I knew that by choosing the right questions I was going to be able to prove to these people that the project was just wrong, or at least not practical. My first list of questions was the following:

- Is it a starch-filled product? NO
- Is it going to be very expensive? NO
- Is it safe to use? YES
- Is it difficult to manufacture? NO
- Will it be difficult to process in the diaper lines? NO
- Is it difficult to control its shelf life? NO
- Will it require special packaging requirements? YES
- Will it degrade in the landfill? YES (but not quickly)

Well, after I heard these answers, I just had to give this project a try. Somehow deep in my mind, I still believed I was going to be able to prove them wrong, so I was decided to get the evidence. From that moment, it became Absormex's R&D department number one priority. I am glad to say we were lucky to take the challenge, I am also happy to say I was wrong, Joseph Gho and Dr. D.M.Wiles (EPI's top executives) were right.

Let me start defining some simple terms:

What is degradation?

Degradation is the process in which a product is capable of being chemically degraded, changing its mechanical and chemical properties. A product is degradable when it can change its properties in a time scale due to the action of heat, light or mechanical stress

What is biodegradation?

Biodegradation is the process in which a product is capable of being broken down into innocuous sub-products, like CO2 and water, by the action of living things (as microorganisms). A banana peel will biodegrade into biomass, CO2 and water. Products that are susceptible of biodegradation are also referred as "bioactive".

Why are plastics non-degradable?

A plastic product consists of a very large number of molecules, with a molar mass in the hundreds of thousands in the case of polyolefins. (polyethylene and polypropylene). Because of this composition, polyolefins are strong, tough, inert and not water-wettable. It is a combination of these characteristics that make polyolefins resistant to microorganisms (i.e. they are bioinert). Indeed, polyethylene is frequently used as a control standard of non-biodegradability. A simplistic analogy is to consider an ant at the middle of the terminal station, looking at 100 trains put together one after the other, and trying to find the ends of this super-train.

How can you make degradable plastic products?

One way, at least the one I am presenting with this paper is using TDPA^{TM} (Totally Degradable Plastics Additive). It is a technology that uses an additive package that is mixed with the plastic

pellets before the extrusion process. E.P.I.- Environmental Products Inc offered this patented technology to us. Since we are not producers of raw materials, to make the treated plastics we formed strategic developmental teams with our raw material suppliers.

How does it work?

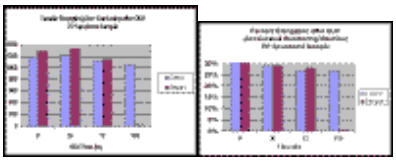
Plastics treated with TDPA™ change their molecular structure after exposure to ultra-violet-light, heat and mechanical stress. Once the product is exposed to any of these conditions; just light, just heat without light, or any combination of heat, light and stress, it becomes brittle and breaks up into much smaller molecules due to an oxidative degradation mechanism. The resultant fragments have an important reduction in their molecular weight.

When the treated PE and PP plastic starts to break, literally the molecular chain fractures into smaller pieces, changing into carboxylic acids and alcohols. They may be expected to continue to reduce their length until they become "bioactive", though not totally proven at this point. These molecules are anticipated to become short enough to be assimilated by microorganisms. The resultant fragments are expected to change into biomass and into CO2 and water, leaving absolutely no toxic by-products.

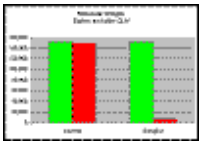
What evidence do we have that they actually degrade?

First thing we did was to expose the treated PE and PP samples to a weatherometer (ASTM-5208). Then we measured percent elongation and tensile properties (ASTM-1682-64)

(Click to Zoom)

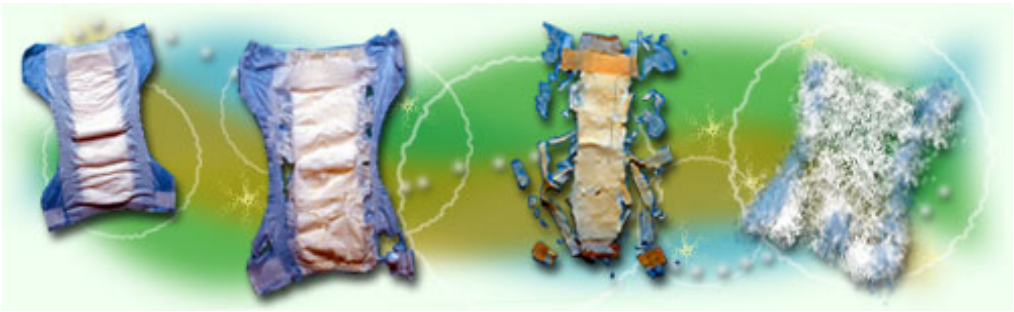


Gel Permeation Chromatography (GPC) tests proved an important reduction in the average molecular weight of the samples.



