Trends and Issues in the Plastics Cycle in China with Special Emphasis on Trade and Recycling

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Abstract

Demand for plastic products in China is increasing rapidly. Yet China has neither the productive capacity to keep pace with demand, nor the management systems to adequately deal with the increasing burden of plastic waste. These problems highlight the potential role for recycling in the industry. This paper provides an overview of the the main trends and issues in the plastic cycle in China, with an emphasis on recycling.

Since China is the world's largest importer of waste plastics, possible effects of this trade are described and priority issues are identified. From an economic perspective, the projected increase in demand for plastics will create markets of sufficient magnitude for both the primary and the secondary plastic industries to develop, with little competition between the two. The current informal sector will play an important role in the development of the plastic recovery industry. From an environmental perspective the post-consumption stage is identified as the most intensive stage in the cycle. From an international perspective, the process of substituting domestic for imported raw materials will mean that Chinese production will have to meet international levels of efficiency to avoid protective trade measures. This will also stimulate exports of plastic products. With regard to the rapidly increasing imports of waste plastics it is still unclear what the exact impact is. A more rigorous analysis is needed to clarify this issue.

Abrégé

En Chine, la demande de produits en plastique connaît une rapide croissance. Or la Chine n'a ni la capacité de production qui lui permettrait de suivre le rythme de cette demande, ni le système de gestion qui lui permettrait de faire face de manière adéquate au fardeau que représentent les déchets en plastique, autant de problèmes qui mettent en lumière le rôle potentiel du recyclage dans ce secteur. Ce texte contient une présentation générale des grandes tendances et principaux problèmes du cycle des matières plastiques en Chine, l'accent étant mis sur le recyclage.

La Chine étant le plus grand importateur du monde de déchets de plastique, les effets de ce commerce sont décrits et les problèmes prioritaires sont identifiés. D'un point de vue économique, l'accroissement prévu de la demande de matière plastique engendrera des marchés d'une telle ampleur que l'industrie des plastiques primaires et celle des plastiques secondaires pourront toutes deux se développer en ne se faisant guère concurrence. Le secteur informel actuel jouera un rôle important dans le développement de l'industrie de récupération du plastique. D'un point de vue écologique, le stade succédant à la consommation est identifié comme étant le moment le plus intensif du cycle. D'un point de vue international, le processus de substitution de matières premières d'origine intérieure à des matière premières importées forcera la production chinoise à atteindre des degrés d'efficacité de type international si elle veut éviter de faire appel à des mesures de protection. Cela contribuera aussi à stimuler les exportations de produits en plastique. Mais on ignore encore quel sera l'effet exact de cette évolution sur les importations, en rapide augmentation, de déchets de plastique. Une analyse plus rigoureuse est nécessaire pour clarifier cette question.

Resumen

La demanda por productos de plástico está creciendo muy rápidamente en China. Cicho país no tiene, sin embargo, ni la capacidad productiva para responer a la demanda, ni los sistemas de gestión para soportar debidamente la carga de los desecho plásticos. Este problema pone de manifiesto el papel potencial del reciclaje en la mencionada industria. La presente mongrafía dibuja un panorama de las principales tendencias y tópicos en el ciclo del plástico en China haciendo énfasis en el reciclaje.

Debido a che China es el principal importador de desechos de plástico se describen acquí los posible efectos de su comercialización y se identifican los asuntos prioritarios. Desde una perspectiva económica, el aumento esperado en la demanda por plásticos creará mercados suficientemente grades tanto para la industria plástica primaria como la secundaria, con poca competencia entre las dos. El sector informal actual jugará un papel importante en el desarrollo de la industria de recuperación del plástico. Desde una perspectiva ambiental, se ha identifacado al estadio posterior al consumo como el más intensivo de todo el ciclo. Desde una perspectiva internacional, el proceso de sustitución de materia prima importada por doméstica, obligará a China a responder a las exigencias internacionales si se han de evitar medidas proteccionistas. Dicho pproceso a su vez estimulará la exportación de productos plásticos. El impacto de la importación acelerada de desechos de este material se desconoce aún por cuanto se hace necesario elaborar un análisis más riguroso para aclarar este asunto.

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Contents

ACRONYMS

PVC	polyvinylchloride
PE	polyethylene (polythene**)**
PS	polystyrene
PP	polypropylene (polypropene**)**
PET	polyethylene terephthalate
ABS	acrylonitrile-butadiene styrene
PU	polyurethane
EPS	expanded polystyrene
LDPE	low density polyethylene
LLDPE	linear low density polyethylene
HDPE	high density polyethylene

Introduction

Plastic is a relatively low cost, low weight and highly durable material. These characteristics have contributed to the popularity of plastic products world-wide[1] and to the rapidly increasing levels of consumption and production. Global consumption has risen from just over half a million tonnes in 1945 to 117 million tonnes in 1995 (Grimaud *et al*. 1970, ECOTEC 1995, p.4), mainly due to increased use in industrialised countries. Since plastic consumption is strongly related to income levels, the demand in developing countries is minimal. Similarly, historical evidence from developed countries, such as Japan, illustrates the changing patterns of consumption: per capita plastics consumption increased from 6 kilograms in 1960, to over 35 kilograms in 1970, and again to over 72 kilograms by 1987 (CSI 1989). It may therefore be expected that any rise in incomes will be accompanied by an increase in demand for plastics.

However, the properties which make plastic so useful are also responsible for a range of environmental problems: litter, pollution from emissions of hydrogen chlorides and dioxins from incinerated PVC; and contamination from chemical additives leaching in landfills. Plastic waste also presents a direct hazard to wildlife. Environmentalists estimate that more than one million tonnes of waste plastics are dumped into the world's oceans each year, affecting numerous sea birds and marine animals. Marine plastic debris can also clog water intakes, pumps and damage propellers.

The production of plastics may also have major ecological impacts. Recycling may contribute to the alleviation of many environmental impacts both pre- and post-consumption: the reuse of plastic materials should reduce the demand for primary resources as well as the scarce space required for landfill. However, constraints, such as the absence of appropriate sorting techniques and the low value of recycled plastic products, mean that current levels of recycling are low. Yet, plastic recycling is gradually becoming more popular, both in the industrialised world and in developing countries. In Western Europe, for example, the recycling rate of plastics increased by 22 percent between 1993 and 1994 (APME 1996).

Not all recovered plastic materials are recycled in the country of origin. As with most commodities, waste plastic is increasingly traded on the world market. In contrast to the international trade of primary plastics, such as synthetic resin or final plastic products, the majority of traded waste plastic is imported by developing countries, mostly in Asia. In 1992, developing countries imported only 36 percent of globally traded primary plastics, while they accounted for 69 percent of the waste plastic trade (UNCTAD 1996). Clearly the bulk of traded waste plastic - 78 percent - came from industrialised countries.

As plastic is a relatively new material, knowledge about its role in the economy, the environment and in trade is rather limited[2]. This is especially true for waste plastic recycling and trade in developing

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[1] An elaborate description of the types and characteristics of plastic is provided in Annex I.

[2] Within its research theme "trade and the environment", the CREED programme aims to address the economic and environmental challenges and threats to developing countries from increased international trade of secondary materials. The outcome of this overall study will be particularly relevant to institutions and governments in developing countries to ensure that their international waste trade policies generate the desired impact on the local economy and the domestic recycling sector in particular. Similarly, the results may support industrialised countries in their decision to prohibit or encourage the trade of waste plastics.

countries. The aim of this preliminary paper, from a study of waste plastic recycling in China, is to fill some of the gaps by investigating the main trends and issues. Special emphasis is put on plastic recycling. The conclusions drawn in this paper are based on a literature review, interviews with stakeholders and a workshop with the main stakeholders held in Beijing in June 1997. The structure of the plastic cycle in China in 1994 is presented in Figure 1. Tentative approximations of its material flows are added. These figures should be interpreted carefully due to uncertainties in the data and the significant changes over time. The underlying issues and trends of this configuration are elaborated in this paper.

Source: compiled and calculated by the authors from various sources

China is an appropriate case country for this study for several reasons. First, along with the rapid development of the economy and a general improvement in people's living standards, the demand and consumption of plastic have increased dramatically. This trend has become evident particularly from the beginning of the 1990s, since when demand has grown by an average of 21 percent per annum. Growth of GNP per capita of approximately 20 percent, has been one of the main reasons for this increase. Another reason is the high rate of substitution of plastics for other materials. Not only does substitution generally improve the characteristics of the final products, it can also lead to significant savings in energy consumption. Although the demand concentrates mainly on primary plastic products, secondary products are becoming more popular in China. In 1994, 16% of the 8.1 million tonnes of plastic consumed in China, were secondary products. The main constraint of

secondary products is still its relatively lower quality. In Annex II, the final demand for plastics in China is explained in more detail.

Second, despite the rapid expansion of the Chinese petro-chemical and plastics industries of 11 percent per annum, production is unable to meet the growth in domestic demand for plastic. This gap between demand and supply has both quantitative and qualitative dimensions. As a result, large quantities have to be imported. For example, imported resins have taken a 50 percent share of the domestic market, rising to as much as 80% for some varieties. One of the reasons for the lack of production is the inadequate supply of raw materials. China has a short supply of ethylene and aromatic hydrocarbon raw materials, as most of China's oil is heavy so that its naphtha content is low. Another reason for the gap between supply and demand is that, compared to the size of international petrochemical enterprises, the local primary industry is relatively small scale; this hinders economies of scale. Annex II provides a more detailed description of the primary plastic industry in China.

Third, China has many large metropolises where solid waste disposal problems are increasing. Large quantities of disposed waste plastics are left uncollected causing surface and ground water pollution. Further, sewage and drainage pipes become blocked which in turn may cause blockage and flooding within cities. A proportion of waste plastic is collected by a comprehensive informal recycling network. However, changing external conditions hinder their operations, with the result that the burden for municipalities to manage the growing volumes of waste plastics is increasing.

Finally, as already indicated above, the Chinese plastic cycle is highly dependent on the international market. While the domestic production of plastic products in 1994 reached 4 million tonnes, the net imports of plastics in the same year were almost 5 million tonnes. To ease the effects of shortages, large quantities of waste plastic materials, in addition to massive imports of virgin plastics, were purchased from overseas markets. As indicated by the statistical data from the Chinese customs, China imported almost half a million tonnes of waste plastics. At present, China is the largest importer of waste plastics in the world. As will be explained in the coming Sections, this type of trade is disputed.

The above overview highlights the importance of using China as a case study.[3] The increasing demand for plastic products and the lack of production emphasise the potential role for recycling. With China being the world's largest importer of waste plastic, it is important to understand the role of this international material flow within the domestic system.

The paper is structured as follows. The following section examines the post-consumption stages of plastic, comprising waste management and recovery. This is followed by a description of the

[3] Effects of trade in waste plastics may occur at various levels in the economy as well as the environment. Given its ability to include economic as well as environmental parameters, the material flow model developed in Beukering and Duraiappah (1996) seems most appropriate for the purpose of specifically addressing the role of trade and recycling of waste plastics in China. Based on this paper, the model can be developed which will calibrate the optimal allocation of resources in the cycle. The results of the model will be presented in forthcoming papers.

secondary plastics industry in China, and then trade. Next the environmental issues relating to the plastic cycle are outlined, followed by a summary of the main finding.

