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Carbon Footprint Evaluation for the Traditional Pottery Village - A Case Study in Hoi An City, Vietnam

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This study aims to evaluate the carbon footprint (CF) value of pottery products in a traditional village in Hoi An City (HAC), Vietnam. Whereby, the flows of materials and energy are presented to identify emission sources from the manufacturing process. Also, CO_{2-eq} emission from energy consumption and fuel combustion was calculated, global warming potential from pottery production in HAC was estimated by IPCC method. The result indicates that the CF of pottery product range from 1.88 – 2.07 kg CO_{2-eq} per pottery product due to the difference in the capacity of the furnace. For a batch of production, about 1.503 tons of CO_{2-eq} emitted from combustion (99 %) and electric energy consumption (1 %). This study also reveals that about 1.9 Gg CO_{2-eq} emits annually from pottery production activities in this village, which is a significant GHG emission to the environment. Furthermore, some suggestions are given aims to reduce CF value towards establishing eco-products.

1. Introduction

Recently, climate change and global warming have become urgent problems that the human is facing and struggling to reduce. CO_2 that is generated from natural disaster and human activities, is one of the causal factors of climate change and global warming potential (GWP) (Muhammad Rozaid et al., 2019). During the period of industrial development, the concept of the product's carbon footprint (CF) has been emerging to establish the strategy of greenhouse gas (GHG) mitigation and develop the eco-products. The study on CF of products is quite widespread in developed countries, but it does not seem to be mentioned in developing countries. This can be justified by the lack of attention to the environment in the priority period for economic development. In the context of the increasing severity of global climate change, the lack of information on emissions from production in developing countries may be a gap in global climate change management. Also, emission mitigation is the collective responsibility of the international community; the emission assessment and mitigation solutions in developing countries should be promoted. According to the report of "A low carbon society", Vietnam is known as one of the poor countries, would be the most seriously affected by climate change. Vietnam has not paid attention to reduce CO_2 emissions. In the view of long term development, if it does not have any intervention of batement countermeasures, Vietnam may significantly contribute to making global warming worsen (Yuzuru et al., 2012).

While the concept of CF has become popular and widely studied for industrial, technical and food products, it seems to be limited in the study for the ceramic industry (Karin, 2014). Furthermore, the CF value of ceramic products has mainly evaluated for big capacity production and modern manufacturing in developed countries. Whereas, ceramic products in developing countries are produced by traditional and manual technology with a small capacity. In fact, the technological process of ceramic production may not be the same in different countries. Also, the CF of ceramic products may be different due to the variety of technological processes, the raw materials, kinds of fuel and types of the products. In Portugal, Paula et al. (2014) indicated that the CF value of various ceramic products is dissimilar (Table 1). Furthermore, Junxia et al. (2012) indicated that a ceramic tile factory in China generated 16.42 kg CO_{2-eq}/m^2 of product. Nevertheless, the emission of CO_2 may be reduced by 31.3 % and 16.7 % by substituting coal with natural gas, and with diesel oil. This information reveals that there is no standard CF value for ceramic products. It is only identified from its manufacturing

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process, also study on reducing emission by appropriate and optimal alternatives is necessary for each case study.

Table 1: The carbon footprint value of ceramic products in Portugal

Product	CF value (kg $CO_{2\text{-eq}}$)		Fuel
Ornamental earthenware	1.22 /product	2.87 /kg of raw material	Electric + Natural gas
Brick	0.51 /product 0.28 /product	0.12 /kg of raw material	Electric + Natural gas Electric + Biomass
Roof tile	0.78 /product	0.31 /kg of raw material	Electric + Natural gas
Wall and Floor tiles	11.29 /m^2	0.58 /kg of raw material	Electric + Natural gas

This study is a case study on the evaluation of the CF and estimation of the emission from a typical traditional ceramic manufacturing in Vietnam. The aim of this study is to (i) evaluate the CF of pottery products, (ii) estimate the global warming potential from a traditional pottery industry in HAC and (iii) suggest the solutions to reduce the emission. This study can contribute to evaluating emission from industry activities of the local area, also forming an overall assessment of carbon emission in Vietnam.

