Study of Life Cycle Assessment of Bricks and the Impacts to the Environment in Malaysia

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Abstract. Life cycle assessment (LCA) is conducted in order to evaluate the environmental impacts of products chosen from the manufacturing phase and the end-of life cycle of the material and in clay brick and concrete were chose as the observed products. Brick is one of the important construction materials that can be seen at the surrounding. Main objective for this study is to investigate the impact of production of different types of brick to the level of emissions of carbon dioxide to the environment. Four stages of life cycle assessment were conducted before the result for the study analysis can be obtained and that stages including goal and scope definition, life cycle inventory (LCI), life cycle impact assessment (LCIA) and the interpretation part. The results obtained from the simulation of the Simapro shown that the concrete contributes more negative impact compared production of clay brick in terms of global warming, ozone depletion, formation of fine particulate matter and ozone formation. Manufacture of clay brick contributes more negative impact to the ionizing radiation, freshwater eutrophication and mineral resource scarcity.

1. Introduction
The building division utilize between 30% and 40% of society’s total energy usage and accountable for almost 1/3 from the total carbon dioxide emissions into the atmosphere. As the construction in Malaysia is growth rapidly thus, increasing numbers of construction material produced every day. Brick is one of the traditional construction materials used which estimated millions of bricks are manufactured to support the construction required numbers of bricks. This is one of the reasons studies should be conducted in order to investigate the impact produced from the production of clay brick and concrete bricks [1]. Brick is most common construction material that can be seen in our daily life even at our wall without knowing what the environmental impact was coming from this material. Various types of bricks can be found these days for example sand lime bricks and engineering bricks. Clay and concrete brick are types of brick that usually being used for construction in Malaysia.

CO₂ emissions has big impacts towards the environment which around 60% of the greenhouse gases are comes from the carbon dioxide emission and a study to identify way to lower the CO₂ gasses released is a major concern as to protect control the effect on climate change [2]. This responsibility is not only on the authority’s shoulder, but the society need to play their own role. Globally, 1.6 billion tons of CO₂ produced every year which around 8% from the total emissions of Carbon Dioxide from human activities. In the manufacturing of the clay brick, combustion phase contributed to high quantity of emission of SO₂ and NO₂ after the emissions of CO₂ which takes the first place as the highest percentage of gasses released to the atmosphere [3]. The main concern is actually the condition of the air that we breath in since the production of both products is actually contaminating our clean
air. IEA data on 2018 stated that 35 Mt of CO₂ has been released from the industrial activities. Action needs to be taken by the engineers to investigate the process of manufacturing the construction material as for the outcome good decision in choosing a sustainable material can be done.

The objective of doing this research is to analyse the environmental issues occurred from the manufacturing of the clay brick and concrete brick. Next, to identify types of brick that has less impact in terms of carbon dioxide emissions and more sustainable types of brick to use.

2. Application of life cycle assessment
A tool used to evaluate the environmental impact over the life cycle of a product, process or the operation involved [2]. There are four phases of LCA in conducting the LCA study, which are the Goal and Scope Definition, Life Cycle Inventory Analysis (LCI), Life Cycle Impact Assessment (LCIA) and Interpretation.

Goal and scope phase is where the reasons of conducting the research were identified and the purpose goal and scope definition being identified and expressed in terms of the functional units act as the prove of the functions that the system works. The outcome from the LCI phase is a collection of the inputs and the outputs of the product of the life cycle which related to the functional unit. Then, the objective of doing the LCIA is to enhance the understanding of the magnitude and significance of the possible environmental impacts from the analysis [4]. Impact Assessment phase is known as the Valuation or Value-choices which the most arguable part in LCA because it suggests the subjective value understanding in deciding on the importance of different impacts. For the interpretation part, the results observed from the earlier phases are analysed as for the goal and scope phase to achieve the conclusions and provide suggestion for future use. Life cycle analysis is a beneficial method used for the observation and documentation to reduce the environmental effect of the materials or productions.

2.1. Methodology
Four phases of the life cycle assessment being applied in the methods towards the investigation of the environmental impacts of both products clay brick and concrete brick.

2.1.1. Goal and scope definition. 1 Kg of brick is the functional unit applied for this study and every single input of raw materials, energy utilization, transportation, release of waste and wastewater must stick to it as benchmark for both types of bricks. Cradle to gate approach is applied for the boundary system which only considering the manufacturing phase and the acquisition phase of the unprocessed material in the observation. Raw materials used in the clay brick production is only clay and the process of manufacturing the brick are mixing, molding, drying and then firing phase. While for the production of concrete brick, materials used are cement with aggregates, sand and then water. The process occurred are mixing, shaping and curing process.