Management of Waste Plastic

In 1994, China's population consumed 8.1 million tonnes of plastics. No accurate estimates were established for the total amount of waste plastic in China; however, given the existing European consumption/waste ratio of 67 percent (IPST 1997, p.26), it may be assumed that approximately 5.5 million tonnes of waste were generated in China in that year. Due to inadequate legislation and environmental standards for waste management and weak infra-structure, only a small fraction of post-consumption plastic was recycled. In 1994 approximately 10 percent of waste plastic was recovered, 20 to 30 percent was either landfilled or incinerated, which implies that 60 to 70 percent was left uncollected or dumped on land or in rivers and seas. With the development of the plastic industry and the rise of living standards, it is estimated that the consumption will reach 15 million tonnes by 2000. An appropriate management system to cope with the accompanying waste burden has yet to be designed. In this context, the present waste management system and its recovery counterpart require significant improvement. Constrained by the lack of information, minimisation of waste plastics and re-use of plastics is not considered in this paper.[4]

Plastic waste in China

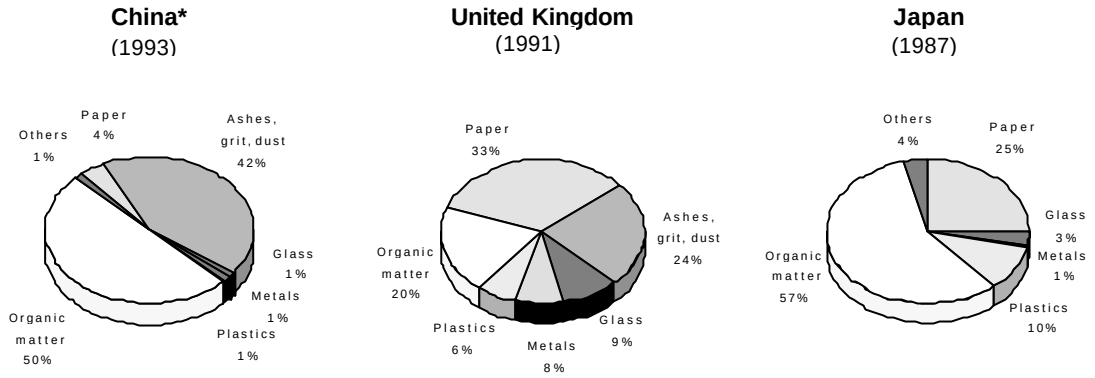
The plastic waste stream emerges from three main sources: agricultural, industrial and municipal solid waste, which account for respectively 63, 16 and 21 percent (NFLI *et al*. 1994). One of the main reasons for the relatively large share of agricultural waste in the plastic waste stream in China is its short lifespan. Agricultural plastics have an average life of only 1 to 2 years while industrial and household plastics may be in use for at least 3 to 5 years and 6 to 9 years respectively (Xu Tongkao 1992). Moreover, industrial plastic waste is more homogeneous and is often recycled. In the category of municipal solid waste, the composition varies greatly from city to city.

As a proportion of the total municipal waste stream, the share of plastics has traditionally been rather small in China compared to other countries (see Figure 2). This has been due mainly to the high percentage of coal ash from heating and cooking - a component which is practically absent in the Northern countries - as well as the low levels of consumption.

However, due to the rapid growth of the packaging industry this situation has changed significantly in the last few years. In Beijing, for example, the share of plastics in the municipal waste stream increased from 0.6 percent in 1993 to 12.6 percent in 1996 (Suo Zhiwen 1997; BESDRI 1997).

[4] The minimisation of waste plastics has two scopes. On the one hand, reducing the amount of excessive plastic packaging is a distinct option to abate environmental damage in the plastic cycle. On the other hand, the plastic packaging industry can also rightly claim that plastic packaging substitution for traditional materials in itself reduces environmental impact. For example, a German study reports the following increases in case plastic packaging would not be applied: 414 percent in weight of packaging, 256 percent in waste volume, 201 percent in energy consumption and 212 percent in economic costs (Ogilvie 1996).

Figure 1. Composition of municipal solid waste in different countries



* average for Beijing

Source: Suo Zhiwen 1997; BESDRI 1997; Coopers & Lybrand et al. 1996; UNEP 1993.

Within the Chinese municipal waste stream, Polyethylene (PE) comprises the main type of plastic waste, followed by Polyvinylchloride (PVC), then Polypropylene (PP) (see Table 1). Polyethylene Terephthalate (PET), a growing source of waste in many other countries, is still a small contributor. However, the composition of plastic waste will change gradually, with household waste increasing and agricultural waste decreasing. The contribution of PE will decrease slightly, but still dominate the plastic waste stream, while PET is expected to double its share by the year 2000.

Table 1 Specification of types of plastics in solid waste in China in 1994

Resin type	Share (%)
PE	52
PVC	22
PP	15
PS*	4
PET	1
Others	6

Source: compiled from various sources (MOA 1996, MOC 1996, Xu Tongkao 1992)

Plastic Recovery

China's plastics recovery sector has undergone two phases of development. During the pre-reform period, from 1950 to 1978, recovery was dominated by the formal sector. During this period stable recovery rates[5] of over 20 percent were attained. Since 1978, China has experienced a weakening of the formal sector as individual ownership has gradually come to dominate recovery. Although the volume of recovered waste plastics increased from 24 million tonnes in 1980 to 73 million tonnes in 1994, the recovery rate decreased from 20 percent to 9 percent. Possible reasons for this could be that it is not economically feasible to recover waste plastics without government support, and that formal recovery centres operate ineffective management practises.

The formal sector, which accounts for approximately 20 percent of total recovered waste, is largely comprised of two nation-wide networks. One consists of state-owned resource reclamation companies under the Ministry of Domestic Trade (MDT). The other comprises collectively-owned material collection enterprises run by the National Federation of Supply and Marketing Co-operatives (NFSMC). The sector employs a total of 880,000 labourers. As these two networks are involved with a range of recyclable wastes, it is difficult to determine how many employees are actually involved in plastic recovery. Most waste plastic recovered by the formal sector comes from industrial waste which is less contaminated than the post-consumer stream. The average cost for one tonne of collected waste plastic is up to RMB 2,500 Yuan[6] which is higher than in the informal sector. There are problems of collection, higher transport costs as well as a lack of systematic and effective networks. Some of the enterprises are suffering economic losses, and therefore are losing their share of the market for secondary plastics.

The informal sector consists of self-employed individual collectors who are often farmers. By the end of 1995, nearly 3 million private individuals were engaged in this sector (NFSMC 1996; MOA 1996). The sector is able to operate profitably because it uses an efficient house-to-house collection method within local districts, thus limiting transport costs. The average cost of the informal recovery of one tonne of waste plastic is RMB 1,700 Yuan - 800 Yuan per tonne less than the formal sector.

The collection of waste plastic by the informal sector increased to 580,000 tonnes in 1994, accounting for 80 percent of the nation's total. The development of the sector has not only provided a livelihood for many surplus labourers from the countryside, but has also promoted the recycling of waste plastics. However, most waste collected by the informal sector is post-consumption plastic which is contaminated to some degree. This effects not only the quality of recycled products, but also presents a possible health hazard. Therefore, pre-treatment of waste plastics is considered a crucial stage in the recycling process. In China, physical sorting is probably the only separation technique used.

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[5] The recovery rate of waste plastics is the total volume of recovered waste plastics as a share of the total consumption of plastic articles in China. If for example in year x, 5 million tonnes are recovered for the purpose of recycling of the totally disposed quantity of waste plastics of 50 million tonnes, the recovery rate is 10 percent.

[6] In October 1997, 1 US Dollar = 8.2843 Chinese Yuan Renminbi (1 Chinese Yuan Renminbi (CNY) = 0.1207 US Dollar (USD)).

Waste management

In 1995, China generated 166 million tonnes of municipal solid waste (MSW) (Suo Zhiwen 1997). On average only 28 percent of waste is properly landfilled or incinerated (MOC 1996), with the result that large quantities of refuse accumulate in the suburbs or remain uncollected. Two thirds of the cities in China have been surrounded by refuse heaps. About 60 percent of total post-consumption plastic is stacked with municipal solid waste or left uncollected, which may cause surface and ground water pollution and human health problems.

Landfill is the major method of disposal in China. The capacity to deal with large volumes as well as its relatively easy management means that landfill has significant advantages over alternative waste disposal options. It also has lower construction and operating costs; for example, the average disposal costs for landfill and incineration are respectively RMB 30 Yuan per ton and RMB 50 Yuan per ton (BESDRI 1997). Until recently landfilling has been uncontrolled and no attempts have been made to recover gas or prevent leakage. However, in the last few years China has built more appropriate landfill facilities based on foreign knowledge, with the result that costs have also increased. A total of 477,000 people are employed in the management of municipal solid waste, including odd-job personnel. Clearing and collection of MSW is more labour intensive than that of waste disposal. The transportation cost for one tonne of MSW is about 33 Yuan RMB.

Incineration can reduce the waste volume by up to 90% (BESDRI 1997). However, for various reasons, the adoption of incineration is still in its infancy in China. Firstly, due to the composition of the waste stream, the low heat value of incinerated waste is inadequate for generating electricity[7]. Second, due to financial and technological constraints, the capacity of most incineration furnaces is under 200 tonnes per day. At these volumes, the generation of electricity is not economically feasible and incinerators are only used as furnaces.

China is currently improving MSW legislation and management. Its environmental plan, incorporating Agenda 21 (1994), cites waste management as an important factor in an integrated strategy for natural resource and energy conservation and pollution control. All cities are expected to construct landfill and incineration facilities for the safe disposal of MSW by 2010. The short term objective for the recovery of recyclable resources is to formulate legislation and establish a development plan. MSW management will increasingly emphasise source separation in order to increase the recovery rate of recyclable resources, although this approach has already been adopted in some cities.

[7] However, in the last two years, with increasing proportions of paper and plastics in the waste stream, the heat value of MSW has risen significantly. For example, the heat value of MSW in Beijing in 1996 was 5484KJ per kilogram which is sufficient for incineration with energy recovery.

Secondary Production

Plastic recycling in China

Until the early 1980s the utilisation rate[8] of waste plastics in China reached levels of over 20 percent. This is much higher than most industrialised countries, eg Europe and the United States, where, on average, the rate is 5 or 6 percent (APME 1996, Curlee and Das 1996). In absolute quantities, the use of secondary materials in plastic production in China has been increasing and is expected to increase further. At present, 1.3 million tonnes of waste plastics are recycled. Various factors contribute to this high level.

- *Profit oriented industry:* The plastics recycling industry developed in the 1950s when people began to use recovered waste plastics granulated into particles. As production costs were limited, which in turn kept the price level of the end-products low, the recycling industry found sufficient demand for its products, especially in underdeveloped and low income areas. An important reason for the costs advantage is the low cost of labour.

