

Estimation of indoor air pollution and health impacts due to biomass burning in rural northern Ghana

Daniel K. B. Inkoom, and Aba Obrumah Crentsil



PHOTO: Practical Action.



CASE STUDIES Estimation of indoor air pollution and health impacts due to biomass burning in rural northern Ghana

EDITED BY

Global Dimension in Engineering Education

COORDINATED BY

Agustí Pérez-Foguet, Enric Velo, Pol Arranz, Ricard Giné and **Boris Lazzarini** (*Universitat Politècnica de Catalunya*)
Manuel Sierra (*Universidad Politécnica de Madrid*)
Alejandra Boni and **Jordi Peris** (*Universitat Politècnica de València*)
Guido Zolezzi and **Gabriella Trombino** (*Università degli Studi di Trento*)
Rhoda Trimmingham (*Loughborough University*)
Valentín Villarroel (*ONGAWA*)
Neil Nobles and **Meadhbh Bolger** (*Practical Action*)
Francesco Mongera (*Training Center for International Cooperation*)
Katie Cresswell-Maynard (*Engineering Without Border UK*)

DL B 10735-2015
ISBN 978-84-606-7546-4

This publication is distributed under an Attribution- Noncommercial- Share Alike License for Creative Commons



Citation: Inkoomb, D.K.B. and Crentsil, A.O. (2015) ' Estimation of indoor air pollution and health impacts due to biomass burning in rural northern Ghana', in *Case studies for developing globally responsible engineers*, GDEE (eds.), Global Dimension in Engineering Education, Barcelona.
Available from: <http://gdee.eu/index.php/resources.html>

Disclaimer: This document has been produced with the financial assistance of the European Union
The contents of this document are the sole responsibility of the authors and can under no circumstances be regarded as reflecting the position of the European Union

ESTIMATION OF INDOOR AIR POLLUTION AND HEALTH IMPACTS DUE TO BIOMASS BURNING IN RURAL NORTHERN GHANA

Dr. Daniel K. B. Inkoom, Department of Planning, KNUST, Kumasi, Ghana (dinkoom@gmail.com)

Dr. Aba Obrumah Crentsil, Institute of Statistical, Social and Economic Research, University of Ghana, Legon (abaodoi@gmail.com)

INDEX

1. INTRODUCTION.....	3
1.1 DISCIPLINES COVERED.....	5
1.2 LEARNING OUTCOMES.....	5
1.3 ACTIVITIES.....	6
2. DESCRIPTION OF CONTEXT	6
2.1 INDOOR AIR POLLUTION.....	7
2.2 THE HEALTH IMPACT OF EXPOSURE TO INDOOR AIR POLLUTION.....	8
2.3 EVIDENCE OF HEALTH EFFECTS OF POLLUTANTS (EPIDEMIOLOGICAL STUDIES)	10
2.4 ENERGY AND GENDER	11
3. CLASS ACTIVITY.....	12
Methodology.....	12
4. HOMEWORK ACTIVITY.....	17
ANNEX 2: HOUSEHOLD ENERGY SURVEY IN THE BONGO DISTRICT OF GHANA	24
ANNEX 3 FURTHER MATERIALS.....	28
BIBLIOGRAFY	29

1. INTRODUCTION

Approximately 2.8 billion people, more than ever before in human history, use solid fuels for cooking. This is including wood, coal, charcoal, and agricultural residues. (Bonjour et al. 2013). When these fuels are used in traditional unimproved, open stoves, they emit substantial amounts of harmful pollutants, such as particulate matter (PM), carbon monoxide, and nitrogen and sulfur oxides. The concentration of particles with a diameter less than 10 μm , known as PM_{10} , is the most widely used indicator of indoor air pollution in developing countries. But $\text{PM}_{2.5}$ (fine particles with a diameter of 2.5 μm or less) has the greatest impact on respiratory health because these particles penetrate the bronchial and alveolar regions of the human body and the body is unable to remove them completely (Bruce et al., 2011). Women and young children are most exposed, and there is a well-documented relationship between indoor air pollution (IAP) and several diseases, most strongly with acute lower respiratory infections (ALRI) and chronic obstructive pulmonary disease (COPD), but also with lung cancer and tuberculosis (Desai *et al.*, 2004).

According to the World Health Organisation (WHO 2014) in the year 2012, household air pollution from cooking with solid fuels was responsible for 4.3 million deaths worldwide. Figure 1 below shows the number of people who died from diseases attributed to household air pollution (HAP).

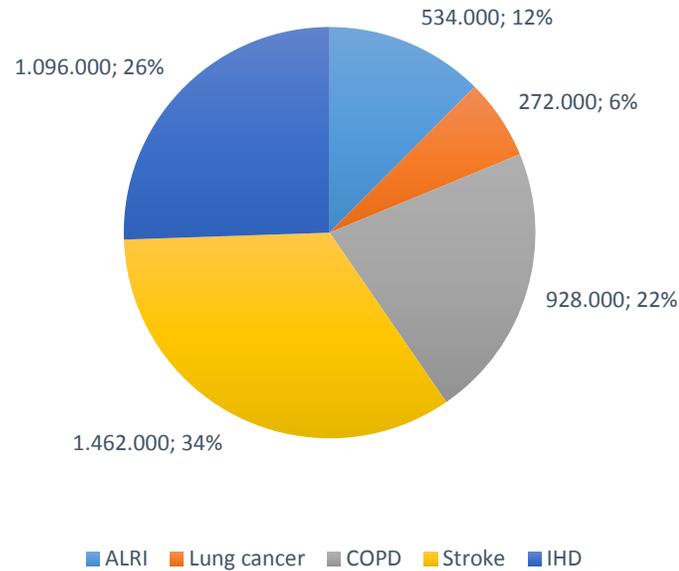


Figure 1: Deaths attributable to HAP in 2012, by disease. Percentage represents percent of total HAP burden (add up to 100%). HAP: Household air pollution; ALRI: Acute lower respiratory disease; COPD: Chronic obstructive pulmonary disease; IHD: Ischaemic heart disease. Source: WHO, 2014.

