Chapter 11

Improvement Plan for Waste Oil and Waste Battery Recycling

11 Improvement Plan for Waste Oil and Waste Battery Recycling

In the previous chapter, the team proposed action plans including making the HW reuse/recycling environmentally acceptable. Carrying out this action plan, the status of reuse/recycling of each type of waste should be studied and improvement measures should be examined. This chapter presents the model implementation of such action plan taking an example of the issue of waste oil and waste batteries in which the team studied the current condition of reuse/recycling and proposed improvement measures.

11.1 Objectives and Work Process

11.1.1 Background and Objectives

a. Background

As defined in the Scope of Work of the study agreed between the two governments of Japan and Thailand, the expected outputs from the study include the following.

- master plan (M/P) for the proper management of non-hazardous waste (non-HW) in the study area with the target year 2010.
- action plan (A/P) for immediate improvement of non-HW management, taking integrated environmental protection and waste minimization/recycling into consideration.
- A/P on hazardous waste management (HWM) concentrating in the area of waste reuse/recycling, industrial cluster and zero emission concepts.

To achieve such outcomes, the team covers all the industrial sectors, but is not going to study a particular industry in depth. Therefore, the plans to be made will be rather general and common to all the sectors. However, the team has recognized that for the actual realization of the M/P or the A/Ps, the development of improvement plans for each industrial sector is necessary, and sector-specific planning requires sector-specific expertise and experience.

Meanwhile, the team recognized that the sectors of waste oil recycling and waste battery recycling require the most immediate improvement measures.

The team therefore proposed the additional component of the said study to deal with this matter to JICA and the proposal was accepted.

b. Objectives

The additional component aimed to demonstrate the formulation of specific improvement plans for waste oil industry and waste battery industry, and to examine how DIW should guide the factories toward improved waste management in terms of hazardous waste reuse and recycling.

11.1.2 Work Process

Three Japanese experts joined the study and stayed in Bangkok for three weeks. During the first half, they visited waste oil recycling and/or waste battery recycling factories in and around the study area. During the second half of the stay, they prepared a report and hold explanation meetings to which the factory owners were invited to receive specific suggestions for improvement.

11.2 Improvement Plan for Waste Oil Recycling

11.2.1 Field Investigation

There are 9 waste oil recycling factories, MOI registration code No. 45, which treat waste oil and recover reformed lubricating oil and such in the whole country of Thailand. Among those, 5 factories accepted the visit of the JICA study team members.

a. List of the factories

The nine factories are listed below. The factories of No.6 to No.9 were not visited because the visit was not permitted.

Table 11-1: List of Waste Oil Recycling Factories

Factory name	Province	Capacity	Date of Visit
1. Sor Charoen Thai Co., Ltd.	Samut Sakhon	10,000 Ltr./D	2002/01/24
2. Hor Brothers International Co., LTD	Samut Sakhon	8,000 Ltr./D	2002/01/24
3. Siam Wattana Oil Co., Ltd,	Samut Sakhon	6,000 Ltr./D	2002/01/28
4. Thai Industrial Oil Co., Ltd.	Bangkok	10,000 Ltr./D	2002/01/31
5. Thai Grease Factory (same as factory 4 above)	Bangkok	not waste oil recycle	2002/01/31
6. Spa Oil Co., Ltd.	Samut Sakhon	unknown	closed
7. Sang Somwang Charoenphol Factory	Bangkok	ditto	ditto
8. Light Factory	Chang Mai	ditto	ditto
9. Mr. Somchai Laow Factory	Saraburi	ditto	ditto

b. Present status

All the visited factories treat mainly waste oil from gasoline stations and recover reformed lubricating oil.

b.1 Waste Oil Collection

Waste oil is collected in several ways. Some is collected by waste buyers (Por Kha Khong Gao), some is delivered by generators, and some is collected by recyclers themselves.

b.2 Process and Recovered Products

The sulfuric acid/activated clay process is employed to recover lubricating oil. Recovered lubricating oil is produced only by removal of ash content and bleaching, and no specific additive is added to improve the performance of the recovered to be proper lubricating oil. The recovered is a low grade lubricating oil and usage of it is limited in pouring oil for bicycle and motorcycle, mixing oil for oily paint and remover of concrete panels.

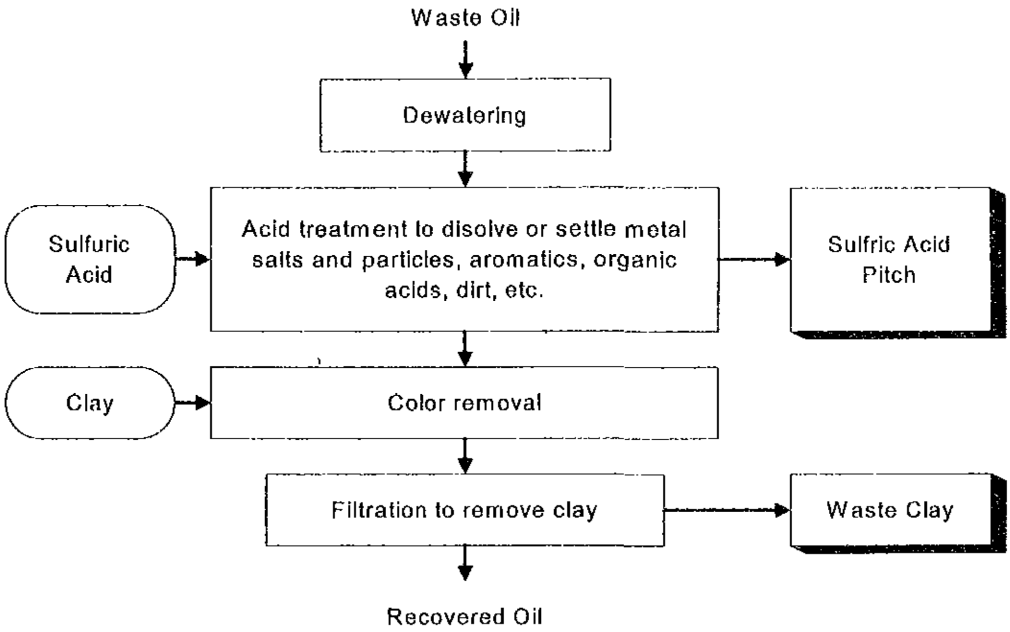


Figure 11-1: Sulfuric Acid/Activated Clay Process

b.3 Raw material (waste oil)

There are two types of raw material.

- Waste oil from gasoline station: Mainly spent engine oil

Factory buys waste oil through middleman and no direct trading with gasoline station is made. Waste oil is transported in drum and/or tank lorry.

- Industrial waste oil:

Industrial waste oil includes hydraulic oil, gear oil, transformer oil, flushing oil, etc. Waste oil is mainly traded with factories directly and transported in drum.

b.4 Sales of the product

Product is sold to middleman, no direct sale to general consumer. Some are exported to Philippine and Indonesia.

b.5 Price

- Waste Oil: 3~4.5 Baht/Kg, (Hydraulic Oil: 4~5 Baht/Kg)
- Product: 8~11 Baht/Kg

b.6 Utility

- Sulfuric acid: Concentration: 98%. Consumption: 7 to 20 % to waste oil. The amount seems not to be grasped correctly. Price: 2~4 Baht/Kg.
- Neutralizing reagent: NaOH flake or $Ca(OH)_2$ powder. $Ca(OH)_2$ price: 5 Baht/Kg
- Activated Clay: also called wonder earth. Consumption: 7%, Price: 16 Baht/Kg.

- Fuel: In the heating furnace to evaporate moisture, waste oil is used as a fuel.

b.7 Treatment of the secondary waste

- Sulfuric acid pitch: Discharged to waste treating company such as GENCO. Treating fee: 3,500 Baht/t (GENCO). Some is landfilled in their own factory area. SO_2 gas is emitted badly from the landfill and a pollution problem may occur shortly. The factories do not properly grasp the amount of the generated pitch. Some said 6 drums/day against 6,000 Ltr/day of waste oil.
- Waste clay: All is landfilled in their own factory area. Oil has been seeped out.

11.2.2 Current Issues

a. Product Quality

For the product to be reused in engines, it is necessary to control additives. The usage of the reformed lubricating oil is limited such as in pouring oil to machinery.

b. Waste Treatment

b.1 Sulfuric acid pitch

All, either on-site or offsite, is landfilled. The contamination of underground water and soil caused by sulfuric acid and oil content in pitch is concerned. Also, the air pollution by SO_2 is a highly concerned issue. The sulfuric acid pitch has very severe and large impact to the environment. As the pitch has very strong acidity, special containers or vessels should be used for storage and/or transportation. At a landfill, the handling is very difficult and problems would occur in drawing it out from vessels, dumping it, and using landfill equipment. Even after landfill, various kinds of problems will be remained, such as heat-up and gas generation by reaction with other waste material.

b.2 Waste clay

All is landfilled. Problems of underground water and soil contamination are latent. After reclamation, ground subsidence due to incomplete compression is also concerned.

11.2.3 Improvement measures for waste oil recycling

a. Present Situation in Japan

In Japan, about 46% of lubricating oil is consumed or vanished with machine operation. Remaining 54% is subject to recycling, but 16% is used as fuel on-site, 35% is recycled as the same off-site. Thus, only 4% of the used lubricating oil is recycled as lubricating oil. Characteristics of the used oil collected in gasoline stations vary depending on the kind of lubricating oil, degree of fatigue of the used oil and content of mixed cleaning oil and water, but the calorific value is usually more than 10,000 kcal/kg and the oil is highly evaluated as a fuel. Thus, very few used lubricating oil is reformed as lubricating oil.

The reformation of the waste oil to fuel is comparatively easy and sometimes it is reused even without any processing. Many are turned to reformed fuel only through rough filtration, heating and settling. The reformation of the fuel oil is carried out through simple facility and operation and fuel with low sulfur is easily obtained, although ash content is high. On the contrary, the reformation of lubricating oil requires comparatively complicated facility and severe control of the component and additives. However, the price difference with fuel oil is very small and economical merit to reform lubricating oil is little. As the demand of users for lubricating oil in terms of quality stability and replacement cycle is increasing, reformed lubricating oil has only a low evaluation.

Through the sulfuric acid and activated clay process for lubricating oil reforming, huge amount of sulfuric acid pitch and waste clay is generated and treatment of those is a serious concern. Especially, the sulfuric acid pitch is very hard to treat. It used to be incinerated, but following the intensification of the air pollution regulation, it became difficult to incinerate it or to find proper alternate treatment processes. Even when it is treated luckily in an incinerator little by little within the air pollution regulation, treatment fee more than 50,000 yen/ton is required.

Normally, in Japan, waste oil from motors is treated to reform fuel oil: firstly, dust and rust are removed through rough filtration, moisture is eliminated by heating up to 100 degree centigrade and settling, and finally light duty oil is separated by heating. The sludge such as waste clay generated in the reforming process is utilized in cement plants as raw material and alternative fuel, or incinerated for final disposal. General situation of waste oil recycle in Japan is as shown below.

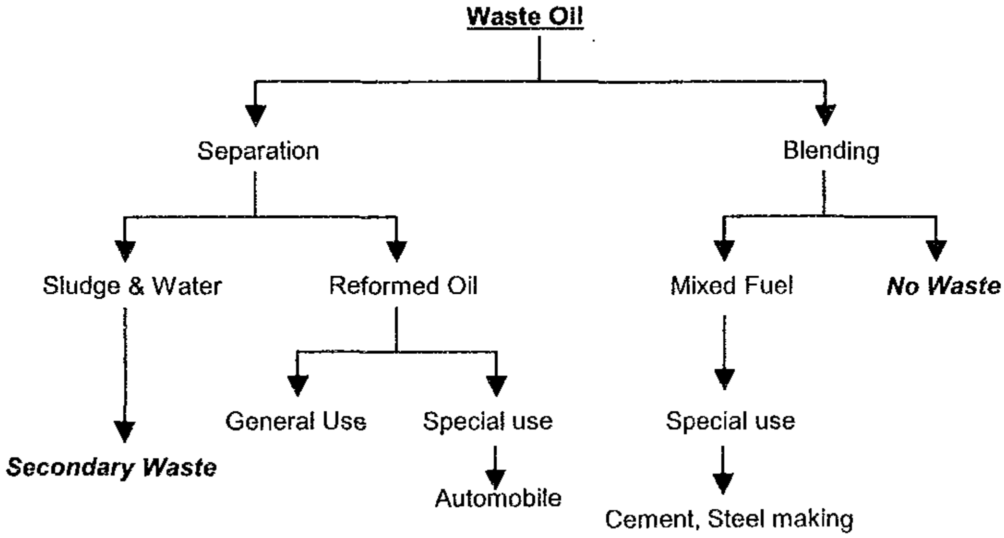


Figure 11-2: Waste Oil Recycling in Japan

b. Short-term improvement plan

In a short-term, waste that is currently generated should be properly treated.

