

“END-OF-THE-PIPE” MATERIAL RECOVERY TO REDUCE WASTE DISPOSAL AND TO MOTIVATE THE INFORMAL SECTOR TO PARTICIPATE IN SITE IMPROVEMENTS AT THE CALAJUNAN DUMPSITE IN ILOILO CITY, PANAY, PHILIPPINES

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SUMMARY: Waste management problems in developed countries differ from those in developing countries. Whereas the former have access to the needed financial and technical resources as well as expertise and a well developed market, the latter countries struggle to provide basic systems to manage waste such as a waste collection system. This becomes even more obvious in urban and built-up areas where solid waste problems go hand-in-hand with other environmental threats such as air pollution, waste water, sanitation and drainage problems.

In Iloilo City, a fast growing urban center, located at the southeastern side of Panay Island, Philippines, solid waste management becomes increasingly more difficult. Presently, only 160 tons out of the estimated 310 tons daily waste generation are collected by a private contractor. Due to the stressed traffic situation, the waste collection can only be conducted during night time, whereas the most of recoverable materials are already segregated prior to disposal before or during waste collection. Nevertheless, there are still about 300 waste pickers who make their living by collecting sellable materials at the dumpsite. Although they are somehow accepted, their presence complicates the efforts for site improvement and requires special measures in the preparation of new waste management projects.

As part of the environmental enhancement program, the Local Government Iloilo proposed to rehabilitate the existing dumpsite and to establish a new landfill. To reduce the waste volume for final disposal and to integrate the local waste pickers into the project, the establishment of an

“*end-of-the-pipe*” material recovery system was proposed. The presented research summarizes the set up and findings of a 20-day segregation test at the local dumpsite, which was conducted together with 30 local waste pickers using a mechanical recovery facility. The latter consisted of an input conveyor belt, a trommel screen and a ring-belt system for manual segregation at the local dumpsite.

1. INTRODUCTION

The segregation and recovery of materials at the earliest possible stage of the solid waste stream is the best approach to minimize that reusable materials enter the waste collection system of any community. However, material recovery may still be applied during later stages of the solid waste stream at collection stations, along roads, during waste collection and at the final disposal location. In many communities in the Philippines, material recovery happens on a low organizational level. Consequently, the true amount, volume and value of recovered materials remains hidden, since the involved stakeholders do not document their work outputs and are either competing or depend on each other in a complex market network.

Iloilo City is the second largest city in the Visayas, the central island region of the Philippines. As almost everywhere in the Philippines, solid wastes are collected with a low efficiency of less than 50 % and the collected mixed waste is delivered to an uncontrolled dumpsite. Due to the stressed traffic situation, the waste collection can only be conducted during nighttime by a private contractor. More than 800 people live in shanties and small bamboo houses surrounding the dumpsite. The most of them find their livelihood as waste pickers at the dumpsite, which receives around 160 tons of solid waste every night.

As part of the environmental enhancement program, the Local Government Iloilo proposed to rehabilitate the existing dumpsite and to establish a new landfill. To reduce the waste volume for final disposal and to integrate the local waste pickers into the project, the establishment of an “*end-of-the-pipe*” material recovery system was started. Through a development grant, a first mechanical recovery unit consisting of an input conveyor belt, trommel screen and a ring-belt system for manual segregation was established. However, the set up for the daily operation seemed difficult for the local decision-makers since key-data and mechanism to operate the unit successfully such as needed employee skills, process organization, operation cost and handling of non-sellable output materials were not clarified. Thus, planning for successful system installation seemed complicated.

Consequently, a 20-day test run was conducted with the support of the German Technical Cooperation to determine the technical, operational, and financial viability of the system. The presented study summarizes the test findings and proposes options to overcome identified bottlenecks and constraints for the improvement of the established first Material-Recovery-Facility system (MRF).

2. DAY-RECOVERY TEST AT THE DISPOSAL SITE

2.1 Objectives

The conduction of a “*20-day MRF test run*” aimed primarily to assess the technical, social and financial viability of the existing recovery facility (MRF) and to determine options for improvement. Specifically, the test was designed to clarify:

- the waste composition and characteristics of incoming waste including assessment of sellable materials and non-sellable recyclables and residual wastes,

- the realistic processing capacity of the MRF (throughput / outputs of the unit),
- the technical, financial and manpower requirements of the recovery facility (operation cost including energy consumption, labor cost, materials, maintenance),
- shortcomings, constraints, bottlenecks in operating the recovery facility considering technical, financial and social aspects,
- socio-economic impact and benefits of the operation for the wastepickers,
- options for the improvement of machinery, operation, system and management.

2.2 Approach, Methodology and Limitations

To obtain a representative sample of the waste generated within the City, five waste collection trucks with an approximate loading capacity of 7 m³ each were designated to collect wastes from sources out of the city center during the daily routine waste collection. The sources included locations from central commercial and business districts.

