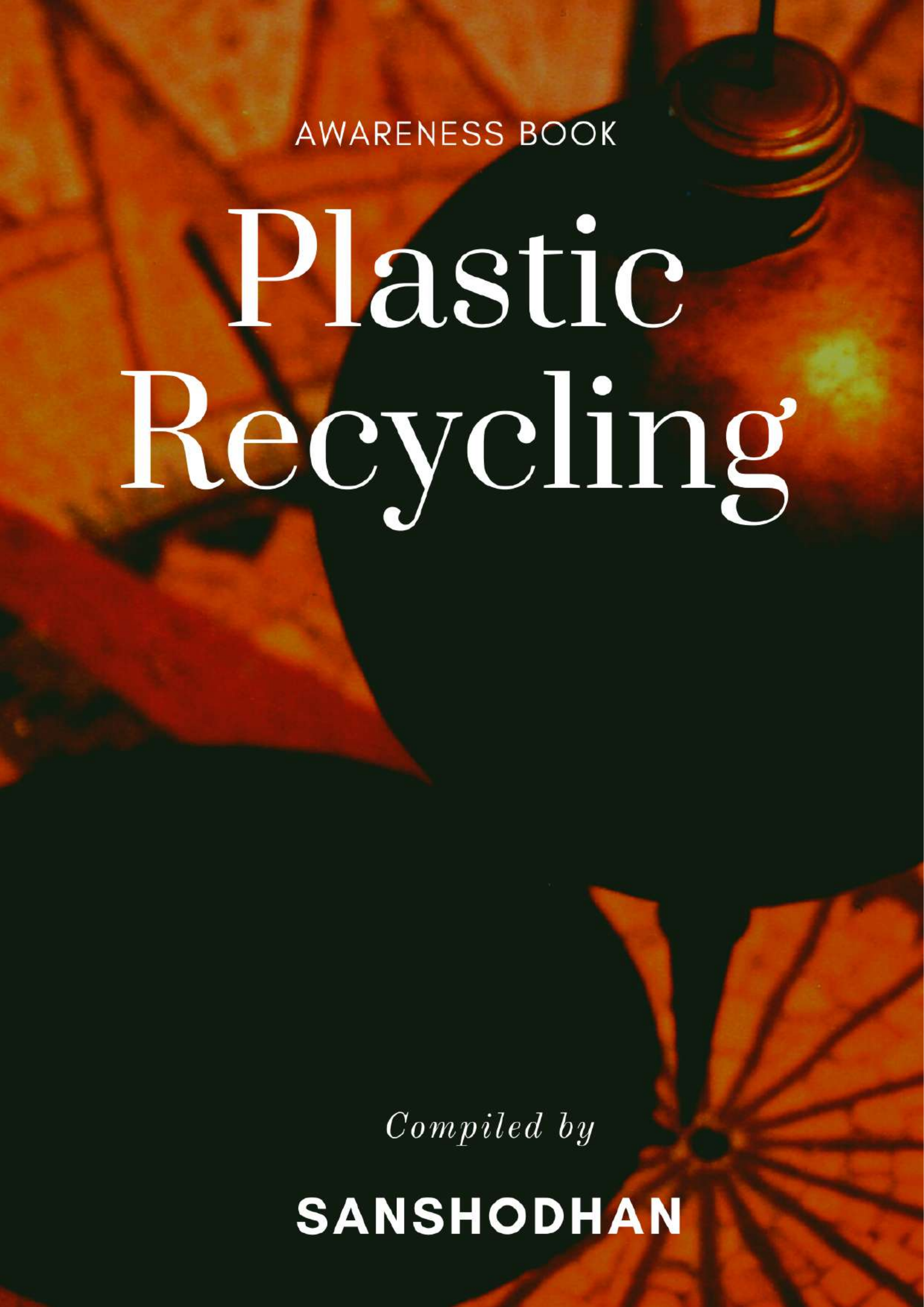


AWARENESS BOOK

Plastic Recycling

Compiled by

SANSHODHAN

Plastic Waste Recycling

Awareness Book

Published by

Sanshodhan

INDIA

www.SustainabilityExchange.World

Disclaimer

Sanshodhan accept no claims for compensation with respect to any wrong, abbreviated incorrectly included content in this booklet. No part of this publication may be reproduced, stored or transmitted in any form or means including electronic, mechanical, zeros or otherwise without the prior written permission from the Sanshodhan, India.

Published By

Sanshodhan
Hyderabad, Telangana 500008
REFERENCE NUMBER: San/04/2022

Copyright

Copyright ©2022

Sanshodhan An E-Waste Exchange Pvt Ltd. All Rights Reserved

This booklet shall not be copied or duplicated, without prior permission from the authors. Some materials contained within this booklet are taken from open, published sources and is the copyright property of others; acknowledgment of those open/published/copyright sources are provided in the chapter 'References'.

