



# Sustainability Newsletter

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Integrating Unconventional Fillers in Plastics Applications

## Chairman's Corner

Chris Surbrook, Midland Compounding & Consulting

At the time of writing, Hurricane Harvey has already wrought substantial damage to Texas and the Gulf Coast, severely impacting the lives of thousands. For those in the plastics industry, the impact on upstream petrochemical feedstocks and resin production have yet to be fully felt. Hurricane Irma is poised to strike Florida, where several industry conferences have been cancelled. The environmental bill from these massive storms will be significant. It remains to be seen what policy changes will result in the future.

It's hard to believe that just over 60 days ago, we were in Orlando with the Re|Focus Recycling Summit. The feedback from this year's conference was encouraging. Attendees seemed to like the smaller, more intimate setting, and many of the sponsors commented on the improvement in not only the amount of traffic, but in the quality of the discussions they were having at the booths. Once again, the quality of the speakers and the information provided topped the list of compliments for SPE Sustainability Division's participation in the event. Next year, the Re|Focus Recycling Summit will be co-located at NPE 2018 and Sustainability Division Conference Committee is already working hard to support that event.

In this issue, we present new and original content, including the second installment of Mike Tolinski's book, *Plastics & Sustainability*. Mike published his book in 2011

and almost every word is still relevant today. Perhaps the broader public is more familiar with sustainability in everyday life, but plastics are still misunderstood. Even recycling, which seems easy and virtuous on the surface, is proving to be an economic and behavioral conundrum. Mike had some prescient words on the topic:

*"To some, the economic pitfalls of plastics recycling and low recovery rates may seem to indicate that it is not wise to expect recycling to flourish in developed countries with efficient petrochemical industries. But it is also possible that the infrastructure and markets for recycling have not developed past a tipping point after which they become strong and stable. This may require intervention outside of overall market forces, as the US government and other governments often consider and do."*

I would be remiss if I didn't take a moment to comment on the improvements to the newsletter we have all been enjoying over this last year. In 2016, we were fortunate to add Conor Carlin to the Board of Directors and he also agreed to act as Newsletter Editor. He has done an amazing job of increasing the quality of content and communication about our division's activities. To date, Conor has made all these improvements with no budget whatsoever, but there is something we can all do to change that. We would like to increase the sponsorships to the newsletter. So, if you and your company enjoy the information being provided, please consider becoming a sponsor. There is more information in this edition about how to become a sponsor. |

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### Polypropylene Recycling Venture Launches \$120 million Project

By **Jared Paben, Resource Recycling**

July 20, 2017—An innovation developed by Procter & Gamble to bolster polypropylene recovery is being put into action, with construction of an Ohio facility beginning today.

A startup called PureCycle Technologies this morning broke ground on a plant in Ironton, Ohio, which is approximately 130 miles from P&G's Cincinnati headquarters. It will be located at the site of a recently closed Dow Chemical Co. facility.

PureCycle has unveiled technology that it says is capable of generating recycled PP with virgin-like properties, and it could help move contaminated and dark-colored polypropylene streams into higher-value applications. The company licenses the process from P&G, a consumer-products heavyweight that currently uses more than a half a million tons of virgin PP a year.

Investments for the PureCycle project in Ohio are expected to total at least \$120 million, a company spokeswoman confirmed. Much of the funding appears to be coming through bonds from local governments.

The first step will be to build a feedstock evaluation unit, followed in the next few years by a commercial-scale PureCycle facility.

"This technology, which can remove virtually all contaminants and colors from used plastic, has the capacity to revolutionize the plastics recycling industry," said Kathy Fish, P&G's chief technology officer.

P&G approached Inventure with an offer to license the technology and sell into the marketplace the resulting recycled PP.

"We felt that it had a lot of upsides, both in terms of market potential and potential to do good for the

environment," Otworth said, describing the technology as a "purification process." It does not involve depolymerization, he said.

"There's no real chemical transformation that goes on," he said. "It's a largely physical process."

Inks and additives are removed in multiple stages. The plastic is heated and the viscosity of the molten resin is varied in a way that creates conditions that are advantageous for efficient purification, he said.

The result is PP with near-virgin-plastic qualities, according to those involved in the project. The process removes odor, contaminants and most color, according to the press release.

Employing 15 people, the PureCycle facility now under construction will serve as a feedstock evaluation unit (FEU), testing a variety of streams to help PureCycle determine what mix to buy to meet end-user requirements.

The press release noted the FEU, slated to begin operation in January, will also assess PureCycle's environmental impact.

The Association of Plastic Recyclers (APR) has identified 1 billion pounds of recycled PP demand in North America, with nearly three-quarters of that for high-quality material. Steve Alexander, APR's executive director, said his group is viewing the announcement with optimism. He also described P&G as one of the pioneers of plastics recycling over the years.

"We're excited about this," Alexander said. "We're hopeful that technology will help address some of that unmet demand that is in the marketplace for recycled polypropylene."

