RECOUP

Leading a more circular plastics value chain

RECOUP PACKAGING RECYCLABILITY & DESIGN TEAM

LABORATORY TESTING SERVICES

Version: 1.0 July 2024

Contents

RECOUP

THE IMPORTANCE OF DESIGN FOR RECYCLING

Packaging function

Packaging plays a crucial role in the product lifecycle, serving multiple functions that are integral to the product's use and disposal. These functions include containment, protection, preservation, identification, communication, and transportation. Each function contributes to the overall user experience, product safety, and environmental impact. As we move towards more sustainable practices, understanding these functions becomes even more important in designing packaging that not only serves its purpose but also minimises its environmental footprint.

Contain:

- Packaging should be designed to use the minimum amount of material necessary to contain the product.
- Ease of use is important, packaging should be easy to open, and be resealable if the product is not used immediately for safe storage.

Protect:

- Packaging needs to protect the product from damage during transport and storage, reducing losses from waste caused by damaged or spoiled products.
- Packaging should also protect the environment by ensuring products are safely contained, and that any components do not contaminate aquatic or terrestrial ecosystems either during use or recycling processes.

Preserve:

- Packaging can help to preserve perishable goods by providing barriers to the environmental effects such as ultra violet, oxygen, or moisture loss, helping to reduce wastage through spoiling.
- Consideration should be given to how the packaging will be handled and recycled once the product has been consumed.

Identify:

- Packaging should clearly identify the product and the brand.
- It should also provide information on how to dispose of or recycled the packaging, such as an On Pack Recycling Label (OPRL).

Communicate:

- Packaging can communicate important information about the product to consumers. Such information includes ingredients, usage instructions, safety guidance, and disposal methods.
- Packaging can be used to communicate a company or brands commitment to sustainability, providing information such as recycled content, or provide interactive functionality through media such as QR codes.

Transport:

- Packaging should be designed to be easily and safely stacked and transported, optimising size and weight to reduce the carbon footprint of the logistics chain.
- Consideration should be given to how packaging can be transported for recycling or reuse in order to reduce both waste and resource use.

RECOUP

How can RECOUP help?

RECOUP is the UK's leading independent authority and trusted voice on plastics resource efficiency and recycling. As a registered charity, our work is supported by members who share our commitments including:

- More sustainable use of plastics
- Increased plastics recycling
- Improved environmental performance
- Meeting legislative requirements

We achieve these by:

- Leading
- Advising
- Challenging
- Educating

Connecting the whole value chain to keep plastics in a circular system that protects the environment, underpinned by evidence and knowledge.

Our main recyclability and testing services include:

- Design guidance
- Technical advice on recycling and recyclability
- Sorting trials at UK material recovery facilities (MRFs)
- Near infrared (NIR) spectroscopic identification analysis
- Mid-infrared spectroscopic materials analysis
- Chemical and non-chemical wash tests
- Fibre loss tests
- Microscopy and infrared microscopy analysis
- Additive and contaminant detection

