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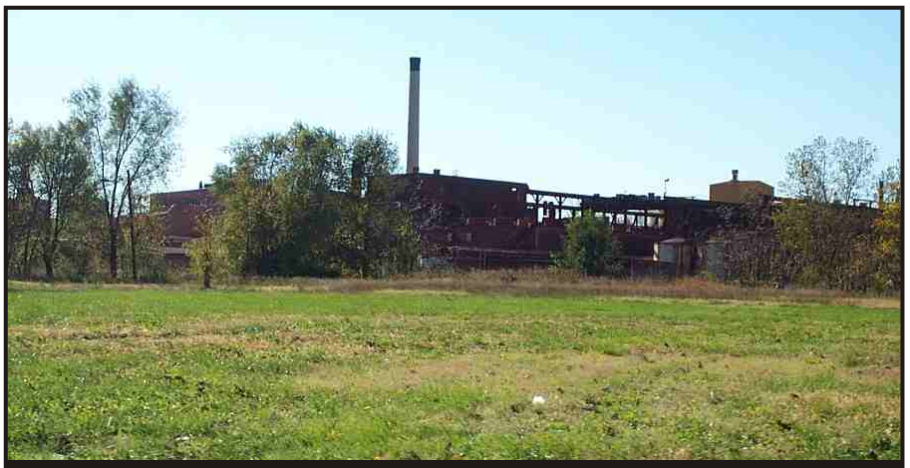


PLASTIC PROCESSING AND ENVIRONMENTAL ASPECTS

Executive Summary of the study carried out at the Shriram Institute of Industrial Research sponsored by the Indian Centre for Plastics in the Environment

Plastics because of their versatile properties and cost-benefit ratio have permeated every facet of human life. These wonder materials have substituted traditional materials in most of the end use applications. On account of inherent advantages, the use of plastics has not only become inevitable but also desirable. Despite such usefulness a debate has been going on about their environmental aspects. Plastics being basically organic materials are processed under heat and pressure into desired shapes for specific end use. To investigate the fact whether plastic processing industries can be classified as environmentally friendly or otherwise, a vital need arose to carry out a systematic study based on the experimental data and available literature. Indian Centre for Plastics in the Environment (ICPE) sponsored a research project to SIIR to carry out such study. The study has been divided into two parts, first based on the existing documents (National/International) and second on data generation by experiments.

Thermoplastic polymers comprise more than 90% of polymer industry and major commodity plastics include Polyethylene, Polypropylene, Poly vinyl chloride (PVC), Polystyrene and PET. A number of processing methods/techniques are available to process these materials and major ones are extrusion, injection moulding, calendering and lamination etc. Trends in the production of various polymers in India have been provided and the role of plastics in sustainable development and environment has been discussed in brief. Benefits of plastics in terms of energy efficiency and resource conservation compared to traditional materials like metal and glass have been highlighted. The present report is an attempt towards qualitative and quantitative study of emission sources such as volatile organic compounds (VOCs) and hazardous air pollutants (HAPs) and generation of particulate matter, if any, during the processing of plastic under review.

Each plastic material has been described in terms of its synthesis, processing behavior and environmental aspects, which has been later reinvestigated based on the experimental data using sophisticated polymer characterization techniques like Gas Chromatography, High Pressure Liquid Chromatography (HPLC) and Thermogravimetric analysis (TGA). Based on the available literature, the safe upper processing parameter especially temperature profile has been reported. Details about emission of products up to processing parameters have been highlighted.

Since, so far no Indian study has been undertaken to evaluate the emission criteria of the VOCs and HAPs during the processing of plastics like PE, PP, PVC, PS and PET, international standards have been taken as the reference. Two international standards, American Conference of Government Industrial Hygienists and Federal Occupational Safety and Health Administration (OSHA) have been taken as the reference point for the threshold limit of emission. Gases generated during processing of these plastics were analyzed for the degradation of any VOCs using GC, HPLC and UV spectrophotometric methods. Further thermal degradation behavior has also been monitored by TGA.

Grades of plastics used in the study are commercially available resins from leading Indian plastic/raw material manufacturing companies. Summary of VOCs generated using these experimental techniques are given in Table 1.

