and PM2.5 were assessed via indoor and personal monitoring, in a cross-sectional survey of 79 Honduran women cooking with traditional or improved stoves (41); and the result of this survey reported that the use of improved stoves was associated with 63% lower levels of personal PM2.5, 73% lower levels of indoor PM2.5, and 87% lower levels of indoor carbon monoxide as compared to traditional stoves. Women using traditional stoves reported symptoms more frequently than those using improved stoves. Lung function and respiratory symptoms were identified. Women using traditional stoves reported symptoms more frequently than those using improved stoves. Nevertheless, no evidence of associations was found between stove types or air quality measures with lung function (41).

Our findings, no association between PM2.5 and lung function, are supported by recent studies where no association between PM2.5 and lung function has been found (42, 43). However, in several other studies an association between PM2.5 and lung function has been found (24, 44-46). Adults exposed to IAP, such as PM from biomass combustion have been found to have decreased lung function,(40, 47). In a 3-years panel study in Seattle with 57 elderly, indoor and outdoor PM measurements were made at all subjects home. The subjects wore personal exposure monitors for 10 consecutive 24-h periods. The researchers assessed the within-subject effect of particulate exposure on FEV1 and peak expiratory flow in adults. The associations were strongest for central site PM2.5 and FEV1 in adults with COPD (47). In Turkey for all pulmonary function test parameters FEV1, FVC, FEV1/FVC, and FEF25-75 a highly significant reduction was observed in biomass users when compared with adults that did not use biomass fuel (48). Observational studies of non-smoking women with long-term exposures to biomass smoke have also shown combined restrictive and obstructive changes in lung function (49, 50).

No association between PM2.5 and women's lung function is supported by recent studies (42, 43). In a panel study which was conducted in four European cities (Helsinki, Athens, Amsterdam and Birmingham); FVC, FEV1 and peak expiratory flow was measured three times a day for 1 week in 135 patients with asthma or COPD, covering a study period of 1 year. Daily concentrations of particle number, PM2.5 and PM10 were measured at a central site in each city and both inside and outside the subjects' homes. Daily average particle number concentrations ranged between 2100 and 66 100 particles/cm3. In the study they found no association between 24 h average particle number or particle mass concentrations and FVC, FEV1 (43). Gamble (42), in a long-term prospective cohort study, also found that PM2.5 was significantly associated with mortality but not with in lung function.

The products of biomass combustion were a compound mixture of CO, nitrogen dioxide (NO_2), and PM. CO and NO2 may go directly into lungs and cause direct impacts on lung function; whereas, the contamination process of particles depends on their size (51). It means that the particle size determines how deep the particles can travel within and beyond the respiratory tract. PM10 are categorized as inhalable particles. Respirale particles include PM2.5 and PM0.1 (51). On one hand, this indoor air pollutant depends on the degree of the concentration; on the other hand, it depends on how this indoor air pollutant penetrates into lungs by the conductive airway (42). A significant association with lung function were found in a cross-sectional investigation on adults (aged 18 to 60 yrs.; n = 9,651) residing in eight different areas in Switzerland. The impact of annual means of air pollutants on FVC and FEV1 was tested. Analyses were done separately for healthy never-smokers, ex-smokers, for current smokers, and for the whole population. (52).

Beside the above elements, the complexity of the air mixture, the highly correlated nature of the pollutants, the inability to completely control for confounders (42) and the limitations of the central monitor may influence the non-insignificant association between PM2.5 and lung function. Differences in IAP exposure among women may not have a significant impact, since the adult lung is thought to be less susceptible to the effects of air pollution (53). Other disadvantages may contribute to the findings of the present study: 1) the measurement instruments did not placed at the right place; 2) house structure or room layout could also have a significantly affect spatial and temporal distribution of pollutant concentrations within a household (24).

The strength of the present study was that lung function, height and weight were measured in a standardized way in all women by the same highly experienced and trained staff. All individual flow-volume curves were also reviewed for technical acceptability and checked for reproducibility according to European Respiratory Society (ERS) (30). There are; however, some limitations in the present study; we only had IAP-measurement in few homes. Due to the cross sectional design of the present study, we cannot conclude that there is any causal relationship between level of CO and lung function.

In conclusion, CO concentration was negatively associated with women’s lung function. PM2.5 concentration was not associated with women’s lung function. These results need; however, to be confirmed by using a longitudinal study design with a larger sample size.

More attention should be paid to improve the cooking stoves, type of fuels and ventilation conditions in rural communities.

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Table 1. Demographic characteristics of the 157 participants in the present study and the 1628 participants without indoor air pollution measurements.

