Researching the Recyclability of Plastic Toys

March 2023

RECOUP

Leading a more circular plastics value chain

Table of Contents

About RECOUP

RECOUP is the UK's leading independent authority and trusted voice on plastics resource efficiency and recycling. As a charitable organisation, our work is supported by members who share our commitments including a more sustainable use of plastics, increased plastics recycling, improved environmental performance and meeting legislative requirements. We achieve these by leading, advising, challenging, educating, and connecting the whole value chain to keep plastics in a circular system that protects the environment, underpinned by evidence and knowledge.

The content and analysis contained in this report is based on the information received. While every effort has been made to ensure the accuracy of the contents of this publication, RECOUP cannot accept responsibility or liability for any errors or omissions. Opinions expressed by external contributors may not reflect RECOUP positions. Recommendations provided herein are offered for the purpose of guidance only and should not be considered legal advice.

Written by:
Richard Cham
Senior Packaging and Recyclability Projects Officer
RECOUP

Introduction

Toys have come a long way since the early 20th century, with marbles, spinning tops, plasticine and wooden toys gradually replaced with plastic toys and figurines as these materials started to become widely available and at low cost.

Today's toys are far more sophisticated and interactive, with gadgets that use advanced technology manufactured from multiple materials, electronic components, and batteries. These inventions, while improving the development of children, create challenges with recyclability and the end-of-life possibilities for the toys to become new products.

Most toys are built to last, and it is likely that most toys will be passed down through families or donated. However, it is inevitable that at some stage, due to their condition, the toys will be disposed of. When this happens there are very few options available for recycling and even more confusion about how toys should be disposed of responsibly.

Kerbside collections from the home are the most widely available route to recycling for many consumers, but the complex construction of many toys means that kerbside recycling is simply not an option.

In the case of toys, it would be beneficial to always refer to the waste hierarchy, this is used to evaluate the different waste options considering processes and sustainability.

Figure 1: Waste Hierarchy picture from iStock

Methodology

This report aims to evaluate a selection of plastic toys, focusing on the material types and components, what these materials are and why they are used, and the reasons why they cannot be recycled. It will discuss other alternative routes for toys, including reuse, repair, and store collections along with the implications of electronics in the recycling chain.

RECOUP has taken a mix of sample toys and their packaging to analyse for recyclability. For the purpose of the report, these analyses have been broken down into separate case studies and tables.

The toys and packaging were broken down into polymer types and tested using Near Infrared (NIR) spectroscopy and Fourier-transform Infrared (FTIR) spectroscopy. These methods can identify different polymers and detect the presence of other additives or mixtures of materials.

Understanding the recycling chain

The recycling chain can be complicated, so it is helpful to understand the five stages of recycling. For toys to be recycled and manufactured into something new they must pass these five stages.

Disposal - It is essential to provide the consumer with clear and consistent instructions when it comes to the disposal of materials, such as packaging, toys, and batteries.

Consumers need to be able to make informed decisions, safe in the knowledge that they are responsibly dealing with their waste at its end of life.

Collection - Kerbside collections for recyclable materials are a crucial step in the value chain. If materials have no collection route, then regardless of the recyclability of the material, recycling cannot happen.

Sorting - Sorting of materials is currently largely completed using Near Infrared (NIR) technology which detects polymers and material types using lasers. If an item is made from mixed materials, it makes it more difficult to correctly identify and sort.

Reprocessing - Sorting is critical in ensuring the quality of recycled materials. Contaminants such as adhesives, colourants and other additives can seriously impact circularity.

Recycling - following the previous steps, the materials may now be used to make new products.

Polymers used in toy manufacturing

Polymers and plastics are a complex subject and there are many different aspects to consider. These range from the science, where they come from and how polymers are formed, the manufacturing and the ways plastic goods are made, why it is made that way, and the use of recyclate after recycling.

Toys can be manufactured using a variety of materials and polymers, each being used for their individual benefits and suitability for the toy. The choice of material will depend on the toys, as they need to be designed for purpose. For example, baby and toddler toys would be soft, easy to handle and food safe. Toys for outside use, such as sandpits, buckets, and garden toys, would need to be strong, durable and shatter resistant.

Non-target materials are polymers that are not widely accepted into mainstream recycling, they are not collected from the home and are not sorted in a Material Reclamation Facility (MRF), as they require more specialist techniques for recycling and often do not have collection schemes in place.

Target materials are those that we come across every day at home, these include food packaging, cleaning products and health and beauty products. They are collected from the home and sorted in a MRF as target materials for further processing.

Non-target polymers that are commonly found in toys.

PVC (Polyvinyl Chloride) - is one of the most widely used polymers in the world. It is inexpensive, rates well for hardness and durability and has excellent strength, it is a long-lasting material that can be used in a variety of applications and colours. The cheap availability of PVC has made it a popular material for soft or flexible children's toys.

ABS (Acrylonitrile Butadiene Styrene) – is used worldwide due to its strength and moulding properties, it's found in items such as office equipment, gardening tools, luggage, construction, and automotive applications.

POM (Polyoxymethylene) – has good strength, rigidity, impact resistant, it is mainly used for parts that need to be very stiff.

PS (Polystyrene) – Can be found just about everywhere from food packaging and computers to construction and toys. It consists in a solid, foam state and the chemical structure gives it valuable properties such as low weight, high strength and is weather and bacteria resistance.

Mechanically recyclable, or target polymers found in toys.