Table 1: Determination of Thermal Degradation Products of Polymers

Polymer (processed at temp °C)	Total air absorbed/ adsorbed collected @ 11 pm (Lit.)	Volatile Organic Compounds (VOCs) and HAPs (ppm)			
		VOC as per ASTM D-3686 (GC)	Formic acid, Acetic acid, Acetaldehyde(HPLC)	Formaldehyde(UV Spectrophotometry)	Hydrochloric acid (Calorimetry)
LDPE (170-205°C) Extrusion/Injection moulding	70	Nil	Nil	<1	Nil
LLDPE (180-240°C) Extrusion/Injection moulding	65	Nil	Nil	<1	Nil
HDPE (210-245°C) Extrusion/Injection moulding	60	Nil	Nil	<1	Nil
PP (210-270°C) Extrusion/Injection moulding	75	<1	Nil	<1	Nil
PVC (150-250°C) Extrusion/Injection moulding	45	Nil	Nil	Nil	Nil
PS (190-270°C) Extrusion/Injection moulding	60	<1	Nil	<1	Nil

Threshold Limit Value (TLV of various gases as per OSHA and ACGIH have been given separately in Table 2.

Table 2: Threshold limit for toxic air pollutants in industrial environment

S. No.	Toxic Pollutants	PPM Level
1.	Acetaldehyde	100
2.	Benzene	10
3.	Acetone	5
4.	Acetic acid	10
5.	Formic acid	5
6.	Styrene	100
7.	Formaldehyde	2
8.	Hydrochloric acid	5
9.	Methanol/ Ethanol	5

**Source: American Conference of Govt. Industrial Hygienists (ACGIH), Federal Occupational Safety & Health Administration (OSHA)*

The experimental data generated at SIIR has been compared with threshold limit for toxic air pollutants in Industrial Environment recommended by American Conference of Government Industrial Hygienists. From the above observations it can safely be concluded that there is no generation of VOCs/HAPs during the processing of plastics under normal conditions of processing. Similarly, Thermogravimetric analysis (TGA) in Dynamic and Isothermal modes has been carried out to study the initial decomposition temperature of plastics and thermal stability over an extended period of time. This study assumes significance since any type of emission during the processing of plastic will take place only after initial decomposition temperature (IDT). IDT of the plastics under study are given in table 3.

Table 3: Initial Decomposition Temperature of Polymers

Polymer	Initial Decomposition Temperature
Polyethylene	260°C
Polypropylene	270°C
Polystyrene	280°C
Polyvinyl chloride	250°C
Polyethylene terephthalate	310°C

In practice the processing temperatures are always kept much below IDT.

TGA in the Isothermal mode also gives an insight into the stability of a polymer over an extended period of time. This study is of great significance because it provides a good clue about stability of a polymer vis-a-vis residence time in the machine at the processing temperature. Again it can be safely concluded that residence time of the Polymer in the processing machine is much lower than the time period through which it remains stable, as evidenced by TGA in the Isothermal mode.

Conclusions and recommendations based on the study have been provided where it has been highlighted that plastic processing is an environmentally safe process since no volatile organic compounds/ hazardous air pollutants are emitted during processing.

CONCLUSIONS AND RECOMMENDATIONS

The present study examines the detailed literature/documentation available to assess whether plastic-processing industries can be classified as environmental friendly or otherwise. The study also comprises of detailed experimental work carried out at SIIR using sophisticated instrumental analysis to ascertain the facts about emission of hazardous chemicals/ volatiles during the plastic processing. Since plastics are organic in nature and

are processed under heat & pressure, there is a likelihood of emissions at very high temperatures, as a result of thermal degradation. However in general practice plastics are processed at temperatures, which are much lower than those where degradation takes place; hence the possibility of emissions in the atmosphere is very less. Based on the present study some conclusions have been drawn which are as under:

- Plastics are a class of materials, which are synthetic in nature and are manufactured by polymerization process and are classified as thermoplastic & thermosetting materials. A number of plastics processing techniques are available to make desired end products. These include Injection moulding, Blow moulding, Extrusion, Rotomoulding, Calendering, Lamination etc.
- Plastics play a crucial role in the development of mankind. If the benefits of plastics are compared with traditional materials, it is evident that they help in conservation of resources & saving of energy.
- Emission to environment during processing of plastics is caused by degradation of polymer. The emissions are classified as Volatile Organic Compounds (VOCs), Hazardous Organic Pollutants (HAPs) and particulate matter.