	With IAP measurement		Without IAP measurement		
	(n= 157)		n= 1628		P-values
Age (yrs.)	44	(10.3)	45	(11.8)	**0.037**
Ethnicity, n%					**<0.001**
Han	55	35.0	579	35.6	
Miao	46	29.3	853	52.4	
Dong	54	34.4	179	11.0	
Other	2	1.3	17	1.0	
Weight (kg)	52	(8.0)	52	(8.4)	0.376
Height (cm)	150	(5.8)	150	(6.2)	0.253
Socioeconomic status, n%					**0.025**
Low	33	21.0	336	22.3	
Medium	88	56.1	1025	63.0	
High	36	22.9	240	14.7	
Stove type, n% *					**<0.001**
Stove with chimney - to attic	3	1.9	37	2.3	
Stove with chimney out	11	7.0	172	10.6	
Stove with chimney out - as using charcoal	54	34.4	538	33.0	
None open fire	15	9.6	366	22.5	
Open fire	71	45.2	506	31.1	
Fuels, n%					**0.034**
Coal/ wood	22	14.0	345	21.2	
Gas/ electricity	135	86.0	1283	78.8	

Data are given as prevalence's with n (%) whereas age, weight, height are given as mean with standard deviation in parenthesis. Statistically significant values are given in bold. * Missing values for some of the participants with and without IAP measurements.

Table 2. Lung function, PM2.5 and CO concentration of the 157 participants. Numbers are presented as mean, standard deviation (SD), and minimum (min) and maximum (max), median and interquartile range.

	N	Mean (SD)		Min-Max	Median	Interquartile range
FEF50 (l/s)	157	3.34	(1.10)	0.58-6.24		
FVC (l)	157	2.43	(0.50)	0.87-3.56		
FEV1 (l)	157	2.13	(0.46)	0.63-3.19		
PM2.5 ($\mu g/m^3$)						
Kitchen	152				493	8673
Living room	153				237	10638
CO (ppm)						
Kitchen	149				1.45	31.80
Living room	148				1.18	37.48

PM2.5, measurement of particular matter; CO, measurement of carbon monoxide FEV1, Forced Expiratory Volume at One Second; FVC, Forced Vital capacity; FEF25-75%, Forced Expiratory Flow between 25% and 75%; Missing values for some of the CO/PM measurements

Table 3. Regression summaries for multivariate analysis with the dependent variables FEFE50, FVC and FEV1; .

	FEF50 (l/s)		FVC (l)		FEV1 (l)	
	Coefficients (95% CI)	P-Values	Coefficients (95%CI)	P-Values	Coefficients (95%CI)	P-Values
Socioeconomic status (high as reference)						
Low	-0.495 (-0.976, -0.014)	**0.044**	-0.088 (-0.303, 0.128)	0.42	-0.120 (-0.306, 0.065)	0.203
Medium	-0.220 (-0.603, 0.163)	0.258	-0.050 (-0.222, 0.122)	0.566	-0.069 (-0.216, 0.079)	0.360
(COPD as reference)						
No COPD	2.538 (1.487, 3.588)	**<0.001**	0.231 (-0.240, 0.702)	0.333	0.852 (0.446, 1.257)	**<0.001**
Age (yrs.)	-0.032 (-0.048, -0.016)	**<0.001**	-0.016 (-0.023, -0.009)	**<0.001**	-0.017 (-0.023, -0.011)	**<0.001**
Height (cm)	0.033 (0.005, 0.062)	**0.021**	0.032 (0.020, 0.045)	**<0.001**	0.026 (0.015, 0.037)	**<0.001**
PM2.5 ($\mu g/m^3$)						
Kitchen	0.0000766 (-0.0000964, 0.000249)	0.383	0.0000444 (-0.0000331, 0.000121)	0.260	0.0000431 (-0.000023, 0.000109)	0.204
Living room	0.0000300 (-0.000121, 0.000181)	0.696	-0.0000352 (-0.000103, 0.0000327)	0.307	-0.0000271 (-0.0000856, 0.0000312)	0.360
CO (ppm)						
Kitchen	-0.018 (-0.056, 0.019)	0.341	-0.017 (-0.034, -0.000103)	**0.049**	-0.015 (-0.029, -0.000331)	**0.045**
Living room	-0.029 (-0.057, -0.001)	**0.040**	0.007 (-0.006, 0.019)	0.272	0.001 (-0.010, 0.011)	0.925

The coefficients are given with 95% confidence intervals (CI). Statistically significant values are given in bold.

APPENDICES

1: Ethic committee approval of China (in English and Chinese)

2: Ethic committee approval of REK

3: Questionnaires

Bureau of Environment Protection of Guizhou Province

December 17, 2008

The Letter of Bureau of Health of Guizhou Province on The Appropriateness of Conducting Medical Investigation in The Cooperation Project between Guizhou Academy of Environmental Science, An Affiliated Institute of Bureau of Environment Protection of Guizhou Province, and Norway

To Whom It May Concern,

Your letter on *The Application of Guizhou Academy of Environmental Science for Conducting Cooperation Project with Norway* is duly received. After discussion, we approve that your affiliated institute, Guizhou Academy of Environmental Science, may conduct the investigation of 6 health indicators regarding women's body height, body weight, blood pressure, blood oxygen, CO and lung vital capacity during the implementation of the project of *The Investigation and Research of Indoor Air Pollution Situation in Rural Area in Guizhou of China*. Please report and conduct works of the project strictly in accordance with relevant state regulations.