CONTENTS

CHAPTER-1

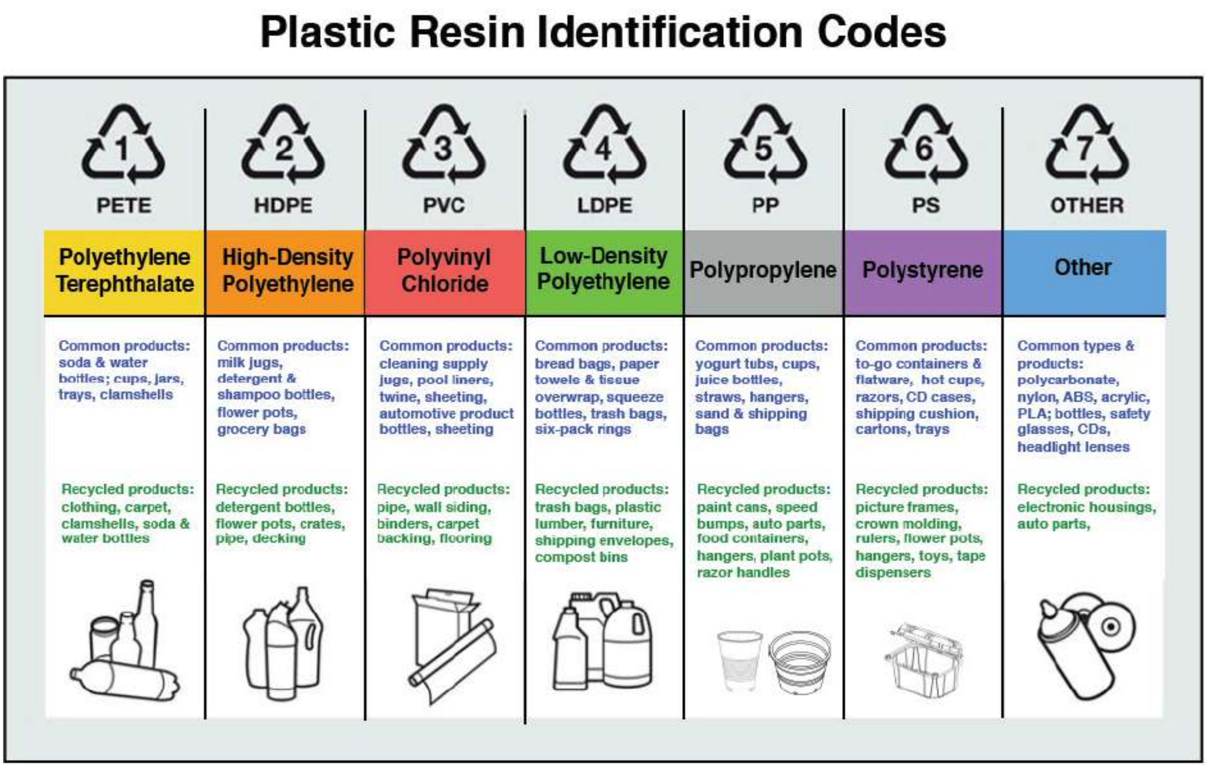
PLASTICS AND ADDITIVES

Plastics are non-biodegradable, synthetic polymers made up of long chain hydrocarbons with additives that can be moulded into completed goods, omitting compostable plastic or polymer satisfying IS/ISO 17088:2008. These polymers are broken down into monomers such as ethylene, propylene, vinyl, styrene, and benzene in the presence of a suitable catalyst. Following that, these monomers are chemically polymerized into various types of plastics.

The main category of plastics include:

1. Recyclable Plastics (Thermoplastics): PET, HDPE, LDPE, PP, PVC, PS
2. Non-Recyclable Plastics (Thermoset & others): Multilayer & Laminated Plastics, PUF, Bakelite, Polycarbonate, Melamine, Nylon and others

Figure 1. Categories of Plastics



ADDITIVES

Additives are chemicals blended into plastics to change their performance or appearance, making it possible to alter the properties of plastics to better suit their intended applications. Additives are therefore one of the reasons why plastic is used so widely. At a minimum all plastic contains some polymer stabilisers which permit them to be meltprocessed (moulded) without suffering polymer degradation. Other additives are optional and can be added as required, with loadings varying significantly between applications. Pure unadulterated plastic (barefoot resin) is never sold, even by the primary producers.

Although additives are blended into plastic they remain chemically distinct from it, and can gradually leach back out. Many of the controversies associated with plastics actually relate to their additives, as some compounds can be persistent, bioaccumulating and potentially harmful. The now banned flame retardants OctaBDE and PentaBDE are an example of this, while the health effects of phthalates are an ongoing area of public concern (Hahladakis et. Al., 2018)

As additives change the properties of plastics they have to be considered during recycling. Presently, almost all recycling is performed by simply remelting and reforming used plastic into new items. Waste plastic, even if it is all of the same polymer type, will contain varying types and amounts of additives. Mixing these together can give a material with inconsistent properties, which can be unappealing to industry. The most obvious example of this is with plastic colorants. Mixing different coloured plastics together can produce a discoloured or brown material and for this reason plastic is usually sorted by both polymer type and color before recycling.

Figure-2: Additive Types and Details. Source: https://en.wikipedia.org/wiki/Plastic

Additive type	Typical concentration when present (%)[28]	Description	Example compounds	Comment	Share of global additive production (by weight)[21]
Plasticizers	10–70	Plastics can be brittle, adding some plasticizer makes them more durable, adding lots makes them flexible	Phthalates are the dominate class, safer alternatives include adipate esters (DEHA, DOA) and citrate esters (ATBC and TEC)	80–90 % of world production is used in PVC, much of the rest is used in cellulose acetate. For most products loadings are at the lower end, high loadings give plastisols	34%
Flame retardants	1-30	Being petrochemicals, most plastics burn readily, flame retardants can prevent this	Brominated flame retardants, chlorinated paraffins	Non-chlorinated organophosphates are ecologically safer, though often less efficient	13%
Heat stabilizers	0.3-5	Prevents heat related degradation	Traditionally derivatives of lead, cadmium & tin. Safer modern alternatives include barium/zinc mixtures and calcium stearate, along with various synergists	Almost exclusively used in PVC.	5%
Fillers	0-50	Changes appearance and mechanical properties, can reduce price	Calcium carbonate "chalk", talc, glass beads, carbon black. Also reinforcing fillers like carbon-fiber	Most opaque plastic contains fillers. High levels can also protect against UV rays.	28%
Impact modifiers	10-40	Improved toughness and resistance to damage[32]	Typically some other elastomeric polymer, e.g. rubbers, styrene copolymers	Chlorinated polyethylene is used for PVC	5%
Antioxidants	0.05–3	Protects against degradation during processing	Phenols, phosphite esters, certain thioethers	The most widely used type of additives, all plastics will contain polymer stabilisers of some sort	6%
Colorants	0.001-10	Imparts colour	Numerous dyes or pigments		2%
Lubricants	0.1-3	Assists in molding the plastic, includes processing aids (or flow aids), release agents, slip additives	Paraffin wax, wax esters, metal stearates (i.e. zinc stearate), long-chain fatty acid amides (oleamide, erucamide)		2%
Light stabilizers	0.05–3	Protects against UV damage	HALS, UV blockers and quenchers	Normally only used for items itended for outdoor use	1%
Other		Various	Antimicrobials, antistatics		4%

CHAPTER-2

USAGE OF PLASTICS AND PLASTIC WASTE GENERATION

Plastics have become an indispensable component of everyone's daily lives. Its annual production exceeds 150 million tonnes, and India consumes around 8 million tonnes of plastic items each year. Films, wrapping materials, shopping and rubbish bags, fluid containers, apparel, toys, domestic and industrial products, and building materials are just a few of the applications. Plastic trash is what happens when plastic is wasted after it has served its purpose. Plastic garbage does not dissolve and can linger on the landscape for several years. Plastic garbage is generally recyclable, however recycled items are more environmentally hazardous since they contain chemicals and colours.