DID YOU KNOW?

A stack of 200 plastic grocery bags will be 7 ½ inches high; a stack of 2000 paper grocery bags will have a height of 7 ½ feet

- Experimental techniques such as GC, HPLC & TGA have been used to assess the emission of VOCs & HAPs during injection moulding, extrusion and two roll milling of commonly used polymers like PE, PP, PVC, PS & PC.
- Detailed experimental analysis reveals that plastics processed at their respective processing temperatures generally do not generate any volatile/ hazardous gases. However, at the very high processing temperature of polymer (above 300 - 400°C), thermo-oxidative degradation of the polymer can take place with the formation of oxidized fragments of the degraded polymer. However, such high temperatures are not used in plastics processing industries.
- The experimental data generated by SIIR has been compared with threshold limit for toxic air pollutants in industrial environment, which is based on American Conference of Govt. Industrial Hygienists. This data has been taken as a reference. No Indian data is available, since such study has not been carried earlier.

Emission of Volatile Organic Compounds/ Hazardous Air Pollutants of various polymers at processing temperature has been found as under:

- Low Density Polyethylene (LDPE) : In the processing range (170 - 200°C) of LDPE no emission of formic acid, acetic acid, acetaldehyde were observed. Presence of formaldehyde was found as < 1 ppm.
- Linear Low Density Polyethylene (LLDPE) : In the processing range (180 - 240°C) of LLDPE no emission of VOCs, formic acid, acetic acid, HCl & acetaldehyde were observed. Presence of formaldehyde was found as < 1 ppm.
- High Density Polyethylene (HDPE) : In the processing range (185 - 245°C) of HDPE, no emission of formic acid, acetic acid, HCl & acetaldehyde were observed. Presence of formaldehyde was found as < 1 ppm.
- Polypropylene (PP) : In the processing range (210 - 260°C) of PP, no emission of formic acid, acetic acid, HCl & acetaldehyde were observed. Presence of formaldehyde was found as < 1 ppm.
- Poly Vinyl Chloride (PVC) : In the processing range (150 - 205°C) of PVC, no emission of formic acid, acetic acid, HCl & acetaldehyde were observed. Cyclisation of PVC occurs only after 500°C as reported in literature. Since the processing temperature of PVC as mentioned is much below 500°C, the possibility of cyclic compounds, also referred to as dioxin, is ruled out.

Thermal analysis of polymers indicates that if the processing temperatures are maintained within the specified limits, the VOC, organic air pollutants etc. would not be generated. Therefore based on the present study the maximum processing temperature of different polymers viz. 270°C for PP, 250°C for LLDPE/HDPE, 260°C for PS, 280°C for PET & 250°C for PVC (rigid & flexible) are recommended. Detection of extremely low levels of volatile or hazardous organic pollutants are much less than the internationally recommended threshold values. In general practice of plastic processing as observed during the present study, there is no threat of the emissions of any hazardous gases.

Based on the available literature and the detailed experimental study it can be safely concluded that at normal processing temperatures, processing of PE, PP, PVC, PET & PS do not pose any adverse effect on the atmosphere. Processing of plastics under these conditions can be safely regarded as environmental friendly and therefore plastic processing industry can be safely classified as "Safe Environment Industry".

Based on the facts, there is enough rationale to say, "Plastic Industry does not pose any adverse effect on the environment".

Clean Up Your World With Safai Sainik

ICPE Launches National Art Contest for Children 'It's My World - Imagination for a Cleaner Environment'

Indian Centre for Plastics in the Environment launched the national school programme, "It's My World. Imagination for a Cleaner Environment", to encourage children to clean up their towns and cities on October 1.

What the contest encourages young artists to do is to draw or paint a poster artwork on the theme "Wealth in Waste. Don't Litter, Recycle It" and win exciting prizes. The national poster art contest will run from October 1, 2003 to December 15, 2003 and is being held in partnership with Tinkle.

It's My World will target 9-13 year old children from across India. It's My World is a critical aspect of ICPE's objective to develop an education and awareness campaign among our future citizens for the responsible disposal of waste in our cities. It highlights how each child can contribute to protecting the environment, conserving natural resources and keeping our cities clean. Held for the first time in India, It's My World seeks to generate awareness and understanding of garbage separation, segregation and recycling - thereby unleashing value in waste - and on dealing with the litter problems in our cities. It also provides children information on the benefits of plastics and how each one of us can use and dispose plastics (including plastic bags) responsibly for the benefit of society. It generates an understanding of the 3R's of plastic bags use - Reuse, Recycle & Recover.

