QUANTITATIVE EVALUATION OF INDUSTRIAL WASTE IN THE MAP TA PHUT INDUSTRIAL ESTATE

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Abstract

Map Ta Phut Industrial Estate (MTPIE), the biggest petroleum and petrochemical industrial estate of Thailand, is located in Rayong province, east of Thailand. MTPIE applied the concept of by product exchange (BPX) and eco-efficiency (EE) into the actions with the objectives of improving environmental performances and industrial competitiveness toward to the goal of sustainable development. In order to reach to sustainability goal, industrial waste is the one important key environmental category, which can increase the efficiency of resource by reuse, recycling and recovery. This paper aims to present the quantitative assessment of industrial waste generated from each industrial groups in the MTPIE, which has become critical for both researchers and practitioners. Quantification diagram of industrial waste in MTPIE was developed to identify the waste characteristics and amount of industrial waste generation. The quantitative circulation performances of industrial waste, which are recyclable waste ratio (RWR), total CO_2 reduction ratio (CRR), and landfill reduction rate (LRR), were evaluated. The results show that the utility group generated the highest amount of industrial waste in MTPIE and demonstrated the highest values of RWR and LRR. The research can provide the framework for quantitative evaluation of industrial waste in macro level, which could lead to the development of eco-efficiency indicators for measure the eco-industrial estate performances in near future.

Keywords: Eco-Efficiency, Eco-Industrial Estate, Industrial waste, Recyclable waste, CO_2 reduction, Landfill reduction, Map Ta Phut Industrial Estate

1. Introduction

The large demand for resource and profit of industrial activities has been built for industrial waste problem. Resource shortages and solid waste management problem became a constraint for industry towards to sustainability goal in Asian developing countries such as Thailand [1]. Proper management and promotion of recycling and reuse of industrial wastes is one of the most important environmental tasks, which can reduce environmental loading and effectively use resources [2].

Industrial Ecology (IE) is a system view of the interactions between industrial and ecological systems. It is a new approach to the industrial design of products and processes and the implementation of sustainable manufacturing strategies. It is an attempt to manage industrial estate as an ecosystem, with feedback loops and minimal use of resources and production of wastes [3, 4]. In order to reach the industrial ecology goals, industrial waste is the one important key factor, which have to manage by industrial plants individually and the estate for the potential for on-site reuse, recycling, recovery or co-treatment for disposal.

An industrial park or estate is defined as a large tract of land, sub-divided and developed for the use of several firms simultaneously, distinguished by its shareable infrastructure and close proximity of firms [5]. The implementation of IE concept into an industrial park could lead to an eco-industrial park. Japan has been developed the Eco-town project by introducing a recycling based society program, which aimed to tackle two challenges of efficient management of solid wastes and effective revitalization of heavy industries at the same time [6]. China implemented the idea of circular economy, which is a model of economic development based on the principles of industrial ecology where economic and environmental systems are integrated [7]. Expanding the by product exchange (BPX) program and eco-industrial network were appointed to the industrial park in South Korea [8].

Based on the comprehensive application of industrial ecology, the characteristic of the segregated industrial waste generated from each industrial groups located in industrial estate must be investigated as well as the quantitative assessment of the performances and environmental benefits of industrial waste generated from an industrial estate. This paper aimed to present the quantitative assessment of industrial waste generated from each industrial groups in the Map Ta Phut Industrial Estate (MTIPE), which located in Rayong province, eastern of Thailand. The characterization and amount of industrial waste in 5 groups was illustrated via material flow diagrams. The quantitative circulation performances of industrial waste, which are recyclable waste ratio (RWR), total CO_2 reduction ratio (CRR), and potential landfill reduction rate (LRR), were assessed.

2. Methodology

2.1 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 factories at MTPIE in fiscal year 2007 was received from the existing monitoring report and database at the MTPIE office.

2.2 Characterization of industrial waste

The gathered data of industrial waste generated from the factories located in the MTPIE group in fiscal year 2007 was classified into 3 categories, which are reuse, recycle and recovery, and disposal wastes. In order to understand the flow of industrial waste in the MTPIE, the 2 categories of industrial waste were characterized and carried out to create the waste flow diagram of each industrial groups in the MTPIE by following the basic principle of MFA [9].

2.3 Quantitative assessment of industrial waste

In order to show the potential performance and the environmental benefits of industrial waste circulation, indicators were designed based on the previous literatures [10].

