Design guidance recommendations for food contact grade PET bottles

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INDIA PLASTICS PACT

List of abbreviations

AA	acetaldehyde
BIS	Bureau of Indian Standards
BOPP	biaxially oriented PP film
CSD	carbonated soft drink
EPE	expanded polyethylene
EVA	ethylene vinyl acetate
EVOH	ethylene vinyl alcohol
FCM	food contact material
FSSAI	Food Safety and Standards Authority of India
HCl	hydrochloric acid
HDPE	high density polyethylene
HMA	hot melt adhesive
IV	intrinsic viscosity
LDPE	low density polyethylene
MDPE	medium density polyethylene
MRF	material recovery facility
MXD6	nylon made from m-xylene diamine (MXDA) + adipic acid
NIR	near infrared
OPS	oriented polystyrene film
PEN	polyethylene naphthalate
PE	polyethylene
PET	polyethylene terephthalate
PET-G	PET, glycol-modified
PLA	polylactic acid
PP	polypropylene
ppm	parts per million
PS	polystyrene
PSA	pressure sensitive adhesive label
PVC	polyvinyl chloride
ROPP	roll over pilfer-proof aluminum cap
rPET	recycled PET
SiOx	silicon oxide (barrier coating)
SS	shrink/stretch sleeve labels
SSP	solid state polycondensation
UV	ultraviolet
WA	wraparound labels

Objective of the design guidance

Polyethylene terephthalate (PET) is the most widely used material globally for making rigid packaging containers for food and beverage packaging applications. PET bottles are transparent, strong, lightweight, chemically inert, durable, safe, and recyclable. In India, about 0.9 million tonnes of PET was used for rigid packaging in 2018-19[1] and 1.08 million tonnes in 2021.[2]

Plastic packaging made from a single polymer resin is easier to recycle than materials composed of multiple resins in one layer (for instance blends of PET and polyethylene naphthalate (PEN)) or different materials in multiple layers (such as PET//nylon//PET). In India, rigid containers for packaging liquid beverages are most commonly made from PET. Polypropylene (PP) and high density polyethylene (HDPE) are also used for some applications, such as retort-sterilized flavoured milk and juice, but form a small share of the market. PET is preferred for beverage packaging, especially that of carbonated soft drinks, because it offers more clarity than HDPE and PP, and has superior barrier properties. There is a large demand for recycled PET (rPET) for use in fibre and textile applications: this translates into a high value for post-consumer PET bottles and a correspondingly high rate of collection, 70% to 90%, and recycling.

Until recently, in India, the use of recycled plastics as food contact material (FCM) was banned by the Bureau of Indian Standards (BIS)[3] and the Food Safety and Standards Authority of India (FSSAI). As a consequence of this ban, almost the entire output of rPET was diverted to non-food, non-packaging applications[4] such as making polyester fibre, in turn used to make clothing, carpets and other textile items. A small percentage of rPET is made into sheets and strapping.

In January 2022, the Food Safety and Standards (Packaging) Regulations, 2018[5] were amended to state that recycled plastic can be, "used for storing, carrying, dispensing, or packaging ready to eat or drink food stuff". The lifting of this ban is expected to lead to a surge of interest in closed-loop bottle-to-bottle recycling applications. Given PET's widespread use and excellent recyclability, it is vital to design PET bottles such that post-consumer PET of a high quality is available for bottle-to-bottle FCM applications, that is, their collection and recycling are maximized.

[1] PlastIndia Foundation. (2019). Indian Plastics Industry Report 2019. https://www.plastindia.org/plastic-industry-status-report.php
[2] Research and Markets. (2022). India PET Resin Market Analysis. https://www.researchandmarkets.com/reports/5028726/india-pet-resin-market-analysis-plant-capacity
[3] BIS. (1998). IS 14534 (1998): Guidelines for recycling of plastics. https://law.resource.org/pub/in/bis/S11/is.14534.1998.pdf
[4] NCL Innovations. (n.d.). PET Recycling in India Understanding PET recycling in India. http://www.petrecycling.in/pet-recycling-in-india/
[5] Food Safety and Standards Authority of India. (2022). File No: STD/SC/A – 40. https://fssai.gov.in/upload/advisories/2022/01/61e7acd01a850Direction_Recycled_Plastics_19_01_2022.pdf

The objective of this document is to provide an overview of technical and design-related aspects which, if put into practice, will ensure that PET bottles intended for FCM applications do not hinder the recycling process, recycler's yield, productivity and the quality of the final product.

Current Indian practices are referenced alongside to provide context, and a comparison with global practice mentioned wherever relevant. The characteristics of manual collection, sorting and their impact on the quality of flakes produced, have been identified and examined.

This guidance can be used by convertors, bottlers, bottle, cap and label manufacturers, and fast-moving consumer goods companies.

PET recycling in the Indian context

As per the Ellen McArthur Foundation's New Plastics Economy Global Commitment[6], a packaging or packaging component is recyclable if its successful post-consumer collection, sorting, and recycling is proven to work in practice[7] and at scale.[8]

Meeting all these requirements, post-consumer PET beverage bottles are the most commonly recovered and recycled type of packaging in India. A PET recycling system is in place operating through a network of waste-collectors, aggregators, traders, material recovery facilities (MRFs) and recyclers. Waste collectors collect mixed plastic wastes from households, streets or commercial establishments and sell to aggregators and traders, where the mixed wastes are manually sorted into categories, based on resin-type and format, and labels are manually removed (depending on agreements and value realization with recyclers). PET bottles are further sorted by colour, then segregated and baled at MRFs. Baled PET bottles are transported to recycling plants, where another round of manual and automatic sorting takes place, after which they are cleaned, shredded, hot caustic-washed, dried and sold to manufacturers of polyester fibre, straps and sheets.

Washed rPET flakes produced in this manner for use in fibre applications, do not require the decontamination and purity levels required for food contact use; a small quantity (<0.5%) of non-PET and non-volatile material can be tolerated, as long as it does not interfere with the extrusion and spinning into fibre.

When food contact grade rPET quality is to be achieved, flakes and/or pellets are further subjected to a rigorous decontamination process to ensure that there is no risk to consumer health, and that the taste, odour and composition of the food/beverage packed in rPET bottles are not adversely affected.

Two steps, decontamination and solid-state polycondensation, are required to make the flakes/pellets suitable for FCM application.

In the decontamination process, volatile contaminants from the rPET resin matrix are removed by heat, vacuum and/or nitrogen flushing.