Sincerely,

Bureau of Health of Guizhou Province

贵州省卫生厅

贵州省卫生厅关于贵州省环保局直属单位
贵州省环科院与挪威开展的合作项目中
有关医学调查是否妥当的函

贵州省环境保护局：

你局《关于环科院申请与挪威开展国际合作项目的函》已收悉。经研究，同意你局直属单位贵州省环境科学院在实施《中国贵州农村地区室内空气污染状况调查研究》项目中，开展涉及妇女身高、体重、血压、血氧、CO和肺活量六项基本健康指标调查。请你局严格按照国家有关规定申报并开展相关工作。

二〇〇八年十二月十七日

UNIVERSITETET I OSLO
DET MEDISINSKE FAKULTET

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Dato: 22.04.09
Deres ref.:
Vår ref.: S-09174a 2009/3726

S-09174a Innendørs luftforurensning og helse i Guizhou, Kina Tittel på prosjektet: "Indoor air pollution. A neglected poverty related cause of global ill Health – Implications for public health and society of promoting clean household fuels in China" (short name in Norwegian Research Council: NEGLECT) [1.2009.574]

Vi viser epost av 20.04.09 med svar på komiteens merknader vedlagt revidert informasjonsskriv med samtykkeerklæring.

Komiteen har ingen merknader til revidert informasjonsskriv med samtykkeerklæring.

Komiteen godkjenner at prosjektet gjennomføres i samsvar med det som framgår av søknaden og tilbakemeldingen på komiteens merknader.

Med vennlig hilsen

Kristian Hagestad

Kristian Hagestad
Fylkeslege cand.med., spes. i samf.med
Leder

Jørgen Hardang

Jørgen Hardang
Komitésekretær

IDENTIFICATION AND PROGRESS

(to be filled in by interviewer)

Comment

Personal ID:	####

This is a unique number for each questionnaire, assigned before start of survey. It will be the SAME ID for spirometry and personal CO tubes!

County ID	
Township ID	
Village ID	
Household ID	

If there are more women being interview in the same household, note the ID number of the other women:	

Visit number:	1	2	3
SURVEYOR ID:			
Date:			
Time at start:			
Time at end:			
Result			

Status codes

1. First part completed (CO tube, consent)
2: Second part completed (interview, health exam)
3: Partially complete
4:Refusal
5: Language barrier
6:Sick
7: Other

In progress status codes

8: No one at home
9: No woman over 30 years at home

If the result of the interview is incomplete:

It must be completed in the next visit: Specify section(s)missing:

Appointment made for	
Time:	
Date:	

Personal CO monitoring

M1	**CO tube ID:**	
M2	**QC number**	

		Date (dd/mm)	Time (hh:mm)
M3	Start time CO tube monitoring:		
M4	End time CO tube monitoring:		

M5	Has the CO tube been worn at all times?	Yes	
		No	

M6	Describe any problems:	

		reader 1	reader 2	supervisor
M7	Length of brown stain in field (cm)			
	Initials of reader			
	Comments:			

I. General information about the dwelling

Dwelling characteristics (to be filled in by interviewer)

1 Building material of house

	Check one
Traditional wood	
Brick	
Other (please specify)	

2 Size of dwelling (Sq m)

Area (Sq m)	

3 Number of rooms (only for living areas or food storage)

Number of rooms	

4 Does the dwelling have: (check off all that apply)

	Check all that apply
Electricity	
Tap water	
A ventilation fan	
Attic for smoke-drying of food	

Ventilation (to be filled in by interviewer)

5 Information about ventilation in cooking room

Number of windows for ventilation in room for cooking	
Approximate area per window	
Number of doors for ventilation in room for cooking	
Approximate area per door	

6 Are there separate rooms for cooking and heating?

Yes	
No	

[If yes]

6a Information about ventilation in heating room

Number of windows for ventilation in room for heating	
Approximate area per window	
Number of doors for ventilation in room for heating	
Approximate area per door	

7 Is there leakage of air through the wall?

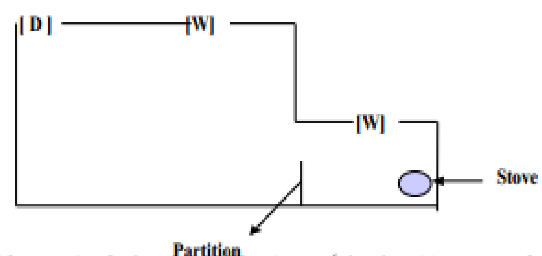
Yes	
No	

Household sketch (to be made by interviewer)

8

PLEASE MAKE SKETCHES AS LARGE AS POSSIBLE

Sample sketch given below:



Please include the following: (check off as completed)

___ Identification of rooms

K: kitchen, L: living room, B: bedroom, S: storage, A: area for animals

___ Location of stove(s)

___ Partition of kitchen (if applicable)

___ Location of all doorways

cm)

____ For households with PM monitoring: Location of UCB monitor

II. Respondent data

9 Age

Years	

9a Is this an exact estimate?

Yes	
No	

10 Relationship to head of household

	Check one
HoH	
Wife of HoH	
Daughter of HoH	
Mother of HoH	
Grandmother of HoH	
Daughter in law of HoH	
Other (please specify)	

11 Highest completed education level

	Check one
Never attended school	
Completed primary school	
Completed junior middle school	
Completed senior middle school	
Completed Vocational school	
Completed College level or above	

12 Literacy

	Check one
Illiterate	
Literate	

13 Ethnic group/minority

	Check one
Han	
Miao	
Other (please specify):	

14 Occupation (check max two)

				Check max 2
Farmer				
Worker				
Teacher				
Business				
Administrative personnel				
Homemaker / caregiver				
Other, specify:				

15 How many hours a day do you usually spend outdoors?

Number of hours	

16 Have you worked a year or more in a dusty or smoky job?

Yes	
No	

[If yes]

16a What kind of job?