2. Methodology

2.1 Study site – Hoi An City, Vietnam

HAC is a small tourist city in the centre of Vietnam (Figure 1). In the area of 6,171.25 ha, HAC has 94,331 people of the population and welcomes 2,517,217 arrivals (Song Toan et al., 2019c). Tourism is the key activity which brings substantial revenue to the city (Giang et al., 2017b). Recently, the tourism industry has been developing quickly lead to the extensive evolution of commercial tourism businesses such as accommodation, dining and shopping industry (Song Toan et al., 2019a). Furthermore, the traditional handicraft production villages are becoming fascinating tourism destinations which attract many tourists and bring substantial benefits to local people (Song Toan et al., 2018). One of these villages is Thanh Ha ceramic village that is the most polluted area in HAC (Department of Statistics of HAC, 2017).

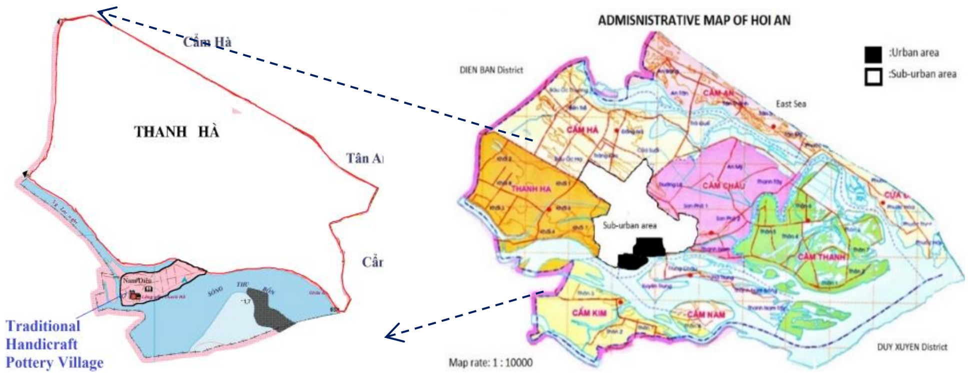


Figure 1: The location of traditional handicraft ceramic village in Hoi An City, Vietnam

The main production activities in the ceramic village are burning the building, household, and interior products that are made of clay at a high temperature for a long time. The traditional heating technology is the firing of wood and coal in a furnace. That is the primary source of environmental emissions. In the ceramic village, there are 30 facilities that produce household and interior products with the capacity around 1,000 product/facility.mth. Also, 75 facilities produce building materials (bricks) with the capacity by 5,000 product/facility.mth.

Table 2: Characterisation of Hoi An City

Characterisation	Number	References
Area (ha)	6,171.25	(Giang et al., 2017a)
Population (people)	94,331	(Song Toan et al., 2019b)
Tourist arrival (2016)	2,517,217	

2.2 Analysing production process

The production process of pottery products is presented in Figure 2. Whereby the raw material, clay, is soaked with water in 24 h to soften. Then the wet material is kneaded by hand or foot to increase the plasticity and adhesion of clay. The pre-products are shaped one-by-one by hand and moved to the yard for sun exposure to fix the shapes. The patterns on the products are sculpted by skilled workers before sun exposure again to reinforce the hardness of the products. The burning process is an important period that aims to harden the elasticity of clay to create rigidity and durability of the products. The burning time in the furnace is around 24 h. Also, the complete production process as above takes from 25 d to 1 mth.

