Helping Plastics Waste Away

By JANET RALOFF

Plastics — the fastest-growing contributors to a mounting U.S. garbage crisis — epitomize today's throwaway society. They're also among the longest-lasting contributors, resisting degradation for decades, even centuries. This durability, while a virtue for product manufacturers, causes headaches for waste managers. Most plastics end up chucked into the trash and entombed in landfills. But now biologists are joining polymer chemists to engineer a better solution to plastics pollution: compostable plastics.

New data suggest that with a little help from their bacterial friends, these novel materials will quickly decay into nontoxic residues.

Between 1976 and 1984, plastics' annual share of municipal trash in the United States nearly doubled — to 7.2 percent by weight, or nearly 9 million tons — according to a General Accounting Office report issued last September. By volume, discarded plastics account for almost 32 percent of U.S. garbage, notes Ramani Narayan of Purdue University's Laboratory of Renewable Resources Engineering in West Lafayette, Ind. With landfill space shrinking and few new municipal dump sites opening, pressure is growing to reduce waste volumes.

Recycling has made great strides. For example, nearly 20 percent of U.S. plastic soft-drink bottles currently wind up in new products — from shower stalls to the fiberfill used in pillows and winter jackets. But recycled discards annually represent only about 0.5 percent of trashed U.S. plastics. Those not destined for reincarnation should degrade, Narayan argues.

Two major structural features contribute to the durability of conventional plastics: a relatively small surface area and the fact that the ends of each of their long-chain molecules are tucked inside of the wrapped chain — effectively hiding this vulnerable end from hungry microbes. Inserting readily degradable starches or fibers — such as cornstarch, cellulose, soy protein and lignin — into a plastic matrix attracts soil microorganisms and gives them a greater opportunity to find and attack the synthetic polymer's vulnerable regions. As they feed, these "bugs" secrete enzymes that both dissolve the starches and fibers and cut through the large, chain-like structure of the conventional plastics to which they're linked.

Though biodegradable plastics are commercially available, most don't incorporate more than 6 percent starch. The challenge comes in increasing the readily degradable portion without diminishing the plastic's performance. At the American Chemical Society meeting in Dallas last month, a number of researchers described progress along this front.

"We can make plastics now with 20 percent starch which are comparable in strength to pure polyethylene," says J. Michael Gould, an Agricultural Research Service (ARS) biochemist at USDA's Northern Regional Research Center in Peoria, Ill. "Our objective is to incorporate 50 or 60 percent starch."

"We're optimistic that environmental impacts of the new plastics will be benign," adds Gould, who is investigating microbes influential in plastics decay. But he notes that his agency's recent interest in biodegradation isn't the force driving this plastics development. "Our funding goal is to create markets for corn."

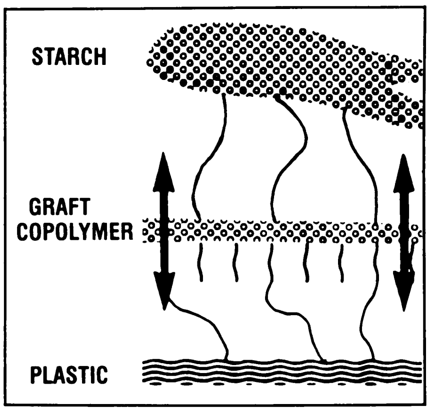
Polyethylene is a plastic used in a wide range of products — from food packaging, paper coatings and toys to garbage bags and squeeze bottles. Unfortunately, says ARS plastics-research leader William M. Doane, the water-absorbing starch and water-insoluble polyethylene won't naturally mix. To forge a peaceful coexistence between the two, his team has modified the conventional plastic by inserting acrylic-acid segments here and there within polyethylene's long-chain molecules. These acid segments loosely associate (hydrogen-bond) with the cornstarch, permitting the researchers to extrude well-mixed plastics incorporating up to 40 percent starch. The end product looks like a tangle of polyethylene filaments chaotically interwoven with individual starch molecules.