- The government should prohibit the on-site treatment (landfill) of the sulfuric acid pitch and direct the oil recycling factories to entrust their acid pitch disposal to licensed treating companies to avoid the air and soil pollution problems.

- The government should also promote the recycle of waste clay as the raw material and/or fuel for cement manufacturing. Actually in cement factories, various kinds of solid fuel are used in many sections such as a pre-calciner beside the rotary kiln where clinker is produced. Among them, waste clay is a kind of the main alternative solid fuel. The oil content in waste clay is used as fuel and the chemical components such as CaO and SiO_2 are utilized as raw material. The receivable condition may differ with the individual factories and it must be confirmed through negotiation with a specific cement factory.

c. Middle- and long-term improvement plan

The treatment of sulfuric acid pitch is so hard that lubricating oil reforming from waste oil through the sulfuric acid/activated clay process can be hardly continued. When the acid pitch is to be properly treated, lubricating oil reforming can not be economical. Also, although the sulfuric acid/activated clay process can produce lubricating oil of higher quality than other processes, the demand of the market for the reformed lubricating oil may not be so high in future as proved in Japan.

Considering these, it is prudent to abandon the sulfuric acid/activated clay process, avoid the generation of difficult waste, and start new waste oil recycling processes as below.

b.1 Production of reformed fuel oil

Waste oil is not used to produce lubricating oil but fuel oil. Since there are limitations to use waste oil as fuel without treatment, some sort of treatment will be required. Reformed fuel oil can be widely used and the existing system of transportation, storage and so on can be utilized as it is. No significant restrictions are either found from the viewpoint of marketing.

Sludge generated in the reforming process can be utilized in the cement manufacturing as raw material and fuel.

In Japan, quality of the reformed fuel oil is standardized and specification is as shown below.

Table 11-2: Specification of Reformed Fuel Oil

Item	Unit	Specification
Density	at 15/4 deg. C	0.87~0.90
Reaction		Neutral
Flash point	deg. C	70~130
Kinetic viscosity	at 50 deg. C cSt.	15~30
Pour point	deg. C	-15~-35
Residual carbon	wt. %	< 3.0
Moisture	vol. %	< 1.0
Ash	wt. %	< 0.5
Sulfur	wt. %	< 1.0
Calorific value	kcal/kg	> 10,500

b.2 Production of mixed fuel

Waste oils which are not suitable for reformed oil production such as those containing much water and/or sludge are to be used to make a mixed fuel which is used in place of low grade coal such as lignite. Since such kind of waste oil has not received at the existing waste oil recycling factories, the production of mixed fuel should be considered not as the substitution of the current sulfuric acid/activated clay process but as a new additional process. It is recommended to produce aforementioned fuel oil and mixed fuel together.

The calorific value of the mixed fuel is adjusted nearly to that of coal. Even waste oil of high water content is received as it is, the calorific value of the mixture is controlled with reformed fuel oil. The mixed fuel is used in the cement kiln as an alternative fuel for coal.

Even though the mixture contains solid matter, as far as it can be transported by pumped, it can be easily used.

A blending facility should be installed. Separated water from fuel oil reforming and oil containing wastewater in various industries can be properly treated.

11.3 Improvement Plan for Waste Battery Recycling Industry

The purpose of this survey is to investigate the present situation of waste battery recycling industry, to clarify problems and to propose improvement plans. During the survey, it was requested from the concerned people of each factory not to disclose their problems and the improvement plan for individual factories. Therefore the team presented the improvement plans individually. This report summarizes the general matters common to all factories.

11.3.1 Field Investigation

For this survey, we visited the factories after getting their approval. After their explanation of the factory such the production process, the team observed and checked the facilities, production process, environmental protection facilities, and waste treatment facilities.

a. Factories surveyed

There are 8 factories classified as DIW registration code No. 60 "Non-ferrous smelter: Lead smelting factory from used battery" in the country, which produce recycled lead, etc. During this survey, the team could obtain permission to visit 6 factories as in the following list. For Nos. 7 and 8, the team was not able to make a contact and did not visit them.

Table 11-3: List of Waste Battery Recycling Factories

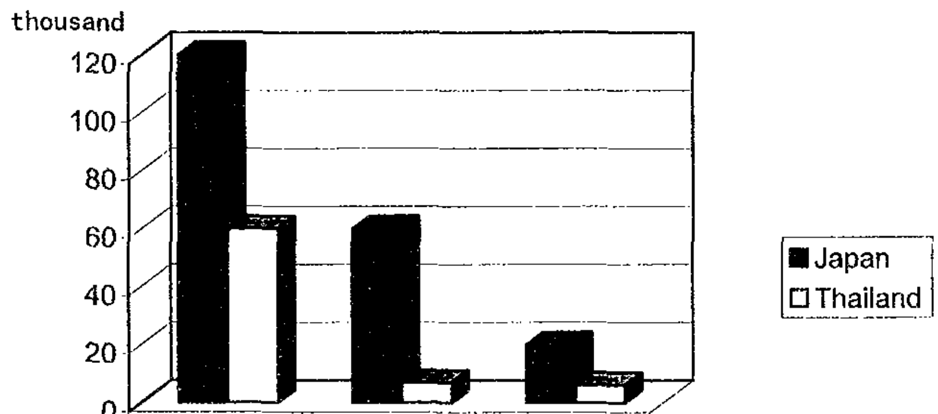
Name of Factory	Location	Factory Capacity	Date of Visit
1.Bergsoe Metals Limited	Saraburi.	800-900t/m	1/29
2.T.K. Metal Trading Ltd.,Part.	Nakornprathom	1000t/m	1/30
3.Thai Nonferrous Metal Co. Ltd.	Chachoensao	1500t/m	1/30
4.Thai China Nonferrous Metals International	Nakornsawan	850t/m	1/31

Co. Ltd.			
5.Thai Metal Smelting Industry Co. Ltd.	Rachaburee.	Unknown	2/4
6.Laow Thai Charoen Industry.	Rachaburee.	Unknown	2/4
7.Lieng Huad Metal Smelting Ltd.Part	Samut Prakarn	Unknown	Not visited
8.Kim Lee Metal Smelting Factory	Rayaong	Unknown	Not visited

b. Present Status

b.1 Recycled quantity

Judging from the result of interview at the factories, the quantity of waste batteries is estimated to be around 60,000 to 80,000 tons per year and out of these scraps, it is estimated that 36,000 to 48,000 tons per year are recovered as recycle lead. This figure is very high compared with that in Japan taking the number of automobiles into account.



	Population (thous)	Nos. of Vehicles (thous)	Waste batteries (thous/year)
Japan	120,000	60,000	20,000
Thailand	60,000	6,800	6,000

Figure 11-3: Comparison of Quantity of Waste Battery

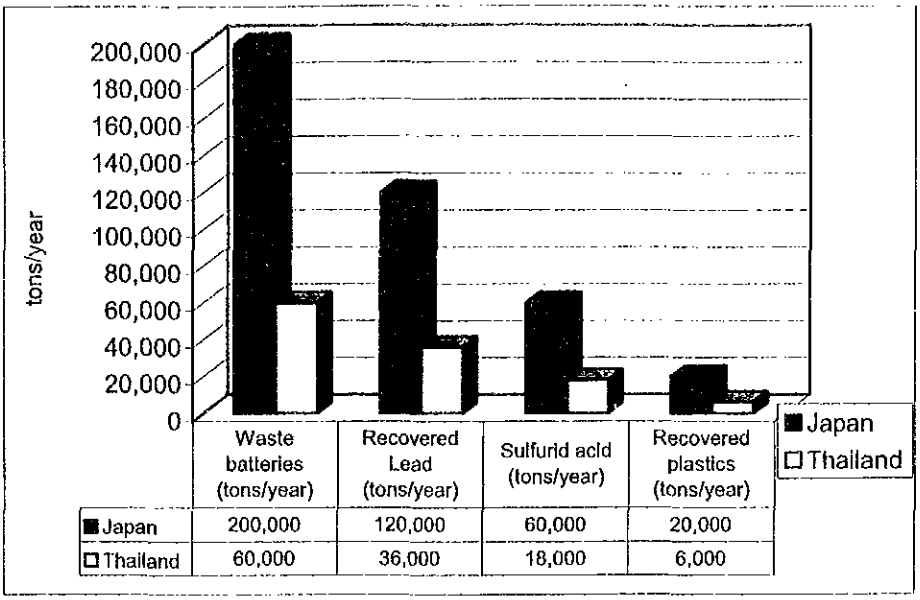


Figure 11-4: Comparison of Quantity of Waste Battery Recycling

The divergence between the two countries will be because of the difference of battery types used. Batteries used in Thailand are lead-antimony type (open type). Water evaporates and sometimes hydrogen is generated. Water has to be added from time to time to adjust sulfuric acid concentration. In Japan, almost all of the batteries are lead-calcium type (sealed type). This type is maintenance free (MF) and has long service life. Sulfuric acid is hermetically sealed and does not leak out easily. Water does not evaporate and when there is hydrogen generated, it is absorbed inside the battery and does not need make up water. When the MF type becomes popular in Thailand, it is necessary to establish refining technology to remove antimony from the scrap lead.

Table 11-4: Comparison of MF (Pb-Ca type) Battery and Normal (Pb-Sb type) Battery

Type	Life	Maintenance	Leakage	Price	Composition
MF	3 years or more	No need	No leakage (sealed)	5 times of normal type	Pb Sn 0.2 - 1.0 % Ca 0.05 – 0.12 %
Normal	1 – 3 years	Adding water time to time	Leakage (open)	Normal	Pb Sb 2 – 5 % Sn 0.01 – 0.02 %

b.2 Price

Waste batteries are purchased at around 9 Bahts per kg while recovered lead is sold at 20 Bahts plus per kg. Plastics (PP: polypropylene), when the color is white, is sold at 10 Bahts plus per kg and when colored, around 8 Bahts per kg.

b.3 Pollution and waste control of each factory

b.3.1 Atmosphere

DIW and PCD has established a committee on the improvement of waste battery recycling industry in order to promote environmental countermeasures in waste battery recycling industry. If a factory is designated by the committee to be well managed environmentally, its product enjoys 5% tax exemption. Four factories among those the team visited during the study are such designated factories. The rest four factories are not operating or carrying out factory modification according to an order of improvement. Designated factories were operating within the regulation limits and almost had no problem with the facilities. However, the factories without designation, which had insufficient pollution control, were not equipped with the facilities to remove heavy metals and SO_2.

b.3.2 Water

Designated factories were with the closed system, not discharging the contaminated water out of the factory but treating within the factory and recycling. Some factory dropped the heavy metal contents to regulation limits and sending wastewater to the final wastewater treatment plants within the industrial estates where they are located. However, the factories without designation had no wastewater treatment facilities and they need improvements. There was a factory proceeding with the improvement according to the instruction made by DIW.

b.3.3 Waste

i. Slag

Slag generated by flux treatment during refining of recovered lead is piled up in the factories or consigned to private companies such as GENCO for landfilling. This treatment charge is approximately 1.5 to 3.0 bahts per kg. Some of the companies were testing the utilization of slag as raw material for cement.

ii. By-product from wastewater treatment

Wastewater treatment should generate by-product of sludge state. According to the person in charge, by-product from water treatment is not generated and water is circulated within the factory, except in some factory. However, in actual practice, by-product is accumulated and need to be treated someway.

