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SOLID WASTE RECYCLING AND REUSE IN BANGKOK

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Materials recovered from solid waste in Bangkok are mainly glass bottles, paper and paper products, plastic products and metals. Materials are separated at three different stages of the collection process: at the source, prior to collection; by the crews of the collection vehicle; and by the scavengers at the dump site. The total daily tonnage of recyclable garbage collected at the source by the waste pickers is estimated at 286 tonnes, about 5% of the garbage collected by the city. There are small scale recycling shops (SSR) located around the main disposal sites where collected materials are sold by the collection crews and the scavengers. The quantity of materials delivered to the SSR shops by the collection crew vary between 1–6 tonnes per day. The amount of materials recovered by the scavengers (at the dump site) varies between 50–150 kg person^{-1} day^{-1}. Therefore around 7.5% of the solid waste is recycled. In Bangkok both formal and informal sectors manufacture paper pulp, cardboard boxes and magazines from the recyclable paper. Paper products which account for 55% of the total waste stream are considered as the largest "product group" in the municipal solid waste. Recyclable glass (1–3% of the total waste stream) or cullet is used to manufacture plain glasses or cups. Plastics constitute about 10–15% of the waste stream. The benefit/cost ratios of production of most of these industries were reported to be higher than 1.5. In order to enhance recycling, legislative measures need to be introduced and enforced. In Thailand, there is, however, no law concerning recycling. There is no incentive for the consumer to separate solid waste for recycling, as the prices of waste in Bangkok are low and inconsistent. Therefore the pricing system should be more organized for recycling to be more effective.

Key Words—Collection crew, composting, disposal site, open dumps, recycling, reuse, scavenging, Thailand.

1. Introduction

1.1 Background information

One of the bustling and famous cities in Asia, Bangkok is known for a number of varied attractions, being located strategically as a centre for trading and business for Asia and the rest of the world. However, as an effect of rapid industrialization in the area, which is directly proportional to population increase, the solid waste problem has become one of the prime concerns of the city government for a number of environmental, social and aesthetic reasons.

The city of Bangkok is situated in the Chao Phraya River Plain, characterized by flat terrain, a high ground water table, clay soil and seasonal flooding events. The climate of Bangkok is tropical, with average temperatures reported to be between 25°C to 33°C. The city of Bangkok consists of 36 districts. The registered population of Bangkok is 5.7 million on 1566 km^2 of area, and the population growth rate is reported to be 1.16% per year. According to JICA (1991), the population density in 1989 was 3738 persons per km^2. Bangkok has about 11.3% of the whole kingdom's population.

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In 1989 the GPP (Gross Provincial Product) of Bangkok was estimated at 225 billion baht, about 40% of the GDP (Gross Domestic Product) of Thailand. According to the National Economic Social Development Board, the GPP of Bangkok is estimated to grow at an average of 7.9% per year from 1997 to 2000. The GPP per capita in 1989 was estimated at about 39,400 baht and 68,300 baht in 2000. The GPP growth is a major factor explaining the increase in waste generation in Bangkok. Manufacturing industries account for about one third of the GPP; the wholesale and the retail trade about 20% of the GPP.

According to ESCAP (1990), the amount of solid waste collected in 1990 was 5240 tonnes per day, a mean per capita rate of 0.93 kg day^{-1} varying from 0.17–2.33 in different districts. Total metric tonnes per day of industrial solid waste was 0.258 tonne per factory per day.

2. Solid waste generation, collection and disposal in Bangkok

2.1 Solid waste generation

ESCAP reports that the BMA (Bangkok Metropolitan Administration) collected about 5240 tonnes per day of municipal waste during the year 1990, which is 81% of the estimated generated waste. It is obvious that some part of the waste is not collected. It may be due to the discharge of solid waste to klongs (canals) or disposed of by burning at households and also due to the difficulty in collecting solid waste in narrow sois (small lanes).

