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CARBON MONOXIDE INTOXICATION FROM DOMESTIC FUEL-BURNING FURNCACES AND APPLIANCES

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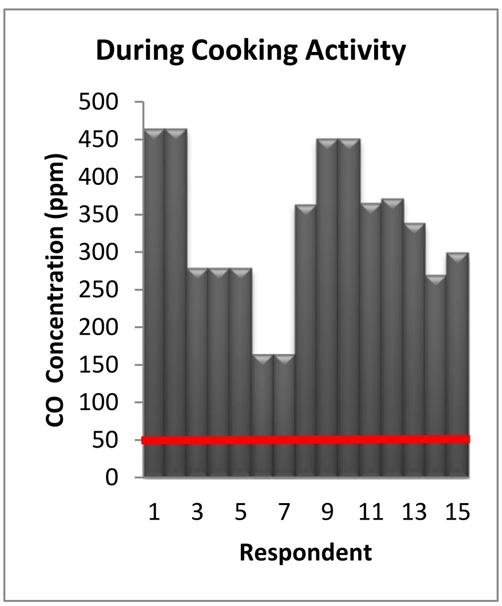
Graphical abstract



Abstract

The aim of this research paper is to determine if dwellers of rural areas who cook using fuel-burning furnaces and appliances such as woods, charcoal and natural gas are exposed to carbon monoxide (CO) intoxication and to measure the extent of CO intoxication on dwellers resulting from their cooking activities. The data on CO concentration and health problems for this research study were gathered through the means of observation and interview. Samplings were also carried out to measure the CO level at the selected areas, which were identified based on the criteria of the research. These two steps were done concurrently. The measurements of CO in the houses at Kampong Orang Asli Simpang Arang, Gelang Patah residential were taken outside of the houses, inside the kitchen areas before switching the stove on, after the stove was switched on, during the cooking process and after the cooking was completed. The study shows that the dwellers of rural areas who cook using woods as cooking fuels are found to be exposed to CO intoxication and the factors that influence the health risks are duration of cooking activities per meal, frequency of cooking activities, the absence of proper ventilation as well as the amount of CO concentration released during cooking activities. The measured CO concentration from woods during the experiment was in the range of 150 to 500 ppm. Through CO samplings of charcoal and natural gas as control experiments, it is also found that both sources did not contribute to any serious health effects to the people using them as cooking fuels. Meanwhile, the average CO toxicant produced from burning woods was the highest and this indicates that the CO level from woods is the most risky one among the other domestic fuels commonly used.

Keywords: IAQ, carbon monoxide, CO, concentration, ppm, charcoal, woods, natural gas

Abstrak

Tujuan kertas kajian ini adalah untuk menentukan sama ada penduduk kawasan luar bandar yang memasak menggunakan relau dan peralatan seperti kayu, arang dan gas semulajadi sebagai bahan api adalah lebih terdedah kepada penghasilan gas karbon monoksida (CO) dan untuk mengukur sejauh mana CO mabuk pada penghuni terhasil daripada aktiviti memasak mereka. Data mengenai CO tumpuan dan masalah kesihatan untuk kajian penyelidikan ini telah dikumpul melalui cara pemerhatian dan temu bual. Sampel juga telah dijalankan untuk mengukur tahap CO pada kawasan terpilih, yang telah dikenal pasti berdasarkan kriteria penyelidikan. Kedua-dua langkah telah dilakukan serentak. Pengukuran CO di rumah-rumah di Kampung Orang Asli Simpang Arang, Gelang Patah kediaman telah diambil di luar rumah, di dalam kawasan dapur sebelum beralih dapur, setelah dapur telah dihidupkan, semasa proses memasak dan selepas memasak itu selesai. Kajian ini menunjukkan bahawa penduduk kawasan luar bandar yang memasak menggunakan kayu sebagai bahan api memasak didapati terdedah kepada CO mabuk dan faktor-faktor yang mempengaruhi risiko kesihatan jangka masa aktiviti memasak setiap hidangan, kekerapan aktiviti memasak, ketiadaan pengudaraan yang betul serta jumlah kepekatan CO yang dikeluarkan semasa aktiviti memasak. Keputusan kepekatan CO yang didapati diukur semasa eksperimen adalah dalam lingkungan 150 hingga 500 ppm. Melalui data penghasilan gas CO daripada arang dan gas asli, ia mendapati bahawa kedua-dua bahan pembakaran untuk masakan itu tidak menyumbang kepada kesan kesihatan yang serius kepada orang yang menggunakan mereka sebagai sumber bahan api. Sementara itu, purata kepekatan CO dihasilkan daripada pembakaran kayu api adalah yang tertinggi dan ini menunjukkan bahawa kayu api adalah salah satu sumber yang paling berisiko di kalangan bahan api.

