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Evaluating household coal slag emissions in Binh Chanh District, Ho Chi Minh City, Viet Nam and recommended solutions

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ABSTRACT

In Viet Nam, apart from coal-fired power plants, coal slag also emitted from households via coal burning activities. However, the quantity of slag emitted from households has been rarely determined, and most of it is not been well-treated. In addition, it is well-known that the untreated or mistreated coal slag can lead to severe impacts on both the environment and human health. Therefore, it is necessary to evaluate the emission of this slag, and thereafter to provide recommendations for improved management. In this study, the emission of household coal slag in Binh Chanh District of Ho Chi Minh City, Vietnam was investigated by undertaking a fact-finding survey coupled with GPS. Coal burning experiments were also performed for various fuels including large-sized honeycomb charcoal (3 kg/piece); small-sized honeycomb charcoal (1.7 kg/piece); charcoal (1 kg) and dried firewood with rice husk (1 kg) to estimate the quantity of household coal slag emissions slag, as well as to primarily examine the impact to the environment and human health. Results showed that the emissions of household coal slag in the study area was considerable, up to 146 tonnes per year, almost 60% of which, was directly discharged into the environment. The burning coal for household purposes was found to dramatically change the quality of air with high concentration of pollutants including formaldehyde (HCHC), total volatile organic compound (TVOC), as well as particulate matters (PM2.5 and PM10) in exceedance of national standards which led to health effects. Finally, solutions for managing the slag were proposed.

1. INTRODUCTION

Coal slag, along with coal ash, is a non-combustible solid waste generated in coal combustion. While ash is discharged through the smoke path, also known as fly ash, slag is discharged through the bottom of the furnace, also known as bottom slag. Usually, the amount of fly ash accounts for about 80–90%, and slag only accounts for the remaining 10–20% of unburnt components. Coal slag is coarser and larger than fly ash with the size ranging from fine sand to gravel (0.125 mm to 2 mm). It is often used to replace sand in the production of unburnt materials, as well as for leveling and filling purposes (Thenepalli et al., 2018; Cwirzen, 2020). According to a report by the Ministry of Industry and Trade of

Vietnam in 2019, the total amount of ash and slag discharged from power plants is more than 16.4 million tonnes per year. Furthermore, it is expected that the amount of ash and slag discharged from such sources, will reach 422 million tonnes by the year 2030 (MONRE, 2019).

Coal usage is widely known to have unsustainable impacts on the surrounding environment including air, water and soil, as well as on human's livelihood and health (Duong, 2016; Munawer, 2018). Particularly, coal combustion emits hazardous gases, mainly carbon oxides (COx), sulfur oxides (SOx) and nitrogen oxides (NOx), into the air. These gases, especially SOx, cause acid rain leading to both water and soil pollution. In addition, the combustion wastes, i.e., coal slag and ash, also produce such impacts on the environment and human health, if they are inappropriately treated and disposed. In particular, fly ash and slag were found to significantly contaminate both the water and food web since they contain heavy metals and radionuclides (Munawer, 2018; Zielinski & Budahn, 1998). These poisonous reagents then are inhaled or consumed by humans and phytoplankton resulting in fatal diseases such as cancers (Debi & Guttikunda, 2013; Tran et al., 2020).

Apart from being generated from power plants, coal slag is also produced from household activities including cooking and catering businesses, especially in rural areas. However, there is a lack of research on household slag generation. Binh Chanh is a crowded suburban district of Ho Chi Minh City undergoing rapid urbanization. Here, many small-scale household businesses using coal have appeared in an uncontrolled manner. Against this backdrop, in this study, we conducted a survey in Binh Chanh District, Ho Chi Minh City to preliminary determine the emission volume and the handling state of household slag. Additionally, the air quality when burning coal to form the slag was also investigated. With the obtained results, several management measures are proposed.

2. MATERIALS AND METHOD

2.1. Fact-finding survey

A survey questionnaire was compiled of 20 questions and 120 survey sheets were delivered to 120 surveying objects including 100 household business establishments and 20 households. GPS was used to pin emission sources and plot the distribution of emission sources in Binh Chanh District, spatially (Figure 1). All the statistical data were collected for the total 120 surveyed objects.

