International Journal of GEOMATE, June, 2018 Vol.14, Issue 46, pp.107-112
Geotec., Const. Mat. & Env., DOI: https://doi.org/10.21660/2018.46.7365
ISSN: 2186-2982 (Print), 2186-2990 (Online), Japan

THE UTILIZATION OF WATER FOOTPRINT TO ENHANCE THE WATER SAVING AWARENESS: CASE STUDY OF A CERAMIC PRODUCT

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*Corresponding Author, Received: 25 July 2017, Revised: 04 Aug. 2017, Accepted: 09 Sept. 2017

ABSTRACT: One of the methods to increase the water saving awareness is the water footprint which is based on the calculation of water usage incurred during the whole life cycle of a product. The case study in this research is the water footprint computation of a ceramic product, a jug. The life cycle of a ceramic jug was studied by focusing on the stage of cradle to gate, resource extraction and manufacturing. The calculation of water footprint is based on the ISO 14046: 2014 guidelines. Another objective of this research is to verify that the water footprint can be utilized effectively as a tool to enhance the awareness and the perception of the ceramic business related personnel towards the water saving issue. According to the research results, the paired t-test statistics were utilized to test the difference in the awareness level before and after introducing the water footprint concept to the business owners. The results indicate that the awareness is significantly built up after the application of water footprint education. This will lead to the sustainable use of water in the ceramic business.

Keywords: Awareness, Ceramic product, Water footprint, Water saving

1. INTRODUCTION

The environment issues have come to the attention of people since the last decade and they are ranged from global warming to water drought. Although the society starts to be aware of the importance of the environment, the pathway which leads the conservation of the environment, in reality, is still unclear and not practical. As a result, the different types of ecological footprints, such as carbon footprint, are introduced in order to be used as a tool to assess the carbon emission due to human activities with the objective of having another medium for carbon trade. Similarly, water footprint is the concept introduced by A.Y. Hoekstra from UNESCO-IHE in 2002 and it is the amount of freshwater used to make goods or provide services. The water footprint of every products or service will reflect the tangible amount of used water which is easy to understand for people who are related to any parts of the life cycle of products or services. The objective of this research is to study the potential of water footprint as a tool to increase the level of awareness among the people.

2. REVIEW

According to Badruzzaman, Oppenheimer, Hess, Smith, Upson, Postle, and Jacangelo [1], the purposes of water footprint are differentiated into four categories, the measurement of water consumption, the identification of environmental influence in term of numerical results due to the consumption, the risk assessment regarding the consumption, the introduction of strategies leading to the reduced consumption. Noga and Wolbring [2] conducted a study on the perceptions of water ownership and water management among one hundred and sixty-four individuals. The questionnaires were used as a research instrument and the questions regarding the water footprint were included. The results reveal that the questionnaire respondents are concerned with the water scarcity. Another finding is that education regarding the water conservation and recycling are needed and it is key leading to the rise of awareness. Moreover, most respondents agree that the water footprint might be a potential tool leading to alleviate the awareness. A study by Attari [3] also points out that the accuracy of water use perception (water footprint) is more precise than other means of perception measurement in the similar category, e.g., carbon footprint.

Hoekstra and Chapagain [4] signify that the amount of water consumed for the production of services and commodities is the clear definition of water footprint and this number directly reflects the water use of the population in a nation. Their study is also extended to the identification of four factors affecting the amount of water footprint, namely, the volume of consumption, consumption pattern, climate (growth conditions) and agricultural practice. Gerbens-Leenes and Hoekstra [5] identify that there are two parts of water footprint, i.e., operational water footprint and supply chain water footprint. Another way to categorize the water footprint is based on the types of freshwater sources, blue, green and gray water footprint. The blue water footprint is the amount of water retrieved from the surface and groundwater while the green water footprint is the water evaporated from the rainwater in the soil. On the other hand, the gray water footprint is the polluted water due to the manufacturing activities. According to Čuček, Klemeša, and Kravanj [6], the footprint is a powerful indicator used to measure the level of sustainability in term of the environment, society and economy. Moreover, the research regarding the agrifood products shows that water footprint has the significant impact on the perception of customers [7]. Therefore, this situation might lead to the opportunity of increasing the market share of green products. The study by Baabou and Galli [8] on the ecological footprint of various coastal cities in the Mediterranean region indicate that the ecological footprint including the water footprint plays an important role in shaping the design of sustainability policies and public attitude due to the environment.