Kata kunci: IAQ, karbon monoksida, CO, kepekatan, ppm, arang, kayu, gas asli

1.0 INTRODUCTION

Carbon monoxide (CO) poisoning is a leading cause of unintentional poisoning deaths. CO is an odorless, colorless gas that usually remains undetectable until the exposure results in injury or death. CO poisoning is preventable, but those with CO poisoning often overlook the symptoms (e.g., headache, nausea, dizziness, or confusion), and undetected exposure can be fatal. In comparison with other pollutants such as particulate matter (PM), the short term exposure usually may cause adverse health effects to respiratory and cardiovascular morbidity, and hence increase in hospital admissions; meanwhile the long-term exposure risks include mortality from cardiovascular and respiratory diseases such as lung cancer [1, 2]. On the other hand, the exposure to CO inhalation often leads to the displacement of oxygen in the blood and deprives the heart, brain and other vital organs of oxygen. A previous study by Lin *et al*. found that the emission of CO readily combines with hemoglobin to form carboxyhemoglobin, hence reduces the blood's capacity to transport oxygen. The bad impacts to health of the exposure to CO when inhaled in low concentrations are headaches, dizziness, weakness and nausea, while the inhalation of high concentrations of CO can usually be detrimental [3].

According to the World Health Organization, traditional biomass and coal stoves used by almost half of the world's population cause about 2 million deaths annually, in which over 1 million deaths are due to chronic obstructive pulmonary disease and almost another million deaths are from pneumonia among children under the age of 5 [4].

These deaths are largely avoidable with cleaner and more energy-efficient stoves. Although many studies have conventionally focused on outdoor air, it is now apparent that elevated air pollutant concentrations are also common in households. Numerous studies have reported elevated indoor levels of nitrogen oxides and carbon monoxide in homes with unvented gas appliances. The evidence that homes with gas cooking stoves have high levels of nitrogen oxides and carbon monoxide has been revealed by studies done by Melia *et al*. and Wade *et al.* [4].

Bhattacharya *et al*., [5] found that the incomplete combustion of biomass can emit high levels of PM and carbon monoxide and these emitted pollutants may contribute to adverse health effects. Moreover, high concentration of indoor air pollution is produced when activities such as cooking are performed inside home. This may cause high risk to the health of the occupants since those gases e.g. carbon monoxide tends to accumulate in frequently occupied spaces such as in the kitchen.

A study by Smith [5] highlighted that women and children are especially vulnerable to the dangers of indoor air pollution because of their age-related susceptibility and also due to the time they spent indoors.

As stated by the World Health Organization, indoor smoke contributed to around 4% of the overall disease burden in 2004, making it the most popular reason of death and illness after childhood underweight, unsafe sex, lack of safe water and sanitation and suboptimal breastfeeding, in low income countries [4].

Balakrishnan *et al*. [5] stated in his study that indoor air pollution resulting from combustion of biomass fuels is now recognized as a major contributor to the global burden of diseases. By far the greatest threat of indoor pollution still occurs in the developing countries, where many people, mostly in rural areas, continue to rely on traditional fuels for cooking and heating [5].

Because of the lengths of time that they spend in close proximity to cooking fires, people who normally cook for the household (women in most cases) are usually the most vulnerable group.

Sapra *et al*. [6], from their study found that when burned indoors in the absence of adequate ventilation, the incomplete combustion of biomass fuels release significant amount of smoke that contains numerous pollutants such as carbon monoxide (CO), particulate matter and other organic compounds into the living environment [6].

Traditional biomass and coal stoves used by almost half of the world's population cause about 2 million deaths annually, including over 1 million deaths from chronic obstructive pulmonary disease and almost another million deaths from pneumonia in children under the age of 5.

These deaths are largely avoidable with cleaner and more energy-efficient stoves. Approximately three billion rural dwellers worldwide get their household energy from solid fuels such as wood, coal, charcoal, dung and crop wastes that are burned in open fires and traditional stoves for cooking and heating activities.

2.0 METHODOLOGY

2.1 Identifying Respondent

In this study, fifteen respondents were selected among the residents of Kampong Orang Asli Simpang Arang, Gelang Patah for the observations and interview sessions, as well as for personal CO sampling from cooking activities that use woods as fuels. House-to-house survey was conducted in Kampong Orang Asli Simpang Arang, Gelang Patah and each house that use woods as cooking fuels is selected at random as the sampling group.