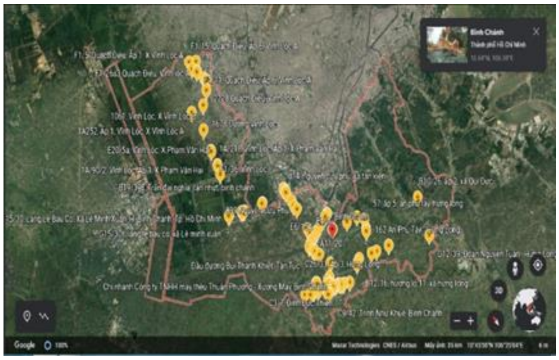

Figure 1. Distribution of surveyed households in Binh Chanh District

2.2. Emissions investigation

The experiment of burning fuel was carried out to investigate the impact on the environment and surrounding population. The burning experiment was performed for the following types of fuel including large-sized honeycomb charcoal (3 kg/piece); small-sized honeycomb charcoal (1.7 kg/piece); charcoal (1 kg) and dried firewood with rice husk (1 kg). The weight of honeycomb charcoals was higher than the other fuels since the burning was carried out for a whole commercial piece to most closely simulate the practical burning by households. The burning of charcoal was done in an open space, while the burning of dried firewood with rice husk was carried out in the kitchen. The burning time of honeycomb charcoal, charcoal and dry firewood/rice husk was 4 h, 1 h and 30 min, respectively.

After 30 min of burning, the quality of the air was determined by measuring the parameters including formaldehyde level (HCHO), total volatile organic compound (TVOC), and particulate matter (PM2.5 and PM10). These measurements were taken at various points, namely the center of the incinerator at the height of 1 m above the ground and 4 positions at a distance of 40 cm from the center of the furnace in all four directions which are East (E), West (W), South (S) and North (N), respectively. The arrangement of sampling points for measurements is illustrated in Figure 2. While HCHO and TVOC levels were recorded by using Multifunctional Air Quality Detector, PM2.5 and PM10 dust parameters were determined via Benetech GM8803 air quality meter. In addition, a Lutron YK-80AP anemometer (25 m/s) was also used to measure the wind speed and direction. All the equipment was made in China.

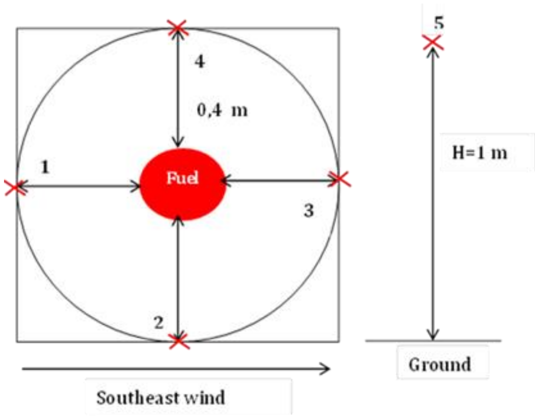

Figure 2. Sampling points for air quality measurements

3. RESULTS AND DISCUSSION

To evaluate the emission of household coal slag in Binh Chanh District, as well as obtain other information including the slag treatment state, and the impact of slag generation on the environment and citizens, surveys were carried out for 120 objects located throughout the district. According to Hair et al. (2006), the sample size for factor analysis should be 100 or larger. The research locations of emission sources were pinned on the maps using GPS mapping techniques as can be seen in Figure 1.

3.1. Potential discharged volume of household coal slag and handling

To determine the types of coal usually used by the residents in the district, the options including honeycomb charcoal, charcoal, biochar, a carbon-rich material produced during the thermochemical decomposition of biomass in the absence or limited supply of oxygen, and rice husks/plant residues were given in the questionnaire. Survey results showed that the preferred type of coal used daily by people in Binh Chanh District was honeycomb charcoal, which accounted for 61% of responses, including large and small-sized types (Figure 3). Charcoal was only used by 28% of investigated cases and is less popularly utilized than honeycomb for domestic purposes. This type of coal is commonly used in barbecue shops or street food restaurants. Meanwhile, rice husks accounted for 11%, mainly being used in households for daily cooking or business purposes. In addition, there was no record of biochar usage within the district due to the fact that the majority of people are not aware of this type of fuel and that the price of biochar is higher compared to others.