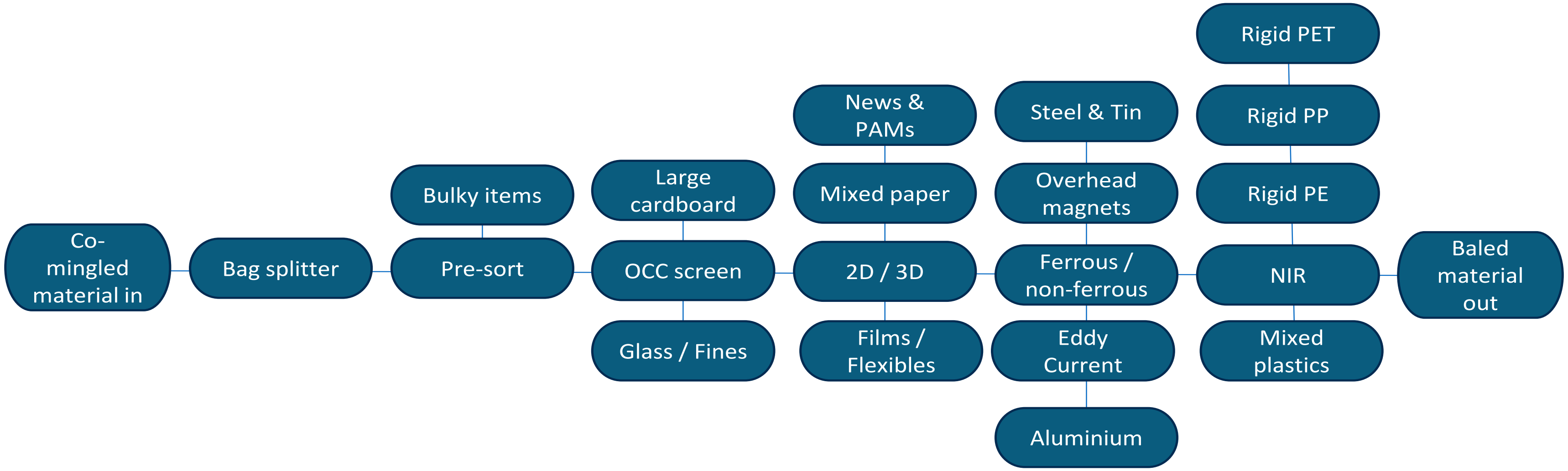
RECOUP

The recycling chain

There are five stages in the recycling chain, and if a piece of packaging is to be recycled it must be able to pass through each of the five stages in order. If a piece of packaging fails at any stage, it will not complete the recycling cycle and the chain will be broken.

- Disposal: Consistent messaging is essential to ensure consumers know how to dispose of packaging.
- Collection: The packaging is collected kerbside by local authorities.
- Sorting: The collected packaging is then sorted at a Materials Recovery Facility (MRF) into different recycling fractions and baled for distributed to reprocessors.
- Reprocessing: The baled materials are then reprocessed and are pelletised ready for manufacturing of new products.
- Recycling: The pellets are used by manufacturers to create new products or packaging depending on the grade of the recycled pellets.

The Materials Recovery Facility Sequence



Co-mingled recyclable packaging is collected kerbside by local authorities and transported to a materials recovery facility (MRF) for sorting. The MRF employs a number of mechanical and manual applications to sort the material into fractions for recycling.

The processes are illustrated in the image above, from point of entry, right through multiple sorting stations, to the final baled material leaving the site.

In the UK, the dry mixed recycling collected can differ a lot for each local authority. The main dry mixed recyclable fractions collected can include:

- paper and cardboard
- glass
- aluminium and steel
- rigid plastics (HDPE, PET, PP)

RECOUP

Disposal

Recycling of plastic packaging is complex, with many consumers admitting to being confused about what they can put in their recycling bins. With each local authority responsible for their own communications on recycling collections, there is currently no consistent solution for consumers.

Companies such as OPRL (On-Pack Recycling Label) provide brands with on pack binary labels (recycle/don't recycle) which communicate to consumers whether a pack is recyclable and provides any special instructions, such as cap on, or remove sleeve, etc[1]. This helps to relieve any consumer uncertainty about which packaging they can recycle at home.

Communication to consumers is important not only to ensure that the correct items are placed in the right bins, but also to inform consumers about rinsing packs to reduce contamination. In 2023, on average, the reject rate across all materials collected for recycling was at kerbside 14%[2]. In some areas this figure was as high as 37%.

Collection

In the UK, 43% of local authorities collect recyclable materials through co-mingled kerbside collections, with 57% using some form of source-separation (e.g. separate paper or glass)[2].

Recycling is collected fortnightly by 71% of local authorities, with only 19% collecting recycling weekly, and the remaining councils collecting every 3-4 weeks[2].

There are also a variety of other schemes for collecting recycling, such as bring schemes and front of store collections. Bring schemes are common for items such as batteries, which are collected at most large supermarkets. Front of store collections for flexibles and soft plastics are available at most large supermarkets.

1: https://oprl.org.uk/how-to-use-labels/
2: https://www.recoup.org/wp-content/uploads/2023/12/2023-UK-Household-Plastic-Packaging-Collection-Survey-compressed.pdf

Sorting

The sorting phase of the recycling chain is crucial in capturing recyclable materials for recycling from kerbside collections. At the Materials Recovery Facility (MRF) there are multiple stages that the materials must pass in order to be recycled.

Stage 1: Bag splitter.
The first stage where the material enters the sorting process is the bag splitter. Here any bags are shredded and opened without damaging the materials contained separating them. The bag splitter also controls the rate materials are fed onto the sorting lines to reduce overloading and ensure sorting efficiency.

Stage 2: Size sort.
The second stage is the size sort, where glass and smaller items <40 mm^2 are separated from larger 2D and 3D rigid packaging. This commonly uses an OCC (old currugated cardboard) screen in the UK which allows large items to carry over onto the sorting lines, while glass and small items are removed to the fines bunker.