11.3.2 Current Issues

a. Illegal dumping of sulfuric acid solution

Sulfuric acid solution in the waste batteries is illegally dumped somewhere and normally, the waste batteries are brought dried to the factories. There is an apprehension of water pollution and soil contamination by this illegally dumped sulfuric acid.

b. Primary smelting by illegal smelters

At present, there are eight smelters registered in the DIW database as primary smelter of waste battery. However, there are many illegal smelters, which are not identified, doing the primary smelting at vacant land using an oil drum during nighttime to escape the arrest. According to the interview at the factories, 40% of primary smelting quantity in the country is by these illegal smelters. It is pointed out that the factories, which are not designated by the committee on the improvement of waste battery recycling industry, are buying primary crude lead from illegal smelters and selling refined lead after secondary smelting. Because of this, there is a disturbance to the business of companies authorized for tax exemption from the committee.

c. Treating capacity of sulfuric acid and heavy metals

In future, when sulfuric acid from waste battery will be steadily collected, there will be problems on waste gas treatment and wastewater treatment because the facilities for treatment of sulfuric acid and heavy metals in the sulfuric acid are insufficient. Further, it is expected that there will be an increase in quantity of sealed type batteries, which inevitably requires for strengthening of treating capacity.

d. Waste treatment

Waste from waste battery recycling includes slag and by-product of wastewater treatment. The latter will be increased when sulfuric acid comes to the recycling factories. The appropriate treatment and disposal of these kinds of waste must be thoroughly enforced, and efforts to reduce or recycle them are desired.

11.3.3 Improvement plan for waste battery recycling

The improvement plan for the individual factories was explained to each of them in the explanation meeting. Here is an improvement plan for the waste battery recycling industry as a whole.

a. Present situation in Japan

There are many different data but the quantity of waste batteries treated in Japan is approximately 20 million pieces per year, each weighing approximately 10 kg (including sulfuric acid). Therefore, the total weigh is 200,000 ton/year and when the lead content is assumed to be 65%, it will become 130,000 ton/year. Primary smelters are 47% of total and secondary smelters are the balance, 53%.

Basically, the primary smelters already have blast furnaces, gas treatment facilities and wastewater treatment facilities. In crushing process, the top of collected waste batteries is not cut but charged directly into a crusher for primary and secondary crushing and then separated into plastics, lead and lead paste by difference in specific gravity. Plastics are crushed to 3 to 5 mm size and sent to plastics manufacturers while lead and lead paste are sent to a blast furnace for smelting. Sulfuric acid and heavy metals in the solution are treated in a wastewater treatment facility.

The secondary smelters separately smelt the lead-antimony type (open type) and the lead-calcium type (sealed type), and the antimony type is sold as lead-antimony alloy after removal of copper and tin. In Japan at present, almost 90% of the sales of battery are sealed type.

The calcium type undergoes the removal of antimony and nickel in addition to the above processes and it is sold as virgin lead. In the secondary smelters, water is recycled as much as possible in order to have the effective utilization of water.

Magnesium hydroxide is used as neutralizer of sulfuric acid and the product, i.e. sulfuric magnesium, remains dissolved in treated water since the wastewater discharge standard in Japan does not specify the limit of total dissolved solids. In Thailand, however, the regulation limits the total dissolved solids to 2000 to 5000mg/l depending on the type of recipient water body and therefore, it may be necessary to use calcium hydroxide, which gives gypsum as product.

A part of slag is recycled but most of them are landfilled.

When we look at the history of waste battery recovery, Japan was also not able to steadily recover sulfuric acid about 30 years ago and just like Thailand today, waste batteries were brought to the smelters after dumping the sulfuric acid. However, around 12 years ago, as MF batteries became popular, the number of waste batteries decreased and the requirement for advanced smelting technology grew up. As a result, the waste battery recycling industry was depressed and the waste battery recycling rate went down. The strong leadership of the government to enforce the manifest system in order to recover the recycling rate, together with the great concern of the people against pollution, stimulated the waste battery recycling industry to be equipped with sulfuric acid treatment facilities. As a result of the fulfillment of manifest system, the flow of wastes was established about 8 years ago.

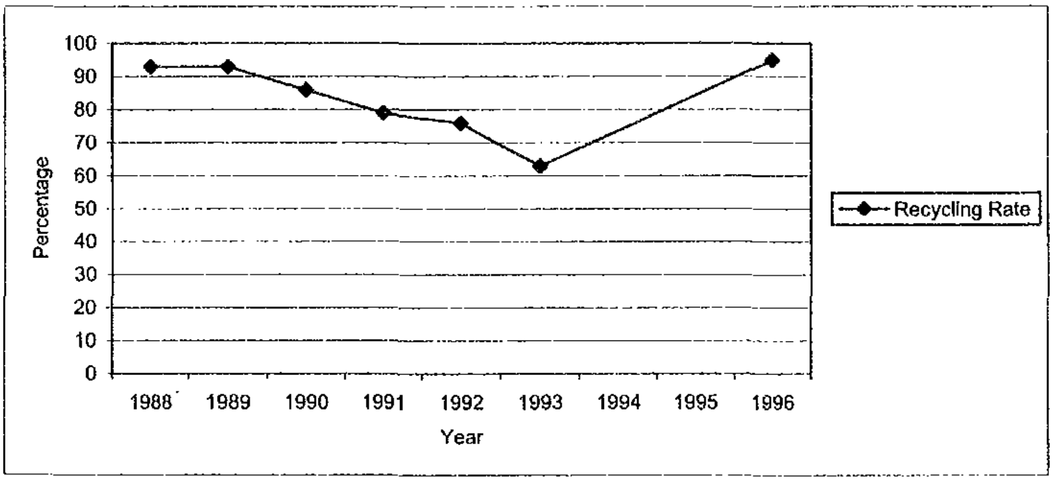


Figure 11-5: Tendency of Waste Battery Recycling in Japan

b. Improvement plan for the prevention of illegal dump of sulfuric acid

b.1 Short-term

b.1.1 Understanding a waste batteries recycling route

Firstly, a route where waste batteries are brought to recycling factories should be well understood. In this process, it will be clarified who are involved in which stage during the recycling route.

b.1.2 Introduction of registration system of collectors/dealers

In order to make sure that waste batteries are securely brought to the smelter with the sulfuric acid inside, a manifest system should be established. The origin of waste battery should be made clear, then the treatment enterprises, the final disposal enterprises and other concerned companies should sign their confirmation on the specified place of the control sheet and each company should record and file his own responsibility and what kind of job was done. This system will make it possible to trace and also confirm the destination of the waste battery.

However, the introduction of the manifest system conditions a tool to control all the concerned parties. The control of factories already exists but the control of collectors/dealers currently does not. Therefore, the team recommends the introduction of a registration system of waste battery collectors/dealers.

In the system, all the enterprises who are to collect and deal waste batteries are required to be registered, and registration will be cancelled when illegal activities are found. This mechanism makes the manifest system, which is to be established in the next step, effective and practical.

b.1.3 Control over sulfuric acid illegal dumping

The authorities should strengthen the control over sulfuric acid illegal dumping by exposing the cases and strictly imposing the penalties.

b.1.4 Public cooperation

The governmental control only will be insufficient to eliminate all the illegal dumping activities and it will be necessary to ask for the public to cooperate. The general public should be aware of the significance of this issue and is expected to apply social sanctions to those who illegally discharge sulfuric acid.

b.2 Middle- and long-term

b.2.1 Introduction of the manifest system

The manifest system should be introduced as already mentioned.

b.2.2 Control of the purchase of waste batteries not containing sulfuric acid

At present, illegal dumping of sulfuric acid occurs because waste batteries not containing sulfuric acid are welcome at the recycling factories. This cycle must be cut off.

Because DIW should have already established the control over the waste battery recycling factories, it is reasonable to strengthen its control and force them not to purchase waste batteries not containing sulfuric acid inside.

c. Improvement plan for the elimination of illegal primary smelters

c.1 Short-term

c.1.1 Control over illegal primary smelters

Illegal primary smelters must be exposed and strict penalties should be imposed on them.

c.1.2 Control of the purchase of primary crude lead from illegal primary smelters

In order to damage the business of illegal primary smelters, the secondary smelters which purchase primary crude lead from them should be also strictly controlled.

c.1.3 Promotion of the purchase of lead recovered by the designated factories

The battery manufacturers should be encouraged to purchase recovered lead from the recycling factories designated by the committee on the improvement of waste battery recycling industry. For this purpose, DIW may take the following actions:

- To explain to the battery manufacturers regarding the background of the designation of factories of good performance, the seriousness of illegal primary smelting and the economic and environmental benefit from the purchase of lead recovered by the designated factories;

- To direct them to purchase of lead recovered by the designated factories; and
- To inspect the battery manufacturers and examine their purchase record of lead recovered and product amount to check compliance with the above-mentioned direction.

c.2 Middle- and long-term

c.2.1 Public cooperation

By asking for public cooperation, a public control mechanism should be established where the consumers behave against illegal primary smelting.

c.2.2 Introduction of the manifest system

The introduction of the manifest system should exclude illegal primary smelters.

d. Waste and environment management

d.1 Strengthening the sulfuric acid and heavy metal treatment facilities

In parallel with the establishment of rule for delivery of waste battery to the smelters, facilities for treatment of sulfuric acid and heavy metals in the waste batteries should be strengthened and improved. In addition, SO_2 must be removed from waste gas by scrubbers.

d.2 Treatment of lead slag

Lead slag which is currently landfilled on-site should be treated and disposed of by HW treatment/disposal companies.

Appropriate treatment and disposal is a minimum requirement, but a further step of lead slag treatment will be recycling at cement plants.

For the treatment of lead slag, improvement should be made to granulate with water to make is fine particles in order to recover as much as possible the lead content and return to the furnace in order to decrease the lead content and to be able to use as a raw material for cement.

During water granulation, there is a fear that lead may be soluble into water, and therefore, it becomes important to build a firm wastewater treatment facility.

d.3 By-products generated from wastewater treatment

The by-products from wastewater treatment differ depending on the chemicals used for neutralization and the process should be selected taking into consideration the needs of the market, reasonable operating cost, ease of handling and other factors. For reference, the chemicals which can be considered are NaOH to produce Na_2SO_4, $Ca(OH)_2$ to produce $CaSO_42H_2O$. The equipment cost of the process using NaOH will be lower than that of $CaSO_42H_2O$, but the latter may have an economic value.

11.4 Conclusion and Recommendation

11.4.1 Waste Oil Recycling

Factories that the team could visit during the study employ a sulfuric acid/activated clay process to recover lubricating oil from waste oil. As lubricating oil is produced by the sulfuric acid/activated clay process, sulfuric acid pitch, which is strong acid and very reactive, and waste clay containing oil are also produced as waste. Currently part of sulfuric acid pitch is landfilled on-site and the rest is treated and disposed of by HW treatment/disposal enterprises. On the other hand, most of waste clay is landfilled on-site.

On-site disposal of these kinds of waste can cause a large environment problem since it is associated with high possibility of groundwater and soil contamination. Sulfuric acid pitch is particularly hazardous since it generates sulfurous acid gas. The handling of this waste is difficult and the treatment and disposal fee can substantially rise in future, although the fee is at present reasonable. Therefore, waste treatment will turn into a great concern.

As a short-term improvement plan, proper treatment of waste generated in waste oil recycling should be promoted. In other words, sulfuric acid pitch that is disposed of on-site must be properly treated and disposed of by HW treatment/disposal enterprises. Waste clay should be diverted from on-site landfill to cement factories to be recycled.

In the middle- and long-term, it is anticipated that waste treatment fee rises and exceeds benefits from production. It will be, however, difficult to encourage factories to change the process lubricating oil recovery from the sulfuric acid/activated clay process to another because it has a large advantage over other processes in terms of product quality. Therefore it will be necessary to change the production process and/or to start a new process to produce the following.