2.3.1 Recycle Waste Ratio (RWR)

Waste management methods by reuse, recycle and recovery waste can reduce the volume of waste the environmental impact. RWR was the indicator which was reflected the ratio between total amount of the 3R materials in ton per total amount of the industrial waste generated from factories in the MTPIE in ton. RWR indicator can demonstrate the efficiency of industrial waste with respect to the reuse, recycle, and recovery activities.

$$\mathrm{RWR} = \frac{\text{3R Wastes}}{\text{Total Waste}} \qquad (1)$$

2.3.2 CO_2 Reduction Ratio (CRR)

Carbon dioxide is a major contributor to atmosphere, when the industrial waste was burned. It can effect the global warming. In order to quantify the environmental benefits from 3R wastes (reuse, recycle, and recovery wastes), the ratio of CO_2 reduction, which was derived from the 3R activities of industrial waste, per total waste input is expressed by the ratio in the following equation:

$$\mathrm{CRR} = \frac{\mathrm{CO_2}\ \text{Reduction}}{\text{Total Waste}} \qquad (2)$$

According to the data availability and various technologies for recycle and recovery waste, the total amount of CO_2 emission in ton was calculated from the amount of CO_2 generated by an incineration following the IPCC guideline [11].

2.3.3 Landfill Reduction ratio (LRR)

As we know that the waste treatment by landfill are common methods and remain so in many places around the world. Landfill sites can be used for a specific purpose because it has been limited area. Therefore, decreasing the landfill site can increase area for other purposes. LRR was the indicator which was explained the ratio between the total amount of materials, which were not treated by regular landfill in ton, and total amount of the 3R waste in ton.

$$\mathrm{LRR} = \frac{\text{Materials were not treated by landfill}}{\text{Total amount of 3R waste}} \qquad (3)$$

3. Results and discussion

3.1 Characterization of industrial waste in the MTPIE

MTPIE was established in year 1989 by state enterprise, Industrial Estate Authority of Thailand (IEAT), Ministry of Industry. It is a petrochemical based industrial estate, which located in Rayong province, eastern of Thailand. There are 53 factories located within the MTPIE, which can divided into 5 industrial groups such as petroleum and petrochemical group (PP), industrial gas group (IG), utility group (U), iron and steel industry group (IS) and chemical industry group (CH). PP group is the biggest group, which are 31 factories or 58.49 percent of the total number of factories in the MTPIE, followed with CH group (8 factories), IS group (7 factories), U group (5 factories) and IG group (3 factories) [12]. The characterization of industrial waste in the MTPIE separately in each group can be studied by using the waste flow diagrams, which are shown in Figure 1-5.