A virgin plastic material can only be recycled 2-3 times since the substance deteriorates due to heat pressure after each recycling and its life expectancy is lowered. As a result, recycling is neither a safe or long-term alternative for disposing of plastic garbage. Approximately 70% of plastic packaging products are anticipated to be transformed into plastic garbage in a short period of time. Plastic garbage is generated in the country at a rate of 5.6 million tonnes per year, or 15342 tonnes per day.

SOURCE: CENTRAL POLLUTION CONTROL BOARD (CPCB)

CHAPTER-3

DISPOSAL OF PLASTIC WASTE : CHALLENGES

Indiscriminate littering and unorganised recycling/reprocessing and non-biodegradability of plastic waste raises the several environmental issues. Few challenges are outlined herewith:

- Release of fugitive emissions during polymerisation process.
- Release of harmful gases such as Carbon Monoxide, Formaldehyde etc. during product manufacturing.
- Land become infertile due to indiscriminate plastic waste disposal.
- Release of toxic emissions such as Carbon Monoxide, Chlorine, Hydrochloric Acid, Dioxin, Furans, Amines, Nitrides, Styrene, Benzene, 1, 3- butadiene, CCl_4, and Acetaldehyde on burning of plastics waste including polyvinyl chloride (PVC).
- Leaching of toxic metals into underground water such as Lead and Cadmium pigments due to indiscriminate dumping of plastic waste on land.
- Multilayer, metalised pouches and other thermoset plastic pose disposal problems.
- Sub-standard plastic carry bags, thin packaging films etc. pose problem in collection and recycling and reuse.
- Indiscriminate and littered plastic waste pose unaesthetic look and choke the drain.
- Soiled and mixed plastics waste interferes its beneficial utilisation.
- Unsound of plastic waste and running of recycling industries in non-conforming areas lead to release of fugitive emissions.

SOURCE: CENTRAL POLLUTION CONTROL BOARD (CPCB)

CHAPTER-4

PLASTIC WASTE : SECONDARY RESOURCE

Plastic has various qualities that makes it an excellent packaging material. Plastics, unlike paper and wood, do not absorb much moisture, and their water content is far lower than that of biomass such as crops and kitchen trash.

The types of waste plastics to be converted into fuel and the qualities of other wastes associated with waste plastic, determine the conversion processes. The need of effective conversion necessitates the selection of relevant technologies, which is also based on local economic, environmental, social, and related features. The type of plastic waste decide its end use or supply chain. For example, non-hazardous and combustible feedstocks are required for the conversion of waste plastic into fuel. Each form of waste plastic conversion technology, has its own suitable feedstock. Some plastic goods may contain undesirable components (eg. flame-retardants comprising bromine and antimony compounds or plastics containing nitrogen, halogens, sulphur, or any other hazardous substances) that pose potential dangers to individuals and the environment are not suitable for conversion into fuel but can be well used to develop the flame retardant products OR panels for use in construction sector.

The pre-treatment requirements, the conversion temperature (and thus the energy consumption required), the fuel quality output, the flue gas composition (e.g. formation of hazardous flue gases such as NOx and HCl), the fly ash and bottom ash composition, and the potential for chemical corrosion of the equipment are all influenced by the types of plastics and their composition.

Further, the example of conversion of plastic waste into fuel- Plastic waste is subjected to a variety of pre-treatment procedures before being converted into fuel, to ensure effective treatment during the conversion process. The pre-treatment equipment used for each form of plastic (crushing or shredding) varies depending on its structure (e.g. rigid, films, sheets, or expanded /foamed material).

CHAPTER-5

STAGES IN PLASTIC RECYCLING

British Plastic Federation (2022) has provided step by step guidance about recycling of plastic. Various stages in plastic waste recycling i.e. mechanical recycling, are detailed below.

5.1. Collection

This is the first stage of the recycling process, it involves the collection of recycling from our homes, businesses, and schools. For this stage it is important that everyone is correctly sorting their plastic ready for collection and recycling all the items they can.

This aggregated material is generally collected by a local authority either directly or using a waste management contractor. It shall be taken to a Material Recovery Facilities (MRF), and/ or a Plastic Recovery Facility (PRF) ready to be sorted. The material may be bulked at a waste transfer station before being transported to these facilities.

The collection of plastic is key for the recycling system to operate well. The more plastic suitable for recycling that is collected the more material available to be reprocessed and used back into new products.

5.2. Sorting

The second stage is sorting plastic from other materials and this is done at a Material Recovery Facility (MRF). This material may then go onto a Plastic Recovery Facility (PRF) for further sorting into the different types of plastic.

The mixed recycling will initially be removed from the collection vehicles and then mechanically placed onto conveyer belts.

Conveyer belts are used to maintain the constant flow of waste passing through the sorting facility. A series of techniques are used to separate the material ready for further processing.

Below are some of the sorting techniques. The techniques used in practice will vary by facility.

Manual Picking

Manual picking involves sorting by hand. During manual picking large items, non-recyclables and obvious contamination is removed. The items removed are sent for further processing or go for disposal.

Trommels

After non-recyclables have been removed the waste is feed into trommels. Trommels are cylindrical drums with holes that allow finer materials to fall through as the trommel rotates.

OCC Screening

The OCC screen separates old corrugated cardboard (OCC) from mixed recyclables. This is achieved by passing material over a rotating disc system. The thick discs provide lateral agitation of materials. The cardboard travels across the top of the screen and the other material fall through the rotating disc.

Ballistic Separator

A ballistic separator is a mechanical device which consists of two oscillating paddles. These oscillating paddles work in a way that means it moves rigid waste items to one end and flexible items (paper, card etc.) to the other allowing glass and finer materials to fall through the mesh. The rigid items can be bottles, containers or cans while the flexible may be paper, card board, newspapers, and plastic wrapping.

Magnet Separator

A magnet separator is used to remove any metal that are present. Waste travels on conveyer belts under a magnet where metals are separated and placed into a separate storage bin.

Eddy Currents – for non-ferrous metals

Eddy Currents separators are used to remove non-ferrous materials such as aluminium and copper from non-metallic material. Non-ferrous materials pass over the shell containing rotating magnets creating eddy currents. In turn this creates a magnetic field around the metals repelling them away from the magnet. This repulsion of the non-ferrous materials separates them from the non-metallic materials. Using an eddy current allows for easy and efficient separation of metals and non-metals.