Stage 3: 2D/3D.
The next stage is where 2D items like newpapers, letters, and other flat items are separated from 3D items such as bottles, cans, trays, and cartons, etc. This can happen using machinery such as trommels, ballistic separators or news screens, which carry 2D items in one direction with 3D items directed the opposite way.

Stage 4: Near infrared detection.
Near infrared detectors (NIR) installed at MRFs can identify the polymers being used in packaging by reading the reflected infrared light, which has a unique signature relative to the chemical structure of the polymer. MRFs use this to separate target polymers such as PET, PP, and HDPE rigid packaging.

Stage 5: Ferrous/non-ferrous.
The MRF uses overhead magnets to capture ferrous items such as steel cans from the 3D mixed recycling, and eddy-current separators removes non-ferrous metals such as aluminium drinks cans and aseptic cartons with an aluminium barrier layer.

Above: Visualisation of the recycling processes that plastic packaging follows through the sorting process at a MRF.

Stage 6: Baler.
Once the recyclable materials have been sorted and passed through the positive/negative picking cabin where non-target materials are removed from the target stream, the materials progress to the baler where they are compacted and tied into bales ready to be transported to reprocessors.

Recycling

The recyclable materials are sent to specialist plastic reprocessors for recycling. Sorted rigid plastics are processed by being turned into flakes. Plastics come in many different forms and are not all compatible in the same streams or applications. This makes plastics recycling more complicated than other materials, as the plastics need to be sorted thoroughly and processed to ensure that other materials do not contaminate the target plastic stream.

Even though plastics can look alike and share similar properties, they can be made of multiple materials such as PET, high density polyethylene, or polypropylene. These materials can be separated by density once they have been flaked.

Using density separation, contaminants and non-target polymers can be separated from each other using water. Water has a density of 1 g cm^3, which means that materials with a density <1 g cm^3 will float and materials with a density >1 g cm^3 will sink. Using this method, PET bottle flakes will sink during separation, while cap and label materials, commonly made of PE (cap) and PP (label) will float meaning the PET isn't contaminated by the cap and label materials.

There are some complicating factors. Some materials also used in packaging for their properties such as silicone seals may sink during density separation, meaning they contaminate the PET stream. Some manufacturers switched to a floatable silicone seal, which means that the silicone, which has a very high melt point then contaminates the PP or PE streams. Sometimes by trying to make changes to boost the recyclability of one material, can negatively impact another stream. This is why material testing and recyclability guidelines are important reference points when making decisions on packaging design.

When the materials are flaked there is also the potential for them to be contaminated with adhesives and labels. To separate these, the materials go through a wash process which uses a caustic solution containing a surfactant heated to between 70-85°C. The surfactant works as a wetting agent allowing the caustic solution to penetrate the adhesive and begin to break it down, releasing it from the plastic materials.

In some applications, the flakes will pass through either a hot or cold water bath. In this instance, a water solulble adhesive allows the labels to be released from the recyclable materials without the need to use a strong alkaline solution like the caustic hot wash process.

Once cleaned and decontaminated, the flakes are then ready to be processed into pellets which can be used to create new products. Some recycling streams such as PET natural and HDPE natural can be considered food grade, and these pellets can be used to create new drinks and milk bottles. Some materials cannot be guaranteed as food safe and so cannot go back into food grade recycled products, though there are a number of pioneer projects conducting research into ways to separate food safe and non-food safe plastics from the recycling stream in the future.

DESIGN PRINCIPLES

Design for recycling plays an important role in the recyclabilty of packaging. The choices made during the design stage affect the end-of-life process the packaging will follow and directly influences the sorting potential and end markets of the resulting materials.

RECOUP publication 'Recyclability by Design' has been informing industry, with recommendations for the recyclability of plastic packaging since 2006. RECOUP worked with WRAP and the British Plastics Federation to create two additional guidance documents which help packaging designers make informed design choices.

Ranging from the full technical version Recyclability by design, with a shortened summary version, to the simplified Design Tips for Recycling. The three guides contain guidance for all of the primary polymer types, including labelling, closures, adhesives and barriers, etc.

Design Tips for Recycling illustrates the common issues that impact packaging recycling.

It is available to download here.

The Summary of Recyclability by Design contains all of the key design principles and guidance tables in an easy to read format.

The summary version is available to download from the RECOUP website.

The full technical version of Recyclability by Design contains all of the RECOUP design principles and guidance together with material specific guidance and tables.

The full version is also available for download from the RECOUP website.

THE RECOUP LABORATORY
Near infrared spectroscopy

Near infrared (NIR) is the standard technology used by a MRF to identify the different polymers types used in recyclable packaging to capture them for recycling.