2.2 Collection, treatment and disposal

Solid waste generated in the BMA region is collected by the cleansing sections of the Districts and Public Cleansing Service Division of the DPC (Department of Public Cleansing). The Public Cleansing Service Division of the DPC is responsible for street sweeping by using sweeping trucks and cleansing the main roads. This division collects waste from hospitals, health centres, public markets of BMA and central government buildings. It also provides the trucks and containers whenever they are required by the districts. The Cleansing Section of each district is responsible for street sweeping by manpower, refuse collection from residences, markets, commercial small industries and uncollected refuse in the public areas of the 36 districts, and transport to the final disposal site (DPC 1992).

There are two types of collection processes; direct collection (door to door method) and the indirect collection system (separate containers are placed near the markets, department stores) (DPC 1992). In the residential areas, collection workers pick up waste receptacles one by one and load the collected waste into the vehicle. Hand carts and bamboo baskets are used to collect and carry waste from narrow streets (sois). In the multi-storey buildings, dust chutes are used for the collection of wastes. One worker enters the chute and collects the waste and the remaining workers receive waste and carry it to a truck where recyclable materials are sorted out. The recycling process is one of the activities carried out by the collection crew. According to JICA (1982), about 40% of the time spent by the crews is devoted to collecting the recyclable materials.

The main disposal practices are open dumping and composting, the former being the most common practice. At present BMA has two disposal sites, one in On-Nooch and the other in Nong-Khaem. The disposal sites consist of open dumping areas, composting

TABLE 1
The amount disposed of at disposal sites (tonnes day^{-1}) (JICA 1991)

Year	BMA area	Ram Intra (closed 1989)		On-Nooch		Nong-Khaem	
		Compost plant	Disposal site	Compost plant	Disposal site	Compost plant	Disposal site
1986	3738	56	871	217	1202	28	1364
1987	4190	31	1584	158	1304	14	1063
1988	4225	1	1190	263	1051	139	1581
1989	4085	125	328	187	1276	83	1529
1990	4340	0	0	139	1214	52	1652

facilities and small incinerators. Since the composting and incineration facilities are not functioning effectively at all the disposal sites, 90% of the delivered solid waste is disposed of by open dumping (JICA 1991). There are three composting plants at the two disposal sites: two at On-Nooch and one at Nong Khaem. These three plants are designed to dispose of about 960 tonnes of refuse per day. At present the capacity of the three plants is about 150 tonnes per day (DPC 1992). Each compost plant has an incinerator with a capacity of 100 tonnes per day.

On average about 20 tonnes of solid waste per day incinerator is disposed of. At the On-Nooch disposal site about 3 tonnes per day of hospital hazardous waste is incinerated.

The average cost for open dumping is about 10 baht per tonne or less, while for composting it is 530 baht per tonne of incoming waste (JICA 1991). The amount disposed of at each disposal site is presented in Table 1. With the population increase and the economic growth, waste generation will increase. According to JICA (1991), in the year 2000 the waste collected will be about 8700 tonnes per year. It is also predicted that the share of household waste, which was 47% in 1989, will decrease while the share of business and other waste will increase.

JICA (1991) also reported that there will not be significant changes in waste composition during the next 10 years. Although paper and plastic contents will increase in the future, it is expected that their share will not change much as increase in recycling activity can be expected.

3. Characteristics of solid wastes

The solid waste of Bangkok reflects a unique blend of residential, commercial, tourist, institutional and industrial activities. The per capita waste production is the highest in the commercial and industrial zones and the lowest in the residential areas. In Bangkok, about 23–44% by weight is putrescible (food) wastes. Paper and plastics constitute 8–22% and 6–13% respectively (TAMS PIRNIE 1989).

3.1 Physical composition

Table 2 shows the physical composition of waste on a dry weight basis at the final disposal sites of Nong-Khaem and On-Nooch during the rainy season and the dry season, respectively.