- Fuel oil
- Mixed fuel

11.4.2 Waste Battery Recycling

DIW and PCD has established a committee on the improvement of waste battery recycling industry in order to promote environmental countermeasures in waste battery recycling industry. If a factory is designated by the committee to be well managed environmentally, its product enjoys 5% tax exemption. Four factories among those the team visited during the study are such designated factories. The rest four factories are not operating or carrying out factory modification according to an order of improvement. Overall, unlike the situation of waste oil recycling industry, the factory operation of waste battery recycling has not seriously affected the environment.

Waste battery recycling as a whole, however, has the following problems, whose environmental influence may be worse than that of waste oil recycling.

- Illegal dumping of sulfuric acid

Sulfuric acid in almost all of waste batteries is illegally dumped before recycling factories receive them. It is anticipated that an environmental impact given by the illegal dumping of sulfuric acid is widespread and serious.

- Illegal primary smelters

There are many illegal primary smelters which are not registered with DIW. According to the interview at the factories, these illegal primary smelters deal with about 40% of primary smelting of the whole country. The illegal primary smelters not only pollute the environment, but also affect the operation of the designated factories which bear substantial cost for environmental conservation. In fact, the price of a waste battery has risen in spite of the decrease in the price of recovered lead.

The team proposes an improvement plan as below in order to prevent sulfuric acid from illegally dumped and to eliminate the illegal primary smelters.

Item	Short-term	Middle- and Long-term
Prevention of illegal dump of sulfuric acid	• To understand the recycling route of waste batteries. • To introduce a registration system of waste battery collectors/dealers. • To strengthen the control (exposure and penalty) over sulfuric acid illegal dumping. • *To ask for public cooperation* for the prevention of sulfuric acid illegal dumping.	• To strengthen the control (inspection, exposure and penalty) over waste battery recycling factories which purchase waste batteries not containing sulfuric acid inside. • To introduce a manifest system to waste battery recycling.
Elimination of illegal primary smelters	• To strengthen the control (exposure and penalty) over illegal primary smelters. • To strengthen the control (exposure and penalty) over secondary smelters which purchase primary crude lead from illegal primary smelters. • To direct battery manufacturers to purchase recovered lead from the recycling factories designated by the committee on the improvement of waste battery recycling industry.	• To ask for public cooperation for the elimination of illegal primary smelters and to establish a public control mechanism. • To introduce a manifest system to waste battery recycling.

If the illegal dump of sulfuric acid and the illegal primary smelters are adequately controlled as a result of the implementation of the above plan, waste battery recycling factories need to be equipped with sulfuric acid treatment facilities which mainly consist of the following.

- scrubber facility to remove SO_2 from waste gas
- wastewater treatment facility to remove sulfuric acid and heavy metals from wastewater.

Chapter 12

Formulation of IWM Plan for the Paint Industry

12 Formulation of IWM Plan for the Paint Industry

12.1 Introduction

12.1.1 Background and Objectives

a. Background

It is recognized that the paint industry in Thailand has pressing concerns about its waste management derived from such issues as the shortage of appropriate waste treatment and disposal facilities. Especially, waste minimization and proper treatment require urgent improvement. Although the main task of the current study is, as the S/W specifies, the formulation of industrial waste management master plan and did not intend to look at a particular industrial sector in depth, DIW requested JICA in March 2002 to additionally carry out the study for waste management improvement in the paint industry and formulate an improvement plan, and the request was approved.

b. Objectives

The objectives of this component are as follows.

- Formulation of waste management improvement plan for the paint industry.
- Upgrading of DIW's knowledge on the sector-specific waste management improvement plan through the attainment of the above objective.

12.1.2 Work Plan

a. Study Procedure

The study on the paint industry followed the procedure below.

i) The Fifth Study Work in Japan

The study team prepared a questionnaire to be used on a visit to factories, by which amount and treatment methods of each type of waste could be understood.

ii) The Fifth Study Work in Thailand

1. Explanation of study outline, discussion, and consensus making.
2. Selection of target factories and requesting the visit permit.
3. Preparation of the questionnaire in Thai and sending it to the selected factories.
4. Formulation of a factory visit plan.
5. Visit to five large sized and five small-medium sized factories.
6. Compilation and data input of the answers to the questionnaires.
7. Analysis of the answers to the questionnaires and the findings of the factory visit
8. Examination of improvement approaches and discussion with the concerned people.

iii) The Sixth Study Work in Japan

Reviewing the result of the fifth study work in Thailand, the team formulated a waste management improvement plan for the paint industry.

iv) The Sixth Study Work in Thailand

The team organized a meeting and explains the waste management improvement plan formulated during the sixth study work in Japan to TPMA (Thai Paint Manufactures Association) and the other relevant people. Discussion was encouraged so that the implementation of the plan was promoted. In the meeting, the team also arranged a visit to model factories which perform advanced waste recycling, reuse, and recycling.

b. Selection of Target Factories

Eleven factories were selected among 39 companies which belong to TPMA as follows. The location of these factories is shown in Table 12-1. Four factories are located outside of the study area.

Table 12-1: 11 Factories Surveyed

Date of Survey	Factory Name	Location	Paint Produced*
03/06/2002	Credo International Co., LTD.	Bangkok	S, W
04/06/2002	Eason Paint Products Co., LTD.	Chonburi	S
05/06/2002	Nippon Paint (Thailand) Co., LTD.	Chonburi	S, W
06/06/2002	Mirotone Co., LTD.	Samut Prakarn	S
07/06/2002	Jotun Powder Coatings (Thailand) Limited	Chonburi	P
07/06/2002	Jotun Thailand Limited	Chonburi	S, W
10/06/2002	ICI Paints (Thailand) Co., LTD.	Nonthaburi	S, W
11/06/2002	V. Powdertech Co., LTD.	Bangkok	P
12/06/2002	TOA-Chugoku Paints Co., LTD.	Bangkok	S
13/06/2002	TOA Paint (Thailand) Co., LTD.	Samut Prakarn	S, W, P
14/06/2002	JBP International Paint Co., LTD.	Bangkok	S, W

Note: S = Solvent based paint, W = Water based paint, P = Powder paint

c. Survey Items and Questionnaire

The interview was carried out on the visit to the factories paying attention to the following issues.

- Quantity and types of waste generated from paint factories.
- Current status and problems of waste management.
- Current status and problems of waste reduction and reuse/recycling.

A questionnaire (Annex 12.1) was prepared to include questions about these matters and sent to the factories prior to the visit. The team categorized waste into 14 types as shown in the questionnaire.

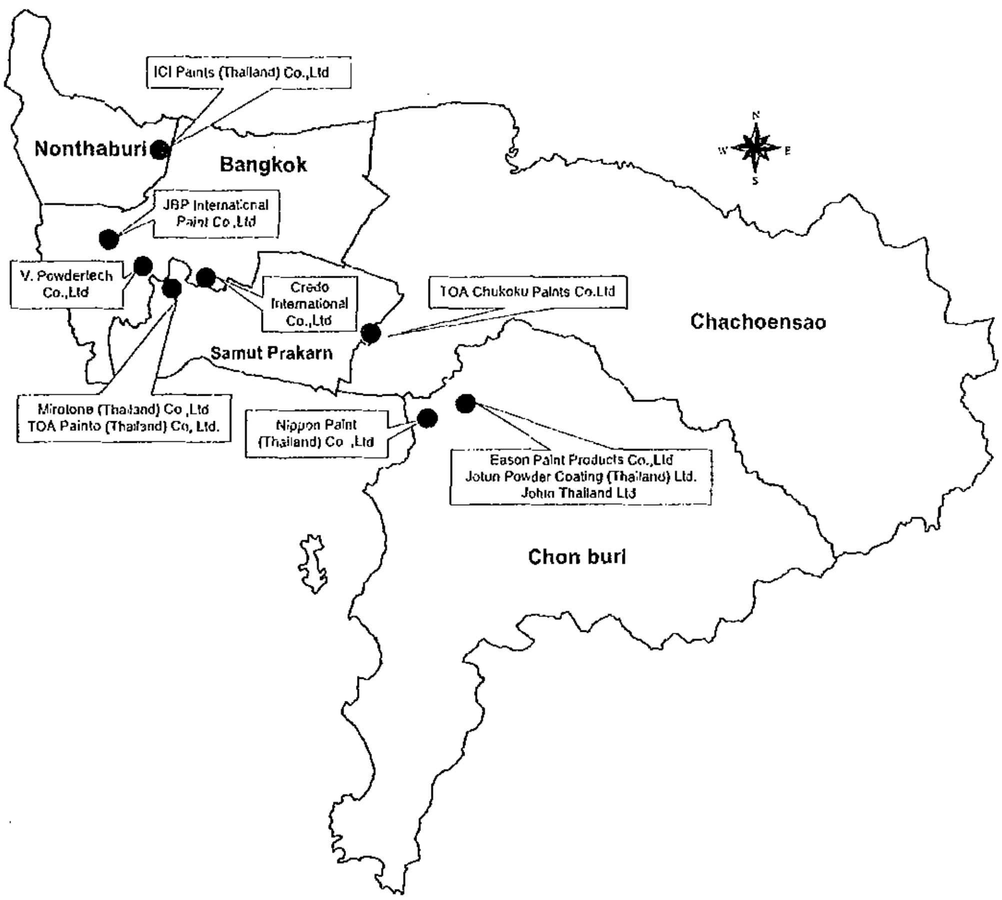


Figure 12-1: Location of 11 Factories Surveyed

12.2 Current Issues of IWM of Paint Industry

12.2.1 Survey Results

a. Waste from 11 Factories Surveyed

Table below shows the amount of waste generated from 11 paint factories surveyed. The waste flow made from the result of the survey of the 11 factories is shown in Annex 12.2.

Table 12-2: Waste from 11 Factories Surveyed

Wastes	Amounts of 11 factories (ton/year)
Others	914
Waste metals	884
Waste paint	756
Waste solvent	604
Sludge	359
Waste paper	85
Dust	76
Waste wood	46
Waste plastics	5
Cotton wastes	2
Total	3,732

b. Waste from Paint Factories in the Study Area

b.1 Generation Amount

The team estimated the waste amount from paint factories located in the entire study area in the following way.

The generation rate per employee was first calculated from the number of employees and total waste amount of the 11 factories. Multiplying the generation rate with the total number of employees of 146 paint factories in the study area gives the total waste amount of the area. The result is shown in Column A of the next table. In principle, such calculation should be done based on the amount of paint production, but the team used the data of employees since the paint production data of the 146 factories was not available. Furthermore, factories should have been grouped depending on what they produce (e.g. solvent based paint, water based paint, or powder paint) because the quality and quantity of waste vary with the type of paint, but they were treated together since production data of each paint type was not available.

Table 12-3: Waste Amount from Paint Factories in the Study Area

Wastes	A	B		C	
	Generation amount (ton/year)	Off-site disposal		Off-site disposal to be paid for	
		(ton/year)	B/A	(ton/year)	C/B
Others	4,048	854	(21%)	854	(100%)
Waste metals	3,915	3915	(100%)	176	(4.5%)
Waste paint	3,350	982	(29%)	982	(100%)
Waste solvent	2,677	2375	(89%)	0	(0%)
Sludge	1,592	1592	(100%)	1592	(100%)
Waste paper	376	376	(100%)	21	(5.6%)
Dust	338	336	(99%)	336	(100%)
Waste wood	205	203	(99%)	0	(0%)
Waste plastics	23	23	(100%)	0.44	(1.9%)
Cotton wastes	7	7	(100%)	7	(100%)
Total	16,531	10,662	(64%)	3,968	(37%)

As shown in Column A of this table, the total amount of waste generated from the paint factories in the study area is approximately 16,000 tons/year. The major types of waste out of this are "others" (wastewater, waste batteries used for forklifts, resin used for cleaning powder paint machine, wasted raw material (alkyd resin)), waste metals, waste paint, waste solvent and sludge.

b.2 Off-site Disposal Amount

Column B of Table 12-3 shows the amount of waste that is collected and transported for off-site disposal (e.g. intermediate treatment, reuse/recycling, and/or final disposal) from paint factories in the study area. B/A is the ratio of off-site disposal to total generation. It is 64% on average.

b.3 Off-site Disposal to be Paid for

Column C of Table 12-3 shows the amount of waste that is paid for disposal off-site.