In principle, NIR operates by irradiating a sample with energy on the infrared spectrum and reading the percentage of energy that is reflected back to the sensor in relation to the original energy output.

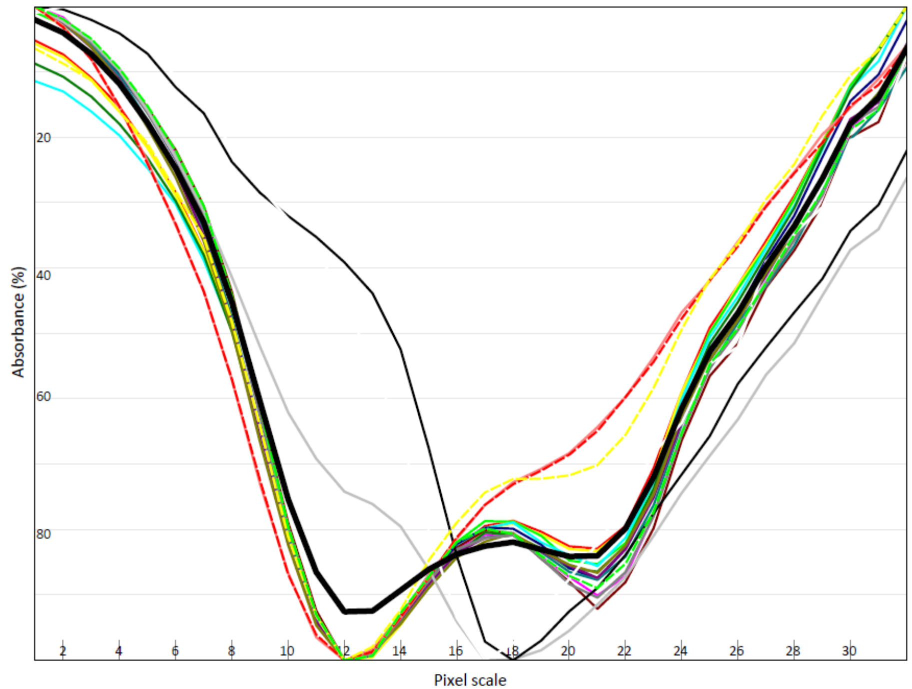
This reflected energy is translated into an absorption or reflectance spectrum which is used to identify peaks where the highest amount of energy was absorbed by the packaging. Energy is absorbed when the bonds between molecules in the packaging react to different wavelengths of infrared energy, causing them to vibrate and absorb the infrared energy. This absorption wavelength is unique to specific bonds based on the mass of the atoms and the strengths of the bonds involved, which means that the unique combination of absorbance patterns can be linked to specific materials like a human fingerprint.

RECOUP uses an IoSys MiroGun 4.0 near infrared spectrometer to analyse samples such as complete packs, using this data we can generate reports that predict how the pack is likely to be interpreted by the NIR systems in use at a MRF operating in the UK.

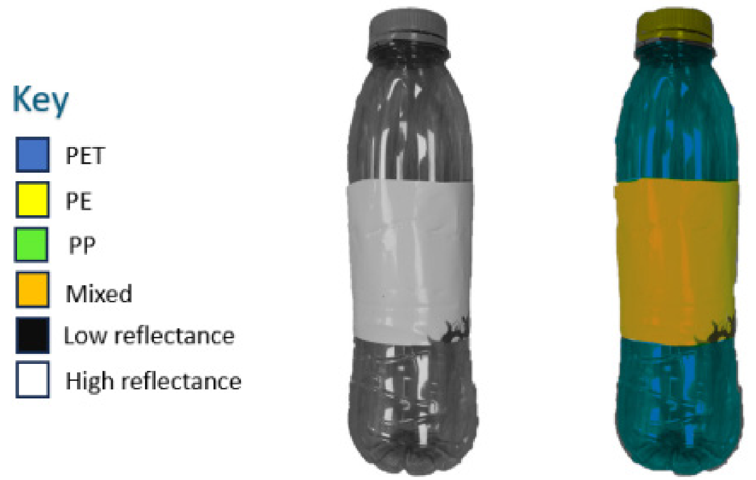
Using the scan data we are able to generate a false colour image called a colour map, which indicates how each area of the pack is seen using a unique colour pallette for each material being recorded.

For instance, where a colour map would show which areas of the pack are seen clearly as one material, such as the blue areas on the colour map image (bottom right), and the orange areas where the label has returned spectra with peaks for both PET and PP, which results in a mixed spectra that does not return an expected result for an NIR attempting to identify a target polymer such as PET.

