Eskom

Air Quality Offsets Project Task Team
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The potential impacts of the Liquefied Petroleum Gas heater use on indoor air quality

REPORT SUMMARY

Unlike outdoor air quality, little attention has been paid to the indoor air quality in South Africa. This, despite numerous suggestions that indoor air pollution levels could be higher than the outdoor levels, especially in developing countries such as South Africa. As a consequence, indoor air pollution is more likely to adversely impact the health of the citizens than the outdoor air pollution, particularly in low-income communities. Although not much research has been conducted regarding the indoor air quality, the few studies undertaken so far present adequate evidence to suggest that indoor air pollution exposure is problematic in many areas in South Africa owing to the extensive use of solid fuels for cooking, space heating and lighting purposes, especially in low-income communities.

At the request of the Air Quality Offsets Project Task Team (AQOTT), a study was carried out to investigate the potential impacts of using Liquefied Petroleum Gas (LPG) heater on indoor air quality. LPG heaters are being considered by Eskom Holdings SOC Limited as one of the interventions in an effort to reduce air pollutant emissions in several low-income communities potentially adversely impacted by emissions from Eskom's coal-fired power stations. These communities have been identified as beneficiaries of the Air Quality Offsets Project that Eskom is implementing in several communities. Eskom seeks to ensure that the interventions to be implemented do not have negative effects on the health of the residents of these communities.

This report presents results of the study carried out to investigate if there are any adverse effects on the air quality as a result of the utilization of LPG heaters in indoor settings. Several parameters were monitored continuously at Eskom Research Testing and Development (RT&D) Department, in a building representative of a typical Reconstruction and Development Programme (RDP) house in South Africa. The results presented here are based on the data collected during the period 26 August - 14 September 2016. The parameters measured include outdoor temperature, indoor temperature, outdoor relative humidity, indoor relative humidity, indoor carbon monoxide (CO), indoor oxides of nitrogen (NOx), indoor ozone (O_3) and indoor particulate matter with an aerodynamic diameter less than 10 microns (PM_{10}). It should be noted that indoor concentration of a given pollutant is a function of its outdoor level, the air exchange rate, the rate at which it is removed by indoor surfaces and the rate at which it is produced or removed by indoor chemistry.

The results show that the outdoor-to-indoor transport significantly contributes to the indoor concentrations of all the pollutants measured in the study. Specifically, the indoor O_3 concentrations are mainly as a result of the outdoor-to-indoor transport. This finding is consistent with results of several indoor air quality studies carried out elsewhere that found that the most important source of indoor O_3 is outdoor-to-indoor transport. In addition, the indoor NO_2 concentrations increased when the heater was turned on, owing to the titration of O_3 to NO_2 by its rapid reaction with NO. The results also show that the LPG heater is a contributor to the indoor CO concentrations as evidenced by the increase in such concentrations whenever the heater was turned on. Although there may be some formation of secondary particulate matter indoors, this was not immediately evident in the results obtained in this study. In fact, most of the peaks in indoor PM_{10} concentrations occurred when the heater was turned off.

South Africa currently does not have indoor air quality standards. However, the Department of Environmental Affairs (DEA) has adopted the National Ambient Air Quality Standards (NAAQS), enforced through the National Environmental Management: Air Quality Act, 2004 (ACT No.39 of 2004). These have been set for the protection of human health. Compared against these standards, the indoor concentrations of all the measured air pollutants remained well within the acceptable levels throughout the study period.

1. METHODOLOGY

The objective of the study was to quantify both the potential impacts of the LPG heater on the indoor air quality as well as the amount of gas required to operate such a heater for a defined period of time. In addition, a questionnaire survey was conducted in order to assess attitudes towards and usage of LPG heaters in South Africa (see Appendix A). A total of 100 people participated in this survey. The respondents are Eskom's RT&D Department employees and some of the attendees of the National Association for Clean Air (NACA) conference that was held in Nelspruit, Mpumalanga during the period 6 - 7 October 2016. It should be noted that most of these respondents are middle-income earners. Therefore, the responses might have been different had the respondents been unemployed or low-income earners. The experiment was carried out in a building that is representative of a typical RDP house without a ceiling in South Africa. This was crucial in light of the fact that the air quality offsets project is mainly focused on low-income communities.