Optic Sorting Machine

This is an important machine for separating different types of plastic.

An optical sorting machine helps to identify plastics at a high and efficient rate using near infrared (NIR) measurements. The NIR sensors are sensitive instruments that measure the absorbencies of samples at specific wavelengths. In this instance identifying types of plastics through their absorption of light. Waste is then separated through upward or downward ejection methods.

Initially, material is fed onto a fast conveyor that causes the material to be spread onto a single layer. A vibratory feeder can be used to feed the material onto the belt because it helps spread the material to the full width of the conveyor. It is scanned by the NIR sensor from around 12inches away. Different plastics such as PVC have different known NIR spectral images. This allows the scanner to identify that objects' plastic type. Jets of air are used to separate the different plastic types in different directions.

Sink-float Separator

Another important method used to separate plastic materials is a wet process known as a Sink-float separator. A tank is filled with water and plastic recycling, the high-density plastic sinks, and low-density plastic floats. The separated plastics will be recovered for more processing.

5.3. Reprocessing

Once the material has been sorted it will be transferred to a plastic re-processor for the next stage.

Further sorting for quality control

Some re-processors will have the equivalent of mini PRFs at the beginning of their processes to undertake further sorting depending on how the material arrives with them. Most facilities will do further sorting even if they purchase already sorted material to ensure any remaining contamination is removed. The sorting may include optical sorting machines and sink float separators to separate plastic by thickness, colour, size, and plastic type. Furthermore, plastic may be rerun through magnets to remove any metals that may have not been completely removed previously.

5.4. Washing

Washing helps remove adhesives, residual waste left in containers, food waste and labels. It is important that these are removed and the material is as clean as possible as it can affect the quality of the recyclate.

This stage is where the actions of people at home can make a big difference. By simply rinsing the plastic quickly to get off some of the food or other materials before they become dry and stick more severely helps ensure that the whole recycling system operates more effectively.

During the washing process the plastic may go through a range of washing methods depending on the contamination and processors. Firstly, friction washer which are the most common form of washer due to their low operation cost and effectiveness. Friction washers use heat, kinetic energy, and pressure to wash plastic of contaminants. Rotary washers use a caustic solution that is heated to removes oils and food stuff, depending on the degree of contaminations rotary washers can be used as a pre-washer.

5.5. Shredding / Grinding

A critical stage in recycling plastic is shredding or grinding plastic into smaller flakes. The washed and sorted plastic is sent through shredding machines where it is ground into smaller pieces of plastic.

The plastic is shredded in different manners depending on the classification and methods of the shredder. An example of a method is Hammer Mills: these are used to pulverize plastics in a rotary drum using swivelling hammers to do so. Other examples being Shear Shredders: using rotary cutters and guillotines to cut plastics to industry size requirements.

Further sorting may take place to ensure a pure stream of material is produced.

5.6. Extrusion : Plastic is Melted and Extruded into New Pellets

This is the final stage of plastic recycling. Extrusion is the process of melting down the plastic and forcing this through an extruder. The plastic is cut as it comes out of the extruder to form pellets.

Pellets are sold onto manufacturers.

For more details, refer https://www.bpf.co.uk/plastipedia/sustainability/how-is-plastic-recycled-a-step-by-step-guide-to-recycling.aspx

5.7. Types of Recycling

Mechanical Recycling
Mechanical recycling is by far the most prevalent recycling of plastic. It is the traditional method that has been in use for decades, responsible for the vast majority of plastic recycling around the world.

Mechanical recycling uses grinding, washing, sorting and reprocessing to repurpose plastic material. The plastic recyclate can then be converted into other products substituting for the use of virgin plastics. This article deals primarily with how plastic is collected, sorted and reprocessed via the traditional mechanical recycling route.

Chemical Recycling
Chemical recycling is the process of recycling plastics through the chemical change of the polymer structure forming a raw material that can be used to manufacture new products. Chemical recycling can deal with plastics that may not be suitable for mechanical recycling.

CHAPTER-6. MECHANICAL RECYCLING TECHNOLOGIES

6.1 Haisi Extrusion Equipment

TECHNOLOGY PROVIDER

Haisi Extrusion Equipment

REFERENCE

https://metalrecyclingmachines.com/waste-plastic-recycling-machines/Plastic-Crusher.html

FIGURES

PURPOSE OF THE TECHNOLOGY

Plastic crushers are used to crush a variety of plastic materials into granules of varying sizes. Plastics that have been crushed can be recycled to make new plastic goods. This equipment can assist reduce the amount of plastic garbage produced, resulting in significant cost and resource savings.

The plastic crusher's motor causes the moving blade cutter to spin at a rapid rate. Fixed blades and high-speed rotating moving blades form a relative movement. Big materials will be crushed into little sizes due to the space between them. The screen mesh will discharge crushed plastics that meet the standards. The final particle output size is determined by the size of this screen.

A plastic crusher can crush PVC, TPR, PP, PE, EVA, PET, PC, TPE materials, waste rubber products, sponge etc. Plastic crusher can crush various kinds of plastics, such as plastic bottles, plastic profiles, plastic pipes, plastic plates, plastic sheets, plastic shells, plastic films, woven bags etc.

BENEFITS

- Small space occupation, low power consumption
- Easy to operate, easy to clean and maintain
- Crusher blades adopting nitriding steel material, durable in use
- Granular size is adjustable
- Cleaning drum is optional and can be equipped to different models.

There are various mechanical equipments for different stages of plastic cleaning, washing and shredding etc. The user need to explore the technology best suited for their operations.

6.2. Utilisation of Plastic Waste in Road Construction

TECHNOLOGY PROVIDER

The technology was initially developed and patented by Mr Rajagopalan Vasudevan of the Thiagarajar College of Engineering.

REFERENCE

https://www.theguardian.com/world/2018/jul/09/the-man-who-paves-indias-roads-with-old-plastic
https://www.cpcb.nic.in/index.php

FIGURES

PURPOSE

The procedure of laying roads with waste plastics has been developed, and the approach is being successfully utilised in India for the construction of flexible roads. This innovative method detailed the reuse plastic waste to construct better, more durable and very cost-effective roads. This method help in making roads much faster and also save the environment.