TABLE 2
Physical composition of solid waste (dry weight basis) during rainy and dry seasons (Tsai Chin I, AIT 1993)

		Rainy Season				Dry Season			
		Nong-Khaem		On-Nooch		Nong-Khaem		On-Nooch	
		30/9/92	13/10/92	23/9/92	21/10/92	18/1/93	3/2/93	12/1/93	27/1/93
Physical Comp. (%)	Paper	16	15	23	12	13	11	16	20
	Fruit/vegetable	20	36	16	21	33	23	33	18
	Textile	11	1.7	2.3	4.7	4.6	3.5	4.0	6.1
	Wood/leaves	3.5	3.0	8.8	4.2	5.2	11	5.9	8.2
	Plastic	19	14	20	21	16	18	20	15
	Leather/rubber	0.1	1.2	0.1	0.5	3.3	2.0	0.2	0.1
	Metals	2.6	0.4	9.4	8.5	4.0	12	2.3	4.8
	Glass	8.1	8.1	1.3	10	10	6.3	7.9	19
	Stone/ceramic/bone	5.9	1.6	10	5.9	2.4	3.7	3.9	3.3
	Miscellaneous	13	20	9.4	12	9.0	10	6.7	5.7
	< 5 mm	9.4	14	7.6	7.5	7.0	6.7	4.7	3.7
	> 5 mm	4.0	6.1	1.8	4.4	2.0	3.3	2.0	2.0
Bulk density ($kg\,l^{-1}$)		0.37	0.36	0.39	0.35	0.35	0.30	0.32	0.29

TABLE 3
Physical composition of waste by type of area (TAMS PIRNIE 1989)

Analytical parameter	A1	A2	B	C	D1	D2	E	F
Waste components, wet weight:								
Combustible								
Paper	18	13	22	15	12	14	7.7	12
Putrescible (food waste)	40	43	23	28	39	34	43	39
Textile	5.6	10	11	2.0	9.1	7.2	4.0	3.2
Wood/glass	10	9.4	7.7	23	12	17	22	15
Plastic	11	11	9.2	13	10	14	6.6	9.4
Rubber/leather	0.2	0.6	11	2.1	1.2	2.2	7.4	1.9
Sub-total	85	87	84	83	83	88	91	81
Non-combustible								
Ferrous metal	1.7	1.6	4.0	1.5	1.2	1.5	0.9	1.6
Non ferrous	0.2	0.1	0.1	0.2	0.6	0.1	0.1	0.1
Glass	2.1	2.4	0.6	1.9	2.2	2.5	1.0	3.2
Stone/ceramics	5.6	2.6	2.1	8.6	5.2	3.7	3.2	6.8
Sub-total	9.6	6.7	6.8	12	9.2	7.8	5.2	12
Miscellaneous								
Size > 5 mm	4.3	4.4	5.4	3.8	5.8	3.3	3.1	6.4
Size < 5 mm	1.9	1.9	3.2	0.8	1.8	1.1	0.6	0.6
Sub-total	6.2	6.3	8.6	4.6	7.6	4.4	3.7	7.0
Total	100	100	100	100	100	100	100	100
Waste components, wet weight:								
Moisture	61	60	43	56	60	60	67	60
Ash	10	10	21	17	12	11	9.1	15
Combustible	29	30	36	27	27	29	24	25
Total	100	100	100	100	100	100	100	100
Gross calorific value (Kcal kg^{-1} adjusted dry basis)	4126	4180	4234	3214	4018	3909	3653	3535
% Combustion content of miscellaneous waste	—	23	—	—	46	—	15	—
Number of samples	6	6	4	5	7	14	6	2

A1, Commercial refuse, central city core and urban zones;
A2, Commercial refuse, semi-urban and semi-rural zones;
B, Industrial wastes, factories within industrial estates;
C, Institutional wastes, government offices and educational institutes;
D, Residential refuse, households in the central city core and urban zones;
D2, Residential refuse, semi-urban and semi-rural zones;
E, Market waste, fresh products markets which include some rating stands;
F, Residential refuse, low income level (slum) housing areas.