12.2.2 Current Issues of IWM of Paint Industry

a. Current Status of IWM of Paint Industry

The team estimated the flow of waste generated from the paint industry of the whole study area based on the result of the survey at 11 factories. The flow of each type of waste is presented in Annex 12.3.

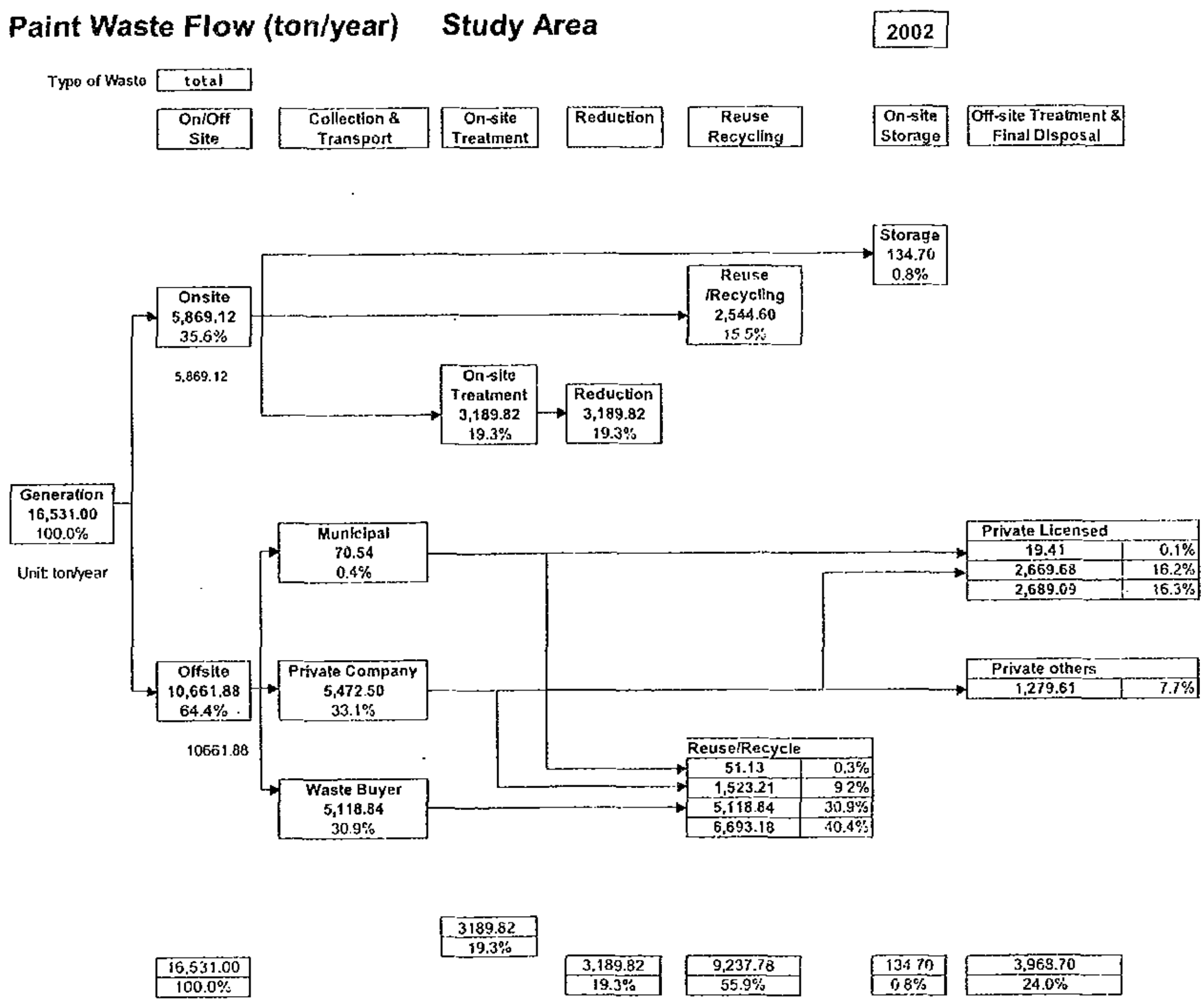


Figure 12-2: Flow of Waste from Paint Industry of the Study Area (2002)

The current status of IWM of the paint industry revealed from this waste flow and the survey result of the 11 factories is described below.

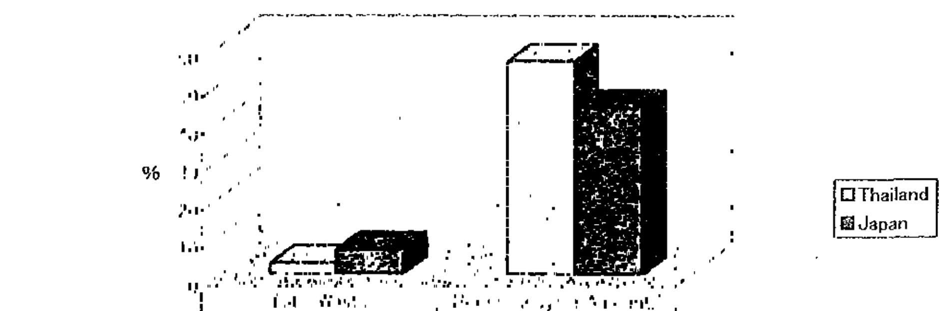
1. As shown in Table 12-3, the **off-site disposal waste amount** in the study area occupied 64 % of total waste generation amount. The proportion of waste amount to be **paid for off-site disposal** was 24% (3,968 ton/year) of total waste generation amount.

2. The off-site disposal amount of waste paint was 29% of total generation, while all or most of waste solvent, sludge, waste plastics waste metals, dust, waste paper, waste wood, and cotton wastes were disposed of off-site. The waste of "others" includes wastewater, waste batteries, waste raw material and resins for cleaning. Waste batteries, resins and part of wastewater were disposed of off-site.

3. Among the wastes to be disposed of off-site, the wastes to be paid for disposal were sludge, waste paint, others (mostly wastewater), dust, waste metals, waste paper, cotton wastes and waste plastics in order of amount. The wastes whose amount of off-site disposal with payment are large will need reduction measures.

4. Waste solvent and waste wood are totally sold for reuse/recycling.

5. The proportion of total waste amount (includes valuables) to the total amount production is less than that in Japan although it varies with factories to a certain extent. According to the study by Japan Paint Manufacturers Association, the proportion of total waste amount to the total amount production is **6.4%** (average of its 112 member companies on a tonnage base in 1999) while it is **2.9 %,** lower than Japan, on average among the eleven factories surveyed. Furthermore, the proportion of reuse/recycle amount to total waste amount is **44%** in Japan, while it is **56%**, higher than Japan, among the eleven factories surveyed.



	Aomount/Total Amount	Total Waste Amount(%)
Thailand	2.9	56
Japan	6.4	44

Figure 12-3: Comparison of the Rate of Total Waste Generation Amount and Reuse/Recycling Amount

6. The reasons why total waste amount is small are (i) the factories **recycle waste on-site aggressively** (by blending part of waste paint into products, producing low-quality paint using waste paint, etc.), and (ii) in Thailand,

materials such as broken test panels for color matching or pallets for loading are not recognized as "wastes". Thus these amounts seem not to be counted as waste amount. It is considered that such attempts to reduce waste largely depend on cheap labor force compared to material cost.

b. Issues to be Improved

It is need to address the following issues of IWM of the paint industry.

1. The most concerned waste that is disposed of off-site is **gelled waste paint**. Waste paint comes from the improper production process (including color matching errors), improper stock control, improper client management, and others. The factories can deal with most part of waste paint by blending it into the same or similar product. The remained part, however, becomes gel after stored long time. It is highly difficult to recycle gelled paint. This is why part of waste paint is recycled on-site and the remained part is disposed of off-site. It is gelled paint that poses the most difficult problem for the paint industry in the study area. The countermeasure to handle gelled paint is an urgent need for the management of waste paint. Since there have been only treatment company that accept waste paint (gelled paint) until recently, the paint factories surveyed expressed increasing dissatisfaction with its high price and poor service. On the other hand, the amount of waste paint to be disposed of off-site from 146 paint factories is estimated at about 982 tons/year, and its amount per factory is small. It also seems to be another reason of the high price and poor service.

2. Waste paint recycling mentioned above for the production of low-quality paint is effective in terms of waste reduction. However, when demand for low-quality paint decreases as the Thai economy develops, the amount of waste paint that can be recycled by the method will decline. Furthermore, excessive reliance on this recycling method deters the willingness to reduce waste paint, and it is afraid that the production efficiency of high-quality paint with high value added remains unimproved, possibly resulted in economic loss. The method is also one of the causes to generate gelled paint that is hard to manage either on-site or off-site. Every factory should attempt to reduce waste paint in the first place. The rate of waste paint to the total paint production in Japan is **1.5 %**. If the rate in Thailand is higher than this, the amount of waste paint should be reduced through the methods introduced later.

3. The next concern about waste disposed of off-site is **sludge** from wastewater treatment and **dust** produced when raw materials are put into tanks for mixing. All the sludge generated is paid for off-site disposal. As for dust, a factory among the 11 recycles it in some way, but the other factories simply dispose of it as waste.

4. **Wastewater** generation should be minimized first, then the installation of wastewater treatment facility should be considered.

5. The most typical manner to deal with **waste solvent** observed in the survey is recycling by blending it into products or using it for cleaning. Waste solvent that can no longer be recycled is sold to waste solvent recyclers at low price or treated by off-site recyclers and brought back to the generators. In this way, a

recycling system of waste solvent has been economically established and waste solvent is not a serious issue. For some factories, for example those which produce many kinds of paint in small quantity, the amount of waste solvent tends to be large and cost for solvent purchasing amounts to a substantial portion of total production cost. Such factories should make further effort to reduce waste solvent.

6. It was found that waste other than what are mentioned above has a proper off-site reuse/recycling system and/or collection/treatment/final disposal system, and the team did not recognize any significant problems.

12.3 Formulation of Improvement Plan for IWM of Paint Industry

12.3.1 Estimation of Future Waste Generation from Paint Industry

Following the method of waste generation estimation performed in Chapter 8, the team estimated future waste amount generated from the paint industry as shown below.

Table 12-4: Future Waste Generation from Paint Industry

Wastes	Generation amount (ton/year)		
	In 2002	In 2005	In 2010
Others	4,048	4093	4109
Waste metals	3,915	3958	3974
Waste paint	3,350	3387	3400
Waste solvent	2,677	2706	2717
Sludge	1,592	1610	1616
Waste paper	376	380	382
Dust	338	342	343
Waste wood	205	207	208
Waste plastics	23	23	23
Cotton wastes	7	7	7
Total	16,531	16,713	16,779

12.3.2 Goals of Improvement Plan and Future Waste Flow

a. Goals

The team formulated an improvement plan for IWM of the paint factory aiming at (i) waste reduction as much as possible, (ii) reuse/recycling of waste that can not be reduced, and (iii) appropriate treatment and final disposal of waste finally discharged.

From the view point of these three points, the current status of IWM of the paint industry can be evaluated as follows.

1. The paint factories have been making significant efforts to reduce waste.
2. They have been reusing/recycling waste as far as they can.

b. Future Waste Flow

With such understanding about the present IWM of the paint industry, it is important to maintain the current high level of waste reduction and reuse/recycling. Therefore, the team set the future waste flow as shown below considering that the present flow should be kept in 2010.

