Indian Centre for Plastics in the Environment

Eco-Echoes

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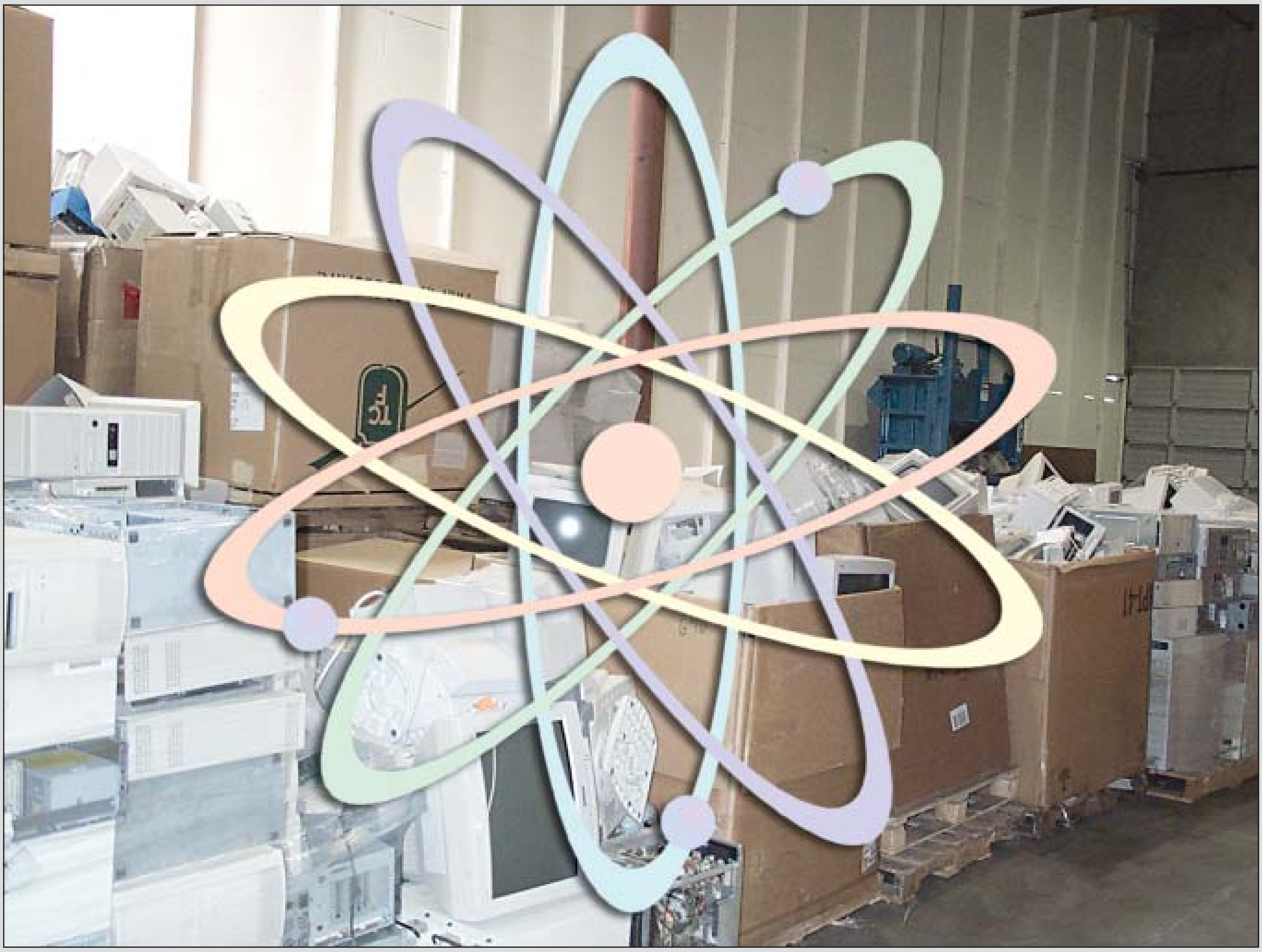
ICPE NEWSLETTER



Recycling of Electronics & Electrical Waste

In this Issue

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Readers are welcome to send their suggestions, contributions, articles, case studies, and new developments for publication in the Newsletter to the ICPE address.

PLASTINDIA 2006

Asia's biggest and one of the largest fairs in the world of Plastics

6th International Plastics Exhibition & Conference
9th-14th February, 2006
Pragati Maidan, New Delhi

PLASTINDIA 2006, one of the largest plastics exhibition, offers an opportunity for global market leaders to meet, exchange ideas and view business prospects. It will provide an opportunity for both, members of the Indian plastics fraternity and their international counterparts, to discuss and display their latest innovations in plastics and a chance to showcase the status of the global industry in terms of market knowledge and polymer technology. It will be a forum where diverse skill sets and industry knowledge are brought together on a common platform.

A two-day conference will be held on 11 and 12 February, 2006, alongside the main event. The aim of this event, which is divided into sessions on business and technology, is to bring together eminent scholars, consultants, professionals, scientists and industrial experts for a fruitful engagement on issues concerning the Plastics Industry.

For further details contact:
PLASTINDIA FOUNDATION
Tel.: (022) 2683 2911
E-mail: plastindia@vsnl.com
www.plastindia.org

ICPE at Plastindia

ICPE will be participating in Plastindia 2006. Photographic and informative panels will be displayed in the stall – to create greater awareness on the need for responsible disposal of waste and benefits of recycling of plastics waste.

Audio-visual presentations and educative films will also be screened.

Visit ICPE Stall No. 1, Hall 8, Pragati Maidan, New Delhi.

For more information on Eco-Echoes and about the contents, please contact Mr. T. K. Bandopadhyay, Technical Manager, ICPE, Mumbai.

Cover Story

Recycling of Waste from Electronic and Electrical Equipment in the Netherlands

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Abstract:

An innovative research program in the Netherlands has shown that it is technically and economically feasible to collect and convert waste from electrical and electronic equipment, WEEE, into sound products for reuse. Redesign of equipment and improved waste treatment can lower the environmental impact in the whole lifecycle of these products. Mechanical testing and field tests have shown that the plastic fraction from WEEE treatment can be purified into its different plastic fractions for reuse in a technically and economically feasible way. Environmental studies have shown that dedicated dismantling, shredding and separation give the largest environmental improvements for larger equipment, e.g., equipment with a cathode ray tube, is treated in such a way. From an environmental point of view separate treatment of small equipment like mobile phones give better results compared to treatment of mixed equipment.

1. Introduction

The use of plastics in electronic and electrical equipment (E&E) is increasing rapidly, see Fig. 1. Besides plastics, steel and glass these products also contain toxic compounds, e.g., CFC's, flame retardants and heavy metals like mercury, copper, cadmium and lead. These components will leak into the environment when E&E discarded products are not treated in the right way. For this reason the Dutch government set up rules regarding the collection of different types of E&E products. Collected products are being dismantled and shredded in order to reclaim hazardous materials like CFC's but also useful materials like ferro and non-ferro metals. The plastic waste fraction was not seen as a useful stream for a long time and would therefore be incinerated or land filled.

