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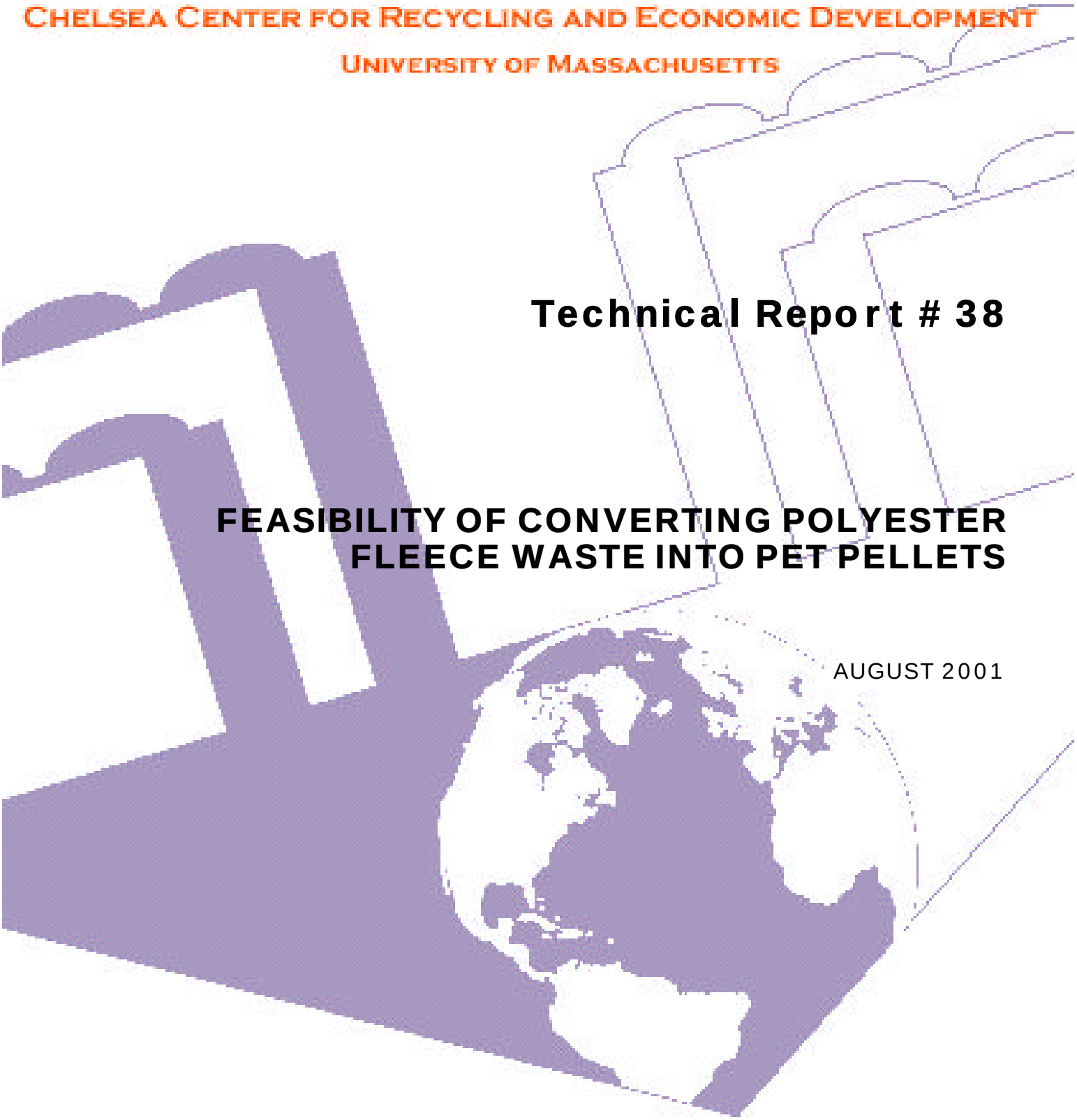

