Welcome
Repak
Plastics Circular Economy Webinar

20/11/2023

REPAK
Business *funding* recycling

Agenda

- **Introduction – Gary Browne, Packaging Technologist - Repak**

- **Prof. Ed Kosior Presentation - CEO and Founder at Nextek Ltd**
  - Targets and Blockages
  - Updates on food-compliance regulations
  - Relooping is the new Recycling
  - Packaging design to boost Relooping
  - Q&A - 10 minutes – Gary Browne

    BREAK – 10 Minutes
  - Deep-diving into latest & best technologies to enhance sorting
  - Three essential stages in food-grade PP recycling
  - Update on closing the loop on flexible post-consumer PP
  - Accelerating the Circular Economy for Plastics
  - Q&A - Gary Browne

- Summary - Sorcha Kavanagh

Prof. Ed Kosior

CEO and Founder at Nextek Ltd

- 48 years Plastics recycling experience.
- Instrumental in designing numerous modern recycling plants and he has achieved a number of patented recycling breakthroughs.
- Transformational projects include NEXTLOOPP, the Award-winning global multi-participant project to close the loop on post-consumer plastic packaging and turn it into high-quality food-grade recycled Polypropylene.
- Nextek Ltd won the IOM3's Circular Economy Award last night (2 November 2023) with the COtooCLEAN technology, a unique supercritical carbon dioxide ($ScCO_2$) cleaning process that efficiently and effectively cleans and decontaminates post-consumer polyolefin films to a food-grade status.

Closing the loop on food grade recycled plastics packaging

20th November 2023

PROF. EDWARD KOSIOR
Managing Director, Nextek Ltd and NEXTLOOPP Ltd

London UK, Sydney Australia and Pune India

REPAK Circular Economy Webinar

nextek

NEXTLOOPP
CLOSING THE LOOP ON FOOD GRADE PP

NEXTEK LTD

WHAT WE DO

Recycling plant design and Feasibility studies.

Strategic advice to Multi-National Corporations and Recycling Co's.

Food-grade recycling of post consumer plastics – process development.

Research and development of novel materials and processes including plastics and bioplastics.

Business support, productivity improvement and problem solving.

Ground breaking projects for governments and major commercial organisations in the EU, UK, India, Malaysia, USA, South America, Middle East, North Africa and Australia/NZ.

Strong ties to Universities and Scientific Centres of Excellence in the UK and Europe.

AWARDS

Circular Economy: Targets and Blockages

- **The Circular Economy = USE "WASTE" to make NEW MATERIALS (BUT DON'T CALL IT WASTE) and put it back into products,……. preferably the same products**
- The majority of materials have been designed to be processed once only. **Recycling friendly formulations are needed. CHANGE NEEDED**
- In the circular economy, you can only recycle what is put out by the retailers. **Printing and pigmentation limit re-use. CHANGE NEEDED**
- **Not all packaging is recyclable**. Mono materials are more widely recyclable to high value. In many countries around 25% of packaging has poor recyclability.
- **Food grade recycling** is possible but difficult to achieve unless sorting of food/non-food and powerful decontamination is available
- Odour removal from LDPE, HDPE and PP is often necessary
- Polyolefins are oxidised by the thermal recycling processes which will be problematic at high recycling rates such as >50%
- **Potential recovery of plastics for recycling and CO2e benefits.**

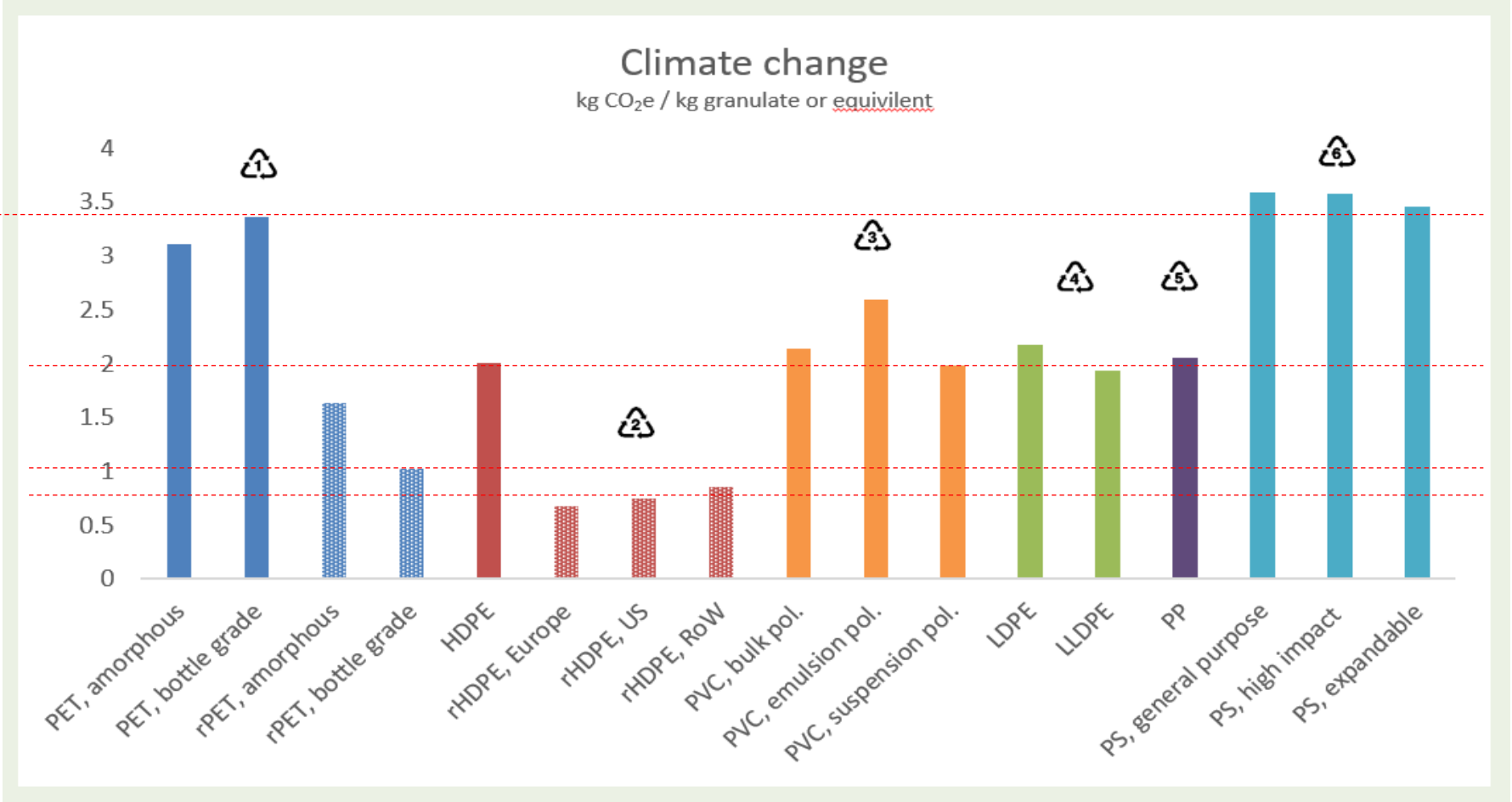
75% **collection** x 95% **sorting** x 85% **recycling** = **60% Recovery**