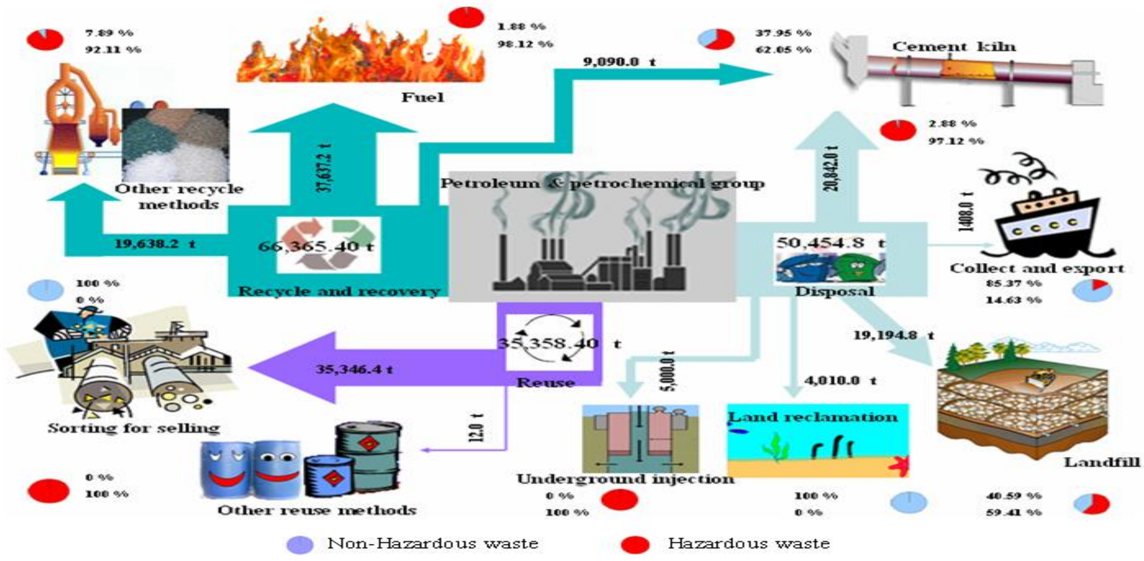

Fig. 1 Waste flow diagram of the PP group

3.1.1 Waste flow diagram of the PP group

The total amount of industrial wastes from 31 factories in the PP group was created a waste flow diagram, which is illustrated in Figure 1. Total industrial waste generated from the PP group in fiscal year 2007 was 152,178.6 ton, which can segregate into hazardous waste (96,006.3 ton or 94.38 percent of the total amount of industrial waste generated from the PP group) and non hazardous waste (5,717.5 ton or 5.62 percent of the total amount of industrial waste generated from the PP group). Amount of total waste were classified into 2 categories comprising of 3R waste 101,723.8 ton or 66.84 percent and disposal waste 50,454.8 ton or 33.15 percent. More than 60 percent of total waste generated from the PP group was classified into the 3R waste. The amount of recycle and recovery waste was 66,365.4 ton, which comprised of hazardous waste and non hazardous waste as 60,659.9 ton and 5,705.5 ton, respectively. The amount of reuse waste was 35,358.4 ton that consisted of hazardous waste 35,346.4 ton and non hazardous waste 12.0 ton. Most of disposal waste generated from the PP group was sent to cement kiln and landfill site as 79.35 percent of the total amount of disposal waste. In addition, recycle and recovery waste was usually used as fuel substitution or burn for energy recovery.

3.1.2 Waste flow diagram of IS group

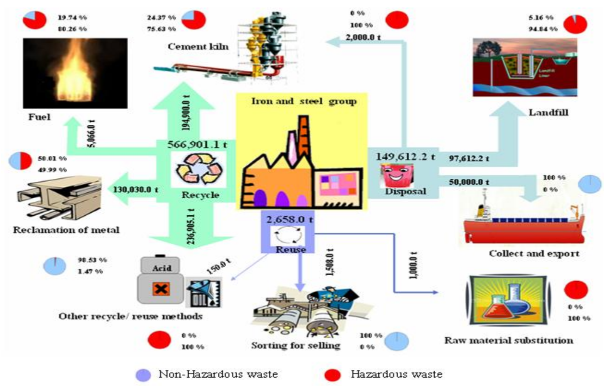

Fig. 2 Waste flow diagram of the IS group

Figure 2 shows the waste flow diagram of IS group. The 7 factories locate in the IS group generated industrial waste 719,171.3 ton in fiscal year 2007, which can be divided into 3R waste as 569,559.1 ton or 79.20 percent of the total amount of industrial waste generated from the IS group and disposal waste as 149,612.2 ton or 20.80 percent of the total amount of industrial waste generated from the IS group. It was also comprise of hazardous waste 315,675.3 ton or 43.89 percent of the total amount of industrial waste generated from the IS group and non-hazardous 403,496.0 ton or 56.11 percent of the total amount of industrial waste generated from the IS group. The recycle and recovery wastes of the IS group was 431,805.1 ton or 76.17 percent of the total amount of industrial waste generated from the IS group, which was carried out for other function and used as fuel substitution in cement kiln. The amount of reuse waste was 2,658.0 ton of reused 1,508.0 ton or 56.73 percent of the total amount of reuse waste was sorted for selling. Most of the disposal waste generated from the IS group was sent to landfill site as 97,612.2 ton or 65.24 percent of the total amount of disposal waste. The 33.42 of the disposal waste left of the IS group was sent to abroad.