Technical Report # 38

FEASIBILITY OF CONVERTING POLYESTER FLEECE WASTE INTO PET PELLETS

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FEASIBILITY OF CONVERSION OF FLEECE WASTE INTO PET PELLETS

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The Chelsea Center for Recycling and Economic Development, a part of the University of Massachusetts' Center for Environmentally Appropriate Materials, was created by the Commonwealth of Massachusetts in 1995 to create jobs, support recycling efforts, and help the economy and the environment by increasing the use of recyclables by manufacturers. The mission of the Chelsea Center is to develop an infrastructure for a sustainable materials economy in Massachusetts, where businesses will thrive that rely on locally discarded goods as their feedstock and that minimize pressure on the environment by reducing waste, pollution, dependence on virgin materials, and dependence on disposal facilities. Further information can be obtained by writing the Chelsea Center for Recycling and Economic Development, 80 Everett Avenue, Chelsea, MA 02150.

EXECUTIVE SUMMARY

Malden Mills Industries, Inc. (Lawrence, MA) considered that high quality PET (polyethylene teraphthalate polyester) made from shear waste (small polyester fabric fibers) could have a competitive alternative in the plastics marketplace over virgin PET pellets. Prior work at Malden Mills Industries, Inc. demonstrated that shear waste material from polyester fleece production was capable of being converted into repelletized PET plastic. To further evaluate the technical and economic feasibility of converting shear waste into PET on a large scale, it was necessary to study if adding pigments could lighten the color of the resulting PET, if any emissions are released during the conversion process, and what equipment would be necessary to convert current operations to the production of re-pelletized PET.

Virgin PET is clear or green, but the fibrous test PET produced at Malden Mills Industries, Inc. from shear waste was dark blue-black due to the many colors mixed together within the bales. Knowing that lighter colored plastics are more profitable than dark, pigment tests were conducted in an effort to create a lighter, more marketable plastic. In general, the pigment tests on the shear waste had very little effect on the color of the molded samples. The addition of a white pigment caused the color to change from a dark blue to a dark brown-purple color. Other color pigments had virtually no effect and it was concluded that only very dark color PET can be made from these shear wastes.

Two tests were conducted to evaluate emissions during conversion from shear waste to PET plastic. The first test looked at weight loss at elevated temperatures (that would occur during conversion). A sample heated to 165ºC showed a 1.01% weight loss. The sample was heated further to a temperature of 250ºC and an additional weight loss of 0.73% was detected. The volatiles given off at the higher temperature could have been additional moisture, additives, dyes, coatings, contamination, or PET decomposition products. Qualitative GC/MS test indicated the presence of many different volatile compounds. However, their concentrations were likely to have been relatively small. During any full-scale shear waste conversion, volatiles that escape the production process may need to be captured with conventional ventilation equipment used for plastics manufacturing.

The last part of the project was conducted to determine what equipment and what raw material criteria would be needed to convert Malden Mills Industries, Inc., current baling operations to a pelletizing/extrusion process. The results found the PET material that was extruded and solidified was brittle and would likely be useable for only a limited number of applications as is.

Malden Mills Industries, Inc. had committed itself to find some alternative way to deal with its shear waste material and is now selling this shear waste to various manufacturers instead of disposing of it in landfills. Since the conversion to PET does not seem promising at this time, it is recommended that the shear waste continued to be sold rather than converting Malden Mills Industries, Inc.' current baling operations to a pelletizing/extrusion process that may not be economically beneficial. If buyers and users of dark PET pellets materialize, this recommendation could change.

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1. INTRODUCTION

Malden Mills Industries, Inc. Lawrence, MA facility had the idea to make high quality PET (polyethylene teraphthalate polyester) from shear waste material that would have a competitive alternative in the plastics marketplace over virgin PET pellets. Prior work at Malden Mills Industries, Inc. demonstrated that shear waste material from polyester fleece production was capable of being converted into re-pelletized PET plastic granules and that there was interest in the industry in using this PET.