RECOUP uses the results from near infrared (NIR) analysis to enable members to make predictions and informed design choices before commiting packaging designs to full MRF sorting tests.



Above: near infrared spectra showing the absorbance percentage on the vertical axis and the corresponding pixel on the horizontal axis. This image shows peak absorbance at 12 pixels (PET) and a strong peak at 21 pixels (PP).



Above: colour map image showing how a PET bottle with a PP label covering 60% of the bottle could be viewed by an NIR operating in a MRF.

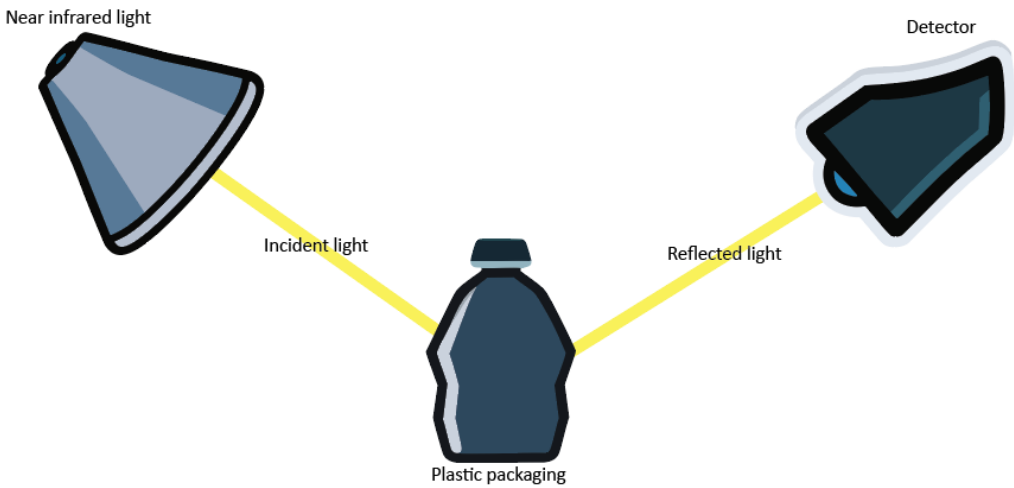
RECOUP

NIR detection - how does it work?

1. The near infrared light source is positioned high above the moving belt, providing a clear and unobstructed view of the materials passing below.

2. The packaging moves along the belts at high speed and is irradiated with infrared energy from the infrared unit above.

3. This light is called incident light, and some of the energy is absorbed by the packaging, with the rest being reflected.



4. Near infrared light is reflected from the sample towards a detector, which reads the intensity of the reflected incident light.

5. The signature of the reflected light is unique to the material of the packaging, enabling the packaging to be separated by polymer type.

6. The identified packaging is then positively ejected by air jets and is able to be recycled.

Above: interpretation of how infrared light is reflected and detected.

What can be detected by NIR?

- Polyethylene terephthalate (PET)
- Polyethylene (PE)
- Polypropylene (PP)
- Paper

Limitations of NIR

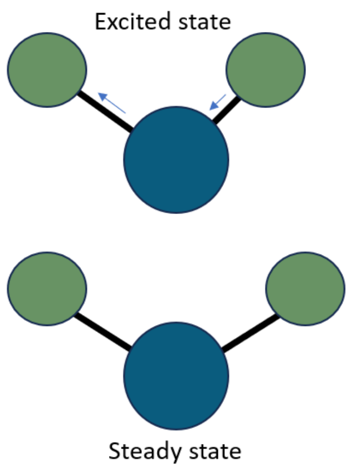
- Extremely thin materials
- Black plastics
- Metalised surfaces
- Shiny materials
- Laminated materials
- Glass
- Aluminium
- Steel

Near infrared detection is a form of vibrational spectroscopy and is a non-destructive procedure, meaning that packaging does not need any preparation to use it.

Materials are comprised of different chemical compounds, and vibrational spectroscopy measures the vibrational energy in the material. Each chemical bond within a material corresponds to a unique wavelength of infrared energy, which is as distinctive as a fingerprint.

As the material is irradiated with energy, the molecule enters an excited state and will stretch or vibrate, which absorbs the energy on that particular wavelength. The remaining energy is reflected and detected by the infrared sensors, which then calculates the absorbed energy to generate a spectrum.

Using the spectrum, it is then possible to determine which material has been scanned based on the interactions of the molecules and the infrared energy.



