CHAPTER V

RESULTS AND DISCUSSIONS

In this research 2 methods, Eco-indicator 95 and Eco-indicator 99 in the SimaPro® 6.0 software, are used to analyze data. This chapter will show the results of the research and discussions of the wood – plastic composites. The results of inventory of this research divided into two parts, one is plant location decision. The next is result of impact assessment and economic performance.

The results of impacts assessment of wood-plastic composites using Eco-Indicator method were presented by single score graph of environmental impacts because it is easy to understanding. The graphical results are indicated in 2 cases. The first type of graph is showed environmental impacts from impacts categories such as Carcinogenic effect, Respiration of organic substance, Respiration of inorganic substance, Climate change, Ozone layer depletion, Acidification, Eutrophication, Ecotoxicity, Land use, Mineral and Fossil Fuels. The other type of graphical results were presented by combine impacts that damage to 3 group which are :

1. **Damage to Human Health** which resulted from impact categories as followed: Carcinogenic effect, Respiration of organic substance, Respiration of inorganic substance, Climate change and Ozone layer depletion
2. **Damage to Ecosystem Quality** which resulted from impact categories as followed: Acidification, Eutrophication, Ecotoxicity and Land use
3. **Damage to Resource depletion** which resulted from impact categories as followed: depletion of Mineral and Fossil Fuels

5.1 PLANT LOCATION DECISION

In this section, the environmental impacts from transportation were used for compare the suitable plant location of 2 places which are Bangkok and Rayong.

Environmental impacts were calculated by considerate quantity of raw material and transportation method. Therefore, we have to know quantity of raw materials for production of WPC. From data collection, raw materials for production of WPC which prepared from PVC and PP were shown in table 5.1 and 5.2, respectively.

Table 5.1 Formulation for production of WPC based on PP

Materials	Unit	Quality
Polypropylene	kg	100
Sawdust	kg	48
Impact modifier	kg	10.6
Coupling agent	kg	7
Processing oil	kg	1
Total WPC	kg	166.6

Table 5.2 Formulation for production of WPC based on PVC

Materials	Unit	Quality
PVC suspension	kg	100
PVC emulsion	kg	4
Sawdust	kg	50
Organic complex stabilizer	kg	3.5
Lubricant	kg	0.6
$CaCO_3$	kg	12
Calcium stearate	kg	0.6
Processing aid	kg	5
Total WPC	kg	175.7

5.1.1 Comparison of environmental impacts of plant for plant location of WPC-PP/Sawdust

Data collecting for transportation shown in Table 5.3 present materials used, manufacture/distributor, transportation model and distance, which measured by using PointAsia® software, for consideration of environmental impacts from transportation of raw materials to plant and product to distribution center by using SimaPro®6.0

software with Eco-Indicator 99 and GWP method which concentrated on human health, ecosystem quantity, resource depletion and global warming.

Table 5.3 Distance and transportation method of transportation of raw materials and product for WPC based on PP

Materials	Manufacture/Distributor	Transportation	Distance (Rayong)	Distance (Bangkok)
PP 1100 NK	IRPC Public Co.,Ltd.	6 wheel	23	161.5
Sawdust	Lucha Timber	pick-up	190	53
Impact modifier	Chemical Innovation Co.,Ltd.	pick-up	157	23.5
Coupling agent	Chemical Innovation Co.,Ltd.	pick-up	157	23.5
Processing oil	vickerpigment Co.,Ltd.	pick-up	190	56
WPC	Distribution center	10 wheel	170	57

The environmental impacts are calculated by consideration of weight of raw material, distance between suppler and plant, and transportation method. From using data in Table 5.3 and using Eco-Indicator 99 method, the result of transportation for WPC-PP/Sawdust production shown in Figure 5.1 indicates that mineral used, ozone layer depletion and respiratory of inorganics substance are the major the environmental impact categories of the transportation because transportation used fuel generated sulfur compound dioxide which effect to respiratory of inorganics and carbon effect to ozone layer depletion, climate change. After compare kg CO_2 equivalent and environmental impact of various impacts by GWP and Eco-Indicator 99 method, it can be seen that the environmental impact of transportation when plant is located at Rayong is higher than located at Bangkok because overall mass-distance (kg-km) of transportation of plant located at Rayong is higher than plant located at Bangkok. The overall kg CO_2-equivalent emission from transportation of raw materials and product to plat for production of WPC-PP/Sawdust when plant located at Rayong and Bangkok are 0.438 and 0.294 kg CO_2-equivalent respectively. Therefore, the suitable plant for WPC-PP/Sawdust should be located at Bangkok.

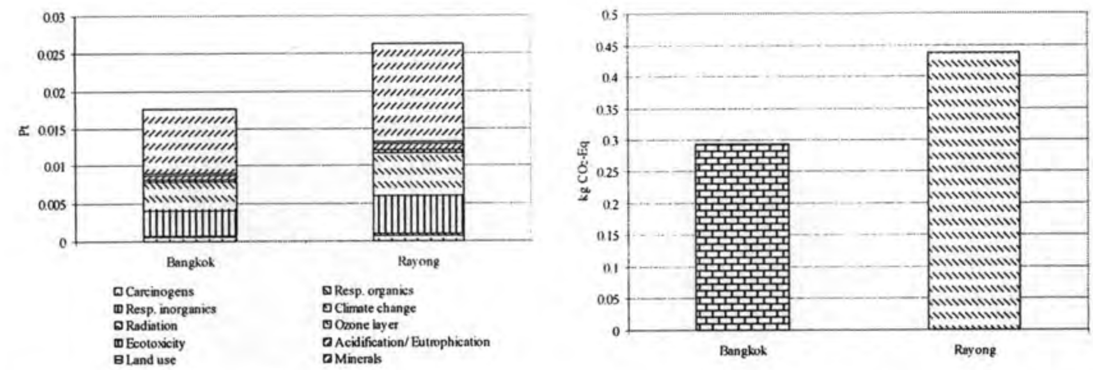

Figure 5.1 Environmental impacts from transportation of 2 WPC-PP/Sawdust plant location obtained by using Eco-Indicator99 and GWP method

5.1.2 Comparison of environmental impacts of plant location for WPC based on poly(vinyl chloride)

Data collecting for transportation shown in Table 5.4 present materials used, manufacture/distributor, transportation model and distance for consideration of environmental impacts from transportation of raw materials to plant and product to distribution center by using SimaPro®6.0 software with Eco-Indicator 99 and GWP method which concentrated on human health, ecosystem quantity, resource depletion and global warming.

Weight of raw materials, distance of transportation and transportation method are used for calculation of environmental impacts. After using data shown in Table 5.4 and using Eco-Indicator 99 method for calculation, the result of transportation for WPC-PP/Sawdust production shown in Figure 5.2 indicates that mineral used, ozone layer depletion and respiratory of inorganics substance are the major the environmental impact categories of the transportation because transportation used fuel generated sulfur compound dioxide which effect to respiratory of inorganics and carbon effect to ozone layer depletion, climate change. After compare kg CO_2 equivalent and environmental impact of various impacts by GWP and Eco-Indicator 99 method, it can be seen that the environmental impact of transportation when plant is located at Rayong is higher than located at Bangkok because overall mass-distance (kg-km) of transportation of plant located at Rayong is higher than plant located at Bangkok. The overall kg CO_2-equivalent emission from transportation of raw materials and product to plat for production of WPC-PP/Sawdust when plant located at Rayong and Bangkok are 0.415 and 0.276 kg CO_2-equivalent respectively. Therefore, the suitable plant for WPC-PP/Sawdust should be located at Bangkok .

Table 5.4 Distance and transportation method of transportation of raw materials and product for WPC based on PVC

Materials	Manufacture/Distributor	Transportation	Distance (Rayong)	Distance (Bangkok)
PVC suspension	Thai Plastic and Chemicals Public Co.,Ltd.	10 wheel	2.5	144.5
PVC emulsion	Thai Plastic and Chemicals Public Co.,Ltd.	10 wheel	2.5	144.5
Sawdust	Lucha Timber Co.,Ltd.	pick-up	190	53
Lubricant	Olefine organics (Thailand) Co., Ltd.	6 wheel	184	42
CaCO3	Sand and Soil Industry Co.,Ltd.	10 wheel	115	32
Calcium stearate	Nicho Co.,Ltd.	10 wheel	170	28
Stabilizer	Nicho Co.,Ltd.	10 wheel	170	28
Processing aid	Nicho Co.,Ltd.	10 wheel	170	28
WPC	Distribution center	10 wheel	170	57

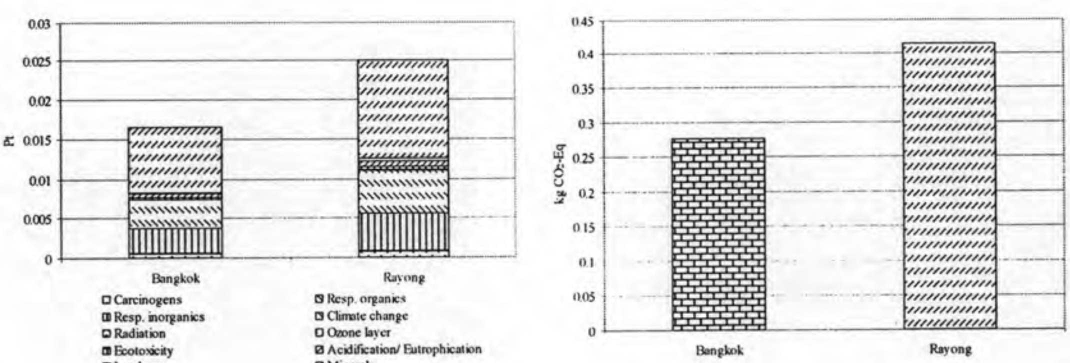

Figure 5.2 Environmental impacts from transportation of two WPC-PVC/Sawdust plant location obtained by using Eco-Indicator99 and GWP method

5.2 LIFE CYCLE INVENTORY (LCI)

Life cycle inventory is a process of quantifying energy, material, waste emission and, also, other releases for the entire life cycle of a product, process or activity (EPA, 1993). In this chapter, LCI is performed on the production of two wood-plastic composites, WPCs prepared from PP composite with sawdust and PVC composite with sawdust, in the cradle-to-grave framework which covers from material acquisition, transportation, production, and waste disposal. This chapter in two life cycle inventories being generated for the corresponding two products.

5.2.1 Life Cycle Inventory of WPC-PP/Sawdust

The process for the production of WPC based on PP are shown in Figure 5.3 Basically, there are 4 processes, in this case, which include mixing of raw materials, which are PVC, sawdust, Impact modifier, Coupling agent, and Processing oil, production process, transportation, and disposal. LCI is performed on these 4 processes based on the production of 1 kg of WPC. Detailed of input and output data collection are shown in Table 5.5.