17 How long have you lived in this house?

Number of years	

[If less than 10 years; ask question 17a-e]

17a Building material of previous house

	Check one
Traditional wood	
Brick	
Other (please specify)	

17b What was the main type of stoves for cooking and heating in previous dwelling?

	Check all that apply
1. Coal stove without chimney	
2. Coal stove with chimney extending to attic	
3. Coal stove with chimney extending outside	
4. Biomass stove without chimney	
5. Biomass stove with chimney extending to attic	
6. Biomass stove with chimney extending outside	
7. Open fire without chimney	
8. Gas stove (LPG or biogas)	
9. Kerosene stove	
10. Electric stove	
11. Other (Specify)	

17c The **main** COOKING fuel in previous dwelling (use coding from 81)

	Summer	Winter
Main cooking fuel		

17d The **main** HEATING fuel in previous dwelling (use coding from 81)

	Winter
Main heating fuel	

If relevant:

17e The **main** fuel for boiling pig's food (use coding from 81)

	Summer	Winter
Main fuel for boiling pig's food		

III. Health questions: COPD

These questions pertain mainly to your chest. Please answer yes or no if possible. If you are in doubt about whether your answer is yes or no, please answer no.

Section A: Cough

[Note: please proceed to section B if your answer is marked with asterisk (*)]

18 - Do you usually cough when you don't have a cold?

Yes	
No	

18a Are there months in which you cough on most days?

Yes	
No	*

18b Do you cough on most days for as much as three months each y

Yes	
No	

18c For how many years have you had this cough?

Less than 2 years	
2 - 5 years	
More than 5 years	

Section B: Phlegm

[Note: please proceed to section C if your answer is marked with asterisk (*)]

19 Do you usually bring up phlegm from your chest, or do you usually have phlegm in your chest that is difficult to bring up when you don't have a cold?

Yes	

No	*

19a Are there months in which you have this phlegm on most days?

Yes	
No	*

19b Do you bring up this phlegm on most days for as much as three months each year?

Yes	
No	

19c For how many years have you had this phlegm?

Less than 2 years	
2 - 5 years	
More than 5 years	

Section C: Wheezing/whistling

[Note: please proceed to section D if your answer is marked with asterisk (*)]

20 Have you had wheezing or whistling in your chest at any time in the last 12 months?

Yes	
No	*

20a In the last 12 months, have you had this wheezing or whistling only when you have a cold?

Yes	
No	

20b In the last 12 months, have you ever had an attack of wheezing or whistling that has made you feel short of breath?

Yes	
No	

Section D: Breathlessness

[Note: please proceed to section E if your answer is marked with asterisk (*)]

21	Are you unable to walk due to a condition other than shortn	Yes	
		No	

[If yes, please describe this condition on the line below and then proceed to section E. If "no" or unsure, continue with next question]

21a	Condition (s):		

22	Are you troubled by shortness of breath when <u>hurrying on the level</u> or <u>walking up a slight hill</u>?	Yes	
		No	*

22a	Do you have to walk slower than people of <u>your age</u> on level ground because of shortness of breath?	Yes	
		No	
		Does not apply	

22b	Do you ever have to <u>stop for breath</u> when walking at your own pace on level ground?	Yes	
		No	
		Does not apply	

22c	Do you ever have to stop for breath after <u>walking about 100 yards</u> (or after a few minutes) on level ground?	Yes	
		No	
		Does not apply	

22d	Are you too short of breath to leave the house or short of breath on dressing or undressing?	Yes	
		No	
		Does not apply	

Section E: Other diagnosis and medications

23	Have you ever been to a doctor?	Yes	
		No	
	[if no, please proceed to question 31 but don't ask 31a]		
24	Has a doctor or other health care provider ever told you that you have emphysema?	Yes	
		No	
25	Has a doctor or other health care provider ever told you that you have asthma, asthmatic bronchitis or allergic bronchitis?	Yes	
		No	
25a	[If yes:] Do you still have asthma, asthmatic bronchitis or allergic bronchitis?	Yes	
		No	
26	Has a doctor or other health care provider ever told you that you have chronic bronchitis?	Yes	
		No	
26a	[If yes:] Do you still have chronic bronchitis?	Yes	
		No	

27	Has a doctor or other health care provider ever told you that you have chronic obstructive pulmonary disease (COPD)?	Yes	
		No	
28	Has a doctor or other health care provider ever told you that you have lung cancer?	Yes	
		No	
29	Has a doctor or other health care provider ever told you that you have tuberculosis?	Yes	
		No	
29a	[If yes:] Are you currently taking medicine for tuberculosis?	Yes	
		No	
29b	[If no to 29a:] Have you ever taken medicine for tuberculosis?	Yes	
		No	
30	Has a doctor or other health care provider ever had you blow into a machine or device in order to measure your lungs (i.e., a spirometer or peakflow meter)?	Yes	
		No	

[If yes:]

30a	Have you used such a machine in the past 12 months?	Yes	
		No	

31	Have you had pneumonia in the past year (last 12 months)?	Yes	
		No	

[if yes]

31a	Was it confirmed by a doctor?	Yes	
		No	

32	Did you have breathing problems as a child?	Yes	
		No	
		Don't know	

MEDICATION

Now I am going to ask you about medicines that you may be taking to help with **<u>your breathing</u>**. I want to know about medicines that you take on a regular basis and medicines that you may take only for the relief of symptoms. I would like you to tell me each medicine that you take and how often you take it.