The MRF test-run was conducted in two shifts. The first shift started at 8:00 PM until 4:00 AM and was followed by a second shift from 4:00 AM to 12:00 Noon. Each shift was run and managed by a team of 15 personnel who were selected among the local waste pickers. The team was lead by a self-selected foremen. Each team member was assigned to a specific station indicated by color code. External observers were at site to document activities and significant events during the entire shift on an hourly basis. Recorders were also assigned to gather throughput and output data during the test run. All data gathered during the test were processed and verified during a multi-stakeholder meeting one month after the test. Furthermore, the involved waste pickers were interviewed individually prior and after the test run to identify changes in their perception related to the segregation test.

A major limitation of this study is the accuracy of volume and weight of the waste samples. Comparing the results of input and output records, a significant discrepancy between the weight (kg) of the inputs and outputs became obvious. As a consequence, material balance equations could not be established. Listed below are some of the causes of the said discrepancies, namely:

- The five compactor trucks delivering waste samples per shift (8 hrs/shift) could not be accounted accurately since the facility has no weighbridge and hence waste samples from the compactor trucks could not be weighed before delivering their load to the MRF, whereas the material outputs right after processing were meticulously measured item by item at site based on the established waste composition and category.
- Amount of waste leftovers or unprocessed wastes at the input side could not be accurately measured. Unprocessed wastes were estimated by volume, *i.e.*, in cubic meters and sometimes in tons. However, these leftovers were not segregated before the next batch of 5 trucks waste samples were delivered at the beginning of the following shift.



MRF at the Calajunan disposal site

2.3 Description of the Material Recovery Facility (MRF)

The MRF consists of the processing building, the input / receiving area, in-feed conveyor system, trommel screen, and a 4 – way conveyor system, whereas each conveyor belt is powered by an individual motor. At the output side, a hammer mill is established as an option for further processing as part of the system. However, the hammer mill was not used during the test run. The MRF was designed to process up to 40 tons of wastes per day according to the technology provider. The conditions under which this output could be achieved were not known.

2.3.1 Recovery Building

The MRF building measures approximately 30 x 40 meters in total covering an area of 1200 square meters. It is made-up of concrete posts and flooring, steel beams and galvanized steel roofing materials. The building has no walls and partitions.

A second building opposite the MRF is about 8 x 30 meters. It is likewise open without partition. This building was originally designed and constructed to provide office space. No specific area was identified for storage of the processed wastes.

2.3.2 Tipping floor / input area

The tipping floor or input area is made-up of concrete flooring in a u-shape structure out of concrete blocks with a height of about 1.5 feet. The corners towards the MRF building are in a rectangular shape fronting the in-feed conveyor. The picture on the right side shows the Bobcat machine loading waste from the tipping floor to the in-feed conveyor.

2.3.3 In-feed conveyor and trommel screen

From the input area, the waste materials were transferred to the in-feed conveyor, from there into the rotating trommel, where a waste segregation in an undersize fraction (waste components < 1 inch=undersize and waste components > 1 inch=oversize) was conducted.

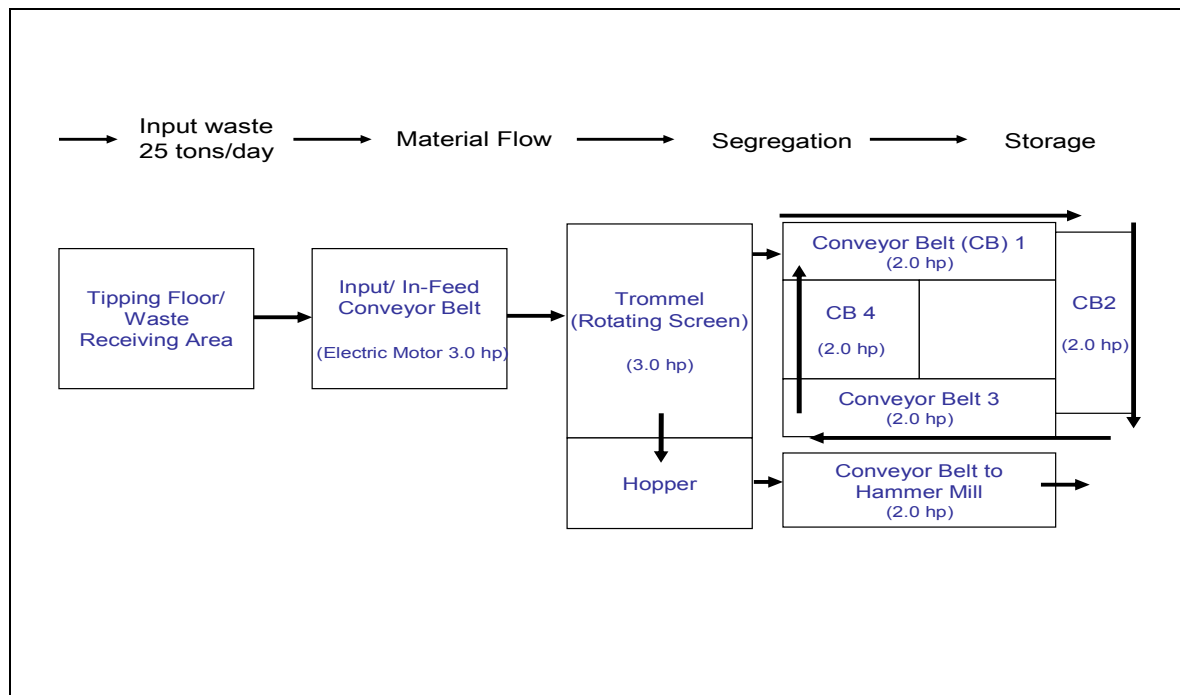
During the process, the fine materials were screened out and transported to a hopper/funnel. These fine materials were then collected and put into a wooden box at the output end of the conveyor system. The wooden box was emptied when full and the content weighed and recorded. Parallel, all materials of the oversize fraction which passed the trommel screen, were forwarded to the four-way conveyor system for further manual segregation. A “bottleneck” at this location and along the conveyor belts was identified during the test especially when the waste materials were wet.