The approach to the study suggested by the AQOTT is detailed below:

- Measure the weight of the gas cylinder before commencing with the experiment.
- Open the gas feed 100% (i.e. ensure that the gas flow from the cylinder is not constrained).
- Turn the gas heater on at one panel setting.
- Take note of the duration of the operation of the gas heater (the heater was operated for a period of 24 hours).
- Measure the weight of the gas cylinder after the experiment.
- Repeat the same approach with two and three panel settings.

Figure 1: Indoor air quality monitoring site at RT&D. (a) Room in which the experiment was undertaken, (b) Analysers used for data collection, (c) The scale used to weigh the gas cylinder before and after each setting and (d) The building in which the experiments were performed.

2. RESULTS

Figure 2 displays indoor and outdoor temperature and relative humidity for the duration of the study. The indoor environment of the study area was often warmer than the outdoor environment as can be seen in the figure. When the heater was turned on, the indoor temperature increased by a certain amount and stayed within the acceptable range, for human thermal comfort, for the duration of the operation of the heater (i.e. from 16°C to 32°C). However, the magnitude of the increase in indoor temperature varied with the number of panels used and as expected, such increase was highest when all three panels were used, while it is lowest when only one panel is used. The relationship between temperature and relative humidity can also be clearly seen in Figure 2b. It is well established that the relative humidity drops as temperature rises. This is evident in both the outdoor and the indoor environments. A strong temporal variation is evident in both indoor temperature and relative humidity, mirroring variations in the outdoor temperature and relative humidity. Furthermore, the indoor relative humidity is generally lower than that in the outdoor environment, which is consistent with the above-mentioned fact that the indoor environment in the study area is often warmer than the outdoors. On a few occasions, both the indoor and outdoor relative humidity dropped below 30% during the study period. This occurred both when the heater was turned on and when it was turned off. It is important to note that the acceptable range for relative humidity is from 30% to 65%, as a combination of high temperature and high relative humidity was found to increase heat stress.

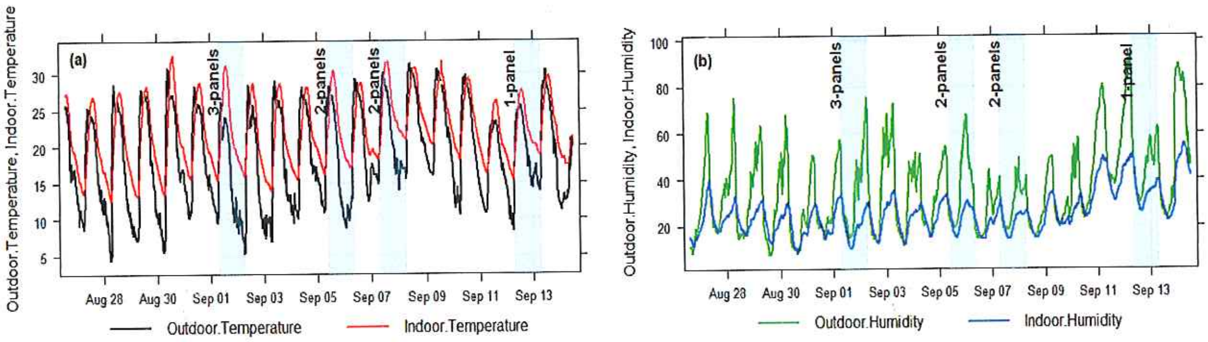


Figure 2: Parameters measured during the LPG heater experiment at Eskom RT&D. (a) 10-minute average outdoor temperature (black line) and indoor temperature (red line) and (b) 10-minute outdoor relative humidity (green line) and indoor relative humidity (blue line).The light blue polygons indicate the time periods when the heater was turned on. Also shown are the number of panels at which the heater was operating. Temperature is in °C and relative humidity is in %.