However the health burden from IAP is greater in rural areas and among poor families who tend to use cheap biomass and low quality fuels in primitive stoves without proper ventilation (Kaplan 2010). According to the Ghana Statistical Service Report in 2010(GSS 2010), biomass usage for cooking is about 73.7 % consisting 40% wood and 33.7% charcoal. Seven in every 10 households in the northern and Upper East Regions used wood as the main cooking fuel. Exposure to IAP is responsible for the annual loss of 502,000 disability adjusted life years (DALYs.) The WHO also estimates that exposure to IAP is responsible for 16,600 deaths per year in Ghana. A disproportionately high number of such deaths involve women and children. The percentage of national burden of disease attributable to solid fuel use in Ghana is 2.2 (WHO 2007).

Yet monitoring of air pollutants in every study may not be practicable frequently since this will result in increased costs for organizations. Studies with limited financial resources will have to rely on factors that influence the pollutant concentrations such as

fuel type, stove type, ventilation situation, house type, etc. most of which are essentially categorical in nature. As a result, it could be beneficial if we can identify some statistically significant factors and build statistical models for associating these factors with pollutant concentrations

In this context, the aim of this case study is that students to analyse and predict indoor air pollutants using categorical regression and estimate the burden of disease attributed to indoor air pollution from household use of solid fuels in rural Northern Ghana.

1.1 DISCIPLINES COVERED.

Main disciplines explored include: the estimation of indoor air pollutant; the burden of disease attributed to solid fuel use in a rural setting.

A background understanding of exposure measurement of indoor air pollution is required as well as and understanding of basic regression analysis.

The aim is for students to measure pollutants due to indoor air pollution and understand the health risk associated with biomass burning , especially among women and children (until they can work) and girls (as the learn cooking skills) who bear the responsibility for household cooking in rural areas.

1.2 LEARNING OUTCOMES.

As a result of this case study, students are expected to be able to:

- Understand the problem of the lack of access to modern cooking fuels worldwide and its consequences on human development, especially among women and children.
- Know the main components of rural household cooking systems and the technical relationships between them.

- Quantitatively measure Concentration of the different pollutants while burning the biomass fuels to meet the domestic energy need.
- Estimate the exposure time of the residents in polluted air.
- Predict health impact of the residents due to inhale the polluted air

1.3 ACTIVITIES

Accurately estimating pollutant levels and estimating disease attributed to indoor air pollution from household use of solid fuels requires that students thoroughly understand literature. Data sets are available for such analysis. In the first activity (in class) students are introduced to the field data to help them draw descriptive tables. This should be done in groups of preferably 5. Again students should be introduced to single box and exposure dose equations to be used to estimate the disease attributed to indoor air pollution from household use of solid fuels, concentrate levels and exposure levels. At the end of the activity a discussion between all the students should be led by the lecturer in order to clarify the concepts and solve any doubts that may arise. This activity should last approximately two hours.

In second activity (at home) students are to predict ill-health due to exposure from the use of biomass fuels. In groups (comprising a maximum of 5), students should estimate the disease attributed to indoor air pollution from household use of solid fuels in rural Northern Ghana using the WHO exposure methodology. This activity duration is expected to be 10 hours, although this time can be slightly increased or reduced. The evaluation is divided between the two activities as detailed along this document

2. DESCRIPTION OF CONTEXT

In this section a description of the context of the case study is realized

2.1 INDOOR AIR POLLUTION

The household sector (primary for cooking and lighting) is the largest energy consumer in Ghana, where traditional biomass fuels predominate. It accounts for almost 50 percent of the country's energy consumption (Energy Commission 2014). Burned in traditional stoves (three stone stoves) these biomass fuels release a cocktail of harmful pollutants (product of incomplete combustion) , posing health hazards.

Leading the list of PIC in terms of total mass and number of carbon atoms is carbon monoxide (CO), an invisible odorless but nevertheless toxic gas with a number of potential short-term and long-term impacts on health. Following are dozens of simple and complex hydrocarbons and organic compounds, some in gaseous and some in solid form. In addition, a portion of the PIC is released as elemental carbon, or "soot," in the form of small particles (PM). The quantity of each pollutant released is dependent on combustion conditions such as energy density, combustion temperature and air flow, and pollutant emission rates which vary with time and stove geometry (Ballard-Tremeer and Jawurek, 1999; Ezzati *et al.* 2000;).