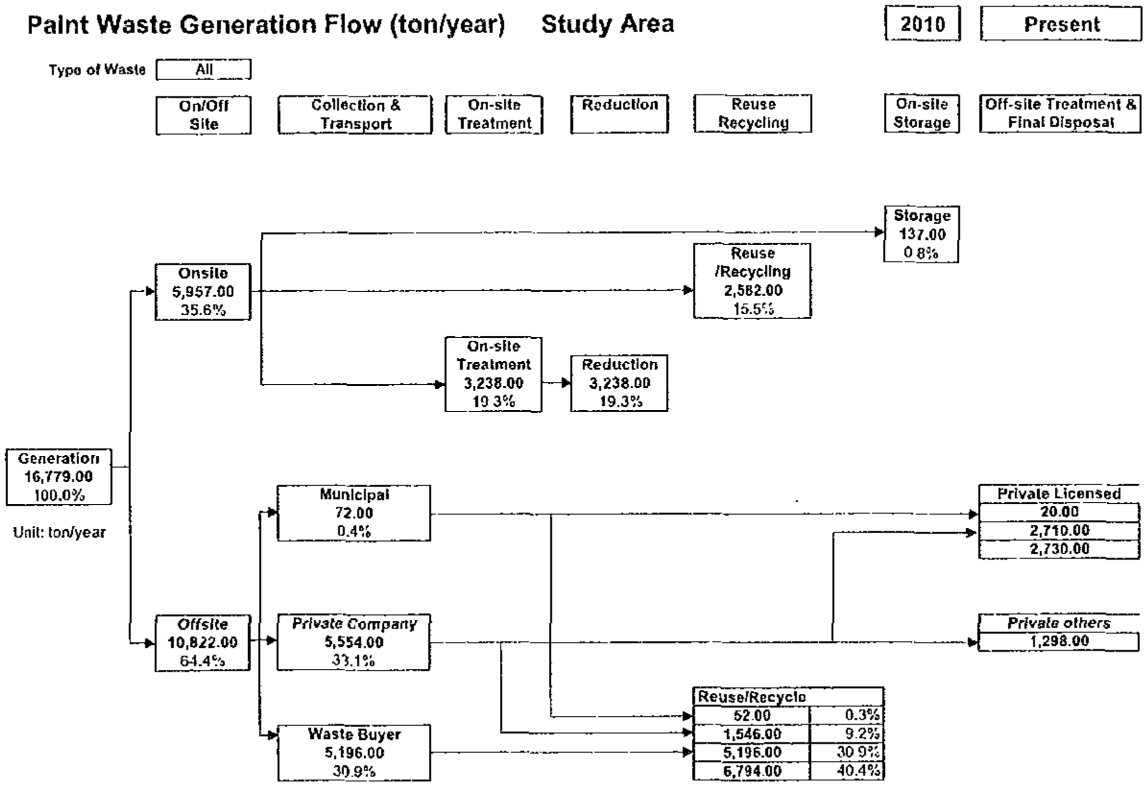


Figure 12-4: Flow of Waste from the Paint Factories in the Study Area in 2010

12.3.3 Improvement Plan

Most waste that is discharged off-site is for the reuse/recycling purposes, but the problem is that five types of waste listed below are treated and finally disposed of off-site with payment.

- Sludge
- Waste paint
- Wastewater (the major part of "others")
- Dust
- Waste solvent

Therefore, the team formulated an improvement plan that focuses on these types of waste. For the reference to understand the plan, Figure 12-5 illustrates the paint production process, followed by Figure 12-6 that shows the sources and countermeasures to be proposed in this section of each type of them.

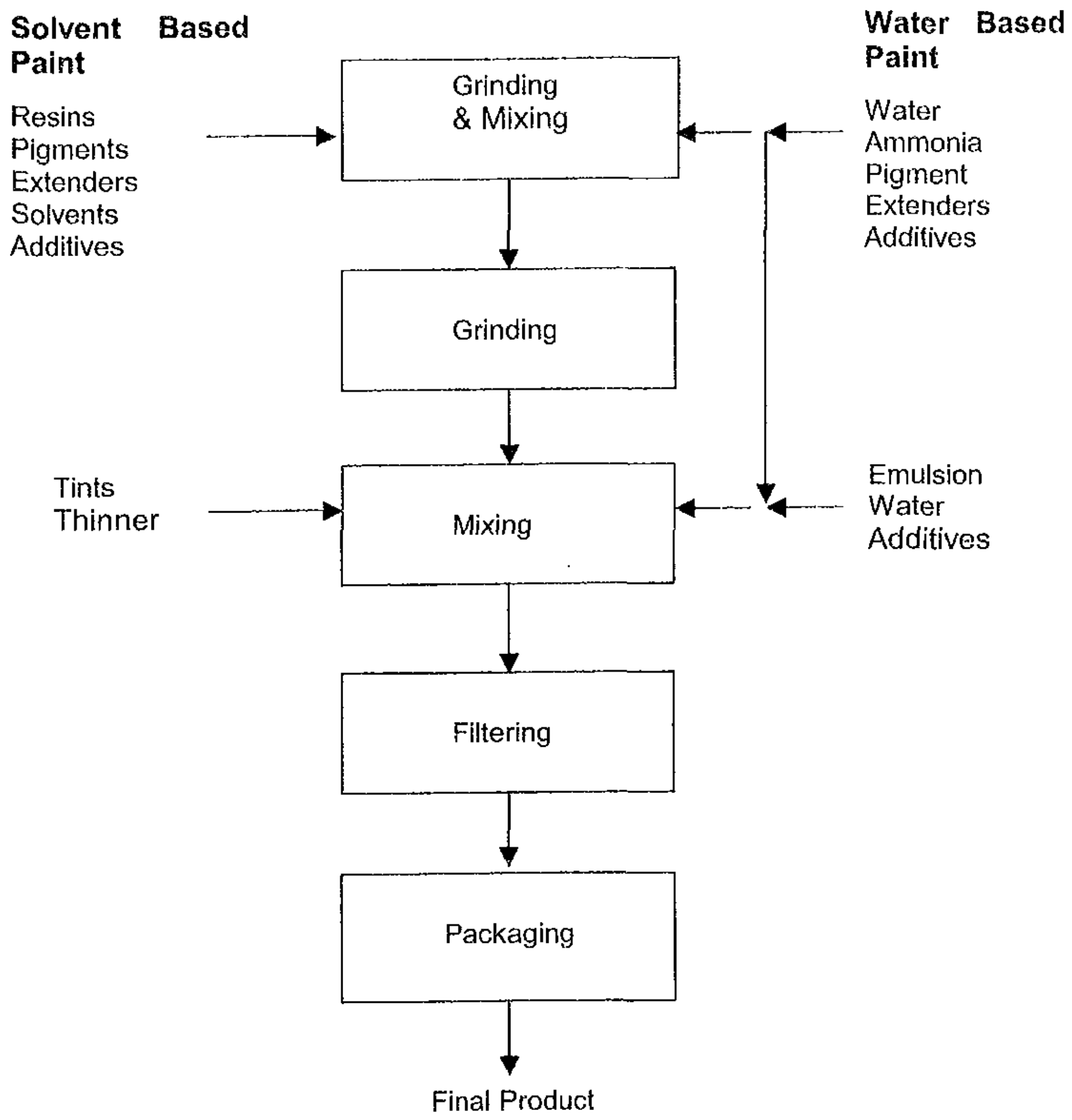


Figure 12-5: Production Process of Paint (except for Powder Paint)

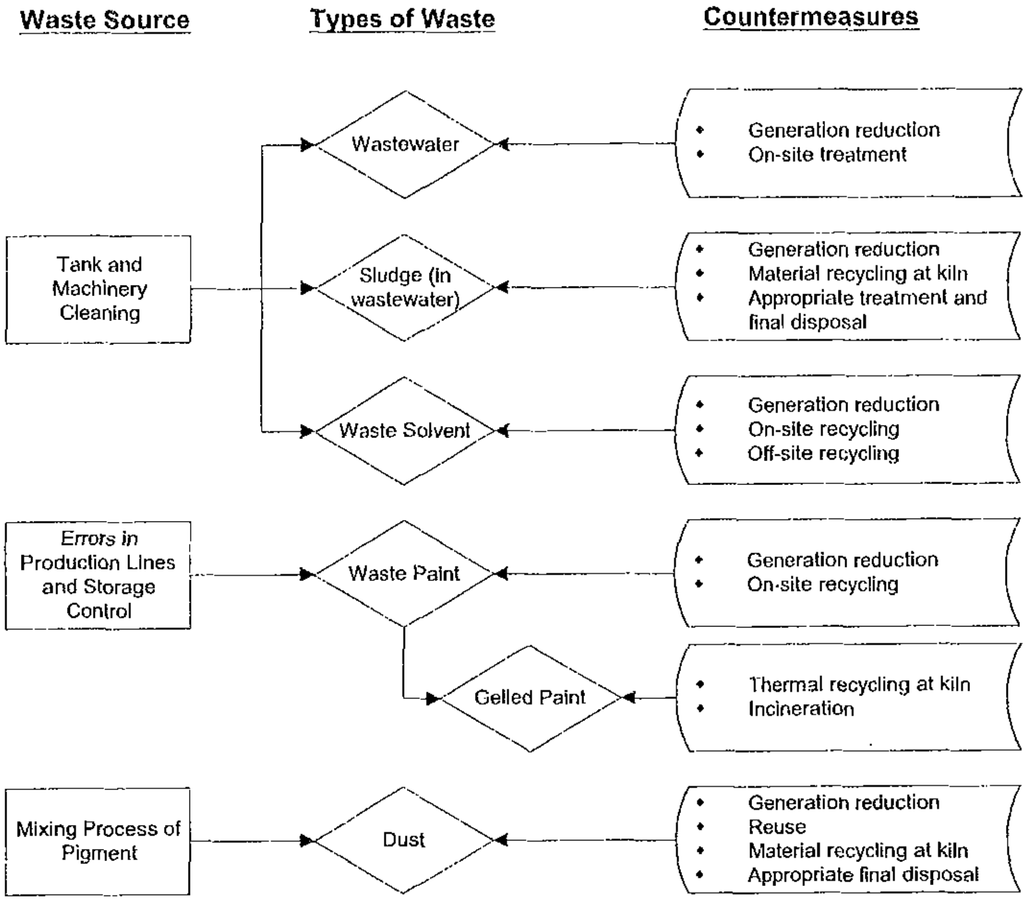


Figure 12-6: Sources and Countermeasures of Waste Generated from the Paint Industry

a. Sludge

Sludge is generated from the cleaning process in the production lines together with waste solvent form solvent based paint production, or with wastewater from water based paint production. In the case of solvent based paint production, sludge is contained in waste solvent which is taken out of factories for off-site disposal, and sludge does not exist as it is in the factories. In the case of water based solvent, most factories treat wastewater by themselves and sludge is separated as filtration residue and needs off-site treatment with payment.

a.1 On-site Disposal

Paint is produced in batches. Therefore, all the machinery and tanks must be cleaned after each batch. Due to the nature of such practice, sludge production is unavoidable, but it is still possible to reduce the amount of cleaning water and thus the amount of sludge by the following measures. Since wastewater and waste solvent are generated together with sludge, they can be reduced in the same way.

a.1.1 Wiping Paint off the Internal Wall

As paint is transferred from the mixing tank to the filling tank, and from the filling tank to product packages, the surface level of paint within the tanks goes down leaving some paint on the internal wall. The paint remained on the wall becomes dry gradually and needs a great volume of cleaning water to be removed. Therefore, when paint is packed in the packages, paint residue on the tank wall over the paint surface should be wiped off to reduce paint remained in the tanks.

a.1.2 Using Part of Process Water to Wash the Internal Tank Wall

It is recommended for the same reason with **a.1.1**. Part of process water (water used as ingredients) is set aside. When paint is transferred from a tank to tank or packed from a tank to packages, the separated water is used to wash the tanks and machinery. The water is mixed with paint, not producing wastewater.

a.1.3 Covering Tanks to Prevent the Internal Tank Walls from Drying

It is recommended for the same reason with **a.1.1**.When methods **a.1.1** or **a.1.2** cannot be applied for some reasons, the mixing tank and the filling tank should be covered to prevent their internal walls from getting dry, although this is less effective than methods a.1.1 or a.1.2.

a.1.4 Blending Water Used to Rinse Light Colored Paint into the Product of Dark Colored Paint

Cleaning water used in the production line of light colored paint does not much affect the color of dark colored paint. Therefore, cleaning water from the production of light colored paint can be used as process water that is mixed with dark colored paint as one of the ingredients, so that the volume of wastewater can be reduced. This method is applicable by formulating a production plan that allows the production of lighter colored paint before that of darker colored paint.

a.2 Off-site Disposal

Sludge which still generates after these countermeasures are applied should be treated and disposed of in a proper manner as below.

