PAPER PULPS FROM MUNICIPAL SOLID WASTE

A. R. NOLLET and E. T. SHERWIN
AENCO, Inc., Subsidiary of Cargill, Incorporated
New Castle, Delaware

ABSTRACT

Attempts to extract marketable paper fibers from mixed municipal solid waste by mechanical means have not been successful on a large scale in the United States. The Franklin, Ohio Plant, which extracted such fibers for sale to the roofing industry, has been closed because of excessive operating losses. Hand-picking of corrugated board and newspapers from municipal solid waste has been successful, and is often practiced by waste collectors when waste paper prices are high. The recent development of new processing machinery a device to separate the incoming wastes aerodynamically at the first processing step, and a second device that reliably separates large plastics and textiles from paper fibers now makes it technically feasible to recover a Corrugated-Rich Pulp and a News-Rich Pulp from unsegregated municipal solid waste in high tonnage plants.

BRIEF HISTORY OF PAPER RECOVERY FROM MUNICIPAL SOLID WASTE

It is beyond the scope of this paper to give a complete history of past attempts to recover marketable paper or paper fibers from municipal solid waste. The authors apologize to previous authors whose extensive contributions to the literature cannot be acknowledged in this space. Previous attempts to recover waste paper from municipal waste can be divided into three broad categories - Hand-Picking, Dry Mechanical Processes, and Wet Mechanical Processes.

HAND-PICKING

Hand-picking of paper products, particularly Old Corrugated, was practiced in most of the 22 composting plants that were built from about 1960 to about 1971. Many such plants were equipped with balers to densify the hand-picked products. Unfortunately, all but one of these composting plants have been closed - owing, it is said, to lack of market for compost - which caused the plants to become economically unattractive. Since about 1971, a number of waste collectors, particularly those equipped with transfer stations, have established hand-picking systems to remove paper products from the waste stream. Because it commands a generally higher price than does Old News, Old Corrugated is the product most often sorted by such waste collectors. Typically such operations are activated only when the price of waste paper is high, and are shut down when the price is low. Thus, these sporadic operations tend to stabilize the market for waste papers. It may be significant that two of the country's largest waste collection/disposal firms established subsidiaries to sort waste paper from municipal solid waste - and subsequently closed the subsidiaries during a period of prolonged low waste paper prices.

DRY MECHANICAL PROCESSES

Many systems that recover waste paper from municipal solid waste have been demonstrated. No such system is in operation in the United States, although at least four production plants are under
The authors are not familiar with the details of the Sorain-Cecchini process. The operation of the Flakt dry separation system has been published extensively. Basically, the incoming solid waste is shredded as the first step. The shredded wastes are then processed through trommels, air-classifiers, secondary shredders and flash dryers. The system is based on the sound principle that plastics are not reduced in size in a shredder as much as paper products are. Thus, after a shredding operation, pieces of plastic will tend to be larger than pieces of paper. Additionally, the flash dryer tends to “ball-up” residual plastics. The Flakt System produces two dry fractions – one that is rich in corrugated and heavy boxboard and one that is rich in light-gage papers. The particle size of the final product is generally less than 2 in. (51 mm).

The U.S. Forest Products Laboratory has experimented with a number of processes. We understand all of the work done by the Forest Products Laboratory for the separation of paper fiber from mixed solid waste involved shredding the solid waste as the first processing step.

In a number of technical papers [7-9], the authors have detailed the reasons that shredding of solid waste is a very poor first processing step, especially if one wishes to recover paper fiber:

1. Explosions are inevitable when shredding is the first processing step.
2. The act of shredding intimately mixes toxins, putrescibles, glass, bacteria and other deleterious substances in the waste stream, thus greatly contaminating the paper fibers.
3. Shredding is a very costly first processing step.
4. Mixed solid waste contains items and materials which cannot, in fact, be shredded. Our seven years operating experience indicates that about one-third of all solid waste trucks contain so much unprocessible material that such trucks must bypass the shredding plant and dump at a landfill.

For the foregoing reasons, we consider that processes to recover paper from mixed solid waste should not involve shredding as the first processing step.