Consequently, levels of IAP from fuel burning, exposure levels and potential health risks to individuals can vary greatly amongst dwellings. It is instructive to see what a kilogram of wood will generate. On a typical three stone wood-fired stove, about 18 percent of the energy goes into the pot, 8 percent into the smoke and 74 percent is waste heat (Warwick and Doig, 2004)). But it is the pollutants that are of more concern. A kilogram of burning wood can produce significantly harmful levels of gases, particles and dangerous compounds. Figure 2 shows the Pollutants generated from burning one kilogram of wood are well beyond World Health Organization guidelines

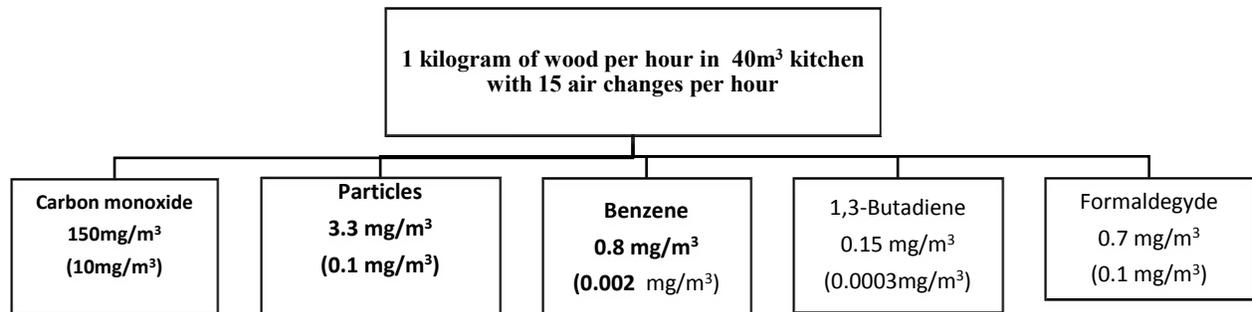


Figure 2: Pollutants generated from 1kilogram of wood burned. Source: Smith and others, 2000 cited in UNDP 2000.

Note: Dozens of other health-damaging pollutants are known to be in wood smoke. Mg/m3 stands for milligrams per cubic metre. Numbers in parentheses are typical standards set to protect health.

In order to better understand how these pollutants create adverse health effects, one must first look at the physiological processes underlying the health impacts of exposure.

2.2 THE HEALTH IMPACT OF EXPOSURE TO INDOOR AIR POLLUTION

To understand the physiology and movement of pollutants through the body, pollutants must first be divided into two categories: aerosols (PM) and gases (CO, CO₂, and SO₂). Aerosols are small solid or liquid particles that are suspended in air to form a mixture (Yassi et al., 2001). These particles are generated with different size distributions depending on the source, and the size of the particles in turn determines how the particle behaves in the human respiratory tract. While larger particles carry much more substance, they are less likely to have an effect on the body because they do not penetrate into the lower respiratory tract. Smaller particles, those with aerodynamic diameters of less than 10 µm and especially those with diameters less than 2.5 µm, enter the airways with greatest efficiency and may be deposited in the alveoli, which are

the deepest structures of the lungs (Yassi *et al.*, 2001). Patterns of deposition within the lungs are shown in Figure 3.