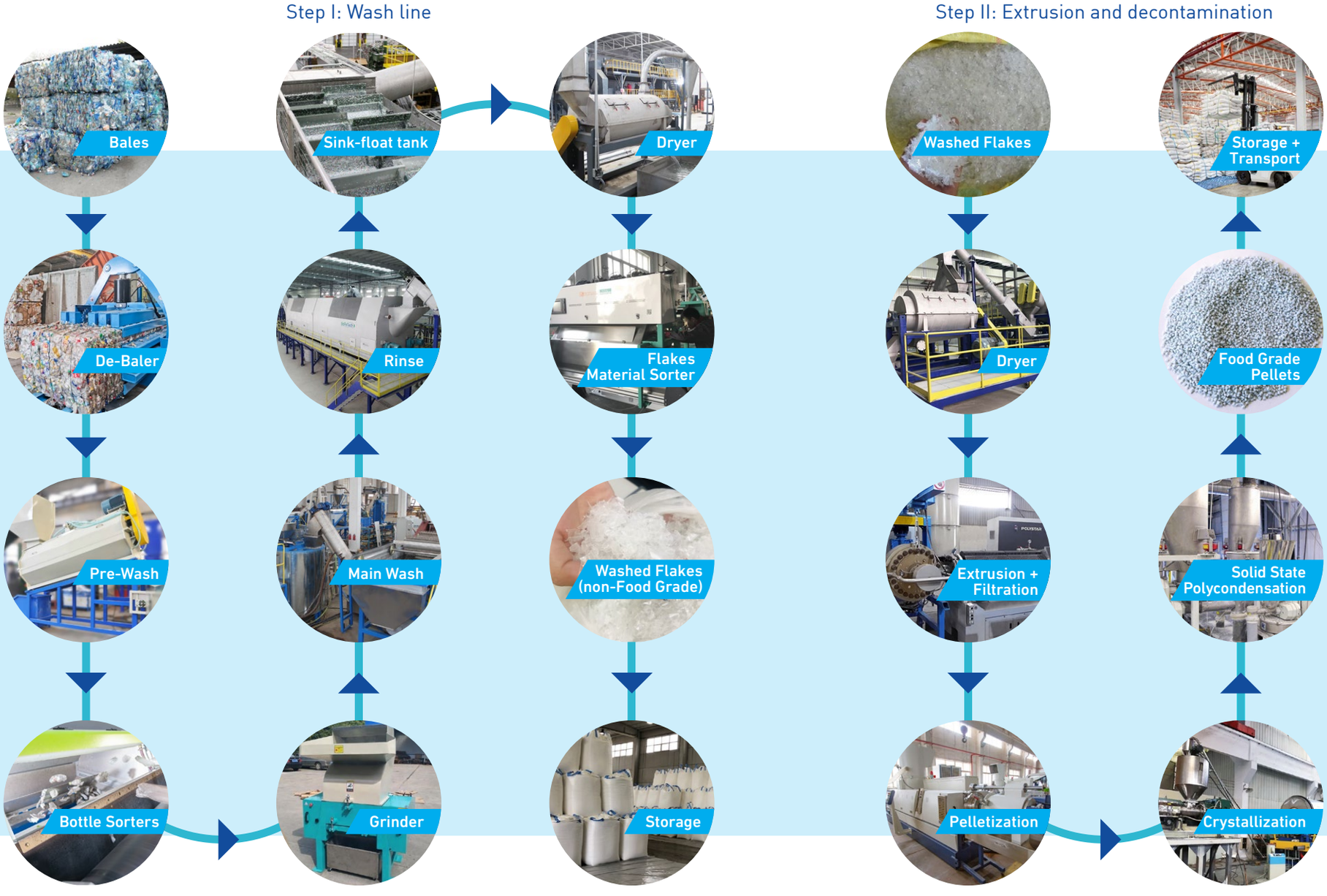
In solid state polycondensation (SSP), the rPET flakes/pellets are heated to approximately 210°C (below the PET melting temperature of 280°C) in the absence of oxygen, to increase the intrinsic viscosity (IV) of the PET resin.

[6] Ellen MacArthur Foundation. (2020). New Plastics Economy Global Commitment: Commitments, Vision and Definitions. https://emf.thirdlight.com/link/pq2algvgnv1n-uitck8/@/preview/1?o

[7] 'In practice' means that within each of these regions, the recycling system (end-to-end system from consumer to recycled material) effectively recycles a significant share of all packaging of that type put on the market. In other words, in that area a significant recycling rate is achieved for that type of packaging

[8] 'At scale' means that the proof needs to be more than a lab test, a pilot, or a single small region. It means that recycling of a certain packaging type needs to be proven to work in practice in multiple regions, collectively representing a significant geographical area in terms of population size, ideally across different country and city archetypes. This to indicate that the recycling in practice is replicable, and that the design of the packaging is not the barrier to realise recycling in practice in other countries.

Figure 1: PET recycling: process flow



PET bottle design guidance

Figure 2: Components of a PET bottle

The following aspects of a PET bottle and its components have implications on the ease of their recycling and should be addressed when they are being designed:

- **Bottle size and dimensions**
- **Bottle colour (including fillers)**
- **Barriers**
- **Additives**
- **Caps and closures**
- **Liners, seals and valves**
- **Labels and sleeves**
- **Adhesives**
- **Printing ink**

Design aspects that will facilitate the production of high-quality food contact grade rPET are described below with recommendations suited to the Indian context. The recommendations have been categorized into

Recycling-friendly	Conditional	Problematic
These have minimal or no negative effect on the productivity of recycling operation or final product quality. Packaging with these features are likely to pass through the recycling process into the most appropriate material stream with the potential of producing high quality material.	These present known technical challenges to the MRFs and recyclers' yield, productivity or final product quality but are tolerated by most MRFs and recyclers.	These pose significant adverse technical impact on the MRFs and recyclers' yield, productivity or final product quality. The majority of MRFs and recyclers cannot remove these features to the degree required to get a quality end product.

Bottle size and dimensions

Figure 3: Trommel drum screen

Source: Amstar Machinery Co., https://www.plasticrecyclingmachine.net/trommel/

PET bottles are produced in different dimensions, sizes, and, filling capacities, ranging from as low as 20 ml up to 20 L. The size and shape of PET bottles determines the ease and likelihood of collection, sorting, and segregation. Small size bottles (150 to 250 ml), typically used for single-serve drinks, are less likely to be collected by waste pickers because of their low weight and value realization.[9] Sorting at trader-level or in a material recovery facility is also affected by bottle size, with smaller bottles requiring more effort per kilo of bottles, to inspect and sort. Sorting and separation are typically by size first, and then by material. Smaller bottles are, therefore, less likely to be collected but may also be lost in automated sorting equipment.

