Evaluating the Eco-Efficiency of 3R Waste from the Petroleum and Petrochemical Group in the Map Ta Phut Industrial Estate, Thailand with the Environmental Improvement Productivity Indicator

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Abstract

The concept of eco-efficiency has become increasingly popular in the environmental debate of product systems, processes, and/or companies in recent year. Eco-efficiency is generally described as a ratio between environmental impact and value of production. This paper presents the eco-efficiency indicator, called environmental improvement productivity (EIP), for assessing the environmental improvement from 3R waste of the petroleum and petrochemical (PP) group in the Map Ta Phut Industrial Estate (MTPIE), Thailand. The EIP is defined as the ratio of total 3R waste, as a value of production, to the total amount of CO_2 reduction by the 3R activities, as an environmental impact value or environmental improvement of 3R waste, which was evaluated by the CO_2 emission calculated from the basis of 3R waste incineration. The total amount of waste and 3R waste generated from the PP group in fiscal year 2007, which was separated into 4 quarters, were collected and used to create the waste flow diagram of the PP group. The results show that more than 60% of the total waste generated from the PP group in the MTPIE was classified to be as 3R waste. The evaluation of eco-efficiency shows the rather decrease of EIP values from quarter 1 to quarter 4, which refers to the increase of environmental improvement. The research can demonstrate the environmental benefits from the 3R waste, which will feed into strategic development and would enable to encourage the 3R activities for industrial sector in Thailand.

Keywords: Eco-efficiency, Environmental improvement productivity, 3R waste, Waste flow, Map Ta Phut industrial estate

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Introduction

Industries have been contributing factors for both enhancing economic activities as well as sources of environmental pollutions. Industry is indispensable motor for economic growth of modern society and inevitable to developing countries. Most of human need are fulfilled through goods and services produced by industry (WCED, 1987). Map Ta Phut Industrial Estate (MTPIE) is located in Rayong province, east of Thailand. It was developed in 1989 by the state enterprise, Industrial Estate Authority of Thailand (IEAT), Ministry of Industry. MTPIE is considered to be industrial area No. 3 as factories located within this area are entitled to receive the most benefits, encouraging investments from both Thai and foreign investors. Presently there are 53 factories located within the MTPIE, which can divided into 5 industrial groups, which are petroleum and petrochemical (PP) grouup, Eco-efficiency can be used as an evaluation tool, which can apply both in micro and macro scales. The eco-efficiency evaluation of iron industry in Nepal (Kharel and Charmondusit, 2008) and the eco-efficiency evaluation of the petroleum and petrochemical group in the MTPIE (Charmondusit and Keartpakpreak, 2008) were shown as an extra sparkling application of eco-efficiency evaluation in micro and macro scales, respectively. Those studies are useful moreover in applying tool of eco-efficiency that integrates ecological and economic excellence of industrial sector.

In this study, the eco-efficiency indicator, called environmental improvement productivity (EIP), was used for assessing the environmental improvement from 3R waste of the PP group in the MTPIE. Thailand. The total amount of waste generated from the PP group in the MTPIE was collected in the fiscal year 2007 and classified into 2 categories, which are disposal and 3R wastes. The characterization of the industrial waste in the PP group was studied by using material flow analysis (MFA). Finally, quantification of environmental benefits from 3R waste was evaluated by using EIP indicator.

Methodology

Data Collection

Data collection was mainly done by field site investigation. Total amount of industrial waste, which includes hazardous and non-hazardous waste, generated from the PP group in fiscal year 2007 was received from the existing monitoring report and data availability at the MTPIE office, industrial gas group, utility group, iron and steel industry group and chemical industry group. Petroleum and petrochemical group was found to be the main important group in MTPIE, which are 31 factories or 58.49 percent of the total factories located in this group (Charmondusit et al.,2007).

Eco-efficiency concept has emerged as a valuable tool towards the target of sustainable development. The general definition of eco-efficiency is referred to the relation of 2 elements, which are environmental impact and value of production. The 4 basic terminologies referring to eco-efficiency, which are environmental productivity, environmental intensity of production, environmental improvement cost, and environmental cost-effectiveness, have been proposed by G. Huppes and M. Ishikawa (2005).

