CHAPTER II

PLASTICS RECYCLING

Plastics Recycling Industry

1. Types of Plastic Waste

Although plastic have been used by consumers for nearly 50 years, their use in packaging has increased dramatically over the last 20 years and is expected to increase another 70 percent by the year 2000. Because most packaging is disposable, plastics in municipal solid waste are increased from 3 percent in the early 1970s to 7 percent (by weight) in 1990. The growth in use of plastics in consumer products has occurred because plastics have largely replaced metal and glass as a container material and paper as a packaging material. Plastics have several advantages: They are light and thus reduce shipping cost. They are durable and often provide a safer container (e.g., shampoo bottles). They can be formed into a variety of shapes and can be formulated to be flexible or rigid. They are good insulators, and they are well suited to wet foods and microwave oven use.[2]

The amount of plastic wastes are expected to rise rapidly in the future and do present a trouble some disposal problem so they can be recycled into useful products. Wasteplastics consist of plastics resin or product that must be reprocessed or disposed of.

Post consumer plastic waste is any plastic that has been used by the consumer and discarded. It applies to an individual plastic or to a mixture of

plastics. It could be one type of plastic, such as HDPE milk jug two types of plastic, such as PET beverage bottles with HDPE base cups; or a mixture of a large variety of plastics.

Commingled plastic waste may be a mixture of two plastics or a variety of plastics. PET and PE, the focus of most post-consumer plastic waste collection programs, are said to be commingled. "Commingled" also is used to describe post-consumer plastic waste that includes a mixture of all types of resins that are in multilayered, printed, laminated, plated, pigmented, painted, or modified forms.

Industrial plastic waste is nonconsumer plastic, which includes waste from molders, converters, packers, resin manufacturers, and so on. Normally this plastic waste is easy to be identified, comes from a single source, can be processed on traditional molding equipment, and may be commingled. Some cleaning may be required.

Contaminated plastic waste may have nonplastic material enclosed, such as paper foil, wood chips, floor sweepings, lunch bags, product residue, aluminum closures, wire reclaim, fiber waste, magnetic strips and plating.

Nuisance plastics are waste plastics that cannot be reprocessed under the existing technoeconomic conditions.

Scrap plastics are waste plastics that are capable of being reprocessed into commercially acceptable plastic product.[3]

2. Types of Plastic Now Recycled

Type of plastics are considered in the following [2]

a. Polyethylene terephthalate (PET). PET is recycled primarily to polyester fibers used in the manufacture of sleeping bags, pillows, quilts, and cold weather clothing (green bottles are processed seperately because green

fibers may be used only in garments with a dark-colored outer shell). Postconsumer PET is also used for carpet backing and fibers, molded products, polyisocyanate insulation board, film, strapping, food and nonfood containers and engineering grade plastics for the automotive industry.

In a departure from conventional recycling technology, two large resin producers are now chemically depolymerizing postconsumer bottles to ethylene glycol and terephthalic acid, which are repolymerized to virgin-quality resin for new soft dink bottles.

b. High-density polyethylene (HDPE). The properties of HDPE vary widely depending on the product to be manufactured. Milk jugs are made from resin having a low melt index (roughly a measure of the viscosity, which determines the stability for different manufacturing processes), which allows the resin to stretch while being expanded during blow-molding. Rigid HDPE is made from resin gaving a high melt index, which allows the resin to flow easily into a precision mold form. In turn, the properties of HDPE "regrind" depend on the feedstock material (regrind is the term used to describe granulated, cleaned plastic). To control quality when producing a regrind, processors do not mix different types of resins, or mixtures of the same resin with different melt indexes. Instead, flakes or pellets are produced from homogeneous resins and blended by either the processor or end-use manufacturer to produce the melt index required.

The most common consumer items produced from postconsumer HDPE are detergent bottles which are usually made in three layers, with the center layer containing the recycled material. The inner layer of virgin resin provides a dependable barrier, and the outer layer provides uniform color and appearance. Recycled HDPE is also used for protective wrap, grocery sacks, pipe and molded products such as toys and pails.

c. Polyvinyl chloride (PVC). PVC is widely used for food packaging, electrical wire and cable insulation, and plastic pipe. Although postconsumer PVC is a high-quality resin that needs little or no compounding, very little PVC is now recycled, because the cost of collection and sorting is prohibitive. Typical recycled products include nonfood containers, shower curtains, truck bed liners, laboratory mats, floor tiles, garden hose, flower pots, and toys. There is a huge potential market in the form of drainage pipe. Fittings, moldings, sheets, and injection molded parts, all of which could be made from recycled PVC.