PE (Polyethylene) - a strong impact resistant material with good elasticity, suitable for many applications that is widely recycled.

PP (Polypropylene) - a highly robust material that is recyclable, durable, and resistant, maintains shape and does not deteriorate.

PET, Polyethylene terephthalate - Widley used across industries, food safe, clear, strong and lightweight, easy to manufacture and efficient to transport it is completely recyclable and has a variety of end markets.

High-density Polyethylene (HDPE), PP and PET are known as Thermoplastics. These soften when heated and harden when cooled. This means that they can be moulded into a variety of shapes and be reused, making them recyclable. Thermoplastics are the most commonly used type of plastic today and include: (HDPE), low-density Polyethylene (LDPE), PP, and PET.

Other Thermoplastics include PVC, PS, and Styrene Acrylonitrile (SAN) which looks like glass and is used for drinking bottles, kitchen equipment and cosmetic packaging. Similar structure to SAN is ABS, also containing styrene. This is impact and shatter resistant and is used most notably in Lego blocks, electrical items, kitchen ware and musical instruments. Polycarbonate (PC) is also a Thermoplastic which is commonly used for contact lenses, medical devices and CD and DVD casing.

The opposite to Thermoplastics is Thermoset plastics. These are softened when heated and can only be moulded once to remain in a solid state. Typical Thermoset plastics include Polyester, Polyurethane and Vinyl ester resin. Thermoset plastics include construction components, electrical items, parts for vehicles and aviation and many toys.

With increasing pressure on manufactures and brands to produce more sustainable goods and packaging, as well as changing legislation, there is a heightened interest in how things are produced and the effect they have on the environment.

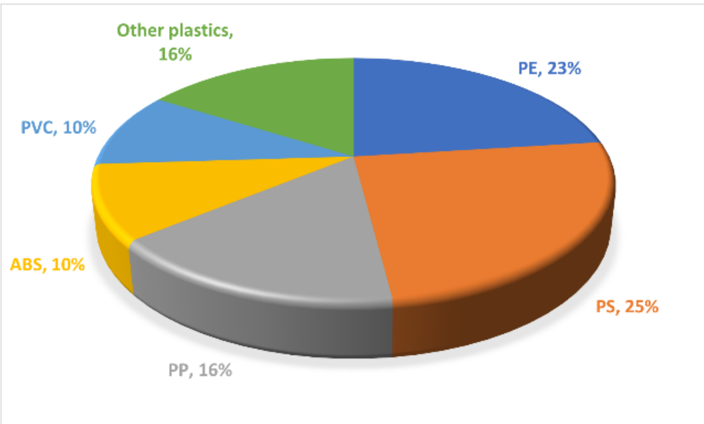

Figure 2: Plastic Materials used in the toy sector (percentage). Taken from the British Plastics Federation.

Sorting and Separation

One of the challenges with the recyclability of plastic toys is the mixed materials used to make them and the use of electronic parts and batteries. As toys become more technical in their designs, so too does the difficulty in their safe and ethical disposure. Modern toys contain such a variety of complex polymers and components these need to be separated in order to be recycled efficiently.

Recyclate that is collected from the home are items that are specified by the Local Authority, these are materials that can be handled in a MRF and tend to be food and other household packaging. These are the common most used polymers for packaging PE, PP and PET.

At the sorting facility materials are sorted by shape, 2D items being flat, such as paper and card, and 3D items including containers, cans, bottles etc. Plastic items are identified by the NIR optical sorters that are programmed to select these polymers. Plastics that contain other materials can be unidentified by the NIR and end up in residual waste, this is because technology in the MRF is not able to consistently identify multi-polymer toys and is also unable to differentiate between electronic and non-electronic toys.

Once the materials are sorted into polymers, they are baled and sent to be reprocessed by recyclers who turn the material into flake/pellet to make new products. At this stage, the materials are chopped, washed and go through a series of cleaning and filtration. If there are too many unwanted materials or components this can result in contamination and have a severe impact on the process.

Small Plastic items

Material that reaches a sorting facility is sorted at the primary separation stage as 2D and 3D items. 2D being large flat items like card and paper and 3D being items such as bottles, cans, pot, tins etc. To separate these materials glass and other non-target materials need to be removed.

Small plastic items that are less than 50mm in diameter such as bottle caps, blister packs, pen lids, and cosmetic packaging, which are made from recyclable materials, are routinely lost during sorting because they fall through these screens at the beginning of the process.

This screening process allows the large items such as cardboard and rigid containers to pass over while separating broken glass and small materials. This lost fraction is known as fines.

These small items generally end up in the residual waste stream, most likely destined for Energy from Waste (EfW) facilities.

It is recognised that this fraction of material presents challenges for producers of plastic packaging that is deemed unrecyclable due to its size.

Figure 4: Picture taken from a MRF fines bunker.

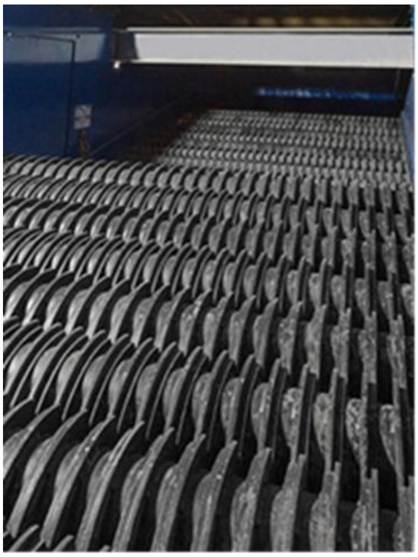

Figure 3: glass breaker in a MRF.