2.2 Observation and Interview Sessions

This is to collect data on the self-reported health status of each respondent. The surveyed respondents were asked a series of recall questions on symptoms experienced in the last 30 days, such as coughs or flu, cough with blood, etc. and also the severity of the symptoms. Besides, the interview sessions were conducted to obtain information regarding the respondents' age, health problems and how long they have been inflicted with the disease (if they are suffering from any disease), frequency of cooking per day, duration of time per cooking session, and symptoms of having respiratory problems.

The interview sessions involved female respondents because in the case of carbon monoxide pollutants from cooking fuels, exposure levels are usually much higher among female, who tend to do most of the cooking. It is also due to majority of the female cook with firewood. Similar approach was also used in a study done in India, in which the subjects were also female.

On top of that, as age increases, the risk to CO exposure becomes more prevalent. Higher exposure risk is also associated with higher age groups. This in other words means that the more vulnerable groups were senior citizens and adults [8].

2.3 CO Sampling from Cooking Activities using Woods as Fuel Source

After the 15 respondents were interviewed, CO pollutant is measured from cooking activities that use woods as fuel source. Both of the data from interview sessions and CO samplings from these 15 respondents' houses are tabulated as in Table 1. For measuring the carbon monoxide (CO) exposure level among the respondents exposed to this pollutant, TPI 1010 Indoor Air Quality (IAQ) device was first calibrated in order to obtain an accurate reading.

Firstly, the measurement of the CO concentration outside of the house was obtained as a basis to be compared with the air quality inside the house. Next, the CO concentration level within the cooking area was taken right before the stove was switched on. Then the stove was switched on in order to once again obtain the measurement of CO, this was then followed by taking both of the measurement during the cooking process and after completing the cooking.

For consistency in taking the readings, it is ensured that the distance from the CO meter (both the height and horizontal distances) to the stove/ fire was approximately the same for all the households. The readings were taken repeatedly 3 times at each sampling process to enhance the accuracy and the readings of the CO concentration. For measuring the CO level, firstly the device was turned on outside of the area to be tested. This was to ensure that the unit of TPI 1010 IAQ was in fresh air; that is with the absence of carbon monoxide prior to turning the device on as it will allow the sensor of the device to be set to zero properly. This step was done since the device is capable to measure CO level specifically at a source, and not suitable to be used to measure CO level in an ambient environment.

The CO concentration was measured in parts per million (ppm). The sensor of the CO device was placed perpendicular to the supply of air flow, nearest to the cooking area. Once the measurement and reading have been stabilized, the main key at the center of the device was pressed and a 30 seconds countdown began. Within that time, the TPI 1010 IAQ performed a self-diagnosis and the CO sensor was set to zero. Once the countdown ended, the readings of the following parameters including CO2, CO, temperature, and humidity were captured and displayed on the LCD screen.

Finally, the TPI 1010 IAQ was turned off. Every data was recorded to be analysed [9]. The same procedure was repeated for the other houses of the selected respondents. In addition to wood fuel source, the CO concentrations from other fuel sources e.g. charcoal and natural gas were also recorded using the same method. Readings of CO composition in the vicinity of homes using these "sources other than wood" were also recorded as data for the control experiments.

2.4 CO Sampling from Cooking Activities using Natural Gas and Charcoal Fuel Source

For dwellers of homes in which the cooking activities use other fuel sources such as charcoal and natural gas, the experiments involving these other sources are conducted as control experiments in order to compare the CO intoxication that dwellers are exposed to burning woods. Since this step requires the measurement of CO concentration only, there is no interview sessions and observation involved. The results of CO concentration from wood combustion, including natural gas and charcoal that act as control experiments are tabulated in Table 2, summarized as the average or mean CO concentration value.

3.0 RESULTS AND DISCUSSIONS

3.1 Data from Interview Sessions and Carbon Monoxide Samplings from Wood Combustion

Table 1 shows the findings obtained from the interview sessions and experiments involving readings of carbon monoxide concentration released from burning woods taken in each house. The interview sessions are conducted to find out the age, gender, health symptoms, the frequency of cooking per day, the duration per cooking, and the cooking area of each respondent.