2.3.4 Four-Way-Conveyor-Belt

Working side by side along the conveyor belts, the workers separated the various recyclables, biodegradables, and residual wastes manually. The system was designed to allow continuous movement of waste materials from one conveyor to another in a loop until all the wastes could be sorted out properly. During the test run, at least 6 workers were assigned to sort the wastes along the square conveyor belts. Wastes were categorized, packed and weighed accordingly. Sellable materials were sold directly to the nearby junk shops after the shift while residuals were collected, weighed, recorded and disposed into the dumpsite. The chart below shows the recovery and segregation process at the MRF facility.



2.3.5 Waste Dozer / Bobcat

The waste dozer (Bobcat mini loader) was an integral component of the MRF operation. Its main function was to transfer and load the waste inputs into the in-feed conveyor belt. The waste dozer was useful during the 20-day MRF operation due to the inherent design of the receiving station, which requires pushing the waste materials into the in-feed conveyor belts. However, during breakdown of the waste dozer (bobcat), waste had to be loaded manually.

2.3.6 Drainage System

The facility has only one (1) drainage canal located at the western site of the MRF-building, approximately 1 meter wide and 1.5 meter deep. Untreated leachate from the dumpsite and surface run-off drains into this canal towards the rear portion of the building and finally to the local creek system a few meters away from the MRF. However, this open canal is mostly not functioning due to wrong design, whereas waste fills up the drainage channel and hinders efficient drainage. Since the MRF lacks the necessary drainage canals, the road in-front of the MRF is usually wet and sometimes flooded with leachate, particularly during heavy rains.

2.4 Test procedures

The following procedure was applied during the MRF test run:

- The designated trucks were requested to dump the waste at the platform near the input conveyor,
- Waste was pushed into the in-feed conveyor using a mini loader (Bobcat),
- Two wastepickers assigned at the in-feed conveyor started the loading and segregation of the materials. Large components e.g. cartoons, and bulky materials were taken away from the conveyor system, closed bags were opened prior to entering the conveyor belt,
- Passing the rotating trommel screen, wastes were further segregated particularly fine residuals,
- Fine residuals were collected and recorded at the conveyor receiving the undersize fraction at the base of the trommel screen,
- Further manual segregation of the various materials which passed the trommel screen (oversizes such as compostables, recyclables, synthetics, packaging materials, metals, etc.) was conducted at a following square conveyor system (four connected conveyors),
- At the end of the shift, segregated materials were placed in different containers, weighed and recorded,
- Recyclables were collected and sold to the nearby junk buyers, while the residuals were loaded to the truck and brought to the disposal area.