The major impediment to PVC recycling is collection and sorting. To date, most sorting has been manual, based on either identify codes or the characteristic "smile" line on the bottom of blow-moded PVC bottles. Both the EPA and resin producers have provided funds for sorting research. National Recovery Technologies has used electromagnetic processes to detect chlorine in plastics, and the Center for Plastics Recycling Research has used radiation technology, but neither process is yet cost-effective for full-scale operation.

d. Low-density polyethylene (LDPE). In 1988, the production of polyethylene film was 3.6 billion pounds, including 1.2 billion pounds for food packaging and 2.1 billion pounds for trash bags, disposable diapers, agriculture, and construction. Most film eventually ends up in the solid waste stream, and although it does not contribute much volume in a landfill, film accounts for about 16 percent by weight of discarded plastics.

e. Polypropylene (PP). Polypropylene is commonly used for automotive battery cars, container closures (caps), bottle and jug labels, and, to a minor extent, for food containers. Polypropylene labels and caps are normally granulated with polyethylene products, and 10 to 13 percent can be left in bottle-grade HDPE regrind. A larger amount of polypropylene is left in the

mixed flake only for low-specification products such as plastic lumber, outdoor furniture, posts, and fencing. Lead-acid battery processors also recover polypropylene for use in new batteries.

f. Polystyrene (PS). Approximately 5.2 billion pounds of polystyrene are produced annually in the United States, and about 25 percent is used for food packaging. Familiar to foamed products are clamshell fast-food containers, plates, meat trays, cups, and rigid packing material. Other common items are food utensils, clear drinking glasses and pigmented cottage cheese and yogurt containers which are produced by extrusion and injection molding.

According to the plastics industry, PS comprises only 0.26 percent of municipal solid waste by weight and only, percent by volume, and thus does not reserve the bad repulation it has acquired. Critics disagree, pointing out that much packaging is not necessary, and have called for legislation to reduce or eliminate from products; some bans have been enacted. As a result of public pressure, eight resin producers formed the National Polystyrene Recycling Company in the late 1980s. The goal of the National Polystyrene Recycling Company is to recycle 25 percent of specific post-consumer products. Company has set up five regional processing plants in the United States to reach this objective, and has provided funds to nonaffiliated PS recyclers who already have plants in operation.

The different types of PS packaging or food service containers can be reclaimed seperately or together. A typical process includes semi-automatic sorting, granulation, washing, drying and pelletizing. Solid foam board is processed differently, the foam is chopped without heat to form a taffy-like mixture, and then sprayed with water and chopped into pellets. Recycled polystyrene is used to produce foam foundation insulation board, office accessories, food service trays, trash receptables, insulation, toys, and injection-

molded products. Manufacturers are apparently satisfied with the reclaimed resin, but processors may require subsidies to cover collection, sorting and shipping costs.

g. Mixed and Multilayer plastics (other). Manufacturer also use with special requirements (such as salad dressings and ketchup). These containers have no value as a regrind product because there is no market. However, processors are using mixed streams of postconsumer plastics (especially polythylene and polypropylene) to produce resins for manufacturers of products that are massive and do not require strict resin specifications, such as outdoor benches, tables, cars, fence posts retaining timbers, pallets, and stakes. Because the plastics are not sorted, processors are usually able to obtain their feedstocks at very low cost. Polyethylene terephthalate is kept out of the regrind because it melts at a higher temperature than the other resins and forms inclusions in the final product.

These plastic wastes can be marked code on them to be collect and sort easily. Table 2.1[4] gives various of codes on plastic products that take easily for Recycling.