The Characterization of Industrial Waste in the PP Group

The gathered data of industrial waste generated from the PP group in fiscal year 2007 was classified into disposal and 3R wastes. In order to understand the flow of industrial waste in the PP group, the 2 categories of industrial waste complicated in fiscal year 2007 was characterized and used for create the waste flow diagram of the PP group by following the basic principle of MFA (Hammer et al., 2003).

Eco-Efficiency Evaluation

As we know that the general definition of eco-efficiency is referred to the relation of product or service value and environmental impact. Due to the data availability of environmental impact from 3R waste and various types of recycle and recovery technologies, the 4 basic terminologies referring to eco-efficiency, which have been proposed by G.Huppes and M. Ishikawa, were not appropriate for evaluation of the 3R waste eco-efficiency. In order to quantify the environmental benefits from 3R waste, the eco-efficiency evaluation for 3R waste, which was used in this study, was developed and expressed by the ratio of production value per unit of environmental improvement, which is called environmental improvement productivity (EIP) indicator.

$$\text{EIP} = \frac{\text{Production Value}}{\text{Environmental Improvement}} \quad (1)$$

In this study, the production value can be expressed by the total amount of waste generated from the PP group in ton. The environmental improvement denominator can be expressed by the total amount of CO_2 reduction due to the reuse, recycle, and recovery of 3R waste. According to the data availability and various technologies for recycle and recovery waste, the total amount of CO_2 emission from 3R waste was used to present as a total amount of CO_2 reduction. The method for calculating the CO_2 emission from 3R waste was base on the carbon content of the incinerated wastes and the CO_2 emission from the metal process following the IPCC guidelines (IPCC , 2006; IPCC, 1996). The mathematic notation used for eco-efficiency evaluation of 3R waste is shown in equation (2).

$$EIP = \frac{\Sigma W_t}{\Sigma (Co_2)_t} \quad (2)$$

Where ΣW_t is the total amount of waste generated from the PP group in unit of ton and the total amount of CO_2 reduction from 3R waste in unit of ton is referred by $\Sigma (CO_2)_t$. The can be further expressed with the function of total amount of reuse waste and total amount of recycle and recovery wastes.

$$\Sigma (CO_2)_t = f\,[\Sigma (CO_2)_{reuse}, \Sigma (CO_2)_{recycle+recover}] \quad (3)$$

Results and discussion

Waste Flow of Petroleum and petrochemical group

Waste flow diagram was importance and necessary for the characterization of the industrial waste. It was reflectively the waste characterization of the area and verification of source and final sink of the waste flow diagram of the PP group in MTPIE, which is shown in Figure 1. The total waste from 31 factories in the PP group in fiscal year 2007