Figure 5: Picture taken from a MRF fines bunker.

Electronics and batteries

Electronics and small electrical items are not accepted via kerbside recycling collections, usually packaging or products of this kind will contain a picture of a crossed-out wheelie bin on the packaging as pictured below meaning batteries in the item cannot be disposed of in normal household bins. They are accepted at Household Waste Recycling Centres (HWRCs) and can be reprocessed at specialist WEEE (Waste Electrical and Electronic Equipment) recycling facilities.

Items that cannot be placed in kerbside collections include items with:

- Batteries
- Plugs
- Toys that have lights and sound

The use of electronic parts in some toys makes it dangerous to shred them prior to these parts being removed. Lithium-ion batteries pose a high risk of fire if they are punctured or damaged. Incorrectly disposed batteries are blamed for the majority of MRF fires, costing over £100 million[1] in damages to recycling facilities each year.

Even if some consumers removed batteries prior to disposal, the toys would still need to be checked before being sorted and processed for electronic components such as wires, circuit boards, metals, speakers, and bulbs, as these would still need to be removed.

To avoid these risks, all of the above would need to be removed prior to shredding and sorting. This is a process that would need to be completed by hand, increasing costs and infrastructure requirements. The complex nature of these materials means that a wide range of infrastructure would be required to carry out this process and the costs involved in generating this could outweigh the returns from the materials collected for recycling.

Batteries

Inappropriately disposed batteries can be extremely hazardous in the waste stream. Lithium-ion batteries are a constant threat to MRF operations and most fires at sorting facilities originate from discarded lithium-ion batteries causing millions of pounds in avoidable damage each year.

Figure 6: MRF fire damage (credit: Manchester Fire Service)

[1] Eunomia report January 2021

Take Charge+

The Take Charge+ Campaign was created in 2020 by the Environmental Services Association (ESA). The ESA represents many of the UK's waste management companies and has been compiling data relating to fire incidents across the UK's many waste management facilities.

The ESA found that between 250-300 fires at waste management sites are started every year by lithium-ion batteries.

Take Charge+ advocates the safe disposal and recycling of used batteries in the UK and offers resources online to find out where consumers can safely recycle their used batteries.

Using the battery recycling location tool on their website, www.takecharge.co.uk, consumers can search for their nearest battery deposit locations.

These are generally found in most supermarkets and DIY stores, but some councils also offer free battery and electrical collections (Take Charge+. 2023).

Take Charge+ offers 5 tips to help avoid waste batteries becoming a hazard.

1. Use rechargeable batteries instead of single use where possible.
2. Sell or donate working battery-powered items instead of throwing them away.
3. NEVER place waste batteries in general waste or recycling bins.
4. If possible, remove batteries from devices and dispose of them safely at a battery drop-off point.
5. If you are unable to remove the batteries from an electronic device, dispose of the device responsibly using a council collection service or by dropping the electronic item off at your local HWRC.

Figure 7: Supermarket battery recycling bin

Household Waste Recycling Centres (HWRCs)

HWRC collections rely on the willingness of the consumer to make the journey to their local centre to drop off any toys that they would like to dispose of.

The potential pitfalls of this come down to two key factors; is the consumer a keen recycler and willing to make the trip to the HWRC; and do they have the means to make the trip to the HWRC.

The social demographics of the consumer as well as their enthusiasm for recycling are key factors when considering the viability of HWRCs as suitable locations for collections of toys for recycling.

If a toy is made from hard plastics, HDPE, or PP, it can be taken to a HWRC. Here the operatives will view the products and if suitable sometimes they can be taken to a local charity shop or auction. This depends on the site's procedures.

If the item is not suitable for reuse and is made of either HDPE or PP, it will be placed into the hard plastics stream. The material will go to a holding facility to be sorted into the different polymer types and then transported to a recycling facility. Here it is washed and shredded before being extruded into pellets, at which point it is no longer considered waste. It is bagged and labelled and sold onto moulding companies where it is formed into new items.

Toys which are small and not made of HDPE or PP are disposed of in the general waste stream during this process. If they are plastic toys which contain electrical fittings, they are segregated into the Small Domestic Appliances bin at the HWRC which are then taken by a metals re-processor and subjected to the ferrous/non-ferrous recycling process. However, toys which are made from multiple parts, metals and electrical components can be very difficult to economically sort and separate into individual fractions and so are not typically recycled.

HWRC re-use stores

Our research has shown that there are multiple locations across the UK at a number of local authorities that have taken the initiative and have opened reuse stores at, or close to HWRCs. These reuse items that have been sent to HWRCs for recycling or have been donated directly by consumers.

Many items that are discarded in general waste or sent to HWRCs are still in a usable condition, or in need of some minor repairs and capable of being reused.

The toys that are taken to HWRCs may potentially be allocated to re-use stores if they are still in a usable condition and can be sold on for further use.

Some council re-use schemes also operate repair cafés/centres that mean that there is potential for some toys to be repaired and given a new lease of life for a few more years of play.

Figure 8: Picture of material from hard plastic bunker at HWRC.

Existing solutions

Take back systems can be costly but are an opportunity which is sometimes used by producers to demonstrate responsibility where traditional recycling systems cannot accommodate their products or materials. These are based at either public drop off locations or through post back services using pre-paid postage which is promoted to the consumer and /or sellers of the product. These approaches could be modelled for toys.