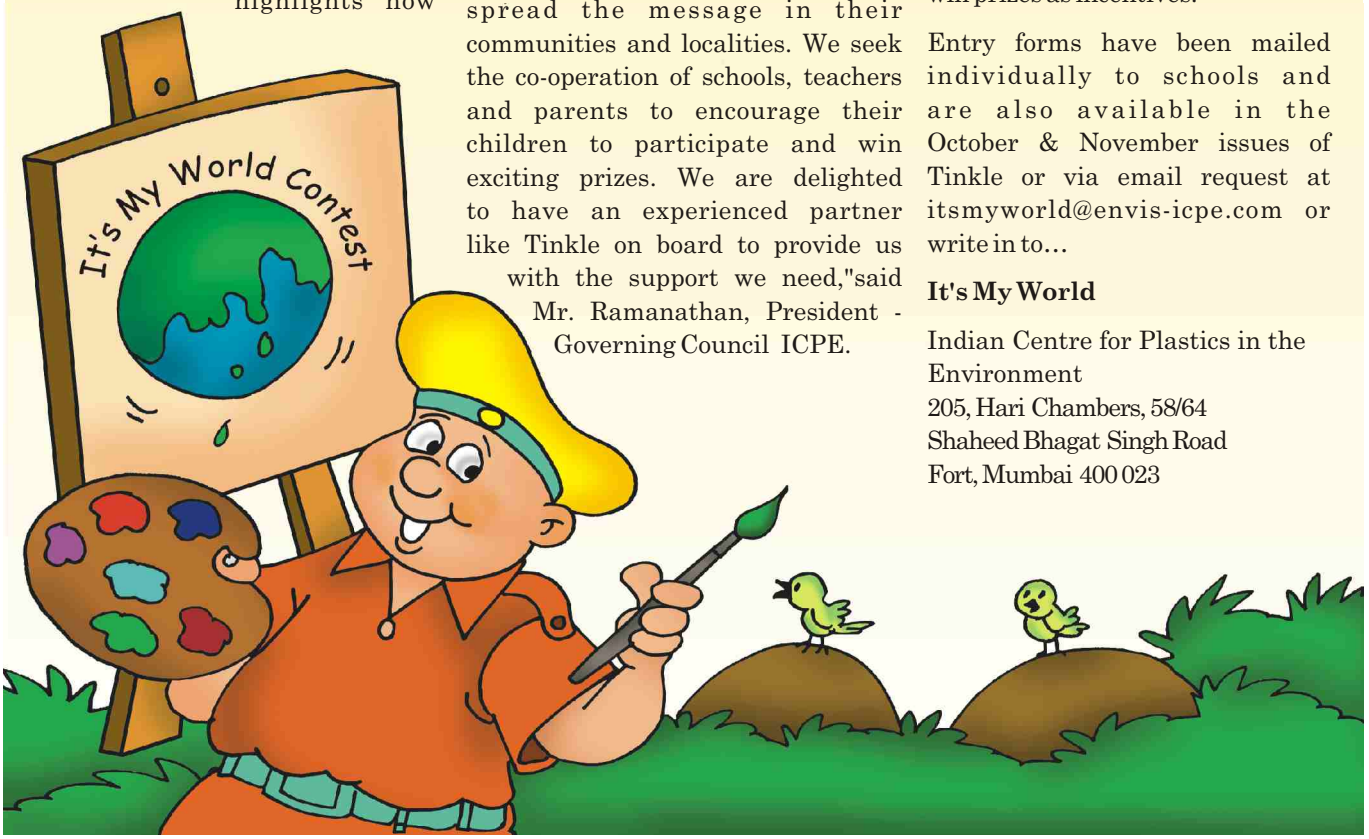
"As representatives of the plastics industry and its efforts to encourage and promote plastic waste management in India, ICPE has developed It's My World. We believe that this programme will instill a positive attitude towards littering and garbage disposal, and have enlightened school children spread the message in their communities and localities. We seek the co-operation of schools, teachers and parents to encourage their children to participate and win exciting prizes. We are delighted to have an experienced partner like Tinkle on board to provide us with the support we need,"said Mr. Ramanathan, President - Governing Council ICPE.