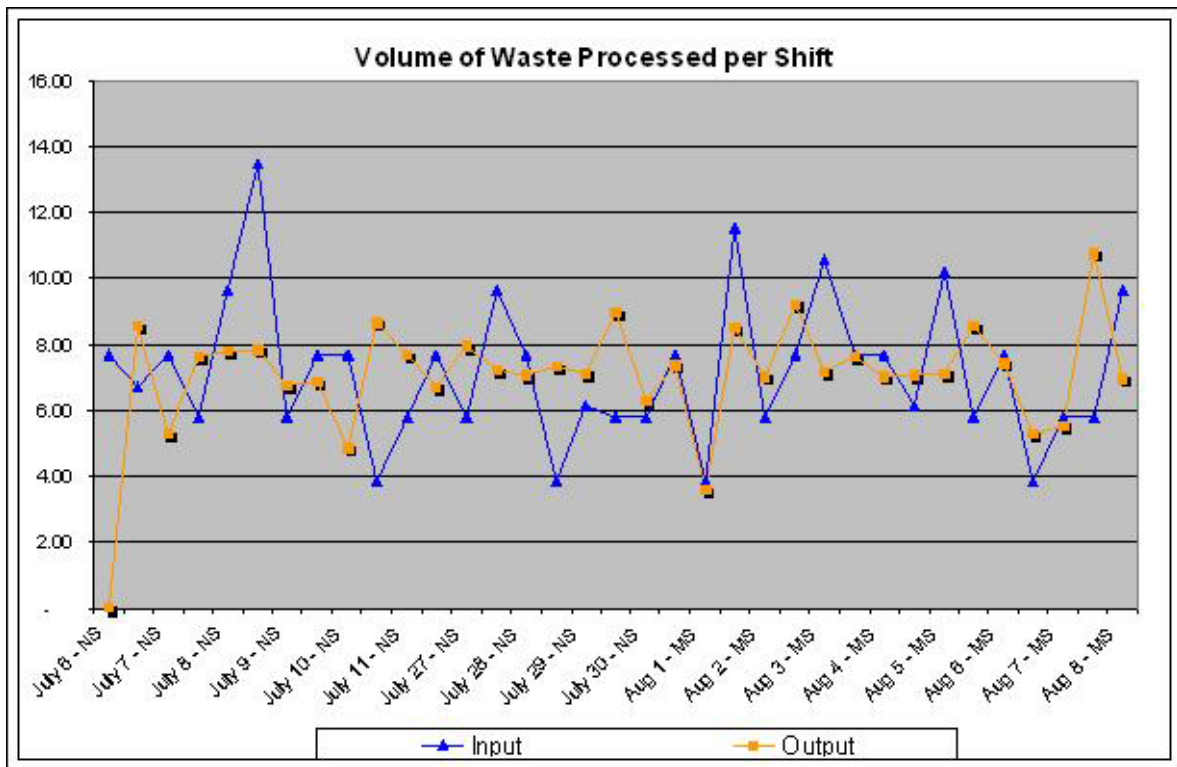
3. ANALYSIS AND FINDINGS

3.1 Delivered and processed wastes

Waste delivered and processed during the 20-day Test varied significantly from day to day. The records revealed that daily wastes brought to the MRF facility varied from 3.85 to 13.48 tons. For the entire test duration, the total volume of processed wastes was estimated with 915 m³ equivalent to 251.6 tons based on a waste density of 275 kg/m³. From the input waste about 898 m³ or 246.9 tons or 98% were processed.

Table 1. Summary of Total Waste Input and Output

Date	Total Input		Total Output	
	m ³	tons	m ³	tons
July – August (20-day test)				
Average/ Shift (8- hr)	26.1	7.19	25.7	7.06
TOTAL	914.9	251.6	898.1	246.96



Based on the test data, the average quantity of waste processed per 8 – hour shift was 7.06 tons. Hence, the existing MRF may process 14.24 tons on a two-shift work cycle, which is only 35.6% of the manufacturers claimed capacity. The table below presents the total input and output data of the MRF test run. The daily amount of wastes processed during the test run varied in a range from 3.5 to 10.75 tons per shift as shown in the graph below. The test also revealed that the input materials were not totally processed within one shift. In many instances, wastes delivered at the beginning of a shift were processed in the succeeding shift. This fact may be one explanation for the observed differences in input and output weight on daily basis. Further reasons for the delayed processing will be discussed in the proceeding sections.

3.2 Waste characterization and material balance

Wastes processed at the MRF facility were classified and recorded according to types; i.e. biodegradable, fine materials, recyclables (sellable and non-sellable), light packaging materials (synthetic residuals) and other residuals. The following table presents the composition of the wastes processed and its quantity.

Results show that more than half or 51.8% of the total waste processed during the test were fine residuals. These fine materials are the wastes screened out from the trommel screen measuring < 1-inch diameter. This fraction is composed of combined waste materials, mostly soily like small waste particles. This waste fraction could be used as soil cover at the sanitary landfill.

About 30.21% of the wastes segregated during the test run were light packaging and synthetic, often combined materials. These synthetic materials are not sellable at present. Together with the 0.06% residual wastes and the fine residuals, these materials were disposed at the dumpsite. Hence, about 82.06% of the delivered wastes had to be disposed after the test.

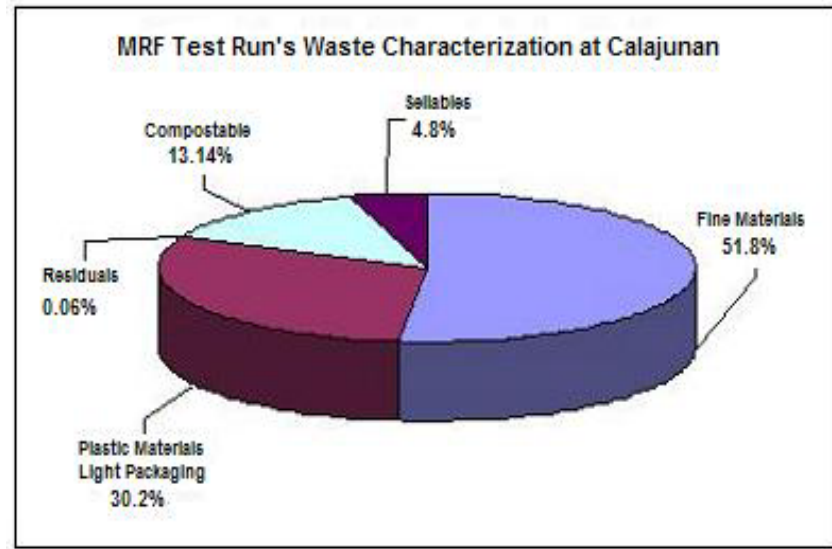
Compostable materials such as garden and vegetable residues and some kitchen wastes accounted for 13.14% of the total wastes processed while the residual wastes out of the oversize fraction > 1 inch accounted for 0.06%. Residual wastes consisted of non-reusable materials such as soiled disposable diapers, napkins and other unclassified materials.