BENEFITS

Stripping and pothole formation: Water penetration causes the bitumen layer to be removed from the aggregates, resulting in pothole formation. This is accelerated while the car is moving. When polymer is coated over aggregate, the coating inhibits the aggregate's affinity for water due to the polymer's non-wetting characteristic, preventing water penetration. As a result, water penetration is limited, preventing stripping and preventing the formation of potholes on these roads.

Leaching: Even if the road is laid with waste plastics, the polymer will not leach from the bitumen layer - a combination of bitumen and aggregate.

Effect of bleeding: Bleeding has a greater softening temperature in the waste polymer-bitumen combination. During the summer, increase in temperature, is envisaged to reduce bitumen bleeding.

Effects of Fly Ash: Roads made from plastic-bitumen mix inhibits leaching of toxic compounds into soil.

6.3. Co-processing: Plastic Waste as an Alternative Fuel

TECHNOLOGY PROVIDER

TonToTon

REFERENCE

https://tontoton.com/co-processing-what-more-do-we-need-to-know-about-it/

https://www.cpcb.nic.in/index.php

FIGURES

PURPOSE

Co-processing is the process of using waste materials in industrial processes such as cement and power plants, as well as any other major combustion plants. Co-processing refers to the use of waste to replace primary fuel and raw materials, as well as the recovery of industry and materials from waste. Alternative fuels and raw materials are waste materials such as plastic waste utilised in co-processing. TonToTon have chosen co-processing as their waste management method because it allows them to address a growing problem: orphan plastic.

Similar projects are operational in few cement industries in India.

Co-processing:

- Burns waste at a high heat
- Completely destroys waste
- Converts waste into energy

- Reduces greenhouse gas emissions
- Avoids chemical pollution through stable temperature control.

BENEFITS

Co-processing of plastic trash benefits both the cement industry and the municipal authorities /in charge of waste management. Cement companies and power plants, on the other hand, can reduce their use of fossil fuels and raw materials, resulting in more environment-friendly output. Furthermore, one of the benefits of the existing facility's recovery strategy is that it eliminates the need to engage in alternative plastic waste operations.

6.4. Conversion of Plastic Waste into Liquid RDF (Oil)

To initiate the process of conversion of plastic waste into oil, plastic garbage is mechanically separated from municipal solid waste (MSW). The segregated plastic trash is delivered through a conveyor belt equipped with an optical segregation mechanism to ensure that all plastic waste is separated at the source. The mixed plastic waste is then catalytically pyrolyzes to produce liquid refuse derived fuel (RDF), which is more usable.

The process is known as random de-polymerization because the breakdown of bonds into monomers occurs at random. This method is used to break down plastic into smaller hydrocarbons. In the absence of oxygen and in the presence of particular catalytic chemicals, random de-polymerization is carried out in a specially built Reactor. 350°C is the maximal reaction temperature.

There are various types of recycling. It can be close loop recycling, open loop recycling or chemical recycling.

6.5. Primary Recycling

Closed-loop recycling is a type of primary recycling. The material can be recycled to create items that have the same qualities as the previous one, keeping the plastic polymer in the same 'loop.' Pre and post-consumer (mono-stream) plastics are recycled in primary recycling.

6.5.1. Closed Loop Mechanical Recycling

Mechanical recycling for pure plastics is considered as primary recycling. Plastics that aren't contaminated with other materials or polymers can be recycled in a closed-loop system.

6.5.2. Dissolution of polymers with two solvents

This method of physical recycling is similar to supercritical solvent dissolution(s). The polymer is dissolved in a specified solvent and then cleaned to remove any potential contaminants, with co-solvent utilised to separate the polymer and recover the used solvent. The polymer is re-granulated after it has been extracted. The solvents used to retrieve the polymer vary by polymer, and certain dissolution processes do not need co-solvents. For the time being, not all polymers can be recycled through dissolution. All polymers can be treated with dissolution, according to the model.

6.6. Secondary Recycling

Open-loop recycling is also known as secondary recycling. The material can be recycled, but the recyclate is of poorer quality than the original, thus the plastic polymer is used in other, typically lower-value products before being recycled in an 'open-loop' system.

This is currently the most common method of consumer plastic recycling.

6.6.1. Open-loop mechanical recycling

There is a large level of contamination in waste plastic polymers collected in mixed waste streams. Other materials or polymers can induce this in complicated goods, as can contamination from the usage phase or additions like colours.

Recycled plastic i.e. the outcome of secondary recycling, is generally of low quality, non-food grade plastic.

In developing and least developed nations, secondary recycling is a big challenge, specially due to non-availability or lack of quality control, quality standards and standard criteria for final products.

6.7. Chemical Recycling

Various methodologies are detailed in the 'Compendium of technologies', UNEP (2009). A brief about the few chemical recycling processes is provided herewith.

6.7.1. Gasification to feedstock products

This method of chemical recycling is similar to high-temperature gasification. The polymer is employed as a refuse-derived fuel in this technique, and it is converted to syngas with an H2/CO molar ratio of 2:1 in a gasifier. Depending on the polymer type, the amount of syngas produced and the associated CO_2 emissions too.

6.7.2. Pyrolysis to feedstock products

The polymer is employed as a refuse-derived fuel and transformed to pyrolysis oil, which is thought to be equivalent to diesel, in this chemical recycling method. The calorific value of the polymer determines the energy content of the diesel.

6.7.3. Pyrolysis to wax products

The polymer is utilised to obtain medium length hydrocarbon chains (C10-C14) to replace paraffin-like waxes in this chemical recycling method, which might also be used to replace lubricating oils.

6.7.4. Thermochemical recycling to monomers through gasification

At a medium to high temperature, the polymers are gasified, yielding a mixture of compounds, including BTX, monomers, and short carbon molecules (C2-C5). The finished product can be utilised to create new polymers. The polymer has a big influence on the compounds that are produced. Product separation is a crucial need for monomer recovery.

6.7.5. Thermochemical recycling to monomers through pyrolysis

The polymer is pyrolyzed at a medium temperature to produce an oil containing a variety of compounds, including monomers, BTX, and shorter carbon molecules. These can be reused to make new polymers, and the chemicals generated are very dependent on the polymer. Separation of the remaining oil is a crucial need for monomer recovery.

6.7.6. De-polymerization through glycolysis

Ethylene glycol is added to particular polymers (PET, Nylon 6) in the presence of a catalyst, and the polymer is de-polymerized to its building blocks, which can be re-used to manufacture new polymers.