Table 2.1 Various codes of recycled plastic products.

code	Plastics
	PET polyethylene terephthalate
	HDPE High Density polyethlene
	R-PVC polyvinyl chloride
	P-PVC
	LDPE Low Density polyethylene
	PP polypropylene
	PS polystyrene
	ESP E
	Other

Plastic recycling is on the thermoplastic component of the plastic garbage stream. The entire of plastic packaging is thermoplastic. Nearly 80 percent of the major thermoplastic resins used in packaging in 1989 were polyolefin (LDPE, HDPE and PP) as shown in Table 2.2 [5]

Table 2.2 Plastics used in packaging, 1989

Polymer	Billion pounds	Major use
Low-density polyethylene (LDPE)	5.7	Shrink wrap
High-density polyethylene (HDPE)	4.4	Milk, water, juice, detergent bottles
Polypropylene (PP)	1.5	Snack food, film, ketchup bottle
Polystyrene (PS)	1.3	Pharmaceutical bottles, foam caps, etc.
Polyethylene terephthalate (PET)	1.0	Soft drink bottles
Polyvinyl chloride (PVC)	0.6	Water and salad oil bottles, household food wrap
Other	0.5	
Total	15.0	

On a volume basis, it is interesting to note that about 80 percent of plastics packaging is in form of rigid containers. On a volume basis, film represents only about 20 percent. On a weight basis, however, they goes into the waste stream (Table 2.3).[5]

Table 2.3 Plastic Packaging by Volume.

Type of plastic packaging	volume
Beverage bottles	25
Nonbeverage bottles	25
Other rigid containers	30
Films	20

3. Local Plastics Recycling Industry

3.1 Structure of Local Plastic Recycling Industry

The local plastic recycling industry is labour intensive. Recycling plant are of small scale. These plants have been operating for years. The equipments are old and of local made. Investment are relatively low. Usually, a recycling plant does not cover the entire recycling process. A plant may have only grinding operation, while another plants have only pelletizing operation. Thus there are many parties involve in plastic recycling industry. The structure of local plastics recycling industry is shown in Figure 2.3.

Household Source : Household wastes are generated by individual householder. They are mixed refuse or hetergeneous.

Street Collectors : Street Collectors go from house to house by plastic waste and to sell them to waste dealers

Waste Disposal Site : Waste disposal site is a place for collect and disposal array. These refuses are collected from household and city by vehicles.

Waste Dealers : Waste dealers purchase waste from various plastic waste collectors which include street collectors and waste sorters. Some plastic waste are from for a way provinces. Waste dealers classified plastic waste with respect to generic types and sell them to grinders.The labour cost for classifing plastic waste is about 0.2 bath/kg. Some waste dealers also operate grinding machines.

Grinders : Grinders obtain plastic waste from waste dealers and/or plastic fabricating plants. Plastic waste from fabricating plants may pass through middle man before it reaches the grinders. Upon receiving plastic waste, the grinders will involves five operations, namely, seperation, grinding, washing, water shredding, and drying. Some grinders also operate pelletizing machines themselves.

Pelletizers : Some pelletizers also own fabrication plants in which their own recycling pellets are consumed. The pelletizing plants and fabricating plants are not the same compound.