WET MECHANICAL PROCESSES

To the authors' knowledge, only one long-term attempt has been made in the United States to recover paper fibers from mixed solid waste. The Black Clawson Plant in Franklin, Ohio, was built in about 1969 in order to demonstrate the recovery of such fibers. This plant has recently been closed due to severe operating losses. The plant did produce paper fibers from mixed solid waste, and for a time these fibers were sold to a nearby roofing manufacturer. The process involved wet-pulping as the first processing step. Wet-pulping as the first processing step has significant disadvantages when used to process mixed solid waste:

1. The paper fibers are intimately mixed, under water [10], with all of the toxins, putrescibles, glass, bacteria and other deleterious substances in the waste stream, thus greatly contaminating the paper fibers.
2. Only mixed paper fibers can be extracted by this method, and such mixed fibers have a much lower value than do fibers separated by type.
3. The high-speed pulper used at Franklin reduced the size of much of the plastics and textiles so that such material reported to the paper pulp – thus further reducing its marketability.

Beginning in the mid-1970's, the Ahlstrom Company of Karhula, Finland, developed a machine called the FIBREFLOW Drum. This unit has been described extensively in the literature [11, 12]. Fig. 1 is a photograph of a production FIBREFLOW Drum.

The Drum was not designed to process mixed solid waste. Rather, it was designed to remove plastics and textiles from a dry feed-stock consisting of large pieces of paper and large pieces of plastics and textiles. The Drum is set at a small angle from the horizontal, and is fed from its upper end. The Drum is divided into two sections as shown in Fig. 2.

Feed material remains in the upper portion of the Drum for about 25 min. In this section enough water is added so that the material in the upper section contains about 15 percent dry solids. The feed material is lifted and dropped often during its residence time in the upper part of the Drum. The lifting and dropping frees most paper pulp particles from one another. However, the action...
FIG. 1 AHLSTROM FIBREFLOW UNIT FOR PROCESSING WASTE PAPER

FIG. 2 FLOW DIAGRAM – AHLSTROM FIBREFLOW SYSTEM
of the Drum is sufficiently gentle so that even very light-gage plastic sheets are not reduced in size.

The depulped paper, together with the large pieces of plastics and textiles, pass over a weir into the rear perforated section of the Drum. Water is sprayed over the top of the perforated section of the Drum. The depulped paper is washed through the perforations in the Drum, and the pulp emerges therefrom at about 3.5 percent dry solids. The contraries (or rejects) proceed down the Drum, pass over a weir section, and tumble out of the low end of the Drum.

The Drum is especially adaptable to the relatively large amount of European papers that are coated on one side with plastics. The Drum is capable of depulping the paper from the noncoated side, and causing the sheet of plastic covering to report to the rejects.

FAILURE TO RECOVER FIBERS FROM MIXED SOLID WASTE IN THE UNITED STATES

With the exception of sporadic attempts to hand-pick paper products from the mixed solid waste stream, and with the exception of the Franklin, Ohio Plant (now closed), there has been no large-scale success in recovering marketable paper fiber from the mixed solid waste stream in the United States.

Up to now, there may have been little valid economic reason to do so. In 1978, approximately 16.9 million tons (15.3 million t) of waste paper were recycled - out of about 69 million tons (62.6 million t) of paper produced in the United States. This waste paper included paper converting-trim and paper-mill broke, together with waste-paper separated at the source of generation.

Now, however, there are compelling reasons to recover more secondary fiber. It is undeniably true that less energy is required to produce a ton of paper using waste paper as furnish than is required if wood is the furnish. In 1977, Iannazzi presented a comprehensive discussion of this matter [13]. Iannazzi pointed out that integrated mills that produce paper from trees obtain a high percentage of their energy from burning byproducts. The result is that such mills often purchase less energy than do recycling mills that manufacture paper from waste paper. Such recycling mills are often located in areas of high population density, and usually burn oil or natural gas. The price trends of these fuels, combined with the fact that some such mills cannot convert to coal because of lack of space for coal storage, may tend to reduce the amount of paper produced from secondary fibers in the years ahead.

Moreover, the trend of solid waste management is clearly in the direction of burning all of the solid waste to produce energy. In order to insure a supply of waste, many communities have enacted legislation that gives curbside ownership of the waste to a Waste Authority. These Authorities often invest millions of dollars in plants designed to produce steam or electricity from burning the solid waste. Such investments, sometimes as much as $80,000 ton/day of capacity [14], make it imperative for the Waste Authority to insure that all solid waste (especially including highly-combustible paper) be delivered to the Authority. This trend (referred to as "The Burning Issue" by the American Paper Institute) may greatly reduce the amount of paper available for recycling.