Figure 3 shows the temporal variation in indoor concentrations of NO, NO_2 and O_3 during the period of the study. It is clear that the LPG heater is a source of NOx as the peaks in the NO_2 concentrations tend to occur when the heater was operating. Such concentrations tend to decrease when the heater was turned off. This rise in NO_2 concentrations is due to the fact that O_3 reacts rapidly with NO to produce NO_2. As a result, significant concentrations of O_3 can only accumulate when little NO is present and vice versa. As can be seen in Figure 3b, the 10-minute average NO_2 concentrations are all below 80 ppb. Therefore, if averaged over hourly intervals, the resulting concentrations would be well within the hourly ambient air quality limit value of 106 ppb. Similarly, if the 10-minute average indoor O_3 concentrations were to be converted into 8-hourly running means, the resulting concentration values would be well within the 8-hourly ambient air quality limit value of 61 ppb. There is no NAAQS for NO.

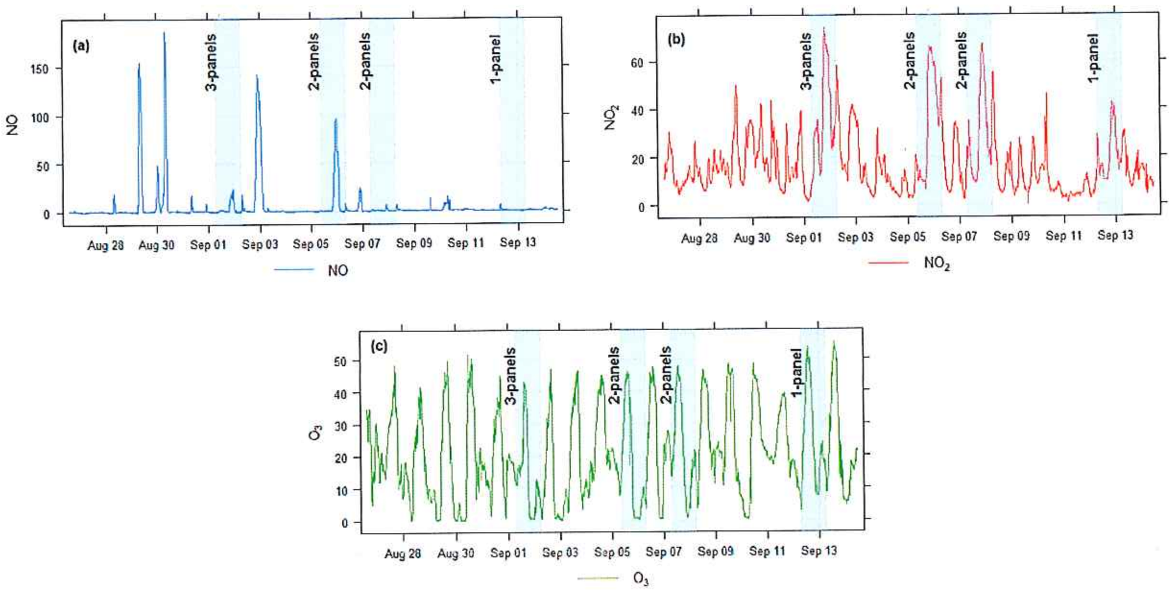


Figure 3: Parameters measured during the LPG heater experiment at Eskom RT&D. (a) 10-minute average indoor NO concentrations (blue line), (b) 10-minute average indoor NO_2 concentrations (red line) and (c) 10-minute average indoor O_3 concentrations (green line). The light blue polygons indicate the time periods when the heater was turned on. Also shown are the number of panels at which the heater was operating. Concentration unit is ppb.

Figure 4 depicts the temporal variation in the indoor concentrations of CO and PM_{10}. As for NOx, it can be seen in the figure that the LPG heater is a source of CO (Figure 4a). The CO concentrations exhibit increases in magnitude in all the periods when the heater was operating. All the other times show lower CO levels. However, the resultant concentrations remain low. With respect to indoor PM_{10} concentrations, most of the peaks occurred either before or after the periods in which the heater was turned on. Therefore, the increase in the concentrations of PM_{10} that occurred occasionally, cannot be attributed to the contributions of the emissions from the heater. The ambient air quality limit value for CO is 26 ppm and the daily limit for PM_{10} is 75 $\mu g.m^{-3}$. If the 10-minute average CO concentrations shown in Figure 4a were to be averaged over hourly intervals, the resulting concentrations would be below the above-mentioned limit value. Similarly, if the 10-minute average PM_{10} concentrations shown in Figure 4b were to be averaged over 24-hourly intervals, the resulting concentrations would be within the aforementioned limit set to protect human health.