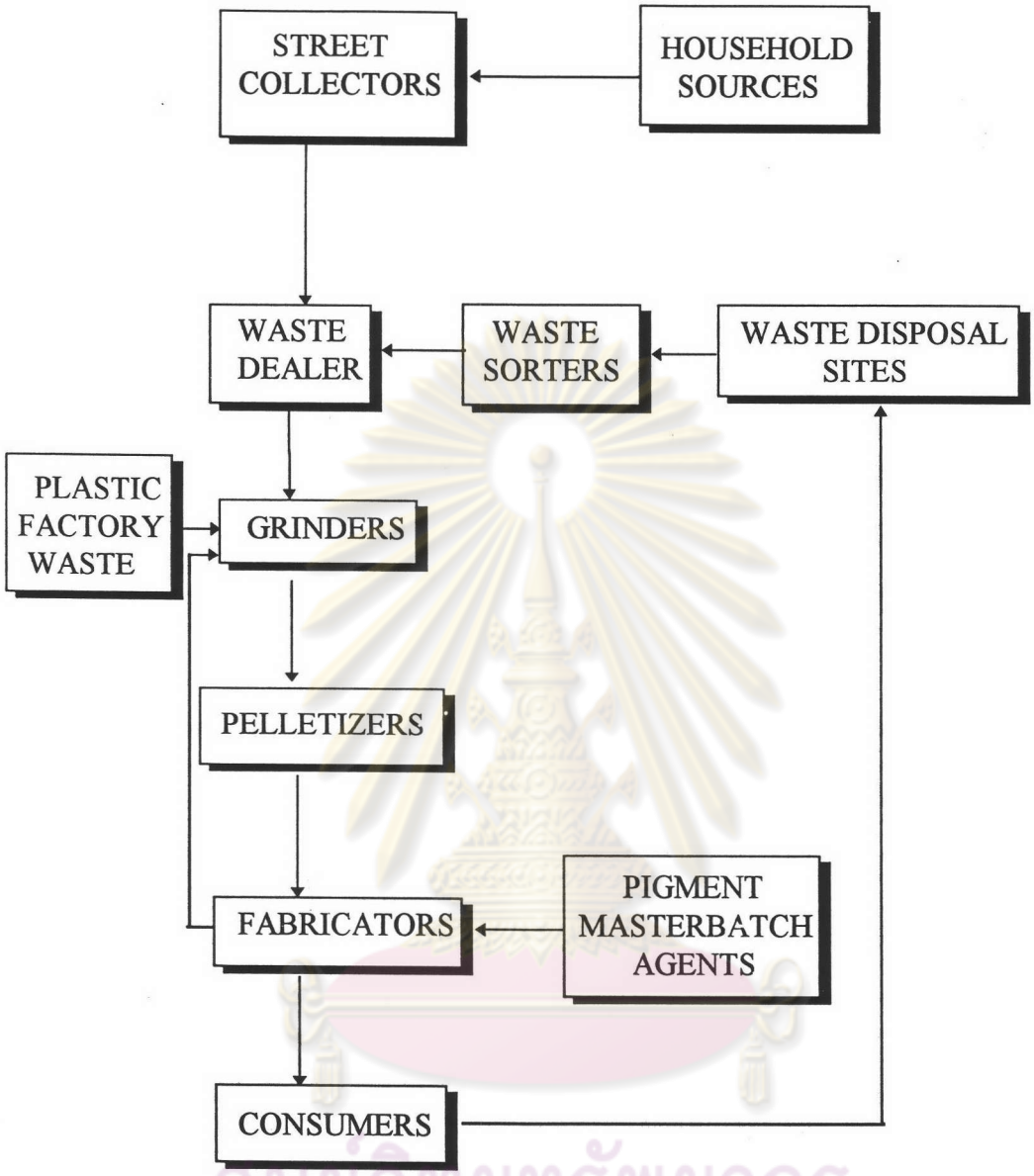

Figure 2.1 Structure of local plastic recycling industry.

Fabricators : Fabricator or manufacturer is a key decision maker in the life cycle of many plastic item. He close to the consumer and is very sensitive to his need. The very large companies often design the product such as package,automobile,etc,. Many of large fabricators use consumer panels and elaborate testing to determine what the consumer wants, and how he makes his choice. Fabricator can distribute his product in three different ways to the wholesealer, directly to the retailer, and to the consumer.[6]

3.2. Processing of Plastic Waste

Various plants have recycling process consisting of several stages as shown in Figure 2.2.