3. METHOD

In this study, there are two folds of processes used to carry on the research, the total water footprint calculation and the increasing level of awareness after the workshop regarding water footprint were introduced. The main concept of water footprint calculation is based on the identification of the framework of life cycle analysis. In term of the framework, there are five steps incorporating with the framework creation as follows:

-identify the studied impact
-identify the studied product
-identify the functional unit of product
-identify the period of data collection.

The initialization of the framework is shown in the following Fig. 1.

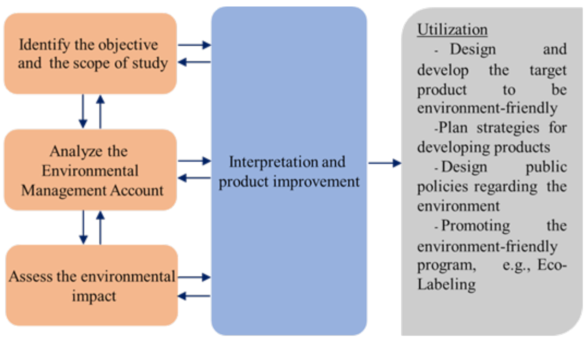

Fig. 1 Research framework.

The life cycle analysis is depicted in Fig. 2 as material flow analysis (MFA) which shows the scope of product life assessment (in this case, cradle to gate). For cradle to gate, the analysis focuses the life cycle only from resource extraction (cradle) to factory gate. However, if it is cradle to grave, the scenario will cover the whole life cycle of a product (resource extraction, manufacturing, distribution, use and disposal). Moreover, another critical function of MFA is to identify the flow of materials in the manufacturing process of a certain product. Elaborately, MFA breaks the whole process into sub-processes and each sub-process has inputs (resources), waste (emission), and output [9]. Another important method used to assess the potential of water footprint as a tool to raise the level of awareness is the questionnaires. They were distributed before and after the workshop regarding the water footprint was carried on. The paired t-test was utilized to signify the different level of awareness after the workshop.

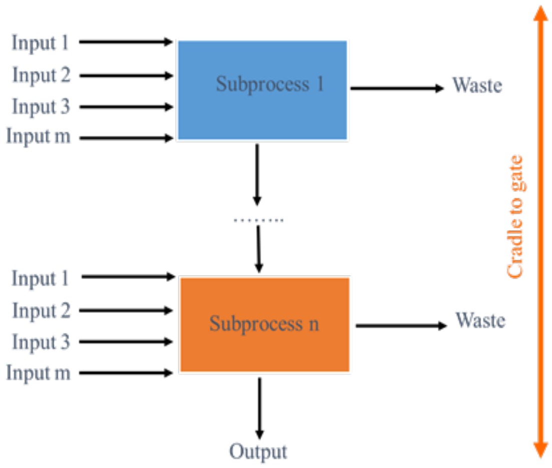

Fig. 2 Material flow analysis.

4. RESEARCH PROCEDURES

Since the target group of this study is the ceramic business owners, executives and people of the shop floor, the life cycle analysis of the ceramic product is limited to only cradle to gate which covers the impact from a partial product life cycle, i.e., resource extraction and manufacturing. A ceramic product which is used as the case study is a ceramic yellow jug for serving water. The weight of this jug is 500 gram and it is shown in Fig. 3. Therefore, the function unit of product is a jug. To illustrate the life cycle analysis, the manufacturing flowchart is depicted in Fig. 4 and it composes of six steps as follows: forming and finishing, biscuit firing, glazing, glost firing, polishing, and packaging. Each step has different inputs. For example, the first step, i.e., forming and finishing, needs the input of prepared ceramic body weighing 450 gram to produce a jug. Moreover, the electric power of 0.004 kWh is also used to supply the jolly machine in order to form and finish a jug.