Designed specially for 9-13 year old children, It's My World has targeted over 3500 schools in India. Each school has been mailed a school kit containing a Teachers Activity Guide, school poster and entry forms for the contest. The programme hopes to encourage class teachers to share the information in the Teachers Activity Guide on responsible waste disposal, recycling and littering with students. It also provides teachers with useful classroom activities that they can incorporate into their civic science or socially useful productive work (SUPW) classes. Children can win exciting prizes - the Grand Prize being a multimedia computer, five zonal first prizes of CD Roms of National Geographic Encyclopedia with a video CD player, 10 second prizes, 100 consolation prizes and 500 early bird prizes. Schools that send in the largest number of entries will also win prizes as incentives.

Entry forms have been mailed individually to schools and are also available in the October & November issues of Tinkle or via email request at itsmyworld@envis-icpe.com or write in to...

It's My World

Indian Centre for Plastics in the Environment
205, Hari Chambers, 58/64
Shaheed Bhagat Singh Road
Fort, Mumbai 400 023



NEWS YOU CAN USE

INDIA

City of Plastics

What do Injecto Plast, a unit of the Kanpur-based Lohia Starlinger group, Netplast, a supplier to a number of two wheeler manufacturers, and Kanpur Plastipack, a major exporter of flexible intermediate bulk containers, have in common? They are all producers of plastic products - and all are located in Kanpur.

To be sure, Kanpur is an unusual site to locate a plastics business. It has no source of raw material in the vicinity or anything else that would help a plastics industry to flourish, apart from skilled manpower, regularly trained at ITIs and at CIPET in Lucknow.

But over the last 30 years, entrepreneurs have created a formidable industry here. Kanpur is now home to some 400 small and medium-sized plastics units, which directly employ about 10,000 people and produce an estimated Rs 500 crore worth of plastics and plastics products every year, according to R K Agarwal, managing director of Netplast, which manufactures plastic automotive components. That figure may be an underestimate - substantial production and turnover go unreported.

Indeed, Kanpur is one of north India's largest hubs of plastics products manufacture in northern India. Kanpur has always been a mandi, a wholesale market hub to which people in Uttar Pradesh, flocked to buy goods. The city catered to the requirements of the hinterland. So were born units that turned out household goods like cans and mugs. Then in the 1970s, Food Corporation of India required bleached tarpaulins for food stocks. These were brought in from Gujarat and Nepal and then laminated and sold. Local businessmen who did this made good profits.

But in the process, a lamination industry developed, explains Manoj Agarwal, executive director at Kanpur Plastipack, a pioneer in the city's woven sack industry. Businessmen also soon began turning out high-density polyethylene (HDPE) pipes to replace galvanized pipes for agricultural use. Next came ICI, which established a fertilizer factory in Kanpur in 1968 (ICI later sold it to Duncan Industries). ICI wanted woven sack bags, not jute bags. So the demand for woven sack bags shot up, leading to the establishment of the woven sack industry.

In the early 1980s, the LML scooter factory was set up in the city resulting gradually in local businessmen focusing on the production of plastic products for two wheelers. So an engineering plastics industry was born. Other plastic component companies to cater to the automobile industry too sprouted, including Netplast, Sutlej Engineering and Krishna Plastics and a host of other engineering firms. Auto component suppliers apart, Kothari Products, the makers of Pan Parag, spawned another business-the establishment of producers of multi-layer plastic pouches whose inner layer is impermeable.

It has also to be recognized that manufacturers in the city supply tarpaulins and other plastic goods used by the Defence services.

Last but not least, several companies shifted from Mumbai to the city. Among them are Supreme Industries with its range of furniture, and Neelkamal Plastics with its crates. More recently, the Defence Research and Development Organisation (DRDO) invited over 100 entrepreneurs and showcased their products and their requirements. This is viewed as a most encouraging development for the industry's future.

Agarwal of Netplast points out that the industry doesn't buy technology from outside. "Earlier, for small problems we used to go to Taiwan and South Korea for designing and to make a die. But that is all in the past. Now entrepreneurs are making their own dies and their own design outfits," says he. While some companies seek Taiwanese collaborations, two major city-based engineering institutions, HBTI and the Indian Institute of Technology, Kanpur, help the industry. HBTI has a full-fledged plastics department, IIT can test prototypes and has excellent rapid prototyping facilities.