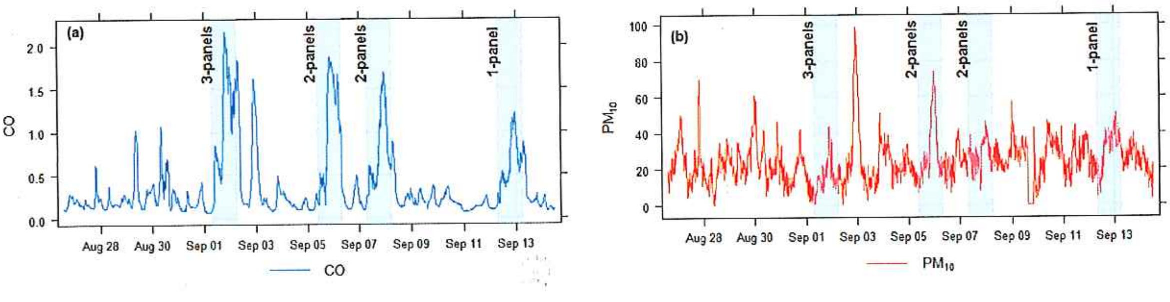
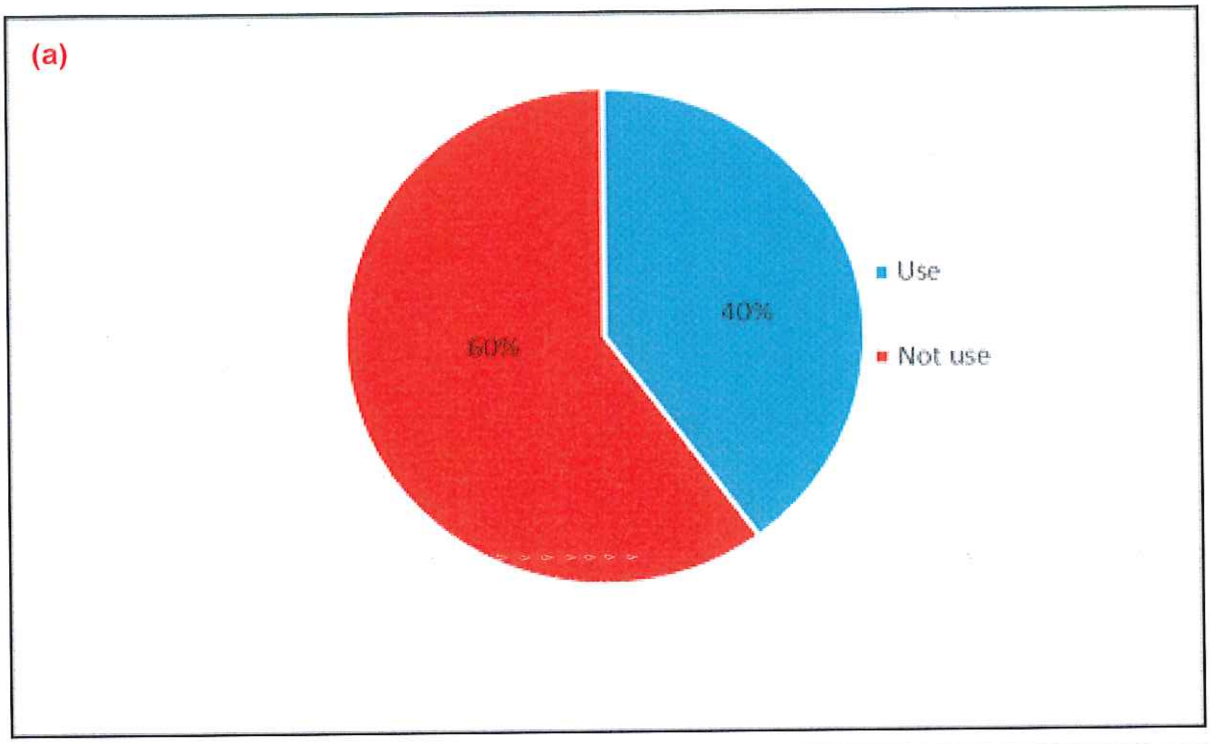


Figure 4: Parameters measured during the LPG heater experiment at Eskom RT&D. (a) 10-minute average indoor CO concentrations (blue line) and (b) 10-minute average indoor PM_{10} concentrations (red line). The light blue polygons indicate the time periods when the heater was turned on. Also shown are the number of panels at which the heater was operating. CO concentration is in ppm and PM_{10} is in $\mu g.m^{-3}$.