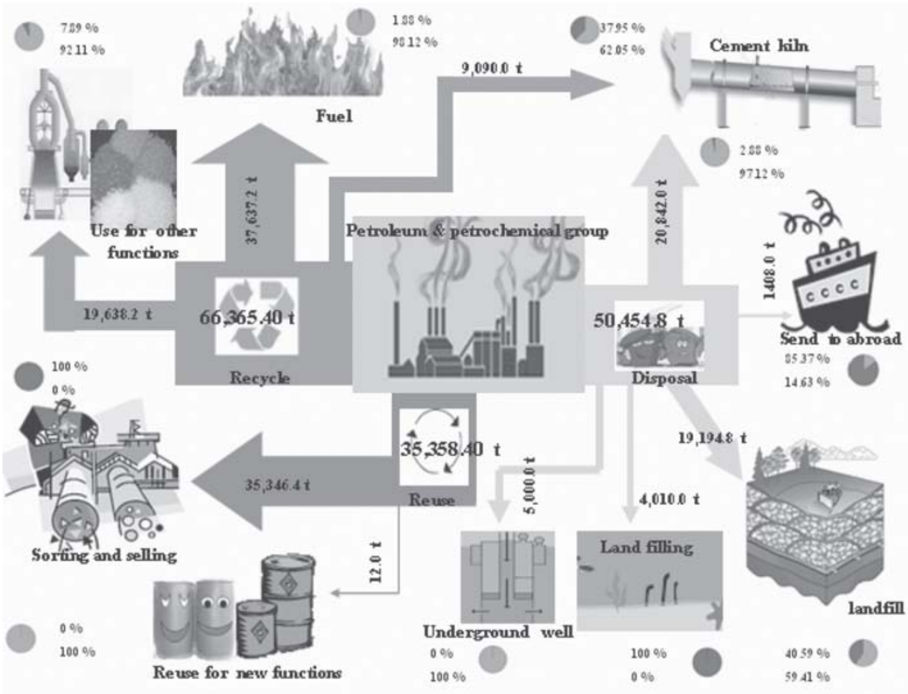


Figure 1. Flow diagram of industrial waste in the PP group.

was 152,178.6 ton, which can be divide into hazardous waste 96,006.3 ton or 94.38 % of the total waste generation in the PP group and non-hazardous 5,717.5 ton or 5.62 %. The industrial waste generated from the PP group can be classified into 2 categories comprising of 3R waste 101,723.8 ton or 66.84 % and disposal waste 50,454.8 ton or 33.15 %. Most of the disposal waste from the PP group was sent to incinerator and landfill site as 79.35 % of the total disposal waste. 66,365.4 ton of the total amount of 3R waste, which consists of 60,659.9 ton of hazardous waste and 5,705.5 ton of non-hazardous waste, can be recycled and recovered. Most of recycle and recovery wastes was used as fuel substitution or burning for energy recovery. Consequently, 35,358.4 ton left, which was hazardous waste 35,346.4 ton and non hazardous waste 12.0 ton, can be reused.

Eco-Efficiency Evaluation of 3R Waste

EIP of Reuse Waste

The evaluation of reuse waste eco-efficiency is shown in Figure 2. The total industrial waste generated from the PP group in fiscal year 2007 was 152,178.6 ton, which can be divided into 4 quarters. The results of total industrial waste in each quarter were 14,205.4 ton in quarter 1, 60,315.0 ton in quarter 2, 28,154.3 ton in quarter 3, and 49,503.9 ton in quarter4. The amount of reuse waste was 1,796.0 t in quarter 1, 11,352.9 t in quarter 2 and rising gradually in consecutive quarters were 2,400.0 t in quarter3 and 35,071.9 t in quarter 4, respectively. The composition of reuse waste demonstrates in Figure 2 indicated that metal is the main material of the reuse waste following with the plastic, wood, paper, other, and rubber wastes. The CO_2 reductions from the total