33	In the past 12 months, have you taken any medications for your breathing (including medications for nasal congestion)?	Yes	
		No	

	[If yes:]	Medication 1	Medication 2	Medication 3	Medication 4	Medication 5
33a	Code (1: Traditional Chinese, 2: Western medicine)					
	Medication name:					
	Is the medication taken on most days, or just when you have symptoms, or both? (1.Most days, 2.Symptoms, 3.Both)					
	Days/week					
	Months/year					

34	Please tell me about any other products that you take or things you do to help your breathing that you have not already told me about.	Medicine or activity:	
35	Have you ever had a period when you had breathing problems that got so bad that they interfered with your usual daily activities or caused you to miss work?	Yes	
		No	
	[If "no", proceed to section IV(question 36). If "yes" ask next question]		
35a	How many such episodes have you had in the past 12 months?	Number:	
	[If 35a = one or more episodes:]		
35b	For how many of these episodes did you need to see a doctor or other health care provider in the past 12 months?	Number:	
35c	For how many of these episodes were you hospitalized overnight in the past 12 months?	Number:	
	[If 34c = one or more times]		
35c-1	All together, for how many total days were you hospitalized overnight for breathing problems in the past 12 months?	Number of days:	

IV. Health questions: CVD

Section A: Chest pain on effort (Angina Pectoris)

[Note: please proceed to section B if your answer is marked with asterisk (*)]

36 - *Have you ever had any pain or discomfort in your chest?*

Yes	
No	

[If "No"]

36a - *Have you ever had any pressure or heaviness in your chest?*

Yes	
No	

[If "No", proceed to section C

If "Yes", ask next question]

37 - *Do you get it when you walk uphill or hurry?*

Yes	
No	*
Never hurry	

38 - *Do you get it when you walk at an ordinary pace at the level?*

Yes	
No	

39 - *What do you do if you get it while you are walking?*

[Record 'Stop or slow down' if subject carries on after ta

Stop or slow down	
Carry on	*

40 - *If you stand still, what happens to it?*

Relieved	
Not relieved	*

41 - *How soon?*

10 minutes or less	
More than 10 minutes	*

42 - *Will you show me where it was?*

[record all areas mentioned]

Sternum (upper or middle)	
Sternum (lower)	
Left anterior chest	
Left arm	
Other:	

43 - *Do you feel it anywhere else?*

[if "yes", record additional information above]

Yes	
No	

44 - *Did you see a doctor because of this pain (or discomfort)?*

Yes	

		No	
44a	[if "yes"] - *What did he say it was?*		

Section B: Possible Infarction

[Note: please proceed to section C if your answer is marked with asterisk (*)]

45	- *Have you ever had a severe pain across the front of your chest lasting for half an hour and more?*	Yes	
		No	*
46	- *Did you see a doctor because of this pain?*	Yes	
		No	*
46a	[If Yes:] What did he say it was?		
46b	How many of these attacks have you had?	1st attack: date_______ duration of pain_______ 2nd attack date_______ duration of pain_______ 3rd attack date_______ duration of pain _______ 4th attack date _______ duration of pain _______	

Section C: Intermittent Claudication

[Note: please proceed to section D if your answer is marked with asterisk (*)]

47	- *Do you get pain in either leg on walking?*	Yes	
		No	*
48	- *Does this pain ever begin when you are standing still or sitting?*	Yes	*
		No	
49	- *In what part of your leg do you feel it?* [If calves not mentioned, ask: Anywhere else?]	Pain includes calf/calves	
		Pain does not include calf/calves	*

50 - *Do you get it if you walk uphill or hurry?*

Yes	
No	*
Never hurries or walk uphill	

51 - *Do you get it if you walk at an ordinary pace on the leve*

Yes	
No	

52 - *Does the pain ever disappear while you are walking?*

Yes	*
No	

53 - *What do you do if you get it when you are walking?*

Stop or slow down	
Carry on	*

54 - *What happens to it if you stand still?*

Relieved	
Not relieved	*

55 - *How soon?*

10 minutes or less	
More than 10 minutes	

[If the participant answered that she has never been to a doctor in question 23, you may skip section D Stroke and Section E hearth failure, and go directly to question 59 regarding elevated blood pressure]

Section D: Stroke

[Note: please proceed to section E if your answer is marked with asterisk (*)]

56	*Have you ever been told by a doctor that you had a stroke?*	Yes	
		No	*
56a	*How old were you when you had your stroke?*		
56b	*Have you had a stroke in the past 12 months?*	Yes	
		No	
56c	*Are you currently (in the last 2 weeks) taking any medicines, tablets or pills because of your stroke?*	Yes	
		No	*
56c-1	*Name the medicines you are taking*		

Section E: Heart failure

[Note: please proceed to section F if your answer is marked with asterisk (*)]

