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PERFORMANCE TESTING OF THE SOLID WASTE SORTING PLANTS

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ABSTRACT

The rising prices of raw materials and environmental benefits from solid waste recycling have resulted in an increasing concern in the material recovery and reuse from both management and technical aspects. Although Taiwan has set a bold agenda of solid waste incineration programs to conserve the landfill space in the last few years, the continuing subsidy to the local government for promoting waste recycling activities has never been tempered. However, the impacts of material recovery on waste-to-energy facility remain unclear. This analysis evaluates a typical sorting plant developed by a local engineering firm in Tainan County, Taiwan. This pilot plant consists of several standard units, such as mechanical shredding, magnetic separation, trommel screening, and air classifying. By conducting a series of sampling and analysis programs, the performance of such a pilot plant is characterized such that subsequent economic feasibility study for the integration of material separation and refuse-derived fuel incineration would be feasible.

INTRODUCTION

Continuous economic development and population growth have inevitably resulted in a rapid increase of municipal solid waste (MSW) in Taiwan. According to an investigation conducted by the Environmental Protection Administration (EPA) in Taiwan, the generation rate of MSW was increasing from 18,468 tons/day in 1990 to 23,268 tons/day in 1994 [1]. Table 1, in general, shows the characteristics and generation rate of MSW in Taiwan. A recent investigation shows that material recycling and waste-to-energy facilities may be coordinated together to deal with the desperate situation of continuous landfill closing. As the sources and prices of raw material become more and more critical, recyclables, which constitute more than half of the physical composition in MSW, would be a valuable resources in the secondary material market in Taiwan. But the heterogeneity, uncertainty and variability of waste composition make the expensive pilot study become essential.

Many studies have been focused on the evaluation of material recovery systems. Experiments were independently conducted for the evaluation of various types of unit operations, such as the shredder [2]-[5], magnetic separator [6], air classifier [6]-[11], trommel [12]-[14], and the vibrating system [15]. General design principles and issues relating to recover ferrous metal, aluminum, plastics, glass, and paper were discussed [16]-[24]. It is noticed that the integration of appropriate equipments to form a workable system is a function of the characteristics of waste inflow and the specifications of the recovered products [21].

In an attempt to start the evaluation of both technical potential and economic feasibility of MSW sorting plant, the first pilot plant, with a capacity of 30 tons/day, was therefore designed and built by the Pai-Ying Machine Manufacturing Company in Tainan County. Several sampling and analysis programs were established by the research group in the National Cheng-Kung University. This paper presents the performance and a preliminary evaluation of this sorting process in which several standard units of shredding, magnetic separation, trommel screening, and air classifying are included.

FACILITY DESCRIPTION

As is illustrated in Figure 1, the designed process of Pai-Ying's pilot plant consists of three major subsystems: shredding, air classification, and screening. The facility may process 30 tons/day at maximum capacity per one line. The MSW is delivered to the facility by packer trucks. Bag-ripping unit, in charge of opening these plastic bags, initializes the material recovery process. Ferrous metal is extracted from the MSW stream by using magnets. Recovered ferrous metal is conveyed to a ferrous storage bin from where it will be recycled. MSW is then shipped into an air classifier by belt-type conveyor. Non-ferrous materials, such as aluminum can and other combustibles, are crashed by a vertical hammermill shredder. To reduce the content of heavy material, an air classifier, blowing with a regular air stream of 200 m^3/min, further isolates the inert materials, such as glass, ceramics, and so on. Light materials, passing through the air classifier, are sent into the trommel screen for advanced separation. The dimensions of the openings on the surface of trommel screen can be varied to fine-tune the processing function and assure maximum combustibles recovery. Three waste stream can be classified in which two of them are trommel undersize. Particle size is controlled by the openings design, such that the material with the particle size less than 25 mm and the particle size between 25 mm and 100 mm are separately arranged by two different sets of openings, and the particle size larger than 100 mm is regarded as the trommel oversize (overflow) which can be used in the waste-to-energy facilities as an alternative fuel. The trommel is thus designed as a two concentric shell. The outer shell, with 2.33 meters in diameter and 4.3 meters in length, have many circular holes on the surface which is designed to remove the shredded materials smaller than 25 mm. The inner shell, with 1.9 meters in diameter and 4.56 meters in length, separates partial waste stream with the size between 25 and 100 mm. The overflow, passing through this trommel screen, would present the most light portion in the MSW with the size greater than 100 mm, and can be exactly identified as the fluff-RDF that is the end product of this sorting process. Every unit is fully enclosed for noise and dust control. However, odor control is not considered in the current stage. The capital cost of this pilot plant is 80 million NT$ (i.e., approximately 3,200,000 US$) in 1994. The specification of energy requirement of each unit operation is listed in Table 2.