2. Program on improving the environmental impact CE

For the last 5 years an innovative research program (IOP Heavy Metals) was carried out to improve the environmental impact of E&E waste in the Netherlands. The objective of this program was to develop an environmentally sound recycling process for plastics from consumer electronics, which cleans the plastics not only from unwanted additives but also upgrades their material performance [1]. The research was focused in several areas of importance, schematically shown in Fig. 2, namely, 1) Design of E&E equipment for better end-of-life performance, 2) Improvement of E&E waste collection, 3) Improvement of technical processes to recycle the E&E waste, and 4) Development of an environmental database of all possible routes for E&E waste treatment.

3. Results

The results of the four sub-studies have shown that the environmental impact of the production, use and waste phase for E&E equipment can be improved. Redesign of the equipment leads to enormous savings in raw materials needed in production. Redesigned E&E equipment also has lower energy use during its use phase. However, the impact of redesigned E&E equipment on the waste phase is rather limited.

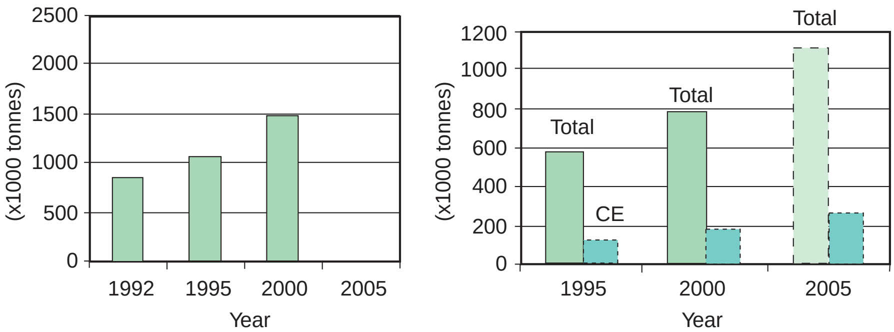

Figure 1. Use of plastics for electrical/electronic equipment and consumer electronics produced in Europe (left); Plastic waste production from all electrical/electronic equipment in Europe and plastic waste specifically from consumer electronic waste, CE (right) [4].

Another important outcome is the fact that collection rates of smaller E&E equipment have to be increased since these are easily lost in the 'normal' municipal waste system. For bigger equipments like freezers and TV-sets collection in The Netherlands is very high (over 80%) [2]. The recycling of E&E waste in order to recover (precious) metals is quite sufficient in The Netherlands, however the fractions containing plastics were just land filled or incinerated, which is very expensive. Studies have shown that it is possible to improve the separation processes such that thermoplasts (e.g., PS, ABS, PE, PP) can be separated from the waste streams and consequently be used again, and in such a way keeping their material value rather than using only their energetic value.

In 2005 the specific plastic waste fractions from Dutch environmental stations who shredder fridges and freezers and also small and medium E&E waste products, are being treated and separated into their different plastic components in an economical feasible fashion. The separation techniques have evolved in such way that plastic fraction containing flame retardants can be separated from the non brominated waste stream, improving the usefulness of plastic recyclate.

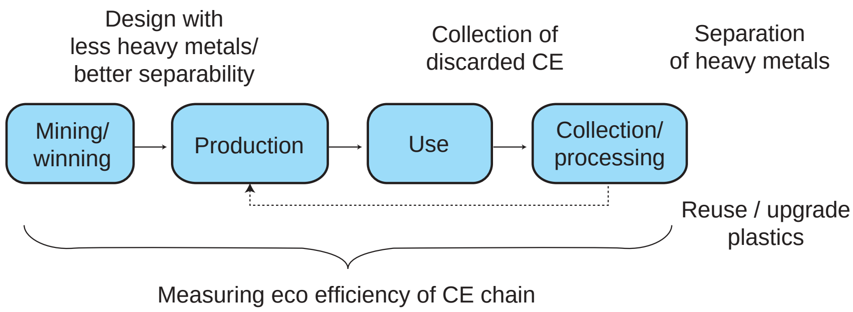

Figure 2. Life-cycle approach for improving environmental impact of consumer electronics.

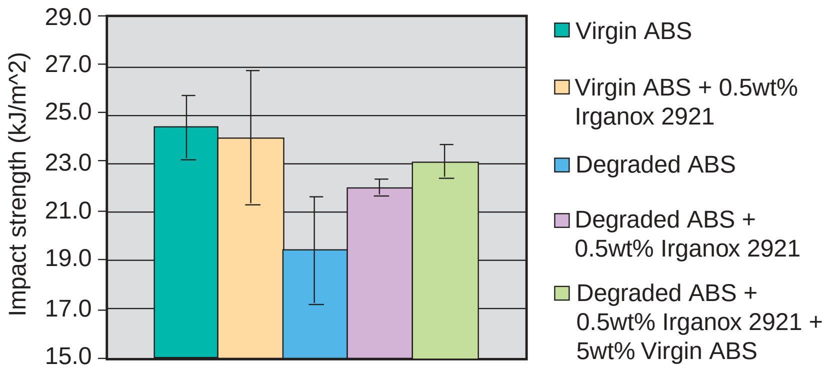

Figure 3. Impact strength of virgin ABS versus thermal degraded ABS and degraded ABS mixed with stabilizers/virgin ABS

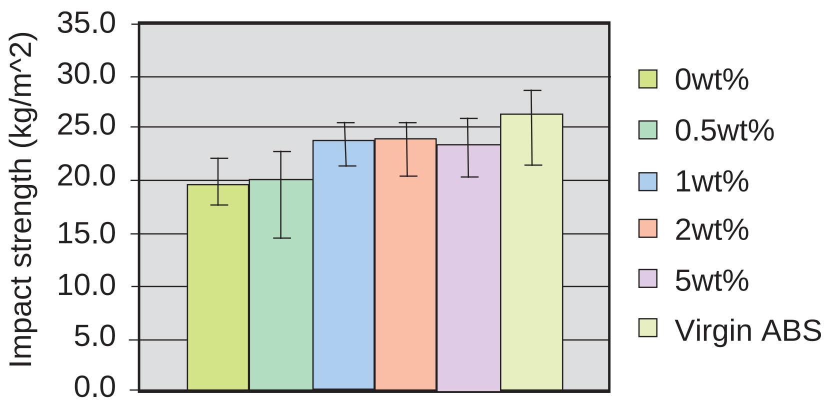

Figure 4. Impact strength of thermal degraded ABS (0wt%) versus degraded ABS mixed with 0.5-5 wt% reactive diphenyldimethoxysilane and virgin ABS.