Another trend has been observed in the heavily-populated Northern part of the country - many households are installing wood-burning stoves. There is a good chance that much waste paper, which otherwise would find its way into a voluntary recycling program, might be burned in the home. When burned in an efficient stove, a ton of paper may yield on the order of 8 million Btu (8.44 GJ) heat in the house. Householders who burn natural gas may be paying on the order of $5 per million Btu (84.74/GJ). A ton of paper thus would have an indicated value of about $40 ($44/t) - compared with a much lower value as waste paper (perhaps $10 to $20 per ton ($11 - $22/t), F.O.B. the household).

We should comment further on the energy problem, as related to the paper industry. Approximately 25 million Btu's (29.1 GJ) are used to make a ton of paper. Approximately 69 million tons (63 million t) of paper were manufactured in 1978 in the United States. Thus the paper industry used approximately $1.7 x 10^{18}$ Btu, or 1.7 Quads (1.8 EJ) of energy in 1978 -- compared with a total national energy usage of about 80 Quads (84.4 EJ). Our estimate of 25 million Btu (29.1 GJ) to make a ton of paper does not include energy used in forestry, in paper converting or in paper marketing. Thus the pulp and paper industry uses over 2 percent of all of the energy consumed in the United States.

If it were possible to extract marketable paper pulps from mixed solid waste, there would remain highly-combustible byproducts, which could be burned to produce the energy to produce the pulp, and to provide energy for a paper mill to manu-
facture paper therefrom. Such Integrated Plants could be compared with Integrated Plants that manufacture paper from trees. Integrated Plants that produce paper from mixed solid waste would use much less purchased energy than do Integrated Plants that produce paper from trees.

Despite the remarkable success in developing new fast-growing trees, we consider it likely that a worldwide shortage of paper pulp will occur because:

1. The increasing literacy of Third World nations is increasing the world-wide demand for paper.
2. The shortage of oil and natural gas has already created a tendency for the householder to burn wood and waste paper.
3. Local governments are tending to seize control of solid waste - for the purpose of burning it to produce steam, thus tending to reduce the quantity of paper available for recycling.
4. Demand for lumber is increasing.

We consider, therefore, that there are compelling reasons to develop a method of extracting marketable pulps from mixed solid waste. This paper describes a system to do so.

THE PULP MARKET

It is beyond the scope of this paper to discuss the pulp market in any detail. There are many types of pulp, which can be broadly divided into Chemical Pulps and Groundwood Pulps. As a broad statement, Chemical Pulps have greater fiber length and greater strength than do Groundwood Pulps. Usually Chemical Pulps are used to manufacture Kraft paper, corrugated boxes, and high-strength papers. Groundwood Pulps are typically used to manufacture newspapers, tissues, boxboard and similar low-strength products. Virgin Chemical Pulps have a market value in excess of $300/ton ($331/t). Groundwood Pulps have a market value of about $165/ton ($182/t).

RECOMMENDED PROCESS

From the foregoing discussion, it seems very desirable to extract paper pulps from the mixed solid waste stream. Such paper in solid waste constitutes about one-third of the weight of the waste, and amounts to about two-thirds of the volume of the incoming waste. Because of very poor markets for mixed paper pulp (i.e., a mixture of Groundwood and Chemical Pulps), it is highly desirable to separate the pulps into these two broad categories. Clearly such separation into categories should be accomplished before shredding or pulping the material. This implies a dry separation process - to produce two types of dry furnish - followed by separate pulping of the two types of dry furnish.

AIR-CLASSIFICATION

We have earlier commented on the great difficulty of extracting marketable paper fibers if shredding of the mixed solid waste is the first processing step. Instead, it appears that separation of the raw refuse by aerodynamic techniques minimizes the deleterious mixing of extraneous materials, toxins, etc as evidenced by earlier test work with a Rotary Drum Air-Classifier by the authors [7]. Fig. 3 shows how this system works.
FIG. 4 PROTOTYPE AENCO ROTARY DRUM AIR-CLASSIFIER

FIG. 5 LIGHT FRACTION PRODUCED BY THE AENCO ROTARY DRUM AIR-CLASSIFIER
Fig. 4 is a photograph of the full-scale prototype AENCO Rotary Drum Air-Classifier (RDAC™) during tests.

About 70 percent by weight and about 90 percent by volume of the mixed solid waste reports, unshredded, to the Light Fraction of the RDAC. Fig. 5 is a photograph of the Light Fraction.

The Light Fraction contains full-size corrugated boxes, boxboard, newspaper, light-gage papers (such as office waste), textiles, plastics, leaves, grass, aluminum foils and aluminum cans. Very little putrescible material and little toxic material report to the Light Fraction. Only small amounts of glass report to the Light Fraction.

