Air pollution emitted during traditional coffee ceremonies in Ethiopia, a health risk for women

JOHAN EDLUND 2019
MVEM13 EXAMENSARBETE FÖR MASTEREXAMEN 30 HP
MILJÖVETENSKAP | LUNDS UNIVERSITET

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2019-11-13

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Lund 2019

Abstract

Indoor air pollution is a problem of great concern, estimating to cause around 2 million premature deaths, with 400.000 cases suspected to happen in Sub-Saharan Africa. In this thesis, indoor air pollution emissions associated with the Ethiopian traditional coffee ceremony has been studied as a model for cooking exposure. Coffee preparation is a ceremony which is conducted in almost every Ethiopian home at least twice a day. The purpose of this project is to get a better understanding of the levels and the characteristics of air pollution from the use of small scale stoves in indoor environments. The study has been conducted in 45 Ethiopian homes (measurements was conducted in 28 homes), in the city of Adama. The data from the measurements conducted in this thesis might help to understand the extent of the problem, especially as there is a lack of data from the region. The result of the study shows that particle mass ($PM_{2.5}$) and particle number ($PN_{0.5}$) and Polycyclic aromatic hydrocarbons (PAHs) increase when stoves are ignited indoors. The use of incense further increases the number of particles and PAHs. The high concentrations of $PM_{2.5}$, $PN_{0.5}$ and Benzo[*a*]pyrene (BaPyr) that have been measured in this study might be hazardous to women in Ethiopia, therefore further investigations are needed to achieve more knowledge about the health effects of this exposure.

Contents

Abbreviations

Ace - Acenaphthene
Acy - Acenaphthylene
Ant - Anthracene
BaAnt - Benz[*a*]anthracene
BaPyr - Benzo[*a*]pyrene
BbFl - Benzo[*b*]fluoranthene
BghiPer - Benzo[*g,h,i*]perylene
BkFl - Benzo[*k*]fluoranthene
$CaCO_3$ - Calcium carbonate
Chr - Chrysene
CO - Carbon monoxide
DBahAnt - Dibenz[*a,h*]anthracene
EPA - United States Environmental Protection Agency
F - Fluorene
Fl - Fluoranthene
GM - Geometric Mean
IPyr - Indeno[*1,2,3-c,d*]pyrene
IS - Internal standard
LOD - Limit of detection
N - Naphthalene
NIST - National Institute of Standardsand Technology
NOx - Nitrogen oxides
P - Phenanthrene
PAH - Polycyclic Aromatic Hydrocarbons
PM - Particle mass
PN - Particle number
Pyr - Pyrene
SIM - Selected ion monitoring mode
WHO - World Health Organization

1 Introduction

In this thesis, indoor air pollution emitted from traditional stoves during coffee ceremonies in the homes of Ethiopians, in Adama, are studied (*see Figure 1*). The Ethiopian coffee ceremony is conducted in almost every home, several times a day (Keil et al., 2010). Indoor air pollution are important to study since inhalation of these might be linked to health-related issues. One group that is especially affected by indoor-generated air pollution are the Ethiopian women since they spend many hours of everyday cooking food and preparing coffee (Dyjack et al., 2005; Keil et al., 2010; Mishra et al., 2004; Pennise et al., 2009). A particularly vulnerable group is children which might be even more affected by the air pollution than adults due to a lighter breathing frequency and since their lungs are still under development (Dyjack et al., 2005). Women who are exposed to air pollution in the indoor environment are three times more likely to suffer from chronic obstructive pulmonary disease compared with women who use cleaner fuels for cooking like electricity and gas (World Bank, 2011). Like in other developing countries, cooking in Ethiopia often takes place indoors without any adequate ventilation (Pennise et al., 2009). A pilot study has shown that the particles which are generated by cooking in Ethiopia resulted in pollution levels that are 60-80 times higher than WHO health recommendation (Lund University, 2018).

Previous studies have mostly been focusing on the health effects from the smoke of fossil fuels (Naeher et al., 2007), analysing the composition of air pollution from the combustion of biomass are important since the lack of data makes it difficult for policymakers, despite some studies of indoor air pollution in Ethiopia (Tefera et al., 2016).

Figure 1: Map of Ethiopia and its location in Africa.

2 Purpose

The purpose of this thesis is to achieve a better understanding of the concentrations and the characteristics of airborne particles $PM_{2.5}$ (particles with an aerodynamic diameter smaller than 2.5 micrometres) and Polycyclic aromatic hydrocarbons (PAHs) emitted during coffee ceremonies. A small survey was as well held with the participants to broaden the perspective of the study.

Research questions

- What is the chemical composition of the PAHs generated during coffee ceremonies?
- What levels of $PM_{2.5}$ and $PN_{0.5}$ does the average women in Adama, Ethiopia get exposed to during the process of making coffee?
- How does the location of ignition and use of incense affect the particle exposure from coffee preparation?

Hypothesis

- Particles and PAH concentrations will be higher when the stove is ignited indoors and when incense is used during the ceremonies.

3 Background

With about 102 million people, Ethiopia is the second most populated country in Africa. The country is located in the northeastern part of Africa (*see Figure 1*), in the region is known as "the horn of Africa". Half of the total households in urban areas in the sub-Saharan African region are considered poor (Karekezi, & Majoro, 2002). Despite a fast-growing economy, Ethiopia is still among the low income countries in the world with a GDP per capita of 767 USD. About 80 % of the population live in rural areas (World Bank[a], [b]). In 2015, the average life expectancy for a newborn was 63 years for a male and 67 years for a female (World Health Organization[a]). In Ethiopia, like in many other countries around the world, air pollution is a big problem causing health problems and premature deaths. One of the main contributors to the adverse health effects is traffic-related air pollution (Naidja et al., 2017), but in many less developed countries, indoor-generated air pollution is also a huge problem (World Health Organization[b]). Burning organic material is a reason for high levels of indoor air pollution in developing countries (Morawska et al., 2013). In developing countries, exposure to indoor air pollution can be directly linked to poverty (Fullerton, Bruce & Gordon, 2008). In sub-Saharan countries, the proportion of people which are dependent on these organic material varies between 68 % and 90 %, in Ethiopia the proportions are over 90 % (Gebreegziabher et al., 2018; Tucho et al., 2014), which is the highest number on the African continent (Alem et al., 2010). The country consumes about 91.2 million tons of wood and 4.2 million tons of charcoal every year. The huge consumption of wood for e.g cooking and coffee ceremonies, is not only related to health problems, but it is also contributing to deforestation, land degradation of the country and climate changes (Benka-Cokeret al., 2018; Mekonnen, 1999). The cost of biomass fuel can vary between urban areas in Ethiopia (Kebede, Bekele, & Kedir, 2002), but the use of biomass as fuel does not often only depend on the affordability, it also has strong cultural connections and is, therefore, a question of preference (Alem., 2010). Many household in urban areas continue to use biomass fuel for cooking, even if alternative energy sources are available (Abebaw, 2007; Mugo, & Ong, 2006). On the other hand, there are studies pointing out that (i) the dependence of biomass fuels for a household is significantly decreasing with income in Ethiopia (Kebede et al., 2002); and (ii) that education is negatively affecting the quantity of firewood consumed in a household (Abebaw, 2007). Only 27 % of Ethiopia's population has access to electricity (92 % urban, 12 % rural population) (Benka-Coker et al., 2018). The Welfare Monitoring Survey (Central statistical agency, 2016) shows that the most used fuel for cooking in Ethiopian urban areas are firewood (54.18 %) followed by electricity (21.42 %) and charcoal (16.73 %), in rural areas firewood (90.42 %) is by far the most used type of fuel, followed by dung/manure (4.42 %) and crop residue/leaves (4.21 %). The proportions are an average value and can vary between locations.

3.1 The Ethiopian coffee ceremony

The Ethiopian coffee ceremony is a tradition with long historical and cultural roots in Ethiopian communities (Pennise et al., 2009). The ceremony of making coffee in Ethiopia is elaborate. First, the charcoal is lit on fire (most often done outdoors), then the stove is carried indoors to a central place in the home and roasting of the coffee beans is initiated (*see Figure 2*). After roasting is done the beans are ground, added to a coffee pot, and water is added. During the boiling process, some charcoal is removed into a smaller vessel to which incense is added. After serving the coffee, new water is added to the beans. This process is conducted three times. During all of the ceremony, the guests are present in the room to savour the aroma of roasted beans and incense. The full procedure takes about 1.5 hours and is in general conducted several times a day (Keil et al., 2010). Snacks like bread, nuts, seeds and popcorn are commonly consumed the process of making the coffee (*see Figure 3*). Inhaling the smoke from the roasted coffee beans during the ceremony is also a common part of the ceremony (Tefera et al., 2016).

Figure 2: Coffee roasting in process.

Figure 3: Picture from a coffee ceremony.

3.2 United Nations development strategies

Despite the concern that burning fuels like e.g charcoal and wood can cause health effects, the magnitude of the problem will grow even more due to increased population. The number of people in the world, which will be dependent on which energy sources for cooking is expected to increase to 2.7 billion people by 2030 (International Energy Agency, 2006). Strategies are an important step for sustainable development, the United Nation has therefore introduced seventeen so called “Sustainable Development Goals” (SDGs). The target was to create new goals which were built upon the previous Millennium Development Goals, which had the aim to end all forms of poverty. The idea of the new goals was to incorporate other aspects of the issues that humans are experiencing and will experience in the future, and countries must contribute to reach the goals (United Nations[a]). Two of the seventeen goals can be directly linked to this thesis, those are: goal number 3 'Ensure healthy lives and promote well-being for all at all ages' and goal number 7 'Ensure access to affordable, reliable, sustainable and modern energy for all. Making a transition to cleaner energies, which more people have access to is a challenging task (Spalding-Fecher et al., 2005). To deal with the problems related to fuels like charcoal and wood, and the health-related impacts of those, United Nations has the target to substantially reduce the death caused by air pollution (United Nations[b]), and to ensure universal access to affordable, reliable and modern energy sources by 2030 (United Nations[c]).