At a recycling plant, after debaling, bottles are put through a series of manual, semi-automatic and automatic sorting and cleaning processes. A trommel drum screen slot is used to remove loose non-PET items such dirt, stones and loose caps. 150 ml-bottles (diameter <50 mm and length <100 mm) may drop through the trommel drum screen slots, along with other waste.

[9] Small size bottles are easy to collect from point sources of waste generation (such as restaurants or banquet halls), but collection is not viable when they are littered.

Bottle size and dimensions

Figure 4: Large size PET cans

After the trommel, bottles pass through a magnet which removes metal parts such as rings and caps. They then enter a manual sorting bay, where any other remaining plastic/metal parts, coloured bottles and labels are removed. The next step is automated sorting of material using laser or other kind of detection, where bottles with a small surface area can escape detection and get ejected.

In the Indian context, most of the initial sorting is manual at street level, and automated sorting is a final step carried out at large (greater than 10,000 ton per month capacity) recycling facilities.

Large size PET cans/jars of capacity 5 L to 20 L are used for edible oil and packaged drinking water for home or multi-serve use. At material recovery facilities, these are cut into pieces before baling to prevent jamming conveyor streams in the recycling process. Also, during the automated sorting process, their separation by air jets is difficult owing to their bulk size and weight.

The table below provides the detailed container dimensions and capacities commonly used in the Indian beverage industry.

Table 1 : Commonly used bottle sizes in the Indian beverage industry

Products	Bottle diameter (mm)	Bottle length (mm)	Typical capacities
Dairy/juice	50 to 120	150 to 350	180 ml to 3 L
Carbonated soft drinks	50 to 120	150 to 350	200 ml to 3 L
Water	50 to 300	150 to 500	200 ml to 20 L

Table 2: Design guidance for bottle size

Recycling-friendly	Conditional	Problematic for recycling
Diameter >50 mm and/or length >100 mm, <400 mm	Diameter 40 to 50 mm and/or length <100 mm	Diameter <30 mm and/or length >400 mm

Bottle colour and fillers

While the majority of PET bottles used are clear, green and amber bottles are also used commonly for some applications and by brands to differentiate their products. In India, clear PET bottles are largely used for water, carbonated soft drinks (CSD), juices, and dairy beverages. Light green/yellow bottles are used for certain categories of lemon-flavoured, pale yellow liquids. Typically, 83% to 88% of PET bottles placed on market are clear, 10% to 15% are green, and 2% to 3% are amber/brown, blue or other colours.

Sometimes the colouration, amber/brown for example, is important to increase the shelf-life (amber/brown coloured bottles reduce exposure to sunlight) and such bottles are used in wellness and pharmaceutical applications. White opaque PET bottles are used in some long-life dairy product packaging applications.

Fillers, such as calcium carbonate, are used to lower the cost of bottles for some applications (dairy and shampoo packaging) while white masterbatches, containing titanium dioxide, are used to impart opacity (for instance in milk packaging). Coloured masterbatches with various pigments are used to impart colours to PET bottles.

Coloured PET bottles are problematic because of the extra time and labour needed to separate them from transparent bottles by traders, at material recovery facilities and by recyclers. If they are not sorted, the resultant flakes would be multi-coloured, not suitable for use in the textile or bottle-to-bottle applications and would need to be tinted black or grey; neither of which is in high demand.

Waste-pickers sell all bottles – clear, opaque or coloured – to traders. Traders are required to arrange for their separation and storage until there are enough of one colour to sell to a recycler.

Bottle colour and fillers

This additional requirement to sort, segregate and store PET by colour leads to higher operational costs (manpower and storage) for traders and MRFs. Coloured bottles are sold at a different price point in the market and each colour has its own demand-supply dynamics, but typically sold at lower prices than clear bottles. For these reasons, colours should be avoided, or minimised as they tend to contaminate the recycled PET stream and impact the clarity of rPET resin.

Fillers such as calcium carbonate, hamper the recyclability of PET bottles by reducing the transparency of flakes obtained after melting.

The Bureau of Indian Standards[10] and an FSSAI 2005 regulation had restricted the use of opaque and dark coloured PET for packaging water, but recently, in January 2022[11], the FSSAI issued a notification amending this standard, and lifting the restriction. While large companies are unlikely to change their practices as a result of this amendment, smaller companies might begin using coloured PET as a convenient way to distinguish their brands from others'. Due to this there is a chance of increased number of coloured PET bottles in the market. This might lead to higher operational costs at MRFs for sorting and might increase the likelihood of coloured PET bottles remaining uncollected.

Table 3: Design guidance for bottle colour and fillers

Recycling-friendly	Conditional	Problematic for recycling
Clear/natural	• Light blue, green tints[12] • Amber/brown colour in light sensitive applications only • Dark green, blue, black, if near infrared (NIR) detectable	• Opaque, strong colourants • Fillers

[10] BIS. (2005). Manual for Packaged Drinking Water (Doc No.: SM/IS14543/01). Available at: https://bis.gov.in/qazwsx/cmd/water_manual.pdf
[11] FSSAI. (2022). Food Safety and Standards (Packaging) First Amendment Regulations, 2022 (F.No. Std/SP-08/A-1.2019/N-01). https://fssai.gov.in/upload/notifications/2022/01/61f2431e10029Gazette_Notification_Water_27_01_2022.pdf
[12] In the Indian market, there is a large proportion of PET bottles with green tint. This should not be a challenge if these are collected, sorted and recycled separately. Please note, green color is a challenge, but green tints are not.

Barriers: coatings, blends, and multi-layers

For most beverage packaging applications, monolayer PET offers a good enough barrier for the intended shelf life. However, certain light- and oxygen-sensitive products, such as orange juice, milk, beer and tomato juice/ketchup, have higher barrier requirements that cannot be met by monolayer PET. For such applications, the use of multi-layered structures or barrier coatings is necessary to protect the packaged product from light and prevent oxygen and gas loss.

Major technologies that are used to enhance gas barrier properties of PET are:

1. Coating materials such as silicon oxide (SiOx) or carbon less than 0.1 micron thick inside PET bottles, that increase the shelf life of a single-serve packaging (<500 ml) almost three-fold, to more than 25 weeks. These coatings are PET-recycling friendly[13] and are the most used barriers in India, primarily in carbonated soft drink packaging.