Table 5.5 Data collection for WPC-PP/Sawdust Production

	Type	Unit	WPC based on PP
Input	PP	kg	0.60
	Sawdust	kg	0.29
	Impact modifier	g	64
	Coupling agent	g	42
	Processing oil	g	6
	Transportation	kg-km	57
product	WPC	kg	1

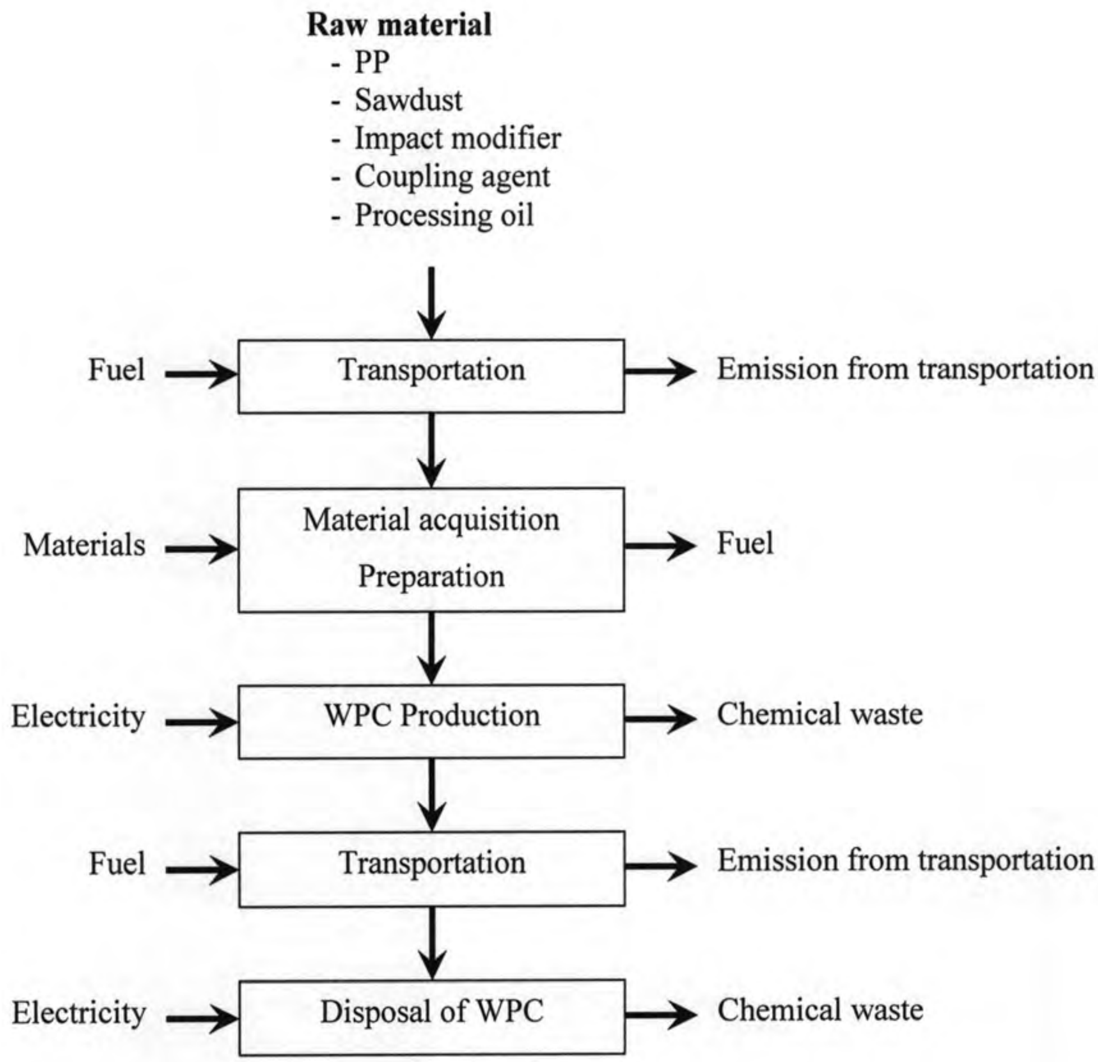

Figure 5.3 Production of Wood – Plastics Composite based on PP

5.2.2 Life Cycle Inventory of WPC-PVC/Sawdust

The process for the production of WPC based on PVC are shown in Figure 5.5 Basically, there are 4 processes, in this case, which include mixing of raw materials, which are PVC, sawdust, Stabilizer, Lubricant, $CaCO_3$, Calcium Stearate, and Processing aid, production process, transportation, and disposal. LCI is performed on these 4 processes based on the production of 1 kg of WPC. Detailed of input and output data collection are shown in Table 5.6. Process flow diagram of the process is shown in Figure 5.4.

Table 5.6 Data collection for WPC-PVC/Sawdust Production

	Type	Unit	WPC based on PVC
Input	PVC suspension	kg	0.59
	PVC emulsion	g	22.76
	Sawdust	kg	0.28
	Organic complex stabilizer	g	19.92
	Lubricant	g	3.41
	$CaCO_3$	g	68.29
	Calcium stearate	g	3.41
	Processing aid	g	28.45
	Transportation	kg-km	57
product	WPC	kg	1

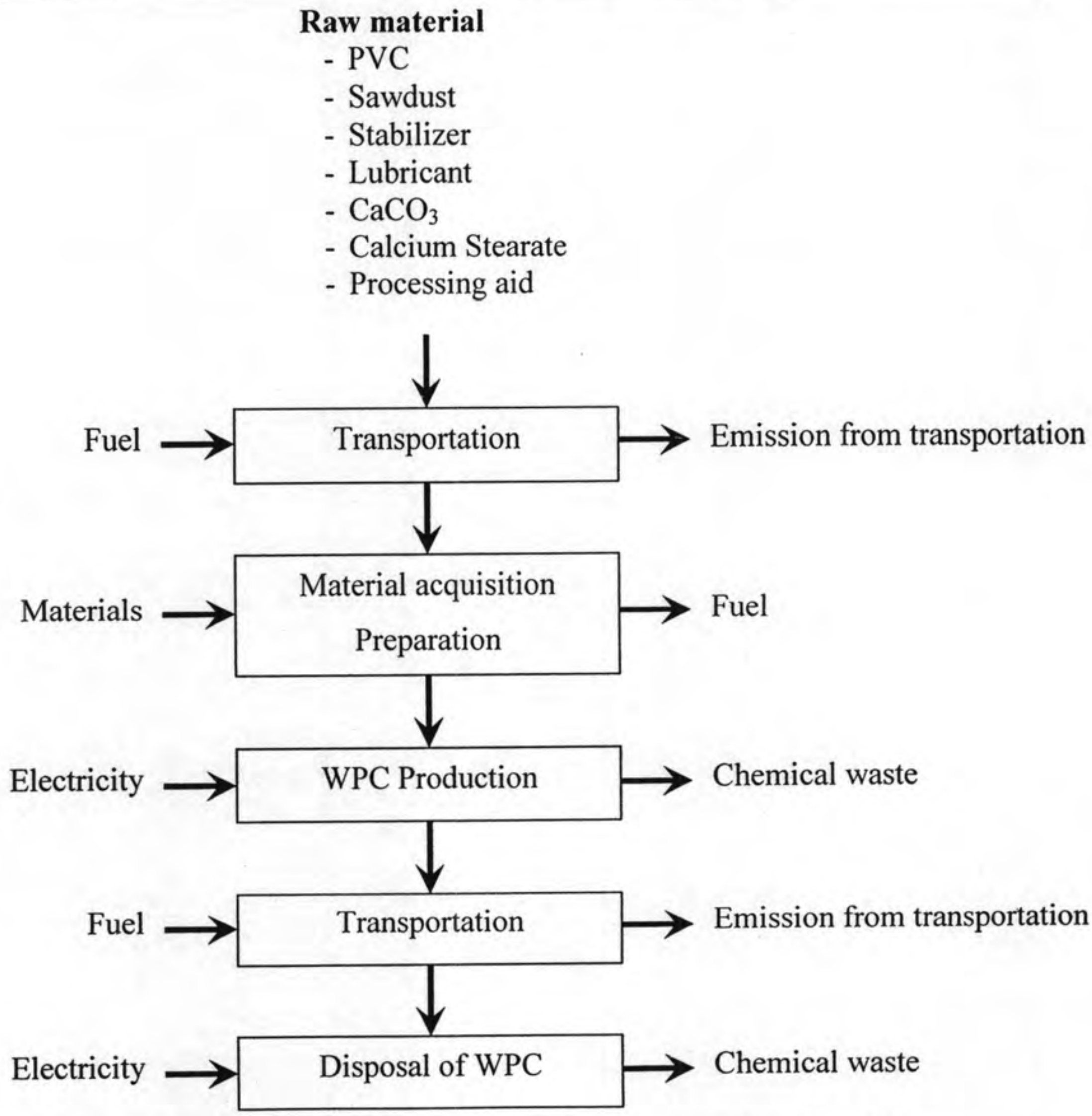

Figure 5.4 Production of Wood – Plastics Composite based on PVC

5.3 ENVIRONMENTAL IMPACTS ASSESSMENT

After the life cycle inventory (LCI) was carried out, life cycle impact assessment (LCIA) could then be performed based on the quantitative information attained from LCI study in order to identify the environmental impacts from the production of WPC based on poly(vinyl chloride) (PVC) and polypropylene (PP). This was done by using the commercial LCA software tool, SimaPro®6.0 with Eco-Indicator 95 and Eco-Indicator 99 methods for environmental impacts assessment. Eco-Indicator 95 is a mid-point approach to the impact assessment whereas Eco-Indicator 99 is an end-point approach. The environmental categories being the focus in this research are greenhouse effect, ozone layer depletion, acidification, heavy metals, carcinogen and resource depletion. In this part of the study, the results from Eco-Indicator 95 were firstly presented followed by the results from Eco-Indicator 99. In addition, the comparison between methods was also discussed.

5.3.1 Environmental Impact Assessment of WPC-PP/Sawdust

Using Eco-Indicator 95, the overall results of the production of 1 kg WPC based on PP shown in Figure 5.5 indicates that acidification and heavy metals are the major the environmental impact categories of the overall WPC-PP/Sawdust process. The comparison of the environmental impacts for all 3 phases of WPC-PP/Sawdust production shown in Figure 5.6 illustrates that the material acquisition phase contributes the most environmental impacts followed by the production transportation phase respectively. In the material acquisition phase, Figure 5.7, shows that the environmental impacts is essentially from polypropylene. Since the production of polypropylene use metal compound with chloride as catalyst, then it contributes to heavy metal and acidification. Also, smog is formed from acid rain which damage to human health in respiration disease. Moreover, using petroleum generated green house gases (CO_2-equivalent). In contract, sawdust contributes the positive effect to the environmental as shown from the minus value in the result which is due to reduction of the use of PP used in production phase.