PureCycle is already looking at a global feedstock acquisition strategy, even though production scale is still a few years away, Otworth said. Customers will probably include a mix of brand owners such as P&G, who are buying resin for their own use, and molding operations supplying products to a variety of customers.

## NatureWorks Creates New Division

### Company Press Release

June 20, 2017—NatureWorks has formed a Performance Chemicals Division to supply lactides, polyols, binder resins, and chemical intermediates to companies that manufacture innovative C.A.S.E. (coatings, adhesives, sealants, and elastomers), toners, and fine chemicals.

“The NatureWorks Performance Chemicals Division delivers renewably sourced chemical intermediates with tailored functionality at competitive prices that help customers move through the R&D process faster with minimal supply chain risk,” said Richard Weber, Performance Chemicals Division General Manager. “This new business focuses on collaborative innovation with our customers across R&D, product development and operations – a far different approach than found today with most global suppliers of functional intermediates.”

Vercet™ is a new tunable platform of lactide-based chemistries from the NatureWorks Performance Chemicals Division. The customizable properties of Vercet polyols provide excellent hardness, solvent resistance, and low color in polyurethanes. As components in polyester resins, Vercet lactides can be used to create low volatile organic compound (VOC), solvent-borne alkyd resins for wood, and metal coatings that have excellent adhesion and impact resistance. Solvent-borne coatings and hotmelt adhesives utilizing Vercet intermediate resins offer a tunable work life, more end-of-life options, excellent adhesion, as well as low dispensing temperatures for food packaging, paper, fiber board, and wood applications. Vercet lactide-based products will have direct and indirect food contact approval as well as inherent health and environmental safety advantages when compared to traditional chemical building blocks.

## China Offers Clues on What Will (and Won't) Be Allowed In

### By Colin Staub, Plastics Recycling Update

August 23, 2017—Chinese authorities have released more specifics about which materials are likely to be affected by a proposed import ban on recovered materials. The action is expected to be implemented at the end of this year.

In recently posted government documents, China elaborated on its previous statements that PE, PET, PS, PVC and “other” recovered plastics will be prohibited from import into the country, according to multiple online translations of the documents and perspective provided by Steve Wong of the China Scrap Plastics Association.

The recent Chinese information appears to indicate the resins noted above will only be banned outright if they come from post-consumer sources.

Post-industrial recycled plastics, on the other hand, are on a list of “restricted” imports, meaning they can still head into the country, according to Wong. Specifically, those plastics include production scraps, off-cuts and regrind, said Wong, who also serves as chairman of Hong Kong plastics recycling company Fukutomi.

There are similar developments on the paper side, where more clarity on specific prohibited and allowed materials was detailed in the new documents.

The ban regulations will take effect Dec. 31, according to Wong, but some North American exporters have already reported problems sending materials to China. The Canadian Plastics Industry Association is compiling an online database to track rejected shipments, in order to quantify the impact of the ban. |



**REDUCE! REUSE! RECYCLE!**

# Plastics Sustainability

Excerpted from *Plastics Sustainability* (2012) by Michael Tolinski with permission from Scrivener Publishing LLC.

**[Editor's note:** *This is the second article in a series that will run over 6 installments. We are grateful to the publisher for granting us this unique opportunity to share excerpts from an important (and enjoyable) book on a topic that is central to our industry. The SPE Sustainability Division is proud to offer this benefit to our members. We encourage everyone to purchase the complete book which is available on Amazon.]*

## The Life Cycles of Plastics

With manufactured products, a cradle-to-grave life cycle assessment (LCA) requires addressing all inputs and outputs (energy and materials) involved in the production, use, and disposal of a product. This chapter describes the basic principles and methodologies used for determining and evaluating these life cycle impacts, with special emphasis given to plastics-related applications and materials.

Any attempt to wade through the materials related to material life cycles and environmental sustainability is grueling, and developing useful conclusions is futile unless the process is anchored to certain guiding principles for sustainability. The basis of these principles is the acknowledgement that human activity makes certain demands on the earth's resources, creating wastes and disorder in the earth's system as a result. Inputted and outputted energy and materials flow through each stage of the production, use, and disposal phases of a man-made (or nature-made) object. Only nature seems to handle this complexity with any real skill; if people interested in sustainability have a shared goal, it would be to understand how to mimic the efficiency of nature in its use and reuse of the earth's resources.

## Life Cycle Assessment (LCA)

Life cycle assessment (or analysis) has mainly been performed on industrial materials and products since the 1990s. Simply put, LCA is a methodology or technique for identifying, measuring, and evaluating all the energy and material flows that result from making, using, and disposing of a target product or material. The resulting assessment

allows manufacturers to identify the most important ways of minimizing waste, energy, and the overall environmental footprint of a product or group of similar products.