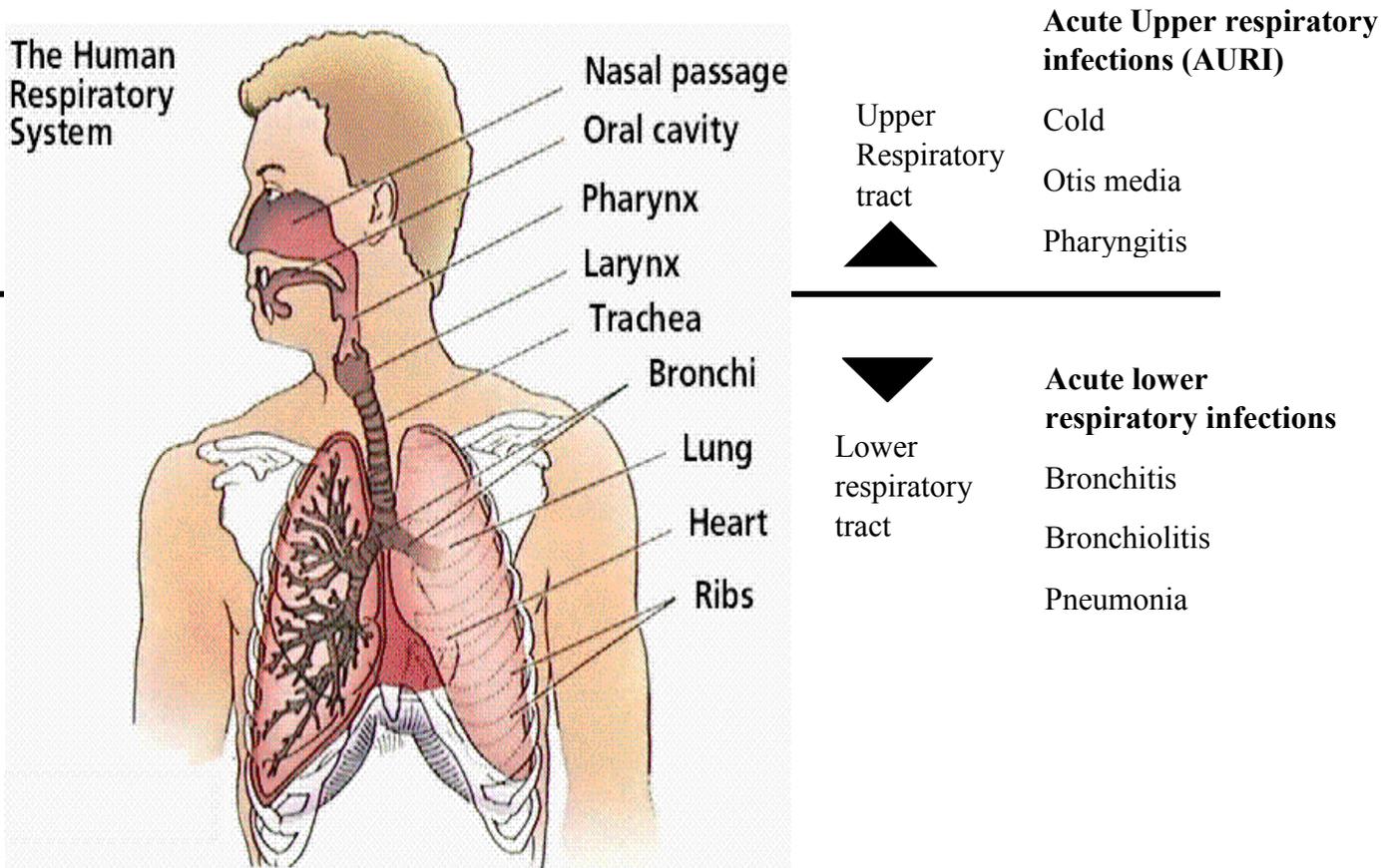


Figure 3: Human respiratory tract. Source: Adapted from Yassi *et al.* 2001. Note: Larger (coarse) particles in air pollution are more likely to deposit in the upper respiratory tract. Smaller (fine) particles penetrate deeply into the lower respiratory tract

Adverse health effects created by gases, on the other hand, are often a result of their solubility in water and their chemical reactivity. Once inhaled, soluble gases dissolve into the water surface of the pulmonary tract and are removed, whereas insoluble gases are not dissolved and removed. Insoluble gases will then penetrate to the alveoli more efficiently. In addition, gases can absorb onto the surface of particulates, which then travel to the alveoli. When this happens the effects may be different and sometimes greater than exposure to either the particle or gas alone. Ultimately once inhaled

particles or insoluble gases reach the alveoli, they may release their constituents readily into the blood stream. The degree to which they enter the blood and are delivered to the body's tissues depends on the concentration inhaled, the duration of exposure, their solubility in blood and in tissue, the reactivity of the compound, and the respiratory rate of the individual (Yassi *et al.* 2001).

Whether adverse health effects are displayed in an individual exposed to these pollutants depends largely on the dose (= pollutant concentration x exposure duration) received as well as their biological susceptibility to adverse health effects from exposure. Population groups that tend to be more susceptible to the effects of air pollution include: infants, children, the elderly, people with cardiovascular and respiratory diseases and people with impaired immune systems (EPA 2001 as cited in Matooane *et al.*, 2004). Epidemiologists conducting IAP and health research in developing countries have attempted to incorporate these issues into their studies with varying degrees of success. These efforts are discussed below

2.3 EVIDENCE OF HEALTH EFFECTS OF POLLUTANTS (EPIDEMIOLOGICAL STUDIES)

Epidemiological studies undertaken in developing countries have aimed to establish a causal link between exposure to IAP and health effects in real life settings. According to reviews of these studies, there is good evidence that exposure increases the risk of acute lower respiratory infections in children, chronic obstructive pulmonary disease in adults, and lung cancer where coal is used exclusively (Bruce *et al.* 2002). A comprehensive survey conducted by the World Health Organization (WHO) in 2014 found that each year these diseases cause a considerable number of deaths (figure 1 above) worldwide.

Research has indicated that a disproportionate risk of exposure to IAP exists in women, infants and young children, as they spend the majority of time indoors, cooking (Sharma *et al.*, 1998). Clear health risks are associated with obtaining and storing fuel for the domestic cooking stove. Collection of biomass fuels is associated with a variety of

mechanical injuries from felling, carrying and splitting wood, encounters with animals such as snakes and scorpions, violence, and exposure to vectors of a number of infectious diseases.

2.4 ENERGY AND GENDER

There is a differentiated impact of access to energy services for women and men but gender and energy concerns hardly enter macro-level policies. In most of the developing world, food processing, and water and firewood collection are traditionally female gender roles and take much of women's and girls' time and energy. Labour intensity of fire wood collection depends on many factors. Availability of wood, for example, influences traveling distance and time women spend collecting it. Household size and the amount of load a woman is able to carry at a time are all important determining factors. Some rural women are reported to carry up to 20 kilograms of firewood traveling an average distance of five kilometers (Warwick and Doig, 2004). Sometimes this is done with a baby strapped on the woman's back.

Exposure models for Product of Incomplete Production in indoor environments

Frequent monitoring of air pollutants in every study may not be practicable since this raises the costs associated with the study. Studies with limited financial resources will have to rely on factors that influence the pollutant concentrations such as fuel type, stove type, ventilation situation, house type, etc. As a result, it is beneficial to identify some statistically significant factors and build statistical models for associating these factors with pollutant concentrations. In this case study, an attempt has been made in this direction by constructing a couple of statistical models based upon the single zone model (students should refer to reference for further reading on the model).

The single zone model

The simplest construct is the single-zone model, with the key ideas as follows. The air in a zone, typically a room bound by walls and a ceiling in the context of indoor air quality, is perfectly mixed such that any pollutant emitted into room air is uniformly mixed throughout the space. (The dimensions of the room are typically determined with a tape measure). The room receives fresh air at a given rate through natural infiltration and/or mechanical means, and this supply is matched by an outflow of room air by exfiltration and/or mechanical means at the same rate. Non-ventilation pollutant loss mechanisms (for example, particle deposition onto room surfaces) can be included. Different pollutant emission rate functions can be considered, but the simplest is a constant rate (for example, emissions during active cooking). The duration of emissions rate can be set to reflect the time the source emits into the zone. The effect of an exhaust chimney or canopy hood, which removes emitted pollutants before they mix into the general kitchen air, can also be accounted for by applying fractional terms to the emissions rate. Based on these parameters, the concentrations in a room can be estimated over time

The single zone model approach was applied to the household energy sector in developing countries as early as the 1980s. In this study, Smith et al. (1983) used a single zone model to predict kitchen concentrations of particulate matter and benzo(a)pyrene of resulting from cooking with solid fuels in A similar single zone modelling approach was employed by Prasad et al. (1985) to predict indoor CO concentrations resulting from cook stove emission.