3.1.3 Waste flow diagram of the U group

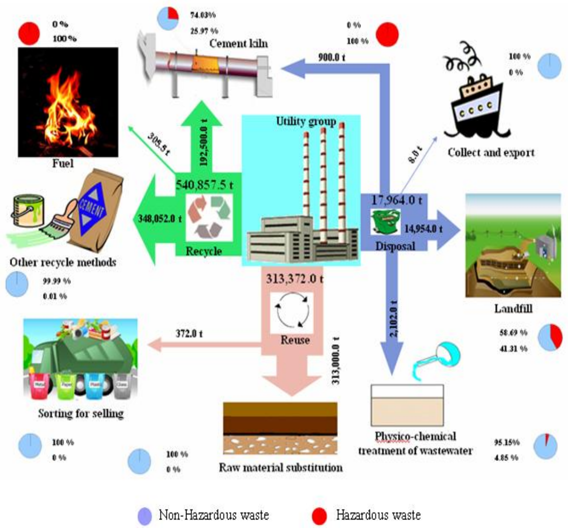

Fig. 3 Waste flow diagram of the U group

The waste flow diagram of the U group is shown in Figure 3. The U group consists of 5 factories, which generated industrial waste around 872,193.5 ton in fiscal year 2007. The industrial waste can be classified into hazardous waste 57,537.5 ton or 93.40 percent of the total industrial waste generated from the U group and non-hazardous waste 814,656.0 ton or 6.60 percent of the total industrial waste generated from the U group. The industrial waste of the U group was comprised of 3R waste 854,229.5 ton or 97.94 percent of the total industrial waste generated from the U group and disposal waste 17,964.0 ton or 2.06 of the total industrial waste generated from the U group. 313,000.0 ton of reuse waste generated from the U group was used as a raw material substitution. While, most of the recycle and recovery wastes was used for other function, such as fly ash from coal burn was recycled to be as a concrete block, and used as a fuel substitution in cement kiln. The major management of the disposal waste generated from the U group was sent to landfill site as 83.24 percent of the total disposal waste followed with physico-chemical treatment, sent to co-incineration in cement kiln, and collected and exported, respectively.

3.1.4 Waste flow diagram of the CH group

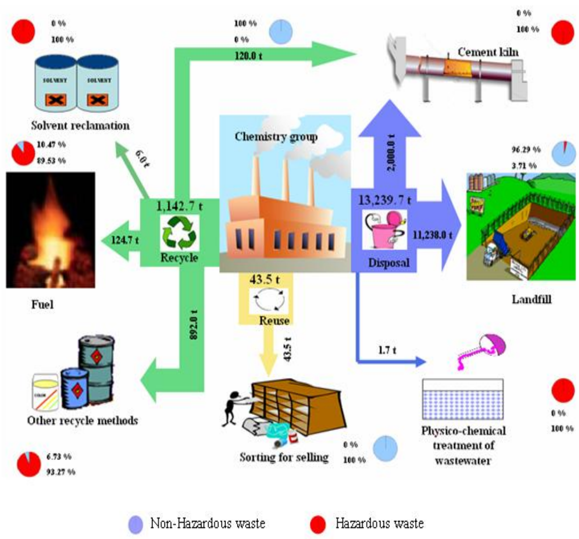

Fig. 4 Waste flow diagram of the CH group

The waste flow diagram of the CH group is shown in Figure 4. The CH group consists of 7 factories, which generated industrial waste around 14,425.9 ton in fiscal year 2007. The industrial waste generated from the CH group can be classified into 3R waste 1,182.2 ton or 8.22 percent of the total waste generated group the CH group and disposal waste 13,239.7 ton or 91.78 percent of the total waste generated group the CH group. It was also can be segregated to hazardous waste 3,376.4 ton or 23.41 percent of the total waste generated group the CH group and non-hazardous 11,049.5 ton or 76.59 percent of the total waste generated group the CH group. 43.5 ton of reuse waste was sorted for selling. While, most of recycle and recovery wastes 892.0 ton or 77.45 percent of the recycle and recovery waste, such as spent activated alumina and used oil, was recycled as a new raw material. 11,238.0 ton or 84.88 percent of the total amount of disposal waste was sent to cement kiln and landfill site.

3.1.5 Waste flow diagram of the IG group

The waste flow diagram of the IG group is illustrated in Figure 5. The IG group consists of 3 factories, which generated industrial waste 2,260.5 ton in fiscal year 2007. The industrial waste can be classified into hazardous waste 1,114.0 ton or 49.28 percent of the total industrial waste generated in the IG group and non-hazardous 1,146.6 ton or 50.72 percent of the total industrial waste generated in the IG group. 350.5 ton or 15.51 percent of the total amount of industrial waste generated from the IG group and disposal waste 1,910.0 ton or 84.49 percent of the total industrial waste generated in the IG group were performed as the 3R waste and the disposal waste categories, respectively. 34.0 ton or total reuse generated from the gas group was sorted for sale. Most of the recycle and recovery wastes were recycled to be a new material as 205.0 ton or 64.77 percent of total amount of recycle and recovery wastes. 1,040.0 ton or 54.45 percent of the total amount of disposal waste generated from the IG group was sent to landfill.