4 Indoor air pollution

Exposure to airborne particulate matter (PM) is of great concern and can be related to several health issues. Almost 2 million premature deaths per year are estimated to be caused by indoor air pollution worldwide, 400.000 of those occurs in Sub-Saharan Africa (World Bank, 2011), and around 41 million disability-adjusted life years[1] (DALYs) are estimated to be lost globally due to indoor air pollution (World Health Organization, 2004). In Ethiopia, pregnancy related preeclampsia is the primary cause of maternal death. The cause of preeclampsia is still not fully understood (Levine et al., 2004), but recent research has shown correlations between increasing levels of air pollution and preeclampsia in Sweden, even with the relatively low levels of pollution (Malmqvist, 2014). Studies have also shown that children whose mothers were exposed to wood smoke during pregnancy achieve lower scores on neuropsychological tests (Das et al., 2017).

Indoor particles and their composition and toxicity are complex since they interact with other particles with both indoor and outdoor origin (Morawska et al., 2013). It is not fully understood which characteristics of the airborne particles that contribute the most to negative effects on human health (Buonanno et al., 2013). Naeher et al. (2007) suggest to study the health effects from a mixture of pollutants rather than the effects by the individual pollutants themselves. Several studies shows that indoor air pollution might causes adverse health effects like cardiovascular diseases, respiratory infections, lower birth weight of children, asthma, laryngeal cancer and tuberculosis (Sanbata, Asfaw, & Kumie, 2014). Exposure to $PM_{2.5}$ may result in a lower life expectancy (Morawska et al., 2017). These particles can be emitted during cooking with organic material like charcoal, animal dung and wood as fuel (Buonanno et al., 2013; Fullerton et al., 2008; Mishra et al., 2004).

[1] Definition: "*One DALY can be thought of as one lost year of "healthy" life. The sum of these DALYs across the population, or the burden of disease, can be thought of as a measurement of the gap between current health status and an ideal health situation where the entire population lives to an advanced age, free of disease and disability.*" (World Health Organization[c]).

4.1 Air pollution from coffee ceremonies and cooking in Ethiopia

In Ethiopia, many households use a traditional type of stove for cooking and coffee ceremonies, it is made of steel (*see Figure 4*) and clay in which charcoal is used as fuel (Keil et al., 2010). A study conducted in 82 households, between 1999 and 2000 in sub-cities to Jimma, Ethiopia, found that the levels of total suspended particles (TSP), PAH and CO exceeded their limits set by WHO guidelines 1987. Fifty out of the households (61 %) experienced levels which exceeded the limit for TSP (120 μg/m^3). The participating women and girls in the study were exposed to pollution from cooking up to four hours per day (Tefera et al., 2016). Another conducted in Addis Ababa, Ethiopia, showed high levels of $PM_{2.5}$ range (136 - 12737 μg/m^3), average: 1580 μg/m^3) in the kitchen of 69 homes (100 %) during 24 hours (Tefera et al., 2016). The levels exceeded the guideline (25 μg/m^3 24-hour mean) set by WHO (World Health Organization, 2006). Decreasing the concentrations of indoor air pollution from cooking and coffee ceremonies is possible. A study in Ethiopia and Ghana by Pennise et al. (2009) indicates that the concentrations of $PM_{2.5}$ and CO can be decrease by 52-84 % and 40-76 %, respectively, by changing the type of stoves. Another study by Dyjack et al. (2005) conducted in Gimbie, Ethiopia, compared airborne particles from the stove that use wood to those without. It was showed that the highest concentrations were found in the homes which used biomass as fuel (Dyjack et al., 2005).

Figure 4: Picture of an Ethiopian traditional stove.

4.2 Air pollution from incense burning

Incense has been used in thousands of years for a variety of reasons, e.g religious ceremonies. Today, incense is stil used in the daily life of many people around the world, e.g coffee ceremonies in Ethiopia (Jetter et al., 2002; Keil et al., 2010). Incenses consist of e.g resins, oils, seeds, herbs, species and chemicals, and can be produced in different forms like sticks and powders. Burning of various types of incenses is an important source of indoor air pollution around the world, especially for PAHs and $PM_{2.5}$ (Cheng, Bechtold, Yu & Hung, 1995; Lung & Hu, 2003; See, & Balasubramanian, 2011), CO, NOx, and volatile organic compounds (VOCs) (Lee, & Wang, 2004). Smoke from incense burning may be linked to asthma, dermatitis or cancer. Some studies e.g Jetter et al. (2002), however, have not found any connection between lung cancer and incense burning, Jetter et al. (2002) measured the emissions from 23 different types of incense and found that the particle concentration emitted from incense burning depends on the type of incense, with $PM_{2.5}$ levels ranging between 5 - 56 mg/g of incense burned, and the emission rates for $PM_{2.5}$ range (7 - 202 mg/h). The same study also measured the emission rate of gases for 7 different types of incense and found levels of CO range (144 - 531 mg/h), SO_2 range (1.4 - 25.5 mg/h) and NO range (0.16 - 4.39 mg/h). Hussein et al. (2006) showed that the total particle number concentration increased from $8{\times}10^2$ to $1.2{\times}10^4$ per cm^3 when an incense stick was burned. Another study from Löfroth, Stensman, & Brandhorst-Stazkorn. (1991) measured the emission in mg/g burned of different incense and found levels of CO range (180 - 220), isoprene (0.8 - 1.1) and benzene (0.42 - 0.44). Incense burning does also contribute to significantly increased levels of carbonyls a study conducted in a home in Hong Kong shows that concentrations can reach up to 179 ppb_v (Formaldehyde 57.5 %, Acetaldehyde 9 %) during the burning period from three incense sticks with the weight of 1.3 g each (Ho, & Yu, 2002). Indoor measurements of 11 incense with an average burning time of 114 min showed that 68.8 % of the particle number was within the range of 10-100 nm in diameter, 23.8 % were in the range of 100-200 nm (Wallace., 2006). Another study by (Géhin, Ramalho & Kirchner, 2008) demonstrated particle sizes of 100 and 180 nm. Experiments by Stabile, Fuoco, & Buonanno (2012) reported a particle size of 200 nm. Measurements conducted in an 18.12 m^3 test chamber on 10 different types of incenses from countries in Asia, Africa and Europe, showed different concentrations of air pollution. Varying levels of pollution from incense burning from the literature is probably due to different types of additives to the incense (Stabile et al., 2012). Results from (Yang, Lin, Peng, Lee & Chang, 2012) shows that it's possible to decrease the particular matter by 5-30 % and PAHs by 9-28 %, from incense stick (bamboo) burning by adding calcium carbonate ($CaCO_3$) to the incense powder.

4.3 Compounds

Polycyclic aromatic hydrocarbons

Polycyclic aromatic hydrocarbons (PAHs) are a group of compounds, some of these are both carcinogenic and mutagenic (World Health Organization, 2010). PAHs are produced by incomplete combustion of organic matter (Karolinska Institutet[a]). In the body, some PAHs gets metabolized and reacts with DNA, possibly causing DNA adducts and later DNA mutations, that might lead to cancer (Kemikalieinspektionen, 2016). Lung cancer is the most serious health-related issue linked to PAH exposure (World Health Organization, 2010). One study has shown that particulates from cooking sources can result in considerable concentrations of high molecular weight PAHs (Ohura et al., 2004; World Health Organization, 2010). There is no general guidelines regarding PAH, instead benso[*a*]pyrene (BaPyr) is used as a marker of PAH, as it is known to be carcinogenic (World Health Organization, 2010; Ohura et al., 2004). BaPyr at levels above 1.0 ng/m^3 is associated with an increased genomic frequency of translocations, micronuclei and DNA fragmentation (World Health Organization, 2010).

Carbon monoxide

Carbon monoxide (CO) is a toxic gas which can be created when e.g biomass is burned under circumstances which result in incomplete combustion (Naeher et al., 2007; World Health Organization, 2010). The gas is toxic due to its chemical properties. When inhaled, the gas binds to the haemoglobin of the red blood cells resulting in an impaired ability for the red blood cells to transport oxygen to the body. This is due to that the carbon monoxide has a 250 times stronger tendency to bind to the haemoglobin compared to oxygen. Lowe concentrations of CO can result in headache, dizziness and nausea, higher concentrations can result in convulsions, breathing problems and unconsciousness. WHO has different guidelines for CO concentrations in the indoor environment depending on the exposure time and type of activity, these are: 100 mg/m^3 for 15 minute period and 35 mg/m^3 for 60 minute period (during light exercise, and persons should also not be exposed to these levels more than once per day), 10 mg/m^3 (arithmetic mean concentration) for 8 hours (during light to moderate exercise) and 7 mg/m^3 (arithmetic mean concentration) for 24 hours (during time the person is awake) (World Health Organization, 2010).

NOx

NOx is a group of nitrogen oxides, two of these are nitrogen monoxide (NO) and nitrogen dioxide NO_2. NO is a radical compound, which primary is produced during combustion, and is therefore common in e.g woodsmoke (Naeher et al., 2007). Upon contact with oxygen in the air, NO can oxidize to NO_2. A large amount of inhaled NO can result in vasodilator effects, and inhalation of NO_2 can result in bronchial reactivity when the concentration is at least 200 µg/m^3 (Karolinska Institutet[b]) and acute health effects if exposed to 500 µg/m^3 during a 60 minute period (World Health Organization, 2006). The WHO guideline for NO_2 in an indoor environments is 200 µg/m^3 (60-minute mean) and 40 µg/m^3 (annual mean) (World Health Organization, 2006).