The physical composition of the waste from eight types of collection area is given in Table 3. It can be observed that commercial waste has a higher percentage of paper, putrescibles and textiles, while industrial waste has a higher percentage of paper, textiles, rubber and leather, and residential waste contains more putrescibles and plastic. Thus the commercial waste and the industrial waste have a higher calorific value than residential waste.

TABLE 4
Chemical composition of solid waste (Tsai Chin I, AIT 1993)

Chemical composition (wt. % in wet basis)	Nong-Khaem		On-Nooch	
	30/09/92	13/10/92	23/09/92	21/10/92
Moisture	58	61	60	57
Ash	12	13	15	17
Combustible	30	26	25	27
C	16	14	13	14
H	2.5	2.9	1.9	1.8
N	0.4	0.3	0.5	0.5
O	11	8.5	9.2	9.7
S	0.1	0.1	0.1	0.1
Cl	0.3	0.2	0.1	0.3

3.2 Chemical composition

The chemical composition was analysed in order to determine the probable composition of compost products and combustion gases from the incineration plant. Table 4 shows the chemical composition of combustible wastes from the Nong-Khaem and the On-Nooch disposal sites.

4. Potential for recycling

Materials recovered from solid waste in Bangkok are: glass bottles, both whole and broken; paper and paper products including newspapers, magazines, books, writing papers, paper boards or cardboard boxes; plastic products including clear (cooking oil containers), soft (containers for liquid soaps, shampoos) and hard (e.g. toilet seats, plastic bags etc.); metals such as Al, Cu, Fe and steel etc.; and used household items and clothing (mainly shoes).

The recycling process can be classified into two stages, material separation and material conversion. In the material separation process, sorting out of the materials from the waste mixture takes place without changing the physical and chemical properties. The reclaimed materials are used as secondary raw materials in the material conversion process. The recovery process is an intricate structure involving several multi-level systems starting with the commercial or industrial establishments generating the solid wastes (Fig. 1).

In Bangkok, materials are separated at different stages of the collection process: at the source, prior to collection; by the crews of the collection vehicle; and by the scavengers at the dump site. A survey conducted by ESCAP (1990) indicated that there were 954 persons involved in door to door collection as well as 2584 and 307 persons involved in the collection respectively at the main dump sites and at the intermediary sites. The collected materials are sold through middlemen to small-scale recycling businesses, who sort and pretreat the materials before selling them to a wholesaler who in turn deals directly with the user industries. In addition to the above process there is also a considerable amount of direct recycling of industrial waste.