Mattel operates a scheme called playback which is only open to non-electronic toys, the toys are shipped directly to Mattel via a post-paid send back scheme. Mattel claims that once they have received the toys, they are sorted by polymer type and cleaned. They are then put through an extrusion process where the materials are flaked and reformed into plastic pellets. Mattel claims that these pellets are used to make new products.

Currently, there are very few options for people wishing to recycle toys, particularly electronic toys. The lack of return options means that electronic toys still only have the option of being taken to HWRCs for disposal or recycling.

One of the most obvious solutions is donation, most toys can be cleaned and repaired meaning they can be donated to charity shops, hospitals, schools, and local community groups to be given a new life.

Case study 1: Barbie and Ken doll.

Figure 9: Barbie and Ken pack.

The Packaging

The dolls come packaged in a cardboard packaging with a large front window which is formed from PET. The dolls are placed on PET moulds that are positioned on a cardboard inner sleeve through which the dolls are secured with PE ties.

The pack is designed to be opened from the bottom, where there are two tabs that can be released so the inner sleeve containing the dolls can slide out. This helps the packaging to remain undamaged for shelf display. The pack also has a top opening flap secured by two tape points.

Material analysis shows that the total mass of the packaging is 222g (table 1), which is almost equal to the mass of the products it protects. The packaging is 70% cellulose based with a 50% coverage of inks, with 30% if the pack containing plastics such as the PET front window and mouldings and the PE ties.

Packaging					
	item	mass (g)	% component	% total	
	Packaging Outer	102.00	45.95%	21.84%	CLLS
	Packaging Outer Clear	50.00	22.52%	10.71%	PET
	Inner	54.00	24.32%	11.56%	CLLS
	Ties	6.00	2.70%	1.28%	PET
	Plastic Inserts	10.00	4.50%	2.14%	PET
sub-total		222.00	100.00%	47.54%	

Table 1: Barbie doll packaging material analysis data

The PE ties may be removed by cutting or by simply pulling them through the cardboard sleeve. There are two attachments connected to each of the doll's heads that would need to be carefully cut to remove, to avoid damage to the dolls. The ties would need to be disposed in general waste as they are too small for recycling collections and would be lost in the system due to their small size.

The PET window is easy to remove from the cardboard body, but there is heavy cellulose and adhesive residue that remains on the PET component. This is a positive in terms of separating the materials for recycling so that the cardboard components may be sent for recycling through the paper fraction without the PET causing contamination. The PET window being flat would not be identified as a 3D pack and would not be recycled through the mechanical clear PET stream. The PET moulds having a 3D shape and being over 50mm could be scanned and captured by the PET fraction.

Accessories

The accessories and clothing items that come packaged with the Barbie and Ken dolls in this pack are all produced using PET to produce the fabrics and moulded pieces. The nature of the design of these items means that they would not be suitable for kerbside recycling as there is no collection or sorting system in place to handle them.

Figure 10: Clothing items and accessories.

Barbie Doll

Figure 11: Barbie doll.

The doll comes with a paper rose attached to her hand by a clear elastomer. The same elastomer is also used to attach the dolls shoes to ensure that they do not fall off during transit.

The construction of the Barbie doll uses multiple polymer types as determined through NIR analysis shown in table 2.

The use of multiple polymers in construction means that the doll cannot be kerbside recycled as there is a high probability that the polymers would be mis-identified if the doll is received at an MRF. The mixed materials mean that there is also a high level of contamination, with 36g of PE and 38g of PP, if these parts are not separated, they will contaminate the opposing recyclate stream in a high concentration.

ABS is not a target polymer at a MRF and would be rejected by the sensors, meaning the most likely destination for the doll at a MRF would be the residual waste stream.

Barbie					
	item	**mass (g)**	**% component**	**% total**	**polymer**
	Barbie head	22.00	21.57%	4.71%	PE
	Barbie torso	24.00	23.53%	5.14%	ABS
	Barbie arms	12.00	11.76%	2.57%	PE
	Barbie legs	38.00	37.25%	8.14%	PP
	Barbie clothes	4.00	3.92%	0.86%	PET
	Barbie shoes	2.00	1.96%	0.43%	PET
sub-total		**102.00**	**100.00%**	**21.84%**	

Table 2: Barbie doll material analysis data representing the mass and polymer type of each component.

Ken Doll

Figure 12: Ken doll.

Like the Barbie doll, the Ken doll is made using multiple polymers (shown in table 3), though the combinations used for each part are different. Like Barbie, Ken has a PE head and an ABS body, however, unlike the Barbie, the Kens arms are made from PP and the legs are formed from ABS. With this combination of materials, the Ken contains 80g of ABS, while the Barbie has only 24g of ABS.

This combination of materials means that the Ken doll is not suitable for kerbside recycling because ABS is not a target material for MRF sorting. Also, the combination of polymers would need to be separated and sorted which would require additional processing and deconstruction. It is likely that if the Ken found his way into a MRF the final destination would likely be the residual waste stream.

Ken					
	item	mass (g)	% component	% total	polymer
	Ken head	16.00	11.19%	3.43%	PE
	Ken torso	32.00	22.38%	6.85%	ABS
	Ken arms	27.00	18.88%	5.78%	PP
	Ken legs	48.00	33.57%	10.28%	ABS
	Ken clothes	8.00	5.59%	1.71%	PET
	Ken shoes	12.00	8.39%	2.57%	PET
sub-total		**143.00**	**100.00%**	**30.62%**	

Table 3: Ken doll material analysis data representing the mass and polymer type of each component.