   Such coatings are generally not used in bottles of large sizes due to cost considerations.

2. Multilayer PET bottles, in which one layer of the material with barrier-enhancing properties, for example, nylon-MXD6 or ethylene vinyl alcohol (EVOH), is placed between two PET layers. Although these are not used in the Indian context, acceptable ranges for their use, with respect to recycling, are presented in the table below to cover the possibility of future shifts in the market towards packaging oxygen-sensitive liquids in PET bottles.

3. Blends with materials such as PEN, are added to PET resin before the injection process. However, these are not commonly used in India.

Figure 5: Schematic showing the difference between coatings, multilayer and blended barriers

Source: Nakaya, M., Uedono, A., & Hotta, A. (2015). Recent Progress in Gas Barrier Thin Film Coatings on PET Bottles in Food and Beverage Applications. Coatings, 5(4), 987-1001. https://doi.org/10.3390/coatings5040987)

Table 4: Design guidance for use of barriers

Recycling-friendly	Conditional	Problematic for recycling
• SiOx coating • Carbon plasma-coating	• Nylon-MXD6 in a multilayer structure with <5% nylon-MXD6 and no tie layers • EVOH multilayer with <3% EVOH and no tie layers	• Nylon-MXD6 in a multilayer structure with >5% nylon-MXD6 • EVOH multilayer with >3% EVOH or with tie layers • PET/PEN blends

[13] Resource Recycling, Inc. (2019). Company unveils RPET bottle with recycling-friendly barrier coating. Plastics Recycling Update. Resource-recycling.com rPET bottle with recycling friendly barrier coating

Additives

PET resins contain chemical compounds or additives to improve the processing performance, functionality and ageing properties of the polymer.[14] The most commonly used additives are antioxidants, light and heat stabilizers, toners for controlling yellowing, and fast reheat additives: these are used in very low quantities (0.001% (10 ppm) to 0.1% (1,000 ppm)) and do not affect the quality of rPET.

However, the use of special functional types of additives, such as ultraviolet (UV) stabilisers, acetaldehyde (AA) blockers and oxygen scavengers must be evaluated to ensure that they do not impact the colour and odour of rPET or produce off-taste in the contents.

Degradation-promoting additives (termed pro-oxidant additives) are sometimes added to make PET material degradable (via the action of ultraviolet radiation or heat to reduce molecular mass). These additives hamper recycling[15] by breaking down PET molecular chains during extrusion, reducing the internal viscosity of rPET and thereby its quality. Bottles with and without oxo-degradable additives are identical in appearance: they cannot be distinguished by manual sorters or automatic sorting methods.[16]

Table 5: Design guidance for use of additives

Recycling-friendly	Conditional	Problematic for recycling
Antioxidants, thermal stabilizers	Optical brighteners, AA blockers, UV stabilisers, O_2 scavengers	Bio/oxo/photo degradable additives

[14] Hahladakis, J., Velis, C., Weber, R., Iacovidou, E., & Purnell, P. (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. https://doi.org/10.1016/j.jhazmat.2017.10.014

[15] New Plastics Economy. (n.d.). Oxo-degradable plastic packaging statement. https://ecostandard.org/wp-content/uploads/oxo-statement.pdf

[16] Same as above

Caps and closures

Caps and closures (both terms mean the same and are used interchangeably in the packaging industry) for PET bottles are usually made of non-PET resin (typically polyolefins) or metal. These should be made of recyclable material and designed so as to not interfere with the PET recycling process. After collecting PET bottles, caps and closures are generally left on the bottle to increase the weight and purchase value. Also, their removal by hand at material recovery facilities or by waste collectors would take up too much time and even then would not be generated in sufficient quantities to sell separately.

During the recycling process, plastic closures are shredded together with PET bottles. Since polyolefins are less dense (density=0.90 g/cm^3 to 0.96 g/cm^3) than water (1 g/cm^3), shredded closures float on the surface and are separated from the more dense PET flakes (1.35 g/cm^3), which settle at the bottom of the sink-float tank.

The floating polyolefin flakes are collected separately and sent into an ancillary recycling stream for use in other applications (plastic dustbins, plant pots, traffic barriers/cones, etc.)

Closures are usually coloured and made of polyolefin resins (PP, HDPE or low density polyethylene (LDPE)) which melt at a lower temperature (180°C to 280°C) than PET resin (260°C to 290°C) in the recycling process. If not removed, they will contaminate the PET stream and discolour rPET flakes (black spots).

Figure 6: Sink-float water tank

PET bottles used to package still (non-carbonated) beverages such as water, juices, dairy products and tea, generally use single-piece HDPE closures, while those used to package carbonated soft drinks, soda and sparkling beverages, have two-piece PP closures with OVC/PE liners.

PET bottles used to package edible oil use LDPE closures; roll-on pilfer-proof (ROPP) aluminium caps are used with pharmaceutical and liquor products, while non-food personal care products (shampoo, body wash, hand wash, sanitizer) are typically packaged in bottles with PP closures.

Closures should be separable from the main container so that they do not hamper recycling of PET, and can be collected for processing. If they are separable, then the likelihood that they will end up as litter in the environment is also higher.

To minimise the separation of closures from bottles, the European Union (EU) has mandated the use of tethered caps for all beverage bottles from 2024. Tethered closures remain firmly attached to the bottle during use and after use, discouraging separation of cap from container by the consumer and preventing or minimizing litter.

At this point tethered closures are not required in India but such practices in foreign markets are usually adopted in India fairly quickly.

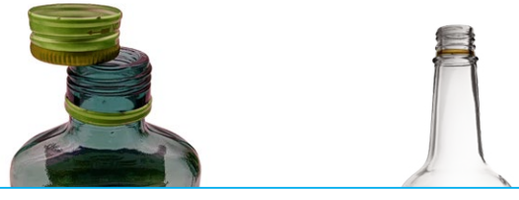
Caps and closures

Figure 7: Typical examples of two-piece, single-piece and tethered caps

Roll-on pilfer-proof (ROPP) aluminium caps when opened, leave behind a metal band around the bottle neck and do not make PET bottles easy to recycle.

ROPP caps are commonly used in the pharmaceutical industry; while packaging has largely shifted to PET bottles from glass without requiring changes in the bottle filling lines, aluminium capping machines continue to be used. Also, aluminium caps are easier to print on which make them the preferred choice.

Figure 8: Typical examples of metal caps and closures



Aluminium can lids are used on PET can packaging of sparkling flavoured water and juice drinks, and easy-open aluminium lids are used on wide mouth PET can packaging of snacks and nuts. They are applied to the container by seaming an aluminium lid to the PET body.

