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HOUSEHOLD CHARACTERISTICS AND POTENTIAL INDOOR AIR POLLUTION ISSUES IN RURAL INDONESIAN COMMUNITIES USING FUELWOOD ENERGY

Haryono Setiyo Huboyo

Environmental Engineering Department, Faculty of Engineering, Diponegoro University, email: huboyo@gmail.com

ABSTRACT

Two rural communities using fuel wood energy in mountainous and coastal areas of Java island in Indonesia have been surveyed to know their household characteristics and the related potential indoor air pollution issues. By random sampling, we characterized fuel wood users only. The fuel wood use was mainly due to economic reason since some of the users were categorized as low-income families. Communities in the mountainous area were exposed to higher risk of indoor air pollution than those in coastal area due to their house characteristics and behavior during cooking. Both communities, however, were aware of indoor air pollution issues and indicated the sources. They also prioritized the factors to be controlled, which they perceived as the main cause of indoor air pollution problem.

Key words *: household, rural, indoor air pollution, energy*

1. INTRODUCTION

It is estimated that over three billions of people use biomass fuel for cooking and heating in developing countries. Furthermore, in this region about 730 million tons of biomass were burnt each year releasing more than 1 billion tons of carbon dioxide (World Bank, 2011). Basically, the use of biomass fuel in developing world is driven by its accessibility, affordability, availability, and acceptability. Generally the energy choice – GDP relation is true for all countries, though in some area it was found that the more affluent families do not necessarily use cleaner fuel (Saatkamp et al., 2010, Heltberg, 2003). It is reported that household income will influence fuel choice in urban area, while it has less influence in rural area.

The housing characteristics, stove and cooking time play an important role in determining the exposure of pollutants to the cooks. The stove parameters are stove type and fuel type, while kitchen location is an important parameter for housing characteristics. Likewise, Clark et al. (2010) detailed the house characteristics as the total area of the kitchen windows, the number of kitchen walls, and the primary material of the kitchen walls and the volume of the kitchen, and the number of walls with eave spaces.

The effects of these several factors on indoor pollution may be well understood in the rural communities but some are not. The basic critical issue is on how the people choose for their own cooking energy which is best suited for them. Masera et al. (2000) using multiple fuel linear model found the factors which are essential for household decision in fuel choice: (a) economics of fuel, stove type and access conditions to fuels, (b) technical characteristics of cooking stoves and cooking practices; (c) cultural preferences; and (d) health impact.

In Indonesia, the villages are basically categorized into non coastal areas (including in mountainous areas) about 77% and at coastal areas i.e. 23% of total of 67,245 villages in which the fuel wood users proportion showed almost comparable 67% (BPS, 2008). It is predicted the fuel wood users in the mountainous region will be higher than 67% due to the remoteness of its location. This will ultimately increase risk of health effect due to indoor air pollution in mountainous region. The cross-sectional study in Indonesia reported that high indoor air pollution from coal/lignite, charcoal, firewood/straw, and dung evidently increased infant mortality (OR 1.305, 95% CI 1.003-1.698) in rural areas (Kashima et al., 2010). Furthermore, regarding to the health outcomes, the prevalence of ALRI in rural areas was higher than that in urban areas.

Given the varying condition of households in the field (due to its location, social-economic status, and resources availability) then in relatively different area, i.e mountainous and coastal area, the people might have different health impact caused by different household characteristics and householder behavior.

For example, if we focus on two provinces in Indonesia i.e. West Java province and Central Java province then we have two different characteristics. Based on BPS (2008) survey, the West Java provinces had a low number of villages with fuel wood users in non coastal areas (42%) than that in Central Java provinces (78%). However the pneumonia incidence in West Java province in 2011 was 9 times higher than that in Central Java province (Ministry of Health, 2012). Historically, West Java province experienced high pneumonia diseases for children <5 year although the fuel wood users showed moderate level. Household characteristics and behavior is a key determinant to this occurrence.

To know the different household characteristics and household behavior related to energy use and indoor air pollution in mountainous areas and coastal region, no study was so far found in the literatures.

The objectives of this research are to provide housing characteristics information of two distinctive rural locations, define cooking practice related to ventilation practice, analyze descriptively indoor air pollution potential (outdoor sources, ventilation sufficiency and probable health effect). Furthermore, we also show household views that reflect to indoor air quality improvement by ranking the important factors provided. Statistical analysis i.e Friedman`s Test will be used to rigorously assess the factor ranking.