Table 1 Data from the Interviews and Carbon Monoxide Samplings from Wood Combustion for all Respondents in Kampong Orang Asli Simpang Arang, Gelang Patah

Respondent	**House**	**Age**	**Health Symptoms (and duration of illness, if they are suffering from any)**	**Frequency of Cooking Per Day**	**Duration per Cooking (hour)**	**Cooking Area**	**Carbon Monoxide Concentration (ppm)**			
							Outside of the House	Inside the House / Around Cooking Area (Before Turning on Cook Stove)	During Cooking Activity	After Cooking
1	1	51	Headache, Nausea, Dizziness, Asthma (few years), Eye irritation, Breathing Difficulty (one week)	Thrice	Never put out fire during day	Indoor	1	2	464	4
2	1	21	Chest Pain (one week)	Thrice	Never put out fire during day	Indoor	1	2	464	4
3	2	52	Poor Vision, Eye Irritation, Headache, Cough, Nasal Congestion, Nausea, Dizziness (years)	Once	1 Hour	Outdoor	1	2	278	2

4	2	56 Died	Respiratory Problem, Lung Infection, Death	Once	2 Hours	Outdoor	1	2	278	2
5	3	14	Headache (Every time)	Once	2 Hours	Outdoor	1	2	278	2
6	4	22	None	Thrice	1 Hour	Outdoor	1	2	164	2
7	4	6 m	Flu-like Symptoms (1 week)	Thrice	1 Hour	Outdoor	1	2	164	2
8	5	26	Headache, Nausea, Dizziness, Nasal Congestion (3 days)	Twice	1 Hour	Indoor	0	1	363	2
9	6	65	Headache, Nausea, Dizziness, Breathing Difficulty, Eye Irritation (2 weeks)	Thrice	1.5 Hours	Indoor	1	4	451	6
10	6	25	Breathing Difficulty, Nausea, Vomit, Nasal Congestion, Eye Irritation, Cough (2 weeks)	Thrice	1.5 Hours	Indoor	1	4	451	6
11	7	33	Headache, Nausea, Dizziness, Cough, Eye Irritation (2 days)	Once	3 Hours	Indoor	1	3	365	5
12	8	25	Asthma (since birth), Breathing Difficulty, Nasal Congestion (1 week)	Once	3 Hours	Indoor	1	3	371	5
13	9	71	Asthma (since birth), Breathing Difficulty, Nasal Congestion, Headache (1 week)	Once	1 Hour	Indoor	0	2	338	4
14	10	50	Headache, Dizziness (Every time)	Twice	1 Hour	Outdoor	0	1	269	2
15	11	48	Headache (Every time)	Twice	1 Hour	Outdoor	0	1	299	2

As stated in Section 2.3, Table 1includes the data taken from the interview sessions and CO sampling from cooking activities that use woods as fuel source. The table lists the duration of cooking activity of each respondent. The duration of preparing meals of each family is between 1 to 3 hours. There was also a case where the owner of the house has never put out the fire from the burning woods and just left the fire burning the whole day. The respondent explained that it was easier to just leave the fire turned on continuously inside the house as it was difficult to put the woods back on fire once it is put out. Besides that, the smoke emitted from the burning woods also acted as mosquito repellent as mosquitoes appear to be found frequently and in large numbers around the village.

With regard to the variable 'duration of exposure to CO' on the health risks of the respondents, it appears that the duration of the exposure to CO does have an influence on the health risks of the people involved, especially if the cooking is done indoors. This is because the respondents still suffer from various adverse health effects due to the fact that they are already exposed to more than 50 ppm CO level which is stated as harmful and dangerous to health despite the excessive duration of cooking activities.

All the respondents were selected among females as the males were all out working and earning money when the experiments were conducted during the day. This was also due to the initial objective of the survey to select female respondents as they spend most of their time cooking and staying in the house. Female respondents were selected also for the reason that the relevant literature indicates that females are more susceptible to illnesses resulting from carbon monoxide intoxication.

Compared to men, women and children are at a greater risk because of the longer duration spent at home [8]. Women, who are the ones doing most of the cooking, and also young children, who stay inside the homes and are usually carried on their mother's back or lap while cooking are highly exposed to smoke that comes from cooking fuels. The female respondents who participated in this study were between the ages of 6 months to 14 and 71 years. Respondent 7 was the youngest respondent who was only aged 6 months who stayed together with his mother inside the same house, and was found to be suffering from flu-like symptoms. Young children are susceptible to negative effects of air pollution exposures, which may damage their pulmonary defence mechanisms and expose them further to risks of getting acute respiratory infections due to their immature immune systems and rapidly developing lungs [9].