At Purdue, Narayan's group uses a technique more typical of the commercial polymer industry. To trick polyethylene into marrying starch, Narayan has chemically grafted a polyethylene molecule onto one of starch. The bonded pair readily bridges to molecules of pure polyethylene or starch, effectively gluing them together. Alternatively, plastic films can be produced from a starch-plastic copolymer alone.

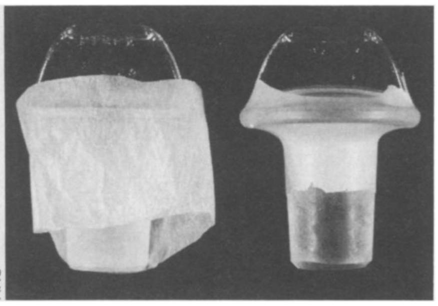
Using his copolymer grafting approach, Narayan has incorporated up to 30 percent starch or cellulose into biodegradable hybrids based on polyethylene or polystyrene. "Where you need very strong, very stiff materials you use a cellulose," he says. "If you want a cheaper, more biodegradable material — and are willing to sacrifice some strength — then starch can be used."

To limit water absorption — and therefore premature degradation of these new materials — the Purdue chemists modify their starch and cellulose by attaching water-insoluble segments. Narayan says he expects to see garbage bags made from his materials on the market within a year — initially for curbside packaging of yard wastes destined for community composting projects.

Cost factors led ARS to weave together its starches and synthetic polymers instead of chemically binding them, Gould says. In plastics, the difference of a few cents per ton in materials costs can make or break a product. ARS' approach, he



Purdue



ARS

Otherwise incompatible materials can be chemically linked into a graft copolymer (diagram). This new material serves as a structural backbone to readily bridge molecules of either starting material. In photo above, unique ARS graft-copolymer example lies loosely over glass stopper (left) at 70°F and 50 percent relative humidity. Increasing humidity to 100 percent makes it shrink-wrap the stopper (right).

says, should turn out biodegradable plastics with up to 50 percent starch at costs comparable to currently available plastics containing only 6 percent starch.

While potentially more expensive, graft-copolymer technology such as that used at Purdue offers better custom-tailoring of desired features. That's why Gould expects this technology ultimately to yield the biodegradable competitors to purely petrochemical plastics. In fact, ARS has already begun developing its own graft-copolymer plastics. One of them has the unique ability to shrink-wrap objects at room temperature, provided the humidity is high enough.

One nagging concern of the biodegradable-research community has been whether degradation products of these new plastics will themselves present an environmental hazard. Preliminary data now suggest the answer is no.

In a six-month study, chemist Michael S. Tempesta at the University of Missouri in Columbia exposed polyethylene films — with or without 6 percent starch — to conditions simulating a landfill, a compost heap, an anaerobic waste-treatment plant and surface litter. His "surprising" data, also described at last month's meeting, show "the starch is removed from the polyethylene under all environments," he says. Its microbial breakdown and removal was quickest in the oxygen-free waste-treatment sludges and slowest in air.

"Even more surprising, the polyethylene degraded to smaller molecules," he reports. Particularly under the anaerobic conditions, where decomposition was greatest, up to 15 percent of the 1,200-carbon-long molecules gradually decayed into natural, nontoxic 25-carbon waxes — like those that form naturally on apples, Tempesta notes.

To optimize plastic breakdown, Gould is identifying the most efficient decay microbes, because plastic-wastes managers will likely have to seed their landfills with decay-fostering organisms, much as backyard gardeners today add soil bacteria and fungi to compost their garden wastes.

Unfortunately, Gould says, today's landfills "are designed by law to be areas where degradation does not occur." Moisture, essential for microbial decay, is the bane of landfill managers; it threatens to leach buried toxic substances into the environment. But if one designs landfills properly, Narayan believes, moisture can be managed to limit toxic-materials migration and foster microbial degradation. It requires a new vision, he says, in which landfills are no longer tombs but renewable compost heaps. □

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In the early 1970s, Robert Fox, a now-deceased archaeologist who lived in the Philippines, studied the stone tools and concluded they were used for simple types of scraping or sawing, such as breaking open nuts or extracting the edible pith from slender palms.