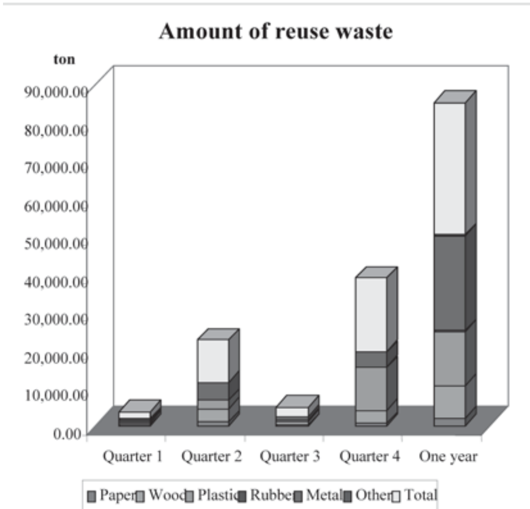


Figure 2. Amount of reuse waste

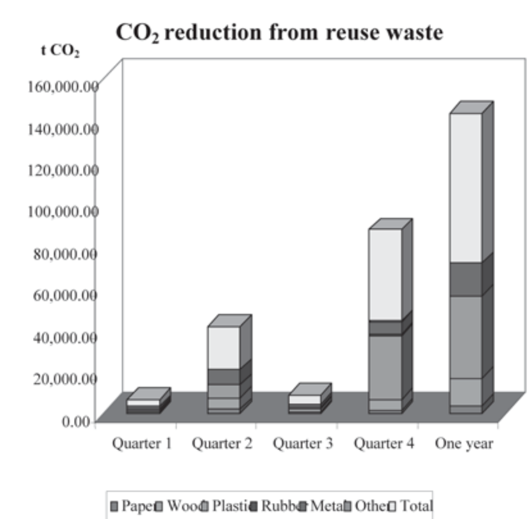
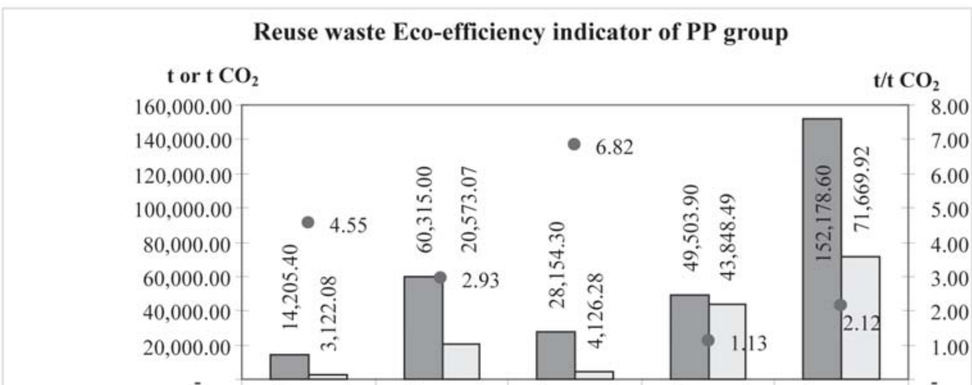


Figure 3. CO_2 reduction from reuse waste



	Quarter 1	Quarter 2	Quarter 3	Quarter 4	One year
Waste (ton)	14,205.40	60,315.00	28,154.30	49,503.90	152,178.60
CO_2reduction (t CO_2)	3,122.08	20,573.07	4,126.28	43,848.49	71,669.92
Eco efficiency in t/tCO_2	4.55	2.93	6.82	1.13	2.12

Figure 4. EIP value of reuse waste in petroleum and petrochemical group

reuse waste in each quarter were 3,122.08 t CO_2 in quarter 1, 20,573 t CO_2 in quarter2, 4,126.28 t CO_2 in quarter 3, and 43,848.49 t CO_2 in quarter4 which is shown in Figure 3. It is obvious that the CO_2 reduction from the reuse of industrial waste in the PP group were increased except quarter 3. Plastics material was shown as the main CO_2 reduction component in reuse waste as 14,184.6 t which could be reduced CO_2 emission as 39,007.6 t CO_2 following with metal, wood, paper, rubber and others were 9,739.0 t or 15,582.4 t CO_2, 8,639.0 t or 13,462.9 t CO_2, 2,097.0 t or 3,183.2 t CO_2, 200.0 t or 412.7 t CO_2 and 212.0 t or 21.0 t CO_2, respectively. The result of reuse waste eco-efficiencies were progressively rather decreasing in a trend of 4.55 t/t CO_2 in quarter 1, 2.93 t/t CO_2 in quarter 2, 6.82 t/t CO_2 in quarter 3, and 1.13 t/t CO_2 in quarter 4 as revealed in Figure 4.