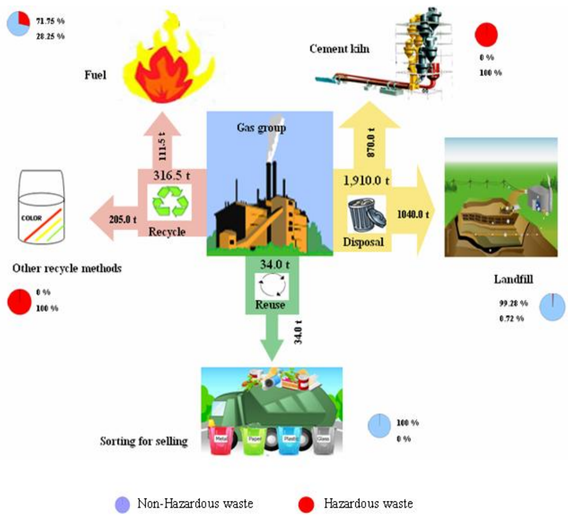

Fig. 5 Waste flow diagram of the IG group

3.2 Quantitative assessment of industrial in the MTPIE

3.2.1 Recycle Waste Ratio (RWR)

Table 1 RWR values from MTPIE

order	Groups	3R waste (ton)	Total waste (ton)	RWR
1	Chemical	1,186.20	14,425.90	0.08
2	Gas	350.50	2,260.50	0.16
3	Iron and steel	569,559.10	719,171.30	0.79
4	Utility	854,229.50	872,193.50	0.98
5	Petroleum and petrochemical	101,723.80	152,178.60	0.67

Table 1 illustrates the RWR ratio of 5 industrial groups in the MTPIE. Finding of recycle waste ratio were 0.98 for the U group, 0.79 for the IS group, 0.67 for the PP group, 0.16 for the IG group, and 0.08 for the CH group. The U group was shown the excellence performance in RWR, which was reflected to the highest potential amount of recyclable industrial waste.

3.2.2 CO_2 Reduction Ratio (CRR)

Table 2 CRR values from MTPIE

order	Groups	CO_2 reduction ($t\ CO_2$)	Total waste (ton)	CRR (tCO_2/t)
1	Chemical	461.71	14,425.90	0.03
2	Gas	100.53	2,260.50	0.04
3	Iron and steel	665,778.63	719,171.30	0.93
4	Utility	85,295.60	872,193.50	0.10
5	Petroleum and petrochemical	95,687.75	152,178.60	0.63

The CRR ratio of 5 industrial groups was shown in Table 2. It can be seen that the CO_2 reduction ratio of waste for the IS group was 0.93 tCO_2/t, for the PP group was 0.63 tCO_2/t, for the U group was 0.10 tCO_2/t, for the IG group was 0.04 tCO_2/t, and for the CH group was 0.03 tCO_2/t. These results showed that the IS group gave higher CRR when compared to the PP, U, IG, and CH groups groups by 32.26 percent, 89.25 percent, 95.70 percent and 96.77 percent, respectively. Higher CRR can demonstrate the higher potential of CO_2 reduction from the industrial waste.

3.2.3 Landfill Reduction ratio (LRR)

Table 3 LRR values from MTPIE

order	Groups	3R materials (ton)	3R wastes (ton)	LRR
1	Chemical	341.90	1,186.20	0.29
2	Gas	44.50	350.50	0.13
3	Iron and steel	565,189.10	569,559.10	0.99
4	Utility	853,966.50	854,229.50	1.00
5	Petroleum and petrochemical	65,708.90	101,723.80	0.65

Table 3 presents the LRR ratio of each industrial group in the MTPIE. As illustrated in Table 3, the LRR for the U group was 1.00, for the IS group was 0.99, for the PP group was 0.65, for the CH was 0.29, and for the IG group was 0.13. These results showed that the U group gave the highest value of LRR, which was higher than the LRR values of IS, PP, CH, and IG groups by 0.8 percent, 35.4 percent, 71.2 percent, and 87.3 percent, respectively. The highest value of LRR was demonstrated the excellent performance in environmental benefit from the reduction of landfill area.

4. Conclusions

Obviously, industrial waste management is one of the environmental problems for MTPIE. The industrial ecology management tools, such as eco-efficiency and the quantitative assessment of industrial waste indicators were created for solving the industrial waste problem. For successfully recycling industrial waste, appropriate technology, good management and governor were needed. This research can demonstrate the basic framework for investigate and evaluate an industrial waste generated from the industrial estate. The quantitative assessment results showed that the utility group generated the highest amount of industrial waste in MTPIE and demonstrated the highest values of RWR and LRR. And waste flow diagram is reflectively the waste characterization and verification of source and final sink of the waste flow of the 5 industrial groups in MTPIE. The scenarios from the waste quantitative evaluation by various indicators should be promoted and supported to real activity for sustainable industry.

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