57	*Have you ever been told by a doctor that you had heart failure?*	Yes	
		No	*
57a	*How old were you when you suffered from heart failure?*		
57b	*Have you suffered from heart failure in the past 12 months?*	Yes	
		No	
57c	*Are you currently (in the last 2 weeks) taking any medicines, tablets or pills because of your heart failure?*	Yes	
		No	*
57c-1	*Name the medicines you are taking*		

Section F: Hypertension & diabetes

58 *Have you ever been told by a doctor that you have diabetes?*

Yes	
No	
Uncertain	

[if yes]
58a *What type?*

Type 1	
Type 2	
Uncertain	

59 *Have you been told by health professional in the past year (12 months) that you have elevated blood pressure or hypertension?*

Yes	
No	
Uncertain	

59a *Are you currently taking medication to lower your blood pressure?*

Yes	
No	
Uncertain	

[if yes]
59a-1 *Record the name of the medicines you are taking*

Name:	

V: Health Examination

Blood pressure and pulse

[If the participant has been resting with no change of position for at least 5 minutes, you may proceed with the

		Measurement 1	Measurement 2	Measurement 3
H1	Systolic blood pressure			
H2	Diastolic blood pressure			

		Measurement 1	Measurement 2	Measurement 3
H3	Pulse			

Oxygen saturation

		Measurement 1	Measurement 2	Measurement 3
H4	Sp 02 %			

Height and weight

H5	Height (cm)	
H6	Weight (kg)	

Pre Spirometry Procedure

60a	Did the participant have a resting pulse of greater than 120 beats per minute? [see measurement result in H3]	Yes	
		No	
60b	In the past three months have you had any surgery on your chest or abdomen?	Yes	
		No	
60c	Have you had a heart attack within the past three months?	Yes	
		No	

60c	Have you had a heart attack within the past three months?	Yes	
		No	
60d	Do you have a detached retina or have you had eye surgery within the past three months?	Yes	
		No	
60e	Have you been hospitalized for any other heart problem within the past month?	Yes	
		No	
60f	Are you in the last trimester of pregnancy?	Yes	
		No	
60g	Are you currently taking medication for tuberculosis?	Yes	
		No	
60h	Is there some other reason why this participant should not perform the spirometry maneuver?	Yes	
		No	

*[If the answer to any of Questions 60a through 60h is "Yes", do **NOT** proceed with the test. Proceed to the Spirometry Outcome section and mark Questions H7a and b as "No", and check the second box "the patient was medically excluded" for question H7c.*

61 Have you had a respiratory infection (cold) in the last three weeks?

Yes	
No	

62 Have you taken any medications for breathing in the last six hours?

Yes	
No	

[If Yes:]

62a Record name/type of medication(s) used.

[If Question 62 is yes and medication used includes a short acting beta agonist, code Question 62b 'Yes', else code Question 62b. 'No']

62b *Did participant use a short acting beta agonist, either alone or in combination with some other product, in the last six hours?*

Yes	
No	

Spirometry Outcome

[To be filled in by interviewer]

H7a Acceptable pre-bronchodilator test completed?

Yes	
No	

[fill out the rest of this section after the post-bronchodilator spirometry test. Wait at least 15 minutes after administration of bronchodilator before performing the second round of spirometry test. In the meantime, complete the rest of the questionnaire interview.]

H7b Acceptable post-bronchodilator test completed?

Yes	
No	

H7c	If unable to obtain satisfactory spirometry (check one)	The participant did not understand instructions
		The participant was medically excluded
		The participant was unable to physically cooperate
		The participant refused
H8	Were any adverse events related to the spirometry maneuver observed by the evaluator?	Yes
		No
H8a	[If Yes] Please briefly describe event	
H9	If the participant had a condition that would affect the result of their spirometry test (e.g., kyphosis, dentures, missing limbs, etc.) note that condition here	
H10	Other comments:	
H11	Record the time (hh:mm) of administering Ventoline	Time:

VI. Cooking activity

63	How many meals were cooked in your household the last 48 hours (while monitoring)?	Number	
			check one
63a	Were the number of meals cooked in your household the last two days typical of the normal cooking activity?	Less than usual	
		Same as usual	
		More than usual	
63b	For how many of these meals were you present in the same room during the preparation (while the stove was lit)?	Number	
64	How many meals do you usually cook?	Meals per day	

VII: Tobacco smoking

Now I am going to ask you about smoking.

65	Have you <u>ever</u> smoked cigarettes?	Yes	
		No	

[Yes," means more than 20 packs of cigarettes in a lifetime or more than 1 cigarette each day for a year
If "no", proceed to question 66]

65a	How old were you when you first started regular cigarette sr	Age:	
65b	Do you still smoke?	Yes	
		No	

[If No]

65b-1	How old were you when you last stopped?	Age:	
65c	On average over the entire time that you smoke(d), about how many cigarettes per day do (did) you smoke?	Cigarettes per day:	
65d	On average over the entire time that you smoke(d), do (did) you primarily smoke manufactured or hand-rolled cigarettes?	Manufactured	
		Hand-rolled	
66	Have you ever smoked a pipe or cigar regularly?	Yes	
		No	
67	How many, if any, smokers in the household (0 if none)	Total	
68	How many cigarettes are usually smoked inside the house? (give number and unit; per day, per week or per month)	Cigarettes per	
69	How many cigarettes did you smoke the last 48 hours while wearing the monitor (0 if non smoker)	Total	