In average, 4.8% of the wastes were sellable components such as bottles, plastics, paper and metals. Consequently, these materials were the most sought materials by the wastepickers as their daily income depends on them. Such segregated materials were sold during the following day, whereas the income was divided among the involved wastepickers per shift. In average, every worker received a daily income of P75 per shift in addition to the P100 per day allowance provided per person and per shift for participating in the test run. Reported highest and lowest daily earnings from the recovered sellable materials are P90 (1.8 US-\$) and P59 (1.18 US-\$) per person respectively. Based on the “waste-pickers-report”, the amount of sellable materials dumped at the dumpsite has decreased over the last few years. This may be an indicator for increasing material recovery at household and barangay level, but also during the collection process. Many people are now collecting sellable materials at source including the garbage collectors.

Table 2. Waste Composition of processed waste during the MRF-Test-Run

N	Waste Component	Total weight	Waste density	Volume	Percent
		kg	Kg/ m ³	m ³	
1	Compostable	32,449	292	111	13.14
2	Fine Materials	127,920	394	325	51.80
3	Saleable	(11,850)			(4.80)
	<i>Bottles</i>	<i>1,750</i>	<i>600</i>	<i>3</i>	<i>0.71</i>
	<i>Plastics</i>	<i>2,873</i>	<i>134</i>	<i>21</i>	<i>1.16</i>
	<i>Paper</i>	<i>4,554</i>	<i>127</i>	<i>36</i>	<i>1.84</i>
	<i>Metals</i>	<i>2,673</i>	<i>500</i>	<i>5</i>	<i>1.08</i>
4	Residuals				
	Light Packaging Materials	74,600	178	419	30.21
	Other materials (Residuals)	145	270	1	0.06
	TOTAL	246,964		921	100.00

Source: Report March 2007, GTZ-AHT, 20-day MRF Test Run at Calajunan Dumpsite, Iloilo City, Philippines.



3.3 Performance and efficiency of the MRF

This section presents two important terminologies namely: performance and efficiency. The MRF performance relates to the MRF's actual functionality and effectiveness during the 20-day test run, while efficiency relates to the MRF output vis-à-vis capacity of the MRF as claimed by the manufacturer.

During the 20-day test run, the performance of the MRF facility was mostly affected by the clogging of the system, overflow of wastes out of the conveyor, and break downs of the mini loader (Bobcat). As shown in the figure below, disruptions due to clogging and overflow accounted to 47.84 percent of the total time of interruptions. This was followed by the mini loader's dysfunction, mostly due to often punctured rubber tires, which accounted for 32.9 percent of total time interruptions. This caused delays for several hours, particularly if repair and tire replacement could not be performed immediately. Another cause of interruption was related to power supply (15.89 percent), and 3.37 percent were attributed to other parts of the system such as trommel screen clogging and personnel related delays.

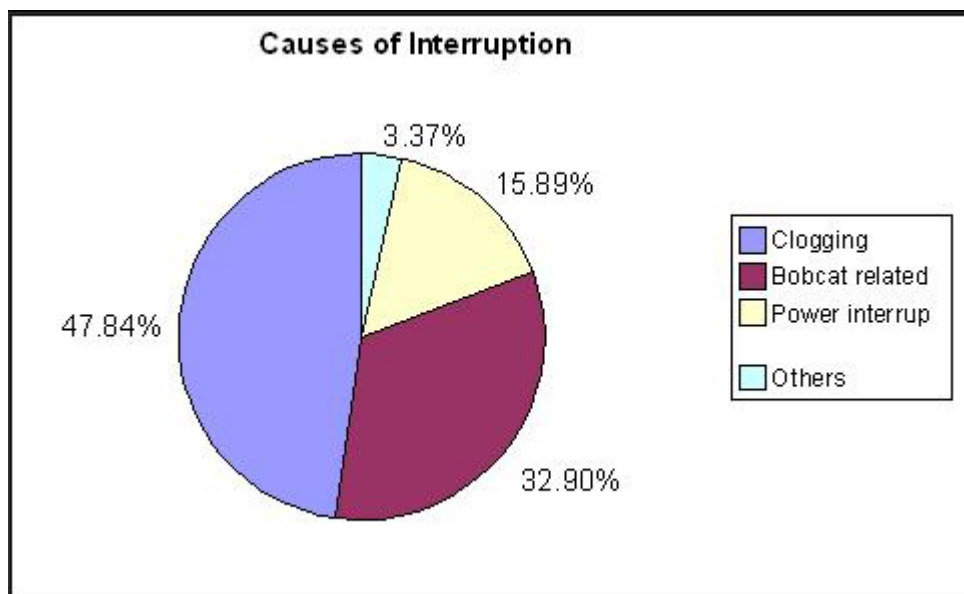


Table 3: Main causes of process interruption during the MRF-Test

Causes of Interruption	Frequency or Number of occurrence	Total time (hours)
Clogging /overflow of system	17	13.5
Bobcat (loader) related	6	9.3
Power interruption	4	4.5
Others	2	1.0
Total	29	28.3