The results of environmental impact assessment using Eco-Indicator 95 presents in term of equivalent units for each impact category for the production of 1 kg WPC-PP/Sawdust. It can be seen that the production of 1 kg WPC-PP/Sawdust utilizes energy resources equivalent to 85.7 MJ LHV and generates green house gas equivalent to 2.08 kg of CO_2, acidification equivalent to 0.021 kg of SO_2, heavy metals 2.73 E^{-5} kg of Pb equivalent, ozone layer depletion substances equivalent to 9.63 E^{-7} kg of CFC11, and carcinogenic effect equivalent to 9.86 E^{-8} kg of benzo(a)pyrene. Green house gases are generated mainly from production and material acquisition phase which account for 44% and 42% respectively. For acidification, the material acquisition and production phase share 66% and 25% of the total kg SO_2-equivalent emitted in the production of WPC-PVC/Sawdust

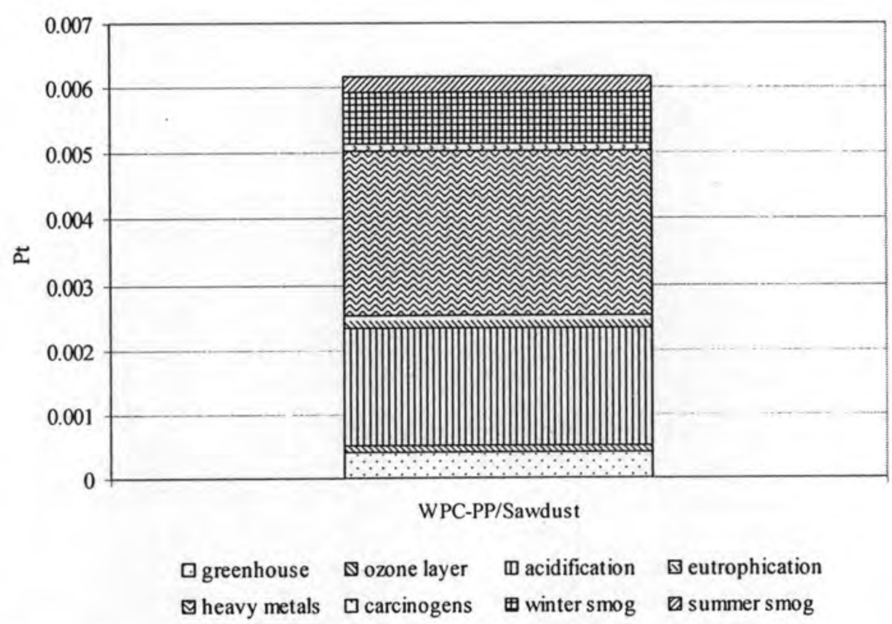

Figure 5.5 Environmental impact categories of 1 kg WPC-PP/Sawdust production obtained by using Eco-Indicator 95

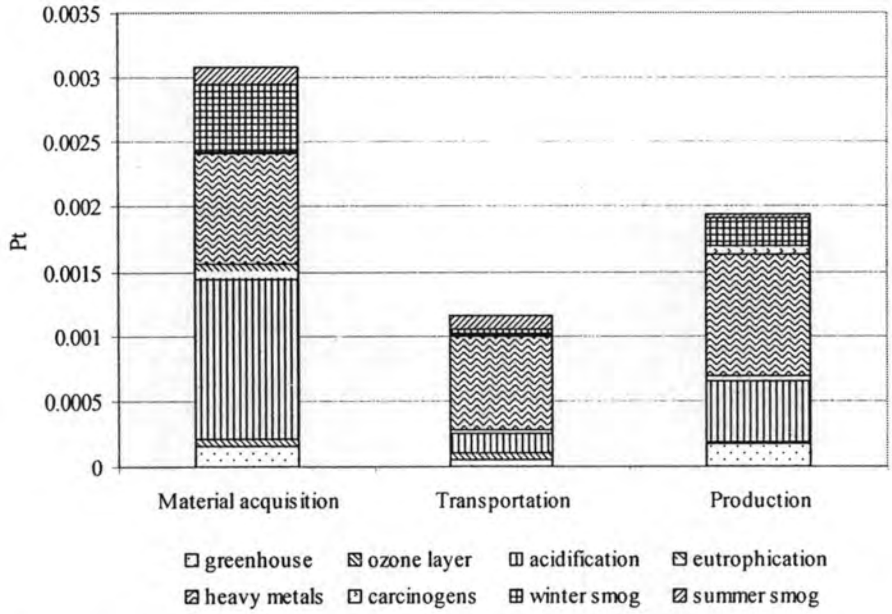

Figure 5.6 Environmental impact categories of each phase in the production of 1 kg WPC-PP/Sawdust obtained by using Eco-Indicator 95

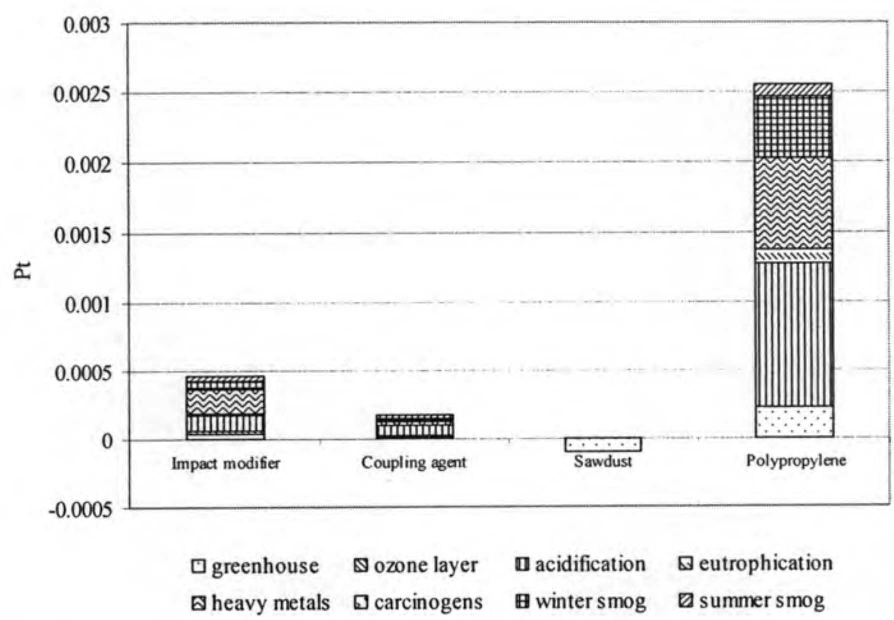

Figure 5.7 Environmental impact categories of the production phase in the production of 1 kg WPC-PP/Sawdust obtained by using Eco-Indicator 95

Using the end-point approach, Eco-Indicator 99, results in a single score for the environmental impacts assessment based on weighting factor assigned for each impact category. In addition, Eco-Indicator 99 also accounts for resource depletion which was not accounted in Eco-Indicator 95. In Eco-Indicator 99 Damage categories are divided into human health, ecosystem quality and resource depletion. Impact categories include and carcinogen, respiration of organics and inorganics, climate change, radiation, ozone layer depletion, ecotoxicity, acidification, land use, and minerals.

Apart from the fact that the results obtained from Eco-Indicator 95, Eco-Indicator 99 also include resource depletion, other environmental impacts are in the same trend as obtained from Eco-Indicator 95. For the damage assessment (Figure 5.8), results are mainly in the human health and resource depletion which resulted from depletion of minerals use, where respiration of inorganic substances and ozone layer depletion effect on human health as shown in Figure 5.8. The impact assessment of various phases in the production of WPC-PP/Sawdust is shown in Figure 5.9. It can be seen that the environmental impact is mainly in the production phase and material acquisition phase which is similar to the result obtained by using Eco-Indicator95.

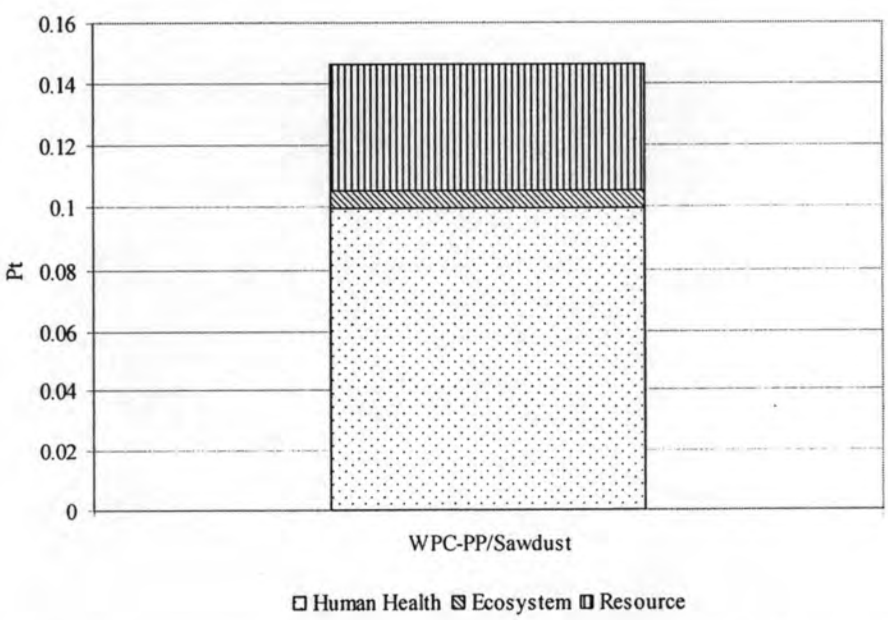

Figure 5.8 Damage assessment of the production of 1 kg WPC-PP/Sawdust by using Eco-Indicator 99

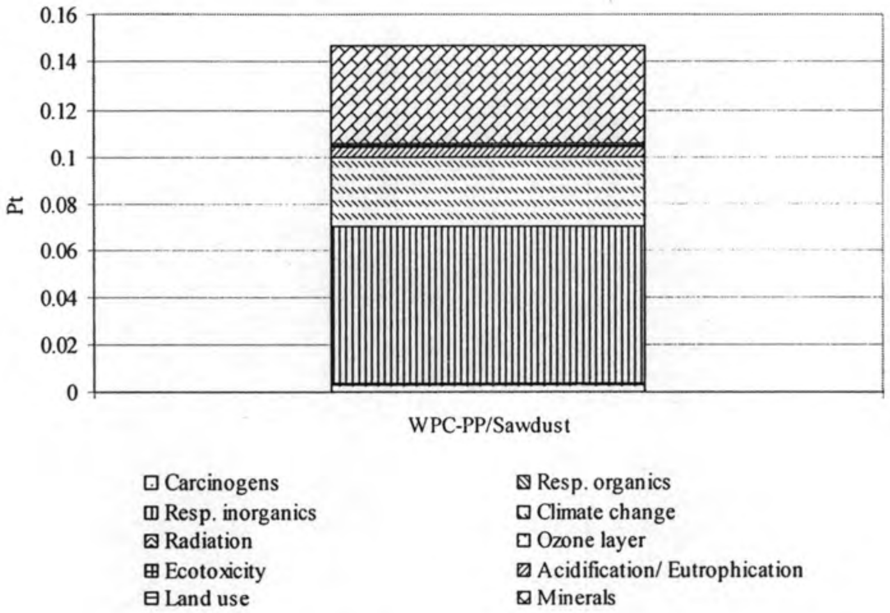

Figure 5.9 Impact assessment for the production of 1 kg WPC-PP/Sawdust by using Eco-Indicator 99