The use and development of LCA has been growing slowly, given its complexities and limitations. (From my own experience, most of the issues discussed during a life cycle conference at Chrysler Corporation in 1997 remain fresh and relevant, and continue to be debated today.) LCAs require a great deal of work to complete, even for simple products. Thus, their objectives and assumptions must be compelling enough to motivate the use of LCA by researchers, manufacturers, and other organizations. General motivating assumptions may include the following: [1] that the earth's ecosystem and climate are being damaged by waste and pollution from human activities (specifically from the production of the material or product of interest), and that this damage can be lessened; [2] that the earth's basic resources, including fossil fuels and fresh water, are being overused and depleted by producing the material/product; and [3] that a manufacturer's internal economic efficiency, environmental impact costs, or public image are less than optimal because of the ways its processes and products use resources or produce waste. Obviously the first two assumptions would motivate environmentally focused researchers; the last assumption could motivate nearly all manufacturing-related researchers, whether they accept arguments [1] and [2] or not.

The full explanation of LCA methodology can be quite theoretical and is beyond the scope of this book. In brief, first an LCA's goal and scope must be defined, as well as its metrics, allocation of inputs and outputs, and system boundaries. An LCA is normally based around a chosen "functional unit" that is meaningful and useful for making comparisons (that is, a measurement or quantity of some "thing" to be assessed). Essentially, the LCA method then breaks down the stages of the unit's (product's) life cycle, looking at the material and energy inputs and waste outputs at each lifecycle stage. Below are life-cycle stages normally of interest, which I have tried to place into context for plastics-related manufacturing:

- Raw material acquisition (such as oil or natural gas production, or in the case of bioplastics, biomass production).

- Material processing (the creation of monomers and reagents for polymerization, and subsequent polymerization and compounding to create bulk plastic materials).
- Manufacturing and assembly (the molding, extrusion, or other forming or conversion of bulk plastic compounds, plus any secondary operations).
- Use-life (the use of the plastic product by the consumer, including the energy for shipping or handling the product, and the effects of its use).
- End of life (the possible recycling or reuse of the product/material, before disposal).
- Disposal (the final resting place of the plastic product, whether it is landfilled, incinerated, or composted, including the disposal method's material/energy inputs and outputs).

### Life Cycle Inventory (LCI)

The LCA process requires identifying all material flows at each stage of a product's production. This "life-cycle inventory" (LCI) lists and quantifies all materials that are present in the product, or that are required or produced in its processing, use, or disposal. This knowledge can be extremely valuable by itself for identifying and quantifying objectionable outputs from plastics production. An LCI can be valuable for minimizing plant emissions, avoiding harm to the environment and stiff monetary penalties for chemical releases. For example, in 2010 an ABS resin plant near a public school in Ohio was fined over \$3 million by the US EPA for excessive emissions, and later faced a lawsuit filed by the local school district<sup>i</sup>.

When the LCI is as complete as possible, its flows are then converted into appropriate per-product basis data for use in the next LCA step – the life cycle impact assessment (LCIA). Here, various environmental impacts are calculated from the LCI outputs and inputs to assess the overall footprint of the product system or material unit. These impacts are then weighed and evaluated in the final interpretation phase of the LCA.

### LCA/LCI Plastics Example

The following summary shows how a life-cycle study was used to evaluate the environmental footprints of certain plastics. Besides providing thought-provoking results, it illustrates the choices that must be made about the scope, assumptions, and metrics of an LCA or LCI and how those

choices can influence an evaluation.

### *LCI of Post-Consumer Recycled PET and HDPE*

Given the interest in expanding the recycling of commodity plastics packaging, it is useful to have LCI data close at hand. To this end, in 2010 Franklin Associates<sup>ii</sup> attempted to identify and quantify the key material and energy flows associated with postconsumer recycled high-density polyethylene and PET, to allow comparisons of environmental impacts between the recycled materials and their virgin, pre-consumer forms. The authors created a usable study of limited length by limiting their scope, identifying only the most important material/energy burdens for which they could acquire data.

The report is also full of stated assumptions (warranted by statistics about recycling) that are necessary in such a task. For example, the researchers had to estimate how much fuel is used by consumers to drop off recycled materials, how much fuel is used by curbside recycling collection vehicles, what percentage of PET and HDPE is contained in the collected materials, and so forth. The authors also calculated values based on the assumption that the recycled material could be expected to have two total "lives" (that is, a second life after recycling, followed by disposal). This determined how they should incorporate the environmental impacts of the virgin resin production when the recycled resin was originally produced. Their detailed quantitative results were of the type that could be used in a full LCA; here, some of their interesting results are summarized:

- The total energy for collecting, sorting, and reprocessing 1,000 pounds of post-consumer PET and HDPE was less than one-sixth as much as that required for producing virgin resin (which inherently possesses great energy content in its chemical composition).
- The greenhouse gas emissions from recycling, including emissions from material collection, were about one-quarter to one-third of those in virgin resin production.
- Solid waste production when recycling the postconsumer materials was higher than with virgin material production, because of the residuals and unusable materials produced by the sorting and reprocessing steps.

### **Plastics Lifetimes: Cradle-to-Gate, Gate-to-Grave**

Raw materials for producing polymer feedstocks all have

potential environmental impacts, whether through the risk of environmental damage caused by drilling for oil (as in the 2010 BP Deepwater Horizon disaster), or the inefficiencies of fertilizing and harvesting crops for bio-feedstock production, which currently still relies heavily on the use of fossil fuels.