In terms of frequency and length of interruptions observed during the 20-day test operation, the following table summarizes the aspects which most affected the system performance. Clogging and overflow of conveyor system accounted for 13.5 hours followed by the Bobcat break-downs with 9.3 hours. Correcting these two problems, the system performance could be increased by more than 7 %.

Another aspect critical in delivering the output is the efficiency of the operation. Efficiency may be tied up with the outputs, which are affected by time (time efficiency), work or activity process (methods applied), requested skills and equipment performance. Thus, Efficiency may be expressed as

$$\text{Efficiency} = f [\text{Time, Process, Skills, Equipment}]$$

In terms of time, the active work process covered 82 percent of the total expected time of operation. The time delays were due to several factors as discussed previously, such as clogging, bobcat or loader dysfunction, power interruption and others. In terms of output, the operation produces an average hourly output (processed or segregated materials) of 883 kg/hour (1,185 kg/hour at maximum efficiency). For a 24-hour operation, the expected output would be 21.19 tons per day (or 28.44 tons/day at maximum efficiency). This is less than the declared capacity of 40 tons (as claimed by the manufacturer). The 40 tons per day (with 3 shifts) are a target, which can not be attained under the present conditions.

In terms of efficiency, the night and the day shifts varied, whereas during the the test run the day shift worked 9% more efficient than the night shift.

3.4 Physical and technical constraints



During the MRF test run the following physical and technical constraints were observed, which affected the operation of the MRF:

Tipping floor: The tipping floor, where the waste was received, was found to be insufficient to accommodate the input waste delivered for processing. No appropriate ramp was installed to receive the wastes. The absence of a properly designed receiving area hindered to move the wastes to the input conveyor and hence made the process more laborious and time consuming. The conveyor at the input side was too narrow to accommodate all the waste inputs, which often resulted in waste spillovers.

Trommel Screen: The hopper beneath the trommel was often clogged-up with wastes especially when the waste inputs were wet. The worker shown in the picture is banging the funnel board with a hard wood/object to remove the clogged waste materials that stick to the board.

Conveyor Belt: Clogging of the waste materials at the in-feed conveyor belt.

Funnel board/hopper: The funnel under the trommel screen was too small to accept all outscreened waste materials onward to the Hammer Mill.

Hammer mill and shredder: Were not functioning at the time of the test run. Although hardly used prior to the test, they were due to be repaired.

Waste dozer (Bobcat): Many delays in the MRF operation during the test run were attributed to the breakdown of the bobcat, whose tires were frequently punctured. Since tire replacement could not be performed timely, the operation was delayed. However, at several occasions when the Bobcat was out of order, the transferring of the wastes to the in feed-conveyor was done manually to maintain the operation. This requested 3 to 4 additional persons to do the job of the bobcat.

Power connections and safety measures: Power supply was crucial. Due to the unfit stormwater drainage and site drainage a longer power cut appeared after a typhoon rain, whereas a conveyor engine was grounded. It took two weeks before the MRF test could be continued.

Other factors that hindered the operation were as follows:

- no weighbridge available on-site,
- no stand-by trucks to dispose un-processed waste,
- no back-up generator,
- shortage of fuel for the bobcat,
- no baler machine,
- no potable water on site,
- long working hours on standing position affected efficiency of workers,
- waste pickers in close contact with the waste,
- lack of water supply and sanitation,
- unclear management and organizational procedures.

3.5 Socio-economic implications of the MRF test run

The conduction of the MRF test run did not only address the technical and physical aspects but also considered the socio-economic implications of the MRF operation. Specifically, the study assessed the impacts of MRF operation on the socio-economic conditions of those who were involved in the MRF test operation.

After the MRF test run, the involved workers were asked which system they would prefer in recovering materials from the wastes. All wastepickers answered, that they prefer the MRF system if compared with the open system at the dumpsite. When asked why they prefer to recover materials using the MRF system rather than to collect at the open dump, they stated that the MRF system is more systematic and makes material recovery easier. They further mentioned

that working in the MRF protects them against sun and rain. Potentials for accidents with garbage trucks and other incidents like puncturing or stepping on unwanted wastes are also minimized from their point of view.

In terms of their working relationship, the wastepickers appreciated the value of teamwork. The MRF system offers individual roles and work places for each team member. As a result they do not need to compete or struggle over the materials to be recovered. However, a significant advantage of the former system over the MRF operation as mentioned by the waste pickers is their freedom to work anytime they like if compared to the ordered 8 hours continuous work at the MRF. Furthermore, in the former system, they only collect what they want to collect whereas in the MRF system, they have to collect and process nearly everything including non-sellable materials and residuals.