Soot

Soot consists of particulate matter from unburned fuel residues and hydrocarbons (e.g PAH). Soot is created when organic material is combusted with low oxygen levels (Karolinska Institutet[c]). Soot particles are a health concern due to their ability to adsorb other toxins, and due to their small size, meaning that they can end up in the alveoli of the lungs (Isaxon et al., 2015).

5 Methodology and materials

The study was conducted in 45 homes in the city Adama also known by the name Nazret (coordinates 8.54°N 39.27°E), Oromia region. Due to limitation in time of the study, most of the participants were chosen among a cohort of 2000 women, who are participating in health related studies regarding tuberculosis and preeclampsia in the town. These women, had given their approval to participate prior to the visits. Other participants were found among the neighbours to those who are participating in the studies regarding tuberculosis and preeclampsia, since their approval to participate as well facilitated the feasibility of the study. The focus on urban areas is also due to the limitation of time during the field period and the fact that the sample group lives in the urban area. To establish scientific grounds to draw a conclusion of how the pollution affect the women, a survey in the research field was done. The articles were found using the database 'Web of Science Core Collection' with all databases selected and the search engine 'Google Scholar'. Search words that were used are combinations of e.g "indoor air pollution" "Ethiopia" "traditional stove" "stove" "PM 2.5" "PAH" "coffee" "coffee ceremony" "coffee ceremonies".

5.1 Survey

A survey is a commonly used as a method to gather data in studies related to human health (Jakobsson, & Westergren, 2005), the survey used in this study (*see Appendix I*) is used as a complement to the quantitative results from the indoor measurements. The survey used is similar to that of a previous study in Addis Ababa, Ethiopia (Keil et al., (2010). As Jakobsson and Westergren (2015) argue, the survey was held in the mother tongue of the respondents, in this case in Amharic. Answers from the respondents were later translated into English.

5.2 Air measurements

Time-resolved air measurements were conducted with two instruments, DustTrak DRX and Purple Air monitor. The DustTrak DRX with a 2.5 µm inlet, was used to measure the mass concentration (mg/m^3) of $PM_{2.5}$ with a time resolution of 10 seconds. The Purple Air monitor was used to measure PM_1, $PM_{2.5}$ and PM_{10} and particle number (particles/cm^3) in fractions $PN_{0.3}$, $PN_{0.5}$, PN_1, $PN_{2.5}$, PN_5 and PN_{10} with a time resolution of 80 seconds. Open filter cassettes with teflone membranes and sorbent tubes (XAD-2 8x110 mm, SKC 266-30) connected to a pump, were used to sample particles/gas phase that was later analysed for Polycyclic aromatic hydrocarbons (PAHs). Five filter membrane and sorbent tubes were used as field blanks for this study, the filter membrane blanks were brought to Ethiopia while the sorbent tubes were not. The flow (ℓ/min) through the pump was measured before and after sampling. All measurements were conducted in the women's breathing zone, i.e no further than 30 cm from her nose/mouth. Due to practical reasons linked to the equipment, measurements were not made in the breathing zone, during the time of ignition for those ceremonies where the stove was ignited outdoors. The measurements were conducted about 1-5 minutes before (to get an exposure baseline), during and after (until the air pollution levels have declined to baseline) the process of making coffee. To study how location of ignition and use of incense affect the exposure, the quantitative data were compared to detailed log books about the coffee ceremony procedure itself. The mass of the charcoal and coffee beans was weighed as well.

5.3 PAH analysis

Sample Preparation for analysis

Membranes from the open filters, were removed from the surrounding plastic ring and placed in a glass tube. The polymeric material from the matching XAD-2 tubes was added to the corresponding filter membrane. Polymeric material from unused XAD tubes was added to the filter blank membranes. To each sample and blanks, 40 μl of deuterium labelled PAHs, (1 ng/ml) and 3 ml dichloromethane was added and then sonicated using a Sonica Ultrasonic Extractor (Soltec) for twelve minutes (maximal amplitude). Extracts were cleaned up using silica columns. Columns were washed with dichloromethane and remaining extracts were combined and evaporated with the extract from the clean up. When half of the volume of dichloromethane was evaporated, 2 ml of hexane was added for solvent exchange. Extracts were further evaporated to near dryness and transferred into a HPLC vial (with glass insert). Samples were spiked with 40 μl of octafluoronaphthalene as recovery standard (1 ng/ml), and one drop of toluene was added.

Gas chromatography - mass spectrometry analysis

In total, analysis was performed for 16 PAHs, suggested by the United States Environmental Protection Agency (EPA) priority pollutant list (EPA, 2014). The methodology used is the same as reported by Strandberg et al. (2018) and Klein, (2018). Samples were analysed using chromatography/low resolution mass spectrometry (HRGC/LRMS) with an Agilent 5975C mass spectrometer (MS) coupled to an 7890A gas chromatograph (GC) (Agilent Technologies). Samples (2 µl) were injected using an Agilent autosampler unit. The capillary column used was a DB-5MS (30 m × 0.25 mm, 0.25 µm, Agilent Technologies). Helium was the carrier gas at a flow rate of 1.0 ml/min. During the GC-phase, the compounds from the samples gets vaporized before entering the column. The temperature program was as follows: initial temperature at 50 °C for 3 min; ramp at 10 °C/min to 180 °C and held for 5 min; ramp at 3 °C/min to 300 °C and held for 20 min; injection at oven temperature at 250 °C; and transfer line at 250 °C. Sample injection volume was 2 µl (splitless injection mode). Once in the column, the compounds gets separated from each other and leave the column after different times. In the MS-phase, compounds get ionization, in this case at 70 eV energy, 230 °C ion source temperature. Ionized molecules than passes through a quadrupole and a magnetic field, at 150 °C. The magnetic field separates the different compounds based on their charge and weight. The MS was operated in selected ion monitoring mode (SIM), (see Strandberg et al., 2018).

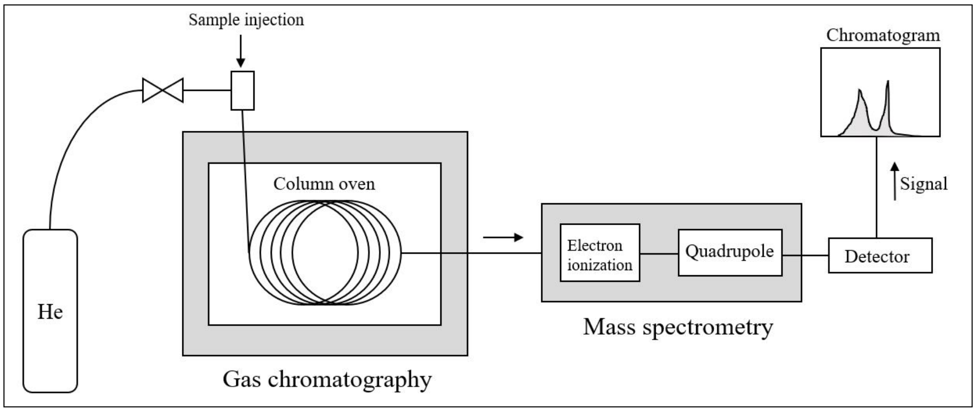

Figure 5: Schematic diagram of the gas chromatography - mass spectrometry analysis.

Quality control

Standard reference material "diesel exhaust 2975" from National Institute of Standards and Technology (NIST) was used as Quality Controls. *Appendix III* shows the results of the quality controls compared to the certified reference value. The analyzed values for PAHs matched closely the values from values reported from NIST, confirming the reliability of this method. For the PAHs, analysis of quality controls can be compared to certified values of the following compounds (according to NIST): N, F, P, Ant, Fl, Pyr, BaAnt, Chr, BkFl, BaPyr, IPyr, DBahAnt and BghiPer. The limit of detection (LOD) was calculated for individual PAHs as 3 times the standard deviation divided by average air sampling volume of the samples. The LODs ranged from 0.007 ng/m^3 (BghiPer) to 0.87 ng/m^3 (N). LOD for respective sample is calculated as three times the standard deviation of the field blanks, divided by the average air sampling volume. The concentration of PAHs found in the field blanks were subtracted from the coffee ceremony samples.

5.4 Statistical analysis

Independent Samples Test (T-test) was used to compare the geometric mean of $PM_{2.5}$, $PN_{0.5}$, PN_1, $PN_{2.5}$, PN_5, PN_{10} and PAHs between coffee ceremonies with different characteristics, P-values < 0.05 was considered as significant. Two-tailed Pearson test was used to analyze the correlation between $PM_{2.5}$, $PN_{0.5}$, PN_1, $PN_{2.5}$, PN_5, PN_{10} and PAHs with the mass of coffee and charcoal. Correlation test was used to analyze the relationship between the concentration of PM2.5 and PAHs with an increased amount of charcoal used as fuel or coffee beans roasted, during the ceremony. PAH compounds with a concentration $<$LOD was treated as LOD $\times 1/2^{0.5}$, for the statistical tests (Keil et al., 2010). SPSS Statistics 25 (IBM) was used for statistical analyses.

5.5 Ethical Considerations

All identifiable variables (location and GPS coordinates of the participants) are stored in a safe place according to ethical guidelines and a linking key was created and stored accordingly. The work will be conducted in line with international rules and agreements. The study was ethically approved by Armauer Hansen Research Institute (AHRI), in Ethiopia. The results are presented in an aggregated form and no individual participant/home will be identifiable (Vetenskapsrådet, 2017). Formal consent for participation was used and the study participants were informed that they could withdraw from participation at any time. Every woman was compensated with 150 ETB (approximately 5 USD during the time of this study) for their time and to cover up for the cost for coffee beans and charcoal.