It is important then to ensure that these babies do not develop more chronic diseases as they get older. In children as well as in women, they run the risk of getting the most exposure to such pollutants, and there is increasing evidence linking indoor air pollution (IAP) to increased risk of respiratory tract infections, exacerbations of inflammatory lung conditions, development of chronic obstructive lung disease, cardiac events, stroke, eye disease, tuberculosis, cancer, and hospital admissions [10]. The findings of this study revealed that the incomplete combustion of wood fuels causes negative implications on health such as respiratory diseases, especially among women and children. The findings reveal that every respondent regardless of their age, suffers from adverse health effects i.e. headache, nausea, dizziness, asthma, eye irritation and breathing difficulty. This is in line with the result found previously which indicates that 83.5% patients were diagnosed of having COHb between 5% and 25%, and the other 16.5% suffered from having COHb reading which is more than 25% [11].

Almost all of the respondents, regardless of their age, suffer from health problems due to carbon monoxide intoxication such as headache, dizziness and breathing difficulty. The health symptoms that were always persistent among dwellers who were involved in cooking activities using wood as cooking fuels were gathered initially from a review of the related literature and questions on whether these symptoms were experienced were subsequently asked to these rural dwellers to gauge the health risks of these individuals. The health symptoms that were on the list include headache, nausea, dizziness, asthma, eye irritation, breathing difficulty, poor vision, cough, nasal congestion, respiratory problem, lung infection, death, flu-like symptoms, and vomiting.

Table 1 obviously indicates that the rural dwellers who cook using wood as cooking fuels are exposed to carbon monoxide intoxication regardless of whether they conduct their cooking activities indoors or outdoors. The difference between these cooking indoors and outdoors is that the concentration of carbon monoxide pollutant where the cooking is done indoors is more intoxicating to the respondents. This can be seen as cooking that is done indoors produced a carbon monoxide level of between 300 to 500 ppm while cooking outdoors produces a CO level which is in the range of 150 to 299 ppm. Based on the table, it can be seen that in environments that are exceptionally intoxicated with CO, with readings of CO beyond 400 ppm, respondents suffered from serious ailments for prolonged periods of time. They suffered from headaches, nausea, dizziness, asthma, eye irritation, nausea, vomiting, nasal congestion, cough and breathing difficulties and even chest pains which could be fatal, for periods of one to two weeks. The higher the CO concentrations such as that observed in Respondent 1, 2, 9 and 10 (CO concentrations of 464 ppm on Respondents 1 and 2 and 451 ppm on Respondents 9 and 10), the more serious the health risks are, on these individuals. Thus, the higher concentration of the CO, the more hazardous it is for the people affected. This shows that in extremely intoxicated environments, respondents are more likely to suffer from severe diseases, some of which could be fatal, for prolonged periods of one to 2 weeks. It is concluded that more heavily CO intoxicated environments lead to more severe health issues in the dwellers who conduct their cooking activities using woods as cooking fuels, and less intoxicated environments lead to less serious health issues. The more CO intoxicated the environment is, the more prolonged the disease stays with the dwellers, in which case it was observed that the respondents experienced those severe symptoms for one to two weeks. Nine out of fifteen respondents (60%) suffer from headaches, regardless of their age. Respondent 3, who is 14 years old, right through Respondent 13, who is 71 years old, suffer from headaches. In fact, the 14 year-old respondent complains about having headaches all the time. 11 out of 15 respondents ((73.33%) , (i.e. Respondents 1, 2, 3, 4, 7, 8, 9, 10, 11, 12, 13) have diseases relating to respiratory problems such as asthma, breathing difficulties, lung infection, and nasal congestion). The dwellers of rural areas who cook using fuel-burning furnaces and appliances are exposed to carbon monoxide intoxication, and the factors that influence the health risks is the existence of proper ventilation and the CO concentration itself. In conclusion, the findings indicate that 93.33 % (14 out of 15 respondents) suffer from various illnesses due to CO intoxication resulting from their cooking activities that use woods as cooking fuels. The only respondent who did not suffer from any diseases is a 22-year old respondent (Respondent 4) who is probably unaffected because the cooking activities were done outside of her house with proper ventilation. Other reason might be due to her better immunization system in comparison with her baby's weak body system. Children are more vulnerable to be affected by the indoor air pollution as they breathe more air per kilogram of body weight than adults do [12-14].

3.2 CO Concentration of Indoor and Outdoor Cooking Areas

The following table (Table 2) compares the health symptoms suffered by respondents who did their cooking activities using wood fuels indoors and outdoors. This table is summarized from the main table, Table 1, in order to clearly see the comparison between CO readings (ppm), health problems and the existence of proper ventilation (indoor or outdoor cooking area). A comparison of the cooking activities done indoors (Respondents 1, 2, 8, 9, 10, 11, 12, 13) with those done outdoors (Respondents 3, 4, 5, 6, 7, 14, 15) reveal several interesting observations. The data in the table are presented in descending order of CO measurement (in Column 2 of the table). The data are organized this way so that the health effects can be compared with the CO readings to see if there is a link between these 2 factors: CO readings and health effects.