70	How many cigarettes were smoked inside the house the last 48	Total	

VIII. Household data

Members of the household

			Number of people in each group
71	How many members are in the household? Fill in according to age.	0-5 years	
		6-14 years	
		15-64 years	
		65 years and over	
		Total	

72	How many members live and work outside the village?	Total	

			check one
73	Is the head of household male or female?	Male	
		Female	

74	Has any female family members passed away the last 10 years?	Yes				
		No				

		Person 1		Person 2	
	[if yes]				
74a	Cause of death				
74b	Age				
74c	Relationship to HoH (mother, sister, etc)				

Other household information

75 Does the household own: (check off all that apply)

	Check all that apply
A :Motorcycle	
B: Cell phone	

76 Does the household have a cat or dog? (check all that apply)

	Check all that apply
A: Cat	
B: Dog	

77 How many pigs or cows does the household own?

A: Number of pigs				
B: Number of cows				

78a In the summertime: How often does your household open the door/windows while **cooking**?

		Check one
Summer	Most of the time	
	Sometimes	
	Never	

78b In the wintertime: How often does your household open the door/windows while **cooking**?

		Check one
Winter	Most of the time	
	Sometimes	
	Never	

78c In the wintertime: How often does your household open the door/windows while **heating**?

Winter	Most of the time	
	Sometimes	
	Never	

79 Where does your household normally cook?
K: kitchen, L: living room, O: outside, X: other

	Summer	Winter	*Last 48 hours*
Cooking			
Boiling pigs food (if relevant)			

IX. Stoves

80 Number and type of stoves for cooking and heating

	Number of stoves	*Season: summer: s winter: w all year: a*	*For how many years has the household had this kind of stove?*	*Check the stoves that has been used in the last 48 hours*
1. Coal stove without chimney				
2. Coal stove with chimney extending to attic				
3. Coal stove with chimney extending outside				
4. Biomass stove without chimney				
5. Biomass stove with chimney extending to attic				
6. Biomass stove with chimney extending outside				
7. Open fire without chimney				
8. Gas stove (LPG or biogas)				
9. Kerosene stove				
10. Electric stove				
11. Other (Specify)				

X. Fuel Use

81 relevant)?

	Type (check the fules that are used)	Season: summer(s), winter (w), all year (a), occasionally (o).	Check the fuels that has been used in the last 48 hours
1. Wood (logs)			
2. Wood (twigs/branches)			
3. Crop residue			
4. Dung			
5. Raw coal			
6. Coal briquettes			
7. Coke			
8. Charcoal			
9. Kerosene			
10. Liquefied petroleum gas (LPG)			
11. Biogas			
12. Electricity			
13. Other (please specify)			

82a The **main** COOKING fuel (use coding from 81)

	Summer	Winter
Main cooking fuel		
Fuel use (give unit)		

82b The **main** HEATING fuel (use coding from 81)

	Winter
Main heating fuel	
Fuel use (give unit)	

If relevant:

		Summer	Winter
82c	The **main** fuel for boiling pig's food (use coding from 81)	Main fuel for boiling pig's food		

XI: PM and CO household monitoring

[This section applies ONLY to those households that have the UCB PM monitor and CO tube for area monitoring]

Additional monitoring questions

83	were the activities in your household over the last 2 days different from normal activities (for example compared with last month)? (For instance, the last 2 days, were the number and types of meals cooked different than in other days, were the types of work and leisure activities that took place different, did anyone in the household travel, or did any other household activities change?)	Yes	
		No	

[If Yes]

83a	Describe the activities that were unusual for the monitoring period compared to the past weeks	

Monitoring data

[to be filled in by interviewer]

KITCHEN

M8	**UCB monitor ID: (example 4001K for fieldworker nr 4)**	

Pre sampling bag calibration period (at least 40 minutes)

M9	Location (office or other, specify)	
M10	Date (dd/mm/yyyy)	
M11	Calibration start time, in bag (hh:mm)	
M12	Time of leaving for the field (hh:mm)	

Location of sampler (also record location on sketch in section I)

M14	Height from floor (145 cm)	
M15	Distance from edge of stove (100 cm)	
M16	Additional Comments (distance from window/doors, if shorter than 150cm):	

		dd/mm/yy	hh:mm
M17	Time placed on wall (date and time)		
M18	Surveyor ID		
M19	Time removed from wall (date and time)		
M20	Surveyor ID		

Post sampling calibration period (at least 40 minutes)

M21	Location (office or other, specify)	
M22	Date (dd/mm/yyyy)	
M23	Calibration start time (hh:mm)	
M24	Calibration end time (hh:mm)	

M25	Downloaded? (yes/no)	
M26	ucbpm file name	
M27	Graph ok? (yes/no)	
M28	Initials	

M29	Describe any errors that occurred while you were launching or downloading the UCB Particle Monitor data (note lowest value (mg/m3):	

Condition of equipment

[to be filled in by interviewer]

M30	Were the placement and/or condition of the particulate monitoring equipment the same as when placed?	Yes	
		No	

[If yes, proceed to M31. If no:]