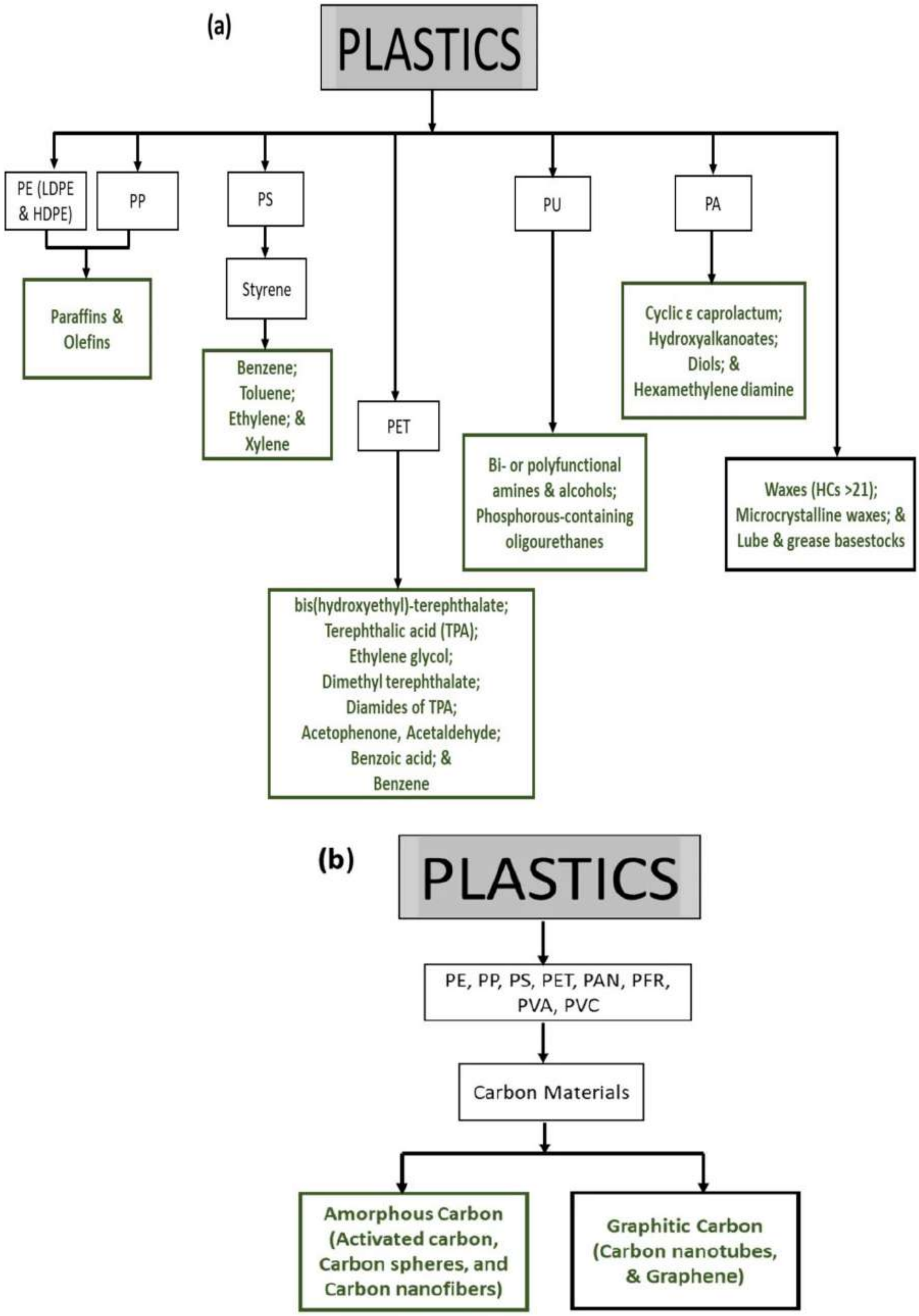
6.7.7. Hydrolysis with water for specific biopolymers

When heated up and broken down to its monomer building components, particular biopolymers (example, PLA) can be dissolved in water. These monomers can be recycled and used to create new polymers.

6.7.8. Chemicals and Carbon Materials

As published by Prajapati et. al, 2021, **Scheme 1.** (**a**) Various chemicals and (**b**) carbon materials produced from plastics are provided below:

Figure: ***Scheme 1.*** *(**a**) Various chemicals and (**b**) carbon materials produced from plastics*



Source: https://doi.org/10.3390/molecules26113175

According to Prajapati et. al. (2021), petrochemical industries need to put more emphasis on the preparation of other value-added products such as chemicals or chemical building blocks from plastic wastes. Figure, Scheme (a) and (b) mainly discusses the type of chemical raw materials and chemicals that can be recovered from plastic wastes (shown in Scheme 1 (a)). Plastic waste can also serve as a carbon source to produce valuable carbon-based products because carbon is the main constituent of plastics. A separate section about carbon materials (refer Scheme 1 (b), that can be made from plastic wastes is included.

6.7.9. Carbonisation

Plastic wastes can be converted to carbon materials such as amorphous and graphitic carbon. The amorphous carbons include mainly activated carbon, carbon spheres, and carbon fibers, while carbon nanotube (CNT) and graphene are graphitic carbon materials (Bazargan & McKay, 2012) (Zhou & Levendis, 2014). A two-step process, i.e., pyrolysis followed by carbonization, is generally used to make these carbon materials, and these processes are collectively termed carbonisation. These processes produce various HC gases and a residual product with a high amount of carbon (carbon materials). Carbonisation processes are usually performed under different conditions and are categorised as anoxic pyrolysis, catalytic, and pressure carbonisation, as described by Chen et al. (2020). A figure below summaries the different carbonization processes that can be used to make carbon materials from plastics.

