**Nghiên cứu về Tính ứng dụng của Lò đốt Chất thải Rắn Đô thị cho Thành phố Hội An  
~ Góc nhìn từ Khả năng cháy của Rác và Giảm Lượng rác Chôn lấp ~**

A Study on Applicability of Municipal Solid Waste Incinerator to Hoi An City  
~ View Points of Waste Burnability and Landfill Waste Reduction ~

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**Tóm tắt -** Thành phố Hội An, nơi có khu phố cổ được công nhận là di sản văn hóa bởi UNESCO, đã đón 2,15 triệu lượt khách trong năm 2015. Đây là một con số rất lớn so với dân số 93.000 của thành phố và nó làm cho lượng phát thải rác tăng đột biến. Tất cả rác bao gồm cả rác từ hoạt động du lịch được đổ ra bãi chôn lấp làm cho tuổi thọ của nó ngắn đi và gây ô nhiễm môi trường nghiêm trọng. Trong nghiên cứu năm 2015, chúng tôi đã xác định lượng phát sinh và thành phần của rác du lịch từ khu vực trung tâm; và của rác sinh hoạt từ trung tâm thành phố, khu nông thôn và khu đô thị/ngoại ô. Trong nghiên cứu này, khả năng ứng dụng của việc thiêu hủy rác tại Hội An đã được điều tra. Cụ thể, chúng tôi đã xác định thành phần hóa học và độ tro của rác qua các thí nghiệm phân tích. Kết quả là có thể áp dụng bởi nhiệt lượng của rác là khoảng 9,3 MJ/kg. Hơn nữa lượng rác chôn lấp có thể giảm đến 80%.

**Từ khóa:** Rác du lịch, rác sinh hoạt, thiêu hủy rác, thành phần hóa học của rác, giảm lượng rác chôn lấp, Hội An.

**Abstract -** Hoi An city, which has an ancient town recognized by UNESCO as the world cultural heritage, received 2.15 million tourists in 2015. The number is hugely comparing to 93,000 population of Hoi An and rises waste generation amount in the city. All the waste including tourism waste is disposed into landfill directly, making its lifetime shorter and causing serious environment pollution. Our previous study in 2015 identified the generation and compositions of tourism waste from the city center area as well as those of household waste from city center, rural and urban/suburban areas. In this study, the applicability of the waste of Hoi An to incineration was investigated. In concrete, we determined waste chemical elements and ash content by laboratory experiments. As a result, incineration was applicable because heating value of the waste was about 9.3 MJ/kg. Moreover, reduction rate of landfill waste was up to 80% of weight.

**Keywords:** tourism waste, household waste, waste incineration, waste chemical elements, landfill waste reduction, Hoi An.

1. **INTRODUCTION**

Hoi An city is one of famous tourist attraction in Vietnam. Which has an ancient town inscribed as World cultural heritage in 1999 [1], belongs to Quang Nam province in the central of Vietnam. The city is located about 30 km south of Da Nang city, 55 km north of Tam Ky city and 6 km west of Cua Dai beach, became an important international trading port and attracted foreign merchants from Japan, China and the Europe during the sixteenth of nineteenth centuries [2]. Hoi An, hitherto, has retained old and unique features in both its multi-architectural structure and daily life of residents. Because of the high potential tourist attraction, Hoi An has received millions of visitors each year. Hoi An’s statistics presented that the value of trade and services in 2013 increased 116.72% comparing to 2012 with 1,629,725 of tourists visited [3].

The development of tourism can contribute to promotion of municipal economic growth but also impact on environment negatively. Waste raise is concerned by the residents and administrators. Josep et al. (2013) published when the tourist population increases 1% it causes on average an overall MSW increase of 0.282% [4]. Our previous study indicated that the average waste generation per capita in tourist old town and urban area (0.203 and 0.264 kg capital-1 day-1) was almost double that of rural area (0.12 kg capital-1 day-1) in Hoi An city [5]. Therein, the generation of municipal solid waste (MSW) year by year is the urgent issue requiring effective and affordable waste treatment system. Whereas, in the city, current open-dumped landfill have become overload due to short life expectancy and composting production has been low efficiency due to trouble in treatment system in which input waste contains a lot of incompatible impurities. In order to solve MSW problem and reduce the waste amount to landfill, incineration and waste separation is suitable to approach.

For the above reasons, we conducted this study to assess the applicability of MSW for incinerator in Hoi An city, the objectives of this study are to determine chemical properties for calorific value evaluation and to estimate ash content for reduction rate of landfill waste.