Anthropologist Gerald Berreman of the University of California, Berkeley, a critic of Tasaday research, sides with Carneiro's analysis. "These tools are clearly fakes," he asserts.

In addition, Berreman says, observers at the Tasaday caves have found no floor middens — the anthropological term for the inevitable mounds of garbage at human occupation sites. While he argues that this suggests the tribe has been fabricated, researchers who visited the site, such as Molony, maintain that further fieldwork would undoubtedly locate middens.

Berreman views the Tasaday as rain-forest clock punchers, reporting for work as primitive hunter-gatherers in the morning and sneaking back to their home villages at night after journalists and researchers had left by helicopter.

Both critics and defenders of the Tasaday wonder how the tribe survived, given its population of only 26 individuals in 1972.

"It would be impossible for a group of that size to sustain its population, unless it were able to obtain spouses from neighboring tribes," Headland says. Demographers generally concur that a group requires at least 400 members to continue reproducing new generations as large as the old one, he notes.

All the scientists who originally visited the Tasaday agree the tribe would have disappeared without some kind of contact with outsiders, Molony says. Perhaps an illness, introduced through brief encounters with people from other tribes, devastated the original population. In 1972, Molony points out, the Tasaday spoke of a plague that killed many of their people a few generations back.

In addition, Nance says, the Tasaday initially spoke of two neighboring bands of rain-forest people with whom they intermarried — the Tasafeng and the Sanduka. Investigators have located neither band.

Questions about the tribe's size, tools and middens do not alter Nance's opinion that "there is no good evidence that the Tasaday are not real."

Nance says he has visited the Tasaday five times in the last few years and knows of several expeditions to the mountain caves turned back by gunmen in the area. The Philippines' political situation remains volatile, Nance notes, with Marxist guerrillas, disaffected soldiers from the Marcos regime and armed tribal groups all operating out of the Mindanao rain forest.

"I don't see how scientific work can go on in that atmosphere," he says.

Nance maintains that political pressures fuel the hoax charges. If the Philippine government comes to regard the Tasaday as impostors, the tribe will be stripped of its land preserve, opening the rain forest up to logging companies and other groups desperate for land amid a burgeoning population crunch on the islands.

For now, the land is off limits to loggers and the "gentle Tasaday" continue to fuel a rancorous scientific debate. "The session at the anthropological meeting this November should bring together the major insights on the Tasaday," remarks Johnston. "But I doubt it will resolve the issue." □

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Kelheim: A prehistoric Pittsburgh?

In "Iron and Industry: Ancient Links" (SN: 3/18/89, p.170), I think Blair is closer to the track. Kelheim, like early Pittsburgh, was an iron center — but for fabrication and shipping. The early iron business in the Pittsburgh area was slash and burn. A furnace was built, ore and lime dug, charcoal made and the lot turned into iron. When it became unprofitable to haul in the charcoal, you abandoned the furnace, moved on to another place with lots of trees nearby and put up another smelter.

When coal/coke smelting and steam transport became the rule, Pittsburgh became "steel town" — smelting and working could profitably be done all in one spot. In the Kelheim area, one should look for furnaces in the middle of nowhere (but with ore, lime and trees all about), then roads or paths for bringing in charcoal and taking the iron to a river for shipping. Deep-green slag in streams is a good indicator of an upstream smelter, at least in western Pennsylvania.

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Diver's defect

Either your reporter or the researchers studying decompression sickness ("Heart defect may lie behind 'bends,'" SN: 3/25/89, p.188) are being overly conservative in hypothesis formation. The key facts in the article are that patent foramen ovale, a heart defect, occurs more frequently among divers (37 percent) than among the general population (5 percent) and that a high percentage (61 percent) of divers with the most serious decompression symptoms have the defect. The main conclusion is that the defect may explain many cases of the bends.

What I think needs further investigation is the origin of the defect, which is implied to be congenital ("left over from early development in the womb") in all cases. It would be more plausible to explain the defect among only 5 percent of the divers (as among the general population) as a congenital abnormality, and among the remaining 32 percent by the activity of diving itself.

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