Above: a molecule stretching in excited state compared to steady state.

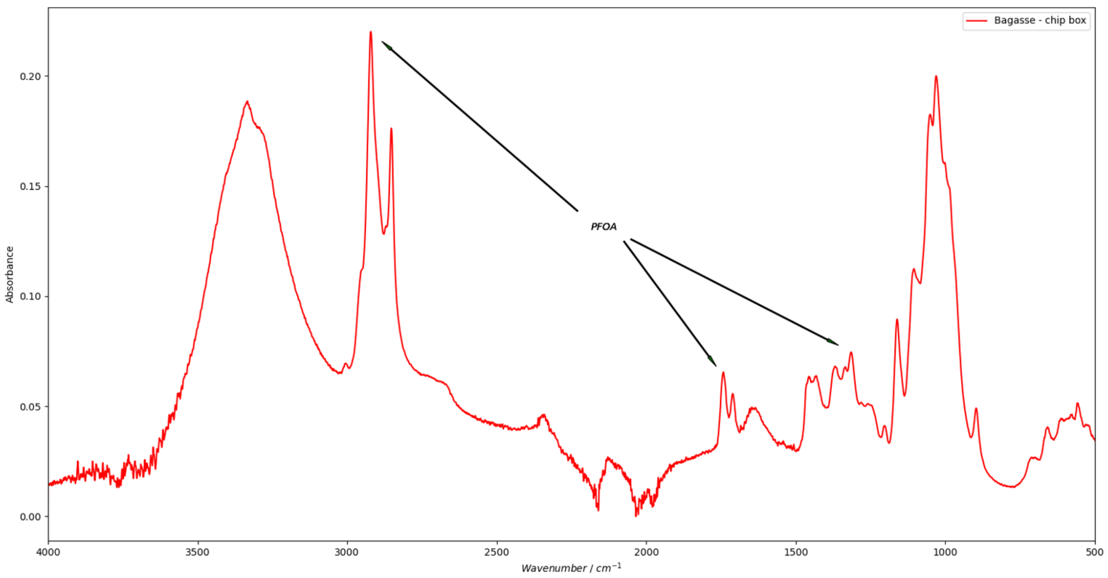
RECOUP

Fourier transform infrared spectroscopy

Fourier transform infrared spectroscopy (FTIR) like near infrared spectroscopy is a form of vibrational molecular analysis, which uses the reflection of infrared wavelengths from the surface of a sample to determine the bond structure of a material.

The difference between FTIR and NIR is in the depth of detail that can be ascertained through FTIR techniques. NIR can be used for a rapid identification of the material, whilst FTIR can provide a deeper and more detailed picture about the molecular structure of a material. This includes being able to detect and identify some contaminants or additives that have been used for packaging materials.

The image on the right shows an FTIR spectra collected from a bagasse clam shell container to identify the material, the scan also revealed that the grease and moisture barrier on the inside of the container contained perfluroroctanoic acid, a compound which is related to a group of problematic substances called PFAS.



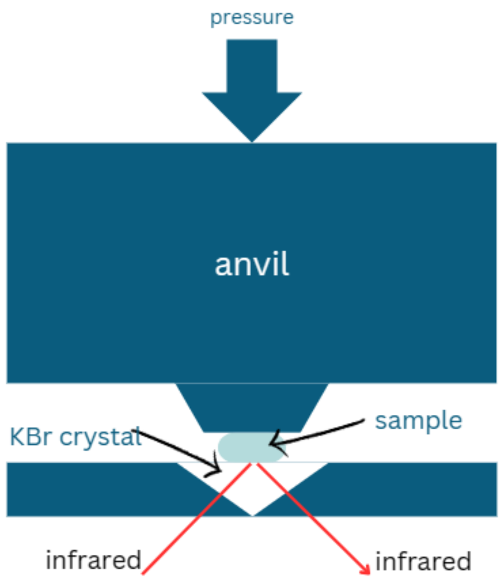
Above: FTIR spectra captured from a bagasse container with anotated peaks for PFOA (perfluorooctanoic acid).

How does FTIR work?

RECOUP uses single bounce attenuated total reflection (ATR) spectra when analysing plastic samples. FTIR differs from NIR spectroscopy in that the wavelengths used extend from the near-infrared into the mid-infrared range.

The single bounce ATR technique passes a single beam of infrared energy through a prism or crystal of a high refractive index, usually a diamond, zinc selenide, or germanium crystal prism, into a sample with a low refractive index.