Economic pressures will also affect the choice of fossil- or bio-based feedstock. Most polymer feedstocks are still based on the commodities of oil and natural gas. These commodities' prices ebb and flow, sometimes staying in a narrow price range for a long period (as oil did in 2010), or dropping or rising radically (as oil did in early 2011), throwing supply chain cost planning into chaos<sup>iii</sup>. And of course, these are not renewable commodities; they are theoretically finite in supply and eventually will become much more costly and polluting to produce.

Conversely, most current bioplastics are based on renewable agricultural "biomass" commodities such as corn and sugarcane, synthesized mainly by the free light of the sun and the greenhouse gas CO<sub>2</sub>. But their price is affected by the weather, government subsidies, fertilizer costs, water consumption, land use competition, and global food supply trends.

Whatever the biofeedstock source, the true bio-content of the resulting polymeric material must be confirmed if the product can be called bio-based. The ASTM standard D6866 can be used to calculate the actual percentage of bio-based organic carbon in a material by measuring the proportion of the isotope carbon-14 in the material, and comparing it with a standard. (In other words, the organic fossil carbon in a traditional polymer would be expected to be all carbon-12; the carbon from a 100% plant-based polymer, however, would be expected to have a certain proportion of carbon-14 that was created by solar radiation in the atmosphere).

Narayan<sup>iv</sup> suggests that although there is no "magic number" as to what this bio-content percentage should be for a plastic to be called a bioplastic, a bio-carbon content of at least 25% would signal that the material allows significant CO<sub>2</sub>-reductions, especially if the material is used in high enough volumes to displace traditional fossil fuel-based plastics.

## Recycling

Source reduction, or minimizing the amount of resin per product, is the key way of reducing the life cycle impacts of plastics. But ultimately at least some polymer must be used in a product, and if current practices prevail, most of it will continue to be disposed of at end of life, the full value of its chemical bonds lost forever. Thus, the recycling of most plastics will remain an important goal, despite the particular challenges recycling presents.

Plastics production continues to outgrow plastics recovery, in the United States at least. This has helped keep the recycling rate of all plastics in the United States extremely low, at about 10%. And the rate for plastic recycling's star performer – the PET container – remained well below 30% in the years following 1997, which was roughly the start of the period when PET water bottle use started increasing. (By comparison, in China, where recycled PET has high value, the bottle recycling rate was recently reported to be around 80%.) For plastics other than PET and HDPE containers, the recycling rate in the United States is well under 10%<sup>v,vi,vii</sup>.

To some, the economic pitfalls of plastics recycling and low recovery rates may seem to indicate that it is not wise to expect recycling to flourish in developed countries with efficient petrochemical industries. But it is also possible that the infrastructure and markets for recycling have not developed past a tipping point after which they become strong and stable. This may require intervention outside of overall market forces, as the US government and other governments often consider and do. Laws requiring deposits on plastic bottled beverages is an obvious example, and this does increase collection rates, though it has traditionally been opposed by retailers and producers who dislike the associated costs and effects on consumer purchasing decisions. Or for instance, the US Senate has considered a law that would allow government agencies to pay a 10% premium for supplies that contain at least 25% recycled material – the argument being that such practices have in the past driven the creation of competitive, efficient markets for supplying and consuming recycled material<sup>viii</sup>. Such interventions arouse ideological approval (environmentalists) and opposition (free market advocates), though one could argue that our oil-dependent economy itself would not exist without certain kinds of government intervention.



[In the next issue: **Polymer Properties & Environmental Footprints**]

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# Have an idea for an article?

### Submission Guidelines

- Articles should be objective and technical
- Format: .doc or .docx

- Topics can include recycling, bioplastics, economics or innovative technologies related to polymers and sustainability

Email Conor Carlin at [cpcarlin@gmail.com](mailto:cpcarlin@gmail.com)

# ISRI Conference 2017 - SPE Plastics Session: Integrating Unconventional Fillers in Plastics Applications

By Chris Surbrook, New Business Development,  
Midland Compounding, Midland, MI

*[Editor's note: this paper was originally presented at ISRI 2017.]*

## Abstract

Integration of waste material streams into plastic composites is an interesting approach to both solving disposal issues and developing useful materials for plastic applications. Projects are described where: (1) wood sawdust is incorporated into polypropylene (PP) and compared to conventional talc filled polypropylene; (2) ground paper waste is dispersed into polyethylene (PE) sheet for a thermoforming application; (3) paint waste and filtration media were collected and compounded in PP for applications such as paint brush handles and dunnage trays; (4) a composite material containing ground tire rubber and PE was developed for a structural foam molded dunnage tray. Physical properties and comparison to conventional materials are described. Key decisions for determining the use of unconventional fillers is discussed.