TESTING RESULTS

Considerable amount of MSW in the Yung-Kang City in Tainan County was collected, and the assessment of the Pai-Ying sorting process was implemented from July to December in 1995. A mass balance diagram showing the movement of the waste stream through the sorting process is provided in Figure 2. This diagram is based on a processing of 21 tons/day of MSW over a testing period. For each 100 tons of MSW processed, approximately 50 tons of RDF are produced (i.e. the summation of trommel oversize), and approximately 2.5 tons of ferrous metal are recovered. The heat value, physical, and ultimate analyses were established, and Figures 3 and 4, presented as a set of bar charts, illustrate the comparative testing results corresponding to the sampling location of (3)-(6), as shown in Figure 1. In general, the combustibles represent over 80% of the dry MSW which implies that the potential of RDF production is observable. After the operation of magnetic separation, about one-tenth of non-ferrous metal exists in the ferrous metal stream. Air classifier effectively differentiates those heavy materials from the incoming waste stream. But part of flatten aluminum and iron cans are found in the stream of heavy materials. This phenomenon reveals that bag-ripping might not be effective enough to provide full exposure environment for subsequent magnetic separation, and, to improve the system efficiency, manual sorting or eddy current separation for those non-ferrous metal materials might be required.

COST/BENEFIT ANALYSIS

The economics of a sorting plant is the unit cost of processing solid waste, including debt service, taxes, insurance, labor, fringes, administrative, parts, supplies, utilities, and other costs incurred for the operation and maintenance of the system. The debt service is basically the amortization of the initial capital investment. These costs are conveniently divided into fixed costs (debt service, taxes, insurance, etc.) and operating and maintenance costs.

In this analysis, the determination of the level of debt service is based on a uniform interest rate of 7% within 20 years that results in a yearly capital recovery factor of 0.09439. The value of 0.9 is assumed as the system availability rate and a yearly throughput of 9,855 tons is therefore chosen. According to the power consumption profile and other information, the long-term operating cost can be estimated as approximately 1,500~2,000 NT$/ton (i.e., 60~80 US$/ton), including the amortization of the initial capital investment. On the other hand, the income by selling the ferrous metal materials in the secondary material market is about 125 NT$/ton (i.e., 5 US$/ton). Therefore, the true benefit of such a sorting plant should be justified from its indirect contribution (i.e., avoided cost) in a solid waste management system analysis.

CONCLUSION

A preliminary evaluation of the pilot plant for MSW sorting was accomplished in this paper. However, in response to the situations with higher moisture content and complex characteristics in the waste stream in Taiwan, further modification of this sorting process is required. Since the prices of recyclables in the secondary material market and the composition of the waste stream are always unstable, the designer must fully grasp the dynamic characteristics of the waste feedstock and the end product property required by the recycling sectors. The results obtained from cost/benefit analysis is also an important indicator for the application of such a sorting technology. In addition, probabilistic modelling derived in this performance testing may provide the basis for future analysis of engineering reliability and the recycling impact on waste-to-energy facilities.