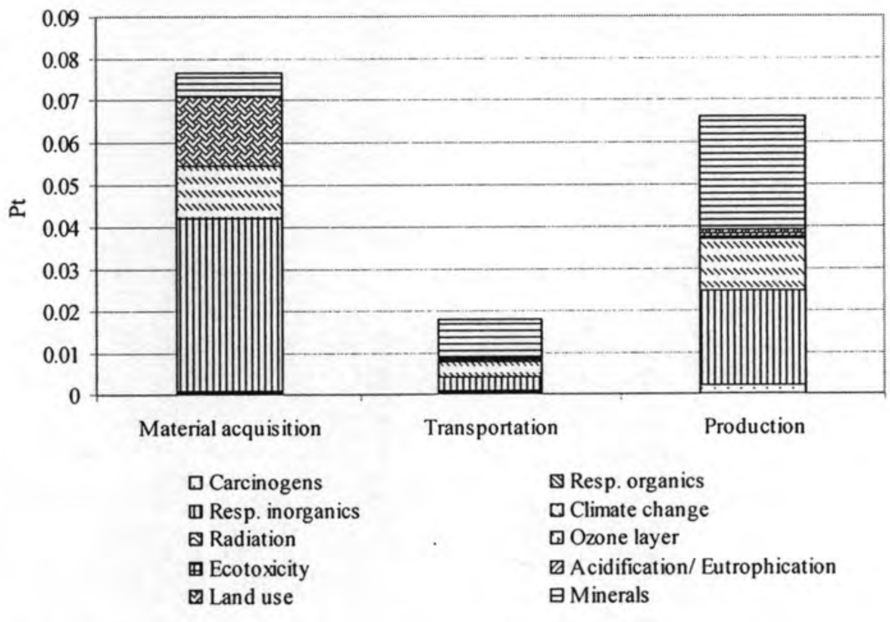

Figure 5.10 Impact assessment of the production of 1 kg WPC-PP/Sawdust by using Eco-Indicator 99

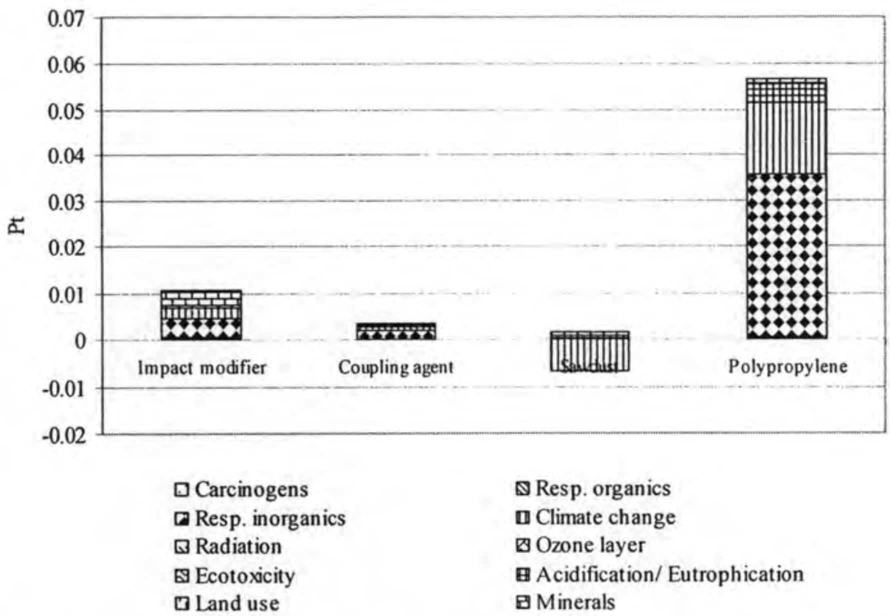

Figure 5.11 Impact assessment of each phase in the production of 1 kg WPC-PP/Sawdust by using Eco-Indicator 99

However, when the resource depletion is accounted for, the production phase contributes more than the material acquisition which is not accounted in the case for Eco-Indicator 95 (Figure 5.6). This is due to the extensive utilization of electricity generated from minerals and fuels in the production phase that effect to depletion of resources. Figure 5.10 reveals the second impact is in respiration of inorganics in material acquisition phase followed by climate change which come mainly from using of polypropylene in the material acquisition phase as shown in Figure 5.11. The production of PP was produced mainly from crude oil and natural gas that contained of sulfur compound which damage to human health in respiration system and also, petroleum generated carbon dioxide that effect to climate change where using of petroleum effect to depletion of resource.

5.3.2 Environmental Impact Assessment of WPC WPC-PVC/Sawdust

Using Eco-Indicator 95, the overall results of the production of 1 kg WPC based on PVC shown in Figure 5.12 reveals that acidification and heavy metals are the major environmental impact categories of the overall WPC-PVC/Sawdust process. The comparison of the environmental impact for all 3 phases of WPC-PVC/Sawdust production shown in Figure 5.13 illustrates that the material acquisition phase contributes the most environmental impacts followed by the production and transportation phase respectively. In the material acquisition phase, Figure 4.14, shows that the environmental impacts is essentially from using PVC suspension as polymer matrices. Since poly(vinyl chloride) produces from ethylene and chlorine using iron(II)chloride as catalyst, then the use of catalyst effect to heavy metals (iron) problem and acidification (chlorine), the use of ethylene can be generated carbon dioxide which effect to green house gas problem and also acidification problem affected to smog problem. In contract, sawdust contributes the positive effect to the environmental as shown from the minus value in the result which is due to reduction of the use of PVC used in production phase.

The results of environmental impact assessment using Eco-Indicator 95 presents in term of equivalent units for each impact category for the production of 1 kg WPC-PVC/Sawdust. It can be seen that the production of 1 kg WPC-PVC/Sawdust utilizes energy resources equivalent to 68.6 MJ LHV and generates green house gas equivalent to 2.1 kg of CO_2, acidification equivalent to 0.02 kg of SO_2, heavy metals 5.01 E^{-5} kg of Pb equivalent, ozone layer depletion substances equivalent to 5.42 E^{-7} kg of CFC11, and carcinogenic effect equivalent to 1.02 E^{-7} kg of benzo(a)pyrene. Green house gases are generated mainly from production and material acquisition phase which account for 44% and 43% respectively. For acidification, the material acquisition and production phase share 65% and 23% of the total kg SO_2-equivalent emitted in the production of WPC-PVC/Sawdust.

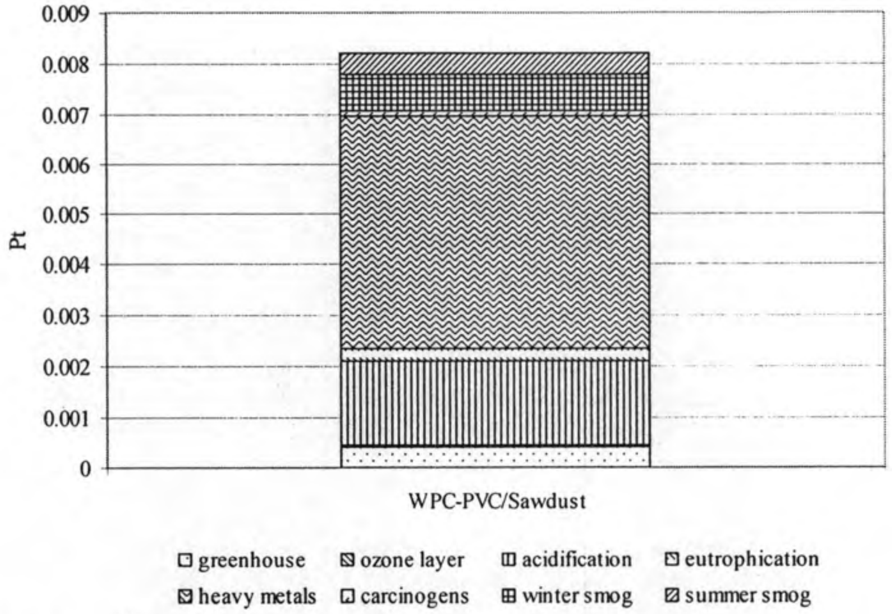

Figure 5.12 Environmental impact categories of 1 kg WPC-PVC/Sawdust production obtained by using Eco-Indicator 95

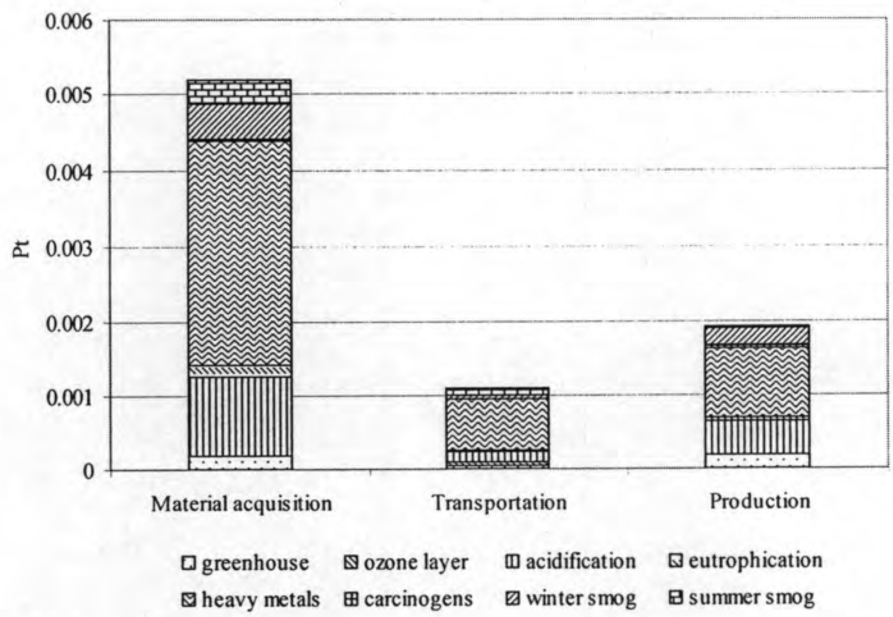

Figure 5.13 Environmental impact categories of each phase in the production of 1 kg WPC-PVC/Sawdust obtained by using Eco-Indicator 95

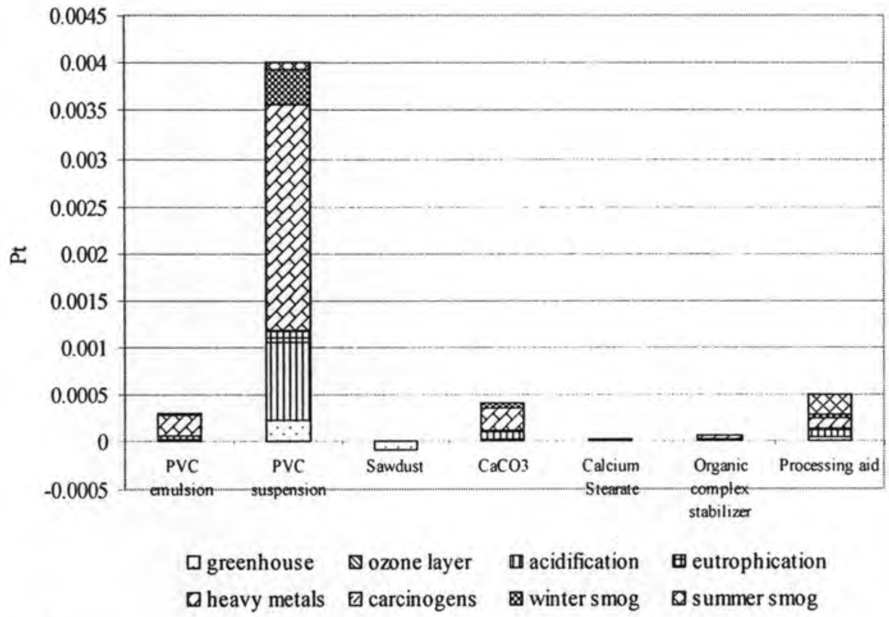

Figure 5.14 Environmental impact categories of the material preparation phase of production of 1 kg WPC-PVC/Sawdust obtained by using Eco-Indicator 95