6 Result

Out of the 28 coffee ceremonies that were analyzed, 3 ceremonies was performed completely outdoors, and 25 indoors. 28 measurements were done with DustTrak, Purple Air monitor was used in parallel during 17 measurements. The coffee ceremonies lasted on average 77 min range (28 - 116 min), the charcoal used weighed on average 208g, range (36 - 342g) and the coffee beans weighed on average 60g range (30 - 128g). Incense was used in 13 of the ceremonies.

6.1 Particle concentration

Since an majority of particles emitted during combustion of biomass has an aerodynamic diameter smaller than 1 µm (Tiwari et al., 2014), only $PN_{0.5}$ and $PM_{2.5}$ will be presented here. Results of PN_1, $PN_{2.5}$, PN_5, PN_{10} is presented in *Appendix II*

Concentration comparison, location of ceremony

Table 1. Total $PM_{2.5}$ levels (mg/m^3) and total $PN_{0.5}$ (particles/cm^3) during coffee ceremonies, measured indoors and outdoors of the homes.

Location	MEAN $PM_{2.5}$ (mg/m^3)	MEAN $PN_{0.5}$ (particles/cm^3)
Indoor	0.98 ± 1.05 (n = 25)	11470 ± 2622 (n = 14)
Outdoor	0.46 ± 0.56 (n =3)	4412 ± 2651 (n =3)

As seen in *Table 1*, the geometric mean concentration of $PM_{2.5}$ was 0.98 mg/m^3 for all ceremonies that were held indoors (range 0.11 - 4.51 mg/m^3). When ceremonies were held outdoors, particles concentrations in the breathing zone was half, with only 0.45 mg/m^3 (range: 0.21 - 1.44 mg/m^3). The geometric mean concentration of P0.5 was 11470 particles/cm^3 for all ceremonies that were held indoors (range 6963 - 16474 particles/cm^3). When ceremonies were held outdoors, particles concentrations were 60 % decreased, with only 4412 particles/cm^3 (range 2281 - 8647 particles/cm^3). Examples of how mass- and number concentration varied with time, from two sites can be seen in *Figure 6* and *Figure 7*.

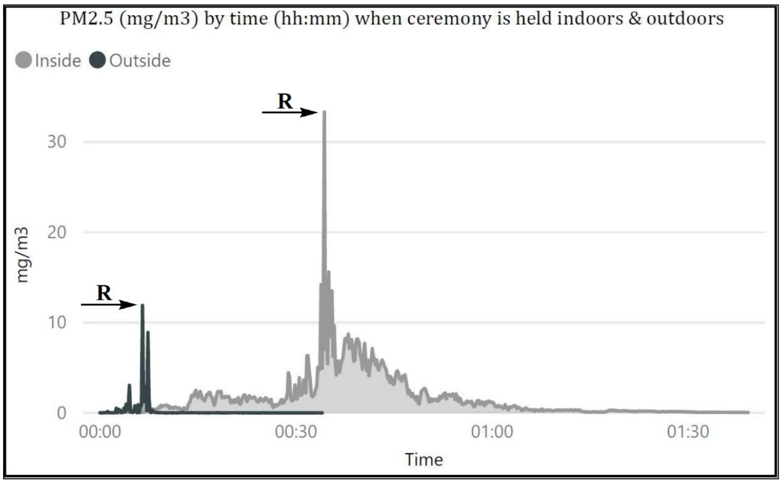

Figure 6: Measurements from site 27 and 9, as seen in the figure both the concentrations of air pollution reached a maximum. ”R” indicates the peak concentration from the roasting process. After the roasting process, concentration quickly declines for the ceremony held outdoors compared with indoors.

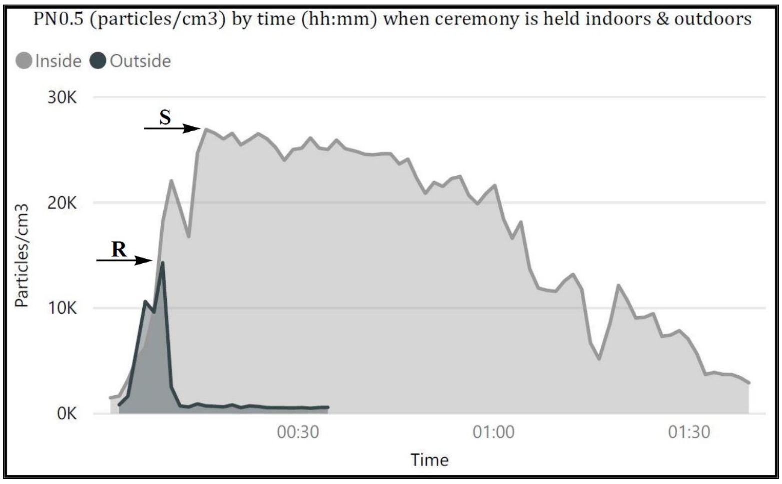

Figure 7: Measurements from site 27 and 9, as seen in the figure both the concentrations of air pollution reached a maximum. ”S” indicates the peak concentration from the ignition, ”R” indicates the peak concentration from the roasting process. After the roasting process, concentration quickly declines for the ceremony held outdoors compared with indoors.

Concentration comparison, location of ignition

Table 2: Total $PM_{2.5}$ levels (mg/m^3) and total $PN_{0.5}$ ($particles/cm^3$) during coffee ceremonies without incense, measured indoors of the homes, when the stove is ignited indoors and outdoors.

Location	MEAN $PM_{2.5}$ (mg/m^3)	MEAN $PN_{0.5}$ ($particles/cm^3$)
Indoor	1.15 ± 0.29 (*n* = 3)	13338 ± 2174 (*n* = 2)
Indoor*	0.83 ± 0.76 (*n* = 2)	14684 ± 0 (*n* = 1)
Outdoor	0.60 ± 0.37 (*n* = 9)	9193 ± 1370 (*n* = 5)

As seen in *Table 2*, the geometric mean concentration of $PM_{2.5}$ was 1.15 mg/m^3 for all ceremonies that were held indoors and the stove was ignited indoors; particle concentrations was decreased by 30 % to 0.83 mg/m^3 when the ceremonies were held indoors, but the stove was ignited [2]indoors*; particle concentration was 50 % lower, 0.60 mg/m^3 for all ceremonies that were held indoors and the stove was ignited outdoors. Due to small sample number, this difference in $PM_{2.5}$ was not significant (P = 0.105). The geometric mean concentration of $PN_{0.5}$ was: 13338 $particles/cm^3$ for all ceremonies that were held indoors and the stove was ignited indoors*; 14684 $particles/cm^3$ for all ceremonies that were held indoors and the stove was ignited indoors* and then put outdoors for some minutes; 9193 $particles/cm^3$ for all ceremonies that were held indoors and the stove was ignited outdoors. The concentration of $PN_{0.5}$ is statistically higher when the stove is ignited indoors compared with when the stove is ignited outdoors (P = 0,018). Examples of how mass- and number concentration varied with time, from two sites can be seen in *Figure 8* and *Figure 9*.

[2]Indoor* = Ceremonies there the stove is ignited indoors, then put outdoors for some minutes, to then be brought indoors again

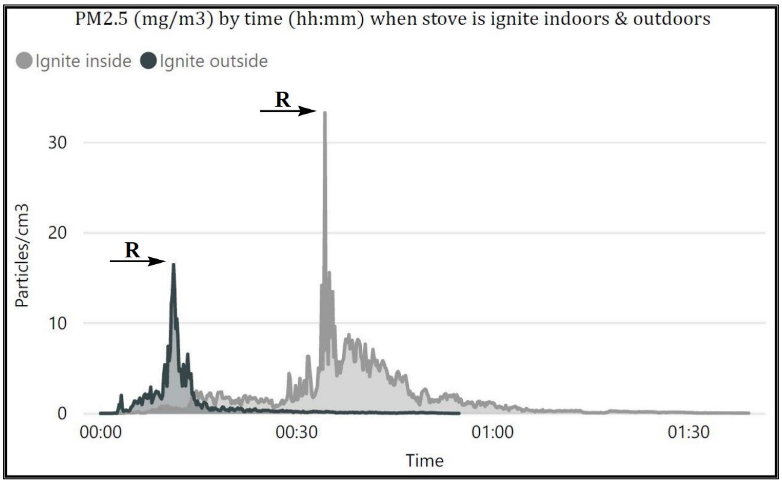

Figure 8: Measurements from site 27 and 22, as seen in the figure both the concentrations of air pollution reached a maximum. "R" indicates the peak concentration from the roasting process. After the roasting process, concentration quickly declines for the ceremony held outdoors compared with indoors.

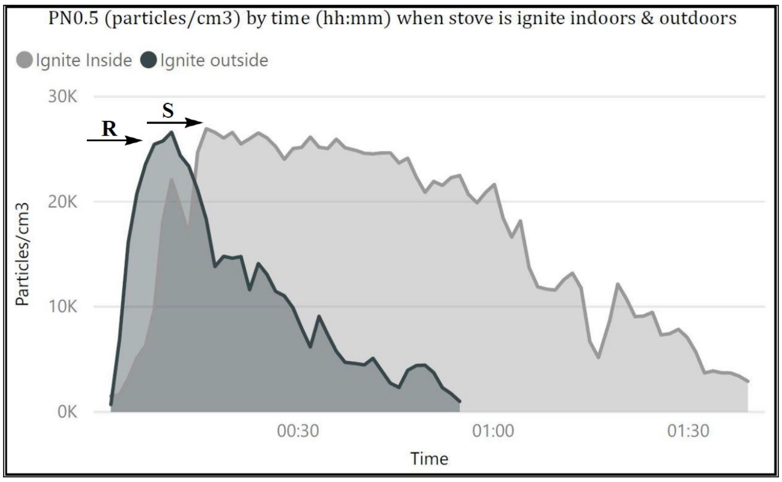

Figure 9: Measurements from site 27 and 22, as seen in the figure both the concentrations of air pollution reached a maximum. "S" indicates the peak concentration from the ignition, "R" indicates the peak concentration from the roasting process. After the roasting process, concentration quickly declines for the ceremony held outdoors compared with indoors.