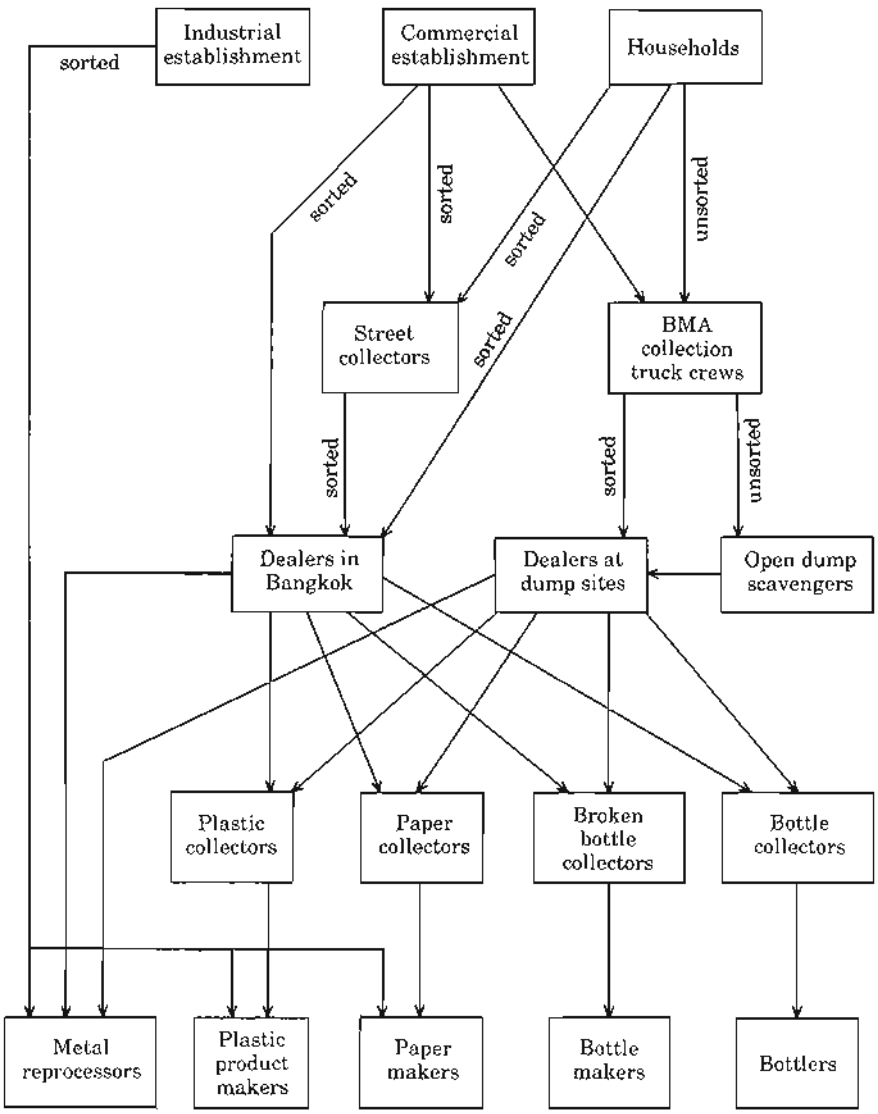

Fig. 1. Flow chart of recyclable materials.

4.1 Waste collection and separation at the source

Materials such as newspapers, magazines, cardboard and bottles are separated at source, often at the residence itself. A deposit may have been paid for returnable bottles, or they may also be sold to the collectors who operate door-to-door with a three wheel cart. A similar process is carried out at the industrial and commercial establishments. Street scavengers also sort out the most valuable items from the waste bins and containers prior to collection by the BMA crews.

According to ESCAP (1990), the total daily tonnage of recyclable waste collected by waste pickers is estimated at 286.03 tonnes, about 5% of this is collected by the city. Types of waste collected by waste pickers are represented in Table 5.

TABLE 5
Percentage of waste materials collected by the waste pickers in Bangkok (ESCAP 1990)

Materials	Percentage (%)
Plastics and rubber	26
Glass and porcelain	48
Cloth	0.7
Newspaper and magazines	3.3
Other paper based products	6.6
Bones	4.3
Wood based	1.2
Metal based (iron)	8.7
Others	0.5
aluminium	
electric wire	
electric machine	
electric bulb	

4.2 Waste separation and collection by the collection crew

The second part of the recycling process is carried out by the collection crews, separating mainly the most valuable items such as larger and cleaner pieces of paper, cardboard, plastic products, bottles, etc. which are segregated in separate baskets according to the type of material and are stored on top of the truck or inside the hopper for the trip to the disposal site.

The investigations conducted by ERL (1988), indicated that in July 1987, about 2.5% of the total waste load collected by the refuse collection crews was recovered and sold to the junk shops. Among the recyclable materials about 50% of the recovered materials were paper products, about 20% were glass and another 20% were a mixture of hard and soft plastics, and the remaining 10% were metals. The study conducted by the TAMS PIRNIE team (June, 1987) indicated that 50% of the recovered materials consist of mixed paper and cardboard, 39% glass, 9% plastics and 2% metal, rubber and textiles. These collected materials are sold to the junk shops at or near the entrance of the open dumps.