Tests on the shear waste material at the University of Massachusetts at Lowell showed that the shear waste material would need to be dried first in order to remove any excess moisture that may have been absorbed (excess moisture within PET plastic reduces its quality). Because the shear waste is similar to lint found in a dryer, and is loose and fluffy, research was also needed on proper drying techniques so a potential fire hazard during drying is not introduced. Additionally, before Malden Mills Industries, Inc. could decide to undertake full-scale conversion of shear waste material to PET, additional information was needed in the following three areas:

Effect of pigments on the color of the resulting PET: Due to the many colors found in the shear waste mixture, PET plastic granules or parts formed during test conversions was dark blue-black, a color that would seriously limit the reuse of the converted PET (e.g., only a limited number of applications can use dark colored plastics). Therefore, it was important to attempt to add different pigments to the waste material before processing and determine if it is feasible or not to lighten its color. This step was considered essential to observe any color changes in the plastic as well as determine if there are any imperfections in the molding or part itself. Such a test would need to be run many times in order to obtain the lightest possible plastic with the least amount of imperfections.

Possible emissions of volatile chemicals during the pelletizing/extrusion process: Determining possible emissions early in the conversion research would allow the necessary time to correct any problem. Emissions given off during processing could be harmful to workers or the environment and controlling any emissions would help facilitate better working conditions. Testing vapors at various processing times and temperatures would give a clear indication if any emissions were present.

Process engineering requirements: additional investigations and an engineering plan were needed to specify the equipment and production process that would be capable of converting the shear waste into useable plastic PET pellet feedstock which could be used to create new PET plastic products.

The remainder of this report details the results of these three aspects of the project.

2. PIGMENT TEST RESULTS

PET is a highly marketable plastic because of its quality and versatility. Although most virgin PET is normally clear or green, Malden Mills Industries, Inc. converted (from shear waste) PET is dark blue-black due to the many colors mixed together within the bales. Understanding that lighter color plastics are more useful and profitable, Malden Mills Industries, Inc. decided that it would investigate the possibility of adding various pigments to its shear waste in order to create a lighter, more marketable product.

The tests were conducted by Professor Robert Malloy at the University of Massachusetts at Lowell in order to determine the effect of pigment additives on the color of the "mixed color" shear waste. The mixed color shear waste was first extruded and granulated without additives. This was done to put the fleece waste into a dense, granular, physical form that could be handled more easily for molding of samples. The granulated material was then dry blended with pigment concentrate additives (plastic pellets containing very high pigment loadings) at various "let down" ratios. Several different pigments were melt blended with the mixed color shear waste.

In general, the pigments had very little effect on the color of the molded samples. This was most easily demonstrated by observing the results of using a white pigment, the lightest available color pigment. A white TiO2 pigment concentrate (in a polyethylene carrier) was dry blended with the mixed color shear waste "granules" at concentrations of 0% (control), 2%, 4% and 8% by weight. The normal/recommended let down ratio recommended for the white pigment concentrate is 2%. The addition of the white pigment caused the color to change from a dark blue to a dark brown-purple color. This color seemed fairly consistent regardless of the pigment concentration. Even at four times the "normal" pigment concentration, the color change was relatively minor. It was therefore concluded that only very dark colors are possible with this shear waste starting material.

3. EMISSION TESTING RESULTS

The second phase of this project was to determine if there were likely to be any emissions of volatiles given off during the pelletizing/extruding process. Analyzing the concentrations of organic compounds in the vapors surrounding the processing equipment at various processing times and temperatures should give a clear indication if emissions are occurring. This step is critical to ensure a working condition that is suitable for the employees and for the environment. This emission testing and analysis was performed by Professor Robert Malloy of the University of Massachusetts at Lowell.