a.2.1 Landfilling

The proper way to finally dispose of sludge is landfilling. The factories that the team visited have enough land unlike the factories in Japan and sludge is dried in the sun. Because its water content is estimated at 85% or below, proper landfill operation will be enough.

a.2.2 Recycling at the Cement Factories

As the waste blending industry develops as proposed by the team, sludge can be utilized as alternative raw material at the cement factories.

b. Waste Paint

b.1 On-site Disposal

b.1.1 Examination of the Introduction of Automatic Color Matching System

Errors often occur in the production lines for example when tinting color is added excessively and white paint must be also added. An automatic color matching system can prevent over production due to such a human error.

b.1.2 Blending Storage Samples into Product

Storage samples taken from the filling tank during paint production are necessary for product quality control, but after a certain period of time, they can be mixed with product. If this is done on schedule, on-site disposal of waste paint is easily carried out. Although the volume of individual samples is small, they are stored every day, making the total volume significant.

b.1.3 Quality Control of Resin

The largest trouble with waste paint is gelled paint. Therefore, not only the generation reduction, reuse, or recycling of waste paint, but also the quality control of raw material is important. Paint is gelled because resin (reactive resin such as alkyd resin), raw material of paint, is gelled. Stock control should be executed by, for example, setting expiration date of resin's quality, checking quality after expiration date, and making a consumption plan. The storage of reactive resin requires temperature control of the storage well adapted to the Thai climate.

b.1.4 Reduction of the Use of Accelerator

Reactive cure paint including paint using alkyd resin contains accelerator (drying agent) to promote the reaction of resin and facilitate the formation of gel. Whether the amount of accelerator is appropriate for performance required for the products should be examined, and it should be reduced if possible.

b.1.5 Rationalization of the Calculation of Raw Materials to be Used

The amount of each ingredient for paint production is automatically determined based on the basic design composition when necessary production amount is given. By this method, however, reactive resin, the cause of making paint gelled, in the storage may be more than needed. The next paint product containing the remained obsolete reactive resin will become gelled faster than usual. If the amount of ingredients to be mixed is determined according to the amount of resin in the storage, resin can be used up and long-term storage of reactive material can be avoided.

b.2 Off-site Disposal

At present, the appropriate disposal of gelled paint is hardly possible in the study area and urgent countermeasures are needed.

b.2.1 Promotion of Thermal Treatment at Cement Factories

Thermal treatment is necessary to appropriately treat gelled paint off-site. Thermal treatment at paint factories is preferable from the viewpoint of energy recovery. The smooth implementation of thermal treatment at cement factories requires separation of gelled paint from containers, homogenization, and stable supply, and waste blending industry should be promoted, as proposed by the team (see Chapter 10 of the Main Report). There are two things to be paid attention for paint blending: handling and feeding method.

i. Handling

How to handle gelled paint depends on its physical character, which in turn depends on the amount of solvent. If gelled paint is hard enough, it can be fed to the cement kiln as explained next, but if not, it has to be mixed with other dry waste to make it easy to handle.

ii. Feeding to Kiln

When the gelled paint becomes easy to handle, it should be segmented. Gelled paint in a size of fist or smaller can be fed to the pre-heater or the material feeder side of the kiln. A solid material feeding line which is separated from the raw material line should be installed.

b.2.2 Thermal Treatment at Incinerator

Waste paint containing chlorine or heavy metals can affect the production of cement and may be rejected by the cement industry if its quantity is large. In this case, it must be promoted to thermally treat waste paint at the incinerator which is under construction in the Bangpoo Industrial Estate and will start to operate in 2004.

b.2.3 Strengthening Waste Paint Collection System

Since the amount of waste paint discharged from one factory is small and the number of waste management business operators is limited, it is difficult to expect good waste management service for waste paint. The collection system of gelled waste paint particularly from small-medium sized paint factories should be strengthened. In Japan, waste collection/transportation can be done only by licensers and there are some cases where companies that transport raw material to paint factories possess the waste collection/transportation license and collect and transport waste paint on the way back. The collection/transportation fee is not very small due to the small quantity of waste paint, but the application of this method to Thailand is still worth examining.

c. Wastewater

Wastewater is mainly generated from the tank cleaning process in the production line of water based paint. Most factories treat wastewater on-site, but some entrust its disposal off-site with payment. Wastewater contains sludge.

c.1 On-site Disposal

Because wastewater generates with sludge, the reduction methods of wastewater are same with those of sludge. Methods a.1.1, 2, 3 and 4 can reduce wastewater generation.

c.1.1 Introduction of Wastewater Treatment Facility

The factories whose wastewater is taken out for off-site treatment with payment should examine the introduction of wastewater treatment facility. If it becomes possible to treat wastewater by themselves, only sludge remains as waste. The merit of waste and cost reduction is not small.

c.1.2 Separation of Water for Cleaning

Water for cleaning should be separated into three: water for the primary cleaning which is dirty, water for the second cleaning which is not very dirty, and water for the final cleaning which is relatively clean. Water for cleaning can be saved.

c.2 Off-site Treatment

It is hardly possible to reuse/recycle wastewater that is treated and disposed of off-site and it has to be properly managed. It should be first treated by wastewater treatment facility of the contractors and separated into treated water and sludge. Treated water is discharged from the facility and sludge is landfilled. The water content of the sludge should be 85% or less, as in the case of on-site disposal.

d. Dust

Dust is mainly powdery raw material such as pigment which disperses into air when powdery material is put into the mixing tank. In the production of powder paint, spilled resin and the product itself can cause dust.

d.1 On-site Disposal

d.1.1 Reuse/recycle for Primer Paint or Products

Dust is part of pigment in case of the production of normal paint. It is mixed with other kinds of pigment from different production lines when it is collected to a dust collector. It can be still recycled as raw material for primer paint which does not affect the color of a final coat. In case of the production of powder paint, dust is part of product. If it can be collected before the dust collector line, it can be reused.

d.1.2 Use of Toner Pigment

When toner pigment, which is already mixed with resin, is used, air dispersion of powdery raw material can be prevented. Since toner pigment is supplied by drum, waste of paper packages of pigment can be eliminated.

d.2 Off-site Disposal

Dust which still generates after these countermeasures are applied should be treated and disposed of in a proper manner as below.

d.2.1 Landfilling

Because dust is powder and water content is null, landfilling is the appropriate disposal method.

d.2.2 Recycling at the Cement Factories

As the waste blending industry develops as proposed by the team, dust can be utilized as alternative raw material at the cement factories.

e. Waste Solvent

Waste solvent is generated with sludge from the tank and machinery cleaning process. The cause is the same with that of wastewater from water based solvent production. Waste solvent can be reused/recycled or used as an energy source, and at present, nearly 90 % of waste solvent is sold after repeatedly reused on-site for such purposes as tank washing (some factories distill waste solvent for recovery). Because reuse/recycling of waste solvent is economically feasible, there is no urgent need for improvement. However, the team proposes several countermeasures below firstly because waste reduction should precede waste reuse/recycling, and secondly because the economical efficiency of the reuse/recycling system should be maximized in order for the system to be sustainable. As far as the team understands, there are only two solvent recycling factories. New entry into the solvent recycling business should be encouraged.

e.1 On-site Disposal

Since the causes of waste solvent generation are the same with those of wastewater and sludge, countermeasures introduced in a.1.1, a.1.2, a.1.3, a.1.4 and c.1.2 can be applied to reduce its generation volume.

e.1.1 Washing Sand Mill with Resin

Because of the complex internal structure of the sand mill, a pigment disperse system used in a mixing process, it is better to wash it with liquid with higher viscosity. Therefore, it is recommended to set aside part of resin that is to be used as an ingredient and put it into the sand mill after the mixing process is finished and paint is transferred to the filling tank. The resin is then transferred to the filling tank. In this way paint residue in the sand mill can be washed with the resin and cleaning solvent can be saved.

e.1.2 Installation of Solvent Distiller

The installation of solvent distiller can be recommended to factories that generate waste solvent more than a certain volume after generation reduction efforts. There are examples in Japan and in Bangkok, Thailand (capacity: 150 l/batch in Bangkok). Devices observed in Bangkok are in good condition without problems. The feasibility of the introduction of equipment depends on the cost comparison with such options as selling it out. It is to be noted, however, that the use of recycling equipment has a non-financial advantage, in that the recycled solvent can be reused without worries about its quality since its origin is the factory itself. The team attempted financial analysis as explained later.

e.2 Off-site Disposal

There are several solvent recyclers in the study area and the solvent recycling system seems to be working well. The number of solvent recyclers that receive waste solvent from the paint industry is, however, limited. This is because waste solvent from the paint industry is much dirtier than that from other industries and can affect the quality of recovered solvent if distilled together. For the sound development of the market of solvent waste from the paint industry, new recyclers should join the market as competitors.

12.4 Financial Appraisal of Solvent Recycling in the Paint Industry

As the possible measures for improving current HW management in paint industry, this section examines financial feasibility of the solvent recycling business and on-site recycling and reuse of waste solvent within factories.

12.4.1 Financial Viability of the Recycling Business Focusing on Waste Solvent Generated from Paint Industries

a. Estimation of the Project Cost

a.1 Outline of the Project

The Study assumes that the project would build and operate a solvent recycling facility consisting of distillation units, boilers, cooling tower, and so forth. The

Facility will accept waste solvent from painting factories and recycled them for resale.

a.2 Types of solvents and their amount handled

To keep its stable recycling efficiency and quality of the recycled products, the project limits the waste solvents to those generated from paint factories. According to the interview survey by the JICA Study Team, the amount of waste solvent handled are estimated to be 7,200 drums per year, which is equivalent to 1,444 thousand litres per year.

a.3 Recycling technology applied

Since the distillation temperature needs to be differentiated depending on the purity of waste solvents, the Study assumed that 1 distillation unit would consist of 3 different types of distillers as mentioned below:

- Distiller 1 (Capacity: 200l)
- Distiller 2 (Capacity: 500l)
- Distiller 3 (Capacity: 1000l)

} 1 distillation unit

Every distiller has its own condenser and product reception tank. Assuming that the average operation ratio of the unit is 20 days per month and 2 batches per day, its treatment capacity is estimated as follows:

- Distiller 1 (200l)
  200(l/batch)*2(batches/day)*20(days/month)=8,000(l/month)
- Distiller 2 (500l)
  500(l/batch)*2(batches/day)*20(days/month)=20,000(l/month)
- Distiller 3 (1000l)
  1000(l/batch)*2(batches/day)*20(days/month)=40,000(l/month)

To sum up, the treatment capacity of one distillation unit is 68,000 litres per month or 816,000 litres per year.

Considering that the amount of waste solvent handled by the facility is about 1,444,000 litres per year, the number of units required is estimated as follows:

1,444,000 (l/year)/816,000(l/year/unit)=1.769(unit) ≒ 2(units)

Thus, 2 distillation units are required to recycle and treat the above amount. The initial investment amount required is estimated below based on this assumption.

a.4 Estimation of Initial Investment Cost of the Project

Based on the above assumption of the facility to be developed, the initial investment cost of the project was estimated as shown in Table 12-5 below.

Table 12-5: Initial Investment Cost of the Project

Item	Cost (Bahts)
1. Land Acquisition (3 million bahts/rai)*(5.25rai)	**15,750,000**
2. Building (6,000 bahts/m^2)*(5,000m^2)	**30,000,000**

3. Distillation System	**2,700,000**
200l Distiller (2 units)	600,000
500l Distiller (2 units)	900,000
1000l Distiller (2 units)	1,200,000
4. Stand for the Distillation units (6 units)	**600,000**
5. Heating Boiler (100kcal)	**4,800,000**
6. Cooling Tower	**900,000**
7. Waste Haulage Trucks (5 to 6 ton-truck)*(5 trucks)	**4,500,000**
Total Initial Investment Cost	**59,250,000**

Remark: 1 rai = 1,600m^2

Land price applied is the average market price of industrial estates.

a.5 Operation and Maintenance Cost

The Study estimated the annual operation and maintenance cost of the proposed facility as shown in Table 12-6.