1. **MATERIALS AND METHODS**

There are 36 samples were collected from Hoi An. Divided into five waste categories which are Food, Garden, Plastic (plastic bag and other plastic), Paper (and Cardboard), and Combustible. The samples are dried by a dryer, DY300 by Yamato Scientific Co., Ltd., and the weight loss is regarded as moisture. Each sample is shredded by miller IFM-800DG by Iwatani Co., Ltd. to be homogeneous.

* 1. **Muffle furnace**

A small amount of sample was put in a ceramic cup which is set in the chamber of muffle furnace, FO-300 of Yamato Scientific Co., Ltd. [6] and heated at 800oC for two hours. After that, the weight of remaining sample is regarded as ash content, and it weight loss between before and after combustion is regarded as combustible matter

* 1. **CHN analyzer**

The CHN analyzer we used is model 2400 series II of Perkin Elmer. After pyrolysis sample into basic gas such as CO2, N2, H2O… it will calculate percentage of C, H, and N in the sample base on sample weight, which was input before. [7]

* 1. **Experimental analysis**

Percentages of water *W* of waste samples was identified when it was collected. Percentages of ash *a* and burnable *b* in dry basis are determined by using muffle furnace.

100% (wet) = 100% (dry) + *W* (1)

100% (dry) = *a* + *b* (2)

Percentages of ash *A* in wet basis can be calculated by:

*A*(wet%)= *a*×(100*–W*)/100 (3)

Percentages of elements in dry samples such as carbon *c*, hydrogen *h* and nitrogen *n* which was measured by CHN analyzer can be converted into wet basis by following equations.

*C*(wet%)= *c*×(100*–W*)/100

*H*(wet%)= *h*×(100*–W*)/100 (4)

*N*(wet%)= *n*×(100*–W*)/100

Since percentages of sulfur are very low, it is assumed that the element except carbon, hydrogen, and nitrogen is oxygen *o.*

*o*(dry%) *=* 100 *– c – h – n – a* (5)

O(wet%)= *o*×(100*–W*)/100 (6)

Methods to estimate calorific value from elementary components of fuel, such as equations of Dulong, Kestner, and Steuer, have been proposed, and the equations have been applied for solid waste as well. In this study, we use Steuer equation in Eq(7).

*CH* (*kcal/w-kg*)*=* 81×{*C*–(3*/*8)×*O*}+

57×(3/8)×*O* + 345×{*H*– (1/16)×*O*} + *25*×*S* (7)

*CL* (*kcal/w-kg*)= *CH – 6*×(*9*×*H+W*)(8)

Where, *C*, *H*, *O*, *S, W* is the percentage of carbon, hydro, oxygen, sulfur and moisture in weight of samples in wet-base weight %, respectively. As shown in Eq (8), low calorific heat *CL* is lower than high calorific heat *CH* by evaporation latent heat of water.

If the solid waste is burned completely by an incinerator, only ash remains, however, actually a small portion still exists in incineration residue as unburned organic matter. In Japan, in order to keep high quality of incineration, it is regulated that the weight of unburned organic matter must be less than 5% of the remains.

Residue (wet%)= (1 + 0.05)*A* (9)

CO2 emission is calculated as Eq(10)

CO­2 emission (*kg/w-kg*)= (44/12)×*C*/100 (10)

Reduction rate of landfill waste is estimated base on ash content data combine with waste composition from our previous research. [8]

1. **RESULTS AND DISCUSSION**

**Table 1. Chemical elements ratio**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  |  | Average | | |
| Waste category | N | C% | H% | N% |
| Food | 9 | 43.0 | 6.1 | 2.0 |
| Yard | 3 | 24.7 | 3.2 | 1.0 |
| Plastic | 5 | 76.6 | 11.2 | 0.4 |
| Paper | 7 | 37.8 | 5.6 | 0.2 |
| Combustible | 12 | 45.4 | 6.1 | 0.9 |
|  |  | Std. Dev. | | |
| Waste category | N | C% | H% | N% |
| Food | 9 | 3.53 | 0.70 | 0.55 |
| Yard | 3 | 7.75 | 1.17 | 0.60 |
| Plastic | 5 | 3.24 | 1.06 | 0.07 |
| Paper | 7 | 4.46 | 0.87 | 0.09 |
| Combustible | 12 | 10.64 | 2.02 | 1.12 |
|  |  | Std. Dev./Average | | |
| Waste category | N | C% | H% | N% |
| Food | 9 | 0.08 | 0.11 | 0.27 |
| Yard | 3 | 0.31 | 0.37 | 0.63 |
| Plastic | 5 | 0.04 | 0.09 | 0.21 |
| Paper | 7 | 0.12 | 0.16 | 0.57 |
| Combustible | 12 | 0.23 | 0.33 | 1.23 |

The result of C, H, and N components in 35 samples are showed in Table 1. Percentage of carbon is high in plastic waste and low in yard waste, and same property can be seen in Hydrogen. The result that percentage of nitrogen is high in food, yard and combustible waste shows nitrogen is much involved in biodegradable waste.