If the Light Fraction is screened to drop, say, minus 4 in. (102 mm) material, the material on top of the screen consists only of paper products, textiles, and plastics - all above 4 in. (102 mm) in size.

If this oversize material is reprocessed through the AENCO RDAC, using a lower air velocity, then the air velocity can be set to cause newspapers and light-gage plastics and textiles to report to the Light Light Fraction. Corrugated Boxes, heavy-gage boxboard, and heavy-gage plastics and textiles will report to the Heavy Light Fraction.

The paper in the Light Light Fraction will consist of newspaper and other light-gage paper - some of which will be high-strength paper. We refer to this mixture as a "News-Rich" Fraction. The newspaper was originally manufactured using about 75 percent groundwood pulp and about 25 percent chemical pulp. The high-strength paper was originally manufactured using, generally, chemical pulp. We estimate that the paper in the Light Light Fraction may consist of about 70 percent groundwood fibers and about 30 percent chemical fibers.

The papers in the Heavy Light Fraction, on the other hand, will consist of about 50 percent corrugated boxes and about 50 percent heavy-gage boxboard. We refer to this fraction as a "Corrugated-Rich" Fraction. The corrugated boxes were likely manufactured originally using nearly 100 percent chemical pulp (usually a softwood pulp with long fibers). The boxboard, on the other hand, might typically contain 50 percent chemical fibers and 50 percent groundwood fibers. The total Heavy Light Fraction might, therefore, contain about 75 percent chemical fibers and 25 percent groundwood fibers.

Fig. 6 is a flow diagram of our recommended process to produce what we term a Corrugated-Rich Pulp (more accurately, perhaps, Chemical-Rich Pulp) and a News-Rich Pulp.

**EXPERIMENTAL RESULTS OF PROPOSED NEW PROCESS**

**DESCRIPTION OF TESTS CONDUCTED WITH NEW CASTLE COUNTY, DELAWARE WASTE AT AHLSTROM LABORATORY IN KARHULA, FINLAND**

From the mixed waste stream of New Castle County, Delaware, we prepared two samples of plastic-contaminated paper that are representative of the light fraction produced using the RDAC described earlier. These samples were as follows:

1. **News-Rich Sample**
   - Newspapers: 90 lb (40.8 kg)
   - Other Light-Gage Papers: 6 lb (2.7 kg)
   - Light Plastic Film: 4 lb (1.8 kg)

2. **Corrugated-Rich Sample**
   - Corrugated Boxes: 35 lb (15.9 kg)
   - Boxboard: 34 lb (15.4 kg)
   - Plastic Bottles, Heavy Film and Foam: 10 lb (4.5 kg)

**FIG. 6 RECOMMENDED NEW PROCESS FLOW DIAGRAM FOR PAPER FIBER RECOVERY**

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These samples were shipped via air to Finland in order to minimize decomposition. Seventy-seven lb (35 kg) of each sample were placed separately in a laboratory model of the Ahlstrom Drum, which was equipped only to pulp the plastic. The screening to separate the pulp from the plastics and rags is done separately in the Ahlstrom Laboratory. The laboratory pulper is 7.4 ft (2.25 m) in diameter with a length of 1.6 ft (0.5 m). It was operated at 15 rpm. The News-Rich Sample was pulped for 20 min. using water at 140 F (60°C). Sufficient water is used to provide approximately 15 percent solids in the pulper. After 20 min of pulping, the News-Rich Sample was removed from the pulper, and placed in a rotary screen 3.3 ft (1 m) in diameter and 1.3 ft (0.4 m) long. The screen had 0.24 in. (6 mm) holes that provided an open area of 30 percent. A water spray bar was located above the screen to dilute the pulp to approximately 3 percent solids. The pulped paper passed through the 0.24 in. (6 mm) holes, whereas the plastic film, which had not been reduced in size, remained on top of the screen. Screening was conducted for about 15 min, after which no more paper was exiting the 0.24 in. (6 mm) holes.

Approximately 77 lb (35 kg) of light-gage paper and approximately 4 lb (1.8 kg) of light-gage plastic film had been inserted into the pulper. As there were no drying facilities available, no attempt was made to weigh the paper pulp or the plastics after screening. Visual observation showed essentially no plastics in the minus 0.24 in. (6 mm) fibers. We estimate that there was, at most, 0.5 lb (1/4 kg) (dry basis) of paper that remained on top of the screen with the plastics – indicating that at least 99 percent of the paper in this fraction passed through the 0.24 in. (6 mm) holes.