Around each of the main waste disposal sites, there are a number of small scale recycling shops (SSR) where collected materials are sold by the collection crews and the scavengers. The quantity of materials delivered to each of these SSR shops by the collection crews varies between 1 to 6 tonnes per day. Shop size is determined by the physical size and the number of refuse trucks that unload materials at the shops per day. The amount of materials collected by the junk dealers is presented in Table 6.

4.3 Recovery at the dump sites

This is the final stage of the recovery process. The amount of materials recovered by the scavengers varies between 50–150 kg person^{-1} day^{-1} and daily income varies between 30–300 baht person^{-1} (TAMS PIRNIE 1989).

Ferrous metal is also recovered from the compost plants. The amount of recovered ferrous metal by the magnetic separator from the raw waste entering the compost plants is approximately 0.8 tonnes for each 100 tonnes of raw waste. The recovered ferrous

TABLE 6
Recyclable items collected by the junk dealers (ESCAP 1990)

Waste category	Percentage (%)
Plastics/rubber	17
Glass/porcelain	29
Cloth	0.2
Newspaper/magazine	8.6
Other paper based products	11
Bones	0.5
Wood based	0.4
Metal based	21
Others	12
electric wire	
electronic machine	
scrap silver/gold	
aluminium	

TABLE 7
Selling price at the disposal sites (DPC 1992)

Materials	Selling price (baht kg^{-1})
Plastic bottles	3.20– 3.30
Broken bottles	0.20– 0.30
Mekhong bottles (white)	0.70– 0.80
Beer bottles (brown)	0.10– 0.20
Iron	1.50– 1.60
Aluminium	14.70–17.70
Copper	39.70–49.70
Writing paper	3.20– 3.30
Newspaper	1.30– 1.80
Waste paper	0.80– 1.10
Cardboard	1.20– 1.40

metal is compressed into blocks weighing 30 kg on average. There were 2,404,616 blocks (about 72,000 tonnes) recovered by the four compost plants in 1980 (JICA 1981).

The materials collected by the scavengers are sold to the middlemen. Approximately 7–10% of the middlemen buy these salvageable materials from the scavengers. Each scavenger will have a dealer to whom they sell their materials. These middlemen generally buy bottles, plastic, iron and paper separately. The selling prices for recyclable materials collected at the disposal sites are given in Table 7.

In Bangkok the price for each material is different at each level of the recycling process as given in Table 8. Generally an adult earns about 30–150 baht per day and the children about 50–80 baht per day. According to ERL (1988), about 41.9% of the scavengers earn about 30–60 baht per day, while 36.7% earn from 65–90 baht per day. The rest earn about 100–200 baht per day. The average income comes up to 75 baht per day. About 45.3% earn an average annual family income of 10,000 to 50,000 baht, while 42% are

TABLE 8
Prices for recycled materials (DPC 1992)

Material category	Price (baht kg^{-1})	
	Collector	Junk shop dealer
Paper		
Newspaper	1.00	1.50– 2.00
Writing paper		3.50
Waste paper		1.00– 1.30
Cardboard		1.50– 1.70
Bottles		
Beer (brown)		0.30– 0.40
Mekhong (white)	0.50	1.00
Broken bottles	0.20	0.50
Metal		
Iron		1.80
Aluminium		15.00–18.00
Copper		40.00–50.00
Plastics		
Bottles	3.00	3.50
Tiles	5.00	
Kapok	3.00	

Collector collects recyclables from households

within the 50,000 to 100,000 baht range. The remaining percentage earn more than 100,000 baht.