3. CLASS ACTIVITY

Methodology

This activity is prepared for a two-hour session class and is divided in two parts. First, students are introduced to a proposed statement (shown next). During the first hour they have to use the data provided and models to predict emissions and pollutant concentrations. At the end, the lecturer gathers the solutions from each group for their evaluation and during the second hour a debate guided by the lecturer is carried out in

order to solve the model as in the solution (shown later), as well as resolve any doubts that may arise.

Proposed statement

An NGO interested in scaling up improved cooking stoves in rural Northern Ghana and monitoring 24-hr household (kitchen and living area) concentrations of $PM_{2.5}$ and CO in 100 rural households in the Bongo district of the upper east Region of Ghana on a cross-sectional basis. An in-depth socioeconomic analysis of the communities was performed using data collected from questionnaires. In order to ensure cost-effective coverage of the key determinants of HAP concentrations, a stratified sampling technique was followed in this study to select households for indoor air monitoring in rural Ghana. A number of questions were also asked about fuel use, stove type, cooking locations and structural characteristics of kitchens. It was observed that most households used either crop residue, firewood or charcoal as their main cooking fuel. None purchased their fuels.

However due to limited financial resources the NGO was not able to physically measure pollutant levels. Based on the data (See attached data) provided the NGO has asked you to model pollutant concentrations from biomass fuel use for cooking in the surveyed households. This study focused on PM 2.5 and estimated exposure concentrations for the PM 2.5 emitted through the consumption of fuel inside residences in individual households, in order to assess the health risks from the combustion of these fuels.

From this data set, groups are required to develop of models to estimate household concentrations of pollutant burning by:

1. Providing Summary Data on Household Air Pollution Factors

To do this, you are required to go through the data and use simple descriptive statistics construct tables and write ups showing the types of fuel used by household, stoves used by households, amount of fuel used (Kg) by households.

3 Estimate Concentration of the different pollutants while burning the biomass fuels to meet the domestic energy need

In the rural areas the pollutants emitted from the biomass fuel are mainly concentrated with in the kitchen and the surrounding areas, where the women and children spend most of their day time for domestic purposes. Therefore the pollutant concentration is measured in those zones through single compartment air model. The model is follows:

$$C_{ss} = \frac{(1 - \varepsilon) \times G}{Q + \alpha \times V}$$

The input parameters above include volume (V [m^3]), fresh air rate (Q [$m^3 \text{ min}^{-1}$]), emission rate (G [$\mu\text{g min}^{-1}$]), loss parameter (α [min^{-1}]), and fraction of emissions directly vented, or capture efficiency (ε), which can be used to predict the steady state concentration (C_{ss} $\mu\text{g m}^{-3}$). Based on the equation students are to predict concentrations levels and fill the table below.

Note

Data collected by the NGO shows that the average kitchen from is $40m^3$. Fresh air rate Q is $12.5m^3$ for a kitchen, α is 0.05min^{-1} for particle deposition onto room surfaces and that $\varepsilon = 0$ (no stove chimney/hood). Table 1 shows the PM emission factor for each type of fuel. Using the data sets groups are required to complete table 2 below.

Table 1: PM emission factor

	Type of Fuel	Emission factor($\mu\text{g}/\text{min}$)
Biomass	Firewood	3000
	Charcoal	1800
	Crop residue	6000

Table 2: Concentration of different pollutants in μgm^{-3}

Different cook fuel	Concentration of different pollutants ($\mu\text{g m}^{-3}$)		
	wood	Cow dung	Agric residue
PM _{2.5} levels			

3. Comparison kitchen concentrations to international standards.

The World Health Organization (WHO) sets air pollution guidelines to offer guidance in reducing health impacts of air pollution (both indoor and outdoor) based on current scientific evidence. The WHO recently set new Air Quality Guidelines (AQG) for PM 2.5, ozone, nitrogen dioxide, and sulfur dioxide, along with interim targets which are intended as incremental steps in a progressive reduction of air pollution in more polluted areas (WHO, 2005). The guideline for carbon monoxide was set in 2000 (WHO, 2000). National Standards for indoor air pollution in the country have not yet been established by the Environmental Protection Agency (EPA), the organization responsible for air quality standards, in the country.

Groups should fill the table below and construct a graph showing WHO estimates and what they obtained

Pollutant.	24-hr Mean Concentration (in this study).	WHO interim target -1 ¹	WHO Air Quality Guideline. ²
PM2.5 wood		75 ug/m ³ (24-hr mean)	25 ug/m ³ (24-hr ave)
PM 2.5 charcoal			
PM 2.5 Crop residue			

Evaluation Criteria

Model development

- The group has developed a tables that does not respond to the problem and that lacks consistency (for example: getting figures wrong , incomplete tables). 0 points
- The group has developed a tables that responds to the problem, but that lacks consistency. 1 point
- The group has developed a consistent tables , even if there are minor mistakes. 2 points

Debate participation

- The student has not participated in the debate nor shown any interest on the activity. 0 points
- The student has actively participated in the debate and has understood the problem. 1 point

¹WHO 2005

² WHO 2006.

4. HOMEWORK ACTIVITY

This activity is prepared for a dedication time of around 10 hours for five-member groups. This activity involves the use of estimates to determine the health impacts of IAP from biomass flues. For uniformity and comparison of results between groups, single box model (m) is adopted. Based on the emission level table from the class activity students are to calculate

- i. Estimation the exposure time of the residents in polluted air.
- ii. Predicting health impact of the residents due to inhale the polluted air.