Table 2 Relationship of Indoor/ Outdoor and Health Problems

Respondent	CO Readings (ppm)	Health Problems	Indoor/ Outdoor
1	464	Headache, Nausea, Dizziness, Asthma (few years), Eye irritation, Breathing Difficulty (one week)	Indoor
2	464	Chest Pain (one week)	Indoor
9	451	Headache, Nausea, Dizziness, Breathing Difficulty, Eye Irritation (2 weeks)	Indoor
10	451	Breathing Difficulty, Nausea, Vomit, Nasal Congestion, Eye Irritation, Cough (2 weeks)	Indoor
12	371	Asthma (since birth), Breathing Difficulty, Nasal Congestion (1 week)	Indoor
11	365	Headache, Nausea, Dizziness, Cough, Eye Irritation (2 days)	Indoor
8	363	Headache, Nausea, Dizziness, Nasal Congestion (3 days)	Indoor
13	338	Asthma (since birth), Breathing Difficulty, Nasal Congestion, Headache (1 week)	Indoor
15	299	Headache (Every time)	Outdoor
3	278	Poor Vision, Eye Irritation, Headache, Cough, Nasal Congestion, Nausea, Dizziness (years)	Outdoor
4	278	Respiratory Problem, Lung Infection, Death	Outdoor
5	278	Headache (Every time)	Outdoor
14	269	Headache, Dizziness (Every time)	Outdoor
7	164	Flu-like Symptoms (1 week)	Outdoor
6	164	None	Outdoor

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Almost all of the respondents suffer from health problems due to carbon monoxide intoxication such as headache, dizziness and breathing difficulty. There is only one exception to this observation whereby one respondent, Respondent 6, aged 22 shows no negative health effects despite the CO exposure. This is possibly due to the fact that she was cooking outside of the house where the cooking area is properly ventilated thus producing low carbon monoxide level during cooking which was 164 ppm. This observation on Respondent 6 implies that proper ventilation may help lessen the negative impacts on one's health.

Meanwhile, Respondent 5, a teenager aged 14 constantly suffered from headaches every time she deals with cooking activities that use wood as cooking fuels. Her young age might be the cause for her to be vulnerable and having headache every time she cooks or exposed to the carbon monoxide toxicant. The high CO produced from the outdoor cooking area was 278 ppm which was higher than CO reading at outdoor cooking area of Respondent 6, which was 164 ppm. Respondent 5's cooking area was set on the floor and the cook needs to squat to do the cooking activities, compared to Respondent 6's house, which had a cooking area that needs a person to be standing to cook. In methodology section, it is stated that to simulate the height of a person cooking, the CO readings are taken at a point of 1 meter away from the fire and at a height of 1 meter [15]. However, a person who squats tends to have her body and face closer to the combustion area, having them to be exposed to greater amount of CO toxicants. This might be the reason why the CO readings from the wood fuels of Respondent 5 and 6 are different even though they have the same outdoor cooking area setting.

In the case of Respondent 6, her young age prevents her from getting these ailments, at least headache and dizziness, and might be due to the fact that she was the youngest and healthy adult compared to the other vulnerable older female adults. The setting of cooking areas is one of the strong determinants that will lead to negative health repercussions even if the individual is young. The oldest respondent aged 71 complained that she has been suffering from breathing difficulty problem, nasal congestion, and headache for the past one week. She also mentioned that she had been having asthma since birth which causes her to be easily affected by the high carbon monoxide level of 338 ppm that was produced from cooking indoors. The respondents who did their cooking activities indoors suffered from more serious diseases than those who did their cooking activities outdoors. When done indoors, the respondents suffered from more life-threatening diseases like asthma, breathing difficulties, chest pain and nasal congestion. They also suffered from poor eye vision as a result of these activities. Those who did their cooking activities outdoors suffered from lighter ailments but nonetheless, they all suffered from at least headaches.

Those who did their cooking activities outdoors suffered from lighter ailments but nonetheless, they all suffered from at least headaches except for Respondents 3 and 4. Respondents 3 and 4 can be considered outliers in this research as they do not display the traits that would normally be displayed by the people in their group, which is those who cooked outdoors. Respondents 3 and 4 reportedly suffered from severe ailments although they did their cooking activities outdoors. This 52-year-old female respondent complained about how her eye irritation problem had led to serious eyes problem where she had issues to work because of poor vision. The single mother's difficulty had caused her to have money problems that eventually led her family to have issues on accessing health care service and cooking appliances or technology.