## Introduction

Midland Compounding & Consulting compounds prime and post-industrial thermoplastics. Our mission since 1999 is to develop specialty thermoplastic compounds and to offer unique solutions to difficult recycling opportunities, applying expertise in processing, formulation, and compounding to produce value added materials. Our lab is designed for plastic recycling research with processes for validating materials, through fabrication and testing, to verify that new materials will work in commercial practice. We help to develop and prove case studies that demonstrate the benefits obtained from projects. We collaborate with groups like Vehicle Recycling Program, The Sustainable Research Group, and we participate in college research projects.

The use of non-plastic materials as fillers in plastic is a well-established practice for at least the last five decades. Industrial minerals and other materials like calcium carbonate, fiberglass, mica, talc, and wollastonite have

been added to plastics to either reduce the cost of materials, or to improve the performance of the plastic. The resultant compounds have been studied and engineered to help reinforced plastics become one of the most prolific raw materials of the industrial age. The broad commercialization of these materials has earned them the distinction of becoming "conventional" fillers.

This paper will focus on materials other than conventional fillers that are in their infancy of adoption into commercial application with a focus on recycled materials. Some of these unconventional fillers like saw dust, paint, and paper powder aim to displace conventional fillers by offering a stronger economic value proposition. Other materials such as crumb rubber, distillers grain, and biomass fillers aim to promote sustainable manufacturing practices and to improve the margins on the raw materials into higher value applications. All of these fillers are designed to yield plastic compounds with performance properties sufficient to meet the requirements of new end products that will lead to commercial success.

Over the years Midland Compounding & Consulting has participated in many diverse recycling efforts with many different stakeholders. Some projects were driven by brand holders to reduce the amount of waste being generated during manufacturing of their product that was being sent to landfills. Other projects involved improving the amount of plastic being recovered from post-consumer scrap. Each project had its own unique definition for success and barriers for adoption into practice. The following 4 case studies offer a look at the different aspects of using unconventional materials as fillers in their respective programs.

## Case Study 1: Saw Dust into Polypropylene

It was reported that Herman Miller generates 16,425 tons of sawdust per year. This is up from the 1,820 tons that was reported in 1991. Midland Compounding & Consulting has developed a compound that could convert 2,500 tons of that sawdust into functional polypropylene compounds.

The sawdust was pulverized and compounded into post-

**Table 1 - Comparing 50% Sawdust Filled Polypropylene to 40% Talc Filled Polypropylene**

Property	Method	Units	40% Talc Filled	50% Sawdust Filled
Specific Gravity	ASTM D 792	g/cc	1.23	1.09
Tensile at Yield	ASTM D 638	psi	3,450	3,900
Tensile at Break	ASTM D 638	psi	3,450	3,900
Break Elongation	ASTM D 638	%	15	2
Flexural Modulus	ASTM D 790	ksi	380	453
Flexural Strength	ASTM D 790	psi	TBD	7,221
Notched, Izod Impact	ASTM D 256	ft.lbs./in	0.8	0.87
Melt Flow Rate (230°C / 2.16 kg)	ASTM D 1238	g/10 min	10	2.5

consumer polypropylene (PP) regrind resin. Table 1 shows the mechanical properties of that material with 50% loading of the sawdust and compared it to a traditional 40% talc-filled polypropylene commonly used for injection molded parts in automotive, office furniture and building and construction applications.

Comparing the test results, the the following observations were made:

- The sawdust-filled PP material has lower density, higher tensile strength and flexural modulus with similar impact strength to the talc-filled PP
- The sawdust-filled product was made from 50% post-consumer, recycled polypropylene, bottle cap making it potentially eligible for **CI-2009 MRc4: Recycled Content** LEED credit
- The surface appearance of parts made using the sawdust-filled PP were uneven and rough

Based on these observations, it was determined that the sawdust filled material was acceptable to use in certain applications currently using talc-filled PP where appearance was not critical. When the customer reviewed the amount of internal opportunity this new material could fill, it was too small to consume a meaningful enough volume of the sawdust scrap. Ultimately, the sawdust was converted to fuel for energy that helps power manufacturing operations.

### Case Study 2: Paper Powder Polyethylene

A company in Standish, MI had an opportunity to compete for a project that was being manufactured in China using hand-made paper-maché parts. The proposed manufacturing model was to automate production using thermoformed sheets. They wanted to develop an inexpensive compound that was potentially hydrophilic and offered an appearance similar to the paper-maché parts. They commissioned research into a paper-filled PE compound.

Every day, thousands of pounds of paper shavings are generated from commercial printing and publishing activities. Much of this material cannot be recycled because the fiber length is too short to be recycled back into paper. The particle size of this material lends itself to being compounded into thermoplastic, but the residual dye and adhesives cause compatibility issues with the plastic. This material was selected for the research due to its economics and form. It was combined with recycled, post-industrial high-density polyethylene (HDPE).

Initial experiments were performed to understand the compatibility of the paper into the HDPE. Paper was compounded into the HDPE at 25% and 50% by total formulation weight. Samples were injection molded and tested for mechanical properties. There was very little

difference between the sample with 25% paper (Sample A) and that with 50% paper (Sample B). Both had poor mechanical properties. This was believed to be due to relatively poor dispersion of the paper into the base resin matrix.