Using Eco-Indicator 99, the single score results show the same trend as the results assessed by using Eco-Indicator 95, except for resource depletion which is not include in Eco-Indicator 95. For damage assessment (Figure 5.15), the damages are mainly in the human health and resources depletion which resulted from depletion of minerals use, where respiration of inorganic substances and ozone layer depletion effect on human health as shown in Figure 5.16. The impact assessment of various phases in the production of WPC-PVC/Sawdust is shown in Figure 5.17. It can be seen that the environmental impact is mainly in the production phase and material acquisition phase which is similar to the result obtained by using Eco-Indicator95. Figure 5.18 present the impact assessment of material acquisition which effect to, mainly, respiration of inorganics followed by climate change caused by the use of poly(vinyl chloride). The production of PVC used ethylene and chlorine as reactance and iron(II)chloride as catalyst. Since ethylene derived from petroleum which contained sulfur compound, then it effect to respiration of inorganics and depletion of resource and also using carbon compound as ethylene generate carbon dioxide which effect to climate change. For chlorine, it effect mainly to acidification problem. sawdust contributes the positive effect to the environmental

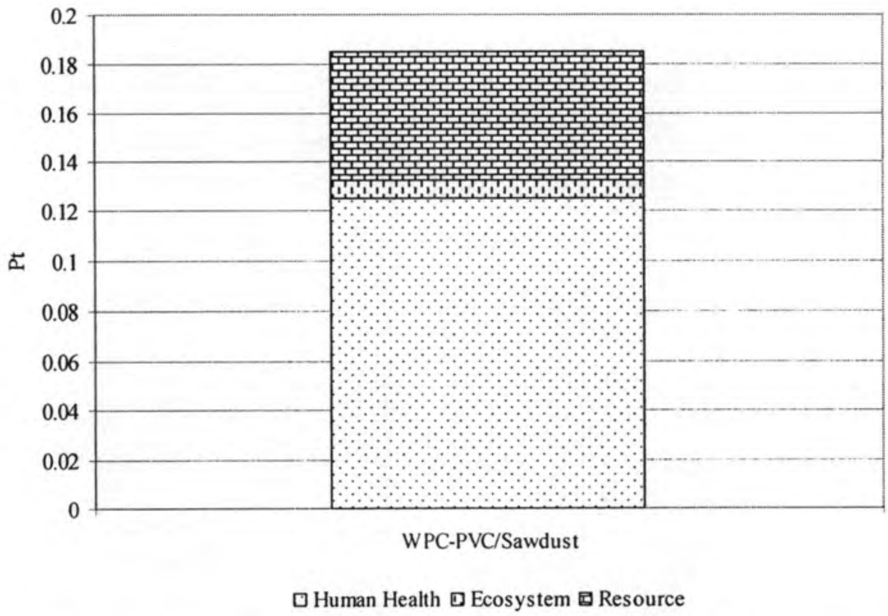

Figure 5.15 Damage assessment of the production of 1 kg WPC-PVC/Sawdust by using Eco-Indicator 99

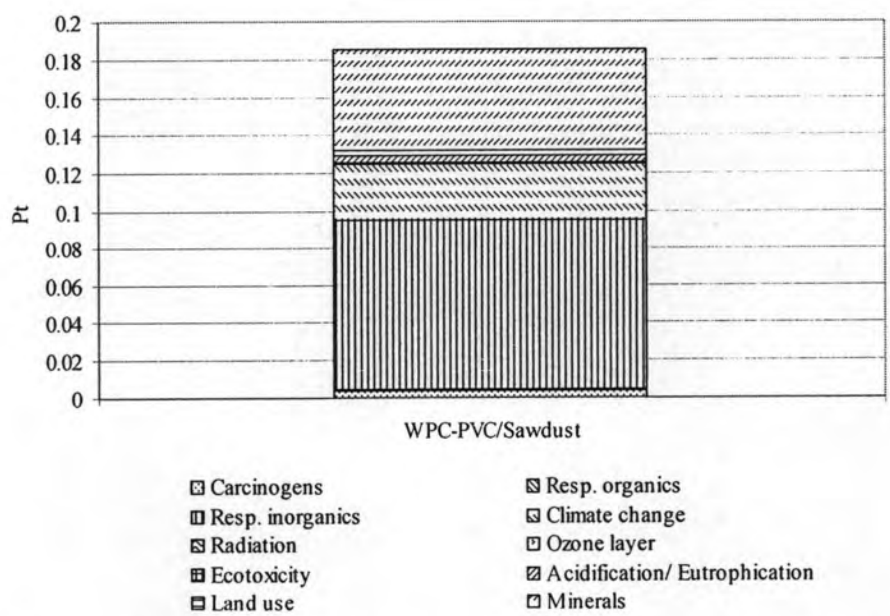

Figure 5.16 Impact assessment of the production of 1 kg WPC-PP/Sawdust by using Eco-Indicator 99

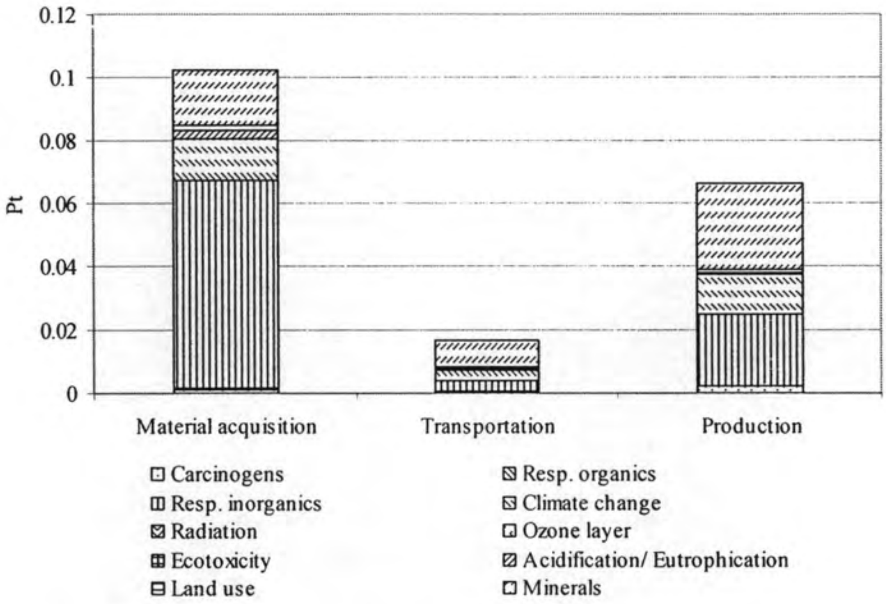

Figure 5.17 Impact assessment of the production of 1 kg WPC-PVC/Sawdust by using Eco-Indicator 99

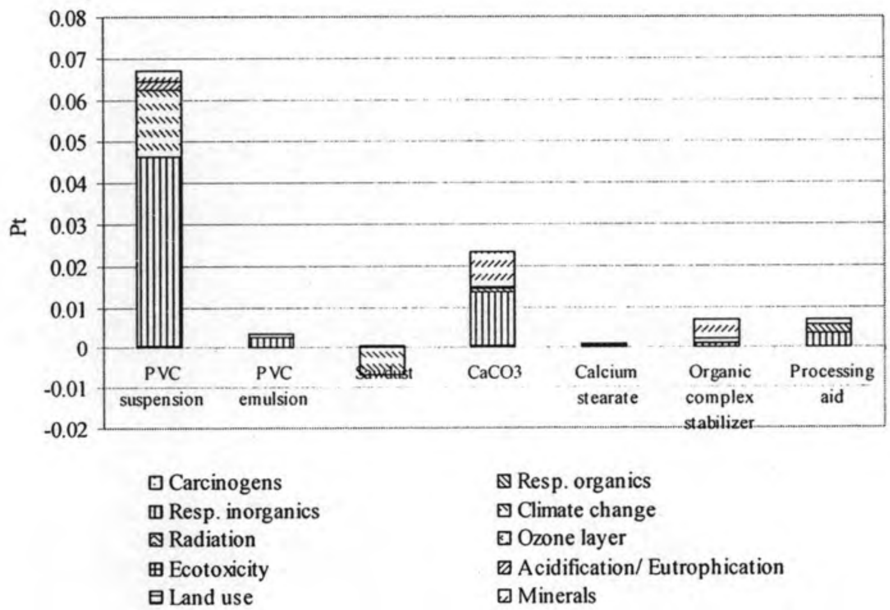

Figure 5.18 Impact assessment of each phase in the production of 1 kg WPC-PVC/Sawdust by using Eco-Indicator 99

5.4 COMPARISON OF ENVIRONMENTAL IMPACTS BETWEEN WPC-PP/SAWDUST AND WPC-PVC/SAWDUST

Figure 5.19 shows the comparison of the life cycle assessment (LCA) of the WPC used in this study, WPC-PP/Sawdust and WPC-PVC/Sawdust. It can be seen that the environmental impacts of WPC-PVC/Sawdust is higher than the impacts caused by the production of WPC-PP/Sawdust. The total impacts of WPC-PVC/Sawdust are approximately 1.3 times higher than that of WPC-PP/Sawdust. For all two WPC, the main impact is in respiration of inorganics followed by climate change and minerals use.

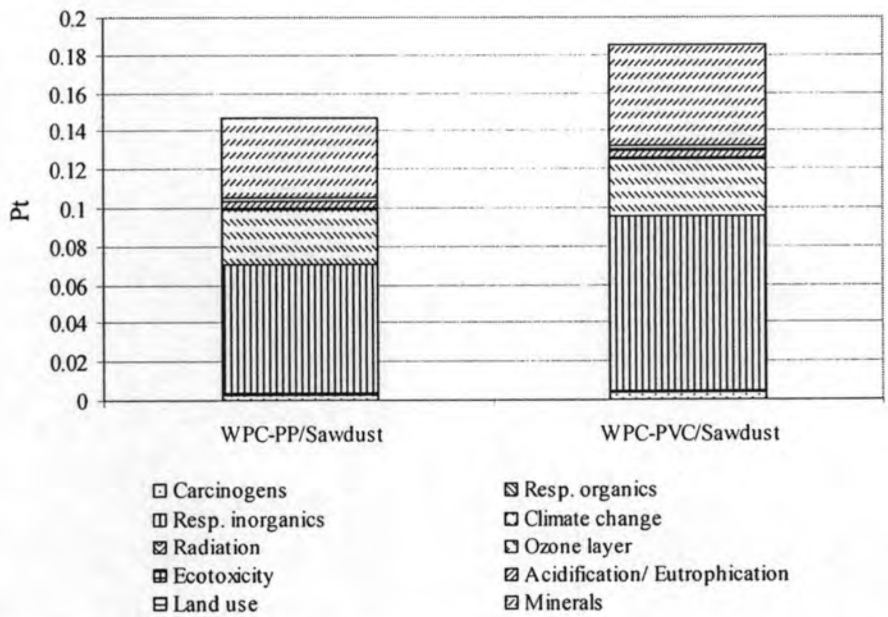

Figure 5.19 LCA comparison between WPC-PP/Sawdust and WPC-PVC/Sawdust

5.4.1 Comparison of green house gas between WPC-PP/Sawdust and WPC-PP/Sawdust

The comparison of green house effect between WPC-PP/Sawdust and WPC-PVC/Sawdust using Eco-Indicator 95 method shown in Figure 5.20 illustrates that WPC-PVC/Sawdust discharge green house gas equivalent to 2.10 kg of CO_2, and also higher than WPC-PP/Sawdust which generate green house gas equivalent to 2.08 kg of CO_2.