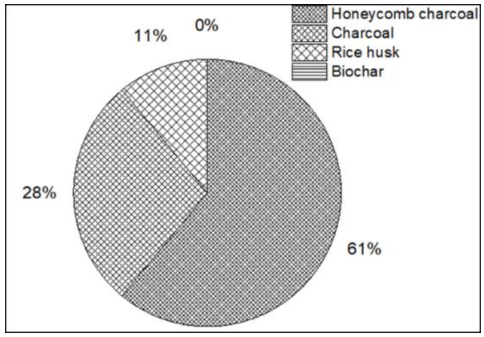

Figure 3. Types of coal used for domestic burning in Binh Chanh District, HCMC

The consumed amounts of corresponding types of coal determined above were also investigated by making statistics from the data provided by the surveyed people. It can be seen from Figure 4 that honeycomb charcoal was used daily with the highest quantity. Particularly, the daily used amounts of large-sized and small-sized honeycomb charcoal (LSHC and SSHC) were 543 kg and 280.5 kg, respectively. This makes up a total amount of 823.5 kg of honeycomb charcoal burnt per day. This might be attributed to its ability to keep heat for longer periods. Hence, it is used more frequently for long-term cooking without needing to add additional coal. The amount of charcoal that was commonly used at barbecue shops or rice stalls was found to be around 377 kg per day. Finally, the utilization of rice husks and residues (mainly dried plants) was smaller at around 153 kg.

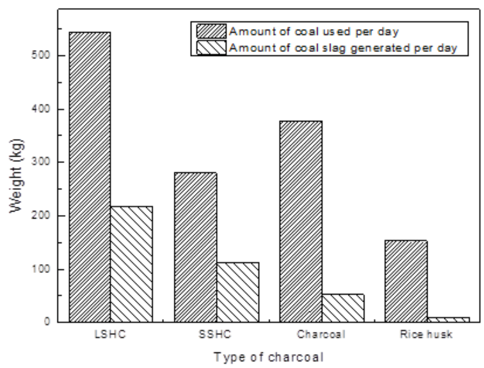

Figure 4. Amounts of various types of coal used and the corresponding amount of coal slag generated per day

Corresponding to the consumed weight of various types of coal, the generated coal slag was also determined by extrapolating the data from burning experiments. According to our obtained results, burning 1.7 kg of small-sized honeycomb charcoal in the natural environment yields about 700-–750 g of coal slag (41-44%), meanwhile burning large-sized honeycomb charcoal of 3 kg produced 1.2 kg of coal slag (40%). With 1 kg of charcoal, there is only about 140 g of slag remaining (14%). Then, based on the used amount of coal that was calculated, the overall daily generated amount of coal slag was calculated and the results in Figure 4 highlight that the total amount of slag obtained was almost 400 kg per day. This acquired amount is considerable for a modern district where the coal combustion is less popular in comparison to rural or peri-urban areas.

Through the survey, several modes of handling for the formed coal slag were recorded as presented in Figure 5. Among them, the most popular way of handling was direct discharge into the environment which accounted for 59% of respondents. This is due to the fact that the consciousness of environmental protection of the citizens in the investigated area was not high and most of them were not aware of the impacts of coal slag on the environment and their health. Only 10% of the respondents discharged the coal slag along with the household waste, while 23% of them used the slag as leveling materials. Usually, the slag was used to fill the front ground or to fill in the hollows in the backyard. No response was found for the handling way of using for sale since most of the surveyed citizens are not aware of this business. Other ways of handling were also documented including (i) using it as a supplement for soil in planting trees or (ii) selling it to others.