FIGURE. *Summary of the different carbonization processes and their carbon products.*

Process	Operating Conditions	Plastics	Products
Anoxic pyrolysis Carbonization			
Without stabilization	T= 500–1000 °C in an inert atmosphere or in molten salt;	PET, PFR	Amorphous carbon products without metal impurities such as activated carbon, mesoporous carbon, and carbon fibers
Oxidation stabilization	Oxidation at T = 200–350 °C in the air; carbonization at T = 500–1000 °C in an inert atmosphere	PAN, LDPE, PVC,	
Chemical stabilization	Sulfonation or Friedel–Crafts reaction	PE, PS	
Catalytic Carbonization			
Catalytic carbonization	T = 400–900 °C in an inert atmosphere; with metal catalysts	PE, PP, PS, PVC, PTFE, PVA, PET, PFR	Graphitic carbons contain trace metals such as carbon nanotubes, carbon nanosheets, graphene, carbon foam
Catalytic pressure carbonization	T = 600–850 °C; with metal catalysts (in sealed reactor)	PP, PE, PS	Graphitic carbons
Pressure Carbonization			
Pressurized atmosphere	T = 600–850 °C (in sealed reactor)	PP, PE, PS, PVC	Amorphous carbon such as carbon spheres, activated carbon, and carbon dots without metal impurities
Hydrothermal carbonization	T = 150–300 °C in the presence of water (in sealed reactor)	PVC	

PE = polyethylene; LDPE = low-density polyethylene; PP = polypropylene; PS = polystyrene; PVC = polyvinyl chloride; PVA = polyvinyl alcohol; PET = polyethylene terephthalate; PFR = phenol-formaldehyde resin; PAN = polyacrylic nitrile; and PTFE = polytetrafluoroethylene.

CHAPTER-7: CASE STUDIES: INNOVATIVE PRODUCTS FROM PLASTIC WASTE

7.1. Wooden Deck From Plastic Bags

Wood decking is attractive and adaptable, but it is not very long-lasting. A Virginia-based company, on the other hand, has discovered a method for making 'wooden' decking almost entirely from waste items. The company makes composite deck boards from recycled sawdust and plastic bags, and it is currently one of the major plastic bag recyclers in the United States.

Trex's entire process is environmentally friendly from start to finish. Its innovative processing procedure cleans and grinds plastic film into granules first. These are then blended with recovered factory sawdust, and the combination is heated to make it soft and flexible. The slurry is formed into boards using profile dies, which are then chilled and cut to the required length.

Around 2,250 plastic bags are used in a standard 16-foot board, the majority of which are the hard-to-recycle thin-film type that is commonly used as sandwich bags, overwrap on kitchen rolls, and newspaper sleeves.

To obtain the plastic, the corporation has established a statewide recycling programme with drop-off locations outside of stores, as well as in local communities and schools.

SOURCE: TREX

7.2. Plastic To Bricks

Nzambi Matee, fed up with waiting for the government to solve Kenya's plastic pollution problem, decided to take matters into her own hands. The entrepreneur established Gjenge Makers, a firm that recycles plastic trash into bricks that are stronger than concrete. The Nairobi-based manufacturer has created a prototype machine that can produce 1,500 bricks each day using a variety of polymers.

Matee gathers waste from packaging units, for free and reimburses other recyclers for the plastic. The machine churns the plastic trash with sand, then heats it and eventually compresses it to produce bricks, using a combination of high-density polyethylene used in milk and shampoo bottles, low-density polyethylene used in sandwich and cereal bags, and polypropylene used in ropes and buckets.

Despite the fact that Matee avoids PET, Gjenge Makers has been able to recycle more than 20 tonnes of plastic trash into paving bricks in a variety of colours since 2017. Matee also intends to break even by the end of the year by adding a larger production line that may triple capacity.

SOURCE: GJENGE MAKERS

7.3. Plastic Waste To Furniture For Public

Every year, an estimated eight million tonnes of plastic enter the world's oceans, adding to the 180 million tonnes already there. Ninety percent of plastic enters the ocean through waterways.

Two designers from Hong Kong's HIR studio have devised a collection of benches to help solve this problem. Howard Chung and Irene Cheng were inspired by the Shin Mun River and collected single-use plastic debris to upcycle into beautiful public furniture. Only 13% of Hong Kong's plastics are repurposed, according to the pair, due to a dearth of recycling containers and collecting stations, and plastics are frequently downcycled into garbage bags or other items.

With the support of NGOs Waste No Mall and the Sha Tin Recycling Centre, which collects recyclable HDPE plastics from public housing estates and green stations every week, Chung and Cheng were able to locate a supply of recyclable HDPE plastics. To verify that the furniture was sturdy enough to resist plastic use, 20,000 pieces of salvaged plastic weighing about half a tonne were mixed with virgin plastic during the design phase.

SOURCE: HIR STUDIO

REFERENCES

1. A.E. Schwarz, T.N. Ligthart, D. Godoi Bizarro, P. De Wild, B. Vreugdenhil, T. van Harmelen, Plastic recycling in a circular economy; determining environmental performance through an LCA matrix model approach, Waste Management, Volume 121,2021, Pages 331-342, ISSN 0956-053X, https://doi.org/10.1016/j.wasman.2020.12.020. (https://www.sciencedirect.com/science/article/pii/S0956053X20307091)

2. "About Us." Brothers Make, www.brothersmake.com/about. Accessed 26 Feb. 2022.

3. Anti. "Homepage." Anti, 8 July 2021, www.anti-waste.com.

4. Bazargan, A.; McKay, G. A review-synthesis of carbon nanotubes from plastic wastes. *Chem. Eng. J.* **2012**, *195*, 377–391.

5. Converting Waste Plastics into a Resource - Compendium of Technologies. UNEP - UN Environment Programme, 2009. www.unep.org/resources/report/converting-waste-plastics-resource-compendium-technologies. Accessed 26 Feb. 2022.

6. Chen, M.; Liu, Z.; Jiang, S.; Hou, H. Carbonization: A feasible route for reutilization of plastic wastes. *Sci. Total Environ.* **2020**, *710*, 136250.

7. Gjengemakers. www.gjenge.co.ke. Accessed 26 Feb. 2022.

8. HIR Studio Hong Kong Architects and Spatial Design Studio. Hirdesign, www.hir-studio.com. Accessed 26 Feb. 2022.

9. https://www.cpcb.nic.in/index.php

10. https://www.theguardian.com/world/2018/jul/09/the-man-who-paves-indias-roads-with-old-plastic

11. https://tontoton.com/co-processing-what-more-do-we-need-to-know-about-it/

12. Hahladakis JN, Velis CA, Weber R, Iacovidou E, Purnell P (February 2018). "An overview of chemical additives present in plastics: Migration, release, fate and environmental impact during their use, disposal and recycling". *Journal of Hazardous Materials*. **344**: 179–199. doi:10.1016/j.jhazmat.2017.10.014. PMID 29035713.