(Source: Business Standard, October 10, 2003)

INTERNATIONAL

N.J. Bridge Puts Recycled Plastic to Unusual Use

Combination of two Petrochemicals may offer Inexpensive and Durable Alternative to Wood, Steel and Concrete

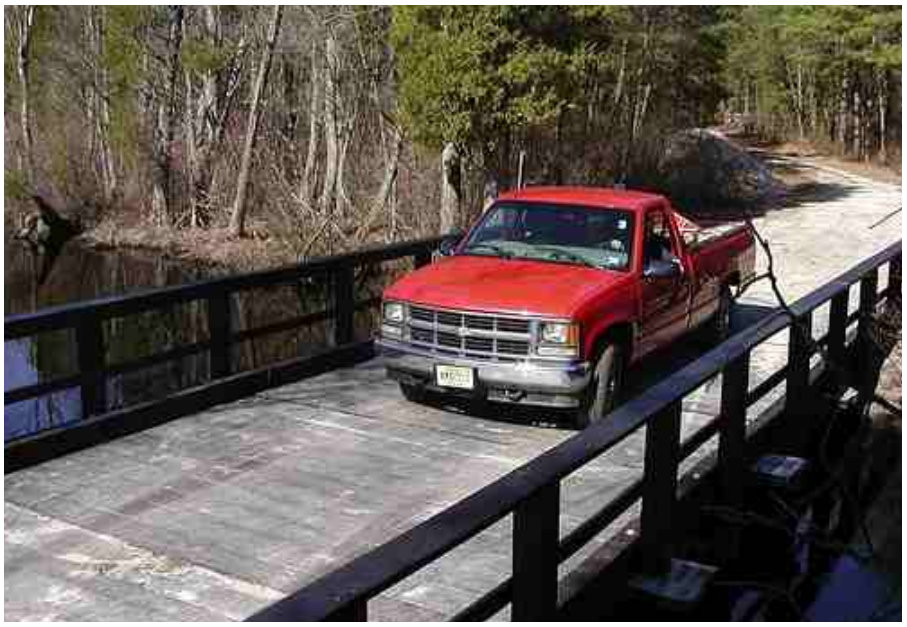
NEW BRUNSWICK, N.J. -- A plastic bridge sounds like something that belongs in Lego Land. But in southern New Jersey's Pine Barrens, a 56-foot-long bridge crafted from recycled soda bottles, coffee cups and similar refuse has been carrying traffic over the Mullica River for more than a year. Although the Rutgers University scientists who invented the novel plastic material used to build the one-lane bridge acknowledge that their technology is not yet ready for use on heavily traveled spans, such as those in the interstate highway system, they say plastic has quickly exceeded their expectations as a bridge-building material.

Most notably, they say, their plastic is already technically and economically competitive with wood, which is used in more than half a million bridges in the United States today.

As long ago as the mid-1970s, the Federal Highway Administration began encouraging and funding research into bridges with decks made of lighter, yet equally strong, fiber-reinforced plastic composites. These systems, often made of glass fibers and polyester or vinyl-based resins, are still in use, FHWA engineers say. The bridges developed by Rutgers, by contrast, represent a breakthrough, they are plastic through and through.

"I don't know that this is interstate bridge material at this point, and I don't know whether or not it will ever be, but it's perfect for replacing smaller wood bridges," said Richard G. Lampo, a materials engineer at the Construction Engineering Research Laboratory of the U.S. Army Corps of Engineers' Research and Development Center in Champaign, Ill. Lampo, who has advised the Rutgers team, said he recently visited the New Jersey bridge and was impressed with how the structure was holding up.

Thomas J. Nosker and Richard W. Renfree, the Rutgers engineers, came up with their plastic unexpectedly. They had been experimenting with two common kinds of plastic: high-density polyethylene (HDPE), which is used to make such items as milk containers and detergent bottles and polystyrene, which is commonly used in coat hangers and disposable eating utensils. Neither material alone is suitable for making bridges. HDPE is not stiff enough, and polystyrene, while stiffer, is too brittle. At the time the two researchers were doing their experiments, nothing suggested that the combination of these two plastics would make a more promising material.