Additional testing was done with 50% paper powder into HDPE. For this work, we evaluated an ultra-fine silica bead (Sample C) and a compatibilizing agent (Sample D) to aid in the dispersion of the paper into the HDPE. Test specimens were manufactured in the exact same manner as the original work and tested for the same type of mechanical properties characterization. Sample C, showed no improvement in dispersion visually, but Sample D showed significant improvement. Samples B and D were compared to the prime HDPE. The results are presented in Table 2.

Comparing the test results from Samples B and D to the base resin material, the following observations were made:

- The paper filled materials both show a reduction in tensile elongation, impact strength and viscosity
- Sample D showed less of a reduction in viscosity and tensile elongation than sample B
- Both samples B and D showed an increase in tensile strength

Based on the mechanical properties of Sample D, a larger batch of compound was produced for a sheet extrusion and thermoforming trial. The compound was extruded into sheet that was 0.040" thick. Sheets were then thermoformed on a small mold and presented to the customer. The customer liked the surface texture and is waiting for the end customer to move manufacturing back to the U.S.

### Case Study 3: Recycled Paint Wastes into Polypropylene

The current method for filtering air in automotive paint shops utilizes a water curtain and bath process that captures the paint overspray as well as other airborne particles, and drains them into a collection basin. A company in Detroit has developed a novel new material utilizing paint waste and compounding it into polypropylene. To recycle the collected paint waste, one first has to evacuate the remaining 20-25% water weight from the sludge. The second difficulty is separating contamination in the sludge (e.g., things like metal shavings and organic growth that were collected during storage). These issues are inherent in automotive paint shops around the world and the industry is looking for ways to re-purpose this material.

The company has developed a solution for recycling and

**Table 2** - Comparison of Paper Filled HDPE to Recycled unfilled HDPE

Property	Method	Units	Recycled HDPE	Sample B 50% Paper Filled PE	Sample D 50% Paper Filled w/modified PE
Tensile at Yield	ASTM D 638	psi	1,902	1,793	3,200
Tensile at Break	ASTM D 638	psi	1,814	1,661	3,052
Yield Elongation	ASTM D 638	%	50	3	8
Break Elongation	ASTM D 638	%	126	4	8
Flexural Modulus	ASTM D 790	ksi	-	152	154
Flexural Strength	ASTM D 790	psi	-	3,294	4,395
Notched, Izod Impact	ASTM D 256	ft.lbs./in	NB	1.44	2.15
Melt Flow Rate (190°C / 21.6 kg)	ASTM D 1238	g/10 min	40-45	64	47

**Table 3 - Comparing recycled paint materials to prime polypropylene**

Property	Method	Units	Prime Injection Grade Impact PP	100% Recycled PP Filters	50% rPP Filter 50% Paint
Tensile at Yield	ASTM D 638	psi	3377	3721	1396
Tensile at Break	ASTM D 638	psi	2330	3654	1385
Yield Elongation	ASTM D 638	%	6.55	7.52	14.4
Break Elongation	ASTM D 638	%	26	9	18
Notched, Izod Impact	ASTM D 256	ft.lbs./in	10.71	0.98	1.1
Melt Flow Rate (230°C / 21.6 kg)	ASTM D 1238	g/10 min	19.69	78.9	28.34

**Table 4 - Polypropylene Filter Media Dilution Study**

Property	Method	Units	Prime Injection Grade Impact PP	100% Recycled PP Filters	45% Recycled PP Filters	25% Recycled PP Filters
Tensile at Yield	ASTM D 638	psi	3377	3721	3616	3491
Tensile at Break	ASTM D 638	psi	2330	3654	3240	2727
Yield Elongation	ASTM D 638	%	6.6	7.5	7.2	7.2
Break Elongation	ASTM D 638	%	26	9	15	21
Notched, Izod Impact	ASTM D 256	ft.lbs./in	10.7	1.0	1.5	2.0
Melt Flow Rate (230°C / 21.6 kg)	ASTM D 1238	g/10 min	19.7	78.9	45.8	29.2

handling liquid filtration by-products such as paint over-spray and other hazardous and non-hazardous filtration materials with little or no changes to the existing filtering process. The paint over-spray collection box is diverted from landfill to a center for processing. This process generates two streams of materials for recycling: one, the filter media which is primarily polypropylene; and two, the captured paint, which at this stage is a sludge.

The sludge is then brought through a proprietary process for separating out contaminants and preparing the sludge for recycling. While the sludge and filter media are being separated, the process captures and segregates the

metals, oils and solvents. The “segregated” sludge and filter media can now be dried and converted into granules that can be introduced into thermoplastics, in particular polypropylene, as a filler material.

Midland Compounding & Consulting, Inc. was contracted to test and confirm the feasibility of recycling these materials. Samples of differing concentrations of paint content and filter media were dried, compounded, injection molded, conditioned, and tested. The results from the tests were compared to prime, impact copolymer PP to determine the effect on material properties.