As part of the surveys, the preliminary study on $PM_{2.5}$ measurements in the kitchens at both sites are also addressed in this work. The findings of the study are expected to give basic information for development in rural Indonesian communities to maintain sustainable energy, promote healthy life, and achieve better environment.

2. METHODOLOGY

The case study was conducted in two distinctive rural villages in Indonesia, namely at Sunten Jaya, Lembang, West Bandung regency (West Java province) and at Bakaran Wetan, Juwana, Pati regency (Central Java province). Fig.1 shows the map of the two locations with Java island as an inzet.

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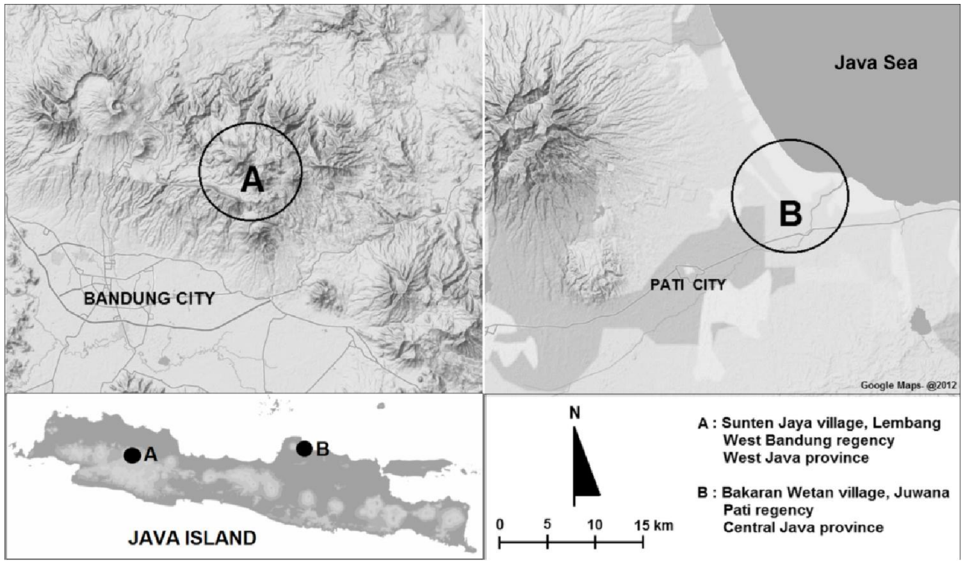

Figure 1. Location of study map

Sunten Jaya village is a mountainous area with an altitude of 1280 m ASL, having 7,539 people (3459 households). The village having an area of 576 ha is divided into 16 sub-villages. About 81% ofthe area comprises of non-paddy agricultural field, while the rest is for residential house and cattle breeding which sparsely spread over the village. On the other hand, Bakaran Wetan village is situated in a coastal area of 2 m ASL altitude and of the population is 4,994 people (1,532 households). The village having an area of 630 ha is divided into 3 sub-villages. More than 92% of this village is brackish-water pond while the residential quarters are clustered on the periphery of brackish-water pond.

Since late 2007, these villages have already engaged in LPG conversion where each household gets a 3 kg cylinder of LPG package including the stove. However fuelwood is still used by large number of people here. Some of these households resell their 3 kg LPG package in fear of gas explosion.

Based on national survey in 2010, about 62.4% of households in rural areas in West Bandung Regency still use fuel wood as a main cooking fuel compare to 36.3% use LPG as the main cooking fuel. While in rural areas of Pati Regency, the household proportion whose the main fuel is fuel wood and LPG were 47.3% and 51.7% respectively. Nevertheless it seems there are large fraction households using dual fuel (LPG-fuel wood) in this area. In the location we surveyed 100 households randomly of fuelwood users randomly. In this survey, we gathered the following household information: household characteristics, housing parameters, activities related to indoor air pollution, and perceived health related to indoor air pollution by combination of open and closed questionnaire as well as measuring the housing parameters.

3. RESULT AND DISCUSSIONS

The proportion of LPG only users in Juwana was higher than that in Lembang presumably caused by better accessibility of Juwana rather than Lembang. Juwana site location close to the main trans-Java island highway. In addition, fuel wood only users were dominated in the elderly who seems to feel resistance in the operation of newly introduced technology for cooking.

The majority of household heads and housewives has a low level education. More than 80% of them finished only elementary school in both sites. This may attribute to their occupations that do not need a high-level education background. Within Lembang site, the predominant occupation of householder is a farmer (54.6%), while in Juwana site brackish-water farmers and workers (43%) dominate it.