As the rim of the aluminium lid is seamed to the PET body, the metal ring remains with the PET container body when such lids are opened by the consumer and do not make for recycle-friendly closures. Waste-pickers and material recovery facilities try to increase the weight of material sold to traders/recyclers and collect these containers together with PET beverage bottles.

The use of aluminium metal (density 2.7 g/cm^3) should be avoided, as these settle under water along with PET flakes, separated in sink-float tanks, and are carried though the entire recycling process, leaving metal residues in the final rPET product. They may also damage the shredder blades, and block the extruder filter mesh/screen.

Table 6: Caps and closure types commonly used in Indian FMCG industry

Products	Primary choice
Dairy/juices	Single-piece HDPE closures
Carbonated soft drinks	Single-piece HDPE (liner less) are preferable Two-piece PP closures with polyethylene (PE)/ ethylene vinyl acetate (EVA) liners
Water	Single-piece HDPE closures
Pharmaceutical	ROPP aluminium cap with expanded polyethylene (EPE) liner
Liquor	ROPP aluminium cap with EPE liner
PET can for liquid	Aluminium can lids
PET can for solids	Aluminium easy open lids
Home and personal care	PP closures

Liners, seals and valves

Liners are used in some food and beverage containers to provide additional protection against product leakage, gas leakage, moisture entering from outside or to provide tamper-evident seals. Heat-seal liners stay attached to the bottle neck while non-heat-sealed type (as found in pharmaceutical applications) stay attached to the cap. Liners can be made of plastics, aluminium foil or a combination.

Liners used in two-piece closures for carbonated soft drink (CSD) and sparkling beverage packaging provide a good seal between the cap and bottle neck, preventing gas leakage and retain the desired carbonation level. These liners are made of soft polyvinyl chloride (PVC) with density around 1.31 g/cm^3 or PE/EVA resin with a density lower than 1 g/cm^3 and the cap body/shell is made of PP. PE/EVA liners are retained within the closure so that they float with the shredded cap pieces in the sink-float tank. PVC liners sink together with PET flakes and are not separated in sink-float tanks.

Recent improvements in the gas retaining performance of one-piece caps have eliminated the need for two-piece caps and thus the use of liner material. Single-piece PP/PE plastic closures, without liners, are the preferred option, and most commonly used for some food and cosmetics applications.

Figure 9: Typical closure liner

Liners, seals and valves

Flow control valves are used inside flip top caps on bottles of sauces and honey. These valves should be made of elastomeric materials such as EVA (density <1 g/cm³). Currently, EVA is not commonly used, because silicone rubber is cheaper. Silicone rubber with a density >1 g/cm³ should be avoided, since the silicone gets separated from the closure during shredding and sinks along with the PET flakes. Natural-coloured silicone, owing to the similarity in colour, is particularly difficult to separate from rPET flakes.

Figure 10: Flow control valve on bottle of honey

Aluminium foil seals are mostly used as tamper-evident and/or moisture-proof seals and are always sealed to the container neck. When peeled off the container, they may leave behind piece(s) of foil and/or adhesives on the neck, and hence are not a recycling-friendly choice.

Figure 11: Aluminium foil seal

Table 7: Design guidance for caps, closures, liners, seals and valves

	Recycling-friendly	Conditional	Problematic for recycling
Caps and closures	HDPE/LDPE/PP	-	Metal/polystyrene (PS)/PVC caps with materials density >1 g/cm³
Liners, seals and valves	PE/EVA/PP foamed PE/PET liner	Paper/silicone swimming valves with density <1g/cm³	Neck foils metal/PVC/silicone with density >1 g/cm³

Labels and sleeves

Labels and sleeves are used for product branding and to provide legal, regulatory and nutritional information to consumers. Labels should be designed for compatibility with the recycling process. Consumers in some developed markets are used to removing bottle labels and discarding the label and container in separate bins: this reduces the operational costs of recycling.

In India, this is not practiced by the consumer and traders and material recovery facilities would rather not employ additional workers to remove labels. Labels are thus typically removed at the recycling plant: small recyclers remove labels before loading the bottles onto conveyors while larger units strip labels off using machines, with any remaining labels being removed in an additional manual step.

The most common types of labels used in beverage packaging are:

1. **Wraparound (WA) labels:** These are applied to flat surfaces on containers by roll-feed reel or cut and stack, pre-cut labels. WA labels extend around the whole circumference of bottle and usually have an overlap, meaning that one end of the label will be stuck over the other end. They are usually long and thin, and are commonly used on bottles for water and CSD beverages.

2. **Pressure-sensitive adhesive (PSA) labels:** These are similar to stickers. The self-adhesive feature of these labels means that pressure only is required to stick the label to the bottle. PSA labels are easily removed by peeling them off the container otherwise they remain firmly stuck. PSA labels are commonly used on bottles for premium water, juices and dairy beverages.

3. **Shrink/stretch sleeve (SS) labels:** Such labels offer more coverage than the above two types of label, do not require any straight labelling panel on the container, can be applied to bottles of any shape and can cover the body completely, or partially. Shrink sleeves can also be used as safety/tamper-evident material and do not require an adhesive for fixing.

There are two different sleeve labelling systems used:

   a. Shrink sleeves, in which heat is used in the application process to shrink the label so that it takes the shape of the container. Hot-filled juice/tea bottles, contour-shaped dairy bottles, manually labelled packaged drinking water bottles use shrink sleeve labels.

   b. Stretch sleeves, in which the label is stretched like a rubber-band and then applied to the bottle. Large size (2 L and above) dairy and food containers, non-food and bottles used to pack floor cleaning chemicals use stretch sleeves.

4. **Direct printing/decorations:** Direct printing can be used to provide branding and consumer information; in India, direct printing is used mostly to print batch codes, not for branding or decoration, owing to the high cost of ink and printing equipment. Only a few brands use direct printing on bottles of face wash and shampoo. Direct printing inks hamper recycling and their use should be minimized because they wash off in the caustic bath and contaminate the water. This increases water consumption (due to the need for changing the water) and discolours PET flakes.

Labels and sleeves

Figure 12: Wraparound labels, PSA labels, sleeve systems and direct printed bottles

The following factors about labels should also be considered from the perspective of recycling PET bottles:

Label material

Adhesive

Printing ink

To enhance recyclability, labels/sleeves should be easily detachable from the bottle and separable from PET flakes by specific gravity (density) separation in flotation tanks or air separators. They should not leave adhesive and ink residue on the bottles. Under Indian conditions, workers at all levels avoid the tedious work of removing labels, so they remain attached to the bottle, right up to the recycler, who has to pay extra for their removal. However, the practice varies and roughly 50% of the time, labels will be removed by hand before bottles reach the recycler.