2.1.2. Life cycle inventory. Site investigation required as to obtain required data such as the size of the brick, raw materials used, fuels consumption and the process of manufacturing of the brick. All of these required data is gain by having phone call interview with the person in-charge from the selected factory.

2.1.3. Life cycle impact assessment. ReCiPe 2016 method is used for the impact assessment as the calculation setups through the Simapro simulation. ReCiPe 2016 method is applied in the impact assessment as an achievable implementation with the combination of midpoint approach. All types of the result of life cycle inventory are linked through 16 midpoint categories to three damage classification. The main highlight in assessing this ReCiPe 2016 assessment is for the global warming which the results of the CO₂ gas emissions [4].

2.1.4. Life cycle interpretation. The results from the Simapro simulation which the outcomes of the inventory analysis were analyzed and evaluated as for to come out with the conclusions of the assessment and hand the recommendations. This phase is where the objectives to be achieved at the end of the interpretation phase. The comparison of the data is made by plotting the results on bar chart
so that easier to evaluate and choose which types of brick is more sustainable to the environment and better for the usage at the construction.

3. Results and discussion
Result and discussion part are the presentation of the data and analysis of the study. This section is where the analysis of the impact of the clay brick and concrete brick to the environment being discussed based on the results from the simulation of Simapro software.

3.1. Functional units
ReCiPe 2016 method has been chosen as the medium of the calculation setups in the analysis and. The functional unit or benchmark of the analysis is 1 kg for both types of brick and considering the raw materials used in the production and the other process happened in the making of the bricks. Table 1 is the data required for the simulation of the Simapro gathered from the interview.

| Characteristic                  | Concrete brick | Clay brick |
|--------------------------------|----------------|------------|
| Brick Weight (Kg)              | 1              | 1          |
| Dimension (m^3)                | 250x125x65     | 250x125x65 |
| Distance travelled of material (Km) | 150           | 100        |
| Load of the Lorry travelled (Tonne) | 10            | 10         |
| Types of raw materials used    | Sand, Aggregate, Cement | Clay |

3.2. Life cycle impact assessment by applying end-point of ReCiPe 2016 method – Characterization analysis
Sixteen (16) categories of environmental impact were applied in the ReCiPe 2016 analysis method through the simulation of the Simapro software shown in the table 2 which proves that this analysis is run in a very detail way. Three main units used in the analyzing are DALY (Disability adjusted life years), Species.yr (species lost in overtime) and USD2013 (U.S dollar reference year in 2013) [5]. Based on the figure 1, the first two categories are focusing on the global warming with two different view which first one is human health and then is the terrestrial ecosystem. Both aspects were more affected by the production of the concrete brick with difference about 14.7%. While the other categories that has been affected more by the concrete brick production are stratospheric ozone depletion, formation of the fine particulate matter, impact of ozone formation and acidification occurred to the terrestrial ecosystem, ecotoxicity on the terrestrial area, impact to the land use and the last category is the scarcity of the fossil resources.

Emissions of carbon dioxide is the main key where all of these categories contributed to the environmental impacts due to the production of the concrete brick. The highest data difference that the concrete brick led is with 67.4% for the ozone depletion of the stratospheric where concrete brick with 1.2E-10 DALY while for the clay brick is only with 3.92E-11 DALY. Ozone depletion can be defined as the event of the ozone layer is getting thinner which allow more UV radiation enter the surface of the earth which endanger the human being. Past studies shown that production of the concrete has contributed to emissions of greenhouse gas which one of the main reasons of the reduction of the thick of the ozone layer and through this analysis is again proves that production of concrete bricks has become one of the reasons why the depletion of the ozone layer happened [6].

Land use for the concrete production also become crucial part because different types of raw materials required to produce one block of concrete brick so that more natural sources from the land need to be collected like the aggregate and sand [7]. More harmful activities towards the land also conducted in order to have the resources. Only 9.02E-11 species.yr for clay brick while 2.75E-10 species.yr for the concrete brick with 67.2% of difference for both results. Strict monitoring is required for the sources collection of the concrete brick’s raw materials as to reduce the number of the species
loss times year and this is important to protect the ecosystem and provide safer environment for all creatures.