According to the wastepickers, the 20-day exposure enhanced their knowledge and skills in operating the MRF, this added to their confidence in operating the MRF, which was “foreign” to them prior to the test.

3.5.1 Economic impacts

During the MRF test run, the waste pickers involved were paid a total of P100 (2 US-\$) per day to cover for their wages and food allowances. In addition, all sellable materials recovered were handed over to the group to sell themselves and to divide the income equally among the group members. Reported highest and lowest daily earnings from the recovered sellable materials are P90 (1.8 US-\$) and P59 (1.18 US-\$) per person respectively. As an incentive, additional P25 (0.5 US-\$) per person per day were further provided for handling the residual wastes during the test run.¹⁾

Based on the above-mentioned earnings, eighty six percent (86%) of involved waste pickers said that their earnings during the MRF test run are comparable with their previous earnings. However, when asked which system of recovering materials they prefer, waste pickers unanimously stated that they prefer to use the MRF than the open system particularly if they would be assured of their daily earnings of P100 (2 US-\$) each. They further said that they would like to continue working in the MRF provided they would be given the P100 daily wage.

3.5.2 Occupational and health impacts

Working with wastes undoubtedly poses health hazards to the workers. Waste workers have to cope with bad odours and exposure to potentially diseases related to dealing with wastes. Some reported, that “they feel already immune working with wastes”. Working in the MRF does not eliminate hazards to human. In fact, during the sorting of wastes at the conveyors, the workers were directly in contact or very near to wastes. Unlike in the open system, where they can stay away or keep more distance to unwanted wastes.

During the MRF test run, involved individuals were provided with the necessary protective gears (mask, shoes and gloves). The provision of these protective gears was intended to instill to the workers the health hazard of waste picking and the need to be protected. For some personal reasons and preferences, most of the wastepickers did not wear the protective gears during the test run while others did not wear their masks properly and some did not even use their gloves and shoes. The waste pickers justified that they are not comfortable using the mask. Some requested for non-absorbent gloves and rubber boots for the next run.

3.5.3 Other impacts and gender-related concerns

Most of the time, working mothers in the dumpsite have no option but to bring along their small children. For some children, wastepicking has already become a part of their daily living. This exposes the children to various hazards including vehicular accidents. Fathers are not exempted;

it was observed, that a waste collection truck driver brought 2 children with him during an early morning (5:43 am) trip to the dumpsite.

1) 1 US-\$ was equivalent to 49 Philippine Peso and 1 Euro was equivalent to 62 Peso on March 31, 2007

3.6 Cost assessment of MRF operation

For purposes of financial planning and in consideration to the prospect of expanding the MRF facility at the disposal site Calajunan, the estimated initial cost of the whole system can be summarized as follows.

Table 4: Summary of Investment Cost

<i>Particulars</i>	<i>Qty</i>	<i>Estimated Cost (in PhP-Peso)</i>	<i>Estimated Cost (in US-\$)</i>
<i>Mini truck (service vehicles)</i>	<i>1</i>	<i>700,000.00</i>	<i>14,000.00</i>
<i>1- Unit MRF Module</i>	<i>1</i>	<i>7,745,450.00</i>	<i>154,910.00</i>
<i>1 Unit Mobile Trommel Screener w/ hopper</i>	<i>1</i>	<i>490,000.00</i>	<i>9,800.00</i>
<i>1 unit Plastic shredder</i>	<i>1</i>	<i>520,000.00</i>	<i>10,400.00</i>
<i>Total</i>		<i>9,455,450.00</i>	<i>189,110.00</i>

Note: it is assumed that the depreciation is linear with 5 years lifespan.

The annual depreciation cost is estimated at P1.89 Million (37,800 US-\$). This does not include the building and other support facilities.

3.6.1 Operational cost

The operation of the Calajunan MRF system requires to employ at least 15 workers per shift and to provide a loader and a dump truck to collect the residual waste, personal protective gears for the workers, and some tools and materials to maintain the operation. The daily operation cost for 15 workers, for power and fuel, maintenance, work safety and tools/materials were estimated with P 6,350 (127 US-\$) per day respectively P 2,32 Mio per year (46,400 US-\$). However, the revenue from the sales of sellable materials based on the test results would only provide P 1,528 per shift (30.56 US-\$, roughly 25 % of operation cost) or P 101 (roughly 2 US-\$) per worker. Hence, a future operation of the MRF would have to be subsidized by the Local Government Unit in any case. Some of the potential benefits, such as the integration of waste pickers into the aimed site improvements, but also the option to produce cover material for the later landfill operation would eventually justify to subsidize an optimized MRF operation. However, it should be mentioned, that the continuous operation of a MRF would request a replacement investment for the machinery at least every five years. This aspect is not included in the above mentioned budget outline.