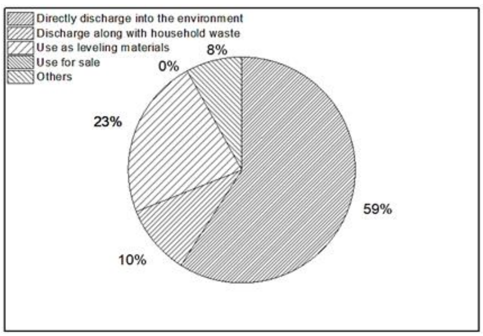

Figure 5. Handling forms of household coal slag after burning

3.2. Quality of air during household coal burning

It is straightforward that coal burning, especially in open air for domestic purposes, leads to detrimental effects on the environment and human health (Munawer, 2018). Coal burning can emit toxic or harmful substances including formaldehyde (HCHO), volatile organic compounds (TVOC) and particle matter (Tran et al., 2020). Therefore, there have regulations for limiting the emission of those components. According to QCVN 06:2009/BTNMT, the allowable HCHO concentration in 1 hour is 20 µg/m^3. Meanwhile, according to QCVN 05:2013/BTNMT, the permissible concentrations of $PM_{2.5}$ and PM_{10} dust in 1 day are 50 µg/m^3 and 150 µg/m^3, respectively. Since the burning time of honeycomb charcoal, charcoal and dried firewood/rice husk was not totally at 1h or 1 day, the formular $C_2 = C_1 \times \left(\frac{t_1}{t_2}\right)^q$ where C_1 is the allowable concentration according to the standard, C_2 is the allowable concentration corresponding to time t_2, t_1 is the time regulated in the standard and t_2 is the converting time with q= 0.17 – 0.2 (Le, 2014), to calculate the corresponding allowable concentration of emitted substances in 4 h, 1 h and 30 min. Herein, q=0.17 was chosen due to the ease of diffusion of the pollutants.

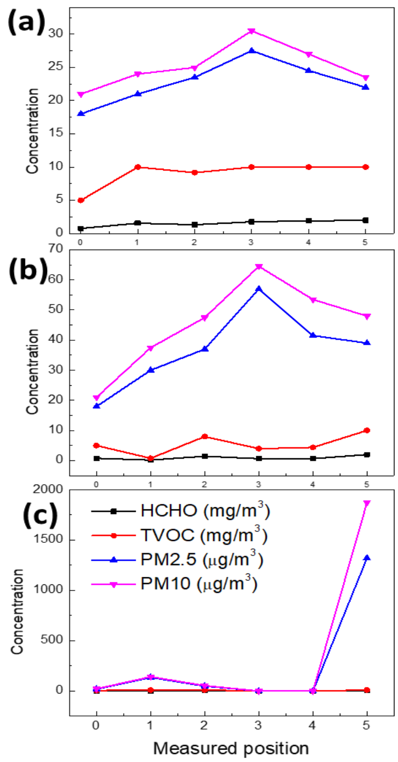

Figure 6. Quality of ambient air and air during burning (a) charcoal, (b) honeycomb charcoal and (c) dried firewood with rice husk at various investigated positions in which position 0 corresponds to the primary air prior to combustion.

Particularly, concentrations of HCHO according to QCVN for 4 h and 30 min were 15 µg/m^3 and 22.5 µg/m^3, respectively. In addition, acceptable $PM_{2.5}$ dust concentrations in 4 h, 1 h, and 30 min were 67 µg/m^3, 86 µg/m^3, and 96.5 µg/m^3, respectively. The corresponding concentrations of PM_{10} dust were 203 µg/m^3, 257 µg/m^3, 289.6 µg/m^3, respectively.

It was observed in our study that the burning of fuel made changes to the quality of air. In fact, the concentration of HCHO, TVOC, as well as particle matters ($PM_{2.5}$, PM_{10}) increased at most positions due to the burning (Figure 6). In general, the recorded concentration of HCHO at all positions exceeded the permitted threshold according to QCVN 06:2009/BTNMT. Additionally, the concentration of TVOC increased many times compared to the surrounding air and reached the maximum threshold of the meter which is 9999 µg/m^3 in most of cases. On the contrary, particulate matter concentration all met the standards allowed by QCVN 05: 2013/BTNMT apart from the case of position 5 when burning dried firewood with rice husk. This might be due to better diffusion capability of the formed slag in this case compared with the one of burning honeycomb charcoal. It is noticeable that at position 3, the concentration of emitted substances, especially particulate matters, was higher than other positions. This could be attributed to the effect of wind direction in comparison to others positions and the close distance to the emission source in comparison to position 5 of position 3.

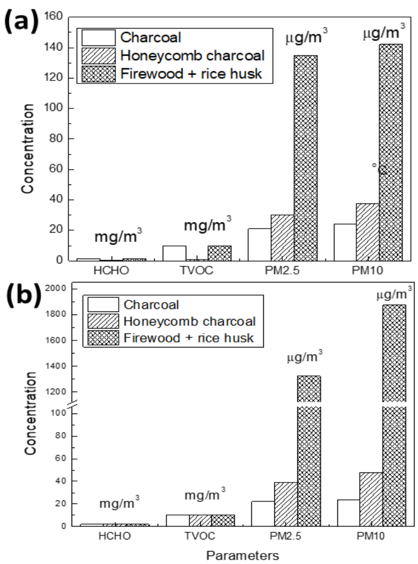

Figure 7. Quality of air at investigated position (a) 1 and (b) 5

It was also found that the burning of firewood with rice husk in the kitchen produced higher levels of harmful substances compared to that of charcoal and honeycomb charcoal (Figure 7). This is straightforward that burning fuel inside the house instead of burning it in open air would lead to the higher accumulation of the generated pollutants. It can also be seen from Figure 7, that burning honeycomb charcoal resulted in more dust than charcoal. However, honeycomb charcoal seemed to produce fewer organic compounds.