Figure 5 shows the number of people who use LPG heaters versus those who do not, as well as the reasons for using or not using such heaters. It can be seen in the figure that 60% of the questionnaire respondents do not use LPG heaters. Respondents provided a variety of reasons for not using LPG heaters. Some of the issues cited were the safety as well as high cost of operating such heaters. The majority of the respondents make use of electric heaters, whereas the rest did not use heaters at all, preferring to use such things as blankets to keep warm.



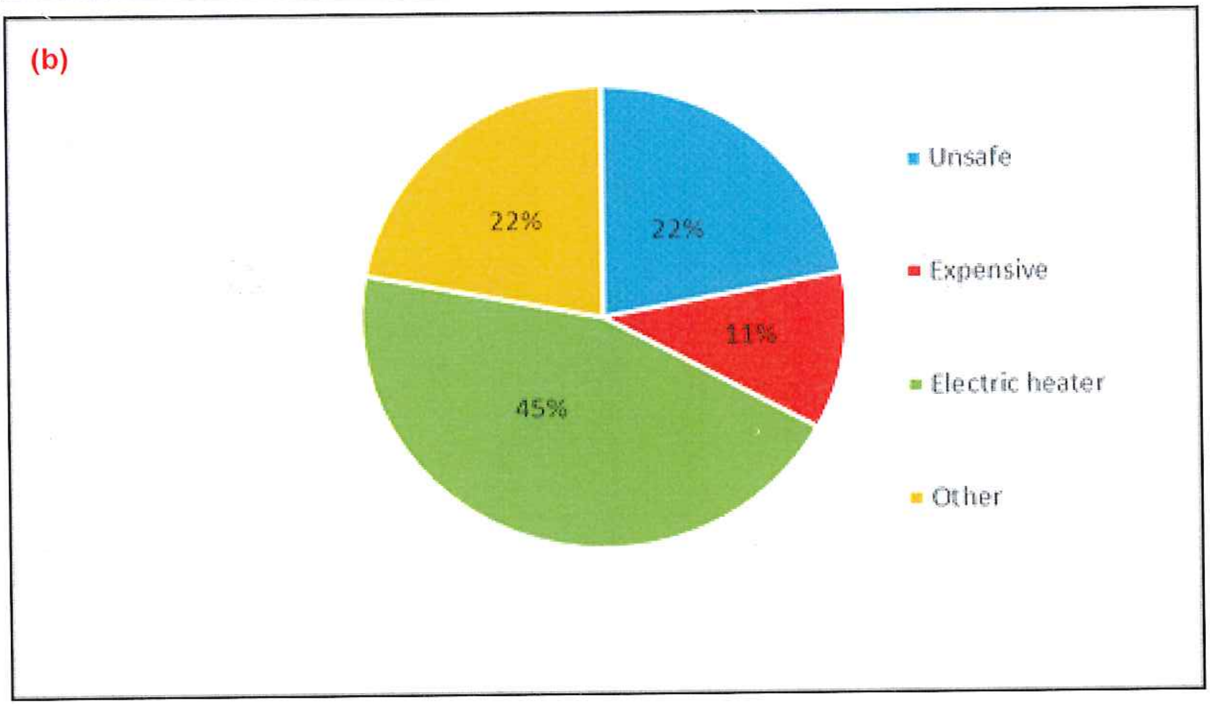


Figure 5: (a) Percentage of respondents that use and those that do not use LPG heaters (n=100). (b) Reasons provided by the respondents for not using LPG heaters.

Figure 6 shows the different comfort levels felt by different users when the LPG heater is turned on together with the amount of gas utilized to operate the heater at three different panel settings. The survey participants rated the comfort they feel when operating the heater at different levels, with most rating it at 4, closely followed by 3. The rating is a subjective measure, whereby a rating of 1 represents least comfortable while 5 represents most comfortable. None of the participants rated the comfort level at 1. As expected, the amount of the gas required to operate the heater depends on the panel setting option used and the duration of time for which the heater is operated. As can be seen in the figure, to operate the heater over a 24-hour period at 3-panel setting requires at least 5.5 kg of the LPG, while 2- and 1-panel settings require at least 2.53 kg and 1.94 kg, respectively.