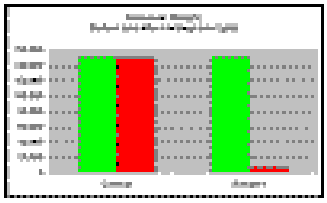
At simulated outside weather conditions the samples not only degraded, they degraded too fast! Future trials helped us fine-tune the TDPA™ active ingredient to our current needs, to avoid insufficient shelf life. Our current product degrades in actual outside weather conditions in less than a month (23 days).

Photographs of a treated diaper
exposed to the outside weather
at one-week intervals



Artistic representation of the degradation process

We also carried tests using forced convection ovens (ASTM-D5510-94) at different temperatures (without any light). We were able to correlate the effect of the temperature in relation to the degradation process. Using the "Arrhenius equation" as a mathematical representation of our data, we were able to forecast shelf life at different temperatures and fine tune the dilution rate for TDPA™. Gel Permeation Chromatography tests were made to the heat aged samples, proving again an important reduction in molecular weight, similar to the QUV aged samples. These experiments demonstrate that the product degrades with ultra-violet-light, and also with heat with no light, they have also helped us in forecasting the time required for degradation at different temperatures.



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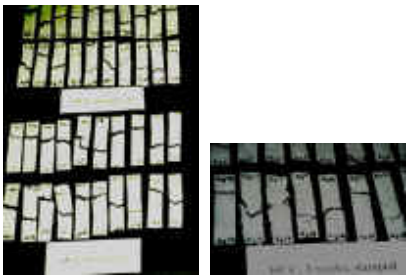
What evidence do we have that TDPA™ is safe to use?

It was proven using extraction testing by PIRA International (UK) that TDPA™ treated films have additive extraction values low enough to meet food contact standards. We sent samples to an external Lab to check for toxicology and cytotoxicity tests. The current evidence indicated that it was completely safe to use, it meets the requirements of the Elution Test, and is characterized as one devoid of irritating and of sensitizing propensities that could be detected by the methods used in the study. The product was not classifiable as a Human Carcinogen by ACGIH, IARC, EPA or NTP. Actual usage of diapers by babies under close medical supervision indicated once again, that the product is safe to use.

What evidence do we have that our plastics degrade in the landfill?

We contracted the services of the University of Georgia, under Dr. Ernest W. Tollner's leadership, to perform a battery of tests under the ASTM D-5525 "*simulated active landfill test*" standard. They continue to do more landfill experiments at this time.

Filling of "active landfill" simulators



Tensile tests samples at different reactor temperatures

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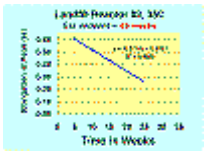

Do they "biodegrade" in the landfill?

Does a banana peel biodegrade? Do leaves from a tree biodegrade? Will a newspaper biodegrade? Will our treated plastics biodegrade in the landfill? This is a difficult question because a definite yes may be an overstatement; something we can say is that we were able to prove, using the ASTM D-5525 "simulated active landfill test", that the polyethylene film and polypropylene nonwoven degraded under simulated landfill conditions.

We were also able to see some bioactivity that suggests that the product will continue to biodegrade; we do not know at this time the extent of this biodegradation and we have no means to prove it at this time. We believe it will biodegrade in most landfill conditions, however we also recognize that if the landfill is not managed properly, even a piece of meat will not biodegrade. Does this mean that the meat is not biodegradable? Of course not! We believe that with the current trend of regulations for landfill operators, our treated plastics will biodegrade, but confirmation is still required through additional testing.

Conclusions:

- It is possible to make friendlier products for the environment, we showed one way.
- E.P.I.'s technology produces plastics that degrade; they degrade in standard ASTM simulated active landfill conditions, and will probably biodegrade in most well managed landfills, but this needs to be proved.
- It is possible to control the shelf life by fine-tuning the ingredients in the formulation.
- Evidence suggests that they are safe to use.
- They are not very expensive.
- They require special packaging to extend their shelf life; a strong UV filter is required for this purpose.

- It is not necessarily the final solution in terms of our environment efforts, but it is a partial solution in the right direction.
- Our diaper is a better alternative for the environment in comparison to all other disposable diapers commercially available at this time.