The penetration of the infrared energy into the sample varies depening on the angle of incidence of the infrared beam, but generally only penetrates up to around 2 microns, this means that while NIR penetrates deep into a sample, FTIR only takes into account the surface of the sample during analysis.



Single bounce ATR is a very useful technique for smaller sample sizes, such as single fibres or micro plastic particles. However, like NIR there are limitations when analysing black materials as they absorb strongly on the infrared spectrum. Luckily, one benefit of ATR is the ability to switch out the crystals. Diamond is the preferred all round crystal, but the germanium crystal allows for the analysis of the darker materials and can be used when reflectance values are poor.

Benefits of ATR spectroscopy:

- **Very fast analysis**
- **Non-destructive technique**
- **Evidence of additives or contaminants**
- **Ability to sample black plastics**
- **Potential for quantitative analysis**

FTIR microscopy - analysis of microplastics and fibres

FTIR microscopy can be a powerful tool for the analysis of microplastics, fibres, and other particles. Microplastics are small plastic particles of less than 5 mm in size, they have been found in many different environments from oceans and soils, and can be found in airborne dusts.

Using FTIR microscopy, it is possible to detect and analyse particles that are invisible to the naked eye. The samples can be provided in dry powdered form, or separared using density separation, filtration and organic digestion. The FTIR microscope can be used to detect the particles suspended in solution or on a filter substrate by capturing background data.

Samples as small as 200 µm have been identified using RECOUP's FTIR microscope unit. Currently our microscope uses a KBr crystal for FTIR microscopy, which is not suitable for the identification of black plastics or rubber particles. These samples can be transferred to our FTIR module and identified using a germanium crystal instead.

Image of a Nicolet IS5 with a SurveyIR accessory.

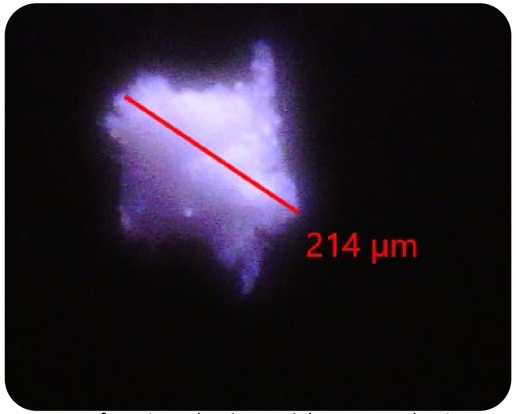


Image of a microplastic particle captured using the Czitek SurveyIr

Applications of FTIR microscopy

- Agriculture/horticultural plastics
- Waterborne plastics
- Plastics in soils (litter, compost)
- Fibre loss (labels, wash testing)
- Visualisation of materials

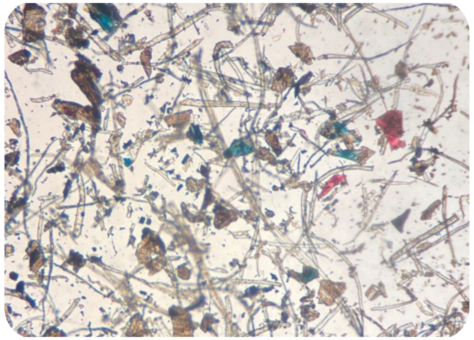
RECOUP

Fibre loss and wash tests

Labels and adhesives can cause problems in the recycling system if they do not separate from the recyclates cleanly leaving no residues on the flakes or fibres in the wash solutions.

RECOUP uses protocols accredited by RecyClass and Petcore Europe to perform label and adhesive wash tests on plastic packaging formats to determine the efficiency of adhesive release and to ensure that no fibres or ink from the labels are shed into the wash solutions.

Right: an image showing a failed fibre loss test from a paper label with paper fibres and ink flakes floating in a solution of water with no added chemicals or surfactants.



Fibre loss

RECOUP can test packaging with label substrates such as paper for fibre loss by flaking the packaging and immersing the flakes into a solution and agitating the flakes for a specified time.

The results will show how the labels react to the wash process and whether any label fibres or inks are lost into the wash solution. A positive result will see no ink or fibres present in the wash solution.

Ink bleeding

Printing inks can contaminate the wash water leading to discolouration of the flakes as well as contamination of the final recycled materials with non-intentionally added substances (NIAS).