Average heating value were calculated and combine with waste composition to estimate total energy of Hoi An waste. The result was showed in table 2. As you can see table, despite its low composition, Plastic waste still contributes the most part of the total energy generated. This can explain by its significant high heating value compared with other waste sources. On the other side, Combustible waste has average heating value and second highest composition result in the second place in heat contribution.

**Table 2. Heating value**

|  |  |  |  |
| --- | --- | --- | --- |
| **Waste category** | **Ave CL (kJ/kg)** | **Compo-sition** | **Total CL** |
| Food | 7684.392 | 40.6 | 3119.863 |
| Yard | 2986.093 | 10.9 | 325.4841 |
| Plastic | 23312.7 | 13.16 | 3067.952 |
| Paper | 9615.846 | 9.2 | 884.6578 |
| Combustible | 11359.69 | 16.6 | 1885.708 |
| Recyclable | 0 | 8.8 | 0 |
| **Total** |  |  | 9283.665 |

Figure 1 showed us a visualized data of what was explain in table 2. We can increase efficiency by remove incombustible content like Metal and Glass or high moisture content like Food and Garden waste.

**Figure 1. Composition and low heating value of each waste categories.**

One of the most important criteria of incineration treatment is reducing waste amount. Our experiment finds out that if incinerated, Hoi An waste can reduce up to 88% of weight as the result showed in table 3. We also can reduce it more if use separate treatment for recyclable and composting waste. Besides, Metal and Glass waste can reduce heat generated and cause damage to the incinerator.

**Table 3. Prediction of waste amount reduction after incinerate**

|  |  |  |  |
| --- | --- | --- | --- |
| **Waste category** | **Ash** | **Compo-sition** | **Residue** |
| Food | 2.384 | 40.6 | 0.968 |
| Yard | 8.435 | 10.9 | 0.919 |
| Plastic | 3.455 | 13.16 | 0.455 |
| Paper | 9.179 | 9.2 | 0.844 |
| Combustible | 5.785 | 16.6 | 0.960 |
| Recyclable | 100 | 8.8 | 8.8 |
| **Total** |  |  | 12.947 |
| **Japan std** |  |  | 13.594 |

Some scenarios were set up to find out what benefit we can achieve if separate waste before incinerate. Figure 2 showed the increase in calorific value if Food waste and Recyclable waste was separated.

**Figure 2. The increase of calorific value.**

**Figure 3. Change in residue position.**

Figure 2 show the change in residue position of each scenario. The most effective way to reduce residue amount is separating Recyclable waste because it is incombustible matter.

CO2 emissionwas calculated for each waste category and shown in table 4.

**Table 4. CO2 emission in each waste categories**

|  |  |  |  |
| --- | --- | --- | --- |
| **Waste category** | **CO2 (kg/w-kg)** | **Compo-sition** | **Total CO2** |
| Food | 0.372 | 40.6 | 0.151 |
| Yard | 0.391 | 10.9 | 0.043 |
| Plastic | 2.051 | 13.16 | 0.270 |
| Paper | 1.093 | 9.2 | 0.101 |
| Combustible | 1.173 | 16.6 | 0.195 |
| Recyclable | 0 | 8.8 | 0 |
| **Total** |  |  | 0.759 |

Plastic waste has the highest CO2 emission due to its high carbon composition. Among six waste categories, Plastic waste is not a major part. Therefore, its contribution in total emission is reduced. This is the same situation with calorific value.

1. **CONCLUSION**

This study built a basic data of municipal solid waste in Hoi An. It provided detail about chemical elements component of Hoi An waste. Heat value was 9.3MJ/kg and suitable for incineration treatment. We recommend to separate Food waste and other recyclable waste in order to increase incinerator efficiency. If we are able to remove Food waste, heat value will increase 10% as current, and even further, 30% if also remove incombustible waste. In term of reducing waste to landfill, this study showed that incinerate is very effective treatment with more than 80% of waste reduction. CO2 emission is about 0.759 kg per 1 kg of waste incinerated.

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