Label material

1. Wraparound labels are generally made of biaxially-oriented polypropylene (BOPP) films. BOPP WA labels cover only a part of the PET bottle, exposing a significant portion which allows automatic sorting cameras to sense the bottle surface. PET bottles used for packaging water or carbonated soft drinks use BOPP WA labels with a film density in the range of 0.55 to 0.90 g/cm^3. These labels float in the sink-float tank, and do not impact the PET recycling processes. For these reasons WA labels are the most acceptable and recycling-friendly label materials. Metallised BOPP films are sometimes used as label material but they may get rejected and hence should be avoided.

2. Shrink sleeve labels are generally made of PVC, polyethylene terephthalate glycol (PET-G), polylactic acid (PLA) and oriented polystyrene (OPS) film. These films have a density greater than that of water and hence sink in water along with PET bottle flakes, making it difficult to separate the two. In addition, all these film materials have a negative impact on PET recycling, because their melting points are lower than those of PET flakes and carry printing inks, which discolours the rPET. Foamed PET labels are also available in small quantities, Which have density less than that of water and hence can be separated in the sink-float tanks.

   a. **PVC** small concentrations of PVC (50 ppm = 0.005%, that is, 0.05 kg of PVC in 1,000 kg of PET flakes), have a negative impact on PET bottle recycling[17]. The melt temperature of PVC is much lower than that of PET. This means that at the temperatures applied during drying, extrusion and SSP of rPET, PVC contamination degrades and releases hydrochloric acid (HCl) and chemically breaks down the PET polymer chains. The decomposed PVC creates yellow or brown discolourations and black spots in the final rPET, which result in an unacceptable and inferior rPET material.

   b. **PET-G** films do not release HCl, but PET-G has the same density as PET flakes and hence sinks and mixes with PET flakes in sink-float tank.

   c. **PLA** material is similar to PET and is difficult for manual sorters to differentiate at MRFs and recyclers. NIR sorting technology, used by large-volume recyclers, and making up about 50% of recycling in India, can detect and separate PLA from PET. PLA has a density of 1.24 g/cm^3, and sinks with PET flakes in the sink-float tank.[18] PLA has a low melting point, 170°C and starts to soften at 60°C. Thus, when PET flakes are dried, any PLA material contaminants will degrade and lead to yellowing of rPET. PLA fragments become sticky, resulting in an agglomeration of flakes and can affect the extrusion process.

3. Stretch labels use PE based films, with a density below 1 g/cm^3. Once shredded, they can be readily removed during the sink-float density separation stage and are therefore PET recycling-friendly.

4. PSA labels use PE, PP, PET or paper-based substrates (film) with either water-based acrylic or solvent-based rubber adhesives. With regard to PSA labels, it is highly desirable to use films that float in water and that can be separated from PET (sinks in water). The use of PSA paper labels is not desirable, as any remaining paper fibres can lead to surface defects and very small, sometimes microscopic holes, known as pinholes, during the blow-moulding of bottles using rPET resin.

[17] Alaerts, L., Augustinus, M., & Van Acker, K. (2018). Impact of Bio-Based Plastics on Current Recycling of Plastics. Sustainability, 10(5), 1487. https://doi.org/10.3390/su10051487
[18] Same as above

Label material

In India, all high-volume (sales) packaged drinking water brands use BOPP wrap-around labels with hot melt glue only on the lap joint. Regional brands, with low-speed filling lines and manual labelling, use PVC shrink sleeve labelling material.

Most juice and dairy brands use shrink sleeve labels, irrespective of the filling line speed while high-volume brands have moved from PVC shrink sleeve material to PET-G material. Local brands still prefer PVC film, because it is cheaper than PET-G film.

Paper can be used for a variety of label styles for beverage bottles: single-piece wraparound labels, two-piece front and back labels, and some pressure sensitive adhesive labels. Paper labels are used mostly for food containers packaging products such as mayonnaise, sauces, pickles, edible oil, and alcoholic beverages, all of which are collected in the PET bottle stream.

Paper labels can be readily removed from PET bottles by wetting the label in water in the label stripper unit of recycling plants. However, the removal efficiency depends on the type of adhesive used, with water-based adhesives easy to wash off, therefore allowing full labels to be removed without tearing. Paper labels with rubber-based adhesives or hot melt adhesives (HMA) are unsuitable because they may tear into small pieces and any paper remaining stuck to the PET flakes will burn during drying and extrusion, contaminating rPET flakes/pellets with black specks. Use of paper labels may necessitate more water changes during the sink-float process.

Paper labels are not commonly used in India and if they are to be used at all, they should be made of high wet strength paper, to reduce tear off and thus the obstruction to recycling.

PET bottles of premium water brands and non-food brands often use PSA labels of PET, PP, PVC, PE and paper material.

Table 8: Design guidance for labels

Label type	Recycling-friendly	Conditional	Problematic for recycling
Wraparound labels	HDPE/medium density polyethylene (MDPE)/LDPE/LLDPE/PP/OPP label with density <1 g/cm^3	Paper labels, metallic foils	Pressure sensitive labels, PVC/PS/paper/metallised labels with density >1 g/cm^2
Shrink sleeve labels	Material density <1 g/cm^3 with perforations and revealing >30% of bottle surface area	Materials with density <1 g/cm^3 without perforations and revealing <30% of PET bottle	PVC/PS/PLA/PET-G, other material with density >1 g/cm^3. Difficult to remove and/or NIR sort with heavy ink coverage
Stretch sleeve labels	Sleeves of PE/foamed PET with density <1 g/cm^3 and revealing >30% of bottle surface area	Sleeves of PE/foamed PET (density <1 g/cm^3) <30% of bottle	

Adhesives

Wrap-around BOPP labels use HMAs while pressure-sensitive adhesive (PSA) labels use water-based acrylic emulsions, solvent-based rubber solutions, or HMA. Paper labels (pre-cut or wrap-around) use water-based acrylic emulsion or starch adhesives.

Although only a very small amount of adhesive is required on a label, removing it adds a significant amount to the cost of recycling. Adhesives that wash off cleanly from PET and remain adhered to the label substrate are preferred as are adhesives that wash off easily in the hot caustic wash at temperatures below 80°C (and preferably below 65°C), without leaving any residue on the PET flake. The separated label pieces should not become tacky/sticky after they are removed from the washing bath otherwise they may adhere to washed PET flakes contaminating and discolouring them.