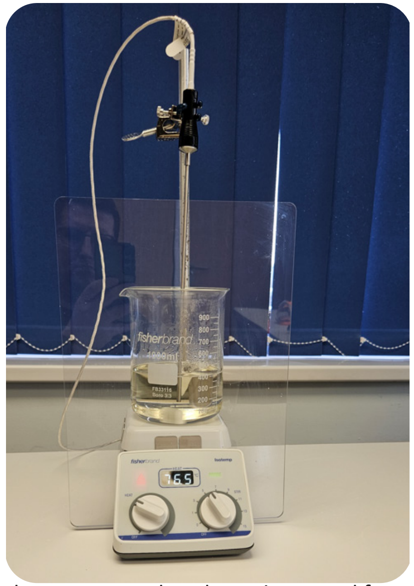
Ink bleed tests will show whether any inks contaminate the wash water and in some cases NIAS can be identified using FTIR spectrocopy of the flake to determine the suitability of the materials for recycling.

Adhesive wash test

Packaging can use adhesives for labels, top films, or to ensure placement of components such as absorbent pads.

RECOUP can perform adhesive wash tests to ensure that adhesives are released from the main polymer of the packaging and does not contaminate the recycling stream.

These tests can be performed as either hot or cold wash water release tests for water releasable labels, or caustic/alkaline hot wash tests using a solution of sodium hydroxide with added surfactants.



Above: Isotemp hotplate stirrer used for hot and cold wash testing.

Suitable applications for fibre loss and adhesive wash tests are described in the tables below:

Adhesive wash tests	Solution	Applications
Cold water adhesive release	Water	HDPE and PP rigid
Caustic hot wash	NaOH + non-ionic surfactants	PP and PET rigid (food grade)

Fibre loss / ink bleed	Solution	Applications
Cold water	Water	HDPE and PP rigid
Caustic hot wash	NaOH + non-ionic surfactants	PP and PET rigid (food grade)

RECOUP

Certification

All RECOUP tests follow strict protocols which are peer reviewed and relevant to the recycling of the packaging being tested. The tests are all carried out in compliance with the standards set out in ISO 17025:2015 and follow strict quality control procedures to ensure valid and repeatable results are obtained.

RECOUP does not certify any test results formally, but any tests will be completed with a full report and a certificate/statement of results. The report will fully detail the samples tested and any preparation that was used prior to testing, as well as the protocols and methods followed to achieve the results.

Most of RECOUP's tests are currently aligned with standard protocols from RecyClass and Petcore for the testing of recyclable materials and packaging under laboratory conditions and also for sorting trials conducted at MRFs, or Plastics Recovery Facilities (PRFs).

The protocols used for each test as well as the decision rules used in determining the final results are available for reference.

RECOUP does not provide any official certification directly, instead chosing to work with recognised companies such as OPRL on an advisory role to provide technical and testing services to assist with their certification schemes.

OPRL - On-Pack Recycling Label

Certified as Recyclable

Many claims are made when marketing new packaging, with ever increasing scrutiny. Brands and consumers need to be able to distinguish truth from greenwashing when thinking about packaging sustainability claims.

The OPRL Certified as Recyclable scheme was developed for OPRL members with the goal of providing objective and robust analysis of their packaging design, providing a clear analysis of suitability for recycling in the UK.

RECOUP currently provides technical services and testing for OPRL as part of the Certified as Recyclable scheme.

Certification of recyclability will give brands, retailers, and others the confidence that the packaging they are purchasing will qualify for the OPRL Recycle label.

RECOUP can provide technical consultancy for those looking to achieve the OPRL Certified as Recyclable for plastic packaging recyclability and test sample packaging for both design and recovery in UK recycling facilities.

Where appropriate and feasible testing will determine:

- Sortability at a MRF or PRF in the UK
- Technical recyclability
- That markets exist for the recycled materials.

The scheme is available for members of OPRL, more information can be found at the OPRL website.

Laboratory testing fees*

RECOUP has set the daily rates for members at £400 and non-members at £600 per day for 2024. All of the RECOUP laboratory testing services are priced in accordance with this day rate at either a fixed rate per sample tested to a quotable daily rate which will be advised on proposal using the testing projects pricing criteria outlined below.

Test type	Fixed or daily Rate	Member costs	Non-member costs
Near infrared analysis	Fixed per sample	£100**	£150
FTIR analysis	Fixed per sample	£200	£300
Adhesive/fibre loss wash test (non-chemical)	Fixed per sample	£400	£600
Adhesive/fibre loss wash test (chemical)	Fixed per sample	£450	£650
Microplastics analysis	Daily rate	£400	£600

*These fees are for paid project and laboratory testing and are not applicable where agreed complimentary membership benefits are in place.
**Basic NIR trials are included free to members for sorting trial and guidance purposes.

RECOUP

Version: 1.0 July 2024

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