Estimation the exposure of the residents to PM_{2.5}.

Duan (1982) defined a space that has a uniform concentration of pollutants and in which people are present temporarily as a “microenvironment.” He further saw the interior space of the residence as being made up of a finite number of microenvironments, and proposed a method of using the pollutant concentrations and the period of time in which people are present in each microenvironment to assess exposure to indoor air-polluting substances, as shown in the following equation.

$$\bar{E} = \sum_m C_m \cdot T_m$$

Where \bar{E} is the average daily exposure concentration of PM_{2.5} indoors ($\mu\text{g}/\text{m}^3$), C_m PM_{2.5} concentration in microenvironment m ($\mu\text{g}/\text{m}^3$) and T_m a Residence time rate a in microenvironment m .

Note.

Students are to use time spent cooking as a proxy of time resident spent in kitchen environment. Only exposures in the kitchen environment are to be measured. Predict exposure levels based on the different cooking fuels. Graphs should also be produced.

It is mostly rural women that are highly exposed to the air pollutants as they spend a big share of their day time in kitchen to prepare three meals per day using traditional biomass fuels.

Predicting health impact of the residents due to inhale the polluted air.

Potentiality of health risk means chances of being affected by a different disease per person or the increasing chances of being affected by a certain type of disease. The equation to predict the health risk for particulate matter (PM), on an annual basis is as below:

Change in lower Respiratory illness (per child) = $0.0169 \times$ change in PM

Change in Asthma attacks (per person) = $0.0326 \times$ change in PM

Change in respiratory Symptoms (per person) = $0.183 \times$ change in PM

Change in Chronic Bronchitis (per person) = 6.12×10^{-5} change in PM

The change in PM is calculated by the following equation:

$$\text{Change in PM} = C_{\text{avg}} - C_{\text{WHO}}$$

Where

$$C_{\text{avg}} = \text{Annual average of PM (24-hour), mg/m}^3$$

$$= E/24 \text{ (E= Exposure)}$$

$$C_{\text{WHO}} = \text{WHO standard, } 0.04\text{mg/m}^3$$

Using the above equations , students are to predict the health outcomes based on the amount of fuel use .

The expected output of this exercise is the production of a report of maximum 3 pages contains the most important points in literature

Evaluation criteria

As stated before, this activity is divided in three main parts: the modeling of the Concentration of the different pollutants while burning the biomass fuels to meet the domestic energy need, Estimation the exposure time of the residents in polluted air and Predicting health impact of the residents due to inhale the polluted air. This whole activity is marked up to 7 points (the remaining 3 points where evaluated in the class activity); and in particular the first part is marked up to 4 points while the second part is marked up to 3 points. Next, some guiding criteria are defined:

-
- The group has not been able to produce solutions that include the proposed three outputs (Concentration of the different pollutants while burning the biomass fuels to meet the domestic energy need. Estimation the exposure time of the residents in polluted air. Predicting health impact of the residents due to inhale the polluted air). 0 points
 - The group has provided the output on concentration of the different pollutants while burning the biomass fuels to meet the domestic energy need 2.3point
 - The group has provided the output on estimation the exposure time of the residents in polluted air 2.3 points
 - The group has provided the output on predicting health impact of the residents due to inhale the polluted air 2.4 points

Appendix 1

Output for class activity

Row Labels	Count of COOKING FUEL
Charcoal	17
crop residue	64
Fire wood	19
Grand Total	100

Row Labels	Sum of AMOUNT OF FUEL USED Kg/month
Charcoal	2003
crop residue	9593
Fire wood	1862
Grand Total	13458

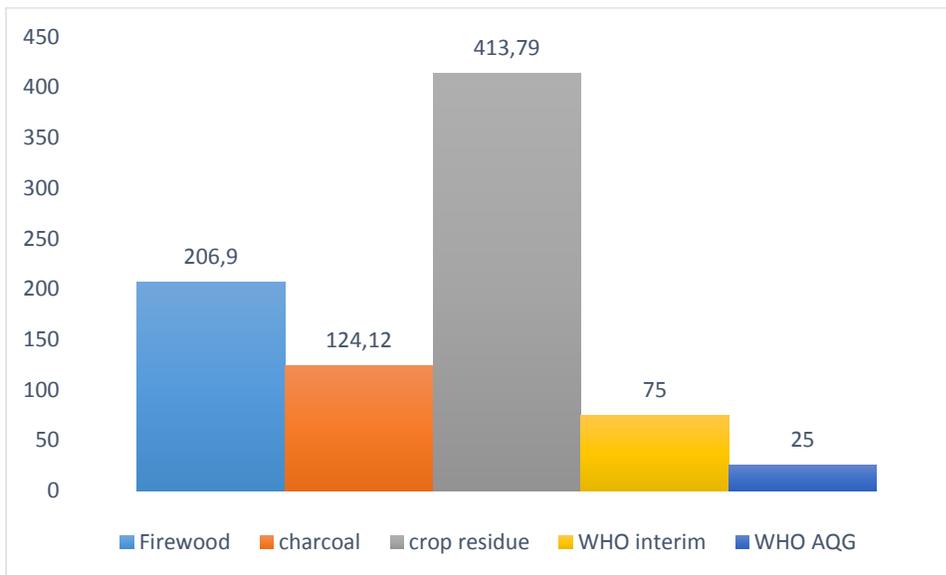
Table 2: Concentration of different pollutants in μgm^{-3}

Different cook fuel	Concentration of different pollutants (μgm^{-3})		
	Fire wood	charcoal	Agric residue
PM _{2.5} levels	206.90	124.12	413.79

Comparison with WHO

Pollutant.	24-hr Mean Concentration (in this study).	WHO interim target -1 ³	WHO Air Quality Guideline. ⁴
PM2.5 wood	206.90	75 ug/m3 (24-hr mean)	25 ug/m3 (24-hr ave)
PM 2.5 charcoal	124.12		
PM 2.5 Crop residue	413.79		

Graphical representation



³WHO 2005

⁴WHO 2006.