Respondent 4, (Respondent 3's late husband) is an example of a worst-case scenario as he died due to lung infection, as attested by Respondent 3. He died at the age of 56 in which from the researcher's observations, a link can be found between the circumstances of his death and the carbon monoxide intoxication that appears to be taking place in his house vicinity, as observed during this study. This is corroborated by the evidence given by his wife, Respondent 3, who informed us that they were initially living in another house where the cooking activities using wood as cooking fuels were done inside the house for the past 30 years and have only just moved into their current house where the cooking is now done outdoors [1-3]. Thus, this explains why Respondents 3 and 4 (who did their cooking outdoors as revealed in the interview) were suffering from severe illnesses that resembled those experienced by the respondents who did their cooking activities indoors. If these 2 outliers (Respondents 3 and 4) are excluded from the data, as is sometimes done in research, then the findings of this aspect of the study would be that individuals would suffer from more severe diseases if the cooking activities were done indoors as opposed to outdoors.

The health risks are greater for people who cook indoors than outdoors. Thus, it makes a difference as to whether cooking is done indoors or outdoors. Proper advice can be given to these dwellers in these rural places who normally lack knowledge on health issues. Even with proper ventilation, the CO level was still high due to the cooking were done while sitting where the respiratory organs were closely exposed to the smoke produced during wood combustion.

This worst-case scenario shows the serious effects of cooking done indoors, in which fatality occurs in a 56 year-old man. What is also interesting about this observation is that males are no exception and even though the literature says that females are more susceptible to diseases related to respiratory caused by exposure to CO, men can also be affected.

These findings conclude that these dwellers suffered from more severe diseases if the cooking activities were done indoors as opposed to outdoors. Thus, it makes a difference as to whether cooking is done indoors or outdoors. Proper advice can be given to these dwellers in these rural places who normally lack knowledge on health issues. Thus, it can be concluded that cooking indoors or outdoors is a factor that affects health risks among the people affected. This is because there is a proper amount of ventilation when cooking activities are done at the outside of the house (outdoors).

3.4 CO Level among Different Domestic Fuel Sources

As stated in Section 2.4, data of CO concentration measured from wood combustion via cooking activities are calculated in mean value, together with the data of CO from charcoal and natural gas combustion that act as control experiments as to compare the CO concentration among the domestic fuel sources. Table 3 shows the CO level for different sources of domestic fuel, comparing the CO concentration among the three types of cooking fuels which are charcoal, woods and natural gas. The readings of these fuels are taken outside of the house, inside the house or around the cooking area, during cooking activities and after cooking are completed.

Table 3 CO Level among Different Fuel Sources

Types of Cooking Fuels \ CO level (ppm)	Outside the house	Inside the house	While cooking	After cooking is completed
Wood	1	1	408	5
Charcoal	0	1	90	2
Natural Gas	0	0	0	0

3.5 Summary of Findings on CO Exposure from Woods to Cooking Dwellers

Using 50 ppm as the reference, Figure 1 shows that the CO exposure for each respondent exceeds the permissible exposure limit of 50 ppm. This indicates that 100% of the respondents are intoxicated with CO from woods as fuel source. The lowest CO toxicant produced from woods as fuel source during cooking activities is 164 ppm while the highest is 464 ppm. Taking into account the duration of cooking activities, frequency of cooking per day, and the CO exposed to rural dwellers, the results will affect the value of hazard quotient. The higher the number of frequency of cooking, the longer the duration of cooking per meal, and the more the CO toxic produced, indicating worse health risk of each rural dweller who cooks using wood fuels. Figure 2 below shows the correlation between CO concentration (ppm) and health risk, while Figure 3 shows the correlation between duration of cooking activities per meal (min) and health risk.

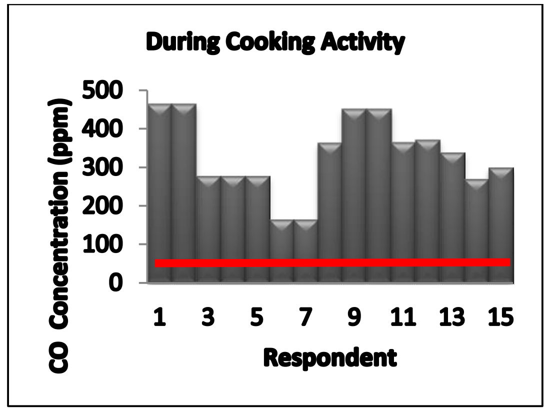

Figure 1 CO (ppm) for each Respondent against 50 ppm Reference during Cooking Activities