In certain cases material properties can be upgraded using specific additives, e.g., siloxanes. Research on this issue has been carried out on ABS material because this is considered to become one of the most important plastic materials in E&E products in the near future. The outcome of mechanical impact tests have shown that via mixing of degraded plastic material with a combination of siloxane, stabilizer and virgin material, in low amounts, recyclate plastics can have the same mechanical impact characteristics and therefore the same usability as virgin materials. Fig. 3 shows results from impact strength tests on ABS, degraded ABS and degraded ABS mixed with thermal stabilizer (Irganox 2921). Fig. 4 shows results for ABS in combination with reactive diphenyldimethoxysilane, which are even more promising compared to treatment with thermal stabilizers and virgin material.

Research on polyesters, e.g., printed circuit boards and polycarbonate, have indicated that a process can be developed that depolymerises plastics and separates the feedstock from metals and additives, using supercritical CO_2. Possible application lies in feedstock recycling of such plastics into monomers for the paint industries based on epoxy resins. It is clear that for any recycling plant based on this technology the scale of the facility should match waste amounts and market demands.

Overall environmental evaluation of E&E production, use and waste processing has indicated that minimum recycling rates in terms of minimum mass ratio's set by the European Commission does not lead to an optimal environmental solution. A better tool has been developed which combines environmental savings with economical savings, which was called QWERTY/EE (Quotes for environmentally WEighted RecyclabiliTY and Eco-Efficiency) [3]. Reclaiming heavy metals and precious metals leads to the highest environmental improvements in the E&E chain. This can be understood from the fact that producing metals from ores create a much larger environmental burden when compared to metal production from scrap metal material. In the case of plastic recycling also such a difference is seen between virgin material and recyclate but the differences are less clear. It is clear, though, that it is easier and more eco-efficient to recycle plastics from large equipment compared to small equipment. Figure 5 reveals this matter.

4. Conclusions

The outcome of the four research projects has lead to new concepts for the recycling of plastics from consumer electronics [4]. With this concept it appears possible to remove unwanted additives from the plastics, like heavy metals, and upgrade the polymer properties to virgin qualities. In this way resources are saved and emissions of additives to the environment are prevented thus contributing to sustainable development.

The project has also revealed general improvement options in the design and waste phase of consumer electronics. Environmental issues like banning toxic metals, energy efficiency, minimisation of packaging materials and end-of-life design should play a much larger role when designing CE equipment as is the case right now. Laws on producer responsibility can play an important role in this respect. In order to reuse the material value of CE and also to minimise waste, like heavy metals, diffusing into our environment, the collection of small and medium equipment should be increased. Waste from large equipment seems to be much easier to control.

Measuring the eco-efficiency of the CE chain has revealed many interesting outcomes. Focusing on metal recovery gives the major improvement in terms of end-of-life processing of WEEE. Larger equipment should be fully recycled, in terms of metals, plastics and glass however for smaller equipment like cellular phones the emphasis should be on metal reclamation and utilization of the energy contents of the plastic materials. For medium sized equipment, like many CE, the route followed should focus on maximisation of the eco-efficiency: i.e., recover all material properties if possible and in other cases recovering the metals plus the energy value of the plastic fraction. The QWERTY/EE method has shown to be a very useful tool to check the eco-efficiency of different waste scenarios. Practical studies at Dutch recycling companies have revealed that in the Dutch situation the plastic fractions from CE can be separated into the different plastic fractions for reuse, in an economical, environmental and technical feasible manner. This would predict that the same, full material recycling of waste from electronic and electrical equipment, will be achievable in all other EU countries in the coming years.

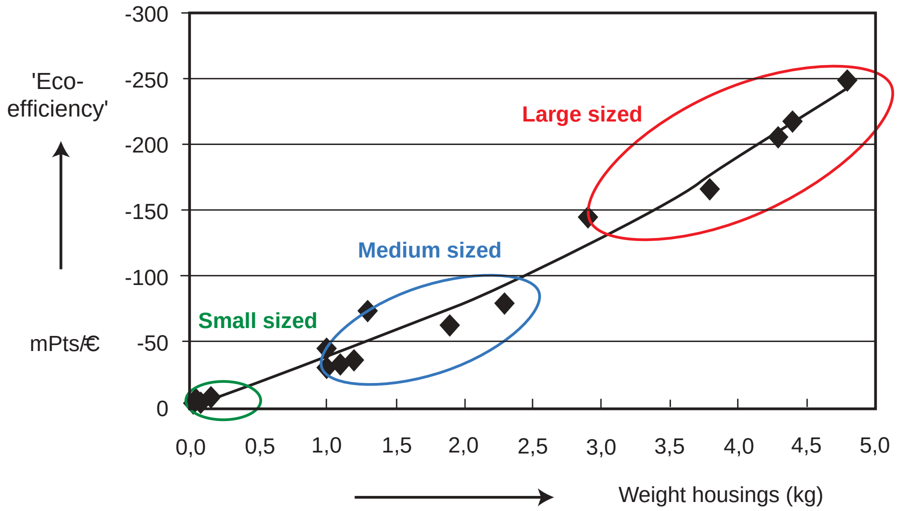

Figure 5. Environmental gains (savings) versus size of equipment recycled [3]

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[1] Kasteren J.M.N. van, Schijndel, P.P.A.J. van, Ron A.J. de and Stevels A.L.N., *Int. J. of Environmental Conscious Design & Manufacturing*, 9 (2), 23-30 (2000).

[2] Melissen F., *Designing collection rate enhancing measures for 'small' consumer electronics*, PhD thesis, Eindhoven University of Technology, The Netherlands, 2003.

[3] Huisman J., *The Qwerty/EE concept – Quantifying recyclability and eco-efficiency for End-of-life treatment of consumer electronic products*, PhD thesis, TU Delft, The Netherlands, 2003.

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ENVIRONMENT DEPARTMENT

Government of Maharashtra,

15th Floor, New Administrative Building, Madam Kama Road, Mantralaya, Mumbai - 400 032

Dated the 13th September, 2005

ORDER

ENVIRONMENT (PROTECTION) ACT, 1986.

DRAFT ORDER

No. Plastic. 2005/CR-38/T.C.III

(i) Every trader (including hawker), shopkeeper, wholesaler or retailer or any other person shall discontinue the use of polyethylene (plastic) bags, for packing, handling, storing, carrying or for any other purpose;

(ii) (a) The Municipal Commissioners of the Municipal Corporations and the Chief Officers of the Municipal Councils, within their respective areas; and

(b) The Collector of Districts, for areas other than those specified in clause (a) above;

shall ensure the compliance of the directions at (i) above.

By order and in the name of the Governor of Maharashtra.

B. P. PANDEY,
Principal Secretary to Government

Above are the salient points of the Draft Order. The public was asked to submit any comments within 30 days.