Concentration comparison, incense

Table 3: Total $PM_{2.5}$ levels (mg/m^3) and total $PN_{0.5}$ (particle number/cm^3) during coffee ceremonies with- and without incense, measured indoors of the homes, when the stove is ignited outdoors.

Incense	*n*	MEAN $PM_{2.5}$ (mg/m^3)	MEAN $PN_{0.5}$ (particles/cm^3)
Yes	7; 2	1.73 ± 1.29	14169 ± 1941
No	9; 5	0.60 ± 0.37	9193 ± 1370

As seen in *Table 3*, the geometric mean concentration of $PM_{2.5}$ was 1.73 mg/m^3 for all ceremonies that were held indoors, when the stove was ignited outdoors and incense was used; 0.60 mg/m^3 for all ceremonies that were held indoors, when the stove was ignited outdoors and no incense was used. Particle concentrations were 65 % decreased when no incense was used compared to ceremonies using incense ($P = 0.014$). The geometric mean concentration of $PN_{0.5}$ was: 14169 particles/cm^3 for all ceremonies that were held indoors, when the stove was ignited outdoors and incense was used; 9193 particles/cm^3 for all ceremonies that were held indoors, when the stove was ignited outdoors and no incense was used. Particle concentrations were 40 % decreased, when no incense was used compared to ceremonies using incense ($P = 0.011$). Examples of how mass- and number concentration varied with time, from two sites can be seen in *Figure 10* and *Figure 11*.

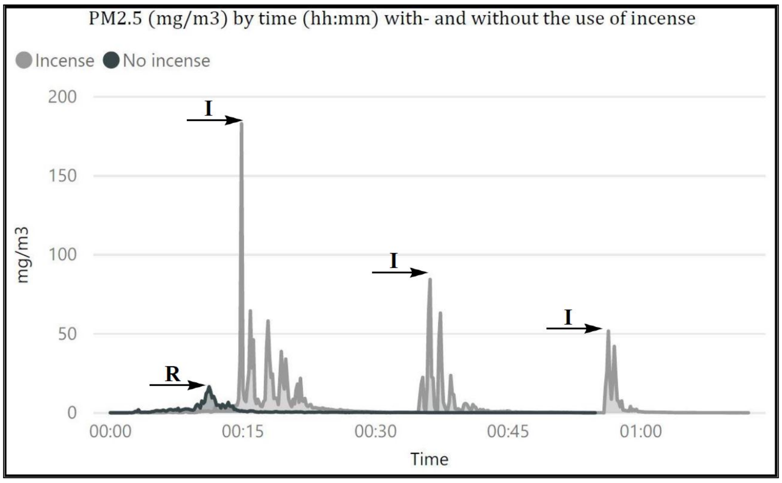

Figure 10: Measurements from site 7 and 22, as seen in the figure both the concentrations of air pollution reached a maximum. ”R” indicates the peak concentration from the roasting process, ”I” indicates the peak concentration from the use of incense.

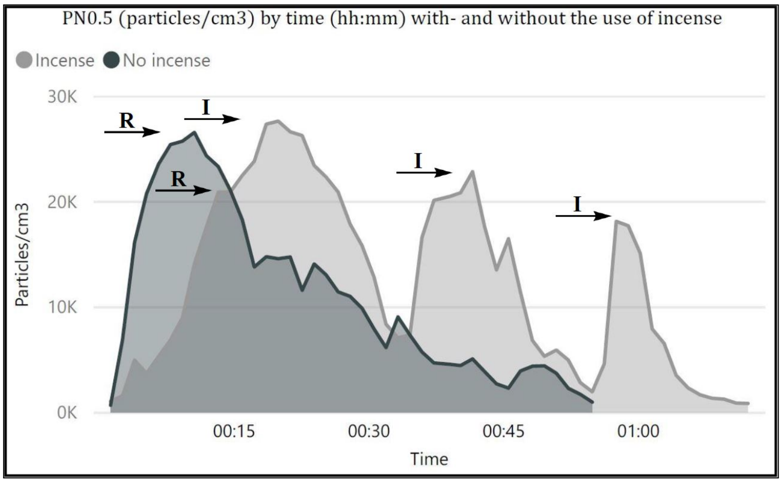

Figure 11: Measurements from site 7 and 22, as seen in the figure both the concentrations of air pollution reached a maximum. ”R” indicates the peak concentration from the roasting process, ”I” indicates the peak concentration from the use of incense.

Concentration comparison, mass of coffee and charcoal

Table 4: $PM_{2.5}$ concentration (mg/m^3), mass of raw coffee beans (g) and of charcoal (g) used used during coffee ceremonies without incense, measured indoors of the homes, when the stove is ignited outdoors.

Site	MEAN $PM_{2.5}$ (mg/m^3)	Coffee (g)	Charcoal (g)
1	0.11	60.2	233.0
3	0.84	55.9	225.1
6	0.49	128.3	197.3
8	0.50	73.4	129.5
10	0.88	36.1	36.2
15	0.38	72.8	64.8
20	1.36	30.3	330.0

As seen in *Table 4*, $PM_{2.5}$ levels were not altered, neither by the mass of coffee roasted (P = 0,197) nor charcoal used as fuel (P= 0.437) during coffee ceremonies.

Mean and 24-h mean exposure of $PM_{2.5}$

Table 5: time (min), $PM_{2.5}$ (mg/m^3) and total $\mu g/m^3$ $PM_{2.5}$ (24h mean).

Site	t (min)	MEAN $PM_{2.5}$ (mg/m^3)	MEAN 24h ($\mu g/m^3$)
1	54	0.11	4.1
2	90	3.51	219.2
3	98	0.84	57.2
4	54	0.83	30.9
5	116	0.66	53.1
6	115	0.49	39.0
7	71	4.51	225.6
8	77	0.50	26.5
10	35	0.88	21.4
11	28	1.03	20.0
12	99	0.37	25.3
13	82	1.85	105.3
14	101	1.44	100.7
15	74	0.38	19.6
16	104	1.89	137.6
17	100	3.27	224.5
18	99	0.72	48.3
19	62	1.10	47.5
20	67	1.36	63.2
21	91	0.89	55.9
22	67	0.91	34.7
24	103	2.02	88.4
26	76	0.53	27.8
27	106	1.60	109.9
28	90	0.93	59.0

As seen in *Table 5*, $PM_{2.5}$ levels ranged from 0.11 to 4.51 mg/m^3. PM2.5 concentrations from 22 houses exceeded the 25 $\mu g/m^3$ 24-h mean exposure limit set by WHO, just during the ceremonies alone (range: 4.1- 225.6).

6.2 Polycyclic aromatic hydrocarbons

Concentration comparison, location of ignition

Table 6: Total airborne PAH levels (ng/m^3) during coffee ceremonies without incense, measured indoors of the homes, when the stove is ignited indoors and outdoors.

PAH	MEAN PAH ignite indoors (ng/m^3)	MEAN PAH ignite outdoors (ng/m^3)
N	8535.3 ± 2292.5 (*n* = 3)	1929.8 ± 2671.0 (*n* = 9)
Acy	566.1 ± 530.6 (*n* = 3)	85.4 ± 98.5 (*n* = 9)
Ace	66.7 ± 12.3 (*n* = 3)	12.2 ± 12.9 (*n* = 9)
F	407.3 ± 72.7 (*n* = 3)	49.5 ± 123.1 (*n* = 9)
P	782.3 ± 135.3 (*n* = 3)	143.6 ± 235.6 (*n* = 9)
Ant	156.0 ± 22.0 (*n* = 3)	18.5 ± 44.3 (*n* = 9)
Fl	9.3 ± 20.1 (*n* = 3)	2.7 ± 15.5 (*n* = 9)
Pyr	12.2 ± 17.2 (*n* = 3)	2.6 ± 15.9 (*n* = 9)
BaAnt	2.8 ± 1.7 (*n* = 3)	0.5 ± 0.6 (*n* = 9)
Chr	3.1 ± 1.8 (*n* = 3)	0.6 ± 1.0 (*n* = 9)
BbFl	12.4 ± 8.5 (*n* = 3)	1.0 ± 1.4 (*n* = 9)
BkFl	2.3 ± 1.8 (*n* = 3)	0.3 ± 0.5 (*n* = 9)
BaPyr	16.3 ± 10.6 (*n* = 3)	0.9 ± 1.5 (*n* = 9)
IPyr	15.5 ± 6.5 (*n* = 3)	1.7 ± 3.0 (*n* = 9)
DBahAnt	1.3 ± 0.5 (*n* = 3)	0.1 ± 0.4 (*n* = 9)
BghPer	16.1 ± 4.8 (*n* = 3)	2.7 ± 2.7 (*n* = 9)

As seen in *Table 6*, the geometric mean concentration of airborne PAHs was decreased by 71 - 92 %, when the stove was ignited outdoors (n=3) compared with when the stove is ignited indoors (n = 9). The difference in concentration of N (P = 0.009), Acy (P = 0.013), Ace (P < 0.001), F (P = 0.003), P (P = 0.004), Ant (P = 0.002), BaAnt (P = 0.007), Chr (P = 0.033), BbFl (P = 0.002), BkFl (P = 0.008), BaPyr (P = 0.001), Ipyr (P = 0.001), DBahAnt (P = 0.003) and BghiPer (P < 0.001) was significant, but not Fl (P = 0.180) and Pyr (P = 0.248).

Concentration comparison, incense

Table 7: Total PAH levels (ng/m^3) during coffee ceremonies with- and without incense, measured indoors of the homes, when the stove is ignited outdoors.