M30a	How was the PLACEMENT of the sampler different than when originally placed? (check all that apply)	1. Sampler orientation changed, but in same place	
		2. Sampler location changed, but in same room	
		3. Sampler in different room	
		4. Height of sampler changed (higher)	
		5. Height of sampler changed (lower)	
		6. No difference	
		9. Other (specify)	

M30b	How was the CONDITION of the sampler different than when originally placed? (check all that apply)	1. Sampler stopped (battery failed)	
		2. Sampler clogged (foreign material in sampler)	
		3. Sampler damaged	
		4. Sampler missing	
		6. No difference	
		9. Other (specify)	

M31	Field notes: Please record any conditions not covered above that may have affected monitoring or indoor air quality	

Stationary CO monitoring

M32	**CO tube ID: (HouseholdID+K)**	

Location of sampler (record location on sketch in section I)

M33	Height from floor (cm)	
M34	Distance from edge of stove (cm)	
M35	Additional Comments (distance from window/doors):	

		dd/mm/yy	hh:mm
M36	Time placed on wall (date and time)		
M37	Surveyor ID		

M38	Time removed from wall (date and time)		
M39	Surveyor ID		

M40	Were the placement and/or condition of the CO tube the same as when placed?	Yes	

No	

[If yes, proceed to M41. If no:]

M40a How was the PLACEMENT of the sampler different than when originally placed?
(check all that apply)

1. Sampler orientation changed, but in same place	
2. Sampler location changed, but in same room	
3. Sampler in different room	
4. Height of sampler changed (higher)	
5. Height of sampler changed (lower)	
6. No difference	
9. Other (specify)	

M40b How was the CONDITION of the sampler different than when originally placed?

Specify:

M41 Field notes: Please record any conditions not covered above that may have affected monitoring or indoor air quality

M42

	reader 1	reader 2	supervisor
Length of brown stain in field (cm)			
Initials of reader			
Comments:			

LIVINGROOM

M8	**UCB monitor ID: (example 4001L for fieldworker nr 4)**	

Pre sampling bag calibration period (at least 40 minutes)

M9	Location (office or other, specify)	
M10	Date (dd/mm/yyyy)	
M11	Calibration start time, in bag (hh:mm)	
M12	Time of leaving for the field (hh:mm)	

Location of sampler (also record location on sketch in section I)

M14	Height from floor (145 cm)	
M15	Distance from edge of stove (try to place it away from heating stove where possible)	
M16	Additional Comments (distance from window/doors, if shorter than 150cm):	

		dd/mm/yy	hh:mm
M17	Time placed on wall (date and time)		
M18	Surveyor ID		

M19	Time removed from wall (date and time)		
M20	Surveyor ID		

Post sampling calibration period (at least 40 minutes)

M21	Location (office or other, specify)	
M22	Date (dd/mm/yyyy)	
M23	Calibration start time (hh:mm)	

M24	Calibration end time (hh:mm)	

M25	Downloaded? (yes/no)	
M26	ucbpm file name	
M27	Graph ok? (yes/no)	
M28	Initials	

M29 Describe any errors that occurred while you were launching or downloading the UCB Particle Monitor data (note lowest value (mg/m3):

Condition of equipment

[to be filled in by interviewer]

M30 Were the placement and/or condition of the particulate monitoring equipment the same as when placed?

Yes	
No	

[If yes, proceed to M31. If no:]

M30a How was the PLACEMENT of the sampler different than when originally placed?
(check all that apply)

1. Sampler orientation changed, but in same place	
2. Sampler location changed, but in same room	
3. Sampler in different room	
4. Height of sampler changed (higher)	
5. Height of sampler changed (lower)	
6. No difference	
9. Other (specify)	

M30b How was the CONDITION of the sampler different than when originally placed?
(check all that apply)

1. Sampler stopped (battery failed)	
2. Sampler clogged (foreign material in sampler)	
3. Sampler damaged	
4. Sampler missing	
6. No difference	
9. Other (specify)	

M31 Field notes: Please record any conditions not covered above that may have affected monitoring or indoor air quality

Stationary CO monitoring

M32	**CO tube ID: (HouseholdID+L)**	

Location of sampler (record location on sketch in section I)

M33	Height from floor (145 cm)	
M34	If relevant, distance from edge of stove (cm)	
M35	Additional Comments (distance from window/doors):	

		dd/mm/yy	hh:mm
M36	Time placed on wall (date and time)		
M37	Surveyor ID		

M38	Time removed from wall (date and time)		
M39	Surveyor ID		

M40	Were the placement and/or condition of the CO tube the same as when placed?	

Yes	
No	

[If yes, proceed to M41. If no:]

M40a	How was the PLACEMENT of the sampler different than when originally placed? (check all that apply)	

1. Sampler orientation changed, but in same place	
2. Sampler location changed, but in same room	
3. Sampler in different room	
4. Height of sampler changed (higher)	
5. Height of sampler changed (lower)	
6. No difference	
9. Other (specify)	

M40b	How was the CONDITION of the sampler different than when originally placed?	Specify:

M41	Field notes: Please record any conditions not covered above that may have affected monitoring or indoor air quality	

M42		reader 1	reader 2	supervisor
	Length of brown stain in field (cm)			
	Initials of reader			
	Comments:			