But Nosker and Renfree found that one combination - 65 percent HDPE and 35 percent polystyrene - worked unexpectedly well. With the help of Washington and Lee University engineer Kenneth Van Ness, the Rutgers team figured out why. It turned out that the polystyrene, when added to a cooling batch of HDPE in the proper proportion, fills the voids in HDPE's sponge-like structure and stiffens the material considerably.

Though Nosker and Renfree made this discovery in 1988, their finding attracted little attention for almost a decade. But they persevered, and around 1996, they began to zero in on bridge construction as the most promising application.

In 1999, Nosker and Renfree oversaw construction of a part-plastic, part-steel bridge in Missouri and, two years later, of a part-plastic, part-fiberglass bridge in New York. Then, around Thanksgiving of 2002, they completed the bridge over the Mullica. Unlike its two predecessors, the Mullica bridge was made entirely of plastic, except for zinc-coated steel fasteners and the wooden piles, which were still in place from the bridge's wooden predecessor.

Building the 36-foot-long bridge, plus 10-foot abutments on each side, was so easy that it took "11 days for three PhDs, one maintenance guy and a few helpers to do it," Nosker says. The

price tag, paid by the New Jersey Department of Environmental Protection, was $75,000 - far less, transportation experts told Nosker at the time, than the $350,000 a conventional wood bridge might have cost. And the plastic bridge has the added bonus of safely and creatively disposing of solid waste.

The New Jersey bridge, they say, weighs half or less of what an equivalent wood or metal-and-concrete bridge would weigh - the plastic logs even float - yet it is just as strong, they say. Plastic is also safer for the environment, Nosker says. Wood used in construction is typically treated with chemicals that keep insects away, but many states have banned some commonly used treatments because of concerns that they contribute to environmental pollution.

In addition, plastic does not have to be cut from irregularly sized logs into precise shapes. It can be easily molded into any form desired. Plastic also needs less maintenance than wood, metal or concrete. Bugs have no interest in eating plastic beams, and plastic does not need to be painted. For the New Jersey bridge, an Edison, N.J.-based company called Polywood Inc. - a licensee of the Nosker-Renfree technology - created I-beams.

The big question is how well plastic bridges will stand up to years of traffic, said Myint Lwin, director of the Federal Office of Bridge Technology. "There is no credible, currently available way to predict 50 to 75 years of structural performance from short-term material test data. The most reliable method now available to predict performance over the long term is the straightforward - and slow - method of constructing a bridge made from the material and monitoring its condition over its service life."

However, the FHWA "sees a tremendous market potential" for new bridge-building materials that involve plastics, Lwin said. The agency's Innovative Bridge Research and Construction Program has sponsored 44 other projects involving experimental plastic composite bridge-deck systems.

The professors and Polywood are encouraged by the modest success of the company's plastic railroad-tie business. While plastic ties account for less than half of 1 percent of railroad ties in use nationally, sales to railroads and transit agencies have been growing in recent years.

For the company, the Mullica River bridge was a key advance, since it demonstrated that plastic bridges can be cheaper than wood bridges. "Breaking into a 100-year-old industry takes a while," said Marc Green, Polywood's chief financial officer.

http://www.washingtonpost.com/wp-dyn/articles/A43920-2003Dec7.html

DID YOU KNOW?

The manufacture of paper bags requires two and a half times the energy as compared to plastic bags of the same size and for comparable performance

ICPE at the 2nd Training cum Performance Evaluation Workshop

ICPE participated in the 2nd Training cum Performance Evaluation Workshop at Bhubaneshwar, during 6-8 November 2003. This annual gathering of all the ENVIS nodes reviews their overall performance and discusses future activities and plans. The ENVIS Programme was initiated in 1982 with just 4 nodes, and today comprise of 85 nodes with 23 centres. The ENVIS nodes are becoming the largest point of information on the environment, in the world.

Inauguration workshop by Dr. Harjeet Singh, Sr. Advisor, MoEF, Dr. (Mrs) Indrani Chandrashekharan, Director MoEF and Dr. (Mrs) Nanditha Krishna, Hon. Director, C.P.R Environmental Education Centre

ICPE receives recognition at the workshop

The ICPE newsletter received recognition as being among one of the best newsletters, in terms of its content. ICPE has also been advised to upload onto their website, all the controversies, questions and answers related to the plastics industry in order to update other members on the issues they are faced with.

Indian Centre for Plastics in the Environment

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