**Table 5 - Polypropylene Paint Compounds Dilution Study**

Property	Method	Units	Prime Injection Grade Impact PP	50% rPP Filters 50% Paint	Sample A 55% Prime PP, 22.5% Filters, 22.5% Paint	Sample B 75% Prime PP, 22.5% Filters, 12.5% Paint
Tensile at Yield	ASTM D 638	psi	3377	1396	2681	2913
Tensile at Break	ASTM D 638	psi	2330	1385	2354	2400
Yield Elongation	ASTM D 638	%	6.6	14.4	9.4	8.8
Break Elongation	ASTM D 638	%	26	18	22	24
Notched, Izod Impact	ASTM D 256	ft.lbs./in	10.7	1.1	1.3	1.3
Melt Flow Rate (230°C / 21.6 kg)	ASTM D 1238	g/10 min	19.7	28.3	22.6	27.3

The recycled materials were then compounded with the prime polypropylene at 2 different levels, molded and tested to understand the effect diluting the recycled materials content has on the final mechanical properties. The test results from that work diluting the PP filter media are listed in Table 4 and for the paint compounds in Table 5.

Comparing the test results from these efforts, the following observations were made:

- The prime polypropylene material selected is a high-performance grade of material
- The recycled materials have a higher melt flow rate and lower notched impact resistance than the prime material
- Melt flow rate can be successfully modified with blending the recycled material with the prime polypropylene
- The loss in impact strength is too great for the recycled materials to be used as filler in the same applications as the impact polypropylene

After review of both sets of work, it was ultimately concluded that formula for Sample A could be used in the production of dunnage containers for returnable packaging.

**Case Study 4: Crumb Rubber Polyethylene**

The EPA estimates that only 35.3 percent of the millions of tires sold in 2009 were recycled. Tires are viewed as one of the most problematic sources of all waste. This

is mainly due to the high quantities produced and their great durability, prohibiting the tire from breaking down. By recycling tires we also reduce the amount of raw rubber needed for manufacturing, saving natural resources like crude oil. From 1990 to 2003, the total number of scrap tires going to market increased from 11 million to 233 million. In 2005, 290 million new tires were manufactured and 259 million tires were deemed scrap material. Of all the scrap tires discarded today, over 75 percent are recycled or used for fuel or other applications.

Tire durability makes reuse and recycling of scrap tires easy. There are several common commercial practices for recycling tires:

- Re-treading to reuse as tires
- Asphalt production
- Fuel for manufacturing energy
- Synthetic turf

In an effort to improve the use of recycled tires, and to enhance the value of crumb rubber, applications are being developed to use crumb rubber as filler in thermoplastics. One such effort is the use of crumb rubber in polyethylene to make inexpensive pallets using structural foam molding. Initial research was performed to determine mechanical properties of polyethylene-filled crumb rubber from different sources of rubber. The results are reported in Table 6.

**Table 6 - Comparing different sources of crumb rubber**

Property	Method	Units	Recycle HDPE	Sample A	Sample B	Sample C	Sample D
Tensile at Yield	ASTM D 638	psi	3127	1858	1317	1580	1525
Tensile at Break	ASTM D 638	psi	1904	1649	1289	1454	1464
Yield Elongation	ASTM D 638	%	10	18	10	29	35
Break Elongation	ASTM D 638	%	172	27	11	42	43
Flexural Modulus	ASTM D 6790	ksi	113	54	42	43	38
Flexural Strength	ASTM D 790	psi	3029	1571	1467	1416	1356
Notched, Izod Impact	ASTM D 256	ft.lbs./in	1.66	2.54	3.48	4.1	4.57
Melt Flow Rate (190°C / 21.6 kg)	ASTM D 1238	g/10 min	8.8	3.7	–	1.8	–

Comparing the test results from these efforts, the following observations were made:

- Crumb rubber reduces the tensile strength and break elongation, as well as decreases stiffness, but the amount of change differs depending on the source of crumb rubber
- Notched IZOD impact strength is increased by all sources of rubber, but the amount of improvement also changes depending on the source of crumb rubber
- There is no direct correlation between the reduction of tensile and flexural properties and increased impact strength base on the source of crumb rubber

These findings, along with economic considerations, allowed for selection of a crumb rubber supplier to move forward in the research. With the rubber and plastic raw materials selected, the formulation was further refined to meet all the performance requirements for the pallet. Several formulas were scaled up for production molding trials and pallets were produced using the structural foam molding process. As of the writing of this paper, parts were being validated for approval.

### Key Decisions for Determining the Use of Unconventional Fillers

The aforementioned case studies encompass a diverse set of performance requirements, value propositions and stakeholders, but they all share several key factors that need to be considered whenever determining if

an unconventional filler is a good fit for a program. The following are some of the factors that apply:

1. **What is the end application that will consume the new material?** In order for most development projects to be successful, they must start with the end application in mind. The more detail that can be used to define the end application, the easier it will be to navigate the developmental process and help to answer myriad questions that arise to move to the next stage of research. Questions include:
  - a. Will the new material meet the mechanical property requirements?
  - b. What is the desired part appearance?
  - c. Will it be exposed to elements that may alter or degrade the material?
  - d. What conditions should be used to age the material and what tests should be run on the parts once their aged?