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Table 1 The generation rate and characteristics of municipal solid waste in Taiwan

Area	Fiscal year	Total amount (tons/day)	Disposal method (%)			Physical composition (on dry base,%)					
			Landfill	Incineration	Others	Paper	Plastics	Leather/rubber	Metal	Glass	Textiles
Taiwan Province	1992	16863	90.2	1.1	8.7	22.8	18.10	2.33	7.54	8.26	4.22
	1993	17119	93.2	1.2	5.6	24.5	18.23	2.39	8.14	8.63	3.81
	1994	17599	91.4	1.3	7.3	30.4	19.21	0.94	5.75	5.32	4.13
Taipei City	1992	3463	84.8	15.2	0.0	33.0	21.66	0.09	6.60	7.46	3.60
	1993	3621	85.0	15.0	0.0	28.4	17.23	0.05	6.88	4.24	6.74
	1994	3754	74.2	25.8	0.0	25.1	16.90	0.22	3.34	3.21	7.77
Kaohsiung City	1992	1589	100.0	0.0	0.0	23.5	21.09	2.15	5.80	6.39	5.86
	1993	1773	91.5	0.0	8.5	34.8	18.11	0.76	7.12	7.12	6.93
	1994	1914	100.0	0.0	0.0	34.1	19.72	0.68	9.52	4.84	5.15

Table 1 The generation rate and characteristics of municipal solid waste in Taiwan (Continued)

Garden trimmings	Food waste	Ceramics & china	Stone & sand	Others	Proximate analysis (on wet base,%)			
					Moisture	Ash	Combustibles	LHV(Kcal/Kg)
7.10	25.57	0.86	1.58	1.62	50.51	18.40	31.12	1239
7.82	22.95	1.21	0.91	1.46	49.90	18.50	31.56	1262
5.23	21.15	1.18	1.23	5.45	53.95	12.60	33.43	1500
2.91	23.42	0.97	0.26	0	52.27	11.10	36.64	1569
2.78	32.48	0.77	0.38	0	52.06	10.20	37.75	1767
3.66	37.74	0.52	0.88	0.63	50.42	11.60	37.99	1584
6.45	23.74	0.98	1.95	2.13	49.18	17.30	33.55	1358
3.44	18.08	0.37	1.82	1.29	52.92	14.60	32.46	1676
2.52	18.75	0.28	2.59	1.83	52.26	12.30	35.45	1567

Source : Ref 1

Table 2. The specification of major equipments

Equipment	Capacity	Energy requirements (hp)
Bag-ripper	30 (tons/hr)	5
Magnetic separator	31 (tons/hr)	3
Shredder	32 (tons/hr)	500
Air classifier	200 m^3-air/min	20
Trommel	32 (tons/hr)	7.5
Cycolne	400 m^3-air/min	40
Conveyors	--	1~10