- *Involvement of foreign investment:* Since the 1980s, a noticeable change has taken place in plastics recycling industry in China. Encouraged by foreign investment, mainly from Hong Kong and Taiwan, several processing factories specifically engaged in secondary production of plastics have been established along the coastal areas. As a result, production technology and industrial scale have been greatly enhanced.

- *Governmental guidance*: The institutional conditions with regard to recycling in China are rather ambiguous. One the one hand, economic reform has led to less direct government involvement in the recovery and utilisation of waste plastic. Therefore formal plastic recycling has reduced significantly. On the other hand, the mounting burden of waste plastic has required more attention from government. With government support, scientific institutions and universities are now intensifying research efforts into this issue, while enterprises in plastics recycling are granted tax reductions or preferential rates for rent.

Declining utilisation rates

Traditionally, the Chinese government has paid much attention to waste recycling. Preferential tax policies have been provided to the industry ever since the foundation of the People's Republic. Nevertheless, though in absolute terms the recycling industry has performed rather well, in relative terms, secondary manufacturing has gradually yielded ground. This has occurred for several reasons including increasing rates of production of primary plastic; this has effectively reduced the utilisation rate. This is depicted in Figure 3.

[8] The utilisation rate of waste plastics is the share of secondary resin used in the production of plastic products in China. For example, if the manufacturing of plastic products in China would be 10 million tonnes in year x, and the use of secondary resin would be 2 million tonnes that year, the utilisation rate would be 20 percent.

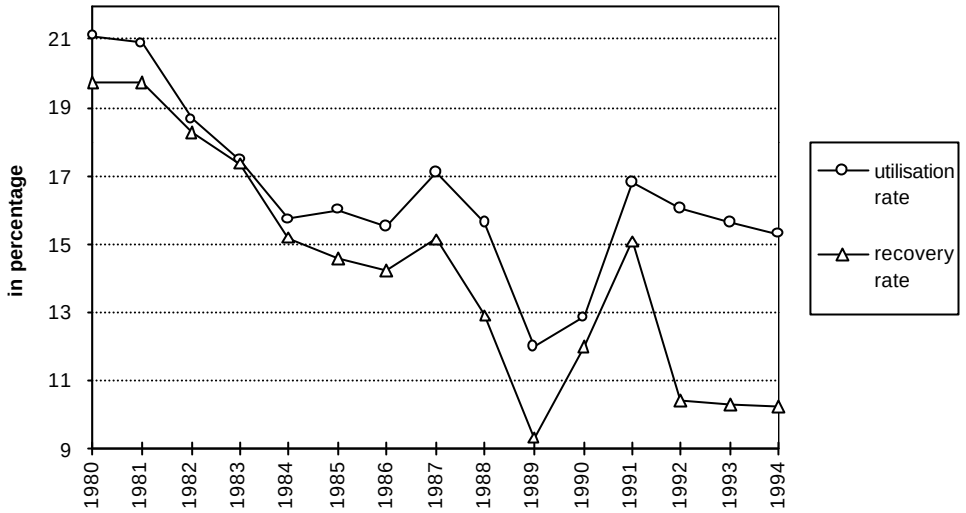


Figure 2 Diversion between utilisation and recovery of waste plastics in China

With the expansion of the market economy, the formal waste material recycling network, which functioned well in the past, has significantly weakened. Meagre funds have been allocated for the development of plastic recycling technologies, so many factories have been forced to rely on outdated facilities or to curtail their production. Since the beginning of the 1990s the decline in utilisation rates has been mitigated to some extent by the fast growth of imports of waste plastics along with the increasing involvement of foreign investors. Nevertheless, several problems for the plastic recycling industry remain:

- The supply of recovered plastic is rather volatile due to the decrease in the recovery rate year by year and the dependency on the fluctuating international market.

- Most plastic recycling enterprises are small and medium sized factories with obsolete equipment and technologies. Financial limitations are a constraint to the technical improvements needed to satisfy market demand.

- China's plastic recycling industry operates under difficult economic conditions. Recent years have seen the relative prices of waste plastic, energy and raw materials increase, with the result that a number of enterprises have suffered economic losses.

- Plastic cannot be recycled indefinitely. A "cascade principle" can be envisaged whereby after continuous recycling, plastic becomes too contaminated and degraded for use as a secondary material. A case study in India identified this phenomenon as a constraint in the plastic recycling industry (Beukering 1994). In that case alternative management options such as tertiary recycling should be available.

- Secondary pollution occurs during the recycling process. Some factories cannot afford to install pollution control facilities and must therefore discontinue production.

Primary versus secondary production

Primary and secondary plastic resin is essentially produced by two separate industries in China, with marked differences between the two in the scale of production, capital intensity and level of technology. Primary plastic resin, as part of the petro-chemical industry, is produced in large scale plants with modern technology and heavy investment. For example, PE producing plants with a capacity of less than 100,000 tonnes are regarded as small scale. Large plants usually have a capacity of over 300,000 tonnes and contain 100 million Yuan of fixed assets. By comparison, plastic recycling factories with 10,000 tonnes of production capacity are considered large scale.

Since the adoption of an open policy, large investments have been made in introducing advanced technology from overseas for the synthetic resin industry. The situation is quite different for secondary production: the plastic recycling industry is characterised by a high degree of individual, collective and small sized township factories, with little evidence of state-run factories. Production capacity is usually small, at around several hundred tonnes per year; production methods of mechanical regeneration require little investment, simple technology and is very labour intensive. It is estimated that China's secondary industry employs between 200,000 and 270,000 labourers. PE, which is the main input for agricultural film, is the most recycled product, followed by PS and PVC. PET is becoming more popular in the industry.

In the late 1970s China embarked on a programme of economic reform. Since then government efforts have focused on developing the petrochemical industry, which produces primary resin. In comparison, the authorities have shown far less concern about the issue of recycling waste plastics. Legislation for recycling was not introduced until 1995[9]. In addition to an income tax reduction measure designed to encourage enterprises to use recycled plastics as the principal raw material, preferential treatment and effective measures are being considered to promote the development of waste plastic recycling in China.

The future of the secondary industry

The secondary plastics industry has yet to make a significant contribution towards meeting the needs of China's economic development, and the current market in secondary products is still limited. Thus it is unlikely that the primary industry will experience any significant effects from increased recycling. But with the growth of plastics consumption, the burden of waste plastic is rapidly increasing. This not only poses a problem for the environment but may also negatively effect the development of the plastics industry itself. The responsibility for waste will not lie solely with the waste management sector; increasingly industries will be held responsible for their impacts. Thus

[9] The Law on the Prevention and Control of Solid Waste Pollution to the Environment was passed by the 16th Session of the Eighth National People's Congress on 30 October 1995 and came into force on 1 April 1, 1996. The law encourages the reclamation and utilisation of packaging materials and agricultural films .

primary industries will also benefit from a well organised recycling industry. This interdependency of primary and secondary production illustrates the importance of considering the plastic cycle as an integral system, consisting of various actors and processes which compete and complement each other. In this context, the following issues should receive more emphasis.

First, it should be realised that primary and secondary recycling are not the only methods of recycling plastics (see Box 1). Mechanical recycling requires sorting, cleaning and drying before feeding into the recycling process. Due to the often inferior quality of the end-products, the market scale is still limited. The problem for the recovery of secondary products is that generally the quality is too low to utilise again in mechanical recycling.

The experience in industrialised countries indicates a kind of maximum rate of mechanical recycling of 20 percent of total waste plastics (IPTS 1997). Beyond this level, other types of recycling are feasible, for example, chemical regeneration with single and mixed waste plastics as raw material. Products from this process include chemical raw material and fuel. The advantage of fuel outputs is that it effectively diverts the low quality material flows from the economy. Thus chemical regeneration is generally accepted as a sustainable way to recycle plastics. This is especially true for household residues where waste plastics are supplied in a mixed form. Successful developments have occurred in the technology of gasfication of mixed waste plastics and depolymeration of PET and PP in recent years. Although, the economic feasibility of chemical recycling is still very limited, this technology may develop as a useful management option in the future.

Box 1: Types of plastic recycling

Waste plastics can be used in different ways:

- ***primary recycling*** the reprocessing of clean factory waste into products with equivalent chemical properties as the reprocessed waste. This type of recycling, which is in fact also a mechanical form of recycling, often takes place within the factory itself;
- ***secondary or mechanical recycling*** the reprocessing of recovered waste materials into products of inferior quality to the original product. This type of recycling generally uses agricultural and packaging waste;
- ***tertiary or chemical or feedstock recycling*** the reprocessing of mixed recovered waste plastics by changing the chemical structure and transforming it into basic chemical blocks, for use as secondary feedstock in refineries, petrochemical plants and chemical reactors (eg. hydrolysis, glycolysis and methanolysis);
- ***quaternary recycling*** direct utilisation of the energy value of the materials by incineration of municipal waste.

Source: Curlee and Das 1996

Second, the development of pre-treatment technologies should be emphasised. Experts predict that the most important technological progress in plastics recycling will not occur in mechanical recycling but in the pre-treatment stage, more specifically the sorting of waste plastics. The major determinant of the quality of recycled plastic products is the quality of the input. Pre-treatment of waste plastics includes several processes such as volume reduction, separation, crashing, washing, and drying. All of these processes have a direct bearing on the quality and cost of secondary products. For example, the market price of clear PET regranulate is five times higher than baled, coloured PET.

Moreover, the cost will drop significantly if the volume of waste plastics collected for recovery can be reduced on the spot, through sorting, cleaning and separation.

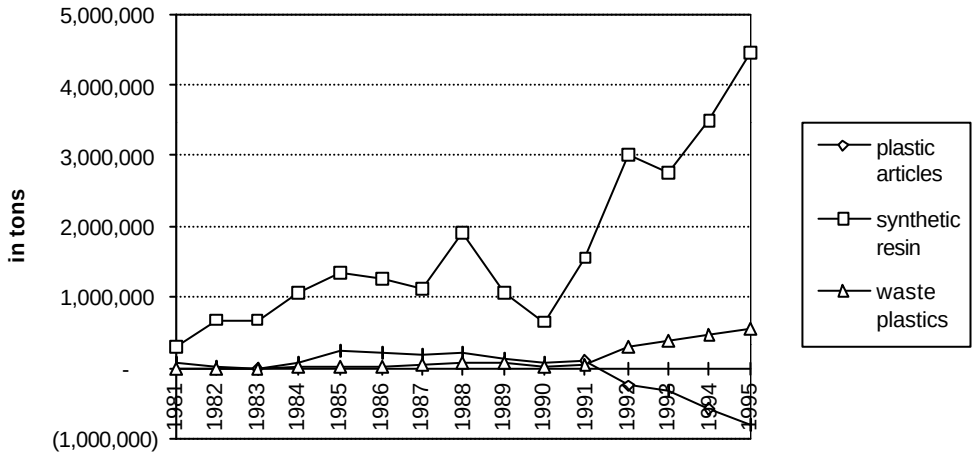
Trade

Since the onset of economic reform, China has increased its imports and exports of various material flows in the plastics cycle. The dependency on foreign supplies and demand has grown. This section highlights the impetus for this development. The main categories of trade are raw materials (eg, ethylene, chloride), synthetic resin (eg, PE, PVC), plastic products (eg,. film), and waste plastics. In this section, the most important developments and issues in the various trade flows in the plastic cycle will be highlighted.