PAH	MEAN PAH incense (ng/m^3)	MEAN PAH no incense (ng/m^3)
N	2868.4 ± 1392.4 (*n* = 7)	1929.8 ± 2671.0 (*n* = 9)
Acy	112.0 ± 54.9 (*n* = 7)	85.4 ± 98.5 (*n* = 9)
Ace	19.8 ± 11.4 (*n* = 7)	12.2 ± 12.9 (*n* = 9)
F	84.6 ± 49.9 (*n* = 7)	49.5 ± 123.1 (*n* = 9)
P	204.8 ± 147.1 (*n* = 7)	143.6 ± 235.6 (*n* = 9)
Ant	25.7 ± 23.5 (*n* = 7)	18.5 ± 44.3 (*n* = 9)
Fl	3.9 ± 12.5 (*n* = 7)	2.7 ± 15.5 (*n* = 9)
Pyr	4.1 ± 131 (*n* = 7)	2.6 ± 15.9 (*n* = 9)
BaAnt	1.2 ± 6.2 (*n* = 7)	0.5 ± 0.6 (*n* = 9)
Chr	1.9 ± 17.2 (*n* = 7)	0.6 ± 1.0 (*n* = 9)
BbFl	5.0 ± 8.7 (*n* = 7)	1.0 ± 1.4 (*n* = 9)
BkFl	1.2 ± 3.0 (*n* = 7)	0.3 ± 0.5 (*n* = 9)
BaPyr	5.4 ± 10.0 (*n* = 7)	0.9 ± 1.5 (*n* = 9)
IPyr	4.4 ± 3.8 (*n* = 7)	1.7 ± 3.0 (*n* = 9)
DBahAnt	0.5 ± 0.6 (*n* = 7)	0.1 ± 0.4 (*n* = 9)
BghPer	5.0 ± 2.3 (*n* = 7)	2.7 ± 2.7 (*n* = 9)

As seen in *Table 7*, the geometric mean concentration of airborne PAHs was decreased by 24-92 %, when no incense was used compared to ceremonies using incense. The difference in concentration of BbFl (P = 0.033) and BaPyr (P = 0.024) was significant, and N (P = 0.736), Acy (P = 0.977), Ace (P = 0.310), F (P = 0.957), P (P = 0.803), Ant (P = 0.959), Fl (P = 0.873), Pyr (P = 0.805), BaAnt (P = 0.103), Chr (P = 0.156), BkFl (P = 0.083), Ipyr (P = 0.244), DBahAnt (P = 0.131) and BghiPer (P = 0.202) was not significant.

Table 8 and 9: PAH (ng/m^3), mass of raw coffee beans (g) and charcoal (g) used used during coffee ceremonies without incense, measured indoors of the homes, when the stove is ignited outdoors.

Site	N (ng/m^3)	Acy (ng/m^3)	Ace (ng/m^3)	F (ng/m^3)	P (ng/m^3)	Ant (ng/m^3)	Fl (ng/m^3)	Pyr (ng/m^3)	BaAnt (ng/m^3)	Chr (ng/m^3)	BbFl (ng/m^3)
1	2288,0	36.6	6.8	32.4	160.8	20.4	1.9	2.5	1.6	2.2	3.5
3	1432.5	23.2	3.2	11.0	88.5	7.7	<LOD	<LOD	0.6	0.9	1.6
6	2909.8	130.9	15.6	62.4	165.1	27.5	11.8	11.2	0.4	0.5	1.9
8	1040.0	167.6	9.6	43.0	101.7	13.5	1.7	1.5	0.9	1.3	2.6
10	729.0	48.9	11.5	21.2	66.5	5.8	<LOD	<LOD	0.1	<LOD	<LOD
15	883.7	30.9	7.6	15.1	47.9	5.2	1.2	1.5	1.2	1.7	2.6
20	9626.5	204.2	39.5	351.4	814.2	143.0	51.2	52.9	1.6	3.3	0.2

Site	BkFl (ng/m^3)	BaPyr (ng/m^3)	IPyr (ng/m^3)	DBahAnt (ng/m^3)	BghiPer (ng/m^3)	Coffee (g)	Charcoal (g)
1	1.6	1.5	3.1	<LOD	4.0	60.2	233.0
3	0.3	1.6	1.0	0.1	2.0	56.0	225.1
6	0.4	2.2	3.4	<LOD	3.0	128.3	197.3
8	0.9	2.1	5.6	0.5	5.2	73.4	129.5
10	<LOD	<LOD	<LOD	<LOD	0.6	36.1	36.2
15	1.1	1.0	1.0	<LOD	1.6	72.8	64.8
20	0.6	0.2	9.5	1.2	9.2	30.3	330.0

As seen in *Table 8* and *Table 9* the only PAHs that were altered by the mass of coffee roasted during the ceremonies was BaPyr ($P = 0.031$). N ($P = 0.035$) and BghiPer ($P = 0.048$) were the only PAHs that were altered by the mass of coffee roasted during the ceremonies.

6.3 Survey

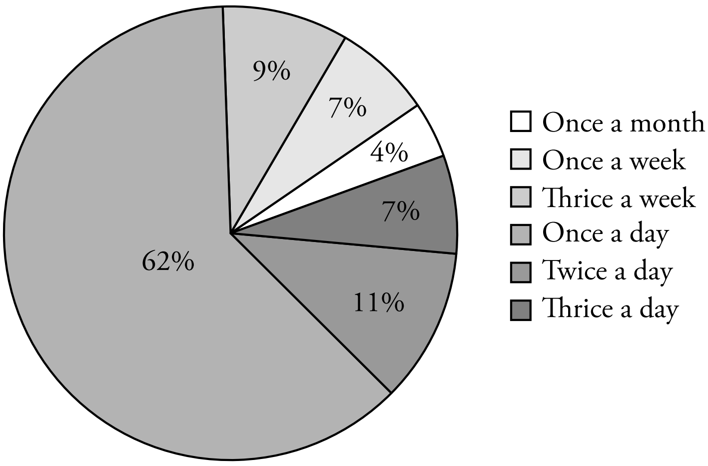

Figure 12: How often the Ethiopian women perform a coffee ceremony.

As seen in *Figure 12*, an majority of the women, 62 % (n = 28) perform one coffee ceremony on a daily basis, followed by 11 % (n = 5) twice a day, 9 % (n = 4) thrice a week, 7 % (n = 3) thrice a day, 7 % (n = 3) once a week, and 4 % (n = 2) once a week.

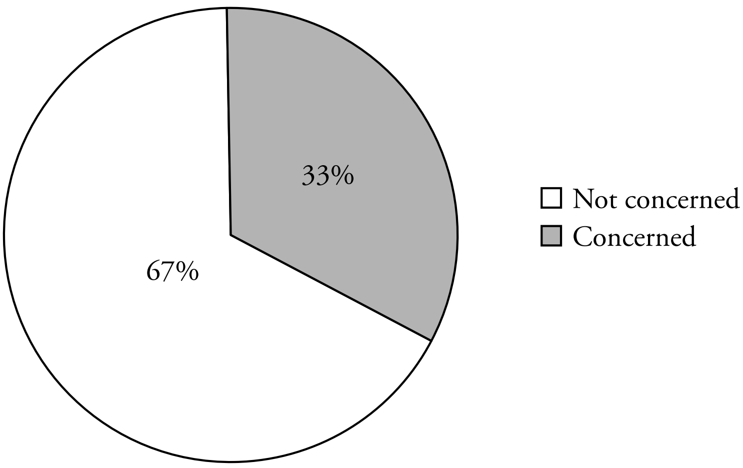

Figure 13: Concerns about the smoke from the coffee ceremony.

As seen in *Figure 13*, two thirds, 67 % (n = 30) of the women answered that they are not concerned to the question "Are you concerned about the smoke from the coffee ceremony?".

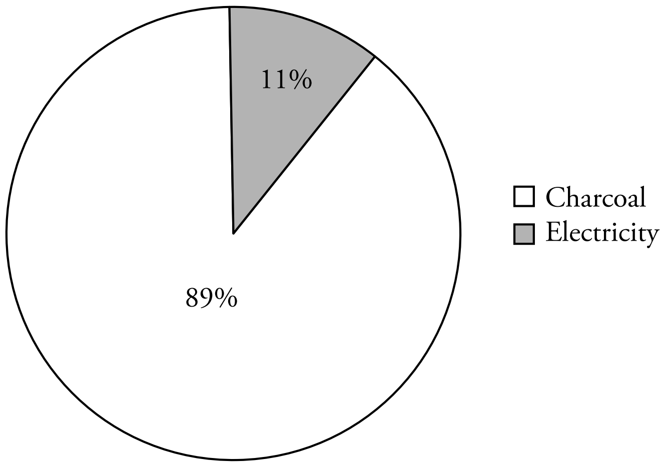

Figure 14: Fuel preference/usage for coffee ceremony.

As seen in *Figure 14*, an majority, 89 % (n = 40) of the women use/prefers charcoal for the coffee ceremony, 11 % (n = 5) use/prefers electricity.

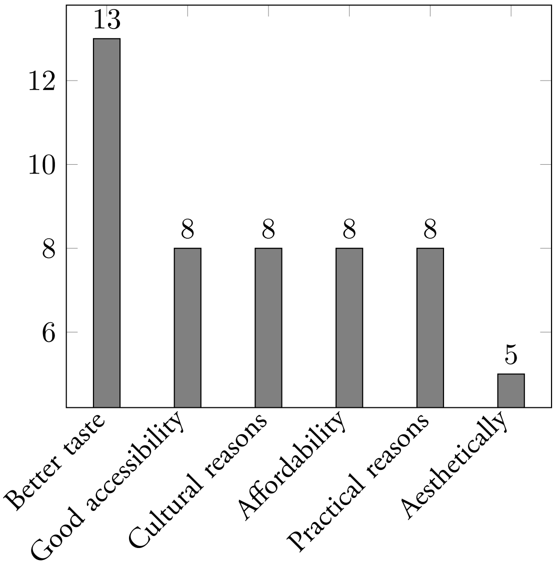

Figure 15: Reasons for choosing charcoal as fuel for coffee preparation.