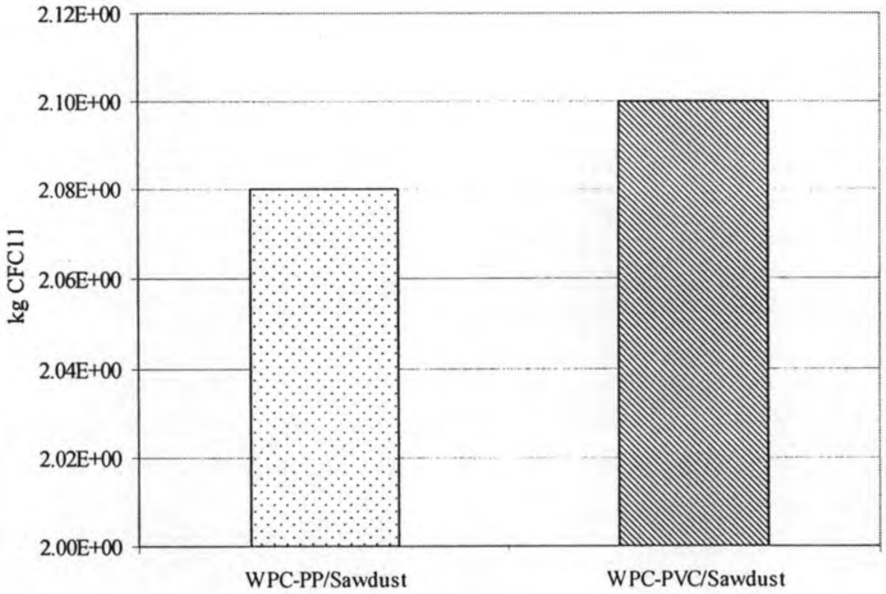

Figure 5.20 Comparison of green house effect between WPC-PP/Sawdust and WPC-PVC/Sawdust

5.4.2 Comparison of ozone layer depletion between WPC-PP/Sawdust and WPC-PP/Sawdust

From evaluation of ozone layer depletion effect using Eco-Indicator 95 method, it was found out that the WPC-PP/Sawdust and WPC-PVC-Sawdust generate CFC11-equivalent which effect to ozone layer depletion equal to 9.63 E^{-7} and 5.42 E^{-7} kg CFC11. The comparison of ozone layer depletion between WPC-PP/Sawdust and WPC-PVC/Sawdust shown in Figure 5.21 presents that WPC-PP/Sawdust is higher effect than WPC-PVC/Sawdust.

5.4.3 Comparison of acidification effect between WPC-PP/Sawdust and WPC-PP/Sawdust

Figure 5.22 shows the effect of acidification of two WPC, WPC-PP/Sawdust and WPC-PVC/Sawdust using Eco-Indicator 95 method. WPC-PVC/Sawdust generate gases which effect to acidification equal to 0.019 kg SO_2-equivalent when WPC-PP/Sawdust generate gases equal to 0.021 kg SO_2-equivalent, which higher than WPC-PVC/Sawdust.

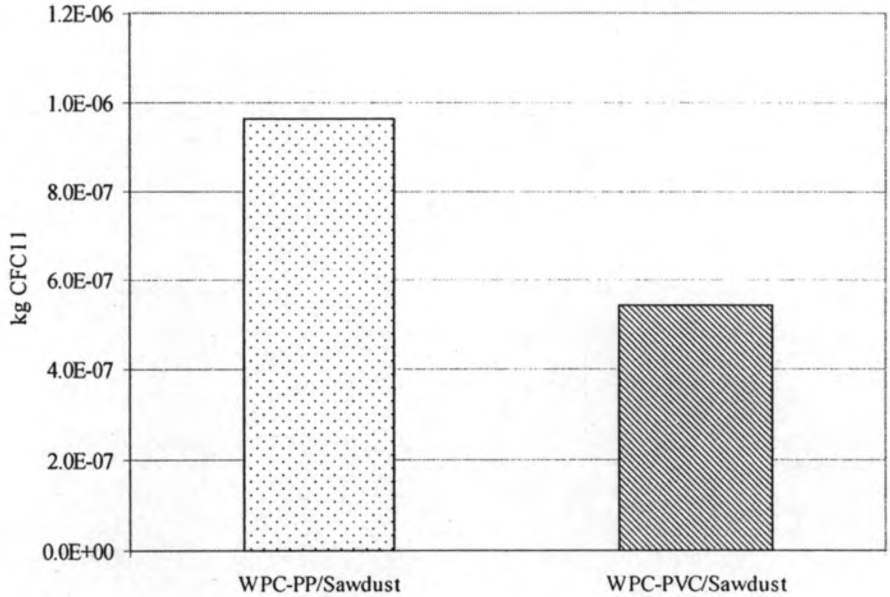

Figure 5.21 Comparison of ozone layer depletion between WPC-PP/Sawdust and WPC-PVC/Sawdust

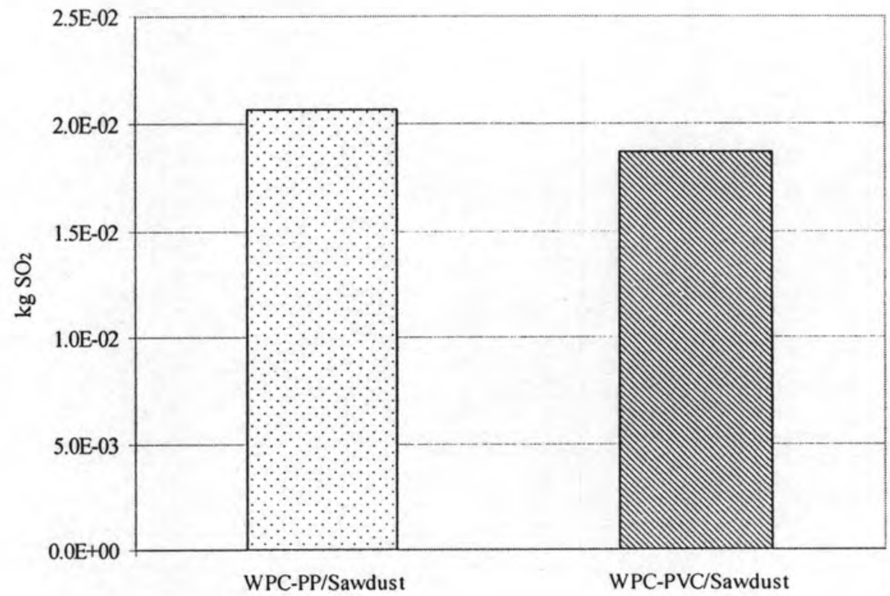

Figure 5.22 Comparison of acidification between WPC-PP/Sawdust and WPC-PVC/Sawdust

5.4.4 Comparison of eutrophication effect between WPC-PP/Sawdust and WPC-PP/Sawdust

The comparison of eutrophication between WPC-PP/Sawdust and WPC-PVC/Sawdust using Eco-Indicator 95 method shown in Figure 5.23 illustrates that WPC-PVC/Sawdust create effect of eutrophication equal to 1.73 E^{-3} kg of PO_4-equivalent and also higher than WPC-PP/Sawdust which generate 1.41 kg of PO_4-equivalent.

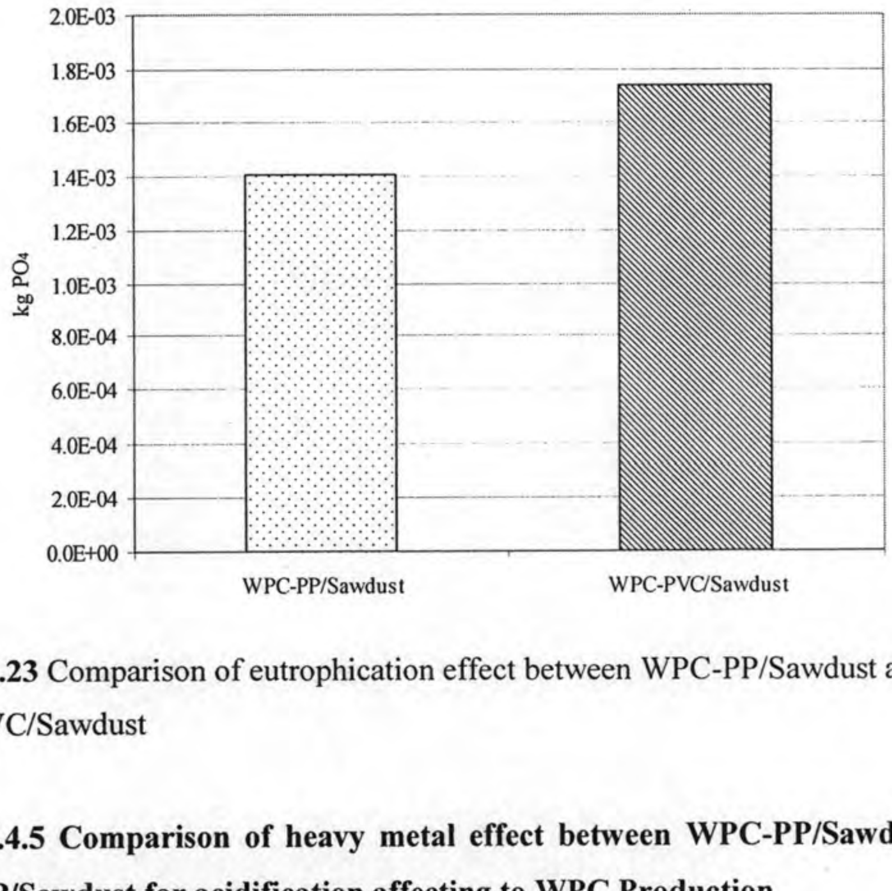

Figure 5.23 Comparison of eutrophication effect between WPC-PP/Sawdust and WPC-PVC/Sawdust

5.4.5 Comparison of heavy metal effect between WPC-PP/Sawdust and WPC-PP/Sawdust for acidification affecting to WPC Production

Using Eco-Indicator 95 method, result of comparison shown in Figure 5.24 illustrate that the effect of heavy metal from WPC-PVC/Sawdust make 5.01 E^{-5} kg Pb-equivalent, WPC-PP/Sawdust create 2.73 E^{-5} kg Pb-equivalent. From the comparison, it was presented that WPC-PVC/Sawdust construct higher effect than WPC-PP/Sawdust.