Press Meets

ICPE and Plastics Associations of Maharashtra had organised a number of Press Meets in various cities of the State. A Press Note was released during those Press Meets. Reproduced here is the Press Release.

Press Release

Maharashtra Government had issued a Draft Order on Discontinuation of Plastics bags ref 2005/CR-35T.C.III dated 13th September, 2005. The Draft Order squarely blames Polyethylene (plastic) bags as a potential source causing grave injury and damage to the environment and the health of human beings and animals. It has put total responsibility for blockage of gutters, sewers and drains of Mumbai after the deluge on 26th July, 2005, on Plastic bags.

From l to r – Mr. S. Banerji, Exe. Secretary/Member, Exe. Committee – ICPE; Prof. Dr. Ashok Misra, Director - IIT (Mumbai); Mr. P. P. Kharas, Convenor-Communications, ICPE; Mr. Vijay Merchant, Member, GC-ICPE. On dais: Dr. U. K. Saroop, Member (Tech)-ICPE.

It is quite difficult to visualize how Plastics can be termed as hazardous to human health or animal life, when Plastics have made significant contribution in the area of medical safety and health care. There is no scientific evidence / medical proof to suggest or support that Plastic products are injurious to human health. Plastic medical products like disposable syringes, blister packing of tablets and capsules, membrane support, sutures, joint replacement prostheses, IV fluid bags, blood bags, catheters, heart valves and artificial skin have significantly helped supporting the human life. Medical devices made of Plastics are implanted into the human body.

Plastic bags have actually contributed in creating a sustainable, cost effective, energy efficient,

Members of Press.

Dr. S. Shivram, Director NCL, Pune & Member, GC-ICPE, is addressing the Press Meet at Pune.

hygienic and environmental friendly packaging system for edible commodities like milk, spices, edible oil, bread, confectioneries, rice, wheat flour, snack foods, medicines and a host of perishable products like fish, meat and poultry products. This has been possible due to non-toxic, inert excellent barrier properties, resistance to moisture and oxygen, non-breakability and light weight, sterilizable and resistance to bacterial and other microbial of plastics. For safe food and pharmaceutical packaging, certification has been received from leading Research Institutes of the country. Plastics conform to all the stringent requirements for safe and hygienic packaging system in contact with food and pharmaceutical products, hence in no way can be injurious to human health.

It has been also alleged in the Draft Order that Plastics bags and ancillary products are grossly responsible for blockage of gutters, sewers and drains resulting in serious environmental problem.

According to a published report of Municipal Corporation of Greater Mumbai in 2001, Plastics constitute just 0.75% of the solid waste in Mumbai. Similarly in the report of Central Pollution Control Board, MoEF, GoI, typical composition of Plastics in Municipal Solid Waste on an average was reported as 0.62%. Some agencies quote the total plastics in the waste stream of Mumbai as around 4-5%. However, all the agencies acknowledge that proportion of plastics in urban solid waste in India is much less than those found in countries in the advanced world who have managed their MSW much better than us without discontinuing the use of Plastic bags.

Various newspapers have also reported of authorities in BMC acknowledging inadequate drainage system, which has not kept pace with the growth of Mumbai, as one of the main reasons for flooding. There are other reasons cited including diversion of Mithi river, encroachments and inadequate cleaning of the drainage systems in many parts of the city.

Based on the above facts it can safely be stated that Plastic bags are not responsible for flooding of Mumbai, since it forms a minor constituent of MSW and there were more significant factors and lapses that contributed to this unfortunate calamity.

The discontinuation of Plastic bags will severely hit the consumer, as Plastic packaging is inevitable for storing, carrying and delivery of essential commodities at affordable price.

Milk Packaging is substantially dependent upon Plastics as 95% of packed milk is pouch packed. Plastic pouch remains as the most cost effective packaging material. Alternative like glass bottle is not viable as glass bottles need 32 times more energy than that is needed for plastic pouches. Transportation of milk in glass bottles (weight of 500 ml empty glass bottle is 430 gms compared to about 2.5 gms for empty plastic pouch for the same capacity) will lead to use of excess fuel consumption both for reaching the packed milk to consumer as well as for collection of empty bottles. The manufacture and reuse of glass bottles will result in high consumption of water posing burden on already stretched availability of potable water. Besides, use of detergent for bottle cleaning will have a deleterious effect on environment. Other possible alternative like tetra pack, which is the composite of different kinds of materials including aluminium and 3-4 layers of plastics, is not viable either. Cost wise this will put heavy burden on consumer and the presence of multiple materials makes it difficult to recycle, resulting in the higher burden on landfills because of dumping.

Dropsy deaths in Delhi and other parts of the country prompted the Government of India to formulate rules for unit packaging of edible oil. Government of Maharashtra decided vide notification No. PFA/Edible oil/ 14/05/7 dated 03/03/05 to implement the edible oil packaging regulatory order published in 1998 by the Central Government. Plastics pouches have proven to be most efficient and cost-effective solution to provide unadulterated oil to the consumer. Discontinuation of plastics packaging will bring it under serious threat and the society will be exposed to the adulterated loose oil.

Plastic bags play an important role in packaging of bread, confectionery items, all range of Farsan / Namkeen and bakery products. All these products are very sensitive to moisture and lose taste and quality within no time. Hygroscopic edible products like sugar, salt, jaggery and many other food items susceptible to moisture cannot be effectively packed in alternative materials without sacrificing the quality or cost of packaging. Think of carrying fish, meat, poultry and other wet food products in alternative packaging materials. Plastic bags very well handle their wetness. **Plastic bags play a key role in handling garbage collection and disposal. Plastic bags offer the ideal handling system for domestic waste. In fact there is no better way of collecting wet / kitchen garbage.**

In case Plastic bags/packaging is replaced with alternative materials like paper, cloth, jute, metal, etc., it would lead to a major penalty on the environment as weight of packaging would go up by 3 times and cost of the packaging and volume of waste will almost double. Hence, these cannot be eco-viable alternatives. Besides, paper is not eco-friendly at all. Manufacturing of paper and paper products consumes a lot of chemicals, requires a large amount of water and effluent problems are severe. Besides, paper unless coated with polymeric materials, cannot withstand wet conditions. Such wet spells are widely prevalent in Maharashtra and Mumbai, in particular, during monsoon periods. Production of paper will cause higher energy and pulp demand resulting in mass scale forest destruction. Packaging food product by reusing the printed paper leads to food coming into contact with toxic ink.

Mr. Harpal Singh, President, AIPMA, addressing a Press Meet in Mumbai. Mr. Ajay Desai and Mr. Arvind Mehta are seated to his right & left respectively.

Versatility of Plastics allows designing the product with less material. It becomes more relevant in case of packaging systems when compared to the traditional alternatives. **Reuse** provides another significant way to conserve resources. Most important property of plastics is easy **Recyclability,** specifically in our country where the industry and the consumers are cost conscious, this has been extremely effective. **Energy Recovery** is yet another important way to conserve resources to recover the energy value of products after their useful life has ended.