Overall trends in trade

Figure 4 illustrates the developments in the trade flows of different plastic commodities. Various observations can be made. First, because of outdated facilities and technologies, the domestic industry cannot meet the growing demand for plastic materials. Over the last 15 years China has had to import increasing volumes of synthetic resins: the average annual growth rate of imported resin in the years up to 1995 was 22 percent by which time net imports reached 4.5 million tonnes. The only recorded decreases occurred between 1989 and 1990 when foreign trade and the economy experienced a downward trend as a result of the "Tiannamen Incident" in June, 1989.

Figure 3 Net imports of main plastic commodities in China



Source: International Trade Research Institute, 1996

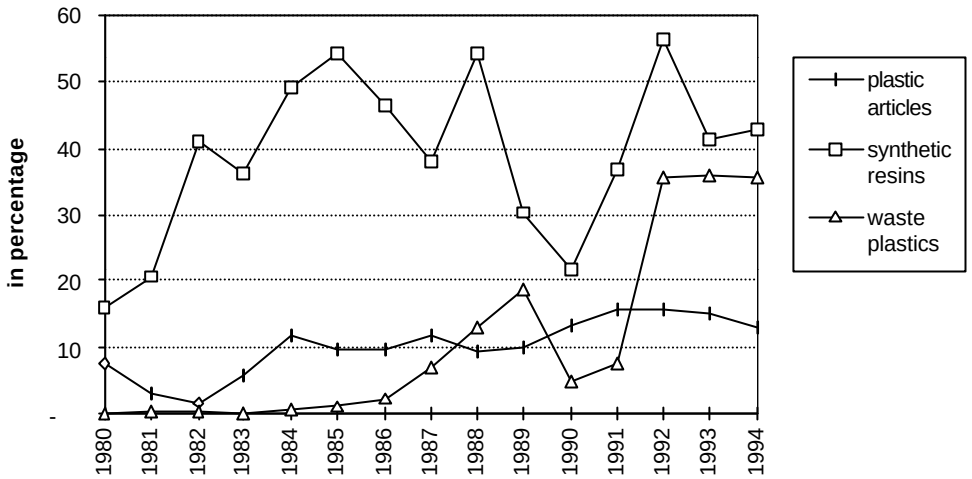
Second, compared to synthetic resin, imports of waste plastics, which accounted for slightly more than half a million tonnes in 1995, seem rather insignificant. Still, the average annual growth rate of imported waste over this period was as high as 80 percent. One of the reasons for the rapid growth is the fact that imported waste plastic is often cheaper than domestic waste plastic of a similar quality. Such economic conditions give a clear indication of the potential contribution of this type of trade to the Chinese plastic cycle.

Third, the trade in plastic articles differs from other plastic commodities. Since the early 1990s exports have outweighed imports. In 1981 exports accounted only for 1 percent of domestic production of plastic articles; in 1994 this share had increased to 16 percent. At present, the export of plastic articles is almost twice as high as imports. Household articles, utensils, garments and accessories, small ornaments, packages and bags particularly are marketed abroad by several small and medium-sized joint ventures with investment from Hong Kong, Taiwan and other overseas partners along the south-eastern coast. China's plastics goods imports mainly consist of various semi-products such as plates, sheets, film, foil strip and artificial and synthetic leather goods, which account for 60-70 percent of the gross plastics goods imported.

Finally, an essential commodity in the plastic cycle which has not been discussed much so far is oil. Petroleum used to be one of China' s main export commodities: it accounted for 17 percent (13 percent for crude oil) and 23 percent (16 percent for crude oil) respectively of the nation's gross value of foreign exchange earned through exports during the periods of the fifth and sixth "Five-year Plan" (starting from 1976-1985). However, manufactured goods have rapidly increased their share of total export in the last decade or so, and exports of primary products, including crude oil, has declined at the same time. In 1994, the country's oil exports fell to 18 million tonnes from the peak export volume of 30 million tonnes in 1985, dropping by an average 4 percent annually. Meanwhile, demand for oil at home has been growing in the wake of economic development and reshaping of the industrial sector, which has led to an increased reliance on imported oil. Between 1990 and 1994, China's imports of crude oil soared by 147 percent, and the country became a net importer of oil based products in 1993.

Absolute numbers do not necessarily provide a clear insight into the relative importance of a particular trade flow in the plastic cycle in China. One has to compare the trade flow with the total volume consumed or produced of a particular commodity in the Chinese economy. Figure 5 illustrates how China's dependency on all foreign plastic commodities increased over the period of 1980 to 1994. In 1980, for example, less than 1 percent of the recycled plastics in China came from abroad. By 1994, this share had increased to more than 35 percent. For synthetic resin a similar trend may be identified. The content of imported resin used in the plastic processing industry increased from 16 percent in 1980 to 43 percent in 1994. The increase in dependency on imported plastic articles was less notable. Another interesting observation is the sudden decrease in dependency on plastic inputs in the years 1989 and 1990. As mentioned above, an obvious reason for this distortion could be the "Tiannamen Incident" in June 1989.

Figure 4 Import dependency of main plastic commodity



Source: International Trade Research Institute, 1996

A more detailed look at trade

The description outline above is based on rather condensed information. These aggregated data hide much relevant information and particular issues further attention. First, an important aspect of international commodity markets is their volatility. Obviously, the more volatile a market, the more difficult it will be for entrepreneurs to deal with its uncertainties. Volatility can be measured in terms of price fluctuations and the growth rate of the imported quantities. Waste plastic is the most volatile of the plastic commodities. Over the period 1981 to 1995, the price of waste plastics decreased 4.4 percent annually, reducing its price to approximately US$200 per tonne in 1995. The import prices of synthetic resin and plastic articles were more constant during this period, and increased at respectively 0.3 and 2.1 percent, resulting in resin and article prices of respectively US$800 and US$1,800 per tonne. In terms of import volumes, waste plastic is also the most volatile commodity. In the years 1987 and 1992, waste plastic imports grew by more than 200 percent, and in 1990 the imports rapidly declined by 70 percent. Resin and articles generally remained within a range of plus and minus 50 percent. The volatility of the international market for secondary materials is often attributed to its relatively small volume which makes it more vulnerable to fluctuations in supply (Grace *et al*. 1978).

Developments in the foreign supply of inputs to the plastic cycle, as depicted in Table 2, reveal relevant information. The most prominent change has taken place in the synthetic resin sector. Suppliers from Western Europe and the United States have seen their market share shrink as a result of increasing competition from Asian producers, mainly based in Korea, Japan and Taiwan. Changes in waste plastic imports have been less significant. The European share has increased

slightly but is still dominated by supplies from the United States, Taiwan, Japan and Hong Kong[10], which presently account for more than 80 percent of overall waste plastic imports.

Table 2 Changes in the supply of the main inputs to the plastic cycle in China (in percentage)

	synthetic resin		waste plastics	
	average 1981-1989	average 1990-1995	average 1981-1989	average 1990-1995
Europe	34	19	3	6
United States	21	7	37	36
Asia	30	67	56	53
other	15	7	3	5

Source: International Trade Research Institute, 1996

The remaining input for plastic is oil, which also comes mainly from the Asian continent. Refining facilities along China's coastal area are inadequate for processing sulphur-bearing crude from the Middle East. Sweet crude from Asia is still the preferred variety for all refineries. This is illustrated by the fact that in 1994, 38.3 percent of China's imported oil came from Indonesia and 27.3 percent from Oman. In recent years there has also been a notable increase in imports from emerging oil producers such as Vietnam and Papua New Guinea.

A more detailed investigation into the components of each imported input category will provide a better understanding of trade in plastic. For synthetic resin, in absolute terms, polyethylene (PE) has always been the largest import. Next come polystyrene (PS) and polypropylene (PP). Imports of Polyvinylchloride (PVC) are small since China has a strong local capacity for PVC production. The most import-dependent resin in China is PP of which 81 percent came from foreign sources in 1994. For waste plastics, the picture is less clear.[11] Almost every other year, the hierarchy of imported types differs, although over the longer term, the share of PE, PP and PVC in imports of waste is more or less equal. Similarly to synthetic resin, secondary PVC and PP have a higher value, at around US$300 per tonne, to PE and PP which presently cost US$200 per tonne.

[10] The hand-over of Hong Kong to China, which took place in July 1997, is not expected to have significnat impact on the trade relations between the two partners. Hong Kong has always performed as an intermediate between China and other trading countries. Since Hong Kong will be able to maintain its independent trading policies, no major changes are foreseen.

[11] For the years 1992 to 1995, trade statistics suddenly indicate a category of "other types" which takes account of almost half the imports of waste plastics. The overall volume of waste plastics for the period before 1992 is corrected for the absence of this category. "Other types" might include PP and PET.

Driving forces

There are many reasons for China's large-scale imports of plastic raw materials. First, in recent years, China's expanding export market for processed plastic products relies heavily on imported raw materials. Second, inadequate research on processing and application of resins has affected the market share, with the result that demand and supply are often mismatched. For example, most domestically produced polypropylene is in the form of wire drawing materials, although there are shortages of polymer structures, fibre and membrane. Thus large quantities of polypropylene have been imported, even though local resin production has expanded and in some cases supply has outstripped demand. Thirdly, at present the world's large petro-chemical producers are engaged in intense competition for China's markets. Their large scale production, advanced technology and high labour production give them a competitive edge relative to local prices.

In recent years, China has adopted a series of measures to open its market to promote trade liberalisation. China has repeatedly lowered import tariffs since 1992. In April 1996, China again dramatically cut tariffs from 66 percent to 23 percent. At the same time the basic tax rate of most of the duty on plastic commodities dropped from 30-35 percent to 18-20 percent. Reducing tariffs has helped reduce import costs, and no doubt will be conducive to satisfying the demand of the domestic consumption market. However, it will also bring still greater pressure on China's plastic industry. A comparison between domestic and foreign prices shows that the price of domestic petrochemical raw materials has always been low, while the price of finished products is high. The liberalisation of trade and increases in imports will present a dual challenge to China which is faced with rising costs and falling price of products.

Waste dumping versus imports of recyclable plastics

Based on the above description, a range of highly relevant issues emerge regarding trade and the plastic cycle. In the context of this paper, the controversy over importing recyclable waste plastics and waste dumping is probably a very important one. In the last two years the government of China has taken various rigorous measures. In November 1994, the National Environmental Protection Agency (NEPA) established "The Provisional Rules on Tightened Control of Waste Materials Imports from the European Community". This legislation lists waste plastics among waste materials that are not permitted until being examination and sanction by the authorities. The regulation also applies to waste imports from non-EC countries.

However, in the past two years, some local and overseas businessmen have broken the law and were found to be importing unrecoverable waste in the name of raw material utilisation. This problem reached a climax in 1995 when a series of "overseas container trash incidents" occurred consecutively in a number of Chinese cities. These incidents have provoked a response in the form of a rule, introduced in 1 April 1996, which banned imports of waste plastics in China.