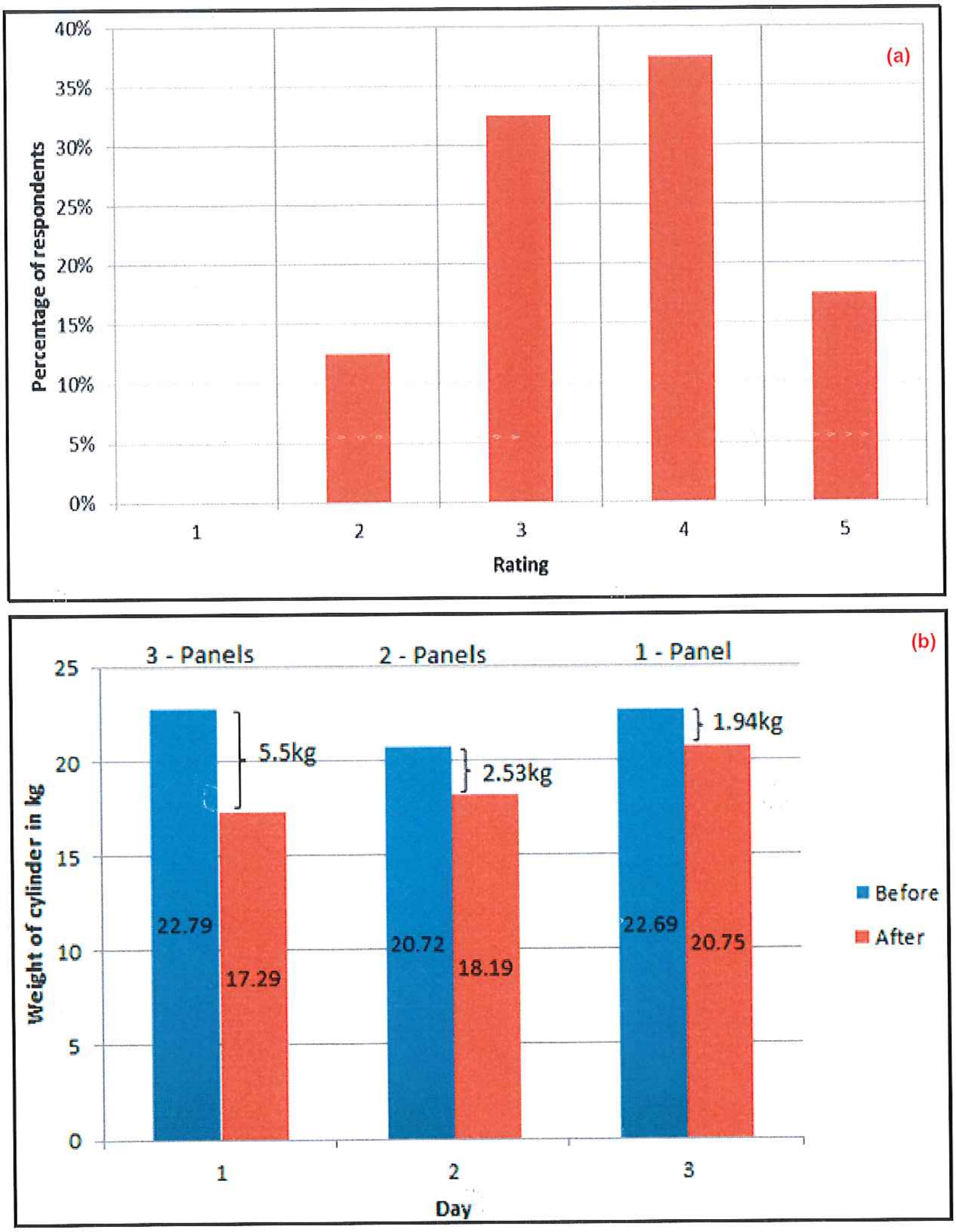