Homework activity

Estimation the exposure of the residents to PM_{2.5} by cooking fuel

a. Estimation the exposure time of the residents to PM_{2.5} using crop residue

Average time used by crop residue uses for cooking is 2.5

PM_{2.5} for crop residue is 413.79

exposure of individual cook to PM_{2.5} using crop residue is 1034.48 (µg/m³)

b. Estimation the exposure time of the residents to PM_{2.5} using firewood

Average time used by firewood uses for cooking is 2.4

PM_{2.5} for crop firewood is 206.90

exposure of individual cook to PM_{2.5} using firewood is 496.56(µg/m³)

c. Estimation the exposure time of the residents to PM_{2.5} using charcoal

Average time used by charcoal uses for cooking is 2.4

PM_{2.5} for charcoal is 124.12

exposure of individual cook to PM_{2.5} using charcoal is 298.08 (µg/m³)

Predicting health impact of the residents due to inhale the polluted air (relative chance of being infected by the disease.

Health Impacts due to the use of crop residue

Change in PM is = $(1034.48/24) - 0.04 = 43.04$

Change in lower Respiratory illness (per child) = $0.0169 \times 43.04 = 0.73$

Change in Asthma attacks (per person) = $0.0326 \times 43.04 = 1.40$

Change in respiratory Symptoms (per person) = $0.183 \times 43.04 = 7.88$

Change in Chronic Bronchitis (per person) = $6.12 \times 10^{-5} \times 43.04 = 0.0026$

Health impacts due to the use of firewood

Change in PM is = $(496.56/24) - 0.04 = 20.65$

Change in lower Respiratory illness (per child) = $0.0169 \times 20.65 = 0.35$

Change in Asthma attacks (per person) = $0.0326 \times 20.65 = 0.67$

Change in respiratory Symptoms (per person) = $0.183 \times 20.65 = 3.77$

Change in Chronic Bronchitis (per person) = $6.12 \times 10^{-5} \times 20.65 = 0.0012$

Health impacts due to the use of charcoal

$$\text{Change in PM}_{10} = (124.12/24) - 0.04 = 5.13$$

$$\text{Change in lower Respiratory illness (per child)} = 0.0169 \times 5.13 = 0.087$$

$$\text{Change in Asthma attacks (per person)} = 0.0326 \times 5.13 = 0.172$$

$$\text{Change in respiratory Symptoms (per person)} = 0.183 \times 5.13 = 0.970$$

Change in Chronic Bronchitis (per person)

Annex 2: Household Energy Survey in the Bongo District of Ghana

<i>Cooking Fuel Type of Stove</i>	<i>Amount of fuel used kg/m</i>	<i>Time used for cooking</i>
Fire wood mud stove	106	2
Fire wood mud stove	78	3
Fire wood mud stove	103	2
Fire wood mud stove	102	2
Fire wood mud stove	99	3
Fire wood mud stove	95	2
Fire wood mud stove	98	2
Fire wood mud stove	107	3
Fire wood three stone	107	4
Fire wood three stone	90	2
Fire wood three stone	78	3
Fire wood three stone	94	2
Fire wood three stone	89	2
Fire wood three stone	190	3
Fire wood three stone	43	2
Fire wood three stone	97	2
Fire wood mud stove	98	2
Fire wood mud stove	99	2
Fire wood mud stove	89	3
crop residue three stone	78	3
crop residue three stone	65	2.5
crop residue three stone	178	3.5
crop residue three stone	187	2
crop residue three stone	156	1
crop residue three stone	198	1
crop residue three stone	156	1.5
crop residue three stone	187	3
crop residue three stone	174	2
crop residue three stone	113	2

residue			
crop			
residue	three stone	122	2.5
crop			
residue	three stone	136	4
crop			
residue	three stone	178	3
crop			
residue	three stone	156	2
crop			
residue	three stone	165	3
crop			
residue	three stone	189	4
crop			
residue	mud stove	204	3
crop			
residue	mud stove	189	2.5
crop			
residue	mud stove	198	1.5
crop			
residue	mud stove	168	2
crop			
residue	mud stove	189	3
crop			
residue	mud stove	168	4
crop			
residue	mud stove	109	2
crop			
residue	mud stove	109	2
crop			
residue	mud stove	189	2
crop			
residue	three stone	109	2.5
crop			
residue	three stone	179	2.5
crop			
residue	three stone	187	1.5
crop			
residue	three stone	198	3
crop			
residue	three stone	198	4
crop			
residue	three stone	167	3
crop	three stone	175	2.5

residue			
crop			
residue	three stone	199	1.5
crop			
residue	three stone	178	2
crop			
residue	three stone	178	3
crop			
residue	three stone	164	4
crop			
residue	three stone	102	2
crop			
residue	three stone	111	2
crop			
residue	three stone	123	2
crop			
residue	three stone	89	2.5
crop			
residue	three stone	116	2.5
crop			
residue	three stone	119	1.5
crop			
residue	three stone	102	2
crop			
residue	three stone	106	3
crop			
residue	three stone	178	2
crop			
residue	three stone	137	2
crop			
residue	three stone	189	3
crop			
residue	three stone	107	2
crop			
residue	three stone	200	2
crop			
residue	three stone	175	3
crop			
residue	three stone	176	4
crop			
residue	three stone	107	2
crop			
residue	three stone	167	3
crop	three stone	189	2