Given the present characteristics of the plastic cycle in China, such as the underdevelopment of the plastics industry, serious shortages of supplies, inferior quality of raw materials required by several small and medium-sized plastics goods manufacturers, limited recycling capabilities and relatively high recovery costs, it might at least economically rational to consider importing waste plastics into China. It is therefore not surprising to note that the ban did have a severe short term impact on the

performance of the local plastic recycling industry. Faced with a lack of alternative inputs for production, the industry requested the Chinese government to relax the trade ban. As a result, the government modified the ban on waste plastic imports in October 1996 to allow industrial waste plastic to be imported but maintained the ban on household waste plastics..[12]

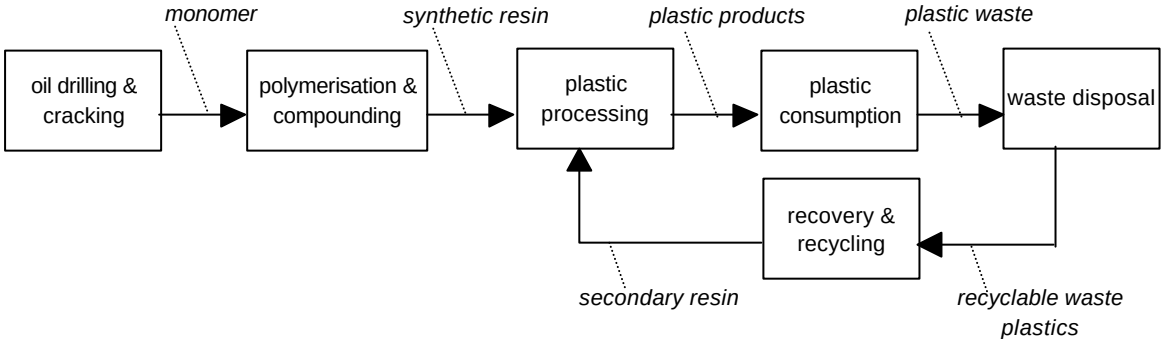
In the meantime, the State Commodity Inspection Bureau issued "The Administrative Measures for Preshipment Inspection of Import Waste" in September 1996, which prescribes a preshipment inspection on imports of permissible waste to be used as raw materials. This inspection is to be conducted by SCIB accredited agencies with a legal person status in the exporting countries (or regions), while the Bureau will supervise the related business performance of the agencies. Given the recent implementation of this measure, it is difficult to assess its success. However, whatever the outcome in the long-term, it is clear from these sudden and inconsistent policy interventions, that the precise role of waste plastic imports is still not well-understood.

[12] In international trade waste plastics are subdivided according to quality. Industrial waste is generally of grade A or B. Household waste, which is much more heterogeneous and contaminated is generally classified as grade C. The modification of the trade ban on waste plastics consisted of the allowance of import of grade A and B. Importation of Grade C remains prohibited.

Environment

Each of the sectors contributing to the plastic cycle impacts to some degree on the environment. This is expected to increase in conjunction with the growth in demand, thus affecting the overall impact of the cycle. However, substitution effects and technological improvements may reduce this trend. In order obtain a better understanding of the critical stages in the plastic cycle, the environmental effects of each stage in the plastic cycle will be described, and possible abatement options addressed. Figure 6 demonstrates the activities which should be considered in an analysis of current environmental impacts of the plastic cycle. The flow chart only shows the present plastic cycle in China. Potential processes which may become relevant in the future, such as tertiary recycling, will only be included in the material flow model.

Figure 5 Simplified flow diagram of the plastic cycle



Post consumption

In the post-consumption stage, waste plastics may be landfilled, incinerated or recovered. In reality, however, in China about 60 percent of post-consumption plastic is dumped or left uncollected due to inadequate legislation and environmental standards on solid waste management. This is one of the most serious environmental problems in the plastic cycle. For example, China's consumption of agricultural film in 1994 of 1.9 million tonnes ranks highest in the world. Yet, about 0.3 million tonnes of waste film are left on farmland annually, affecting the soil and causing intestinal disease to animals (Zhang Xiaochuan 1993). The growing problem of litter from plastic dinner boxes and packaging deposited along roads and railway lines is wider known. Municipal plastic and other solid waste is frequently piled up outside cities: this not only pollutes surface and ground water but also affects the prospects for urban development.

Experience of landfilling plastic is very limited, so its behaviour in landfill is not fully understood Some reports claim that plastic deteriorates after 1 year while others cite 40 years. In order to cause leachate, plastics would have to degrade in landfill, but no strong evidence of degradation exits. Thus it may be concluded that plastic itself does not significantly contribute to leachate. However, chemical additives such as heavy metal compounds, and contaminants such as food residue may leach, causing ground water pollution. The characteristics of high durability and non-

degradability also implies that waste plastic permanently occupies significant space in landfills. Its contribution to greenhouse gas emissions is very limited (Hunt 1995).

Since plastic has a similar energy value to oil, incineration of waste plastic may be considered an option. However, harmful emissions such as hydrogen chlorides and dioxins coming from PVC may occur if the incinerators are not equipped with scrubbing equipment. Moreover, incineration has so far proved to be an unfeasible option in developing countries because of the high moisture content of MSW in general. This means that waste plastics would have to be collected separately from wet waste in order to be used to generate energy. Incineration in China is still in a pilot stage: only one imported incineration furnace, constructed in Shen Zhen City, utilises the energy value for generating electricity, while others with low treatment capacity are used only to burn wastes. Although standards have been formulated for controlling air emission from incineration in China, enforcement of these standards is still very weak.

Studies from Europe demonstrate that, from an environmental perspective, recovery of waste plastics is often the best choice (Brisson 1997, Fraunhofer-Institut *et al*. 1996, Powell *et al*. 1996). Recovery saves on resources, reduces the volumes of uncollected waste materials and conserves landfill space. Obviously, it is premature to use these studies to draw similar conclusions for China. Social, demographic and economic differences may have a significant impact on the outcome of such evaluations. For example, the environmental impact of related transportation appear to be significant in the European studies. In China, however, the bulk of recovered materials are transported by tricycles in Chinese cities, thereby mitigating the problem urban air pollution. On the other hand, health effects should be taken into account: waste pickers and collectors may suffer from health problems resulting form their direct contact with contaminated plastic wastes.

Secondary production, using recovered waste plastics as feedstock, has obvious advantages in terms of savings in resources and energy. The emission levels from secondary production is also lower than that of primary production. However, since most enterprises in this sector are small and medium-sized factories, using low technologies and suffering financial difficulties, environmental problems, such as water pollution and health threats to the workers, cannot be overlooked. Similarly, it should remembered that secondary products are generally of a lower quality than their primary equivalents. Both their lifespan and the quality of their use will be much reduced. This means that a direct comparison between primary and secondary production is not appropriate.

Pre consumption

If we start with the oil drilling and refining processes which supply the monomer to the resin industry, the major environmental problem is the waste water containing oil discharge which finds its way into surface water. The oil film on the water surface may prevent oxygen from being absorbed by the water. Treatment technologies are available and applied in China.

It is difficult to analyse the environmental impact of synthetic resin production as it consists of several individual processes (monomer preparation, catalyst compounding, monomer polymerisation, separation, refining, and post treatment) and processes are very much interconnected. Moreover, both the type of synthetic resin which is produced and the type of plant are important. For example, small and medium-sized factories may cause relatively more environmental problems due

to the lack of funds for installing pollution control facilities. These factories are often scattered and contribute to surface source pollution which is difficult to control. However, some generalisations may be made.

Box 2: Harmful substances related to the plastic cycle

A number of substances exist which are emitted in the plastic cycle either during production, usage, incineration, recycling or landfilling. The most important harmful substances are:

- *benzene* - a colourless and highly-flammable liquid used as a solvent in the production of PVC and LDPE and as a raw material for styrene. A recognised human carcinogen that causes leukaemia and, in case of direct exposure at the workplace, depresses the central nervous system, causing headaches and other irritations;
- *cadmium* - used as pigments in PET, LDPE, HDPE, PP, PP and other plastics and is a suspected human carcinogen. In the past it was used as a stabiliser of PVC, but this function has been replaced by zinc;
- *dioxins* - highly toxic by-product of the production and incineration of some plastics such as PVC, which may cause abnormalities in the male and female reproductive systems, learning disabilities, different cancers, leukaemia and other diseases;
- *vinyl chloride* - a colourless, odourless gas about twice as dense as air, used as monomer for PVC and is known as a human carcinogen. Mortality data of workers in VC and PVC plants indicate shorter life-spans and increased liver and other diseases.

Source: Wirka 1988, Fehringer and Brunner 1997

The main environmental impacts during resin production are emissions and water pollution. Waste water may contain chemical and organic compounds, such as heavy metals, benzene, and organic chloride, which can be very harmful to human and animal life. When waste water contain such nutrients as fat, protein and ammonia, it may cause eutrofication in the water body and threaten the ecosystem dependent on these resources. Waste water may also contain acid and alkali, which can be very irritating to eyes and skin, as well as change the pH balance in soil when farm land is irrigated with contaminated water. Some large scale factories have constructed waste water treatment plants for water pollution control, and some have even installed primary treatment facilities to ensure treatment effectiveness. Production of PVC, which emits vinyl chloride, is particularly harmful in terms of emissions as it may cause dizziness, liver and spleen damage in humans. To control this hazardous gas, several options, such as active carbon and trichlene absorption, are used to reclaim vinyl chloride.

Compared to oil refining and primary resin production, the emission levels from processing plastics is rather low. Yet, processing manufacturers are often small and medium sized factories which lack pollution control facilities. This may result in uncontrolled emissions and surface water pollution. Processing methods predominantly include extruding, injection moulding and blow moulding, when various additives are used which may result in environmental impacts. Waste water from plastic processing may contain hazardous substances such as Cd, Cr^{6+}, Pb, phenol and cyanide.

Recycling plastics has advantages as well as disadvantages. Generally, less energy is consumed in remelting waste plastics and, because it already contains additives, less additional inputs are necessary. The disadvantage of plastic recycling is the loss of quality of the output which inevitably shortens the life span of the product. The presence of contamination in waste plastic increases the odour during the remelting process. Besides affecting the factory workers, odours also annoy surrounding neighbourhoods: in Nepal, such impacts have led to the closure of plastic recycling factories (Beukering and Badrinath 1995).

Policy options

In general, China's environmental legal system is inadequate and the enforcement of environmental laws and regulation is weak. Legislation on solid wastes management was non-existent until quite recently[13]. However, it is clearly stipulated in law that packaging materials and agricultural films should be easily recyclable, disposable or "environmentally friendly" and it encourages the reclamation and utilisation of recyclable packaging and farm films. Reducing solid waste, promoting recycling and the safe disposal of solid wastes are strategic policies for the prevention and control of solid waste pollution. Several measures need to be introduced to ensure their success. These include:

- Shift from end-of pipe measures towards a life-cycle approach by using cleaner production process to reduce emissions and wastes.