**Table 2.** Results of the characterization from the Recipe 2016 of end-point analysis.

| Impact category                                | Unit       | Clay brick      | Concrete brick |
|------------------------------------------------|------------|-----------------|----------------|
| Global Warming, Human Health                   | DALY       | 2.94E-7         | 3.45E-7        |
| Global Warming, Terrestrial Ecosystem          | Species.yr | 8.87E-10        | 1.04E-9        |
| Stratospheric Ozone Depletion                  | DALY       | 3.92E-11        | 1.2E-10        |
| Ionizing Radiation                             | DALY       | 5.81E-11        | 3.47E-11       |
| Ozone Formation, Human Health                  | DALY       | 1.98E-10        | 1.75E-9        |
| Fine Particulate Matter Formation              | DALY       | 2.01E-7         | 3.26E-7        |
| Ozone Formation, Terrestrial Ecosystem         | Species.yr | 1.16E-10        | 2.52E-10       |
| Terrestrial Acidification                      | Species.yr | 1.54E-10        | 2.97E-10       |
| Freshwater Eutrophication                      | Species.yr | 2.73E-11        | 9.57E-12       |
| Terrestrial Ecotoxicity                        | Species.yr | 1.51E-11        | 1.98E-11       |
| Freshwater Ecotoxicity                         | Species.yr | 6.44E-12        | 2.72E-12       |
| Human Carcinogenic Toxicity                    | DALY       | 3.15E-8         | 1.29E-8        |
| Human Non-Carcinogenic Toxicity                | DALY       | 4.11E-8         | 2.41E-8        |
| Land Use                                       | Species.yr | 9.02E-11        | 2.75E-10       |
| Mineral Resource Scarcity                      | USD2013    | 0.00354         | 0.000241       |
| Fossil Resource Scarcity                       | USD2013    | 0.0272          | 0.0275         |

Acidification of the terrestrial also happened more because of the production of the concrete brick with 2.97E-10 species.yr compared to only 1.54E-10 species.yr for the clay brick production. This is a
serious matter where acidification of terrestrial means the changes of the soil properties where the nutrient inside the soil is no longer the same and even turn to bad condition of soil [6]. Acidifying compounds such as nitrogen and sulfur has deposited the nutrients contained inside the soil and even plant cannot stay green for long time once this incident happened. Most of the acidifying compound can be found through the production of concrete brick rather than clay brick.

Main problem happened to production of clay brick is shortage of sources of the clay which proves by the result that shown at the mineral resource scarcity data where almost 94% difference of comparison for the result of clay brick and concrete brick. Only required clay as the raw material for the clay brick formation has led to problem in controlling the extraction of the clay from the sources where this issues irregularly in concrete brick production [6]. Other than that, human carcinogenic also influenced more by the production of the clay brick with 3.15E-8 DALY compared to concrete brick production with only 1.29E-8 DALY. In aspects of exposing human being to cancer, clay brick production has contributed more. This is a very serious matter because cancer is one of the serious diseases which hard to cure so that enforcement to control and avoid this issue from happening without proper precaution plan.

3.3. Damage assessment analysis

In damage assessment analysis, there are three factors being considered as to observe the impacts of both products to environment which are the human health, ecosystems and the resources [5]. The major point here is the impacts toward the ecosystems which including the quality of the air, climate change and even the greenhouse effect. As we can see from the figure 2, concrete brick has more influence in the damage assessment where the human health and ecosystems factors has been affected more due to productions of the concrete brick. While clay brick only has more impact to the resources factor but with not so big difference compared to the impact given by the concrete brick.

![Figure 2](image)

**Figure 2.** Results of the characterization through ReCiPe 2016 of End-Point Analysis based on the results in table 3.

| Damage Category | Unit    | Clay Brick | Concrete Brick |
|-----------------|---------|------------|----------------|
| Human Health    | DALY    | 5.69E-7    | 7.1E-7         |
| Ecosystems      | Species.yr | 1.3E-9     | 1.9E-9         |
| Resources       | USD2013 | 0.0308     | 0.0277         |

Human health and the ecosystems in more danger condition due to concrete brick production compared to clay brick production shown in table 3. 7.1E-7 DALY for damage assessment from human health category for concrete brick while only 5.69E-7 for clay brick which almost 20% more dangerous and this is not small amount not to be worried about and more precaution need to be prepared for the concrete brick production. For the ecosystem category, concrete brick also won this one where the result shown that 1.9E-9 species.yr for the concrete brick and 1.3E-9 species.yr for the
clay brick production and this result is based on the evaluation of species loss times year. This result shown that the ecosystem we live in nowadays is threaten by the production of the concrete brick. For ecosystems category, concrete brick has contributed to 31.6% damage more than clay brick to the ecosystems.

Only for damage to the resources is more to clay brick production and this happened because one main raw material required for the clay brick production which is clay and amount of clay required for every tonne of production is very high so that the resources has become limited [8].

3.4. Life cycle impact assessment by applying mid-point of Recipe 2016 method – Characterization analysis

Mid-point analysis is as same as the end-point analysis based on table 4 but with different unit used for the results of the impact categories which more focus on the type of gas emitted for each impact category for example the amount of carbon dioxide is being calculated at for the global warming category and amount of sulphur dioxide released in terrestrial acidification is being compared for both types of brick. Our main focus in figure 3 is the global warming category where concrete brick production released 0.371 Kg CO2 eq while 0.317 Kg CO2 eq for clay brick production. The higher the carbon dioxide emissions, the lower the quality of the air we breathed in [9]. This is where more strict enforcement required for the concrete brick production as to provide better quality of the air [10].