Discontinuation of use of Plastic bags in Maharashtra will have serious economic implications. More than 1000 factories across the State of Maharashtra manufacturing Plastic bags with a turnover of Rs. 1000 crores generating Rs. 246 crores of tax revenue provide direct and indirect employment to more than 2.5 lakh people. An intended ban will lead to total unemployment of all those workers and also loss of revenue. 730 tiny and cottage scale units operating in Maharashtra involved in recycling of plastic wastes will be directly affected. There are over one-lakh rag pickers in the State of Maharashtra who collect waste plastic bags for recyclers. In Mumbai alone the number of rag pickers would exceed 35,000. Livelyhood of this poor section of people would be in jeopardy in the absence of plastic wastes that currently form the prime source of their income. These rag pickers belong to the poorest section of the society and the ban may create a social problem.

Mumbai is a major port for export of products packed in the plastics bags. We have an apprehension that under the garb of proposed order, enforcement department may harass the exporters and thereby affecting the export potential of the country. The Draft Order is not clear about the transportation of goods from other States to the State of Maharashtra. This can also affect interstate movement of goods and people, as the discontinuation of Plastic bags relates with Maharashtra only. This can lead to harassment to the incoming people, from the local authorities.

Plastics Industry and Indian Centre for Plastics in the Environment, as responsible members of the society, have continuously engaged themselves in developing techniques to recycle all these wastes into value added or non-critical materials of use.

Plastics Industry understands its responsibility and has joined hands with the local civic authorities in managing not only Plastic wastes but also all dry solid wastes. A Scientist in a Nagpur-based college has developed a process for continuous production of Industrial Fuel out of any thermoplastic waste. Plastics Industry is closely working with the inventor to enhance the process and to add further value to Plastic wastes. The Road Department of MCGM has already conducted successful trails for utilizing Plastics Waste in the construction of asphalt road in the main city – Mumbai.

Discontinuation of Plastic bags is no solution and will rather multiply the problem many fold. This will add to the woes of common man. The challenge facing us is to improve the solid waste management system and address littering habits of masses by educating them and creating awareness. Industry is committed to work together and share responsibility for these efforts.

Nagpur Factory which manufactures Fuel from Plastics Waste.

Strict implementation of existing law by restricting manufacture, storage, sale and usage of Plastics carry bags as per MoEF Gazette Notification issued in 1999 and revised during 2003 is the need of the hour. Introduce printing of manufacturer's name in all individual carry bags, with proper declaration of thickness and recycling mark.

Industry would be willing to arrange for buy back of used plastics material including carry bags if a proper scheme can be indicated by Government/ BMC, etc. Government/BMC need to provide space at suitable places for such collection.

In order to encourage scientific recycling of Plastics products particularly carry bags, Industry would help set up recycling plants complying with all environmental standards at a desirable place. State Government in cooperation with BMC may provide land, supply power at reasonable rates. Industry would join hands with local authorities in taking up appropriate awareness drive among the citizens for proper solid waste management.

After receiving the objections/suggestions from the Industry Associations and general public, the Government of Maharashtra has constituted a Committee to look into the matter and make recommendations to the Government.

Plasticon

Awards 2005

RECOGNISING EXCELLENCE

The Plastindia Foundation has instituted the Plasticon Awards to promote and encourage Innovation and Excellence in all segments of the Plastics Industry.

The Awards germinate from a perceived need to honour and recognize excellence of Organizations, Individuals, Companies and Institutions – actively involved in research and development of plastics and related products and honour their path-breaking contribution to the overall development of the Indian Plastics industry.

The Awards were presented at a function held in Mumbai on 1st October, 2005.

Indian Centre for Plastics in the Environment (ICPE) has sponsored an Award for Innovation in Recycling Technology.

The winner of the Award was Centre of Environment Education, New Delhi, for their pioneering efforts in developing recycling technology for producing commercially valuable products and dedicated promotional activity in rural India.

Prof. Dr. Ashok Misra, Director, IIT (Mumbai), presenting the Award to Mr. Karthikeya Vikram Sarabhai, Director, CEE, New Delhi. To the extreme right is Mr. K. G. Ramanathan, President, GC, ICPE. Mr. Subhash Kadakia, Plastindia Foundation, is at the extreme left.

Doll Plast Engineering Pvt. Ltd., Ahmedabad, received the Runner-up award for development of efficient and cost-effective machinery separating plastics and paper from laminates in an energy efficient manner.

PFFCA STAR Awards 2005

Awards for Excellence in Design, Development and Creativity

Paper, Film & Foil Converters Association organized PFFCA STAR Awards 2005 function at Hotel Orchid, Mumbai on 24th November, 2005. Mr. Jagdeep Kapoor of Samsika Marketing presented the awards.

A Novel Method for the Production of Biodegradable Polylactic Acid (PLA) from Municipal Food Waste

Prof. P. L. Nayak
Ph.D., D.Sc.
Biodegradable Polymer Research Laboratory
Department of Chemistry, Ravenshaw College, Cuttack-753003, Orissa

The production of plastics and articles produced from them is expanding systematically since they are cheap, lucrative, light weight, coloured, durable and consumes less energy for production. But simultaneously the amount of waste is increasing because the majority of conventional plastics are resistant to the long-lasting action of weather and/or drastic biological conditions and not degradable. Both recycling and combustion are processes, which permit only a partial solution of the above mentioned problems. In the recent years, intensive investigations into biodegradable polymers have been undertaken. It seems that one polymer which may meet our requirements and replace the majority of popular plastics on market is poly lactic acid (PLA).

Municipal Solid Wastes (MSWs), including food waste, are usually incinerated or landfilled, but these processes generate many unnecessary problems. Incineration facilities can be damaged by temperature fluctuations when food waste with high water content is burnt in a semi-continuous process. In addition, it is difficult to recover energy from such waste incineration processes because the heating value of food waste is low. Further, landfill space is very limited, and uncontrolled fermentation of organic wastes in landfills causes secondary problems, such as methane emissions.

Treatment of biological solid waste via microbiological processes improves these wastes and reduces the need for both landfill space and fuel used in waste incineration. Direct composting and methane fermentation, which produce fertilities and biogas, are the alternative ways to reuse food waste, but these processes have been applied only in rural areas. On the other hand, there is economical ways and means for converting solid waste into natural Lactic acid from which biodegradable polylactic acid can be manufactured.