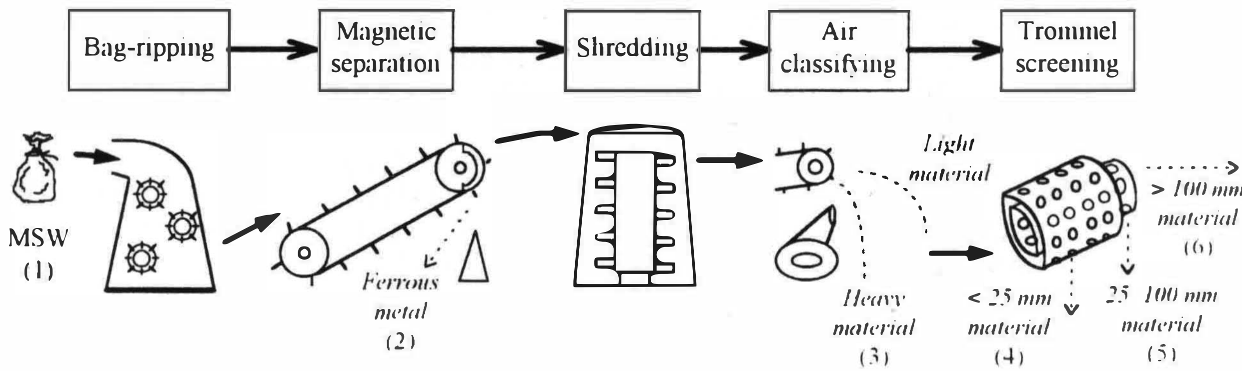

Figure 1. The flow diagram of Pai-Ying prosorting process

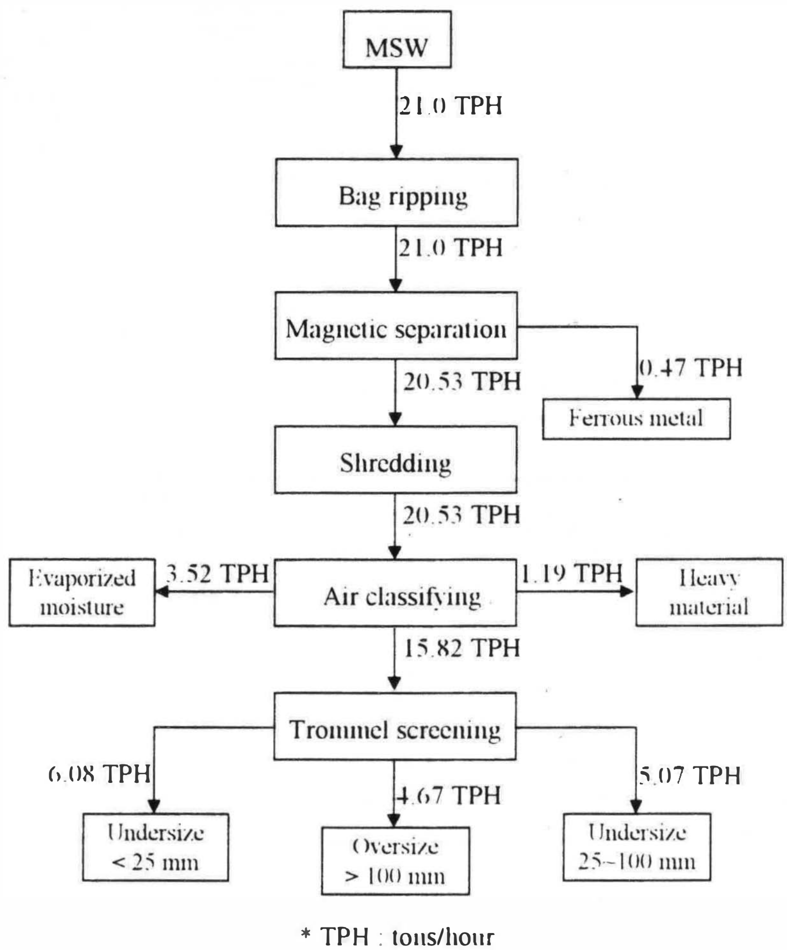

Figure 2 Mass flow diagram of Pai-Ying presorting process