A similar procedure was conducted with 77 lb (35 kg) of the Corrugated-Rich Sample – except that water in the pulper was at 122 F (50°C), and was mixed with caustic soda to yield a 1 percent NaOH solution. Pulp time was 20 min, and screening time was approximately 15 min. Visual observation showed essentially no plastics or textiles in the accepted minus 0.24 in. (6 mm) fibers. We estimated that no more than 1 lb (1/2 kg) (dry basis) of unpulped fibers remained on top of the 0.24 in. (6 mm) screen and was collected with the plastics, rags and textiles. As approximately 53 lb (24 kg) of paper fibers had been introduced into the process, approximately 98 percent of the paper fibers had been separated from the plastics. In an earlier paper [12], it was reported that after 10 min of pulping 96 - 98 percent of mixed papers passed a 0.08 in. (2 mm) screen, and that 99 percent of such papers passed a 0.08 in. (2 mm) screen after 20 min of pulping.

Samples of the pulp accepts – both News-Rich and Corrugated-Rich – were selected from the unrefined drum product (Delaware waste feed-stock) and tested by Ahlstrom Laboratories in Finland. Final test reports are forthcoming, but their interim report describes pulp quality as:

1. **News-Rich**

   According to the analyses and measuring of strength properties, the accept corresponds to normal pulp made of waste paper rich in newsprint.

   Due to careful pre-sorting the ash content was very low. Fiberizing degree of the pulp was good (98.3% < 2.1 mm) and only a few bits of plastics were found in the accept.

2. **Corrugated-Rich**

   Despite the great amount of nonfibrous reject, such as clothes and other textiles, plastic bottles, etc., the separation degree of the fibers was excellent. Fiberizing degree (85.6% < 2.1 mm) of the accept corresponds to the fiberizing degree of this kind of material. Also the ash content was very low. Strength properties were very close to the corresponding values of normal corrugated board. A few small bits of plastics, aluminum foil or rubbish were found in the accept pulp, but when the pulp was screened the major part of the residue on the 0.08 in. (2.1 mm) wire screen consisted of bits of wet strength or heavily-sized paper.

**FDA RESTRICTIONS**

Governmental restrictions on the use of waste paper recovered from the mixed waste stream will, of course, limit the market. The Food and Drug Administration (FDA) has published FDA Food Additive Regulation 21 CFR §176.260, "Pulp from Reclaimed Fiber." This regulation prohibits the use of paper for food, drug or cosmetic containers if such paper "has been used for shipping or handling poisonous or deleterious substances." Another FDA regulation prohibits the use of paper which contains more than 10 ppm of PCB.
It is not possible to determine the prior uses of paper which has been extracted from the mixed waste stream. Consequently, it is obvious that 21 CFR S176.260 would, if unchanged, preclude the use of paper fibers extracted from the mixed waste stream for the manufacture of containers for food, drugs or cosmetics. It is also obvious that great caution should be exercised to insure that paper fibers produced from the mixed waste stream do not contain substances that could damage users of products manufactured therefrom. The need for strict and continuous quality control of the paper fibers extracted from the mixed waste stream is clear.

On the other hand, the use of air-classification as the first processing step does not intimately mix the incoming paper with the deleterious substances in the waste stream – such as is certainly the case when dry-shredding or wet-pulping is the first processing step.

We think it highly likely that acceptably-pure paper fibers can be extracted from the mixed waste stream using an effective raw refuse air-classifier as the first processing step. However, caution dictates that before such paper fiber extraction is practiced on a large scale, a relatively large pilot plant should be established so that laboratory tests can be made on relatively large samples.

CONCLUSIONS

We conclude:
1. It is desirable to recover paper pulp from mixed solid waste.
2. A rotary drum raw refuse air-classifier, which has been demonstrated at full-scale, can produce:
   A. An unshredded fraction containing substantially only corrugated boxes, boxboard, other heavy-gage papers, textiles and plastics.
   B. An unshredded fraction containing substantially only newspapers, other light-gage papers, light-gage textiles and light-gage plastics.
3. These two fractions can be pulped separately in the Ahlstrom Drum to yield a Kraft-Rich Pulp, substantially free of plastics and textiles, and a Groundwood-Rich Pulp, substantially free of plastics and textiles.
4. A relatively large-scale pilot plant (500 to 1,000 tons/day) should be built to demonstrate these techniques operating in continuous production, in order to measure precisely the characteristics of these two types of pulp over a protracted period of time.

REFERENCES


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