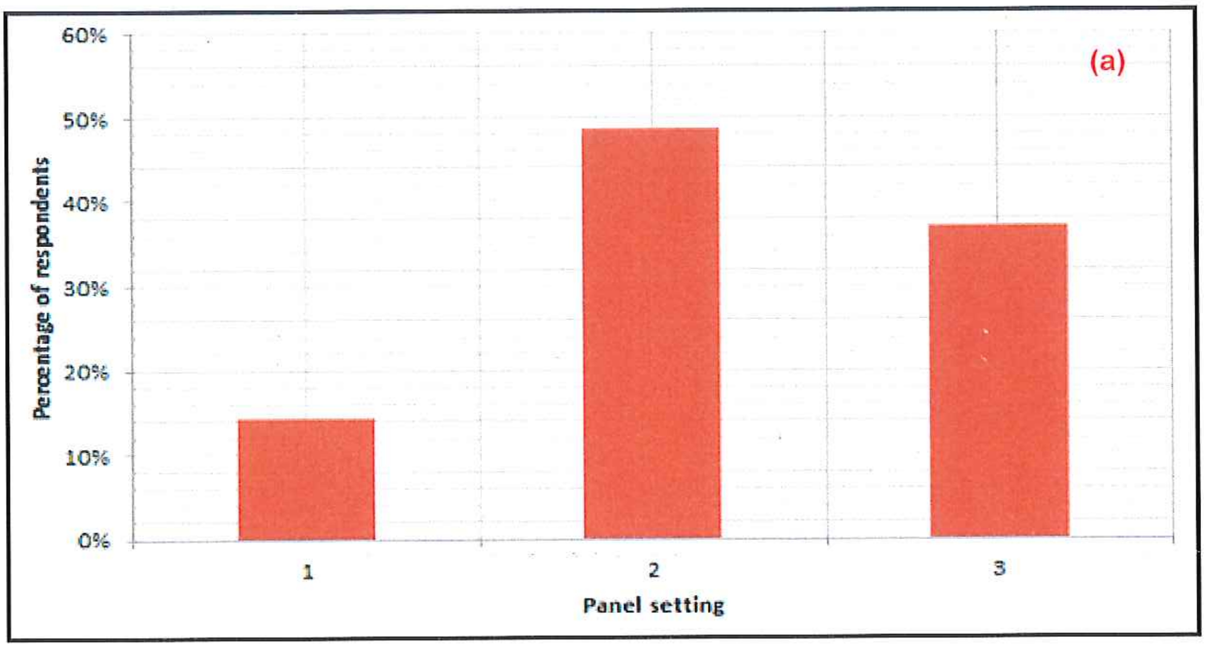