Next, also from the concrete production, high amount of greenhouse gases released have been analyzed from the mid-point analysis where more than 50% difference of amount of Chlorofluorocarbon (CFC) released detected from the concrete brick compared to clay brick production. This is a very serious matter to be highlight and actions required from the authorities so that constant monitor of this type brick production can be provided as to ensure constant check of the amount of CFC gases released so instant action can be taken if the abnormal amount of CFC released is reported. Our ozone layer is part of the earth that we must protect because it is the layer protection to avoid us from exposed to high amount of UV radiation that can affect the skin and more negatives impact might happened.

The other serious category is the ozone formation where both the human health and terrestrial ecosystem are in danger due to production of the concrete brick. 54.5% for the human health factor while 53.8% for terrestrial ecosystem factor of difference for amount of Nitrogen Oxides for both types of brick. Nitrogen Oxide is one of the air pollutants which endanger the human being and the other living things. Different percentage with more than 50% is something to be worried especially who lives nearby the production area. Respiratory disease is the main concern based on the results obtained because most of the unit used is a measurement of the amount of gas released for each impact categories and most of it are dangerous pollutant which already inside the air particle that we breath in daily [11].

For the clay brick production based on the mid-point analysis, the most-risky category is the human carcinogenic and non-carcinogenic toxicity results where 59.1% and 41.3% of differences for the comparison of the results from the analysis for both categories of impact. Carcinogenic is substances that can cause cancer which very dangerous for human being and clay brick production has produced this hazardous substance more than the amount produce from concrete brick production [7]. From the midpoint analysis, the carcinogenic substance used for the evaluation is 1,4-dichlorobenzene as the human toxicity measurement unit.
Figure 3. Results of the characterization through ReCiPe 2016 of mid-point analysis based on the results in table 4.

Table 4. Results of the characterization from the Recipe 2016 of mid-point analysis.

| Impact category                              | Unit             | Clay brick | Concrete brick |
|----------------------------------------------|------------------|------------|----------------|
| Global Warming                               | Kg CO2 eq        | 0.317      | 0.371          |
| Stratospheric Ozone Depletion                | Kg CFC11 eq      | 7.38E-8    | 2.26E-7        |
| Ionizing Radiation                           | kBq Co-60 eq     | 0.00684    | 0.00409        |
| Ozone Formation Human Health                 | Kg NOx eq        | 0.000877   | 0.00193        |
| Fine Particulate Matter Formation            | Kg PM2.5 eq      | 0.00032    | 0.000518       |
| Ozone Formation, Terrestrial Ecosystem       | Kg NOx eq        | 0.000903   | 0.00195        |
| Terrestrial Acidification                    | Kg SO2 eq        | 0.00725    | 0.0014         |
| Freshwater Eutrophication                    | Kg P eq          | 4.08E-5    | 1.43E-5        |
| Marine Eutrophication                        | Kg N eq          | 3.04E-6    | 3.0E-6         |
| Terrestrial Ecotoxicity                      | Kg 1,4-DCB       | 1.32       | 1.74           |
| Freshwater Ecotoxicity                       | Kg 1,4-DCB       | 0.00931    | 0.00394        |
| Marine Ecotoxicity                           | Kg 1,4-DCB       | 0.0126     | 0.00603        |
| Human Carcinogenic Toxicity                  | Kg 1,4-DCB       | 0.00949    | 0.00388        |
| Human Non-Carcinogenic Toxicity              | Kg 1,4-DCB       | 0.18       | 0.106          |
| Land Use                                     | m2a crop eq      | 0.0102     | 0.031          |
| Mineral Resource Scarcity                    | Kg Cu eq         | 0.0153     | 0.00104        |
| Fossil Resource Scarcity                     | Kg oil eq        | 0.075      | 0.0647         |
| Water Consumption                            | m³               | 0.000639   | 0.00233        |
| Global Warming                               | Kg CO2 eq        | 0.317      | 0.371          |
4. Conclusion

Construction industry nowadays must prioritize the material that has low negative impact to the environment because the product used might be one of the sources of the air pollution, degradation of soil or even the depletion of the thickness of ozone layer. From the damage analysis, we can see that concrete brick has been proved as the product where the production contributes more negative impact to the environment compared to production of clay brick which referring to the three damage categories which are human health, ecosystems and resources.

There are a few suggestions and recommendations that can be made regarding the discussion above in order to provide better management of the concrete brick and clay brick production:

- Application of high quality filtration equipment at the factory
- Usage of sun-dried clay brick in construction
- Enforce more strict law by the authorities to control the consumption of the natural resources used
- Use higher loads carrying capacity lorry as to reduce number of transportations involved in the production

5. References

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