Lactic acid has both hydroxyl and carboxyl groups with one chiral carbon atom, and are widely used in food, pharmaceutical, and in general, chemical industries. In addition, Lactic acid can be polymerized to produce the biodegradable and recyclable polyester polylactic acid (PLA) which is considered a potential substitute for plastics manufactured from petrochemicals. Although the ester bond of poly-L-Lactate (PLLA) is susceptible to some enzyme, including proteinase and lipases, and PLLA has been recognized as a biodegradable plastic, its biodegradation in soil is rather slow and depends on morphology and thickness. Therefore, PLLA may better be developed as a chemically recyclable plastic with an appropriate collection system for the used materials and not as a single-use plastic. Recently the production of PLLA from cornstarch has been taken up in the industrial scale by Cargill-Dow and many other companies in the world. Such materials are expected to come into worldwide use, but PLLA and other-plant derived plastics are costly, thus preventing their widespread application. In addition, the process uses corn starch feedstock, which is also a source of food for human and other animals.

Figure - 1 shows schematic diagram for the production of Lactic acid from municipal solid waste.

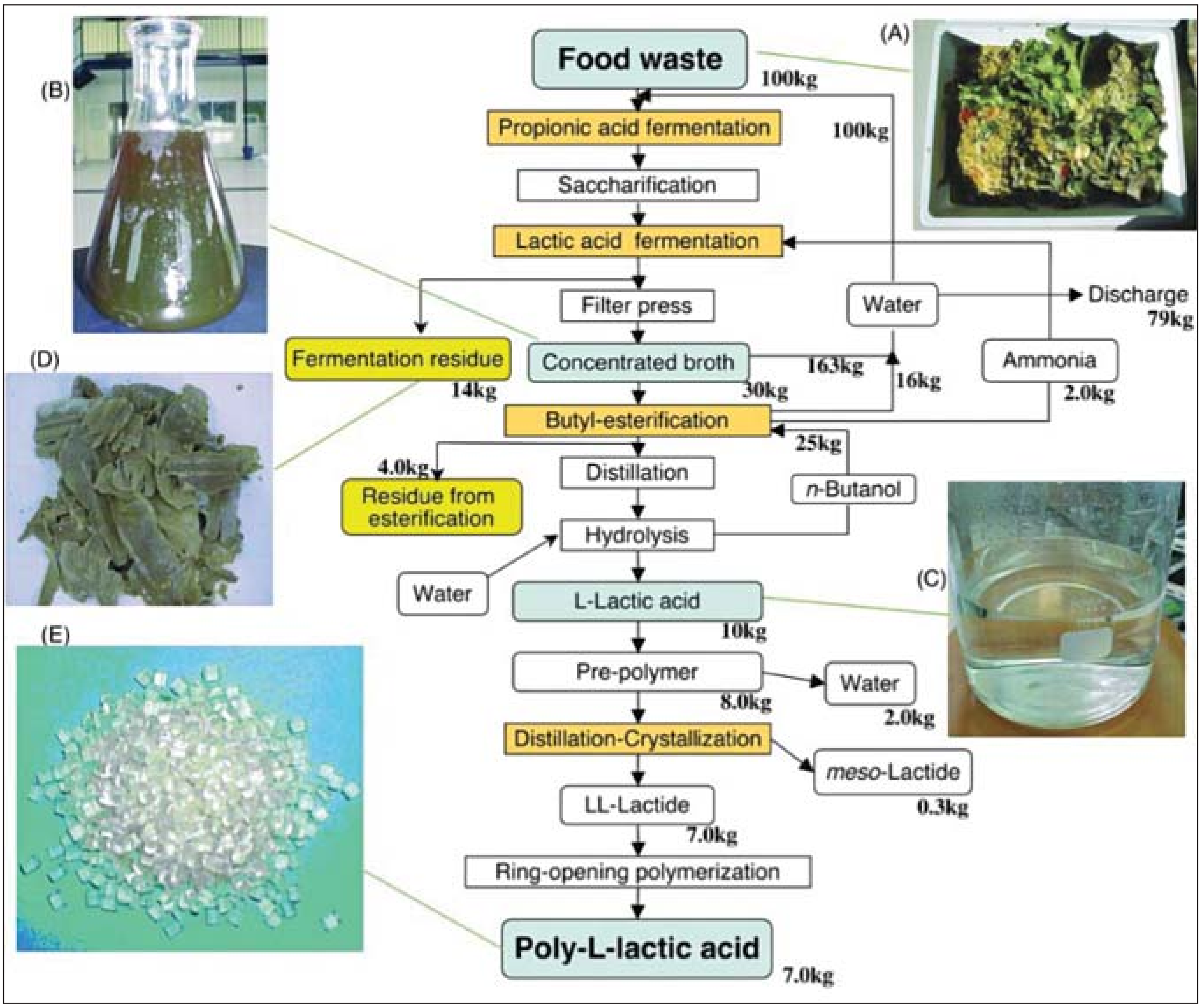


Fig. 1: Out line of the process for PLLA manufacture from food waste.

Figure – 1 shows the four steps, which are required to produce PLLA from food waste and the balance of materials obtained. The four steps consist of (1) removal of endogenous D,L-lactic acids from minced collected food waste by a propionibacterium, (2) L-lactic acid fermentation under semisolid conditions, (3) purification of Lactic acid by esterification, and (4) polymerization of Lactic acid via Lactide ring opening polymerization.

Composition of Food Waste

The food materials collected from different hotels, restaurants and other fast food places were analyzed. They contain approximately 35% of vegetable, 23% of fish and meat, and 42% of cooked carbohydrates including rice, bread and noodles. The collected food waste also contains on average 1.6g/kg wet waste of endogenous D- and L-Lactic acid, produced by native Lactic acid bacteria during transfer and storage of the waste. The presence of D-Lactic acid decreases the optical activity of accumulated Lactic acid and decreased PLLA crystallinity.

Removal of Endogenous D(L)-Lactic Acid by Propionibacterium

It is known that P.*freudenreichii* preferentially consumes D- and L-Lactic acids before sugars as a carbon source under the acidic conditions. Lactic acid in the refuse paste will be quickly degraded and diminished within 10 hours at pH 6.5, whereas glucose began to decrease after several hours of lag and will be then consumed gradually. This was observed more clearly at pH 5.5. The microorganisms assimilate only Lactic acid, and most of the glucose remained after 24 hr. The characteristics of optically inactive Lactic acid, with little effect on the amount of sugar availability for subsequent L-Lactic acid fermentation.

L-Lactic Acid Fermentation Under Semisolid Conditions

After the optically inactive Lactic acid was consumed, polysachharides including starch were solubilized by glucoamylase, *L-rhamnous*, which is an L-forming homofermentative strain, was then inoculated into the treated refuse paste. Nutrient-rich food waste appears to be a superior growth medium for fastidious lactic acid bacteria that generally require a variety of nutritional elements. The amount of water added was minimized to reduce energy input for its distillation from the fermented broth; an equal proportion of water to refuse was sufficient to yield the highest productivity of L-Lactic acid. The concentration of total sugar after solubilization averaged 74 g/l, meaning that the estimated concentration of carbohydrate in the food waste available for Lactic acid fermentation was estimated to be 143 g/kg wet water.