- Technological and economic policies based on the polluter pays principle need to be formulated to encourage the recycling of secondary materials. For example, recycling may be promoted through a Waste Exchange System, where wastes generated by one organisation would supply feedstock to another organisation.

- In 1991, China's National Environmental Protection Agency and Customs Administration jointly issued an Announcement on Strict Control of Transboundary Hazardous Wastes to Move into China. Corresponding enforcement measures have also been published.

- Separation at source of household refuse by the public should be gradually promoted. At the same time, municipal refuse needs to be disposed of safely.

- Promotion of an eco-labelling scheme in China. 'Environmentally friendly' recycled products would be marked with eco-labels and and promoted through the scheme.

- Strengthening international co-operation in the area of waste management. Through multilateral and bilateral co-operation, more technical and financial support would ensue.

[13] On 30 October 1995, The Law on Prevention and Control of Solid Waste Pollution was passed by the 16th Session of the Eighth National People's Congress and came into force on 1 April 1996.

Priority Issues for the Plastic Cycle in China

In the coming years and into the 21st century, plastics will gain importance in Chinese national life. Developments in the pillar industries, such electrics and electronics, automobile manufacturing and construction, will mean growing demands on the synthetic resin and plastics industry. Moreover, households will expand their demand for plastics, both in terms of quantity and quality. The coming decade will be a crucial period for the plastic industry in meeting this challenge. At the same time, the rapidly increasing waste burden of plastics will have to be minimised. This will require intense efforts on the part of both the formal waste management and informal recovery sectors. The actual utilisation of the plastic industry will be of crucial importance in this process. It may reduce the burden of solid waste by creating a market for recovered materials while simultaneously narrowing the gap between the demand and supply of plastic resources.

Socio-economic issues

From a socio-economic perspective, the key question for the plastic cycle in China is how to meet the future demand for plastics. If the current trend for increasing imports continues, China will become more dependent on foreign sources. The following socio-economic issues play an important role in addressing this problem:

- Rapid economic growth, increase in GNP and the wider application of plastics have resulted in a dramatic rise in demand for plastics in China. To ease the stress caused by inadequate supply, it would be desirable to expand production. This would imply that both the primary and the secondary plastic industries could be further developed simultaneously. It has been found that competition between the two sectors is unlikely to be very significant. However, to be more specific, simulations should be conducted with the material flow model.

- Since embarking on policy reform and a movement towards a socialist-market economy, the volume of waste plastics collected by the formal recovery sector in China has been decreasing both in relative and absolute terms. This has been due to high operating costs and the low potential for generating profit. It is not clear whether efforts should be intensified towards rebuilding the formal sector. Perhaps from an environmental perspective, it would be defensible. However, the cost-effectiveness of other environmental investment in the plastic cycle could be more effective. Thus from an economic perspective, policies to promote the formal sector seem tenuous.

- During the same period the volume of waste plastics collected by the informal sector has increased rapidly, accounting for 90 percent of the total collected in 1994. The collectors and operators in the waste plastic recovery and recycling sectors are mainly farmers and the urban poor. Their operating costs both for collecting and recycling are much lower than those of the formal sector, and for most individuals, it is still a profitable business. However, a serious threat to individual operators is the implementation of large scale waste collection systems which do not allow for recovery of the waste. Since these entrepreneurs reduce the waste volume free of cost to society, policies should also recognise and promote the performance of this sector.

- At present, plastics recycling in China is still at its infancy, with the main raw material for recycling coming from leftovers generated in the process of producing plastics products in the factory. Gradually, recyclers are moving towards the secondary stage which use consumer residues as raw material. Plastic recycling production is characterised by small scale and relatively simple technologies. Efficiency gains could be achieved through improved technologies. This may improve the performance of the recycling industry as well the working conditions in the factories.

Trade issues

As mentioned earlier, plastic production in China has been unable to meet the needs of the domestic market. Besides boosting imports of plastic products, it has also raised imports of raw materials, such as monomer, polymers and waste plastics. Based on this trend, several trade related issues were found to be relevant for an additional study:

- Since the 1980s Chinese imports of plastics have increase enormously. In 1995, the net import volume of plastic resin grew to 3.6 million tons. It is expected that this trend will continue over the next few years. From 2000 onwards, with the establishment of several ethylene projects, imports of plastic raw materials are expected to slow down. In the process of substituting domestic for imported materials it will be important for Chinese production to meet international levels of efficiency to avoid protective trade measures.

- Plastic products are a major export item for China, contributing 16 percent of domestic production in 1994. As production is generally labour intensive, which is certainly an advantage for China, this rate is expected to increase further. The expansion of exports of plastics products is acknowledged in the government's industrial policy.

- China is the largest importer of waste plastics in the world. There are two explanations for this phenomenon: one is that import costs are lower than the operating costs incurred in the domestic recovery sector; the other is the high demand for plastics in China. It is expected that the volume of imports will remain at this level, but the composition of waste plastics will change in line with the capacity for domestic production to supply some varieties. For the recyclers in China it is important to know whether the international market will remain a reliable source of raw materials. At present, the international market of waste plastics is expected to grow further[14].
- In addition to the availability on the international market, the effects of imports of waste plastic on the plastic cycle in China need to be clarified in more detail. Impacts may be felt in different ways. On the one hand, there are risks that imported secondary materials may be substituted

[14] "With businesses in the packaging chain to be faced with a statutory obligations to achieve quantified recovery and recycling of packaging wastes, forward-thinking companies will perceive there will be an increase in the supply of recycled plastics and, hence will be considering moving forward incorporating recycled plastics in their products particularly where cost savings can be achieved. The level of plastic recycling looks set to increase over the next few years - indeed, an approximate 2 to 3-fold increase in materials recycling of plastics packaging wastes will be necessary to meet the targets of the Producer Responsibility Regulations which reflect the requirements of the EC Packaging and Packaging Waste Directive. This level of increase will pose a major challenge to the industry." (Ogilvie 1996).

for domestic secondary materials, in which case, the domestic recovery sector will suffer from increased imports and increased amounts of MSW will be generated. On the other hand, imports may upgrade the quality of the feedstock of the recycling industry and thereby improve the marketability of secondary products. In this case, the recovery sector may actually benefit from increased imports. Whether the substitution or the complementary relation prevails is yet unclear. Simulations with the model will be needed to shed more light on this area.

Environmental issues

Besides providing services to society, plastics may also have negative effects on welfare. From the perspective of the environment, the main issue seems to be which part of the plastic cycle contributes most to environmental degradation, and how may these effects be mitigated most cost-effectively. This analysis requires a full life cycle approach, where emissions from each process in the cycle are determined. Although such an analysis has not yet been undertaken, we may draw some tentative conclusions:

- For oil drilling and refining and resin production, state owned large and medium sized enterprises account for the major share of production. Although environmental pollution is generated, pollution control techniques have been installed which decrease emission levels. The situation is different for small scale factories which are mostly township enterprises. These are numerous and widely scattered, making it more difficult to be centrally supervised, and their lack funds and technical capacity means that they usually discharge pollution directly to the environment without control facilities. Therefore, appropriate technologies should be developed to reduce the environmental impact of these small scale enterprises.

- Recycling takes many different forms with varying environmental impacts. As the variety of waste plastics in China is large, it would be optimal to designate a specific form of recycling for specific types of waste. For example, it could be assumed that the principal form of processing of industrial waste plastics, such as cut-offs, is primary recycling. Similarly, secondary recycling mainly focuses on agricultural film, and tertiary recycling could be applied mainly to household waste such as utensils. Heavily contaminated food packaging waste can be processed through quaternary recycling. Such a recycling hierarchy becomes ever more appropriate with the diversification of technologies and recovery systems.[15]

- In view of the fact that some western countries dumped refuse in China in the name of exporting recyclable materials, the Chinese government introduced a ban on imports of waste plastics. This policy received strong reactions because of its positive and negative effects. On the positive side, the policy aimed to protect the environment and safeguard national interests. On the negative side, many factories, especially those engaged in plastic recycling with imported waste plastics as raw material along the coastal areas, risked being forced out of the business. It

[15] Estimates show that even if all economic limitations were to be removed, it is unlikely that mechanical recycling would provide a sensible economic and environmental solution for more than about 20 percent of plastic waste (IPTS 1997). It is claimed that feedstock recycling will provide a route for increased recovery of plastic waste in the future (Curlee and Das 1996).

remains unclear whether the negative effects outweigh the positive effects. Therefore, the model should be used to calculate scenarios with and without an import ban for waste plastics.

- Waste management in China has many problems. The high degree of uncollected waste is hazardous for many cities. As landfill space is limited and incineration of the moist municipal waste is difficult, recovery presents a sound option for reducing the waste burden. The recovery sector in China is rapidly changing. The informal sector is gradually taking over from the formal segment, which raises questions about maintaining the current formal system. The model should also be able to address this question. In all cases, public awareness with regard to the economic and environmental merits of recovery plays an important role in the improvement of urban solid waste management. Separation at the source will increase the value of the waste and thereby reduce the pressure on landfills.

References

Association of Plastics Manufacturers in Europe. 1996. *Information System On Plastic Waste Management In Western Europe: European Overview 1994 Data*. APME, Montrouge.

Beijing Environmental Sanitatation Design Research Institute. 1997. *Environmental Protection*. BESDRI, Beijing.

Beukering, P.J.H. van. 1994. "An economic analysis of different types of formal and informal entrepreneurs, recovering urban solid waste in Bangalore (India)." *Resources, Conservation and Recycling* 12: 229-252.

Beukering, P.J.H. van, and Duraiappah, A. 1997. "International Trade and Recycling in Developing Countries: Waste Paper in India." *Warmer Bulletin* 52: .8-9.

Beukering, P.J.H. van, and Badrinath, G.D. 1995. "Challenges for the Recycling Industry in Nepal." *Warmer Bulletin* 46: .6-7.

Brisson, Inger E. 1997. *Assessing the "Waste Hierarchy": a Social Cost-Benefit Analysis of MSW Management in the European Union*. Samfund, Økonomi & Miljø SØM publication No.19. Copenhagen. p.1-46.

China Chemical Information Center. 1994. *Investigation Report on China Synthetic Materials Industry for the Ninth-five-year Planning*. CCIC, Beijing.

CCIC. 1995. *China Chemical Industry Yearbook 1994-1995*. CCIC, Beijing.

CCIC. 1996. *Recycling Technique and Utilisation of Plastic Waste*. CCIC, Beijing.

China Petro-chem General Corporation. 1990. *Petro-chem Environmental Protection Guide Book*. CPGC, Beijing.

China Petro-chem Information Center. 1994. *China Sino-Pec Corporation Year Book*. CPIC, Beijing.

Coopers & Lybrand, Centre for Social and Economic Research on the Global Environment (CSERGE) and Economics For The Environment Consultancy (EFTEC). 1996. *Cost-Benefit Analysis Of The Different Municipal Solid Waste Management Systems: Objectives And Instruments For The Year 2000*. Report for the European Commission, DGXI, Brussels.