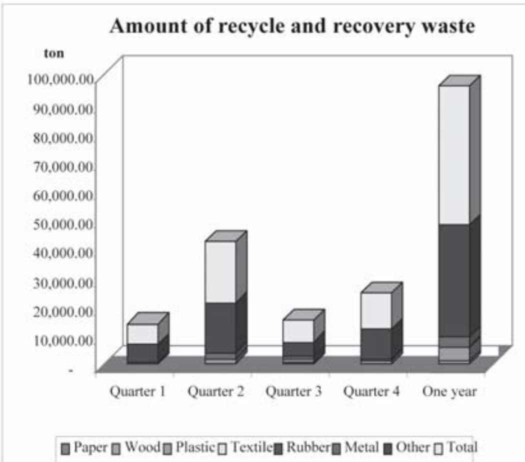


Figure 5. Amount of recycle and recovery waste

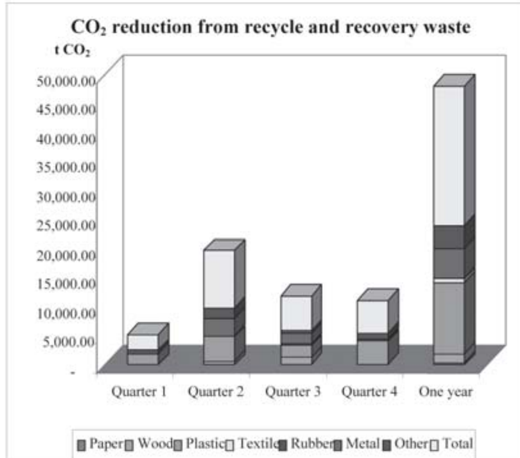


Figure 6. CO_2 reduction from recycle and recovery waste

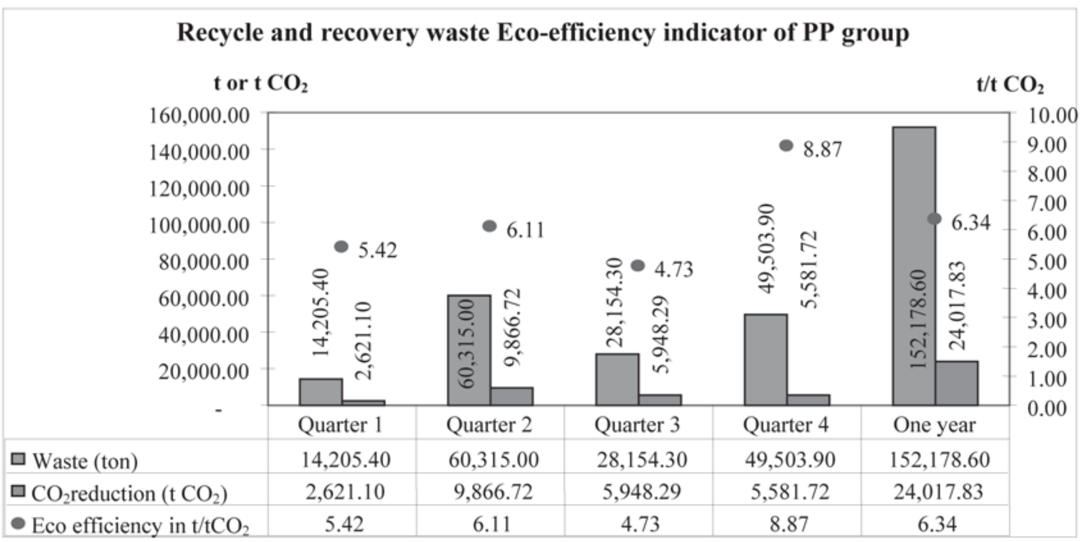


Figure 7. EIP value of recycle and recovery waste in petroleum and petrochemical group

EIP of Recycle and Recovery Wastes

The total amount of recycle and recovery wastes in each quarter is shown in Figure 5. The amount of recycle and recovery waste was 6,980.0 t in quarter1, 21,210.5 t in quarter2 and rising gradually in consecutive quarters were 2,400.0 t in quarter3 and 35,071.9 t in quarter 4, respectively. Other, such as solvent, sand and dust, was found to be the main composition of the recycle and recovery wastes following with the plastics, metal, wood, textile, paper, and rubber wastes. The CO_2 reductions from the total recycle and recovery waste in each quarter were 2,621.1 t CO_2 in quarter 1, 9,866.7 t CO2 in quarter2, 5,948.3 t CO_2 in quarter 3, and 5,581.7 t CO_2 in quarter4, as shown in Figure 6. The main component of the recycle and recovery wastes was plastics as 4,466.0 t, which could be reduced CO_2 emission as 12,281.5 t CO_2, following with metal, others, wood, textile, paper and rubber were 3,245.0 t or 5,192.0 t CO_2, 38,702.5 t or 3,831.5 t CO_2, 1,050.0 t or 1,636.2 t CO_2, 372.0 t or 545.6 t CO_2, 241.0 t or 365.8 t CO_2 and 80.0 t or 165.1 t CO_2, respectively. Figure 7 shows the recycle and recovery wastes eco-efficiencies, which were 2.66 t/t CO_2 in quarter 1, 2.15 t/t CO_2 in quarter 2, 1.29 t/t CO_2 in quarter 3, and 2.20 t/t CO_2 in quarter 4. The results show that quarter 3 gave the lowest eco efficiency, which demonstrates the excellent performance in both of economic and environmental benefits.