Plastics Recyclers Europe (PRE) has issued a list of hot-melt adhesives acceptable for mechanical recycling operations. Adhesives classified as 'good' have removal rates greater than 90%[19].

The Association of Post-Consumer Plastic Recyclers (APR) and the European PET Bottle Platform (EPBP) have developed testing protocols for adhesive manufacturers and packaging producers to evaluate the impact of adhesive products in PET recycling systems[20,21,22]. All label adhesives should be evaluated using these testing methods since all adhesives are imported except for some water-based emulsions, which are made in India.

Table 9: Design guidance for use of adhesives

Recycling-friendly	Conditional	Problematic for recycling
• Water soluble below 80°C • Minimal glue strip • Comply with PRE guidelines[23]	Permanent adhesives with paper labels	Water insoluble (even at elevated temperatures and pH levels)

[19] EuPR. (2001). Positive Glue list. www.epbp.org/download/297/eupr-positive-glue-list
[20] http://www.plasticsrecycling.org/technical_resources/testing/pet_flake_contamination_test.asp
[21] EPBP. (n.d.) Downloads. https://www.epbp.org/page/8/layout-link-5-downloads
[22] APR. (n.d.). Labels, Inks, Adhesives. https://plasticsrecycling.org/labels-inks-adhesives
[23] Packshop. (n.d.). Shrink Sleeves. https://www.packshop.in/shrink-sleeves.php
[24] European PET Bottle Platform. (2017). Quick Test QT 507 - Bleeding label. https://www.epbp.org/download/318/qt-507-label-bleeding

Printing inks

In PET bottle packaging, inks are used to print on labels, on sleeves and closures for batch coding and marking, and in some cases, direct printing is done on the bottle instead of labelling. In all these instances, the inks used should not bleed into the water and caustic hot-wash at 80°C. Ink bleeding can discolour rPET and increase the quantity of water required for washing. If ink separates from the label film in the wash step, it should be readily filtered from the PET flake as well as the wash water, and if the label floats, the ink should remain on the floating label: ink density should not cause a floating label to sink.

Although this method is not used in India, direct printing decoration on PET bottles should be avoided.
If it is being considered, only colours and inks that are removable under hot wash conditions <80°C should be used. PET flakes with any ink that remains on the surface are difficult to sort, as these PET flakes may not be separated and ejected and, therefore, end up discolouring the recycled PET resin during extrusion.

The European Printing Ink Association (EuPIA) have published guidelines on inks that do not introduce hazardous substances into recycled materials and developed test protocols for testing label ink bleeding.[24] These are also relevant in the Indian context.

Table 10: Design guidance for use of printing inks

Printing type	Recycling-friendly	Conditional	Problematic for recycling
Direct printing	Laser marked production or expiry date inks	Inkjet inks for direct printed production or expiry date	• Any other direct printing • Inks that bleed, are toxic, are hazardous or react with PET
Printing on labels	• Label inks are non-toxic • Follow EuPIA Guidelines	-	Label inks that bleed or peel off from label surface

[24] European PET Bottle Platform. (2017). Quick Test QT 507 - Bleeding label. https://www.epbp.org/download/318/qt-507-label-bleeding

Conclusions

Brand owners base the selection of closures, material colours, and label materials for bottles on a number of factors, but perhaps the most influential of these is consumer appeal which makes the brands lean towards highly decorative packaging. These are popular choices based on aesthetics. Recyclability has not been a high priority for brands in the past even though these choices can add significant cost and reduce yield and line efficiency for PET recycling streams.

PET plastics recycling has great market potential for recyclers, but its success depends completely on the decisions of packaging designers, brand owners and packaging converters. All these stakeholders must look beyond the bottle itself and consider the impact of components such as labels, inks and closures on the recycling stream. PET recycling value and efficiency can be maximized by promoting the use of components that are compatible with the existing PET recycling stream.

This guideline covers the most likely components associated with post-consumer PET bottles. Using this guideline as a tool to aid the review of current packaging and the development of new packaging, packaging designers, sales and marketing staff can prevent the use of materials or combinations of materials that might create problems in collecting, sorting or recycling PET bottles.

The use of the guideline will also drive a change, as more bottles get into highly recyclable categories, it will improve the overall quality of recycled PET and increase the quantity of high quality of rPET available for reuse back into bottles. This change will allow more widespread use of rPET and reduce the amount of material that is currently being downgraded due to impurities or poor colour.

Summary of guidance

Designing for an improved recyclability Guidelines give practical support and advice on circular economy design principles. These guidelines classify features that are readily acceptable, tolerable and problematic to MRFs and recyclers.

Recycling-friendly features have minimal or no negative effect on the productivity of the operation or final product quality. Packages with these features are likely to pass through the recycling process into the most appropriate material stream with the potential of producing high quality material.

Conditional features present known technical challenges to the MRFs and recyclers' yield, productivity or final product quality but are tolerated by most MRFs and recyclers.

Problematic features pose significant adverse technical impact on the MRFs and recyclers' yield, productivity or final product quality. The majority of MRFs and recyclers cannot remove these features to the degree required to get a quality end product.

Table 11: PET bottle design guidance summary

	Recycling-friendly Materials and aspects that are known to be acceptable in PET recycling and can be used.	Conditional Materials and aspects that might pose a low risk of interfering with PET recycling and should be avoided when possible.	Problematic for recycling Materials and aspects that pose a high risk of interfering with PET recycling and should not be used
Bottle size	Diameter >50 mm and/or length >100 mm, <400 mm	Diameter 40 to 50 mm and/or length <100 mm	Diameter <30 mm and/or length >400 mm
Colourants and fillers	Clear/natural	• Light blue, green tints[25] • Amber/brown colour in light sensitive applications only • Dark green, blue, black, if near infrared (NIR) detectable	• Opaque, strong colourants • Fillers
Barrier coatings, blends and multi-layers	• SiOx coating • Carbon plasma-coating	• Nylon-MXD6 in a multilayer structure with <5% nylon-MXD6 and no tie layers • EVOH multilayer with <3% EVOH and no tie layers	• Nylon-MXD6 in a multilayer structure with >5% nylon-MXD6 • EVOH multilayer with >3% EVOH or with tie layers • PET/PEN blends

[25] In the Indian market, there is a large proportion of PET bottles with green tint. This should not be a challenge if these are collected, sorted and recycled separately. Please note, green color is a challenge, but green tints are not.