Case study 2: Plastic Piggy Bank

Figure 143: Piggy bank packaging

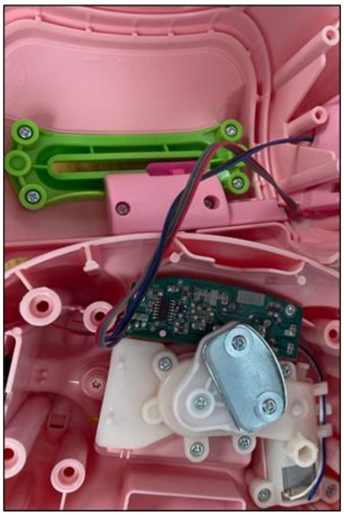

Figure 134: Internals showing circuit board and wiring to the switches and motor.

Packaging

The Fisher-Price Piggy Bank is packaged in a predominantly cardboard pack with an adhered plastic (laminate) containing the ten coins. The piggy bank is secured using elastomer ties that fix through mouldings in the legs.

The laminated layer makes it difficult to separate the paper and plastic for recycling, if the plastic is removed adhesive and paper residue will likely remain and the plastic is not widely collected for recycling kerbside as it would be considered a flexible plastic and would currently require front of store recycling.

When a fibre-based packaging is combined with a non-cellulose-based material by an adhesive or binding agent it is called lamination.

Depending on the strength of adhesion or the materials used in further layers the laminated paper may be difficult to recycle.

Where the film layer does not interfere with the separation of the fibre, the fibres may be recovered. Where multiple layers of film are adhered to the fibre this is very difficult to recover in a traditional paper mill and will require processing at a specialist facility.

The piggy bank contains numerous electrical components such as wiring, circuit boards and motors as shown in figure 14.

Materials analysis

The Piggy Bank is predominantly produced using ABS plastic. 492.05g of ABS is used to make this toy. ABS is not a target material for MRF sorting, meaning that this toy would need to be disposed of through HWRC sites in the UK.

The mixed material construction of the toy means that there are three polymer types used in construction.

The hard-wearing nature of ABS mean this material has been used for the main body, side door, coin slot and the gearbox casing.

The push buttons and switches have all been produced using PP, accounting for 87.13g, while the gears inside the gearbox and the vibration motor parts are made from polyoxymethylene (POM) of which there is 11.37g.

In total the non-plastic content of the piggy bank toy is 139.56 grams. This includes 34.24 grams for the three AA batteries in the base, and 17.34 grams for the steel screws.

The wiring and motor account for 47.41 grams of the toy, which together with the batteries account for one of the main difficulties in the disposal and processing of electrical toys.

Piggy Bank	item	mass (g)	% component	% total	polymer
	Body	419.82	57.50%	57.50%	ABS
	Base	19.54	2.68%	2.68%	ABS
	Coin Slot	16.80	2.30%	2.30%	ABS
	Misc Body	11.24	1.54%	1.54%	ABS
	Misc Body 2	15.82	2.17%	2.17%	PP
	Nose/Switches	9.41	20.37%	11.26%	PP
	Gearbox Body	24.65	3.38%	3.38%	ABS
	Gearing	11.37	1.56%	1.56%	POM
	Coins	61.90	8.48%	8.48%	PP
	Wiring & Motor	47.41	6.49%	6.49%	Other
	Weights	40.57	5.56%	5.56%	Other
	Screws	17.34	2.37%	2.37%	Other
	Batteries	34.24	4.69%	4.69%	Other
Total		**730.11**	**100.00%**	**100.00%**	

Table 4: Piggy Bank material analysis data tables representing the mass and polymer type of each component.

Gearboxes and metals

The internals of the Piggy Bank contain a gearbox which contains a series of small POM gears, which may be considered contaminants within the recycling stream and are difficult to separate.

POM has a density around 1.4 g/cm^3 which means that during density separation it would sink. This would be suitable for separation from low density materials such as PE or PP.

There is also a high proportion of metal components in the construction of the Piggy Bank toy. In total there, is 105.32g of miscellaneous metal components including wiring, circuit boards, screws, a motor, and weights.

These components would not be acceptable in the plastics recycling stream and would need to be separated where possible either using overband magnets or eddy-current separation. However, this could be difficult as the toys would need to be disassembled or shredded to separate the metals from the plastics before sorting can occur.

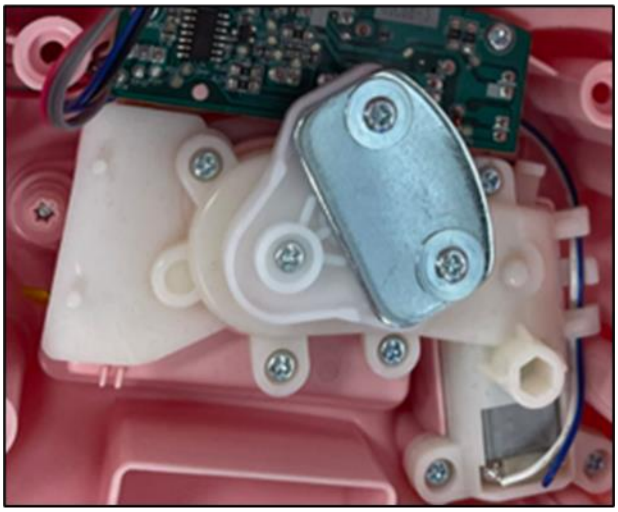

Figure 15: Gearbox assembly with screws, motor and metal plates visible.