2. **What is the base resin matrix for which the filler will be added?** It is important to understand the base resin and its performance requirements. This will guide decisions for approval as the effects of the filler on the resin are tested. Is the filler is compatible with the resin matrix? Knowing this will also aid in determining what modifications need to be made to the base resin in order to receive the new filler, or to maintain the critical performance characteristics. If it is not compatible, then a different set of questions need to be asked:

- a. Is there a compatibilizing agent that will work and can we afford it?
- b. Can we change the base resin matrix to something that is compatible and still meet the performance requirements?

**3. What is the cost to prepare the filler into a reusable state?** Typically, one of the key performance characteristics in the use of unconventional fillers into thermoplastics is economics. It is critical to understand the cost of preparing the new filler to a state that it can be reintroduced to another manufacturing process, and how it will be handled going into that process. For example, if the new filler is going to be fed into an extruder to be compounded into plastic, one would need to know how it is going to be fed into the extruder and the throughput required so that it does not constrain the processes. If the new filler causes significant changes to this process, or impedes the normal flow of materials, then it may become too challenging to use.

**4. What are the costs to manufacture an end product using the unconventional filler?**

- a. Does it offer a raw material cost savings? If not, is it at least cost-neutral? Most recycling programs look for the cost of raw materials to be no more than 70% of the cost of prime materials. This is largely due to the perception that recycled raw materials have a lower cost basis than prime materials. Another explanation for why the price is expected to be discounted is due to perceived risk associated with anticipated lot-to-lot inconsistencies of recycled materials. The reality is that recycled materials require greater quality controls and are typically sampled more often and tested more frequently than manufacturing practices for prime materials. The best-case pricing scenario for most recycled materials that they be the same price as the prime materials.
- b. Is the drive to divert the material being used an unconventional filler from its current end of life strong enough to support a cost increase to the new raw materials? Very seldom does a material using unconventional fillers merit a price higher than that of prime materials. In those cases where the customer will accept a higher price, however, this is usually due to some benefit received by not having to dispose of the unconventional filler from its first run use. Another

benefit can be a credit or incentive provided to offset the higher price. Finally, a new innovation can open up new opportunities for the business.

- c. Are the supply sources of the unconventional filler able to meet demand? One significant issue in opting to use an unconventional filler is source of supply. It is best to use the theory of constraints when vetting this issue; that is, to investigate the capacity and capability of each link in the new “supply chain” and determine their ability to supply, and then identify the most likely interruptions to supply. The lowest output value of that exercise will determine the final capacity for supply of the unconventional filler.

- d. Are there other incentives from the use of the unconventional filler that help to offset the new costs of manufacturing (e.g., tax credits)? Once the cost of converting the unconventional filler into a new raw material form is fully understood, it is important to determine if any credits or incentives exist for the consumer of the new raw material. As mentioned in above, sometimes the greater value for the new material may lie in the taxes it saves the user. One example of this would be from the state of California. Tax exemptions became viable under an AB 199 bill, authored by the assembly member Susan Eggman. The tax exemptions of California Alternative Energy and Advanced Transportation Financing Authority (CAEATFA) imply operations such as “purchases of equipment used to process recyclables for use in other products, or manufacturing new products from recyclable material”. Similarly, the use of the unconventional filler may offer non-monetary incentives like accelerating program approvals, or expanding into new markets. These incentives help to justify the use of the material over price.

**5. What are the other effects of the unconventional filler on the processes used to manufacture the new end product?** There are many other factors that need to be considered for a material using unconventional fillers after the formulation has been fully vetted and approved. Answering these questions can sometimes be more challenging than developing compounds from prime materials, because empirical information about the unconventional materials may not be known, or at least may not be known in the context of the new application. Here are some questions that should be asked regarding



- the new material before concluding development:
- What effect will the new material have on the manufacturing process of your customer?
  - Will it decrease manufacturing throughputs?
  - How will the material be handled and introduced into their process?
  - Will your customer be compelled to modify their process to accommodate any idiosyncrasies of the new raw material?
  - Does using this material create any OSHA or other potential handling concerns?

**6. What are the effects of the new material at the end of new product's life?**

- Will the new material alter the end product's shelf life?
- What will be the environmental impact of the new

- end-product when it's consumed?
- Is the new end-product recyclable?
  - If so, does the unconventional filler contaminate the current recycling stream?
    - If so, does it eliminate the new end-product from recycling?
    - If not, what new handling measures are required when recycling the end-product? New labeling, special handling, new form of recycling (e.g., incineration vs. grind and reuse)

Once questions like these are answered and fully understood, it increases the likelihood for commercial success of the unconventional filler in its new application. The information derived during this process should also help to mitigate the risks for all the stakeholders in approving the use of the new material. |



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