Fig. 3 Ceramic jug.

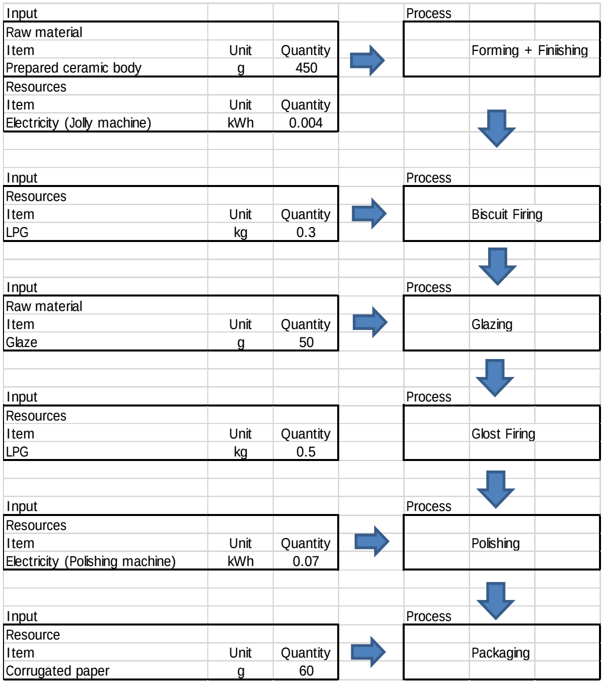

Fig. 4 Manufacturing flowchart.

5. LIFE CYCLE ANALYSIS

According to the material flow diagram, there are three raw materials required to manufacture a ceramic jug, prepared ceramic body, glaze and corrugated paper (for packaging). Due to Table 1 and 2, the water footprint of the prepared ceramic body (l/kg) is equal to 14.4 while the one of glaze is 65 l/kg (the data was forwarded from the suppliers who conducted the in-house experiment to determine the water footprint data). On the other hand, the water footprint of corrugated paper (l/kg) in Table 3 is equal to 38.9 [10]. Therefore, the total water footprint due to the resource extraction equals 6.5+3.25+2.334 = 12.084 liter. The forming, finishing and polishing tools are run by electricity which is generated by natural gas. However, the fuel used is LPG (liquefied propane gas). The water footprint calculation for electricity and LPG is shown in Table 4 and 5.

Table 1 Water footprint of raw material extraction (prepared ceramic body)

Resource	Weight (kg)	Water Footprint (l/kg)	Total(l)
Ceramic body	0.45	14.4	6.5

Table 2 Water footprint of raw material extraction (ceramic glaze)

Resource	Weight (kg)	Water Footprint (l/kg)	Total (l)
Glaze	0.05	65	3.25

Table 3 Water footprint of raw material extraction (corrugated paper)

Resource	Weight (kg)	Water Footprint (l/kg)	Total (l)
Corrugated paper	0.06	38.9	2.334

The water footprint calculation shown in Table 4 and 5 obviously show that the generated electricity is contributed to both blue and gray water footprint. Since the blue water footprint equals 5.6 l/kWh while the gray water footprint is 5.7 l/kWh, the generation of electricity causes more polluted water than the used water (the amount of gray one is higher than the blue one.). In conclusion, the electricity used to manufacture a jug leads to the water footprint of 0.8362 liters.