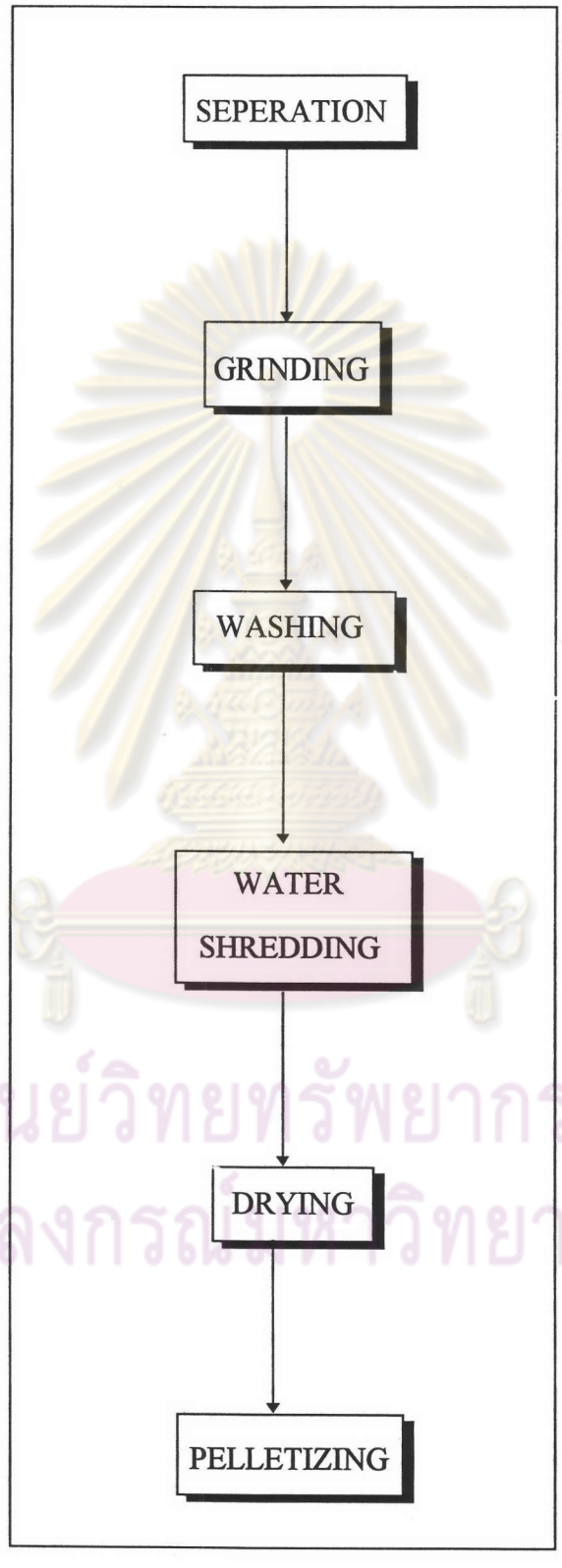

Figure 2.2 Processing of plastic waste.

3.2.1 Seperation

Plastic waste is first, sorted to seperate various generic types, namely, HDPE, LDPE, PP, PS, and PVC.

3.2.2 Grinding

After seperation plastic waste is ground to smaller size of 0.5-2.5 cm. Appearance of ground waste depends on the original waste. For waste bottles, the ground plastic appears as flake of sheet. The grinding machines or granulator are small simple equipment of about 5 horse power and local made. Structure of granulators are generally similar, consist of rotor blade about 2-3 pieces to 7-8 pieces and stator plade about 1-3 pieces. Figure 2.3 [7] shows structure of grinding machine and cross-section of rotor blade and stator blade showed in Figure 2.4.[4]

3.2.3 Washing

It is necessary to have washing or cleaning step to remove contaminants such as dirt, label, adhesive, and residual contents from plastic waste. Ground plastic is washed in a stirred tank with detergent and/or NaOH, then the ground plastic is transferred to pond where it is leached. The pond is divided into two or three sections. The ground plastic is moved along the pond from the first section to the second section and then finally the third section.

3.2.4 Drying

The cleaned ground plastic from the pond is transfered into water shredding unit, to remove adhere water by centrifugal force. Then the ground plastic is dried in a dryer in which drying is accomplished by method of heat conduction and etc, contact with hot surface. Heat is generated from either electricity or cooking gas. Dryers are of local made.

3.2.5 Pelletizing

The dried ground plastic is transfered into the hopper of a pelletizing machine. Usually pigment of the desired color is else added. The thread of plastic from the extruder is water-cooled before it goes to a cutting machine. A typical pelletizing machine is of 25 horse power and is made locally. Figure 2.5 [7] shows pelletizing machine.

Plastic pellets are obtained from this pelletizing machine that called "secondary plastic pellet". These pellet can produce secondary product such as table, pipe, and etc.

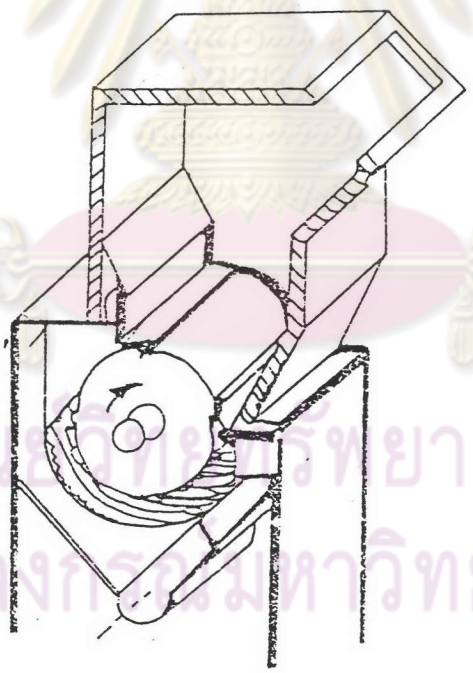

Figure 2.3 Granulator.