With these findings on the quality of air during burning coal, surprisingly, 62.5% of consulted households who used coal daily shared that they feel normal and have no symptoms during usage, in both the short and long term (Figure 8). Meanwhile, 18.3% of respondents reported shortness of breath and 14% of them reported sore throats. Whilst, only 5.2% of them experienced dizziness and headaches.

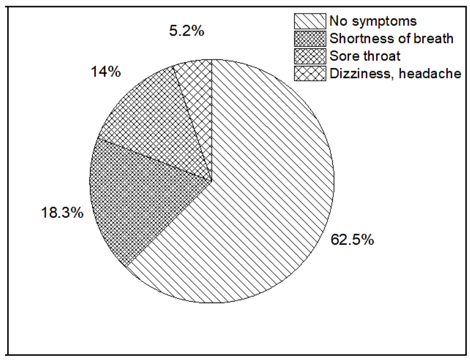

Figure 8. Symptoms that surveyed people experienced when burning coal

3.3. Proposing management measures

According to the statistics from the survey, most residents in Binh Chanh District discharged coal slag directly into the environment causing environmental and aesthetic pollution. Therefore, it is necessary to propagate people to collect the coal slag properly so as not to disperse fine dust into the air, as well as not to spill the slag into drainage leading to water pollution. The local government should establish an effective route to collect coal slag from households. With the content of silica, alumina, and iron oxide and presenting a filler effect in mortars and concretes (Argiz et al., 2017), the collected slag could be reused as filling materials for roads and bridges, housing construction, or for tree planting among other potential applications to reduce annual coal slag emissions in the area.

Most honeycomb charcoals have fairly high sulfur content. When burning in a natural environment with oxygen, sulfur will react with oxygen to produce sulfur dioxide (SO_2). SO_2 gas participates in chemical reactions inside the cells, causing disturbances in protein metabolism. The presence of this gas inside the body also leads to the deficiency of oxygen levels. Hence, it reduces the ability to transport oxygen in the blood. In addition, it causes narrowing of the larynx resulting in difficulty in breathing (Gheorghe & Ion, 2011). Therefore, when using coal, it is necessary to use a mask to limit the inhalation of harmful fumes released from the ignition process and of the fine dust during the burning process to limit the effects on the respiratory system. On the other hand, the burning should be carried out in a well-ventilated area away from the living area to avoid breathing in the black smoke. Additionally, a chimney can be installed so that the toxic smoke is diluted in the atmosphere to limit the impact on consumers.

Since using coal is not only harmful to the environment but also to human health, it is better to replace this type of fuel with other cleaner sources of energy, for instance, electric stoves. For many households this is unaffordable, and the combination of coal with an electric stove or gas stove should be considered to mitigate the generation of coal slag. Households can use higher quality coal which contains lower hazardous substances, higher carbon content, lower ash and dust production instead of honeycomb charcoal. Although it is more expensive than the coal in use, in return, the equipment and tools are less damaged and also have less impact on the health of the user.

4. CONCLUSION

In short, the household burning coal for domestic purposes is still popular in Binh Chanh District,. Coal combustion was seen to reduce the surrounding air quality with the concentration of HCHO, TVOC and in some cases, particulate matters, exceeding the national standards which caused health effects to the residents including shortness of breath, sore throat and dizziness. It was found that a considerable amount of coal slag up to total 400 kg per day or 146 tons per year was produced by the 120 surveyed objects. The extrapolated number for the whole country could be multiplied by remarkable times. Therefore, besides slag from coal power plants, household slag should also be taken into account. In addition, the residents in the study area readily discharged the slag directly into the environment due to a lack of awareness of its impacts on the environment and human health. To mitigate the generation of coal slag, as well as its impacts, alternatives for coal should be applied and an effective collection system should be developed.

ACKNOWLEDGMENT

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