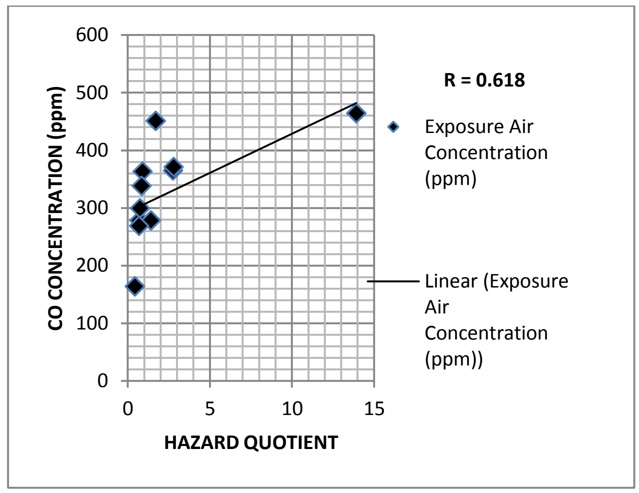

Figure 2 Correlations between CO Concentration (ppm) and Health Risk

Figure 2 shows the correlation between CO toxic exposed to rural dwellers from wood burning source regardless of whether the cooking activities are done indoors or outdoors, and the health risk calculated, is 0.618. The correlation value shows that there is a high correlation between the CO exposed and the health risk that the respondents suffer from, but this parameter gives more serious effect by the effects of duration of exposure. This is because Figure 3 shows the correlation between the length of time spent for cooking activities and health risk is very high which is 0.998, indicating great correlation between duration of cooking and health risk. In conclusion, each respondent suffers from CO intoxication but only around half of them are indicted with health risk. This is mainly due to the duration and frequency of exposure to the CO released from wood combustion.

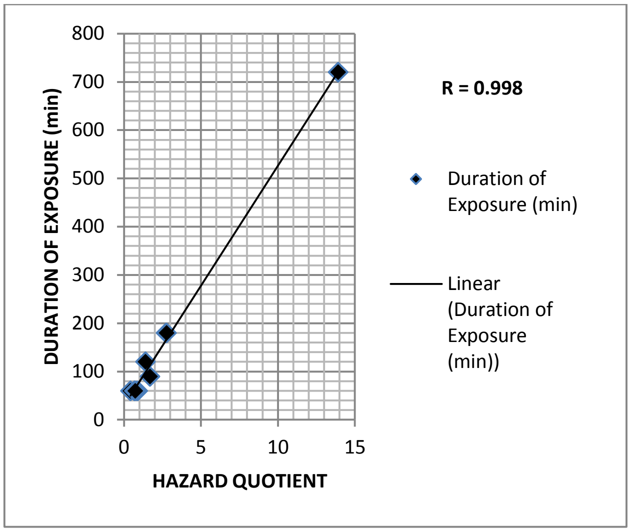

Figure 3 Correlations between Duration of Cooking Activities per Meal (min) and Health Risk

4.0 CONCLUSION

The study shows that 100% of the respondents are intoxicated with CO exposure from wood fuels as they exceed the permissible exposure limit of 50 ppm. The CO concentration range produced from wood combustion as cooking fuels is between 164 and 464 ppm. This findings also found that the higher the number of frequency of cooking, the longer the duration of cooking per meal, and the more the CO toxic produced, indicating worse health risk.

The health risk calculated is 0.618 shows a high correlation between the CO exposure and the health risk, while the correlation between the length of time spent for cooking activities and health risk is 0.998. In conclusion, each respondent suffers from CO intoxication but only around half of them are indicted with health risk due to the duration and frequency of exposure to the CO released.

As a conclusion, since the findings conclude that most of the rural dwellers who cook using traditional fuel sources specifically woods as cooking fuels are exposed to carbon monoxide intoxication, the medical authorities should get involved by educating the dwellers in rural areas of the dangers of these cooking activities and provide support in the use of less hazardous cooking fuel source. In addition, the authorities should also aid in providing incentives of modern cooking appliances in order to protect these dwellers from having various health problems. The results established from this study will hopefully be useful to not only the rural dwellers, but also the authorities who will be responsible in the development of rural areas and the technology they use in cooking activities.

For future research, it is recommended that future researchers who may be interested in this area of study to conduct their studies with more samples of respondents to provide findings that can be better generalized to a larger population. The research study can also be done on other fuel sources to determine their health risks on users of particular fuel sources.

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