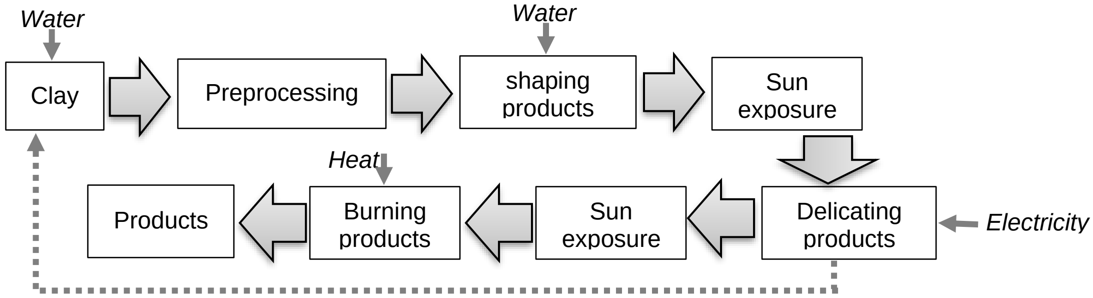


Figure 2: The production process of the ceramic products

There are two types of burning furnace with volume by 7 m^3 and 2.5 m^3. The bigger the volume of the furnace is, the bigger the capacity of the facility is. Also, the amount of fuels for burning may be proportional to the volume of the furnace. In general, the 7 m^3 furnace can contain about 1,000 products for drying in a batch of the production.

2.3 Evaluating the value of carbon footprint and greenhouse gas emissions

In this study, the value of CF will be evaluated by the product. According to the production process, the sources of GHG emission are identified as energy supply (electricity) in shaping and peeling processes, and the combustion process (by coal and wood). The CF of the product for each facility is calculated by Eq(1).

$$CF=\frac{\sum_{ij} E_{ij}}{\sum_{j} n_j} \tag{1}$$

Where E_{ij} is the emission from the source i in facility j, n_j is the number of products in facility j. The emission factors of primary energy can be calculated according to default factors listed in IPCC. Whereby, the emission factors of coal and electricity are 1.978 tCO_{2-eq}/t and 1.052 tCO_{2-eq}/MWh. The data from the production process was collected from all facilities in the CV. The conversion coefficient to CO_{2-eq} from N_2O is 298 (Song Toan et al., 2017). In term of long-term impact, global warming potential (GWP) is a measure of how much heat GHG traps in the atmosphere up to a specific time horizon, relative to CO_2. According to IPCC method, GWP is defined as the ratio of the time-integrated radiative forcing from the instantaneous release of 1 kg of a trace substance relative to that of 1 kg of CO_2. Also, GWP is calculated by Eq(2):

$$GWP(x)=\frac{\int_0^{TH} a_x.[x(t)]dt}{\int_0^{TH} a_r.[r(t)]dt} \tag{2}$$

where TH is the time horizon which is considered as 100 y in this study, a_x is the radiative efficiency, x(t) is the time-dependent decay.

3. Results and discussions

3.1 Material and energy flow analysis

For the furnace of 7 m^3, about 1,000 products will be produced in a batch. Figure 3 illustrates the material flow of pottery in a batch of production. Notably, about 4.4 t of clay is used as raw material. The clay is gathered to the facility by suppliers. There is no vehicle transportation in the manufacturing area. The pre-treatment stage of raw materials, shaping and paring products are conducted manually. Electricity (32.3 kWh/batch of production) is mainly consumed by lighting and civil equipment. Also, 788 kg of coal and wood are the main fuels that provide for the furnace during the firing process. Correspondingly, about 1.5 t of $CO_{2\text{-}eq}$ is emitted from production, whereby, burning fuels in the furnace is the biggest source of the emission by 98.7 %.