Case study 3: Recycling's Recyclies

Packaging

The Recycling's are packaged in a cardboard pack with a PET window to the front and top profiles. The PET window makes up a small proportion of the pack in comparison to the previously reviewed Barbie pack.

The toys are contained inside the pack on a moulded PET insert which retains the toys firmly, without the need for any tethers or ties. There is also a printed decorative carboard backing that acts as a divider to hide an extra toy in the base of the box.

The hidden extra toy is marketed as a mystery item and is packaged in a cellulose pouch.

For recycling, the PET window and inserts can be removed easily, though there is some adhesive residue and cellulose transfer onto the PET when it is separated. The flat dimensions of the PET window mean that the pack may not be caught in the recycling process as it will be seen as a 2D item.

Figure 16: Recycling's packaging

Figure 17: recycling's toy.

The recycling's toys are marketed as being produced using recycled bottle caps. Most bottle caps tend to be produced using PE so we would expect a high proportion of the toys to be PE. PP is also used in some bottle cap applications, so it is not unusual for there to be some PP content. The toys do not claim to be completely manufactured from recycled bottle caps.

The construction of the recycling's toys use a mixture of PE for soft components and PP for rigid components as determined through NIR analysis, shown in table 5.

The mixed use of PE and PP in the construction of the Recyclies toys means that they cannot be mechanically recycled as there is a high probability that the polymers would be mis-identified if the doll is received at a MRF. The mixed materials mean that with 16.06g of PE and 21.2g of PP in the main toy, the mixed polymers will contaminate the recycling streams if not separated.

The heavy use of glitter would also be considered a contaminant in the recycling stream. The head and hood are quite easy to separate, however, the hair is glued firmly to the head and will not separate easily.

Recyclies	item	mass (g)	% component	% total	polymer
	Body	8.80	11.40%	6.30%	PP
	Head	12.40	16.07%	8.88%	PP
	Hair	6.23	8.07%	4.46%	PE
	Hood	9.83	12.74%	7.04%	PE
	Base	10.78	13.97%	7.72%	PP
	Poo	15.72	20.37%	11.26%	PE
	Milk	13.40	17.37%	9.59%	PP
sub-total		**77.16**	**100.00%**	**55.24%**	

Table 5: Recycling's Recyclies figures material analysis data representing the mass and polymers of the components.

Case study 4: Mr Potato Head

Figure 18: Playskool Mr Potato Head Darth Vader toy in packaging.

The Mr Potato Head toy was first introduced in the 1950's as a set of individual pieces that children could use to decorate potatoes or other vegetables.

In 1964, manufacturer Hasbro switched production to include a hard plastic potato shell after concerns about toy safety from the small parts and pins.

Packaging

The Mr Potato Head toy comes packaged in a cardboard outer package encasing a PVC moulded inner casing. The moulded inner casing comes in two pieces and completely encase the toy and accessories. The outer carboard packaging is completely printed on one side.

The total weight of the empty packaging is 135.99g, the outer cardboard makes up 84.72g of the weight, with the inner PVC casing making up 51.27g as shown in table 6.

The cardboard portion of the packaging may be recycled kerbside by households with access to kerbside paper recycling.

The PVC inner casing is not accepted for kerbside collection or sorted as a target material at MRFs, which means that if placed in kerbside recycling, the casing will end up in the mixed plastics fraction.

Mr Potato Head	item	mass (g)	% component	% total	polymer
	Box	84.72	62.30%	23.06%	Clls
	Insert	51.27	37.70%	13.96%	PVC
sub-total		**135.99**	**100.00%**	**37.02%**	

Table 6: Playskool Mr Potato Head Darth Vader packaging material analysis data representing the mass and polymer types of each component.

Potato Head Toy

The Mr Potato Head toy is produced using a mono-polymer ABS moulding for the body, with a variety of polymers used for the body parts and accessories.

The helmet is moulded from PP, with the eyes being moulded from ABS. Many of the body parts are produced using PVC, including the mask, arms, and feet. The accessories including the cloak and sabre scanned as PET then the parts were tested using Fourier-Transform Infrared (FTIR) detection.

The data in table 7 shows that there are 112.86g of PVC parts making up 48.77% of the toy, with the ABS body and eyes making up 31.56% at 73.01g.

PVC has a density between 1.32 g cm^{3} – 1.45 g cm^{3}, while ABS has a density between 1.03 g cm^{3} – 1.06 g cm^{3}. This means that it will be difficult to separate the polymers through density separation because the ABS parts may be neutrally buoyant and can contaminate either low- or high-density plastics.

The parts included in the Mr Potato Head Darth Vader set are mainly moulded using black plastics. This presents a problem for detection when scanning using NIR detection methods.

NIR uses the reflectance of the light emitted from the device to register a series of absorbance spectra which acts as a fingerprint to identify the polymer.

Black plastic does not reflect light as well as lighter plastics, meaning that the NIR device does not receive enough light back to enable a fingerprint to be detected. This means that black plastics cannot be detected through NIR detection systems.