Table 12-6: O/M Cost of the Proposed Solvent Recycling Facility

Item	Cost (Bahts/year)	Remark
Manpower Cost	2,400,000	20(psn/day)*500(baths/psn/day)*240(day/year)
Maintenance Cost	450,000	5% of the initial investment cost
Utility (Water, Electricity, etc.)	720,000	60,000(baths/month)*12(month/year)
Total	**3,570,000**	

b. Financial Feasibility Appraisal of the Project

In accordance with the initial investment and annual O/M cost of the project, the Study evaluated financial viability of the project on the preconditions as shown in Table 12-7 below.

Table 12-7: Preconditions of the Project

Project Period	11 years (inc. one year of construction and 10 years of operation)
Project Revenue	Income from selling recycled/recovered solvents Sale price: to be set up between 20 and 30 bahts/kg for each case (about 70 to 100% of the price of virgin solvent) Sale amount: 648.0 tons/year (recycling rate at 50%, average density of waste solvent at 0.9kg/l) Annual Revenue: 13,608,000 to 19,440,000 bahts/year
Project Expenses	Initial Investment Cost: 59,250,000 bahts Annual O/M cost: 3,570,000 bahts/year Cost of buying waste solvents: 2,000(bahts/ton)*1,300(tons/year)*=2,600,000(bahts/year)
Discount Rate Applied	10% (assumed taking into account commercial interest rate, inflation, etc.)

Under the preconditions established above, the Study estimated the financial feasibility indicators (NPV and FIRR) as shown in Table 12-8 below.

Table 12-8: Results of Financial Feasibility Indicators by Cases

	Sale Price (bahts/kg)	NPV (bahts)	FIRR (%)
Case 1	20	-15,934,899	2.6
Case 2	25	2,163,644	10.9
Case 3	30	20,262,187	18.2

As clearly indicated in the table above, FIRR of the project only reaches 2.6% in Case 1, where recycled solvent is sold at the price of 20 bahts per kg, about 70% of the virgin solvent. Even in Case 2, in which recycled solvent is sold at 25 bahts, the feasibility of the project is still not high enough (FIRR is 10.9%). Assuming that the financially viable level of FIRR is more or less 20% in the case of Bangkok, the recycled solvent has to be sold at the same price of virgin solvent (30 bahts per kg) or more.

However, the low financial feasibility of the solvent recycling above comes from the comparatively large initial investment especially for land and building construction, which covers 77% of it. If the current initial investment cost can be reduced by 30% (reduced to approximately 40 million bahts), the project will be feasible (more than 20% of FIRR) by the current selling price of recycled solvent at 24 bahts per kg.

12.4.2 Financial Viability of On-Site Recycling and Reuse of Waste Solvent by the Paint Manufacturing Factories

a. Estimation of the Project Cost

a.1 Estimation of the Initial Investment Cost

The Study here assumed that a paint manufacturing factory would recycle and reuse waste solvent by making use of the commercially available solvent distillation unit of the following capacity:

Recycling capacity of waste solvent: 35(litre/hour)*5(hours/batch)*2(batches/day)

Recycle ratio: 60% of waste solvent can be recycled.

The initial investment cost is defined as the sale price of the above distillation unit at current price in 2002, which is 11,480 thousand bahts.

a.2 O/M Cost

As the O/M cost, the Study estimated the costs of electricity and fuels used for operating the distillation unit above based on the available data. As to additional manpower cost, the Study estimated it assuming that 0.5 person per day of additional work will arise by the on-site recycling of waste solvent.

Electricity Cost: 0.63 bahts per litre of waste solvent recycled

Fuel Cost: 0.20 bahts per litre of waste solvent recycled

Manpower Cost: 500(bahts/day/psn.)*0.5(psn./day)*300(days/year)

=75,000(bahts/year)

b. Financial Feasibility Appraisal of On-site Recycling of Waste Solvent

The Study established the preconditions shown in Table 12-9 to assess financial feasibility of on-site recycling of waste solvent.

Table 12-9: Preconditions of On-Site Recycling of Waste Solvent

Income	The Study defined the income as the cost reduction of purchasing virgin solvents by substituting them to recycled ones. Meanwhile, taking into account that waste solvents are usually sold to recyclers at the price of 2 bahts per kg, the Study subtract the income from selling waste solvent from the total cost reduced by on-site recycling. Unit price of virgin solvent: 30 bahts/kg Recycling ratio of waste solvents: 60% Selling price of waste solvent: 2 bahts/kg Cost reduction per ton of using recycled solvents as the substitute: 16,000 bahts/tons *1000(kg of waste solvent)*60(%)*30(bahts/kg substituted)* - 1000(kg of waste solvent)*2(bahts/kg of waste solvent)
Expenses	Initial Investment Cost: 1,148,000 bahts Electricity and Fuel Cost: 0.83 bahts/litre of waste solvent Manpower Cost (Fixed): 75,000 bahts/year

Based on the preconditions established above, the Study estimated when the investment can be totally recovered for each case differentiated by the daily amount of waste solvent recycled, starting from 350 liters per day (which is the maximum recycling capacity of the distillation unit above) down to 50 liters per day.

Table 12-10: Results of Financial Feasibility Indicators of On-site Waste Solvent Recycling

	Amount of waste solvent recycled (litre/day)	The year when the investment is totally recovered
Case 1	350	1st year of operation (11 months)
Case 2	300	2nd year of operation (13 months)
Case 3	250	2nd year of operation (15 months)
Case 4	200	2nd year of operation (19 months)
Case 5	150	3rd year of operation (26 months)
Case 6	100	4th year of operation (42 months)
Case 7	50	9th year of operation (108 months)

Remark: yearly operation days are established as 300 days, which are equivalent to the working days of the factory.

The table above indicates that the investment can be returned within 2 years after starting on-site recycling if the amount of waste solvent recycled is more than 200 liter per day. If the average daily amount of waste solvent falls down to 50 liter, it takes about 10 years to recover the investment while FIRR drops to more or less 2%.

The Study estimated that the financial viable level of on-site recycling of waste solvent would be around 100 liter per day of waste solvent recycled.

12.5 Conclusions and Recommendations

12.5.1 Conclusions

Using the result of the interview survey at the 11 paint factories, the team estimated the total waste generation from paint factories located in the study area at about 16,000 tons/year. The factories discharge 64% of this amount out for off-site treatment and/or final disposal. They have to pay for off-site treatment and/or final disposal of 24% of total generation.

The team drew the following findings regarding IWM at the paint industry from the factory survey.

1. The rate of total waste (including valuable waste and invaluable waste) to total paint production amount is much lower in the study area than that in Japan. According to the study done by Japan Paint Manufacturers Association, this rate in Japan is 6.4% (the average of 112 member companies of the association in 1999, tonnage base), whereas it is 2.9% on the average of the 11 factories. The reason will be that materials regarded as waste in Japan go back to the production lines in Thailand and are not counted as waste. This results in waste reduction. Such practice in Thailand seems to be attributed to lower cost for labor force than for raw materials.

2. The waste reuse/recycling activities of the factories are significantly active. The rate or reused/recycled waste to total generation is 56% in the study area, while it is 44% in Japan.

3. Therefore, the current problem with IWM for the factories is waste which has to be treated and finally disposed of off-site with payment. whose treatment/final disposal. It includes, in the order of amount, sludge, waste paint, wastewater, dust, metals, paper, cotton and plastics. The last four items are in so small quantity that they are not a problem.

4. Among those types of waste to be paid for off-site disposal, waste paint, especially gelled paint, is of a particular problem. The factories are frustrated with high disposal cost and inadequate collection service. The major method applied for disposal is landfilling, and whether it is properly managed is questionable.

5. About 90% of waste solvent generated is taken out of the factories and fully recycled. Although being paid by the recyclers, the factories are interested in generation reduction and on-site reuse/recycling of waste solvent, since the proportion of the cost for solvent as raw material to total production cost is not small.

12.5.2 Recommendations

With the understanding as above, the team examined an improvement plan for waste that matters to the factories, namely, sludge, waste paint, wastewater, dust and waste solvent. The team's recommendations can be summarized below.

1. Since the increase in labor cost is anticipated as Thai economy develops, the further promotion of waste reduction is required in order to maintain the present state of low waste generation. In particular, waste listed below that is at present paid for off-site disposal will become more costly for the factories as cost for labor force and appropriate treatment rises. The team recommends the countermeasures summarized below to the paint factories for further waste reduction.

Table 12-11: Measures to Reduce Waste from Paint Industry

Type of Waste	Measures
Sludge	• To wipe paint off the internal tank wall before washing. • To set aside part of process water, use it to wash tank, and mix it with the product. • To cover the filling tank to prevent paint remained on the wall from drying out and sticking to the wall firmly. • To produce lighter colored paint earlier than darker colored paint in order to make it easy to wash the tank when color is changed.
Waste paint	• To introduce an automatic color matching system to prevent over production due to errors in matching colors. • To minimize the content of drying agent that accelerate the formation of gelled paint by examining whether its content is appropriate. • To make a production plan in which reactive resin is used up as much as possible to prevent it from being left in storage. This is because if reactive resin is used as material after stored for a long time, paint turns to gel faster than normal.
Wastewater	• To wipe paint off the internal tank wall before washing. • To set aside part of process water, use it to wash tank, and mix it with the product. • To cover the filling tank to prevent paint remained on the wall from drying out and sticking to the wall firmly. • To produce lighter colored paint earlier than darker colored paint in order to make it easy to wash the tank when color is changed. • To examine the introduction of on-site wastewater treatment facility in case where wastewater is treated off-site. • To separate waste for cleaning into three, i.e. water for the primary cleaning, water for the second cleaning and water for the final cleaning, and use it for each purpose repeatedly.
Dust	• To use toner pigment, i.e. pigment mixed with resin, to prevent pigment, which is powdery, from dispersing into the air when being put into the mixing tank.
Waste solvent	• To wipe paint off the internal tank wall before washing. • To set aside part of solvent to be used as an ingredient, use it to wash tank, and mix it with the product. • To cover the filling tank to prevent paint remained on the wall from drying out and sticking to the wall firmly. • To produce lighter colored paint earlier than darker colored paint in order to reduce solvent needed for tank cleaning. • To set aside part of resin to be used as an ingredient, use it to rinse waste paint in a pigment disperse system, and mix it with the product.

2. In order to keep the present high reuse/recycling rate in spite of the future changes of social and economic conditions, the team recommends the following countermeasures.

   - To reuse waste at cement factories as alternative fuel.
   - To reuse waste at cement factories as alternative raw material.
   - To promote on-site reuse/recycling of waste that is currently reused/recycled off-site, as far as it is economically viable.
   - To properly control stocks of products and samples by blending them into products.
   - To collect such waste as powder paint and mix it with products.

3. As for waste paint, generation reduction should come first. Once generated, it must be properly recycled or treated as follows.

   - To develop a system to collect waste paint from paint factories including small and medium sized factories by, for example, promoting waste collection by waste blenders, or having the raw material transporters collect waste paint on their way back.
   - To reuse waste paint as alternative raw material for cement production. The problem is that the amount of waste paint from individual factories is small and its quality varies from factory to factory. It is required to promote the waste blending industry, which blends waste and adjust its quality and quantity to the requirement of the cement factories.
   - To promote the use of the incinerator currently under construction for the thermal treatment of waste paint which cannot be accepted by the cement factories due to the high content of chlorine and/or heavy metals.
   - To stop landfilling waste paint which is not solidified enough.

4. As for waste solvent, the team recommends the following measures to maintain the present 100% reuse/recycling system.

   - To further promote off-site waste solvent recycling that is well developed at present. The team investigated the financial feasibility of the construction of a new factory that recycles a half (1,300 tons/year) of solvent generated in the whole study area. As a result, it was concluded to be feasible by the current selling price of recycled solvent at 24 bahts per kg if the cost for land and building construction, which shares significant part of estimated initial investment, is hold down enough (see Section 12.3.2).
   - To promote paint factories that consumes large amount of solvent to install waste solvent distillation equipment after thorough examination of financial feasibility. The team investigated the financial feasibility of on-site waste solvent recycling at a paint factory. As a result, it was presumed that the financial viable level of on-site recycling of waste solvent would be around 100 liters per day of waste solvent recycled.