Solubilized sugars including glucose seemed to be involved in the Lactic acid fermentation because over 82% of the total was converted to L-Lactic acid (an average of over 61 g/1) with an average optical purity of over 98%. The amount of accumulated L-Lactic acid was dependent on the C/N ratio such as extracted tea residue or fish residues, yielded rather less L-Lactic acid. Although the amount of accumulated L-Lactic acid varied depending upon the source of the food waste, an average Lactic acid yield of more than 10% per total weight of refuse was confirmed by semisolid, two-step fermentation method.

Purification of L-Lactic Acid

The filtered and concentrated broth containing approximately 35% L-Lactic acid was esterified with n-butanol at 150℃ to 160℃ and distilled in the form of butyl Lactate (130℃, 98% yield), which was then hydrolyzed between 95℃ and 110℃. Soluble proteins and salts were precipitated with n-butanol. Esters, such as those of acetic acid and propionic acid, were separated during this part of the process. The optical purity of Lactic acid did not change during these purification steps. Ammonia stripped at the esterification step was reused to adjust the culture pH at the fermentation step. Condensed water and n-butanol were recycled for subsequent esterification. The purification of Lactic acid by butyl esterification is advantageous in that a wastewater treatment process is not required.

Synthesis of poly (L (+) L-Lactic Acid) (PLA)

Lactic acid polymer, i.e., polylactic acid consists mainly the Lactide units as the monomer and comprises one streoisoform combinations of D- and L-Lactide in various ratio. A disadvantage of polycondensation is that a low molar mass polymer is obtained. There have been studies to obtain high molar mass polymer by manipulating the equilibrium between Lactic acid, water and polylactic acid in an organic solvent or multifunctional branching agent was used to give star-shaped polymers. In the presence of bifunctional agents (dipoles and diacids) they form telechelic polymers, which can be further linked to give high molar mass polymers using linking agents like diisocyanate.

Lactic acid polymers by ring-opening polymerization

The ring opening polymerization route includes polycondensation of Lactic acid followed by a depolymerization into the dehydrated cyclic dimmer, Lactide which can be ring opening polymerized to high molar mas polymers. The depolymerization is conventionally done by increasing the polycondensation temperature and lowering the pressure, and distilling off the produced Lactide. Solution polymerization, bulk polymerization, melt polymerization and suspension polymerization are the various methods of ring opening polymerization. The polymerization mechanism could be cationic, anionic, coordination or free radical polymerization. It is catalyzed by compounds of transition metals – tin, aluminium, lead, zinc, bismuth, iron, and yattrium.

Other ring formed monomers can also be incorporated into the Lactic acid, acid based polymer by ring opening copolymerization. The most utilized comonomers are glycolide, caprolactone, valerolactone, dioxypenone and trimethyl carbonate. The advantage of ring opening polymerization is that the chemistry of the reaction can be accurately controlled thus varying the properties of the resultant polymer in a more controlled manner. The whole process is depicted in Fig.2.

The USA based giant agro-based company Cargill - Dow is building a sustainable material and chemicals starting with polylactide polymers (PLA). The introduction of PLA into the marketplace is based on the performance, price and sustainability profile of the material. Cargill - Dow has increased its manufacturing capacity for polyactide (PLA) polymer from 4,000 tons per year to 140,000 metric tons per year with the completion of its Blair, Nebraska polylactide manufacturing facility. The facility was started up in November 2001, was producing prime material since December 2001 and gone through a complete product cycle during February 2002.