residue			
crop			
residue	three stone	123	2
crop			
residue	three stone	143	3
crop			
residue	three stone	127	2
crop			
residue	three stone	127	2
crop			
residue	three stone	128	2
crop			
residue	three stone	125	2
crop			
residue	three stone	109	3
crop			
residue	three stone	110	3
crop			
residue	three stone	129	2.5
crop			
residue	three stone	86	3.5
Charcoal	Coalpot	132	2
Charcoal	Coalpot	119	1
Charcoal	Coalpot	154	1
Charcoal	Coalpot	145	1.5
Charcoal	Coalpot	123	3
Charcoal	Coalpot	167	2
Charcoal	Coalpot	116	2
Charcoal	Coalpot	140	2.5
Charcoal	Coalpot	74	4
Charcoal	Coalpot	126	3
Charcoal	Coalpot	87	2
Charcoal	Coalpot	90	3
Charcoal	Coalpot	128	4
Charcoal	Coalpot	99	3
Charcoal	Coalpot	108	2.5
Charcoal	Coalpot	106	1.5
Charcoal	Coalpot	89	2

Annex 3 Further Materials

http://www.statsghana.gov.gh/pop_stats.html

BIBLIOGRAPHY

- Ballard-Tremere, G. and Jawurek, H. (1999). Emissions and Efficiencies – Five Rural Cooking Devices. *Biomass and Bioenergy* , 11 (5), 419 - 430.
- Bonjour S, Adair-Rohani H, Wolf J, Bruce NG, Mehta S, Prüss- Ustün A, et al. 2013. Solid fuel use for household cooking: country and regional estimates for 1980–2010. *Environ Health Perspect* 121:784–790; doi:10.1289/ehp.1205987.
- Bruce, N., Perez-Padilla, R. and Albalak, R. (2002). Indoor Air Pollution in developing countries: a major environmental and public health challenge. *Bulletin of the World Health Organisation* , 78 (9), 1078-1092.
- Desai, M., Mehta, S., & Smith, K. (2004) *Indoor Smoke from Solid Fuels: Assessing the Environmental Burden of Disease at National and Local Levels* Environmental Burden of Disease Series, No. 4. Geneva: World Health Organization.
- Energy Commission, Ghana, 2014b. 2014 Energy (Supply and Demand) Outlook for Ghana. Accra: Energy Commission. Available at http://energycom.gov.gh/files/Energy%20Commission%20-%202014Energy%20Outlook%20for%20Ghana_final_2014.pdf. . [Accessed: 20th January 2015]
- Ezzati, M., Saleh, H., and Kammen, D.M. (2000). The Contribution of emissions and spatial micro-environments to exposure to indoor air pollution from biomass combustion in Kenya. *Environ Health Perspect* , 108 (9), 833-839.
- Ghana Statistical Service (2012) 2010 Population and Housing Census (PHC) Final Results, Accra: Ghana Statistical Service
- Kaplan C (2010) Indoor air pollution from unprocessed solid fuels in developing countries. *Reviews on Environmental Health* 25(3):221–242
- Matookane, M., John, J., Oosthuizen, R. and Binedell, M. (2004). Vulnerability of South African communities to air pollution. *Proceedings of the 8th World Congress on Environmental Health*. Durban, South Africa.
- Prasad KK, Sangen E, Visser P. Woodburning Cookstoves. In: Hartnett JP, Thomas F. Irvine J, editors. *Advances in Heat Transfer*. Volume 17: Elsevier; 1985. p. 159-317.
- Sharma, S., Sethi, G., Rohtagi, A., Chaudhary, A., Shankar, R., Bapna, J., Joshi, V. and Sapir, D. (1998). Indoor Air Quality and Acute Respiratory Infection in Indian Urban Slums. *Environmental Health Perspectives* , 106 (5), 291-297.

Sitara J, 2003, Cost of air pollution of Dhaka city, Unpublished Undergraduate Thesis, Environmental science discipline, Khulna University, Khulna.\

UNDP. (2002). World Energy Assessment: Energy and the Challenge of Sustainability. Retrieved November 12, 2006, from <http://www.undp.org/seed/eap/activities/wea/drafts-frame.html>.

Smith KR, Aggarwal AL, Dave RM. Air pollution and rural biomass fuels in developing countries: A pilot village study in India and implications for research and policy. *Atmospheric Environment* (1967). 1983;17(11):2343-62. doi: 10.1016/0004-6981(83)90234-2.

Warwick, H. and Doig, A. (2004). *Smoke-the Killer in the Kitchen. Indoor Air Pollution in Developing Countries*. London: ITDG.

World Health Organization (2007) *Indoor Air Pollution: National Burden of Disease Estimates Year 2002*, WHO Press: Geneva. Accessed on 16 January 2015. http://www.who.int/indoorair/publications/Indoor_air_national_burden_estimate_revised.pdf.

WHO (2002) *The World Health Report 2002: Reducing Risks, Promoting Healthy Life* (Geneva: World Health Organization).

Yassi, A., Kjellström, T., de Kok, T. and Guidotti, T. (2001). *Basic Environmental Health*. New York: Oxford University Press.



GDEE

GLOBAL
DIMENSION IN
ENGINEERING
EDUCATION

<http://www.gdee.eu>



This project is funded by