Mr Potato Head					
	item	mass (g)	% component	% total	polymer
	Body	66.61	28.79%	18.13%	ABS
	Helmet	30.19	13.05%	8.22%	PP
	Mask	26.73	11.55%	7.28%	PVC
	Arms	37.63	16.26%	10.24%	PVC
	Feet	48.50	20.96%	13.20%	PVC
	Eyes	6.40	2.77%	1.74%	ABS
	Sabre	13.58	5.87%	3.70%	PET
	Cloak	1.72	0.74%	0.47%	PET
sub-total		**77.16**	**100.00%**	**55.24%**	

Table 7: Playskool Mr Potato Head Darth Vader toy material analysis data representing the mass and polymer types of the components.

Case study 5: Kitchen Set

Figure 19: Kitchen Set outer packaging.

Figure 20: Kitchen Set packaging.

Figure 21: Kitchen Set

Packaging

The Kitchen Set is packaged in a large cardboard box that is sealed on the top and bottom with small pieces of tape. The box is completely printed on the outside and is plain on the inside.

A large plain cardboard divider separates the toys inside and keeps them from moving around excessively during transport.

Many of the toys inside the box are wrapped individually using plastic bags, in total there are five bags inside the box.

There are no additional components in the packaging and no small parts that are difficult to recycle.

The cardboard portion of the packaging may simply be placed in kerbside recycling where paper and cardboard is accepted.

The bags are accepted by very few councils in the UK, so the most likely option available to most households for the recycling of the plastic bags will be front of store recycling, available at most supermarkets in the UK.

Some of the bags are heavily inked which has an adverse effect on the recyclability of the film if it cannot be removed during the wash process.

The Kitchen Set is targeted at imitation play for children, many of the items in the set are produced from mono-materials, which is a positive in terms of recyclability and sorting. With the exception being the toaster, which contains four metal screws and a small spring, and the coffee machine, also containing a small metal spring.

There is a wide range of polymers used in the production of the set, with ABS being the most prolific polymer used. While not recyclable at kerbside a take back or collection scheme could direct these materials to a recycler with most of the toys being acceptable with little contamination.

Morphy Richards Kitchen Set (minus coffee machine)				
	item	mass (g)	% total	polymer
	Toaster	154.24	39.38%	ABS
	Kettle	97.43	24.88%	ABS
	Cups/saucers/plates	100.09	25.56%	PP
	Cutlery	10.99	2.81%	PP
	Bacon	1.46	0.37%	PP
	Sausage	3.66	0.93%	PE
	Egg	3.92	1.00%	PS
	Toast	19.84	5.07%	PE
total		391.63	100.00%	

Table 8: Kitchen Set data (minus coffee machine), showing the mass and polymer type of each component.

The main risk factors to recyclability that would need to be separated are the metal parts in the toaster and the coffee machine, which could damage the equipment during the flaking and reprocessing processes.

The coffee machine is the most complicated part of the set, in terms of materials used as it contains a mixture of polymer types and metal components.

A bonus to the design of the coffee machine over the toaster is that the joining of the parts to the base is facilitated through clips rather than the screws in the base of the toaster. This removes some metal contamination from the process.

The mixed polymers in the coffee machine are mostly easy to separate with the parts mainly being held together by plastic clips. This means that the parts should separate rather simply during reprocessing as they will break apart without leaving any metal contamination behind.
It may be possible to investigate replacing the metal springs either with plastic springs or bellows to facilitate the toaster action or coffee machine water dispensing, which would remove the metal issue and ease recyclability.

Morphy Richards Coffee Machine				
	item	mass (g)	% total	polymer
	Coffee machine body	69.36	30.45%	PP
	Coffee machine fascia	20.63	9.06%	ABS
	Coffee machine base	27.82	12.21%	PP
	Coffee machine top	44.92	19.72%	PP
	Coffee jug	64.13	28.15%	ABS
	Spring	0.67	0.12%	Metal
	Washer	0.27	0.29%	PE
total		227.80	100.00%	

Table 9: coffee machine data showing the mass and polymer type of each component.

Case study 6: Pop Vinyl Toys

Figure 222: POP Heroes packaging.

Figure 23: POP heroes' figure

Packaging

The POP vinyl figures and collectibles are packaged in cardboard packaging with a large plastic viewing window usually covering the front and either top or side profiles of the packaging.
The viewing window on the packaging was made from PVC, meaning that it is not collected for recycling through kerbside collections.

The insert holding the figure is also moulded from PVC, so it is also not collected and sorted through kerbside collections as a target material.

If the plastics from the packaging were to be placed into a recycling collection, they would pass through the system to the residual or mixed plastics streams and may be passed on to a plastic reprocessing facility for further sorting. Alternatively, they may go to residual streams.

If the window was not removed from the box before being placed in a recycling bin, the window would be seen as a contaminant in the paper recycling stream.

Joker Toy

The Joker POP Heroes figure is not generally considered a toy but instead a collectible piece, though they are still routinely sold in toy stores and departments across the UK.

The figure is produced entirely of polyvinyl chloride and weighs 69.54g.
PVC is not a target material for kerbside collections, and POP vinyl figures and collectibles are likely to be purchased for collection and display and may be stored a long period of time rather than being disposed of.

However, if a POP vinyl was to be disposed of the best route for recycling would not be kerbside recycling as it would not currently be sorted as a target material and may be landfilled or incinerated rather than recycled.

Joker	item	mass (g)	% component	% total	polymer
	Figure	69.54	100%	54.13%	PVC
	Insert	18.69	100%	14.55%	PVC
	Window	6.20	100%	4.83%	PVC
	Box	34.04	100%	26.50%	Clls
Total		**128.47**			

Table 10: Joker POP figure material analysis data representing the mass and polymer type of each component.