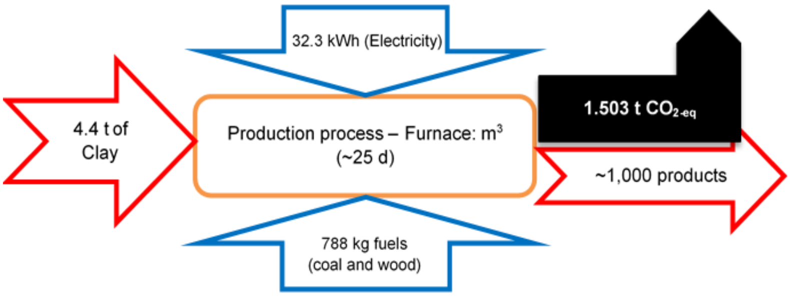


Figure 3: Material flow and emission in a batch of pottery production

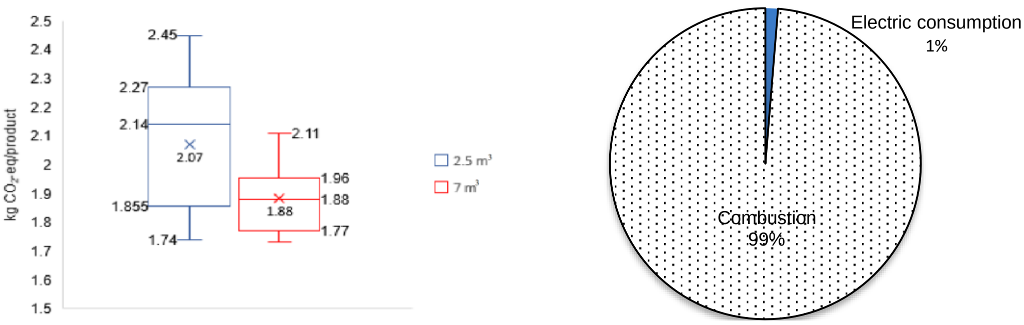
Worldwide, burning fuels is a common way that is applied widely in the incinerators and thermal power plants. Also, the exhaust gases from combustion are required to treat before emission to reduce pollution. Nevertheless, in this village, the furnace is a traditional open burning (Figure 4) without exhaust gas treatment systems. Thus, in the furnace, the natural combustion may take place with the incomplete combustion process. This causes some problems of release energy and produces carbon monoxide, which is a poisonous gas.

(a) *(b)*

Figure 4: (a) gathering pre-products for combustion; (b) burning wood and coal in the furnace

3.2 The carbon footprint of pottery product and global warming potential

According to the material flow analysis, the consumption of electricity and fuels is the critical source of emission. To evaluate the CF value of a pottery product, the survey was conducted on two types of furnaces such as 2.5 m^3 and 7 m^3. Figure 5 indicates that there are differences in the CF value of pottery product in the furnace by 2.5 m^3 and 7 m^3.



(a) (b)

Figure 5: (a) Carbon footprint values of pottery product in different capacity of the furnace, and (b) the proportion of $CO_{2\text{-}eq}$ emission from sources

Notably, CF value ranges from 1.74 to 2.45 kg/product for 2.5 m^3 of the furnace and from 1.77 to 2.11 kg/product for 7 m^3 of the furnace. This result reveals that the furnace by 2.5 m^3 has a wider range of CF value than that of the furnace of 7 m^3. Also, the mean value of CF from furnace 2.5 m^3 is higher (2.07 kg/product) than that from the furnace of 7 m^3 (1.88 kg/product). This disparity of CF values of the pottery product from various furnaces may be explained by the difference in heating performance at the same time of burning and the number of products in the furnace.
Table 3 shows the CF of ceramic products that are defined in a variety of the unit. Notably, Junxia et al. (2012) presented that the CF of final ceramic products is 16.42 kg/m^2. The spray drying and firing activities are the primary sources of emission with proportions of 26 % and 57 %. Likewise, the average CF of brick manufactured in Portugal was estimated to be 0.51 kg/brick (Paula et al., 2014). Also, the firing process was responsible for about 60 % of the total CF. Another study identified the CF of ceramic products by per ton of product. Whereby the CF value ranges from 263 to 338 kg $CO_{2\text{-eq}}$/t product due to the different manufacturing technologies. Also, electric energy and thermal energy consumption account for 8.7 % and 91.3 % of the total $CO_{2\text{-eq}}$ emission (Monfort et al., 2011). The CF of ceramic products in various studies may be different due to the variety of manufacturing technologies.