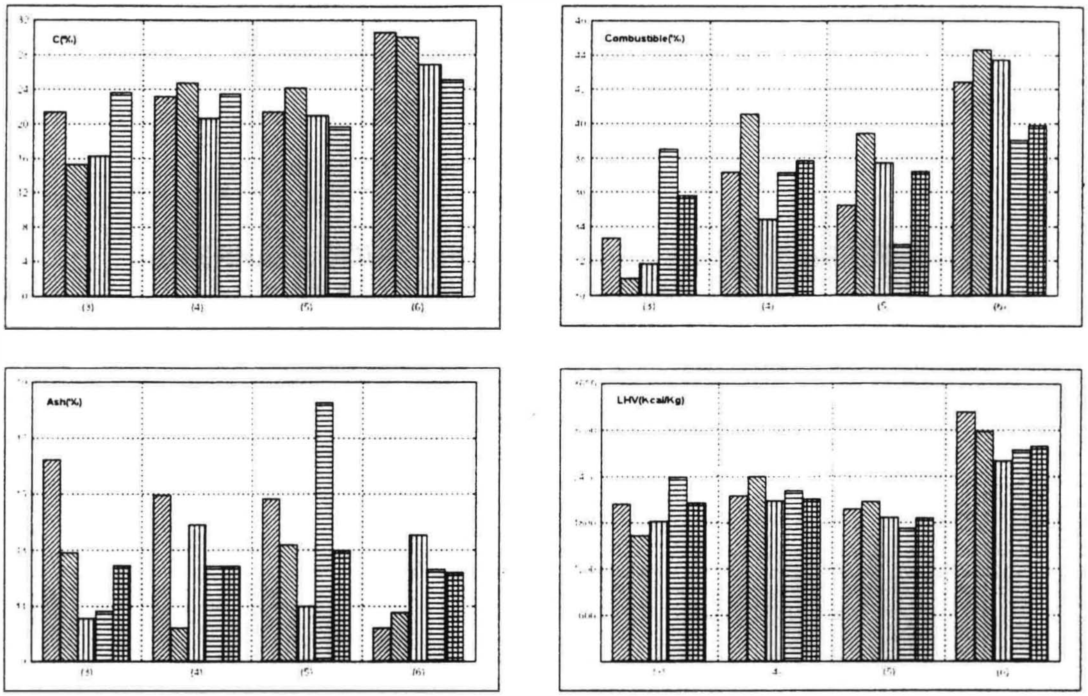

Figure 3 Comparative study of carbon content, combustible, ash, and LHV

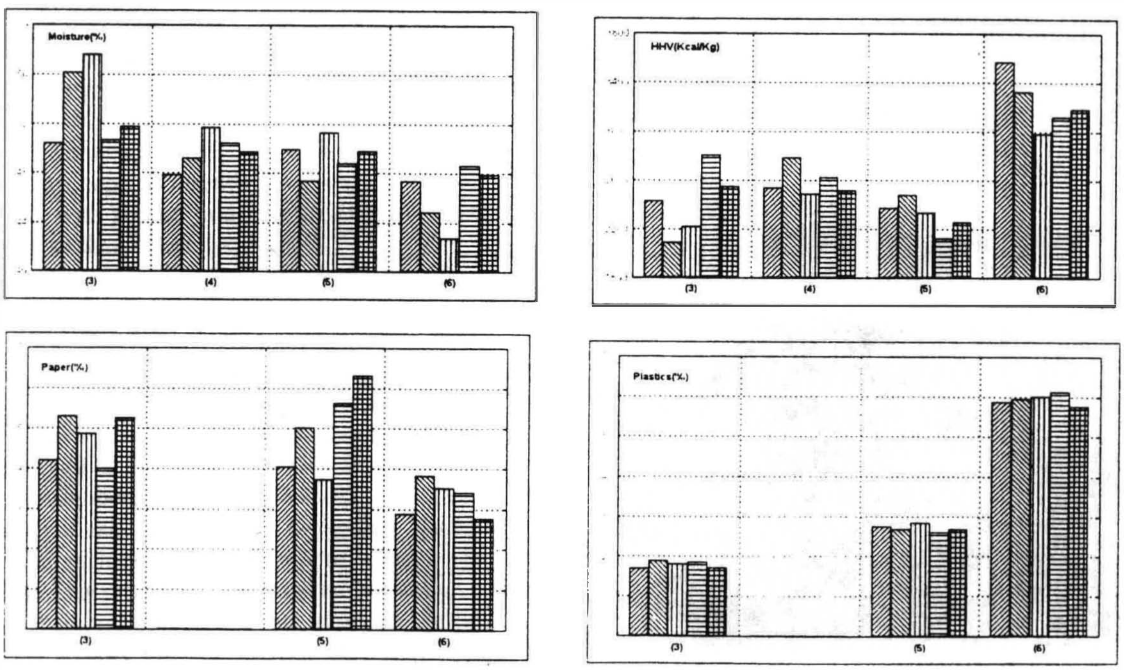

Figure 4 Comparative study of moisture content, paper, plastics, and HHV