4. CONCLUSIONS AND RECOMMENDATIONS

Based on the findings the following conclusions are made:

- The maximum processing capacity of the MRF was established with **7.06 tons** per 8-hour shift, which is only about **21.18 tons** per day if a 3-shift system would be established. This is short of the manufacturer's claim of 40 tons per day output.

- The existing MRF system produced a surprisingly high volume of **51.8% fine mixed-materials** from the processed waste. Although this fine mixed, highly organic residuals contain 80 % soil like materials, this material fraction also contains various contaminants (ashes, small batteries, unknown liquids, broken glass and sharps) and hence cannot be used for composting but would be an option to be used as cover material in the landfill;
- Of the total waste processed, about 82% had to be disposed at the dumpsite. These materials accounted for the fine materials, residual plastics and light density packaging materials and other residuals. Only 13.4% were found compostable and 4.8% were sellable materials, which is much lower than the projected 40% recyclables. This high percentage of residual wastes would shorten the lifespan of the landfill if left unabated;
- Day shifts worked more efficient than night shifts;
- Current set-up and condition of the MRF needs rehabilitation. There is a need to improve its physical facilities, equipment, logistical and administrative support for more effective and efficient operation. Physical facilities that need improvement include the tipping floor or ramp, storage area, drainage and electrical system, water supply and sanitation facilities.
- The current equipment set-up needs to be retrofitted to enhance the material recovery system, i.e., widening of conveyor belt, resizing of mesh, designing the receiving platform, and other MRF components such as the shredder and hammer mill;
- The MRF is underutilized for lack of financial and administrative support from the LGU. Earnings from the recovered materials from the wastes can not compensate for the cost of the MRF operation and machine/equipment depreciation. Hence, the MRF operation would have to be subsidized if not fully being funded by the LGU;
- Although the management of the MRF is proposed to be under the General Services Office, the test operation of the MRF was not properly organized and managed. It therefore needs to redefine the appointment of responsible persons who will be tasked to focus and be accountable for the daily operation of the MRF (Note: cost for supervision and management were not assessed in this study);
- On social aspects: Results of the post-evaluation survey revealed that all workers (or 100%) who participated in the MRF test run, believed that the continuous operation of the MRF will be beneficial to the solid waste management system of Iloilo City. In the same manner, all interviewees indicated that the present operation and management of the MRF needs improvements, specifically on the following components:
 - Physical facilities
 - Equipment
 - Logistics
 - Budget
 - Manpower
- The General Services Office and the wastepickers were identified as key players for the operation and management of the MRF at Calajunan dumpsite;
- The General Service Office and the supporting project office of the German Technical Cooperation were identified to be in the best position to help the City in ensuring the improvement of the MRF operation and management;
- Majority or 64% of the MRF test run participants believed that the operation of the MRF is replicable in other cities and municipalities in the Philippines.

Based on the results of the MRF test run and its analysis, the following recommendations are made:

- On the physical aspect: upgrade the MRF facilities and equipments by refurbishing, constructing or procurement of the following items:

- Construct an appropriate tipping floor or ramp at the entrance of the in-feed conveyor belt;
 - Construct additional roofing that will cover the tipping floor and protect the operator of the waste dozer as well as the waste inputs from negative effects such as heavy rain, extreme heat, wind and typhoons;
 - Allocate compartmentalized storage facilities for the segregated recyclable materials and a temporary storage facilities for the biodegradable as well the fine residual/compostable;
 - Construct storage facilities for tools, equipment, spare parts and lockers for the MRF staff, which include washing area, showers, etc;
 - Establish potable water lines;
 - Declog existing drainage and construct an appropriate drainage system;
 - Improve the funnel board below the trommel in order to minimize the spillover of the fine waste materials that cannot be caught by the conveyor belt;
- Establish bio-digester for the readily compostable material as a supplementary component for the treatment of biodegradable materials;
 - On Management aspect: Establish an office and/or body that will continually look into the planning, management and operation of the MRF;
 - Assign a qualified Site Manager who will supervise and oversee the operation of the MRF on a daily basis;
 - Establish a separate MRF accounting system or a funding system exclusively for MRF to guarantee maintenance and efficient operation;
 - Organize the wasteworkers into a formal and legally-recognized organization;
 - Develop and implement occupational safety precautions;
 - Strict enforcement of vaccination, regular annual check up and wearing of work safety equipment;
 - Monitoring of local recycling market and especially buying price of recyclables;
 - Prohibit children's entry to the dumpsite and establish child care facilities;
 - Provision of toilet/ comfort rooms for the area;
 - Prohibit animals at the MRF;
 - Conduct regular capacity building/ training for MRF workers;
 - Provision of cleaning facilities/ equipment;
 - Restriction on access to the MRF, to authorized personnel only;
 - Improve lighting and air quality condition.

It is further recommended to discuss options with a technology provider to technically simplify the MRF system likewise increasing the throughput per hour. This could assist to reduce the annual budget needed to subsidize the MRF operation. As one option, the installation of two larger trommel screens (=increased amount of soil cover for the SLF operation) with a lesser number of conveyor belts (=reduction of energy and maintenance cost) is proposed.

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