Table 4 Total amount of electricity used

Resource	Process	Quantity (kWh)
Electricity	Forming&Finishing	0.004
Electricity	Polishing	0.07

Table 5 Water footprint of electricity used

Process	Blue Water Footprint (5.6l/kWh)	Gray Water Footprint (5.7l/kWh)	Total(l)
Forming& Finishing	0.0224	0.0228	0.0452
Polishing	0.392	0.399	0.791
			0.8362

According to Table 6 and 7, the blue and gray water footprint are equal to 2.51 l/kg and this implies that the extraction of LPG spends the same amount of surface water as the water it polluted [11]. Totally, the water footprint of LPG for a jug is equal to 4 liters. In conclusion, the total water footprint of the resource extraction and fuel used is shown in Table 8. Therefore, the water footprint of a ceramic jug (cradle to gate) is equal to 16.9202 liters.

Table 6 Total amount of LPG used

Resource	Process	Quantity (kg)
LPG	Biscuit Firing	0.3
LPG	Glost Firing	0.5

Table 7 Water footprint of LPG used

Process	Blue Water Footprint (2.51l/kWh)	Gray Water Footprint (2.51l/kWh)	Total(l)
Biscuit Firing	0.75	0.75	1.5
Glost Firing	1.25	1.25	2.5
			4

Table 8 Total water footprint of a ceramic jug

Stage	Material/fuel	Water footprint
Resource extraction	Ceramic prepare body	6.5
	Glaze	3.25
	Material	2.334
	Electricity	0.8362
	LPG	4
Total		16.9202

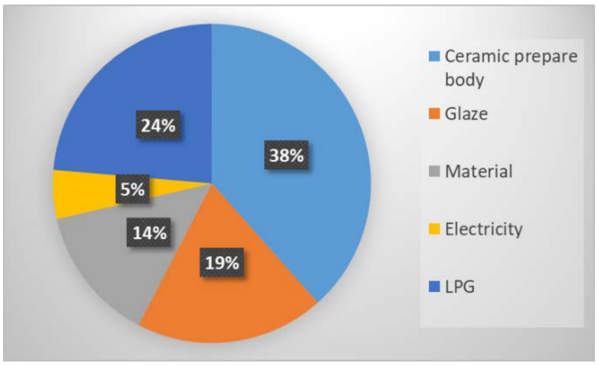

Fig. 5 Pie chart showing the percentage of water footprint for each resource extraction.

The amount of water footprint contributed to each resource is shown in the form of the pie chart (Fig. 5). The extraction of ceramic prepare body seems to contribute to the highest proportion of water footprint (38 percent) followed by the extraction of LPG (24 percent). It is interesting to note that the lowest water footprint is the contribution of the electricity generation (only 5 percent).

6. LEVEL OF AWARENESS

Two groups of samples are selected to be studied. The first group is the business owners and top executives (N=9) while the second group is the mid-level management (N=15). The last group is the operators in the workshop (N=20). All of them is working in the ceramic business. To cover all the workforces, their responsibility positions are ranged from the top executive to the people working in the shop. For the assessment, the level of awareness is started from distributing questionnaires by mails to all groups of respondents. Afterwards, all respondents were invited to participate in a one-day workshop. The content covers the life cycle analysis, the water footprint calculation as well as the above case study. After the class, the same set of questionnaires is re-utilized to assess the awareness. The questions are adapted from Carbon awareness questionnaires (available on https://www.dorsetforyou.gov.uk/) which are designed to assess the following aspects: attitude, environmental impact, water cost and waste, water saving, water usage reduction and motivation. All questions are shown in Table 9 and the results indicating the scores of pre- and post-workshop. The number in parenthesis is the standard deviation (S.D.). The first three questions (Q1-Q3) depict the basic knowledge regarding the relationship between the water conservation and the environment. On the other hand, Q4 and Q5 are used to assess the awareness of people roles on how to save water. The importance of water footprint as a key to consume water wisely is represented in Q6 and Q7 consecutively. The questionnaire response is in the form of a rating type which is the Likert scale ranged from 1 to 5 (1 = strongly disagree, 2 = disagree, 3 =neutral, 4 = agree, 5 = strongly agree). After the average scores before and after the workshop are compared, they obviously illustrate that the post-workshop scores are significantly higher than those of the pre-workshop. To statistically test the difference, the paired t-test was conducted to assess the knowledge and awareness of experimental group regarding the water footprint by comparing the pre-workshop and post-workshop averages. The results signify that both averages differ significantly ($p<0.01$) when the level of α is equal to 0.01. Therefore, the conclusion is that the awareness of the top-executive and workforces towards the environment increases dramatically after water footprint has been used a primary tool in the workshops which are conducted by researchers. The application of water footprint also tends to increase the basic knowledge of people regarding the water conservation.