4.4 Conversion of reusable materials into new products

The reclamation process involves the removal of components from the waste stream and physical reprocessing into a useful product. Finally, chemical conversion processes transform it into a new product for the market. Among the reusable materials, ferrous metal, paper, glass and plastic are used for recycling. Paper products which account for 55% of the total waste stream are considered as the largest "product group" in the municipal solid waste. The main sources of paper generation in Bangkok are computer offices, printing shops, newspaper presses, offices, warehouses, factories, shops, households, refuse dumps and disposal plants. In Bangkok both formal and informal sectors manufacture paper pulp, cardboard boxes and magazines from recyclable paper. Recyclable glass or cullet is used to manufacture plain glasses or cups. Glasses are sold at a rate of 0.1–0.33 baht kg^{-1}. Glass constituted about 1–3% of the general waste stream in 1987 (TAMS PIRNIE 1989). The main sources of generation of glass in Bangkok are glass making factories and work shops, breweries, dairies and beverage industries, hotels, restaurants, shops, factories, office canteens, households and refuse dumps.

Plastics constitute about 10–15% of the waste stream. Plastic oxidises faster if used with recycled material. Therefore careful sorting is essential if these plastics are used as one of the raw materials of granulated plastics. Plastics are purchased at a rate of 39

baht kg^{-1} for polyproplyene and 26 baht kg^{-1} for polyethylene respectively (TAMS PIRNIE 1989).

Some of the factories use recyclable materials as raw materials (waste paper, glass, plastics etc.) and the benefit/cost ratio of production of most of them were reported to be higher than 1.5 (Butsapak 1984).

5. Legislation

In Thailand, the existing laws and regulations on solid waste management are outmoded. Most of the present acts deal with either regulation of the refuse container or general tidiness of refuse in the city area; particularly from the public point of view, there are no laws governing the recycling process. By implementing laws and regulations concerning disposal bans, mandatory deposits and requirements or introducing advanced disposal fees for goods as in the U.S.A. (BIOCYCLE 1992), a reduction of waste disposal can be achieved.

5.1 On-going projects in Thailand

The BMA recently operated a three stage project to improve the recycling process. In the first stage, recycling materials were separated at the BMA City Hall II at Din Daeng, Bangkok. About 2000 kg of waste was collected of which paper (29.8%), plastics (1.82%) and others (68.38%) were separated. The project was successfully accomplished. In the second stage of planning BMA has decided to extend it further in schools managed by BMA, to make the younger generation more aware of solid waste management. In the third stage, BMA has decided to execute the project in a small village called Muban Sevallai at Bangkok Yai district. The BMA, National Bureau, Ministry of Education along with the Thai Environmental and Community Development Association (TECDA) are jointly organizing projects to enhance solid waste management effectively. The BMA has also decided to convince people to use easily biodegradable materials such as bags made out of water hyacinth for their household rubbish, as the BMA has failed to clear the plastic bags.

In order to conserve the environment, Seagate, a company in the Rayong Industrial Park, is taking measures to reuse and recycle their supplies of cardboard and paper, recycling chemical materials and locating surplus equipment within the company before purchasing new equipment. The Asian Institute of Technology (AIT), at Pathumthani, is conducting a project in connection with recycling. Several mitigating steps for the possible reuse of solid waste generated (electronic batteries, paper etc), have been formulated.

6. Conclusions

Recycling offers a substantial reduction in the cost of waste disposal. It saves energy and expensive raw materials, and also protects the environment. Growing population, rising incomes and changing consumption patterns complicate the waste management problem. In most of the developing countries the ability to manage the waste effectively lags far behind its rate of growth. To increase the rate of recycling processes the following steps should be considered.