13. Innovation in Fashion - Remeant Textile Innovation in Fashion Industry. Remeant, 24 Aug. 2021, www.remeant.com/innovation-in-fashion.

14. Prajapati, Ravindra; Kohli K; Samir K. Maity and Brajendra K.Sharma; Potential Chemicals from Plastic Wastes. 2021. https://doi.org/10.3390/molecules26113175

15. Step by step guide to recycling. British Plastic Federation. 2022. https://www.bpf.co.uk/plastipedia/sustainability/how-is-plastic-recycled-a-step-by-step-guide-to-recycling.aspx

16. Zhou, C.W.; Levendis, Y.A. Upcycling waste plastics into carbon nanomaterials: A review. *J. Appl. Polym. Sci.* **2014**, 131. [**Google Scholar**] [**CrossRef**]

USEFUL GUIDE BOOKS & REFERENCE

Plastic Waste Management (Amendment) Rules, 2022, Government of India.

Handbook of Plastics Recycling.

Understanding Plastics Recycling: Economic, Ecological, and Technical Aspects of Plastic Waste Handling.

Plastic Waste and Recycling, Environmental Impact, Societal Issues, Prevention, and Solutions.

Sustainable Home: Practical Projects, Tips and Advice for Maintaining a More Eco-friendly Household, by Christine Liu

No. More. Plastic.: What You Can Do to Make A Difference, by Martin Dorey

Live Green: 52 Step for a More Sustainable Life, by Jen Chillingsworth

Junkyard Planet, by Adam Minter.

Trash Talk: An Encyclopedia of Garbage and Recycling around the World, by Robert W. Collin.

High Tech Trash, by Elizabeth Grossman.

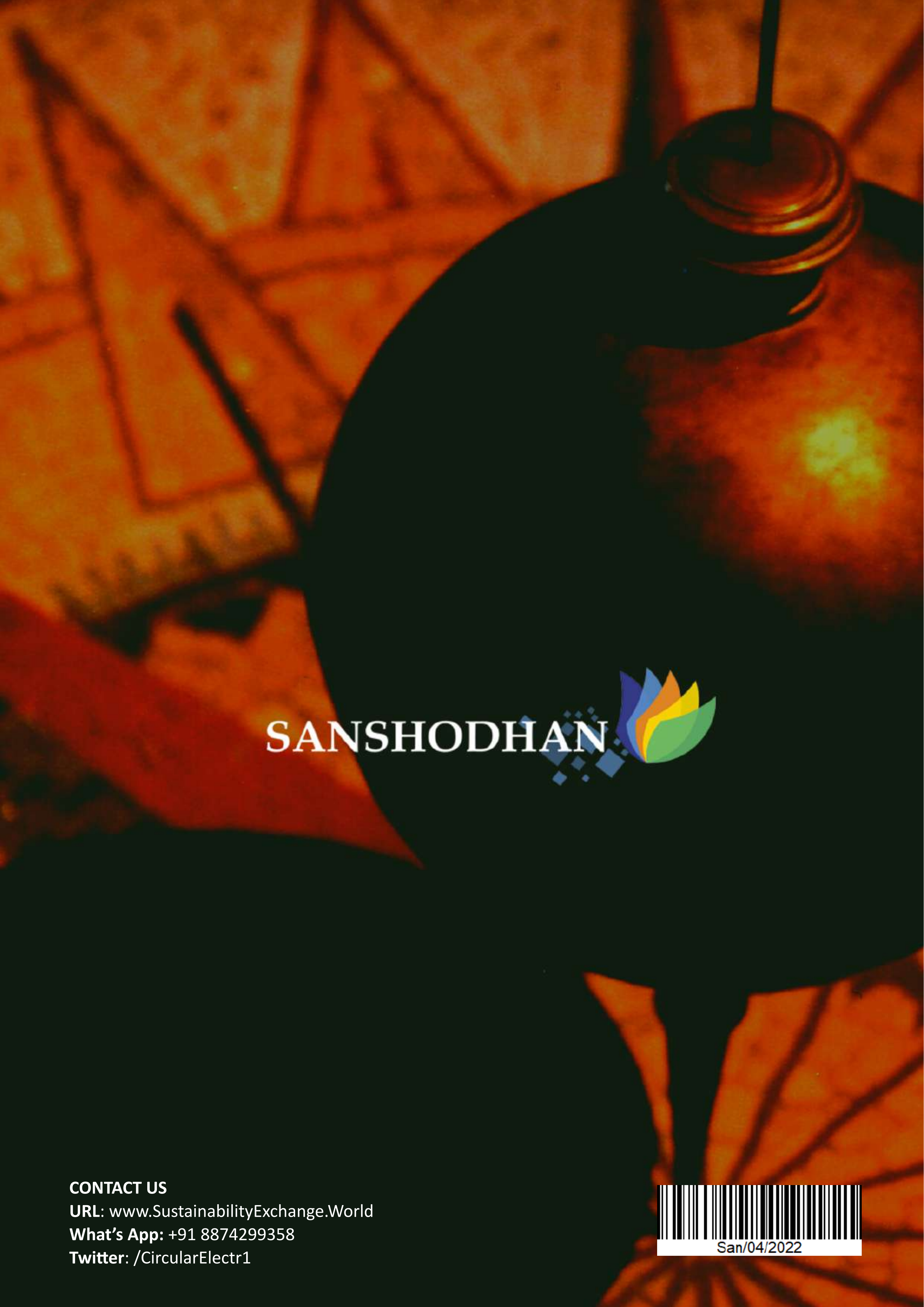
Understanding Plastics Recycling, Economic, Ecological, and Technical Aspects of Plastic Waste Handling **by** Rudolph, N. , Kiesel, R., Aumnate, C.

Plastic Waste and Recycling: Environmental Impact, Societal Issues, Prevention, and Solutions, by Trevor M. Letcher.

Plastic Lead Market Using Plastic Waste: Global markets to 2026. ID 5458842.

Global Plastic Recycling Market (2021-2027) by Application, Process, Material, And Geography, IGR Competitive Analysis, Impact of Covid-19, Ansoff Analysis.

10 Ways to Reduce Plastic Pollution, NRDC. https://www.nrdc.org/stories/10-ways-reduce-plastic-pollution



SANSHODHAN

CONTACT US
URL: www.SustainabilityExchange.World
What's App: +91 8874299358
Twitter: /CircularElectr1

San/04/2022