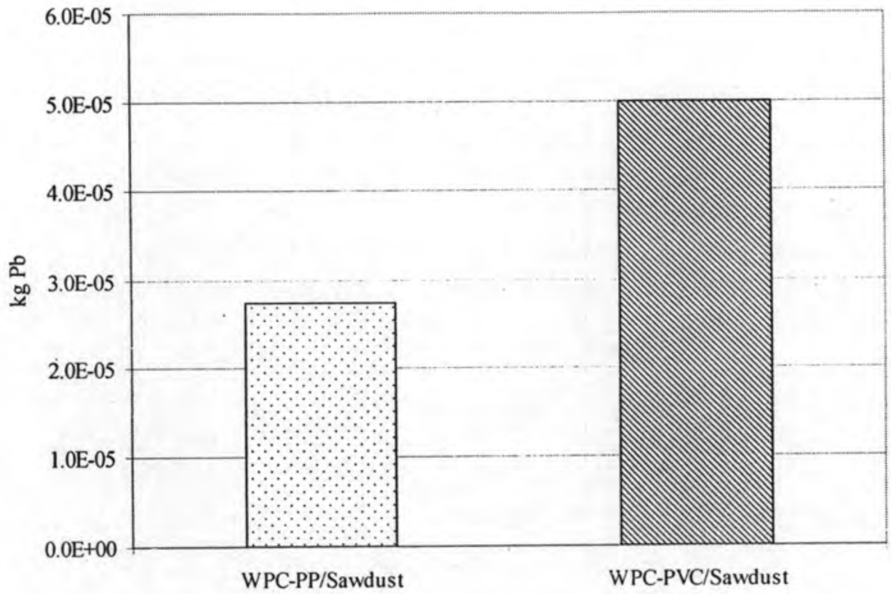

Figure 5.24 Comparison of heavy metals effect between WPC-PP/Sawdust and WPC-PVC/Sawdust

5.4.6 Comparison of carcinogen effect between WPC-PP/Sawdust and WPC-PP/Sawdust

The evaluation of carcinogen substances which generated from WPC using Eco-Indicator 95 method shown in Figure 5.21 present that WPC-PP/Sawdust and WPC-PVC-Sawdust generate benzo(a)pyrene equivalent equal to $9.86E^{-8}$ and $1.02\ E^{-7}$ kg B(a)P equivalent. The comparison of carcinogen effect between WPC-PP/Sawdust and WPC-PVC/Sawdust shown in Figure 5.25 presents that WPC-PVC/Sawdust is higher effect than WPC-PP/Sawdust.

5.4.7 Comparison of energy resource depletion between WPC-PP/Sawdust and WPC-PP/Sawdust

The comparison of energy resource depletion between WPC-PP/Sawdust and WPC-PVC/Sawdust using Eco-Indicator 95 method shown in Figure 5.26 illustrates that WPC-PP/Sawdust consume energy resource equal to 85.7 MJ, and also higher than WPC-PVC/Sawdust which consume energy resource equal to 68.6 MJ.

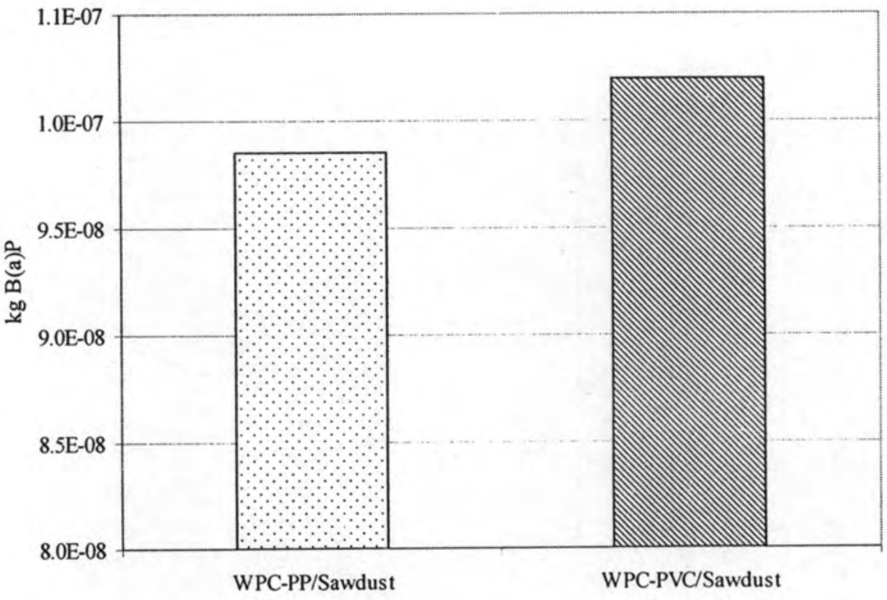

Figure 5.25 Comparison of carcinogen effect between WPC-PP/Sawdust and WPC-PVC/Sawdust

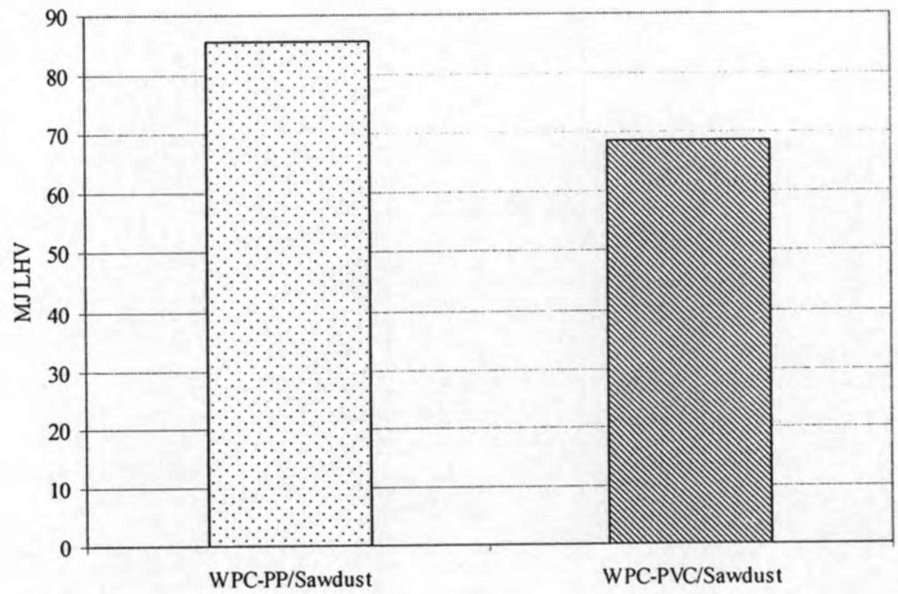

Figure 5.26 Comparison of energy resource depletion between WPC-PP/Sawdust and WPC-PVC/Sawdust

5.5 COMPARISON OF ENVIRONMENTAL IMPACTS OF WOOD-PLASTIC COMPOSITES BY USING ECO-INDICATOR METHOD WITH THE OTHER METHODS

This part is the investigation of convince of the evaluation by using the comparison between the Eco-indicator and the other impact assessment methods, to indicate the deviation of the results. In the current part, the climate change and acidification effects were elected to investigate. Because it is the current interested problem, the comparison between IPCC and CML were applied to exhibit the hot climate effect and the acidification respectively.

5.5.1 Comparison of Environmental impacts of WPC by using Eco indicator method with Eco-Indicator 95 and IPCC methods

The Intergovernmental Panel on Climate Change (IPCC) method is the way to report the environmental effects only in the global warming effect which explained by the kg CO_2-equivalent, the similar to Eco-Indicator 95 which one of impacts is green house gas effect. Thus, in comparison, these two methods were investigated.

The comparison of green house gas effect of wood plastic composite from Eco-Indicator 95 and IPCC method which referred to kg CO_2-equivalent exhibited that the amount of carbon dioxide calculated from Eco-Indicator 95 method is less than calculated from IPCC method which resulted from the difference of characterization factor. But the values of carbon dioxide are the same trend as shown in Figure 5.27

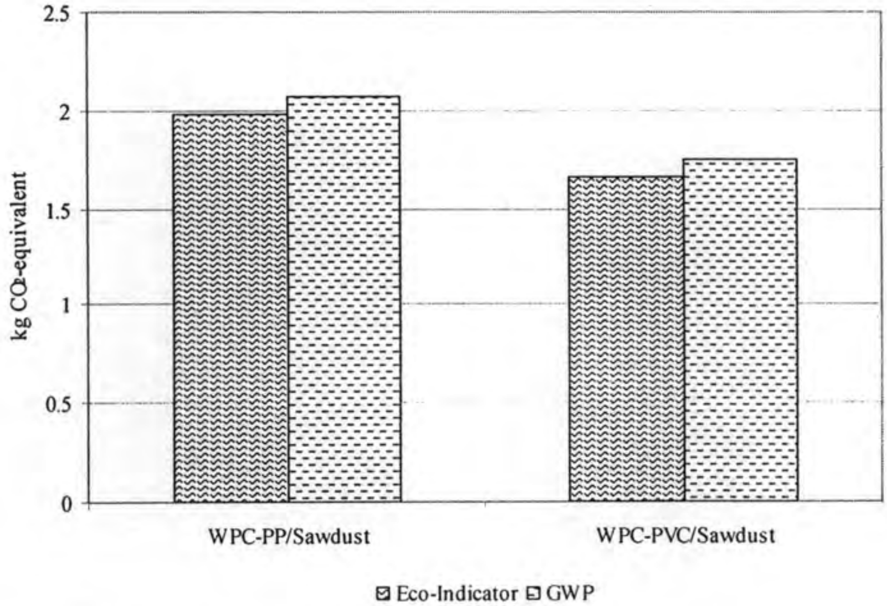

Figure 5.27 Comparison of green house gas effect between WPC-PP/Sawdust and WPC-PVC/Sawdust using Eco-Indicator 95 and IPCC method

5.5.2 Comparison of the effects of WPC on the environment by using Eco indicator method with the Indicator 95 and the CML methods

The CML method is the way to report the environmental effect which separated in 2 categories. The first one is the human health and the last one is the ecosystem quality. However, the CML method have some impact categories which different to those of the Eco-Indicator method such as the resource consumption. Because the CML method is the only one that concern acidification effect. Thus in comparison, the IPCC and the Eco-Indicator were applied to identified the effect of the acidification of WPC. This problem was explained by the kg SO_2-equivalent value.

The amount of sulfur dioxide which effect to acidification of wood plastic composite calculated by Eco-Indicator 95 and CML are compared. The results reveal that amount of sulfur dioxide computed from Eco-Indicator 95 method is less than calculated from CML method which may be resulted from the difference of characterization factor. But the amount of carbon dioxide is the same trend as shown in Figure 5.28

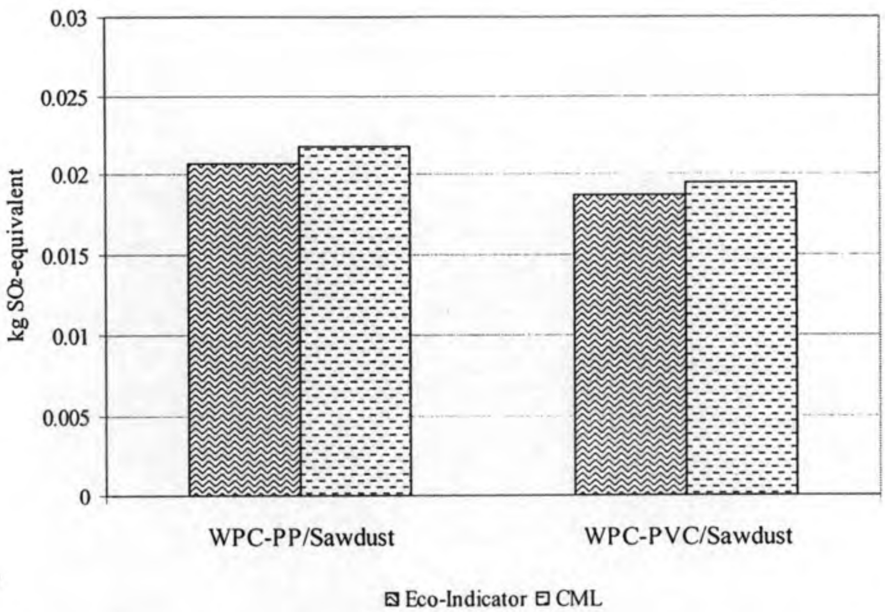

Figure 5.28 Comparison of acidification effect between WPC-PP/Sawdust and WPC-PVC/Sawdust using Eco-Indicator 95 and IPCC method

5.6 INTERPRETATION AND AMPLIFICATION

According to the evaluation of the environmental influences of WPC which prepared from PVC and PP as the polymeric matrix by using the Eco indicator method, the experimental results exhibited that WPC generates both acid and heavy metal. These phenomenons took places in the raw materials phase, which most affect from the synthesized polymeric matrices. Thus, the investigations of the polymer production process are needed to find out the primary cause of the problem.