- Educational programmes. Conducting public education programmes that stress the benefits of recycling. The public should be made aware of adverse social, environmental and health effects of unregulated open dumping systems prevailing in Bangkok.
- Legislative measures. In order to enhance the recycling processes stringent legislative measures should be reinforced as there are no laws concerning recycling. National legislation, incentives, policies and programmes encouraging waste minimization and waste recycling/reuse are vital to the attainment of a successful recycling organization. Legislation could start with encouraging waste minimization through special tax incentives for producers/industries. Recycling programmes should be integrated within a city's overall solid waste management plan.
- Organizational measures. In order to operate the system effectively, economic benefits should be given to the consumers. For example, in Thailand a deposit-refund system is implemented for items such as bottles. This system if operated for other reusable materials could encourage recycling and prevent pollution. Community participation should be strengthened by public awareness campaigns organized by legal authorities and NGO's (Non-Governmental Organizations).
- Economic aspects. Separation at source should be encouraged wherever possible to increase the potential for waste recycling. Since the pricing system for recyclable/reusable materials in Bangkok is inconsistent, it should be organized for recycling to be more effective. A solid waste pricing system which provides ongoing incentives for households is needed. Subsidies can be provided to waste authorities and the private sector for various aspects of solid waste management. Subsidies for resource conservation, resource recovery and reducing interest on loans financing waste recycling investments, could enhance the recycling process. A deposit-refund system should be applied to materials such as beverage containers, automobile batteries and pesticide containers, etc. From an administrative perspective, these measures will be efficient since they require no monitoring or other involvement by authorities. The future development of small waste recycling industries will provide an excellent return on investment for entrepreneurs. Benefit/cost ratios in excess of 1.5 have been reported in many of the small scale industries. In order for these industries to be economically viable extended credit should be made available to entrepreneurs to encourage development of small scale waste recycling industries. Funding could be supplied by a combination of private and municipal finance.
- Technical aspects. Discarded products can be reused in the same basic shape as the original. For example bottles are reused in Bangkok. Waste can be reprocessed into a new product of comparable composition (e.g. glass cullet). In Bangkok there are few small scale industries which use the recyclable materials in manufacturing processes. Waste is processed into a different material or form of energy at this level of recovery and reuse. For an example, composting, bio-gas and ethanol production.
- Other options. Health, safety and the training of operating personnel in waste recovery streams.

References

BIOCYCLE (1992) *Journal of Waste Recycling* 30–35.

Butsapak Surcerut (1984) Engineering and socio-economic aspects of municipal solid waste recycling. AIT Research Report No. EV 84-2, AIT, Bangkok, Thailand.

DPC (1991) Public Cleansing Service in Bangkok, Department of Public Cleansing, Bangkok, Thailand.

DPC (1992) Public Cleansing Service in Bangkok, Department of Public Cleansing, Bangkok, Thailand.

ESCAP (Economic and Social Commission for Asia and the Pacific) (1990) Urban Environmental Data Questionnaire. ESCAP/UNCHS Joint Unit on Human Settlements. Division of Industry, Human Settlements and Environment, UNESCAP, UN Building, Rajadamnern Avenue, Bangkok 10200, Thailand.

ERL (Environmental Resources Limited) (1988) Promoting private sector involvement in the production of energy and other useful products from urban solid waste in Bangkok (with other possible applications in other ASEAN countries). Commission of the European Communities, Ministry of Industry of Thailand.

JICA (Japan International Cooperation Agency) (1981) The Bangkok solid waste management study, Bangkok, Thailand.

JICA (1982) The Bangkok Solid Waste Management Study, Bangkok, Thailand.

JICA (1991) The study on Bangkok solid waste management Vol-4, The Royal Thai Government, The Bangkok Metropolitan Administration.

Muttamara, S., Visvanathan C. & Alwis, K. U. (1992/1993) Solid waste recycling and reuse in Bangkok, *Environmental Systems Reviews*, ISSN 0125-5088, No. 33.

Statistical Profile of BMA (1990) Department of Policy and Planning, Thailand.

TAMS PIRNIE International, in Association with Act Consultants Co. Ltd. (1989) Feasibility Study on the Management of the Disposal of Bangkok Municipal Waste. National Energy Administration, Ministry of Science, Technology and Energy in cooperation with Bangkok Metropolitan Administration, Bangkok, Thailand.

Tsai Chin, I. (1993) Solid waste recycling and reuse in Bangkok, AIT Master Thesis, AIT, Bangkok, Thailand.