Figure 6: (a) Rating of the level of comfort the respondents indicated they feel when using LPG heaters, where 1 indicates the most uncomfortable and 5 indicates the most comfortable. (b) The weight of the gas cylinder before and after each experiment setting. The heater was operated overnight for each panel setting. Also shown are the quantities of the gas used for each panel setting.

Figure 7 displays different panel settings preferred by the survey participants together with the amount of time they prefer to operate the heaters on a given day. Most of the respondents prefer to set the heater to 2-panels, closely followed by those that prefer 3-panels as shown in Figure 9. The duration of time for which the respondents operate the heater varies from 1-2 hours to 4-5 hours a day, most of whom prefer 2-3 hours a day.



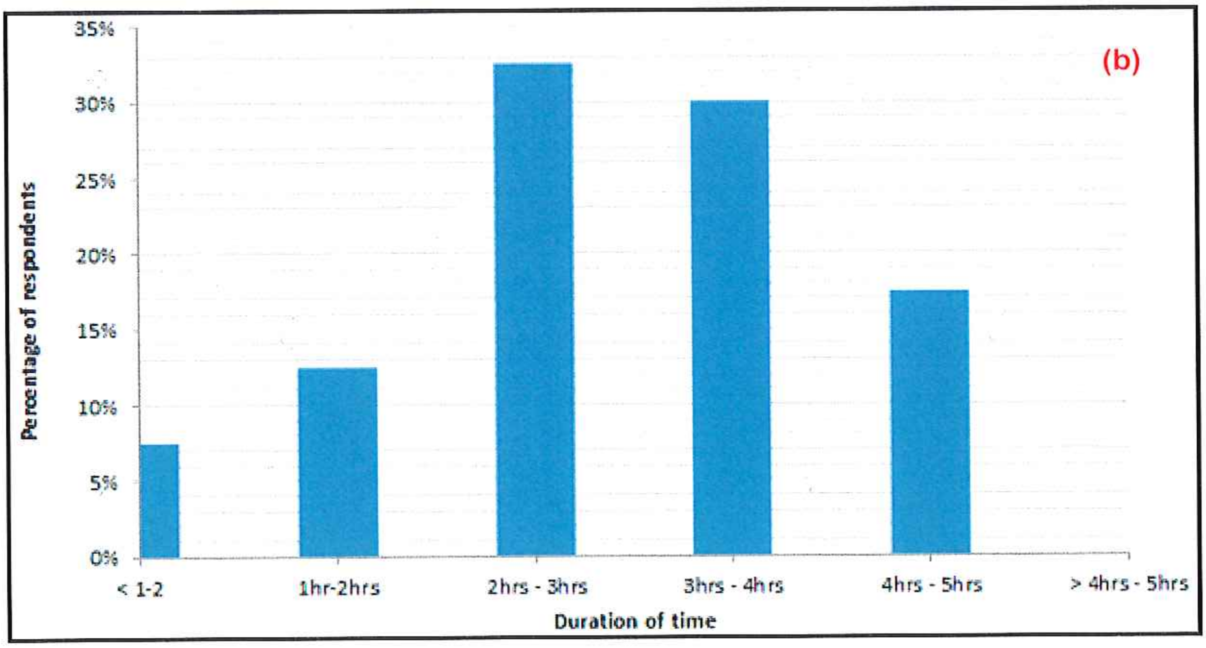


Figure 7: Panel setting preferred by the respondents when using the LPG heater. (b) Duration of time the respondents prefer to operate the LPG heaters.

3. CONCLUSIONS

The outdoor-to-indoor transport of air pollutants significantly contributes to the air pollution levels measured indoors. The LPG heater is a source of both indoor NOx and CO concentrations. The oxidation of NO by O_3 leads to increase in indoor NO_2 concentrations. However, it must be noted that even though the study represented the worst-case scenario in that the heater was left operating and the windows closed overnight, the concentrations of these pollutants remained within acceptable levels. Therefore, the impact of the emissions from the LPG heater on the indoor air quality would not pose a health risk to the inhabitants. There was no clear evidence to suggest that LPG heater contributes to the indoor PM_{10} concentrations. It can be concluded that the use of the LPG heater would result in improved air quality as compared to the use of solid fuels. However, it is important to ensure that prior to the implementation of the LPG heater interventions as an offsets option, sufficient awareness and education on the effects of air pollution and the use of LPG heaters need to take place in order to address the issues raised by the respondents to the survey, especially cost and safety.

APPENDIX A

Questionnaire on the attitudes towards and usage of LPG heaters

1. Do you use an LPG heater in your home?

If **NO**, please indicate an option that relates best to your reason;
(Mark with an X)

You feel it is unsafe

You feel it is too expensive to maintain

You own an electric heater instead

Other – kindly write a short description below;

If **YES**, please continue with survey…

2. How long do you keep your gas heater on (on the average day)?
(Mark with an X)

Less | 1-2 hrs | 2-3 hrs | 3-4 hrs | 4-5 hrs | More

3. What time of day do you usually turn your heater on?

4. How big a gas cylinder do you use (in kg)?

5. On average, how long does the gas usually last? (days, weeks, months)

6. What setting do you usually turn your heater on to? / How many bars do you prefer to turn your heater on to?
(Mark with an X)

1 Bar | 2 Bars | 3 Bars

7. On a scale from 1 to 5 (where 1 is the most uncomfortable and 5 is the most comfortable)- what would you say is your comfort level after a few hours of having your heater on? Your comfort level could pertain to how dry the air feels around you, if the smell of the gas bothers you etc.
(Mark with an X)

1 | 2 | 3 | 4 | 5

8. Do you keep your heater on after you fall asleep or do you turn it off?
(Mark with an X)

Keep it on | Turn it off

9. Do you prefer turning your heater on during the day or at night or does it not matter?
(Mark with an X)

Day | Night | Does not matter

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