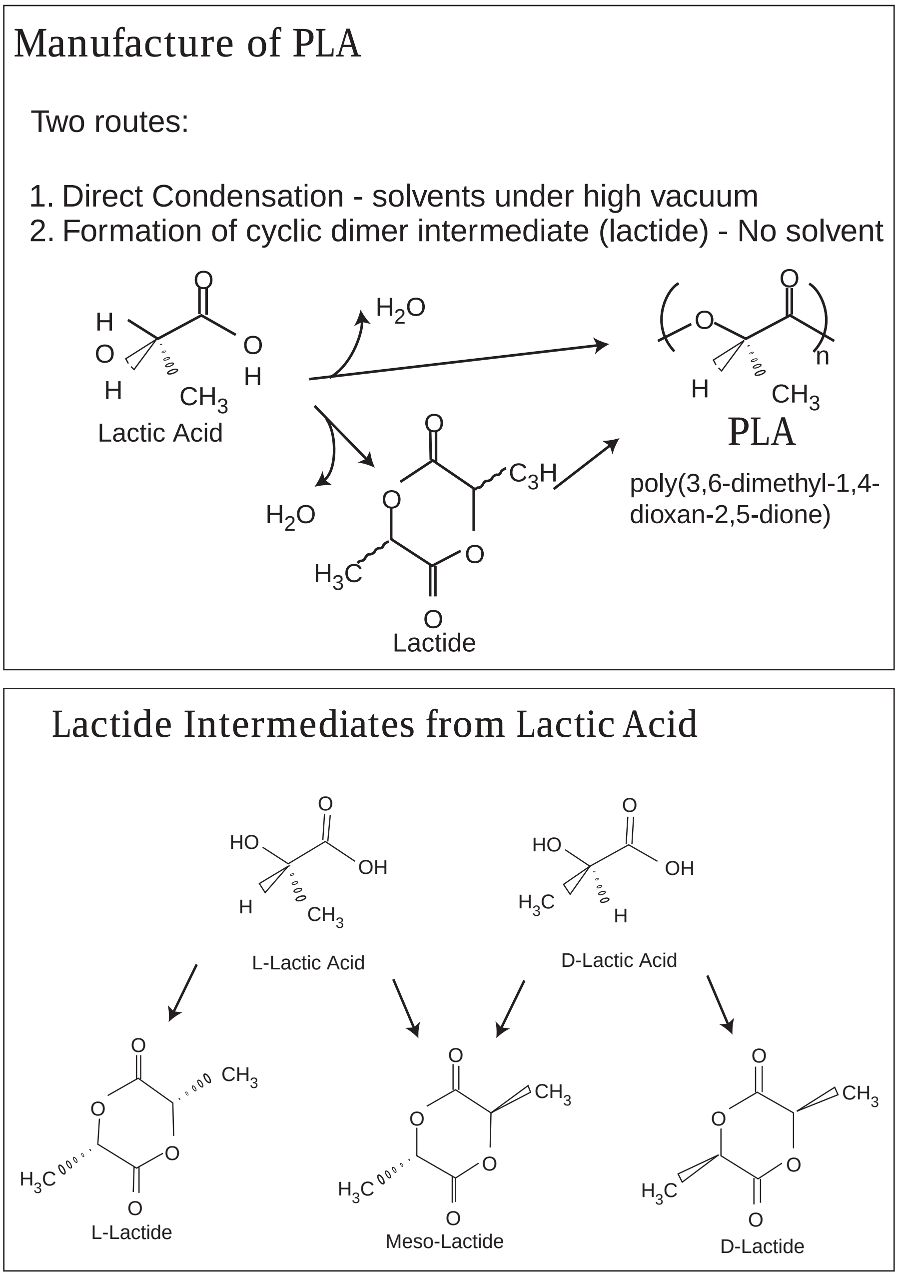


Figure – 2

Commercially, Cargill - Dow has focused on applications in fibers and packaging materials. A fiber application with strong support in the marketplace, for example, pillow and comfort fiberfill products marketed under the Nature Balance line at bed, bath and beyond. A packaging application is the produce trays utilized by the grocery chain IPER in Italy. For polylactide to reach its full potential in the marketplace Cargill - Dow has contributed to reduce the price of production and improve the sustainability of the business system for producing polyactide. Cargill - Dow believes that sustainable production of PLA will require a new agricultural business and improvement to renewable energy sources. Surprisingly many of the renewable energy sources are close to economical implementation particularly, biomass hydrolysis and wind energy.

In conclusion, the innovative practical process described here can produce high-quality PLLA from food waste. The stem is designed as a total material recycling process for municipal food waste, with minimal environmental emissions and energy savings. It has also the potential to produce from MSW a valuable, renewable product that can substitute for currently produced non-renewable, petrochemical polymers. This system would also be applicable to the production of PLLA from other waste streams that contain fermentable sugars with high proportion of water, such as agricultural wastes. This is really a challenging field of research and innovation with unlimited future prospects.

Solid Waste Management at Sanjay Gandhi National Park, Borivali, Mumbai

It was observed that this particular area of national importance was being subjected to littering of all sorts of dry waste both by the visitors as well as others.

SGNP – Before Cleaning

SGNP – After Cleaning

ICPE took up the initiative to create an awareness and to instal a Solid Waste Management System inside the park so that the sanctity of the area could be maintained.

The system comprised of collection – segregation – disposal/recycling of waste and also composting of food waste/organic waste.

The work is continuing.

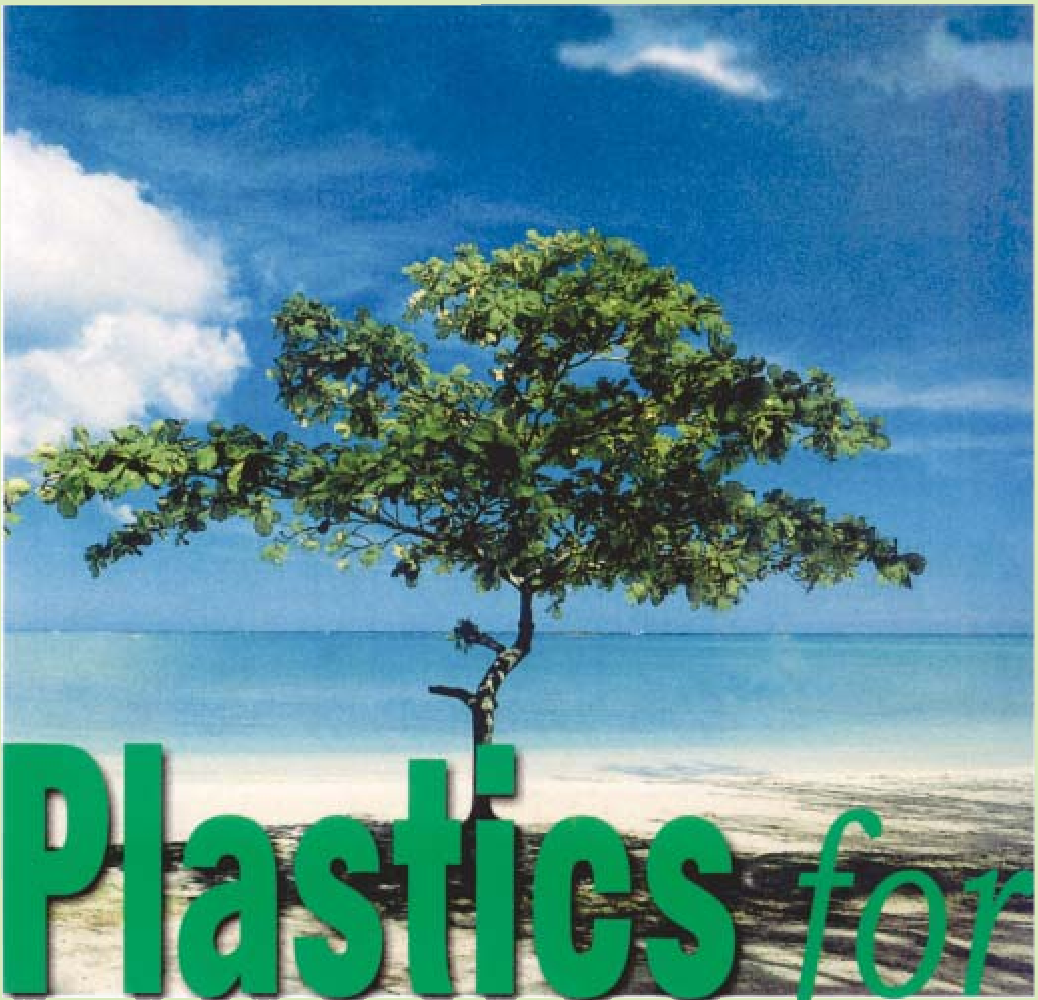
Waste-by-Rail System

Since the late 1980's, the Sanitation Districts of Los Angeles County, in conjunction with other public agencies, have been studying means to address the projected shortfall in local solid waste disposal capacity. Currently, nearly all refuse in Los Angeles County is transported to disposal sites in the metropolitan area by truck. However, as public opposition to siting new or expanding existing disposal facilities near urban areas has grown, sites farther from the Los Angeles Basin have become more desirable, despite the transport costs associated with longer transport distances. For some sites, such as the Mesquite Regional Landfill in Imperial County, rail transport is an efficient means to transport refuse to remote disposal sites. Transitioning to remote disposal of refuse that involves rail transport requires that new infrastructure be developed. This concept of rail transport of refuse, which includes an integrated system of local and remote infrastructure, is called "Waste-by-Rail."

Regional System

The Sanitation Districts have taken the lead role in implementing the Waste-by-Rail System, a remote disposal program for Los Angeles County. The Waste-by-Rail System will provide long term disposal capacity to replace local landfills as they reach capacity and close. The starting point of the Waste-by-Rail System will be materials recovery facilities (MRFs) or transfer stations located throughout Los Angeles County. Residual waste from the MRFs or transfer stations will be transported via rail to remote landfills for disposal.

(Source: http://www.lacsd.org)



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