Two different tests were conducted. The first test looked at material weight loss at elevated temperatures. This was done by Therm-Gravimetric Analysis (TGA). In short, a sample of the shear waste was continuously weighed as it was heated. The sample, granulated mixed color shear waste, was first heated to a temperature of 165ºC, and held there for four hours. This is typical of the drying conditions for PET before conversion. After four hours, the sample showed a 1.01% weight loss, most likely due to loss of internal moisture (i.e., PET is a hygroscopic material). The sample was then heated further to a temperature of 250ºC, a typical melt processing temperature, and held there for ten minutes. An additional weight loss of 0.73% was detected. This test represents an extreme condition since the melted plastic is normally contained inside of closed process equipment. Normally, the melt is in contact with the ambient environment only during purging or as an extrudate exits the die before entering a water bath (perhaps an exposure of a few seconds, not ten minutes). The volatile material given off at the higher temperature could have been additional moisture, volatile additives, or decomposition products.

In an effort to identify any emissions of organic material, a second sample of granulated mixed fleece materials was evaluated using a Short Path Thermal Desorption Gas Chromatograph (GC) equipped with a Mass Spectrometer (MS). The specific unit used was an HP5890 Series II GC interfaced with an HP5971 Mass Selective Detector. The granulated mixed color shear waste sample was dried in a vacuum oven for four hours at 165ºC prior to testing to remove moisture. It was then inserted into a GC tube and heated to 250ºC for five minutes. The GC separates volatile organics that are emitted and delivers them to the MS unit over time based on their molecular size (i.e., the travel time through the long column relates to molecular size and is evidenced on a graph by peaks at the various times). The MS unit then measures the molecular size and make-up of each volatile compound. It compares this molecular size and make-up information to a "chemical database" in an effort to find a match and attempt identification of the compound. A control test (no sample) was also run to zero out any contamination.

The GC/MS test indicated the presence of many different volatile organic compounds. The results of the chemical database match listed a variety of possible chemical names for each compound and the likelihood of the match for each chemical identification. For example, for the compound eluted at 12.005 minutes, methoxy-benzene had a 97% quality point match and was very likely actually present at some concentration. Benzaldehyde shows up with a 91% quality point match at 12.822 minutes. A number of hydrocarbons and amines were also tentatively identified in the analysis. The source of an amine, such as N,N-dimethyl-benzenamine (15.113

minutes) or 4-methoxy-N-methyl-benzenamine (18.498 minutes) is unknown. Other fibers, additives, dyes, contamination, etc. are all possible sources of the volatile chemical observed.

Without standards of known compounds for comparison, the GC/MS instrument cannot measure absolute concentrations; however, peak height is an indication of relative concentration. Many different chemicals were detected during this test, however, it should be noted that the instrument can detect chemicals at concentrations much less than parts per million in the air. The TGA test described above was performed to get a better indication of the total amount of volatile emission during processing. Based on the relatively low total volatile content, the concentration of any individual chemical detected is expected to be quite low, especially under less severe real life manufacturing conditions.

4. PRODUCT TESTING RESULTS

The third goal for this project was to produce an engineering plan that specifically outlines the types of machinery needed to accommodate a production process capable of converting shear waste into useable PET plastic pellet feedstock which can be used to create new PET plastic products.

To reach this goal, Malden Mills Industries, Inc. subcontracted to Charles Crumb of Black Clawson Inc., a converting and pelletizing equipment company in Fulton, NY to run the shear waste through some of their equipment.

The setup included a 3.5", 30:1 l/d extruder. The test plan was to test the product feeding, product dryness requirements, ideal viscosity for pelletizing, and other related criteria. The first test was to evaluate the feeding of the material to the screw. The product was fed to the extruder screw with minor efforts that could be overcome (i.e., there were nails, paper, and other foreign materials in the product that had to be dealt with). The product melted and carried moisture with the melt (likely due to the high surface to volume ratio) whether it was pre-dried or run with a vent opening in the barrel that was intended to remove the residual moisture.

Polyester has an inherent problem of turning to a very low viscosity (similar to water) material with even the slightest amount of residual moisture or melt temperature change. During these tests, if the melt was cold enough to be in the viscosity range to pelletize, it would solidify, freeze off, and cause a total flow blockage. The temperature/viscosity window was only a couple of degrees and far to narrow to control on a routine process basis. Numerous temperature profile tests from increasing, reverse to flat, etc. were unsuccessful in eliminating the problem of melt temperature/viscosity control. With the slightest temperature increase, the material acquired a water-like viscosity which is far too low to pelletize by almost any method.