As seen in *Figure 15*, most women (n = 13) stated that they use charcoal, since it gives a better taste to the coffee, other reasons for using charcoal was: (n = 8) it is cheap, (n = 8) good accessibility, (n = 8) cultural reasons/normal to use, (n = 8) practical reasons, and (n = 5) because it is aesthetically appealing/beautiful (note that some persons gave multiple answers). Reasons for using electricity: (n = 3) it is quick to use.

7 Discussion

Decreasing the concentrations of indoor air pollution is important for reducing the risk of health effects like cancer, cardiovascular diseases, respiratory infections, and lower birth weight of children. Previous studies have mostly been focusing on the health effects of the smoke of fossil fuels (Naeher et al., 2007).

The data from the measurements of this study are therefore important, for better understanding the exposure of indoor air pollution. This is especially crucial for sub-Saharan Africa where 20 % of the total premature deaths in the world are caused every year by indoor air pollution (World Bank, 2011). In Ethiopia, women are an exposed group since they spend a lot of time indoors cooking and preparing coffee among other things, without any adequate ventilation in the homes (Pennise et al., 2009). In this study, most participants were chosen among a cohort of 2000 women in Adama, who are participating in health related studies regarding tuberculosis and preeclampsia in the town, this selection may have affected the result. It would therefore be of interest to study ceremonies from other participant e.g from rural areas of Ethiopia, or more participants in general outside the cohort.

Particle concentration

The geometric mean concentration of $PM_{2.5}$ for all the measured ceremonies held indoors was 0.98 mg/m^3 (range: 0.21 - 1.44 mg/m^3), the variation in concentrations can be described by the location of ignition and the choice of using incense or not. Measurements conducted by Keil et al. (2010) that reported a geometric mean concentration of PM_4 of 1.03 mg/m^3 (range: <0.72 to 2.40 mg/m^3). Although the result from this study reports concentration in $PM_{2.5}$, the results can still be considered to be in line with the study from Keil et al. (2010) since an majority of particles emitted during combustion of biomass has an aerodynamic diameter smaller than 1 µm (Tiwari et al., 2014), meaning that the different particle fractions ($PM_{2.5}$ and PM_4) would probably not play any significant role in these cases. As mentioned earlier, the measurements was not done in the womens breathing zone during the time of ignition, for the ceremonies held indoors and there the stove was ignited outdoors, this will of course affect the result but probably not to a any large scale. The result of $PN_{0.3}$ from the Purple Air monitor could neither be used since these particles reached levels above the limit of the instrument, suggesting that the Purple Air monitor is not the optimal instrument to use for these types of measurements.

Out of the 25 ceremonies held indoors in this study, 21 exceeded the 25 µg/m^3 24-h mean exposure limit of PM2.5 set by WHO, during the ceremonies alone (World Health Organization, 2010). The result clearly indicates that different actions are required regarding the procedure of the ceremonies, to reduce the risk of heath related issues, especially since the ceremonies are preformed on a daily basis.

The trend shows that GM of $PM_{2.5}$ (P = 0.105) seem to increase when the stove was ignited indoors compared to outdoors, the difference is not significant, probably due to small sample sizes, GM of $PN_{0.5}$ (P = 0.018) and PN_1 (P = 0.024) showed an statistically increase when the stove was ignited indoors compared with outdoors. The difference are due to the ignition phase, which contribute to additional air pollution to the indoor environment, especially $PN_{0.5}$. GM of $PM_{2.5}$ (P = 0.014) and $PN_{0.5}$ (P = 0.011) was statistically higher during ceremonies with incense compared with ceremonies without, this can as well be explain by that incense contribute to additional air pollution, which may includes more particles with an aerodynamic diameter larger than 0.5µm, compared with the air pollution emitted from ignition or roasting, however, this cannot be determined with certainty due to a small sample size. More measurements are therefore reacquired. The variations of concentration (range: 0.66 - 4.51 mg/m^3) during the coffee ceremonies when incense is used can partly be described by the fact that different incense was used between ceremonies and those can have different types of additives. The high concentrations, partially contributed by the use of incense, involves an increased risk of cancer. Some studies, however, have not found any connection between lung cancer and incense burning, suggesting that particle concentration depends on the type of incense (Jetter et al., 2002). Further research are essential to better understand which characteristics of the incense that can be derived to cancer. Since the use of incense increases PM and PAH, it would also be of interest to investigate if additives of $CaCO_3$ to the incense used in Ethiopia would decrease the concentrations similar to experiments conducted by Yang et al. (2012).

Polycyclic aromatic hydrocarbons

As stated by World Health Organization. (2010) no threshold for PAHs can be determined and all indoor exposures to these are considered relevant to health. It is difficult to say at which concentrations the PAHs might affect human health, more research are therefore required to better understand the health effects of breathing in these pollutants. The data can, however, still indicate that igniting the stove inside contributing to the highest levels of PAHs and therefore affecting most the women's health. The results show that the airborne concentration of most PAHs was higher when the stove was ignited indoors compared to outdoors, concentrations ranging from 11108 ng/m^3 (N) to 0.042 ng/m^3 (BaAnt) indoors. The concentration of BbFl and BaPyr were increased when incense was used during the ceremonies. The PAHs N and BghiPer could be linked to increasing the mass of charcoal used during the coffee ceremonies. BaPyr (P = 0.031) was the only PAH increases with an increasing mass of coffee that's roasted during the ceremonies. The increasing levels of PAH are problematic, especially for BaPyr which is carcinogenic (World Health Organization, 2010) the highest concentration found in this study was 33.13 ng/m^3, this result further demonstrate the importance of tackle the issue with indoor air pollution from the coffee ceremonies. It would as well be of interest to measure the CO, NOx and soot concentrations during the coffee ceremonies since these also are emitted during combustion om biomass and have a harmful effect on the health.

Survey

One third of the women expressed that they were concerned about the smoke, this number varies a bit from the result presented by Keil et al. (2010) which showed that half of the participating women expressed concern over their exposures from the coffee ceremonies. The result may be affected by the number of participants in each study, suggesting that the concerns about the smoke during coffee ceremonies can be a bit lower than reported by Keil et al. (2010) in urban areas. The respondent's attitudes towards using other fuels than charcoal for the coffee ceremonies were almost completely of no interests. The proportion of women using charcoal in this study was 89 %, the reasons to use charcoal reported to be: the better taste of the coffee, lower price of the fuel, higher accessibility, cultural/normal, practical reasons, and esthetical appealing/beautiful to use.

Reasons for using electricity was that it was quicker to use. Similar preferences have also been reported in studies by Keil et al. (2010) and Alem et al. (2010). This result can, therefore, confirm results from previous studies. Reporting biases in the answers from the survey are possible in this study, previous studies have shown that respondents who attend face-to-face interviews are more likely to give

" *... more socially desirable responding and lower accuracy than computer-administered questionnaires or paper-and-pencil questionnaires*" (p.885) (Podsakoff, MacKenzie, Lee, & Podsakoff, 2003). As mentioned earlier it would also be of interest to study ceremonies from other participant outside the cohort, to reduce further potential bias.

8 Conclusion

The data has shown that particle concentration ($PM_{2.5}$ and $PN_{0.5}$) and PAHs increase when stoves are ignited indoors. The use of incense further increases the amount of particles and PAHs. BaPyr increased with the mass of coffee beans roasted, N and BghiPer increased with the mass of charcoal. Based on the results of this study, it is strongly suggested to ignite stoves outdoors and use less incense. The high concentrations of $PM_{2.5}$, $PN_{0.5}$ and BaPyr might be hazardous when preparing coffee daily. Therefore further investigations are needed to achieve more knowledge about the other PAHs as well as other chemical constituents and their health effects. The results from this study might help policy makers to develop informative guidelines on the possible health effects of the coffee ceremony, while preserving the cultural aspect of the ceremony. As Tefera et al. (2016) discuss, raising awareness about the harmful particles, to the public is important for improving the indoor environment.

Acknowledgments

First I would like to thank my supervisor Christina Isaxon of the Department of Design Sciences, Ergonomics and Aerosol Technology at Lund University; Ebba Malmqvist of the Department of Laboratory Medicine, Division of Occupational and Environmental Medicine at Lund University; Axel Eriksson of the Department of Design Sciences, Ergonomics and Aerosol Technology at Lund University and Asmamaw Abera Kebede of Ethiopia Institute of Water Resource, Water and Public Health at Addis Ababa University, for their commitment in this thesis and for making the field study in Ethiopia feasible. I also would like to thank Tseganesh Mitiku Mekonnen which has been with me during all the visits to the women homes, and translated all conversation between Amharic and English. I would like to grant my gratitude to Bizuayehu Jembere and Eyuel Asemahegn Bogale for their help with finding the participating women in this study. I also want to acknowledge Annette Krais and Bo Strandberg of the Department of Laboratory Medicine, Division of Occupational and Environmental Medicine at Lund University, for their time and help with the laboratory parts of this thesis. Finally I would like to give my thanks to Armauer Hansen Research Institute, which made it possible to conduct this study in Adama, Ethiopia.

This thesis was possible to conduct thanks to the scholarship Minor Field Studies, founded by Styrelsen for internationellt utvecklingssamarbete (Sida), and a travel grant from Stiftelsen ÅForsk.

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Appendix

Appendix I

Table 10: Answers from survey in random order.