Discussion

The life cycle analysis of WPC revealed that the main cause of the problem came from the polymeric matrices. Nowadays the production process of PVC and PP were detailed as follows; the current PP production process uses the Zigler-natta method. The production process is conducted by feeding the naphtha in to the reactor at 60 °C for 8 hr under nitrogen atmosphere, the Zigler-Natta catalyst, for instance

Titanium tri chloride, Ferric chloride, Aluminum diethyl monochloride, is used and carried out by the suspension polymerization process.

The PVC production process is conducted by the reaction between ethylene and chlorine under the liquid phase at the temperature of 30-50 ^{o}C and the Ferric chloride is used as a solid catalyst. This procedure generates the Ethylene dichloride and HCl. After that the dehydrochlorination reaction is applied to eliminate the HCl by the 300-500 oC incineration. After the burning process, the VCM is generated and fed to the reactor to polymerize by the suspension process.

The investigations indicated that most of the catalysts used are the heavy metal catalyst which affects to the environment. The conclusion can be drawn for the heavy metal case is mainly come from the solid catalyst in polymer production process. Furthermore, the main source of the polymer production is the petroleum, this was well established that the petroleum comprises of the sulfide substances includes Sulfur dioxide and Sulfur oxide. Both of these chemicals led to the acidification. So, the acid problems come from the petroleum can be summarized. Moreover, the use of petroleum led to the reduction of the natural resources.

Effect of heavy metal problem

The human enzymatic systems are interrupted when the heavy metal is transfer to the body. Some heavy metal will immobile to the cell wall and led to the failure of the chemicals delivery. The toxicity of the heavy metal depends on the chemical conformation of the metal complexes and the transfer route such as respiratory, digestive and epidermal system. To date, the heavy metal liberation is controlled by the law as follows;

Table 5.7 The industrial waste emission standard which influences to heavy metal problem

Pollutants	Emission to	
	Air (mg/cm3)	**Water (mg/l)**
Cupper	Not exceed than 30	Not exceed than 2.0
Mercury	Not exceed than 3	Not exceed than 0.005
Lead	Not exceed than 30	Not exceed than 0.2
Arsenic	Not exceed than 20	Not exceed than 0.25
Manganese		Not exceed than 5.0
Selenium		Not exceed than 0.02
Cadmium		Not exceed than 0.03
Zinc		Not exceed than 5.0
Nickel		Not exceed than 1.0
Barium		Not exceed than 1.0

Source: pollution control department

Effect of Acidification problem

The main cause of the acid rain is the reaction between the sulfur dioxide, the vapor and the others chemical substances in the atmosphere and generates the sulfuric acid and other toxic substances. These chemicals will dissolve in the rain and lead to the rain become acid. The acid rain destroys the ecological system for example; it leaches the fertilizer in the soil makes the plants grow slowly, it leads to the acidification of the land water. Moreover it can merge with the smog and affect the respiratory system of the humans. Now, some acid source substances is controlled by the law as follows.

Table 5.8 The industrial waste emission standard which influences to acidification

Pollutants	Emission to Air (ppm)
SO2	Not exceed than 500
NOx	Not exceed than 200
HCl	Not exceed than 200

5.7 COST ESTIMATION

When developing a business plan for a new product, planners typically make cost estimates in order to assess whether benefits will cover costs. This is done in both business and government. This research, therefore, calculate cost of raw materials and manufacturing cost for production of WPC.

5.7.1 Fixed costs

The fixed cost for WPC Production included equipment and machine used for the production for evaluate and compare cost and find the break-even point for the production of WPC based on two resins. The cost of equipment and machine are shown in Table 5.7

Table 5.9 Fixed cost for WPC production

Equipment & Machine	Price (baht)
Extruder	912,000
Mixer	100,000
Total	1,012,000

* **Ref.** Ever Marketing (Thailand) Co., Ltd.

5.7.2 Variable costs

In this study, the variable costs are cost of raw materials and cost of electricity. The cost comparison of two WPCs production, the variable cost is indicator which indicates the minimum cost process since materials and equipments for production of two WPC are the same. Table 5.8 present cost of each raw materials production of two WPC, WPC-PP/Sawdust and WPC-PVC/Sawdust.

Table 5.10 Comparison of price of raw materials for production of WPC 1 kg.

Materials	Manufacture/Distributor	Cost (Baht)	
		WPC-PVC/Sawdust	WPC-PP/Sawdust
PVC suspension	TPC	19.92032	-
PVC emulsion	TPC	1.024474	-
Sawdust	Lucha Timber	5.69152	-
Lubricant	Olefine organics	0.307342	-
CaCO3	Sand and Soil Industry	0.341491	-
Calcium stearate	Nicho	0.170746	-
Organic complex stabilizer	Nicho	1.394422	-
Processing aid	Nicho	3.699488	-
PP 1100 NK	IRPC	-	30.012
Sawdust	Lucha Timber	-	5.762305
Impact modifier(EOC)	Chemical Innovation	-	7.635054
Coupling agent(MAPP)	Chemical Innovation	-	10.92437
Processing oil	Vicker pigment	-	1.5006
Total cost		**32.55**	**55.83**

The comparison of cost of raw materials shown in Table 5.7 illustrated that the use of polypropylene as resin for WPCs production has higher cost than using poly(vinyl chloride) as resin although formulation of WPC-PP/Sawdust has less ingredients than WPC-PVC/Sawdust but polypropylene has higher cost than poly(vinyl chloride) and also, because of additives used for WPC-PP/Sawdust are expansive. The materials cost for 1 kg WPC-PP/Sawdust and WPC-PVC/Sawdust production are 55.83 baht and 32.55 baht respectively.

In this research, electrical cost is variable cost which calculated by consideration of energy consumption for WPC production. These equipments are mixing and extruder where electrical cost is referred from Metropolitan Electricity Authority in Thailand. Because of production of WPC based on PVC and PP is the same process therefore the electricity costs for two WPCs production are the same as shown in Table 5.9

Table 5.11 Electrical cost for production of WPC 1 kg.

Process	Electricity consumption (kWh)	Price (Baht/kWh)	Total (Baht)
Extruder	0.002	2.61	0.05
Mixer	0.175	2.61	0.45
		Total	0.50

Table 5.9 shows electricity cost for production of WPC 1 kg which equal to xx baht/kg WPC. When compare raw materials cost with electrical cost, it was found out that total variable costs of WPC-PP/Sawdust is higher than WPC-PVC/Sawdust where main cost come from raw materials cost as shown in Table 5.10

Table 5.12 Comparison of cost for production of WPC 1 kg.

Category	Cost (Baht/kg)	
	WPC-PP/Sawdust	**WPC-PVC/Sawdust**
Raw materials	55.83	32.55
Electricity	0.50	0.50
Total	56.33	33.05

5.7.3 Break – Even Point

The break even point in economics is the point at which cost or expenses and income are equal. There is no net loss or gain, one has "broken even". The break even point can be determined by the Lawson criterion. The point at which a firm or other economic entity breaks even is equal to its fixed costs divided by its contribution to profit per unit of output, which can by shown by the following formula : -

$$\text{Break even point} = \frac{\text{Fixed costs}}{\text{Contribution per unit output}}$$

For this case, the contribution of WPC equal to price of WPC minus by total cost where the price of WPC shown in Table 5.10

Table 5.14 Price of WPC1 kg

Cross sectional area (cm^2)	Price (Baht)
2.0 x 4.5	65
1.0 x 4.0	98
2.0 x 5.0	83
2.0 x 7.5	84
2.0 x 1.0	83
average	82.5

For WPC-PP/Sawdust

Fixed costs = 1,012,000

Variable costs = 56.33

Total cost = Fixed costs + Variable costs

= 1,012,000 + 56.33 x

Price of WPC = 82.5 Baht/kg

Then, Break even point is

82.5 x = 1,012,000 + 33.05 x

x = 38670 kg

For WPC-PVC/Sawdust

Fixed costs = 1,012,000

Variable costs = 33.05

Total cost = Fixed costs + Variable costs

= 1,012,000 + 33.05 x

Price of WPC = 82.5 Baht/kg

Then, Break even point is

82.5 x = 1,012,000 + 33.05 x

x = 20,465 kg

From the result, it indicates that break even point for WPC-PP/Sawdust and WPC-PVC/Sawdust production equal to 38,670 and 20,465 kg respectively which means that if the production of WPC more than 38,670 and 20,465 kg for WPC-PP/Sawdust and WPC-PVC/Sawdust, it lead to profit of this investment.

5.7.4 Gross Profit

Gross profit or sales profit is the difference between revenue and the cost of the making product or providing a service be deducting overheads, payroll, taxation and interest payments. In general, it is the profit shown on a transaction if one disregards the indirect costs. It is the revenue that remains once one deducts the costs that arise only from the generation of that revenue. Gross Profit should be broken out and clearly labeled on the income statement. Here's the formula to calculate it yourself:

Total Revenue - Cost of Goods Sold = Gross Profit

Assumption for gross profit of this case

1. The capacity of extruder is about 150 kg/hr
2. The capacity of mixer is about 50 kg/batch
3. Operating time is 8 hr/day operate 24 day/month and then production rate is 345,600 kg/year.
4. Selling price is 82.5 baht/kg WPC.
5. Operating cost is not included direct labor and all of variable manufacturing costs.

Then gross profit of WPC production, unit in baht per year, is :

	WPC-PP/Sawdust	WPC-PVC/Sawdust
Sale (345,600 x 82.5)	28,512,000	28,512,000
Cost of making products:		
Direct materials	19,296,347.86	11,249,215.81
Electricity cost	172,800	172,800
Total cost of sales	19,469,147.86	11,422,015.81
Gross profit	9,042,852.14	17,089,984.19

From the statement of gross profit as shown in the previous page, it was indicated that the gross profit of WPC-PP/Sawdust and WPC-PVC/Sawdust, which operated 345600 kg per year, are about 9,042,850 and 17,089,985 baht per year but reminder that these gross profit are not included direct labor and all of variable manufacturing costs. From consideration in economic performance (break even point and gross profit, then the production of WPC should be produced from poly (vinyl chloride) since it has the lower cost which leads to the higher gross profit and net income than using polypropylene as polymer resin.