Case study 7: Happy Meal Toy

Figure 23: 101 Dalmatians toy

The McDonald's Happy Meal toy is based on the 1961 Disney movie 101 Dalmatians, released after McDonald's entered a partnership with Disney, licensing a series of Happy Meal toys between 1996 and 2006.

The 101 Dalmatians figure comprises three parts produced using two different polymers. The head and lower body are formed from PVC, and the main body or scarf part is produced from ABS.

The mixed use of ABS and PVC means that the toy is equally likely, depending on the orientation to detect as either polymer, as there is close to a 50/50 composition.

During processing, float sink separation will not be suitable due to the density of the polymers. PVC has a density between 1.32 g cm^{3} – 1.45 g cm^{3}, which means that the PVC flakes would sink in a float/sink tank. However, ABS has a density between 1.03 g cm^{3} – 1.06 g cm^{3}, which means that the ABS flakes will be neutrally buoyant in a float/sink tank. This will cause the ABS materials to potentially contaminate any materials that float or sink during separation.

The small size of the toy means that it is not suitable for kerbside recycling. Most MRFs sort for target materials such as PET, high density polyethylene (HDPE), and PP, meaning that the toy is not made of materials being detected through NIR. The initial size sort at a MRF also separates materials smaller than 50mm x 50mm, with the toy being smaller than these dimensions there is a chance it might fail the size sort and be lost to the fines fraction.

Dalmatian

item	polymer
Head	PVC
Scarf	ABS
Lower Body	PVC

Table 11: Table showing the material analysis data for the 101 Dalmatians Happy Meal toy

Single Polymer Toys

Despite the complexities of some toys, there are still many that are manufactured from a single polymer that do not contain any additional components or containments. These toys, if too big for the kerbside collection, can be taken to a local HWRC and placed with hard plastics. It is easy to identify the type of plastic by the resin identification code that can be found on most plastic products and packaging.

Figure 24:Resin identification codes.

Figure 25: Single polymer toys.

Conclusions and recommendations

Toys need to be robust and able to withstand heavy handling, and they need to be made from materials that meet these demands along with other requirements like flexibility and in some cases food safety for baby and toddler toys.

To keep up with growing trends and advancements in technology, toy manufactures will be looking to develop their products to stand out and disposal is not always a consideration. Often there is no solution for these complex toys and gadgets.

Where possible, toy manufacturers should be working towards designing their toys with their end-of-life process in mind. Some toys will be able to be handed down and reused multiple times, while some will possibly have a lifespan of one or two years before being disposed of. Regardless of their useful lifespan, all toys at some stage will reach their end-of-life process, and this should be factored into the design phase, with a route to recycling and infrastructure in place to deal with the materials.

From the evidence gathered, it is clear that the route to recycling for toys through kerbside collections is not an easy one. The inclusion of mixed polymer types, and potential contamination from dyes, paints, and metal components means that non-electronic toys will present problems for sorting equipment at material recovery facilities.

Non-electronic toys that are processed at a MRF are likely to be mis-identified by NIR detection equipment due to the mixed materials, leading to contamination of the materials streams, or missed completely and ending up as residual waste or mixed plastics.

In the case of electronic toys, the presence of batteries means that traditional kerbside collections should always be avoided. The process of crushing and compacting the materials in the waste collection vehicle increases the risk of fire here and at the MRF.

While it is possible that some batteries could be removed from toys prior to disposal, this is not always a reliable solution, and will not change the recyclability of a product.

The Mattel Playback scheme asks customers to return old unwanted/damaged toys so that the brand has the possibility of recycling any of the materials they can reclaim. There is little evidence that they have been hugely successful with this program, but the presence of a return scheme shows that there is a potential route for toys to be collected.

A toy recycling scheme could follow the deposit/bring back model and see toys being accepted at collection points situated at large supermarkets, or toy stores could have collection points. This would require manual work to sort the materials collected and a route for recycling or reuse.

Given there are no current commercially viable recycling options, the HWRC reuse, and repair schemes currently seems to be the most viable route for used toys. This allows toys to be repaired and donated, an alternative to landfill.

In the case of toys, it would be beneficial to always refer to the waste hierarchy, as this is used to evaluate the different waste options considering processes and sustainability.

Reuse would remain to be the most viable solution for toys where possible, using existing streams such as HWRCs and charity organisations.

Appendix

List of abbreviations

ABS	Acrylonitrile Butadiene Styrene
Clls	Cellulose
ECS	Eddy Current Separator
FTIR	Fourier-transform Infrared
HDPE	High Density Polyethylene
HWRC	Household waste recycling centre
MRF	Materials Reclamation Facility
NIAS	Non-intentionally added substances.
NIR	Near-Infrared
OCC	Old corrugated cardboard/containers
PE	Polyethylene
PET	Polyethylene Terephthalate
POM	Polyoxymethylene
PP	Polypropylene
PVC	Polyvinyl Chloride
PRF	Plastics Recovery Facility
PTT	Pots, Tubs, and Trays

Researching the Recyclability of Plastic Toys 2023

1 Metro Centre
Welbeck Way
Woodston
Peterborough
PE2 7UH

T |01733 390021

E |enquiry@recoup.org

W | www.recoup.org

RECOUP

Registered in England & Wales number: 02435729
VAT registration number: 546 5837 10
Registered Charity Number: 1072029
RECycling Of Used Plastics (RECOUP) Limited