EIP of 3R Waste

Figure 8 shows the total amount of 3R waste in each quarter. The amount of 3R waste was 8,776.0 t in quarter 1, 32,563.4 t in quarter 2, 10,0920 t in quarter 3 and 31,797.0 t in quarter 4. The CO_2 reductions from the total 3R waste in each quarter were 5,743.2 t CO_2 in quarter 1, 30,439.8 t CO_2 in quarter2, 10,074.6 t CO_2 in quarter3, and 49,430.21 t CO_2 in quarter4 as revealed in Figure 9. It is obvious that the CO_2 reduction from the 3R of industrial waste in the PP group were increased except quarter 3. When looking at the components in 3R waste generated from the PP group, Plastics material still was the main component of the total 3R waste as 18,650.6 t, which could be reduced the CO_2 emission as 51,289.2 t CO_2. Metal, wood, other, paper, textile and rubber were followed components as 12,984.0 t or 20,774.4 t CO_2, 9,689.3 t or 15,099.2 t CO_2, 38,914.5 t or 3,852.5 t CO_2, 2,338.0 t or 3,549.1 t CO_2, 280.0 t or 577.8 t CO_2, and 372.0 t or 545.6 t CO_2, respectively. Figure 10 shows the EIP of the 3R waste in the PP group. The EIP values of the 3R waste from the PP group were 2.47 t/t CO_2 in quarter1, 1.98 t/t CO_2 in quarter 2, 2.79 t/t CO_2 in quarter3, and 1.00 t/t CO_2 in quarter4. Quarter1 gave the lowest amount of 3R waste but the eco-efficiency was better than that of quarter3. This can be explained that the main component of the 3R waste in quarter1 was the higher carbon substances, which can give more CO_2 reduction.

Feedbacks

The eco-efficiency evaluation of 3R waste from the PP group in the MTPIE with EIP indicator can lead to the suggestions as follows:

- The EIP value can quantify the efficiency of industrial waste output from the PP group. The decrease of EIP value could be from 3 reasons: 1) reduction of the total waste 2) increase of 3R waste and 3) increase of higher carbon substances, which usually give more CO_2 released by incineration such as plastics, in the total amount of 3R waste.