Chem Systems International Ltd. 1989. *Biodegradable Plastics: Future Trends In Western Europe And The USA*. NRLO-Report 89/34. CSI Ltd, The Hague.

Curlee, T. Randall and Das, S. 1996. *Back to Basics? The Viability of Recycling Plastics by Tertiary Processes*. PSWP Working Paper #5. Yale School of Forestry and Environmental Studies, New Haven, Connecticut.

Economics Institute of China Ministry of Light Industry. 1995. *China Light Industry Yearbook*. EICMLI, Beijing.

ECOTEC. 1995. *New Clean And Low Waste Products, Processes And Services, And Ways To Promote The Diffusion Of Such Practices To Industry*. ECOTEC Research and Consulting Ltd, IVAM Environmental Research and Zenit GmbH, Brussels.

Fehringer, R. and Brunner, P.H. 1997. *Kunstofflüsse und Möglichkeiten der Kunststoffverwertung in Österreich*.. Monograph M-080. Umweltbundesamt/Federal Environmental Agency, Vienna.

Fraunhofer-Institut München, Technische Universität Berlin and Universität Kaiserslautern. 1996. *Life Cycle Analysis of Recycling and Recovery of Households Plastics Waste Packaging Materials (Summary Report*). Association of Plastics Manufacturers in Europe, Brussels. pp.1-40.

Grace, R., Turner, R.K. and Walter, I. 1978. "Secondary materials and international trade." *Journal of Environmental Economics and Management* 5: 172-186.

Grimaud, M, Aboulafia, J. and Wyseur, D. 1970. *Recent Development In The Plastic Industry Since 1964 And Their Special Interest For Developing Countries*. United Nations Industrial Development Organization (UNIDO), Vienna.

Hu Chenxi and Li Lijun. 1996. *Recycling Technology and its Application*. China Chemical Information Centre, Beijing

Hunt, R.G. 1995. "LCA Considerations of Solid Waste Management Alternatives for Paper and Plastics." *Resources, Conservation and Recycling* 14: .224-231.

Institute for Prospective Technological Studies. 1997. *The Recycling Industry In The European Union: Impediments And Prospects*. EUR 17271. p.1-58. IPTS, Seville.

MOA. 1996. *Internal Data From Ministry Of Agriculture* (MOA). Beijing

MOC. 1996 *Urban Construction Statistics Annual Report*. Ministry of Construction, Beijing.

NFLI. 1994. *Internal Data From National Federation Of Light Industry*. Beijing

NFSMC. 1996. *Internal Data From National Federation Of Supply And Marketing Co-operatives*. Beijng

Ogilvie, S.M. 1996. *Opportunities and Barriers to Plastics Recycling*. Prepared by the Recycling Advisory Unit of the National Environmental Technology Centre for the Department of Trade and Industry. Oxfordshire. AEAT-0114.

Powell, J.C., Craighill, A.L., Parfitt, J.P. and Kerry Turner, R. 1996. "A Lifecyle Assessment and Economic Valuation of Recycling." *Journal of Environmental Planning & Management* 39(1): 97-112.

Suo Zhiwen. 1997 "The Current Situation and Measurements for China's Municipal Solid Waste." *Environmental Protection* 4

Tao Zhihua and Sun Zhenling. 1996. "Further Development of China Petro-chimcal Industry." *Journal of Petrochemical Industry Trends* Feb. China Petrochimcal Information Centre, Beijing

UNCTAD. 1996. *Statistical Review of International Trade in Paper and Plastic Waste*. UNCTAD Commodities Division, Geneva.
UNEP. 1993. *Environmental Data Report 1991/1992*. Third Edition., pp336-359. United National Environmental Programme. Oxford.

Wirka J. 1988. *Wrapped In Plastics. The Environmental Case For Reducing Plastics Packaging*. Environmental Action Foundation, Washington DC.

Xu Tongkao. 1989. *Plastics Foundation and Process Technologies*

Xu Tongkao. 1992. *Waste Plastics Recovery and Utilisation*

Zeng Defang. 1996. "Disposal Technology for China's Municipal Solid Waste." *Environmental Protection* 4.

Zhang Xiaochuan. 1993. "Waste Plastic Recycling in China." *Waste Plastic Recycling* 1.

Annex I. What are plastics?

Plastics are based on long molecules called polymers. Their raw materials are oil and natural gas. Additives and reinforcements are added in the primary production process to modify the properties of the plastic products. These substances have the following properties:

- additives - tend to be organic and can be described as influencing a variety of non-strength properties of a polymer, such as wear resistance, flame resistance, colour, degradation resistance, and processability. Examples are plasticizers and colorants.

- reinforcements - are generally inorganic and are used specifically to increase a polymer's load or stress handling capacity. Examples are carbon and glass fibres.

There are two main types of plastic - thermoplastics and thermosets.

Thermoplastics - soften when heated and harden again when cooled. These characteristics make it suitable for recycling. More than 80 percent of plastics are of this type. Examples of thermoplastics include:

- high density polyethylene (HDPE): bottles for food, detergents, piping, fuel tanks and toys;

- low density polyethylene (LDPE) - cling film, bin liners and flexible containers;

- polyethylene terephthalate (PET) - bottles, carpets and food packaging;

- polypropylene (PP) - yoghurt and margarine pots, vehicle battery cases, cereal packet lining, milk and beer crates, automotive parts and fibres;

- polyvinyl chloride (PVC) - window frames, flooring, wallpaper, bottles, packaging film, cable insulation, credit cards and medical products.

Thermosets - are hardened by curing and cannot be remelted or re-moulded. For this reason thermosets, which account for around 20 percent of plastics, are more difficult to recycle, although they may be ground and used as a filler material elsewhere. Examples include:
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- polyurethane (PU) - coatings, finishes, gears, diaphragms, gaskets, cushions, vehicle seats;

- epoxy - adhesives, sports equipment, boats, electrical and automotive components;

- phenolics - ovens, toasters, handles for cutlery, automotive parts and circuit boards.

Annex II. Final Demand for Plastics in China

Plastic goods have found wide application in various sectors such as industry, agriculture, construction, health-care, packaging and household necessities. Domestic consumption of plastic goods jumped from around 1.22 million tonnes in 1980 to 8.1 million tonnes in 1994 (National Federation of Light Industry (NFL) 1996). Consumption per capita increased from 1.24 kg to 6.76 kg during the same period, with rates growing at 14.5 annually between 1980 and 1990. The 1990s is seen as high growth period for plastics consumption when 21.3 percent annual growth rates have been achieved. Such remarkable increases are rare, especially in developing countries. Based on the assumption that the Chinese economy will continue to develop at a steady and high rate within the next 20-30 years, plastics consumption levels will also be high, with annual growth rates probably above 10 percent. What is behind these remarkable growth for plastics consumption in China? The following points are worth mentioning:

- *Increase in GNP per capita.* Experience of developed countries has shown that increases in GNP has a direct bearing on the level of plastic consumption. Generally speaking, the faster the speed of growth of GNP, the higher the level of plastics consumption. The relationship between GNP and plastics consumption has also been confirmed by Chinese experience. Statistics show that GNP per capita jumped from RMB 460 Yuan in 1980 to RMB 3904 Yuan in 1994 with annual growth rates of 16.5 percent, higher than that of plastics consumption during the same period. The 1990s have witnessed 20.9 percent growth rates in annual GNP per capita, roughly equivalent to plastics consumption.

- *The strong substitution effect of plastics.* Coupled with developments of the domestic plastic processing industry, improved living standards and the emergence of new plastic varieties means that plastics are now being widely used in a range of different sectors. Its excellent properties and performance mean that plastics have been substituted for other materials such as metals and paper. Advances in a host of industries, including communications, machine building, instruments and electronics, will boost the demand for both general and engineering plastics and set a course for high-tech, high value-added and high efficient products. While consumer appliances, electronics products and automobiles currently account for the major portion of plastics consumption, predictions indicate that industrial consumption will expand in the coming years.

- *Less energy consumption and low cost linked with production of plastics.* China's energy shortage is likely to deteriorate as the various economic sectors expand. Consequently, the government regards energy-saving production as an imperative. Plastics have replaced many materials not only because of their excellent properties but also because of the relative low energy consumption level per unit weight in the production process.

Types and uses of plastics in China

- Currently, consumption mainly comprises four types of plastic: polyethylene (PE), polyvinylchloride (PVC), polypropylene (PP), and polystyrene (PS). Apart from these four major varieties, there is a small amount of ABS, PA, PET, AS, PU, etc. In 1994, plastics consumption in China stood at 8.1 million tonnes. Of these, PE and PVC both accounted for approximately 31 percent; PP made up 23 percent while PS accounted for only 5 percent. The remaining plastics made up 8.5 percent. In terms of uses, the plastics market can be broadly divided into three segments: agriculture, industry and household. Table 3 depicts the distribution of plastics market by types and uses.

Table 3 Distribution of Plastics application in China 1994-2000 (unit : 1,000 tons*)*

	1994		2000	
	Consumption	proportion	Consumption	proportion
Plastics for agricultural use	*1960*	*24.2*	*3120*	*25.4*
PE	1430	73	2200	70.5
PVC	300	15.3	520	16.7
PP	100	5.1	150	4.8
PS	30	1.5	50	1.6
others	100	5.1	200	6.4
Plastics for household use	*2700*	*33.3*	*4930*	*30.1*
PE	300	11.1	500	10.1
PVC	700	25.9	1300	26.4
PP	1270	47	2230	45.2
PS	310	11.5	600	12.2
PET	120	4.5	300	6.1
Plastics for industrial use	*3450*	*42.5*	*6950*	*44.5*
PE	800	23.2	1500	21.6
PVC	1500	43.5	3150	45.3
PP	400	11.6	800	11.5
PS	160	4.6	300	4.3
PET	80	2.3	200	2.9
others	*510*	*14.8*	*1000*	*14.4*
Total	***8100***		***15000***	

Source: National Federation of Light Industry, Ministry of agriculture, Ministry of Construction, National Environmental Protection Agency

Each category has its typical characteristics and developments:

- *Agricultural plastics:* Agricultural plastics are mainly utilised in producing agricultural film, package for grain and fertiliser and water pipe for irrigation. Table 3 shows that 1.96 million tonnes of plastics were used for agriculture of which the majority consisted of PE (73 percent) which is the raw material for film. PVC (15 percent) is used for film as well as water pipes. PP (5 percent) is mainly used for the packaging of grain and fertiliser. Based on the above, PE is the most important type of agricultural plastics, which is mainly used for producing mulch and

greenhouse film. As agricultural film has a very short life span, normally 1-2 years, it is a major source of waste in the country. Yet, because of its homogeneity it is also an important input for the recycling industry.