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Housing materials

The housing characteristics between the two sites were quite distinctive (Table 1). In Lembang site brick was the dominant material for the wall and the kitchen. Furthermore the wall materials of living room as well as kitchen were mostly identical. In contrast, the major dominant wall materials in Juwana site were concrete blocks so as to adhere to cultural prohibition of using brick. Interestingly, the wall materials of living room and kitchen were not always alike. Some householders in Juwana did not view the kitchen room as a component part of the main building. Therefore, low-end materials were chosen for the kitchen.

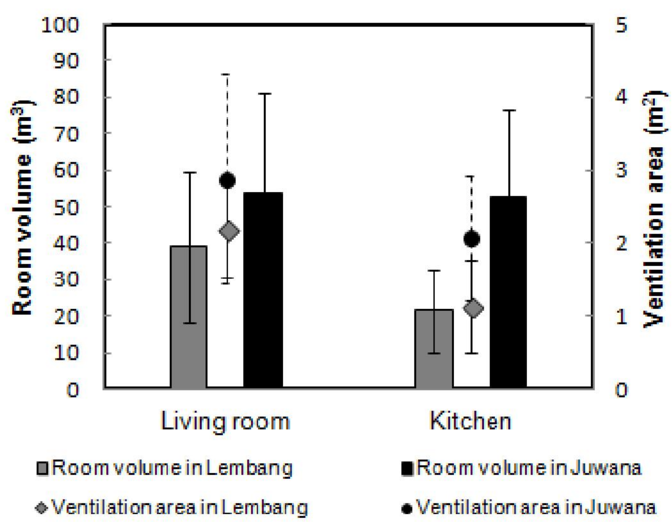
Table 1. Housing materials in both sites

	Wall material		Floor material	
	Living room	Kitchen	Living room	Kitchen
Lembang	Brick (50%)	Brick (49%)	Cemented (38%)	Plank (44%)
	Plank (30%)	Plank (30%)	Plank (33%)	Earthen (34%)
	Bamboo (20%)	Bamboo (20%)	Tiles (25%)	Cemented (20%)
Juwana	Conc block (71%)	Conc block (59%)	Tiles (65%)	Earthen (52%)
	Bamboo (16%)	Plank (21%)	Earthen (19%)	Conc block (23%)
	Plank (11%)	Bamboo (20%)	Cemented (16%)	Cemented (21%)

It is suggested that popular wall materials of better quality give inferior ventilation quality. High quality materials were preferably used for floor materials in the living room than in the kitchen. This is a common condition in high - income households too. Saatkamp et al. (2000) also observed that even affluent households were not willing to improve the kitchen room quality in Mexico. Indeed, in developing countries, the kitchen is often placed in a leftover space, even in the newly-built houses. The high proportions of plank material for the kitchen floor in the Lembang site were primarily caused by elevated building floor to adapt the land terrain.

Room volume and ventilation aspects

The average room volumes of living room and kitchen on Juwana site were higher than those in Lembang site as shown in Fig. 2. This result is an agreement with that of province-level average where household rooms area in Central Java province are higher than those in West Java province.



The ventilation consists of door, window and specified wind opening, the volume did not include outliers in Juwana (4 living rooms, 10 kitchens)