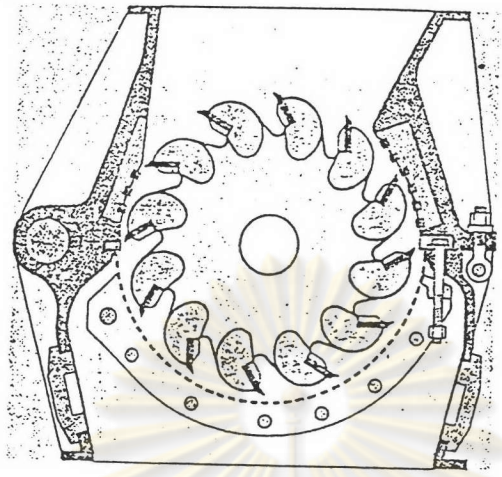

Figure 2.4 The cross-section of rotor blade and stator blade.

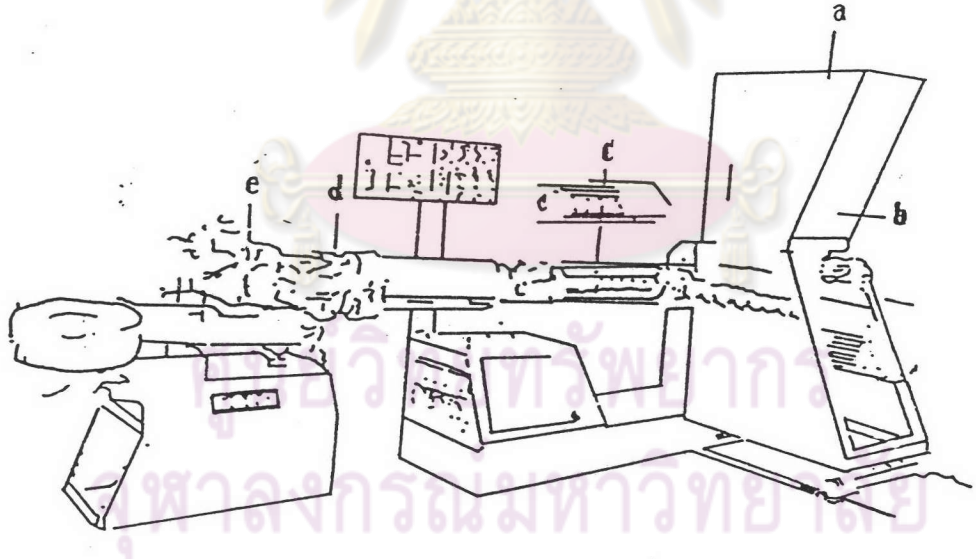

Figure 2.5 Pelletizing machine.

a. hopper b. screw c. extruder d. screening e.die

3.3 Composition of Local Plastic Waste

Table 2.4 shows the composition of plastic waste from On-Nooch and Nong-Khaem areas. The data shown that the composition of plastic waste in these two areas are rather similar.

Data obtained from waste dealers near the municipal dump sites are as follows:

-3,500 tons/year at Nong-Khaem

-3,000 tons/year at On-Nooch

Therefore, the total plastic waste is 6,500 tons/year near two dump sites.

Table 2.4 The composition of plastic waste from On-Nooch and Nong-Khaem.

Type of Plastic	Percent of waste at On-Nooch		Percent of waste at Nong-Khaem	
	Dealer No.1*	Dealer No.2*	Dealer No.1**	Dealer No.2**
PE				
Bottle			40	
-Colored	15	15	-	30
-Colorless	35	35	-	20
Nonbottle	15	15	15	14
PP	15	30	15	16
PVC	-	5	20	20
PS	10	-	-	-

* Date of sample collection : 17-07-92

** Date of sample collection : 15-01-93

Table 2.5 shows the percentage of various plastic waste belonging to bulk plastic waste dealers and grinders. The percentage of HDPE bottle is about 60. Total plastic waste of HDPE and PP collected by street collectors is 71,300 tons of which 10,200 tons being PP.

Table 2.5 Percentage of various plastic waste from waste dealers and grinders.

Type of plastic	Percent of waste at On-Nooch	Percent of waste at Nong-Khaem
PE		
Bottle		
-Colored	50	25
-Colorless	20	25
Nonbottle	-	10
PP	15	10
PVC	-	10
PS	-	10