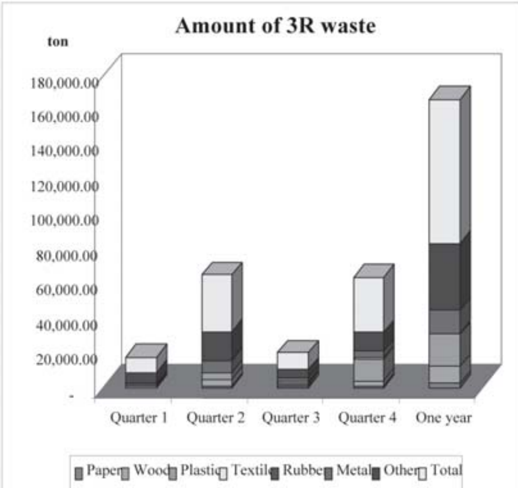


Figure 8. Amount of 3R waste

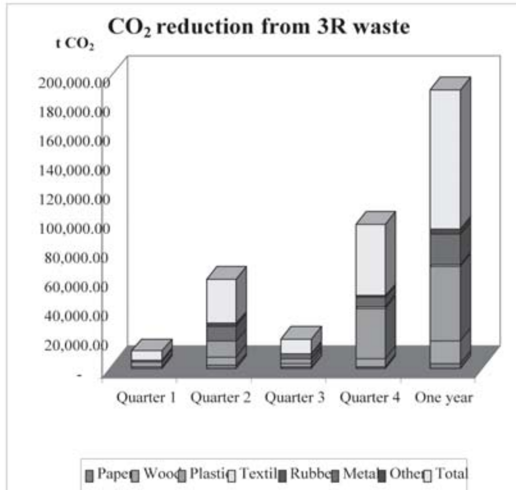


Figure 9. CO_2 reduction from 3R waste

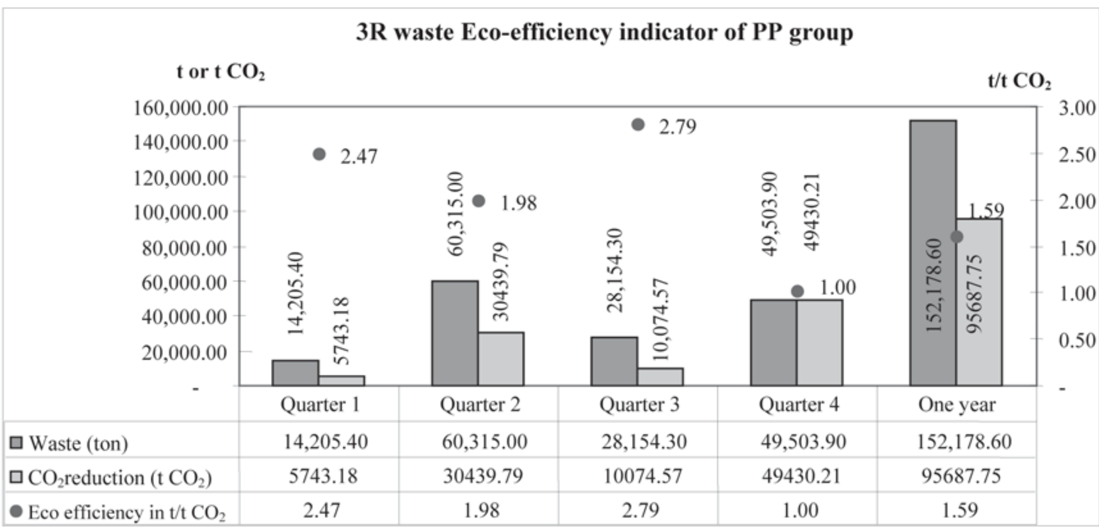


Figure 10. EIP value of 3R waste in petroleum and petrochemical group

- The eco-efficiency evaluation with EIP indicator is just an assessment tool, which has benefits to track and quantify the environmental performance from 3R waste. In order to sustain the higher eco-efficiency, industries in the PP group have to reuse, recycle, and recovery their own waste as reported. Moreover, they must decrease the total amount of waste generation and increase more in total amount of 3R waste by using the 3R materials and applying the eco-design for process and product modification (Dewulf and Duflou, 2004).
- Industries should apply eco-efficiency to annual sustainable in order to promote this concept into reality.
- Eco-Efficiency is fundamentally a ratio of some measure of economic or product value to some measure of environmental impact, which is ability to combine performance along two of the three axes of sustainable development. In order to explain the direction of progress toward the goal of sustainable development, the issues concerning equity and other social properties need to be included for the further study.

Conclusions

Eco-efficiency analysis is now and will continue to be one important assessment method for research and development, production, marketing or waste management. Eco-efficiency should increase the positive environmental performance of an industry in relation to economic value creation or to reduce negative effects.

The research can provide the basic framework on eco-efficiency with respect to waste for the industrial sector in Thailand. Moreover, it can very useful for tracking industrial waste and ensuring continuous improvement to get more benefit (in both of economic and environment) from industrial waste by reuse, recycle and recovery.

This study is reflectively the waste characterization and verification of source and final sink of the waste flow of the PP group in MTPIE. The analyze results of waste eco-efficiencies reflect trend of reuse and 3R waste eco-efficiencies are rather decreasing but recycle and recovery waste are rather increasing. The waste composition demonstrates as an influence indicator, which can indicate the CO_2 reduction and EIP values of the 3R waste. Thus, the eco-efficiency evaluation with EIP indicator could be used as a useful assessment tool for further industrial waste management.

Acknowledgments

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