Are you concerned about the smoke from the coffee ceremony?	What are your thoughts on using other fuels than charcoal for the coffee ceremony?
I am not concerned.	I only use charcoal since it gives the coffee a good taste and it is aesthetically appealing.
I am not concerned.	I use charcoal since it is cheap.
I am a little bit concerned, I know the smoke has some effect.	I only use charcoal since it is cultural gives a better taste. It is also aesthetically appealing and easy to handle.
I am not concerned.	I only use charcoal since it gives a good taste to the coffee.
I am concerned, I can feel a headache due to the smoke.	I only use charcoal since it is cheap and easy to handle.
I am not concerned.	I use charcoal since it is normal to use.
I am concerned.	I only use charcoal since it is accessible.
I am not concerned.	I usually use charcoal since it is normal to use.
I am not concerned, since I ignite outside.	I only use charcoal since it is aesthetically appealing.
I am not concerned, since I do the ceremony outside.	I only use charcoal, I have not tried other options.
I am a little bit concerned.	I only use charcoal, it is cheap and I don't have access to electricity.
I am not concerned.	I only use charcoal, since I only have experience from that.
I am not concerned.	I usually use charcoal, since it is easy to handle.
I am not concerned	I usually use charcoal since it is cheap, and the electricity is not reliable.
I am not concerned	I prefer to use electricity since it is quicker to use.
I know that it is harmful, that why I usually ignite outside.	I usually use charcoal, because of cultural reasons.
I am not concerned.	I prefer to use charcoal.
I am not concerned, but I ignite outdoors so the house won't get warm	Sometimes I use electricity, but I prefer charcoal since it is a hobby for me.I am also used to it from my childhood.
I am not concerned.	I prefer to use electricity, but I use charcoal if guest are around.
I am not concerned, I ignite outside.	I prefer to use charcoal since it is easy to access and are comfortable to use.
I am not concerned, I like the smell of the coffee.	I always use charcoal since it makes the coffee taste better due to a slower heating.
I have some concerns.	I prefer to use charcoal.
I am not concerned.	I usually use charcoal since it is normal to use.
I am concerned, my family have an allergy problem.	I always use electric system.
I am not concerned.	I usually use charcoal since it is cultural and beautiful.

Are you concerned about the smoke from the coffee ceremony?	What are your thoughts on using other fuels than charcoal for the coffee ceremony?
I am not concerned, I like the smell of the coffee.	I usually use charcoal since it makes coffee taste better, electricity makes the coffee boil to fast.
I am a little bit concerned, therefore I ignite outdoors.	I usually use charcoal since the coffee ceremony is not good without it, the charcoal is also aesthetically pleasing.
I have some concern about the smoke from the charcoal.	I usually use charcoal, since it is cheap and accessible. Sometimes I use wood as well.
I am not concerned.	I prefer to charcoal since the electricity is not reliable.
I am not concerned.	I prefer to use electricity since it is quicker to use.
I am not concerned.	I prefer to use charcoal since it gives a better taste.
I am concerned about the kids exposure to the smoke.	I prefer to use electricity since it is quicker to use.
I am a bit concerned, but I like the smell of the coffee-	I only use charcoal, it is cheap and I don't have access to electricity.
I am concerned, I know it can have some effects.	I prefer charcoal for practical reasons.
I am not concerned.	I prefer to use charcoal since it is cheap and accessible.
I am concerned.	I prefer to use charcoal because of cultural reasons and since it is accessible.
I am not concerned.	I prefer to use electricity since it is quicker to use.
I am not concerned.	I only use charcoal since it makes the coffee taste better.
I am not concerned.	I usually use charcoal since it is easy to use and gives a better taste to the coffee. I use an electric system sometimes.
I am not concerned.	I prefer to use charcoal since it is cheap.
I am not concerned.	I use charcoal since it makes the coffee taste better.
I am a bit concerned, therefore I shake the coffee beans outdoors.	I prefer to use charcoal it since it is cultural and makes the coffee tastier.
I am not concerned.	I use charcoal since it makes the coffee taste better.
I am not concerned.	I usually use charcoal since it is comfortable to use. I use an electric system sometimes.
I am not concerned.	I use charcoal since it gives the coffee a better taste. it is also aesthetically appealing for the ceremony and easy to handle.

Table 10 show the answers from the respondents who took part in the study.

Appendix II

Table 11: PM2.5 concentration (mg/m^3) from all measurements.

Site	Location	Ignition	Incense	MEAN $PM_{2.5}$ (mg/m^3)
1	Indoor	Outdoor	No	0.11
2	Indoor	Outdoor	Yes	3.51
3	Indoor	Outdoor	No	0.84
4	Indoor	Outdoor	Yes	0.83
5	Indoor	Outdoor	Yes	0.66
6	Indoor	Outdoor	No	0.49
7	Indoor	Outdoor	Yes	4.51
8	Indoor	Outdoor	No	0.50
9	Outdoor	Outdoor	No	0.21
10	Indoor	Outdoor	No	0.88
11	Indoor	Indoor	No	1.03
12	Indoor	Indoor*	No	0.37
13	Indoor	Outdoor	Yes	1.85
14	Indoor	Outdoor	Yes	1.44
15	Indoor	Outdoor	No	0.38
16	Indoor	Indoor*	No	1.89
17	Indoor	Indoor*	Yes	3.27
18	Indoor	Indoor*	Yes	0.72
19	Indoor	Outdoor	No	1.10
20	Indoor	Outdoor	No	1.36
21	Indoor	Indoor	Yes	0.89
22	Indoor	Outdoor	No	0.91
23	Outdoor	Outdoor	Yes	0.31
24	Indoor	Outdoor	Yes	2.02
25	Outdoor	Outdoor	Yes	1.44
26	Indoor	Indoor*	Yes	0.53
27	Indoor	Indoor	No	1.60
28	Indoor	Indoor	No	0.93

Table 11 shows the concentration of $PM_{2.5}$ from all the ceremonies.

Table 12: $PN_{0.5}$, PN_1, $PN_{2.5}$, PN_5 and PN_{10} (ng/m^3) from all measurements.

Site	Location	Ignition	Incense	MEAN $PN_{0.5}$ (ng/m^3)	MEAN PN_1 (ng/m^3)	MEAN $PN_{2.5}$ (ng/m^3)	MEAN PN_5 (ng/m^3)	MEAN PN_{10} (ng/m^3)
6	Indoor	Outdoor	No	8949	2298	340	98	24
7	Indoor	Outdoor	Yes	12361	6648	1889	711	209
8	Indoor	Outdoor	No	6963	2252	354	99	23
9	Outdoor	Outdoor	No	2281	742	129	40	10
16	Indoor	Indoor*	No	14684	5438	809	240	62
17	Indoor	Indoor*	Yes	13111	5903	1263	423	114
18	Indoor	Indoor*	Yes	10546	3663	521	130	28
19	Indoor	Outdoor	No	10368	3104	472	146	39
20	Indoor	Outdoor	No	9295	3153	645	201	50
21	Indoor	Indoor	Yes	11329	3950	630	185	44
22	Indoor	Outdoor	No	10933	3038	523	163	43
23	Outdoor	Outdoor	Yes	4354	1351	261	84	25
24	Indoor	Outdoor	Yes	16243	8349	1503	422	100
25	Outdoor	Outdoor	Yes	8647	3621	775	257	69
26	Indoor	Indoor*	Yes	10748	3322	414	102	21
27	Indoor	Indoor	No	16474	5681	866	257	64
28	Indoor	Indoor	No	12714	3772	479	130	31

Table 12 shows the concentration of $PN_{0.5}$, PN_1, $PN_{2.5}$, PN_5 and PN_{10} from all the ceremonies.

Appendix III

Table 13: Mass (mg) of filter before and after sampling.

Site	Filter weight before (mg)	Filter weight after (mg)	Difference
7	135.18	134.63	0.55
8	111.86	112.00	0.14
16	124.74	124.75	0.01
17	110.08	110.61	0.53
18	111.22	111.49	0.27
19	125.79	125.91	0.12
20	112.75	112.91	0.16
21	109.29	109.52	0.23
22	109.34	109.57	0.23
23	128.19	128.41	0.22
24	112.89	113.26	0.37
25	116.32	116.51	0.19
26	130.08	130.24	0.16
27	119.87	120.26	0.39
28	112.1	112.3	0.20
Blank 1	125.45	125.45	0.00
Blank 2	117.44	117.44	0.00
Blank 3	117.51	117.52	0.01
Blank 4	109.08	109.17	0.09
Blank 5	119.60	119.61	0.01

As seen in *Table 13* the difference in weight of the filter ranged from 0.01 to 0.55 mg, before compared with after the sampling.

Table 14: Results from gas chromatography mass spectrometry analysis, with SIM mode.

PAH	m/z	Retention time (min)
N	128	12.11
N (IS)	136	12.06
Acy	152	15.92
Acy (IS)	160	15.89
Ace	154	16.34
Ace (IS)	164	16.27
F	166	17.87
F (IS)	176	17.78
P	178	22.27
P (IS)	188	22.15
Ant	178	22.58
Ant (IS)	188	22.47
Fl	202	30.21
Fl (IS)	212	30.08
Pyr	202	31.73
Pyr (IS)	212	31.61
BaAnt	228	40.99
BaAnt (IS)	240	40.81
Chr	228	41.20
Chr (IS)	240	41.02
BbFl	252	48.71
BbFl (IS)	264	48.53
BkFl	252	48.87
BkFl (IS)	264	48.75
BaPyr	252	50.71
BaPyr (IS)	264	50.57
IPyr	276	57.46
IPyr (IS)	288	57.34
DBahAnt	276	57.81
DBahAnt (IS)	288	57.61
BghPer	276	58.80
BghPer (IS)	288	58.66

As seen in *Table 14* retention time from the gas chromatography mass spectrometry analysis ranged from N (IS) 12.06 min to BghPer (IS) 58.66 min.

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