		Recycling-friendly	Conditional	Problematic for recycling
Additives		Antioxidants, thermal stabilizers	Optical brighteners, AA blockers, UV stabilisers, O_2 scavengers	Bio/oxo/photo degradable additives
Caps and closures		HDPE/LDPE/PP	-	Metal/polystyrene (PS)/PVC caps with materials density >1 g/cm^3
Liners, seals and valves		PE/EVA/PP foamed PE/PET liner	Paper/silicone swimming valves with density <1g/cm^3	Neck foils metal/PVC/silicone with density >1 g/cm^3
Labels	Wraparound labels	HDPE/medium density polyethylene (MDPE)/LDPE/ LLDPE/PP/OPP label with density <1 g/cm^3	Paper labels, metallic foils	Pressure sensitive labels, PVC/PS/paper/metallised labels with density >1 g/cm^2
	Shrink sleeve labels	Material density <1 g/cm^3 with perforations and revealing >30% of bottle surface area	Materials with density <1 g/cm^3 without perforations and revealing <30% of PET bottle	PVC/PS/PLA/PET-G, other material with density >1 g/cm^3. Difficult to remove and/or NIR sort with heavy ink coverage
	Stretch sleeve labels	Sleeves of PE/foamed PET with density <1 g/cm^3 and revealing >30% of bottle surface area	Sleeves of PE/foamed PET (density <1 g/cm^3) <30% of bottle	-
Adhesives		• Water soluble below 80°C • Minimal glue strip • Comply with PRE guidelines	Permanent adhesives with paper labels	Water insoluble (even at elevated temperatures and pH levels)
Printing inks	Direct printing	Laser marked production or expiry date inks	Inkjet inks for direct printed production or expiry date	• Any other direct printing • Inks that bleed, are toxic, are hazardous or react with PET
	Printing on labels	• Label inks are non-toxic • Follow EuPIA Guidelines	-	Label inks that bleed or peel off from label surface

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About the India Plastics Pact

The India Plastics Pact is a collaboration between the Confederation of Indian Industry (CII) and WWF India that unites businesses, governments, NGOs and citizens to create a circular plastics economy in India. The CII-ITC Centre of Excellence for Sustainable Development (CESD) anchors the India Plastics Pact, within CII. The initiative is supported by WRAP, a global NGO based in the UK.

Launched in September 2021, the India Plastics Pact is the first Plastics Pact in Asia. As of June 2022, there are 13 Plastics Pacts spread across the globe. 33 organizations are currently part of the India Plastics Pact, including brand owners, recyclers, waste management organisations, packaging producers, resin producers and NGOs. The Pact works on all plastic resins at all stages of the plastics value chain.

www.indiaplasticspact.org

About Confederation of Indian Industry

The Confederation of Indian Industry (CII) works to create and sustain an environment conducive to the development of India, partnering Industry, Government, and civil society, through advisory and consultative processes. For more than 125 years, CII has been engaged in shaping India's development journey and works proactively on transforming Indian Industry's engagement in national development. CII engages closely with Government on policy issues and interfaces with thought leaders to enhance efficiency, competitiveness and business opportunities for Industry through a wide portfolio of specialized services and strategic global linkages.

India's premier business association has around 9,000 members, from the private as well as public sectors, and an indirect membership of over 300,000 enterprises from around 286 national and regional sectoral industry bodies. With 62 offices, including 10 Centres of Excellence in India, and 8 overseas offices in Australia, Egypt, Germany, Indonesia, Singapore, UAE, UK, and USA, as well as institutional partnerships with 350 counterpart organizations in 133 countries, CII serves as a reference point for Indian Industry and the international business community.

About WWF India

WWF India is committed to creating and demonstrating practical solutions that help conserve India's ecosystems and rich biodiversity. With more than 50 years of conservation journey in the country, WWF India works towards finding science-based and sustainable solutions to address challenges at the interface of development and conservation. WWF India is part of the WWF network, with offices in over 100 countries across the world. WWF India works in many states of India, through our state and field offices. The organisation works in different geographical regions and across thematic areas, including the conservation of key wildlife species and their habitats, management of rivers, wetlands and their ecosystems. On the sustainability side, the focus areas are climate change adaptation, driving sustainable solutions for business and agriculture and empowering local communities as stewards of conservation. WWF India also works in combatting illegal wildlife trade and in bringing environment education to students through outreach and awareness campaigns.

About WRAP

WRAP is a climate action NGO working around the globe to tackle the causes of the climate crisis and give the planet a sustainable future. Our vision is a thriving world in which climate change is no longer a problem. We believe that our natural resources should not be wasted and that everything we use should be re-used and recycled. We bring together and work with governments, businesses and individuals to ensure that the world's natural resources are used more sustainably. Our core purpose is to help tackle climate change and protect our planet by changing the way things are produced, consumed and disposed of. We support partner NGOs around the world to deliver real change through collaboration and progress from over 300 of the world's largest businesses. Initiatives we support include: Plastics Pacts in Chile, Kenya and India; food waste agreements in Mexico, South Africa and Indonesia; and food waste citizen campaigns through our Love Food Hate Waste brand in Canada, Australia and New Zealand.

About UKRI

Launched in April 2018, UKRI is a non-departmental public body sponsored by the Department for Business, Energy and Industrial Strategy (BEIS).

Our organisation brings together the seven disciplinary research councils, Research England, which is responsible for supporting research and knowledge exchange at higher education institutions in England, and the UK's innovation agency, Innovate UK.

Our nine councils work together in innovative ways to deliver an ambitious agenda, drawing on our great depth and breadth of expertise and the enormous diversity of our portfolio.

Through our councils we maintain and champion the creativity and vibrancy of disciplines and sector-specific priorities and communities. Our councils shape and deliver both sectoral and domain-specific support.

Whether through research council grants, quality related block grants from Research England, or grants and wider support for innovative businesses from Innovate UK, we work with our stakeholders to understand the opportunities and requirements of all the different parts of the research and innovation landscape, maintaining the health, breadth and depth of the system.

UKRI India

UKRI India plays a key role in enhancing the research and innovation collaboration between the UK and India. Since 2008, the UK and Indian governments, and third parties, have together invested over £330 million in co-funded research and innovation programmes.

This investment has brought about more than 258 individual projects. The projects were funded by over 15 funding agencies, bringing together more than 220 lead institutions from the UK and India. These research projects have generated more than £450 million in further funding, mainly from public bodies but also from non-profit organisations and commercial entities, attesting the relevance of these projects.

INDIA PLASTICS PACT

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