- *Plastics for Industrial use:* Plastics are becoming increasingly important in various industrial sectors. In 1994, 3.45 million tonnes of plastics were used by industry. It is predicted that the share of industrial use of plastics in total consumption will increase until 2000. There are seven sectors which currently comprise the main consumers: chemical building materials, automobiles, communications, machinery, instruments and apparatus, electrical and electronic products. With 1.5 million tonnes in 1994, PVC was the most popular (43.5 percent). Its share is expected to increase further in the near future. PE was the next highest at 800,000 tonnes (23.2 percent). It is estimated that by 2000 the consumption of PE will increase to 1.5 million tonnes, but the proportion in the total of industrial plastics will drop to 21.6 percent. PP, PS, PET and engineering plastics are also used for industrial purposes. Table 3 illustrates the distribution of the application of industrial plastics.

- *Plastics for household use:* Household plastics, comprising PVC, PP, PE, PET, are mainly used in packaging and utensils. PET is generally used for making soft drink bottles, which are easy to recover, whereas EPS is widely used in making disposable food packaging and dinner sets. Because of the difficulty in recovering EPS, the latter is the main source of white pollution[16]. Packing materials made of other materials like PE, PVC, and PP are also largely used for making disposable goods. Typically, the share of PE is very small (11 percent) in household plastics compared to industrial and agricultural uses. A more popular material is PP (47 percent). Similar to agricultural plastics, plastics for household use constitute the principal source of waste plastics in the country as well as the main input for the recycling industry. Currently plastics for household utensil comprise PVC, HDPE, PP, LDPE and PS with finished products ranging from slippers, sandals, soles for synthetic leather, toys, washing basins, etc.

The Role of Secondary Products

Plastics recycling in China in its primary stage. Traditionally, the main raw material in recycling has been leftover remnants from plastic production. However, recycling processes are gradually moving towards a secondary stage which mainly use post-consumer products as a raw material. Still, the problems of recycling equipment and technology mean that about 90 percent of recycled plastics is based on primary recycling and less than 10 percent comes from secondary recycling processes.

[16] The term 'white pollution' is widely used in China to describe the occurrence of EPS food packaging left alongside roads and railway tracks.

The secondary products made from recyclable plastics can roughly be divided into two categories. One is made by the mixture of virgin and secondary material, with the latter constituting less than 20 percent to ensure the appropriate quality of the end-product. Finished products of this kind are largely those used in households such as washing basins, furniture and waterproof materials in construction. The other kind of secondary products are made totally from recyclable material with no virgin material added.

The finished products range from refuse bags, soles for shoes, containers for feeding animals and waterproof materials which do not have strict property requirements. The use of secondary plastics will expand with the advancement of processing technology. By weight, secondary resins account for 10 to 15 percent of the total plastic demand in China.

Chinese people with different income levels may have different choices for plastic consumption. Generally, people with higher income levels prefer virgin plastic products which mean higher prices, while consumers with lower income levels may choose lower-cost secondary plastic products. The quality of the recycled plastic products may not be as good as that of products made from virgin resin. This may, or may not, be a limitation, depending on the size of these markets and the quantity of secondary plastics.

In 1994, the consumption of secondary plastic products and virgin plastic products accounted respectively for 16 and 84 percent of the total consumption (see table 4). From the view of different sectors, daily-use products of the household category holds the biggest share of secondary plastic consumption, second is the construction and light industrial products of the industrial category. It is surprising to note that agricultural plastics comprise mainly primary plastic products since a large number of plastic applications, such as irrigation pipes and plastic sheets could also be performed by secondary plastics. Apparently, the quality requirements for these products are considered more important than the price advantage of secondary plastics.

Table 4 virgin and secondary plastic consumption for each category in China in 1994

Category	Virgin plastic consumption (thousand tons)	Share of total virgin plastic consumption (%)	Secondary plastic consumption (thousand tons)	Share of total secondary plastic consumption (%)
Industrial plastics	2.950	43	500	38
Household plastics	2,000	30	700	54
Agricultural plastics	1,860	27	100	8
Total	6,810	100	1,300	100

Source: Information Center Of The Ministry Of Chemical Engineering (1995)

By 2000, the sector with the largest potential for secondary plastic consumption will be household products; it is projected that this sector will increase from 54 percent to more than 60 percent of total secondary plastic consumption. With the development of new recycling technologies and application areas for recycled products, the prospects for industrial secondary plastics is also bright.

Annex III. Primary industry

From a technical point of view, the primary plastic industry in China consists of two parts: resin production and product manufacturing. Current statistics in China do not follow this subdivision. Moreover, the primary plastic industry is often represented as an integral part of the petro-chemical industry. Therefore, the two sectors will be discussed in an integrated manner.

State of the art

Since the 1980s, the plastics industry in China has expanded steadily. Production capacity and output have increased approximately 3.5 times within the past 15 years. This implies an annual average growth rate of more than 11 percent. Several factors have contributed to this development.

First, a structural change has taken place in the supply side of raw materials. China is a large producer of oil, but due to its weak petro-chemical foundation and backward technology, most of China's plastic chemical raw materials were based on coal, calcium carbide and agricultural products up until the mid-1970s. The shortage of organic chemical raw materials made it impossible for the existing petro-chemical equipment to be used to its full capacity. With the establishment of the ethylene industry at the end of 1970s and the continuous expansion in the following decades, chemical raw materials gradually substituted other raw materials. The development of an ethylene industry boosted the development of the plastics industry.

Second, the development of the plastic industry has been characterised by significant technological improvements. Across all plastic types, the major incentives for these improvements have come from the introduction of technologies and equipment from abroad. For example, of the total of 18 sets of PE production devices by the end of 1994, 15 sets were imported. For PP, even 11 out of 12 sets of devices in operation came from abroad. The production capacity of imported PS devices in 1994 accounted for 95 percent of the total production capacity. Assisted by all these imported technology and equipment, the plastics industry was able to take off from a relatively high starting point and at high speed.

Third, the government played an essential role in the development of the plastic industry by providing direct and indirect support to the primary plastic industry in various ways:

- *Shift of macro-economic policy*: Since 1978, China's economic policies have experienced noticeable changes, implying enhanced utilisation of foreign capital and bringing in technology to speed up China's drive for modernisation. Under the guidance of this policy, China has accelerated the process of introducing new technologies and equipment. As a result the plastics industry has entered a fast growth period during which product technologies are continually improving, the mix of products is constantly being updated and a rapid increase in output is foreseen.

- *Formulation of industry policy*: China's petro-chemical industry began towards the end of the1950s and the beginning of 1960s, but it only took serious shape from the end of the 1970s onwards. The rapid development during this period has been attributed to a series of policies such as providing bank loans on favourable terms, becoming a priority in government investment programmes, allocating foreign exchange outlays for the introduction of technologies and equipment abroad, creating a sound environment to attract foreign investments, and granting tax breaks to imported petro-chemical equipment.

- *Reorganisation of industry*: Among the key factors that have hindered the development of the petrochemical industry and constrained its profitability is the decentralised management system. In 1983, under the initiative of the State Council of China, the petro-chemical industry undertook major readjustments and reorganisation, breaking down the original inefficient system. Currently, only 20 percent of petro-chemical enterprises are state-owned while 80 percent are claimed to be collectively owned, share-holding companies or foreign-funded enterprises. In plastic production, state-owned enterprises account for only 8.4 percent. All these efforts have contributed significantly to China's ethylene production and construction by optimising the resources.

Main economic problems

Despite the significant progress of this sector in China, there are several constraints.

- *The large gap between demand and supply:* The plastics industry has been unable to keep up with diversified needs of customers in terms of quality, quantity and variety, especially for the products with a 'high-tech' content. For example, most of the domestically produced PP products are wire-drawing materials while there is a massive shortage of polymer structures and membranes. As a result, the gap between demand and supply has been filled through imported goods. Currently, imported resins have taken at least a 50 percent share of the domestic market, rising to 80 percent for some varieties. The chances are that this trend will be hard to contain with the gradually opening of the domestic market and greater moves towards integration into the international economy.

- *Inadequate supply of raw material*: Short supply of raw material (oil and natural gas) and inadequate optimisation constitute two important factors adversely affecting China's plastics industry. China is a major oil producing country in the world and used to export oil in large quantities each year. But the recent increase in demand has led to an increasing reliance on imported oil. Moreover, the proportion of crude oil that is domestically refined for petro-chemical production is rather low. In terms of quality, China has short supplies of ethylene and aromatic hydrocarbon raw material as most of China's oil is heavy, so that its content for naphtha is low. Additionally, light hydrocarbon and gas resources are not rich and technical constraints exist in using imported naphtha. The use of heavy raw materials has resulted in high investment costs, and high consumption of energy and raw material for plastics production.

- *Small scale of equipmens and poor economic efficiency*: The scale of production is an important indicator for measuring the level of development in the petro-chemical industry. In China plastic resin production can be regarded as a capital and technology intensive industry. The scale of equipment is generally large but is nevertheless quite small in relation to international standards. Estimates show that the average scale of a foreign PE device is about 167,000 t/a and that of a PP production device about 127,000 t/a. That of China is respectively 99,000 t/a and 73,000 t/a. Owing to the small scale, per-capita labour productivity is low and production costs are high.

Prospects for Primary Industry

In view of the current situation, but even more for the near future, the primary plastics industry will not satisfy the domestic market. Three alternatives are available to address the problem. First, China can choose to rely on the importation of synthetic resins. Given the foreseen growth in population and consumption, this option seems inevitable. Second, China can choose to increase imports of monomers to produce resin. Although this course would promote the development of a less dependent plastic industry than importing resin directly, this approach is vulnerable to extreme fluctuations in import prices of raw materials, and transport costs can be rather high. Therefore, it should only be considered as a supplementary solution. Third, China can speed up the development of its ethylene and aromatic hydrocarbon industries to enhance its total productive capacity and self-reliance rate. This option has been adopted by the Chinese government as the main route to narrow the gap between supply and demand. By the end of 2000, plastics output is expected to increase to almost 9 million tonnes based on a 13.1 percent annual growth rate. The capacity will increase to more than 10 million tonnes. However, according to government plans, it will take another 10 years to turn the petro-chemical industry into a major national industry.

Recycling is now considered a key strategy for alleviating the pressures of human activities on the environment. Keywords. Final Good Final Demand Secondary Material Resin Production Technology Matrix. These keywords were added by machine and not by the authors. This process is experimental and the keywords may be updated as the learning algorithm improves.Â Beukering, P.J.H. van, Li Yongjiang, Zhao Yumin, and Zhou Xin (1997) Trends and Issues in the Plastics Cycle in China with Special Emphasis on Trade and Recycling. CREED Working Paper Series No. 16. London.Google Scholar. Duraiappah, A.K. (1993) Investing in Clean Technology: An Exercise in Methodology, Netlap Publication Series. Bangkok: UNEP.Google Scholar. Export of Recyclable Materials and the Japanese Recycling System: The Case of Used Plastic Bottles. The International Economy, p. 113. CrossRef.Â There have been increasing pressures by governments and NGOs to restrict international trade in secondary material waste in the conviction that imports of these goods are in reality a disguise for waste dumping by the exporting country. Moreover, cheap imports of secondary material waste tend to crowd out the local recovery system leading to a domestic waste disposal problem. Alternatively, proponents of trade argue that a ban on secondary material waste leads to an inefficient use of resources resulting inevitably in higher economic and environmental costs, both in developed and developing co