Table 9 Questions and pre- and post-workshop scores

Question	Results	
	Pre-	Post-
Q1: To what extent is your general attitude towards reducing your water footprint?	1.21 (0.98)	3.95 (0.81)
Q2: How aware are you of the environmental impact of water usage?	1.58 (1.04)	3.51 (0.78)
Q3: What is your level of awareness of water costs and where water is wasted?	1.96 (1.21)	4.05 (0.89)
Q4: How aware are you of the ways in which you can save water?	1.41 (1.44)	4.29 (0.82)
Q5: Other than reducing your water use, how aware are you of the other ways to reduce your water footprint at work?	1.77 (1.13)	3.69 (0.96)
Q6: How motivated are you to reduce your water footprint?	1.28 (1.22)	4.41 (0.85)
Q7: The life cycle analysis for water footprint is used to create environmental awareness.	1.15 (0.98)	4.69 (0.91)

According to Table 9, it is interesting to note that the post-workshop scale of Q6 is the highest. This result obviously shows that the utilization of the water footprint as a mean to enhance the water usage perception is highly effective for the people who are related to the ceramic business.

7. CONCLUSIONS

In conclusion, these research objectives have two folds. The first objective is to derive the water footprint of a ceramic jug and the result show that the main contribution of this ecological footprint comes from the resource extraction and the total amount of water used to produce a jug is 16.9202 liter. Another important finding is that 38 percent of the total amount of water is from the ceramic prepare body which is the prime material used to produce a ceramic jug. On the other hand, only 5 percent of water is used in the process of generating the electricity supplying the jolly machine. Another objective is to alleviate the level of awareness regarding the water conservation among people who involve in the ceramic manufacturing.

Theoretically, environmental awareness is the issue that comes to the interest of many people. Although a lot of information regarding the environment keeps flowing to the society through different mediums, a number of people still finds that the environmental issue is still abstract and not tangible. As a result, this study focuses on the utilization of the water footprint concept an instructional media to raise the environmental awareness of a specific group of people (who works in the ceramic industry). Based on the life cycle analysis, the water footprint of a case study (a ceramic product) is calculated to show a certain amount of water contributed to manufacturing a ceramic jug. Afterwards, the lesson learned from the computation of water footprint was used to train the target group with the objective to raise the environmental awareness. The pre-test and post-test were used to assess the awareness of the corresponding group while the paired t-test shows that the level of awareness before and after the test is significantly different after the water footprint workshop was introduced to the target group. Therefore, the practical water footprint method is proved to be effective in alleviating the awareness of people towards the environment.

8. DISCUSSIONS AND FURTHER STUDIES

The accuracy of water footprint calculation heavily relies on the inventory data. However, the preparation of inventory data in Thailand is still not standardized. If there is a prime government agency responsible for collecting data regarding the inventory data, it is possible to achieve the accurate water footprint. However, most of the data is adapted from the foreign sources or from commercial software like Ecoinvent or SimaPro. This practice has the influence on the final result of the calculation. Moreover, the water footprint of the energy source might lead to the different results if other energy sources, e.g., biogas, is used instead of LPG to fuel the kiln.

Since the target group of this study is the people who work in the manufacturing, the life cycle analysis only covers the manufacturing stage. However, it might be interesting if this study is extended to the whole life cycle of a product (including distribution, use, and disposal). Because this product is the ceramic jug, there is a need for a large amount of water to wash the jug after the drinks. If this stage is put in the consideration, this might affect the calculation of water footprint. On the other hand, the distribution and disposal stage might have a small influence related to the water use.

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