Also, the material that was extruded and solidified was very brittle and would likely be unusable as PET feedstock for most applications. It is possible that the shear waste product has a high shear or temperature history that is created during the inherent processing. This could account for the poor properties after post extrusion.

5. CURRENT SHEAR WASTE OPERATIONS

While performing the research on converting shear waste to PET pellets, Malden Mills Industries, Inc. continued it its efforts to find an alternative way to dispose of its shear waste material. Through much effort, Malden Mills Industries, Inc. is now selling this waste to various companies instead of disposing of it in landfills.

Malden Mills Industries, Inc. produced 484 tons of shear waste from November 1, 2000 through May 31, 2001. Of this amount, 134 tons were sold. This endeavor is saving landfill space (that is depleting at a rapid pace) and is saving money on disposal and transportation costs.

The table below lists the different Massachusetts and non-Massachusetts companies that Malden Mills Industries, Inc. recently sold its shear waste to. This table is broken down to show how much waste is being sold/diverted from the waste stream and how much money is being saved in disposal and transportation costs:

Company	**Tons Sold/Diverted**	**Money Saved** (from disposal costs)	**Money Made**
P.H. White	119	$5,474	$1,564
Capitol Textiles	63	$2,885	$401
E. Butterworth, Dracut, MA	7.4	$339	$148
Leigh Fibers	78	$3,606	$1564
TOTAL	**268**	**$12,300**	**$3,677**

At the current time, Malden Mills Industries, Inc. is being paid about a penny per pound for this material (and the buyers pay for shipping). Malden Mills Industries, Inc. expects the amount diverted and sold for recycling will continue to rise as the year progresses. In addition to the companies listed above, there are others that are in the process of becoming scrap shear waste customers.

Also, a manufacturer without specific color requirements has expressed an interest in and is investigating buying and using dark, repelletized PET made from the shear waste.

6. CONCLUSION AND RECOMMENDATIONS

Based on the findings from tests performed and reported herein, it does not appear to be economically beneficial at this time to convert Malden Mill Industries, Inc. current shear waste baling operations into a pelletizing/extrusion process. This conclusions is supported by the following:

Adding various pigments to the shear waste mixture in order to lighten the color of the extruded plastic was unsuccessful. Dark colors are only possible, and this limits its use and marketability. Gearing up to sell dark PET on the marketplace would be financially risky because there is not a known price for it. If there were, it would likely be much lower than that of clear or green PET pellets. If Malden Mills Industries, Inc. was to convert its operations to produce dark PET pellets, it will need to find someone who is willing to buy the resulting material at a price that exceeds the operating costs.

The test for emissions being released during the pelletizing/extrusion process detected many different hydrocarbons and amines. The sources for these chemicals could be coatings or dyes on the fibers, the polyester itself, contamination etc. Until additional tests were done to quantify the emission mass and concentrations that would result during full-scale production and which could lead to worker exposure, the need for specific emission controls cannot be determined.

The test results from Black Clawson concluded that "the material that was extruded and solidified was very brittle and would likely be unusable for any direct value added recycling post usage". If Malden Mills Industries, Inc. cannot produce recycled PET that has enough characteristics of virgin PET, then it would not likely prove economically beneficial to produce recycled PET as a standard feedstock to sell. This could change if some manufacturing process could use PET with these different characteristics is identified.

At present, Malden Mills Industries, Inc. should continue selling the shear waste to other companies that process it into other products. This process is not only saving landfill space, but it is also saving Malden Mills Industries, Inc. money on transportation and disposal fees. Malden already has the equipment, technological know-how and the trained personnel to continue with the baling process. Converting to a PET pellet production facility could be a huge endeavor, considering that the results did not appear very positive.