Table 3: The Carbon footprint of ceramic products in different definitions

	Unit	Value	References
CF of ceramic products	kg $CO_{2\text{-eq}}$ per m^2 of product	16.42	(Junxia et al., 2012)
	kg $CO_{2\text{-eq}}$ per brick	0.51	(Paula et al., 2014)
	kg $CO_{2\text{-eq}}$ per ton of product	263 - 338	(Monfort et al., 2011)
	kg $CO_{2\text{-eq}}$ per general product	1.88 – 2.07	*This study*

For the ceramic village, the volume of $CO_{2\text{-eq}}$ emits from a batch of ceramic production is about 1.503 t. Also, the annual emission from manufacturing activities in the ceramic village is estimated at 1.9 Gg $CO_{2\text{-eq}}$ per year (Figure 6). Using the traditional furnaces with manual production process is said to be a unique feature of craft village in Thanh Ha, Hoi An which may attract the tourist. Also, the recent income of the residents in the ceramic village has increased from tourism activities, not from production and business activities. Nevertheless, the old firing technology in the manufacturing process may cause the emission of total exhaust gases from combustion without treatment.

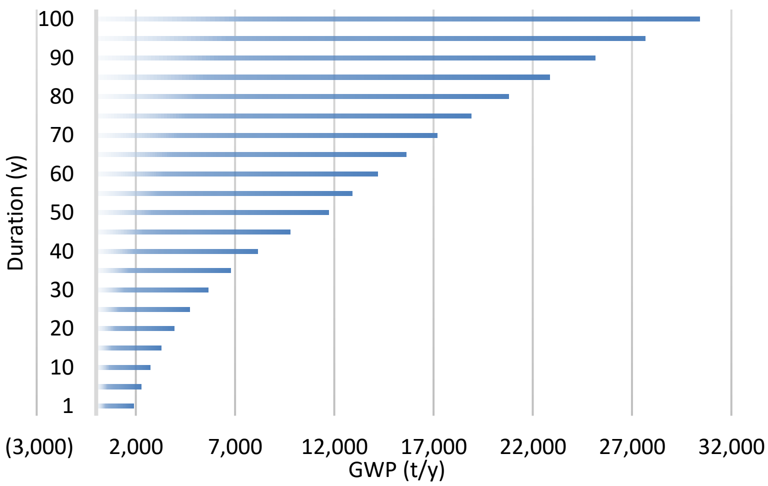


Figure 6: Global warming potential from traditional ceramic production in Thanh Ha village, Hoi An City

The development that the economy is given top priority without considering environmental protection factors is unsustainability. For an industrial scale, some solutions to CO_2 reduction were suggested in China such as substituting coal with natural gas and applying microwave drying technology (Junxia et al., 2012). Likewise, the ceramic production industry in Spain also recommended that technological changes in the facilities that consume thermal energy and/or substitution of current energy sources (Monfort et al., 2011). In order to develop an eco-tourism business in the ceramic village based on saving the traditional value of ceramic production, the reduction of pollutions and emissions should be considered by improving the exhaust gas treatment system. Furthermore, the practical experience activities for tourists should focus on shaping product by hand. Also, the ancient furnace should be preserved for display. The manufacturing furnaces should be designed with a large capacity and applied new technologies instead of many individual small furnaces. Last but not least, improvement of manufacture facilities should be invested and supported by the government. Also, the regulations of emission should be controlled, and the severe sanctions should be promulgated towards eco-tourism industry and sustainable development.

4. Conclusions

This study aims to analyse the process of pottery production, identify emission sources and evaluate CF of pottery products. The results show that the average emission pottery manufacturing process is 1.503 t $CO_{2\text{-eq}}$ in a batch of production. Whereby, combustion and electric consumption account for 98.7 % and 1.3 % of the total emission. Furthermore, the annual emission of greenhouse gases from ceramic manufacture in the ceramic village is estimated at 1.9 Gg $CO_{2\text{-eq}}$. In order to reduce emission, the changes in fuels and combustion should be considered. The new furnaces with an exhaust gas treatment system should be invested for manufacture, while the traditional furnaces are suggested for tourist exhibition. These solutions may contribute to reduce CF of pottery products and develop eco-tourism industry in the ceramic village.

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