Figure 2. Room volume and ventilation area

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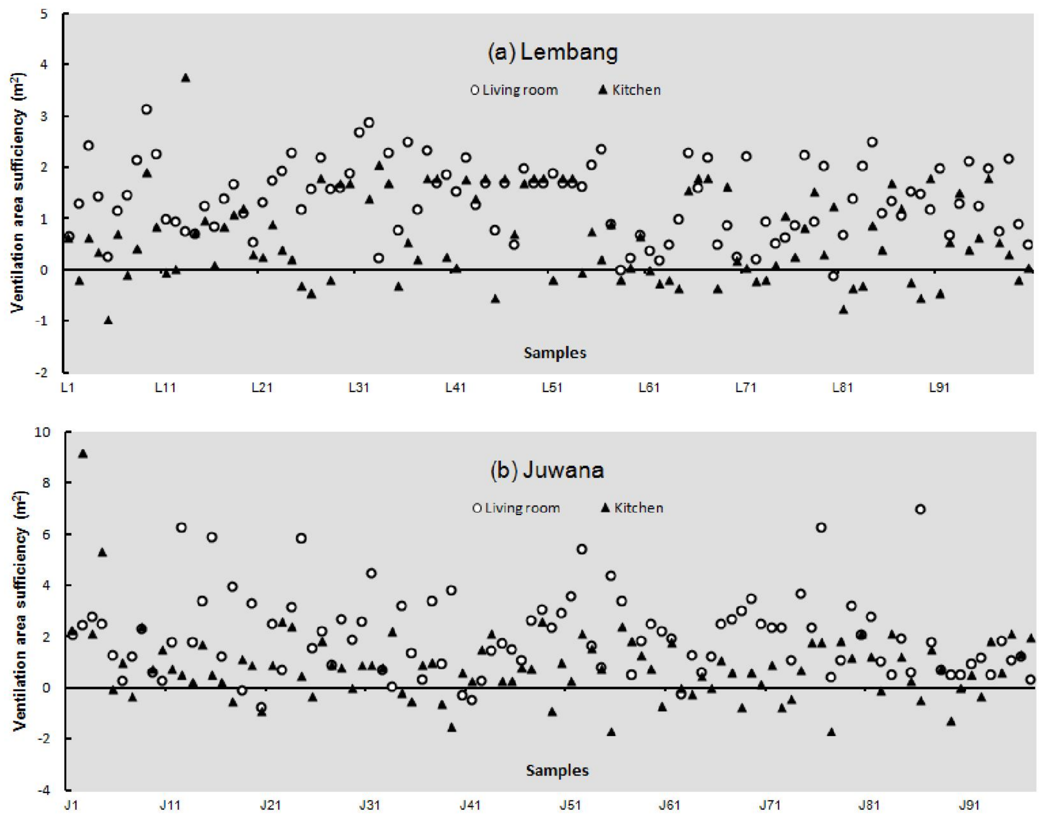
At province level, the dominant room areas are 50 – 99 m^2 (56.2%) and 20-49 m^2 (43.4%) for the Central Java province and for West Java province, respectively. The Javanese culture influences higher room volume of the kitchen in the Juwana site providing good natural ventilation where this kitchen also serve for social interaction medium occasionally. It is expected that the indoor air pollution potential in Lembang site is higher than that in Juwana site because the bigger room can dilute air pollutant more effectively. The low room volumes were aggravated with a low ventilation area in the dwelling room in Lembang site. We measured definite total ventilated area of the living room and kitchen such as doors, windows, and wind opening spaces in each household. The ratios of ventilation area in Juwana to Lembang are 1.3 and 1.8 for living room and kitchen respectively. However, if we inspect to ventilation sufficiency (percentage of the floor area to be ventilated) based on technical guideline on a building from Ministry of Public Works i.e. ventilation area in residential building should be at least 5% of the floor area to be ventilated, then several rooms in Lembang and Juwana particularly in the kitchen were ventilation-deficit (Fig. 3).



Note : ventilation-deficit is denoted by negative value; calculation did not consider unspecified opening such as eaves, hole in roof etc. and door between rooms.

Figure 3. Ventilation sufficiency of the sampled houses

Despite having low ventilation areas, the people on Lembang site (58%) tend to keep closing their doors and windows in the kitchen during cooking events. Only 11%, householders in Lembang opened their window during cooking period. They relied on ventilation mainly through the roof, permeable walls and eave spaces in the kitchen. Relatively cold temperature, about 18 – 20˚C, might be the reason in keeping the door and window closed. In contrast, about 82% of people in Juwana opened their doors to the outside in the course of cooking. This

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will, ultimately, reduce significantly the accumulated air pollutants in the kitchen because natural ventilation plays a pivotal role in dissipating pollutants out of the living space. Small fraction (5%) of Juwana`s households opened both door and window.

As studied by Still and MacCarty (2006), keeping the door open during burning biomass stove will reduce as much as 95% of pollutants (PM and CO) emission compared to that in a closed room. Re-organizing the room architectures to bigger room would be costly, then it is recommended that the householders ventilate the kitchen without cost during cooking period. Widespread use of ventilation can be promoted by media, i.e TV because our survey indicated about 90% of people in Lembang and Juwana use TV as information media.

Pollution perception

About 78% of householders in Lembang perceived indoor air pollution in their houses, while only 13% believed that outdoor pollution is a problem. Whereas in Juwana site, about 55% householder felt no pollution at all derived from indoor as well as outdoor sources, 22% of the people believed the outdoor air pollution affected indoor pollution. Only 11% householders in Juwana realized the presence of indoor air pollution. Furthermore the open burning of garbage and neighborhood smoke were justified as the main sources of outdoor pollution in Lembang site.

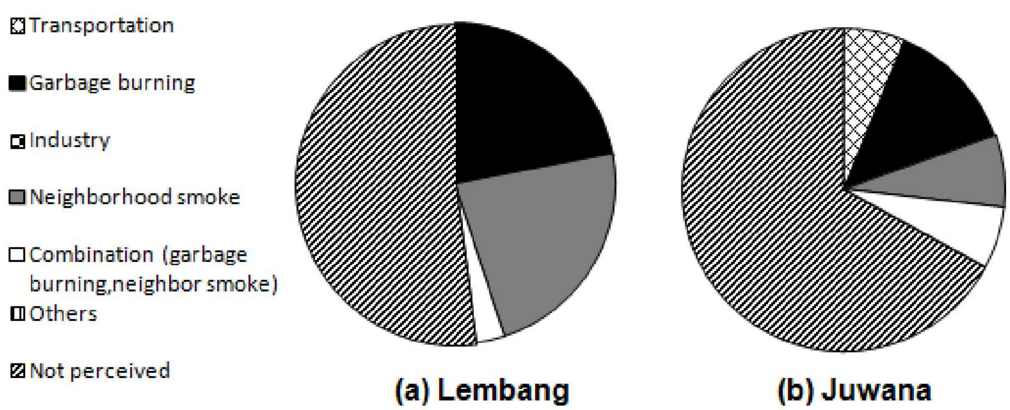

Figure 4. Sources of outdoor pollution

In Juwana site, the transportation also contributes to outdoor pollution because several households reside near roads. Apparently, the mainstream perspectives on health problem for the cooks in Juwana site when they do cooking were surprising. More than 78% people did not feel any problem with their health associated with indoor biomass smoke. In contrast, about 51% people in Lembang a bit complained about their physical health during cooking due to eye irritation (25%) and combined breathing problems and eye irritation (26%). For the same question, only 18% of people in Juwana suffered breathing problem due to cooking fuel smoke. It seems that the people were able to endure these conditions by reducing the exposure to the smoke through cooking intermittently and frequent moving to the living room.

Other important factors in generating indoor air pollutants are smoking at home and burning mosquito coils. In Lembang, 70% of respondents smoked at home (68% of householder head) showing an average consumption of 9.5±4 cigarettes/day. Lower percentage of smoking at home was shown on Juwana site, i.e. 44% with an average consumption of 4.6±3 cigarettes/ day. Mostly they did smoke in the evening after having dinner or during watching

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television together with the family members. Ironically, besides bringing about indoor air pollution in the dwelling room and exposing harmful pollutants to family members, this activity also undermines household income. On average estimation, they spent approximately 32.8% and 12.3% of their monthly expenditures on cigarettes for Lembang and Juwana sites respectively.

Since Juwana is located in plain areas, many brooks undergo stagnant waste water providing breeding grounds for mosquitoes. This condition occurs unlikely at Lembang site, because the terrain enables wastewater in the brooks to flow easily. In Juwana 52% of the people preferred to use mosquito coils. By contrast, 96% people at Lembang site did not use mosquito repellant. This fact will augment the indoor air pollution in Juwana site particularly in the living room in addition to smoking pollution.

If we consider the $PM_{2.5}$ emission factor of mosquito coils burning is the same as 75 – 137 cigarettes burning as suggested by, the indoor air pollution levels in Juwana`s living rooms are predicted to be much higher than those in Lembang, at comparable-sized room.

Taking the causality of indoor air pollution into account comprehensively, we analyzed all prominent indoor pollution factors such as smoking indoor/at home, using non-electricity lamp, changing fuel type, burning mosquito coil repellant and applying ventilation. These factors are common activities which rural people deal with indoor on a daily basis. Actually, we also asked about the frequency of room cleaning (generally only sweeping the floor) which may increase re-suspension of deposited fine particles. Yet we believe this activity does not have a significant effect on indoor pollution. The $PM_{2.5}$ emission rate (mg/min) of sweeping the floor is about 2% to 5% of cooking (frying) and smoking respectively. In addition, this re-suspended fine PM emission is not related to mortality compared to combustion-generated constituents. We asked the householder to prioritize the above factors that should be managed at first in order to improve indoor air quality. Fig. 5 showed the survey results in percentage by comparing side by side of Lembang and Juwana sites.

Fig. 5 shows that the priorities of each factor are more evenly distributed in Juwana site. While in Lembang site, the striking differences are found in certain priority level of each factor. Thus, people in Lembang had a common sense of what should be prioritized to improve indoor air quality. Based on statistical Friedman`s Test, by eliminating non-electricity lamp factor[2)] in both sites and mosquitoes coil burning in Lembang site[3)], the respondents expressed different factor prioritization in Lembang site ($\chi^2 = 42$, $p<0.01$). On the contrary, householders in Juwana viewed relative comparable factor prioritization ($\chi^2 = 4.6$, $p>0.01$). The people in Lembang site prioritized to reduce smoking at home then to use cleaner fuel/stove and to manage house ventilation.

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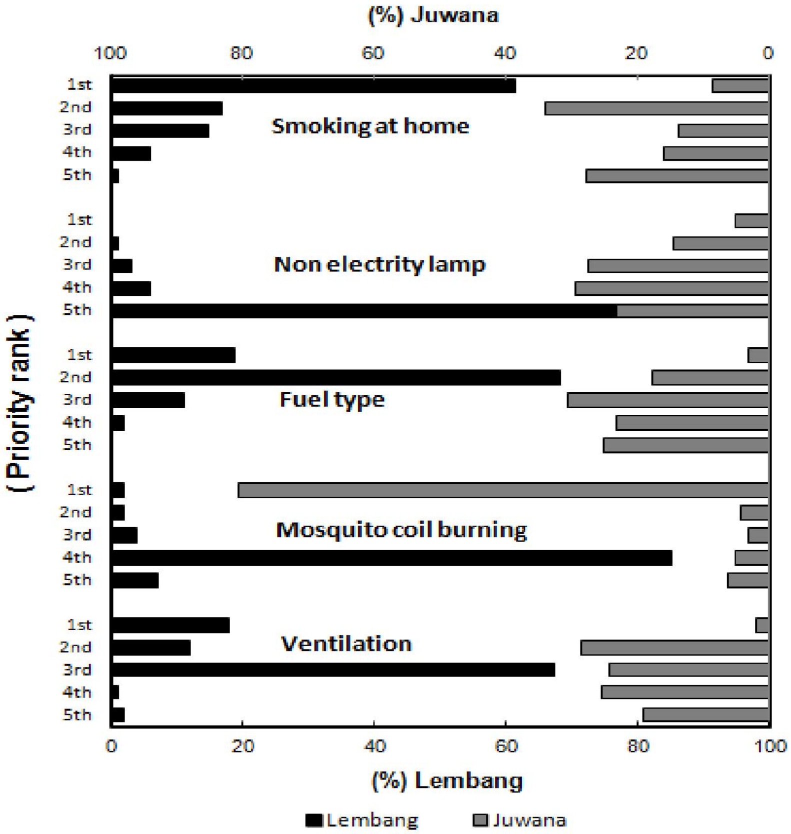

Figure 5. Priority ranking of factors to be controlled

The result indicates that what is perceived as the main source of pollution in the dwelling room is that should be controlled first for improving indoor air quality. Nonetheless, it is not necessarily the countermeasures option to improve indoor air quality will in line with this priority. Smoking and mosquito coil burning are seemingly as habits rather than awareness.

Hence it will take longer time for the people to really extricate from these habits. For that reason, it is expected that conversion of fuelwood by LPG will not reduce the exposure of harmful pollutant significantly in the near future, as other indoor pollutant sources still exist in the living room where the householder members spend the time longer than in the kitchen. It is imperative, therefore, to formulate indoor air pollution countermeasures embedded in the energy policy program.

4. CONCLUSION

As generally the rural people have low income then the economic motive was the main reason in selecting the fuel in addition to accessibility and water cooking purpose. Local housing characteristics influenced by local wisdom, culture, climate, and location have potentially affected the indoor air pollution level. The people in mountainous areas have small rooms as well as insufficient ventilation area and need heating due to cold temperature. Then they encounter the risk of indoor air pollutant exposure rather than the people in coastal areas. On the other hand, mosquito breeding is a real problem in this coastal area where the massive use of mosquito coil burning will eventually deteriorate indoor air quality.

People in these two locations were aware of such indoor air pollutions and therefore prioritized the factors to be managed based on their perspectives of the air pollution causes. This awareness is important in designing integrated indoor air pollution countermeasures to

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be adaptive and to secure sustainable living. This will aid the efficacy of energy conversion that not only promotes cleaner fuel use but also reduces exposure to air pollutants.

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