Each tonne of rPlastic will save around 1.5 tonnes of CO2e

Carbon Footprint reductions for recycled plastics

All plastics are NOT the same!

- vPET has a 70% higher CO2e than vHDPE and vPP
- rHDPE and rPP have a 25% lower CO2e than rPET
- 30%rPP/HDPE content has the same CO2e as 73% rPET content
- Its always more beneficial to recycle HDPE/PP than PET



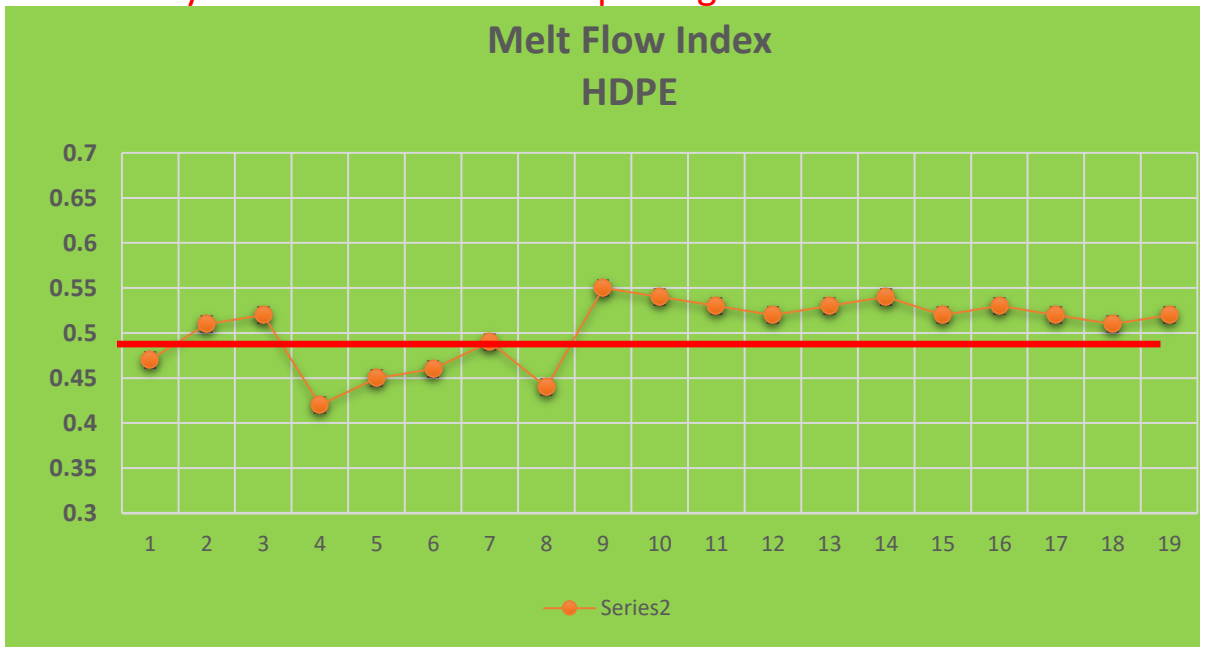
Circularity = Design for Recycling back to (same) products

- **Especially important for food products**
- **RESIN** - ideally unpigmented, stabilised for multi-cycles
- **Printing inks and labels**
  - The label should be recycling compatible and separable or self-peeling from the bottle
  - Inks must not come off during hot washing
  - Direct printing with unstable inks should be avoided
- **Adhesives/Glue**
  - Stay with the label when they peel off
  - Ideally do not leach plasticisers
- **CAPS**
  - Many colours are used and affect final colour of the resin
  - Ideally should be colourless and stay with the bottle
  - Should be recycling compatible
  - Made of one polymer per packaging type

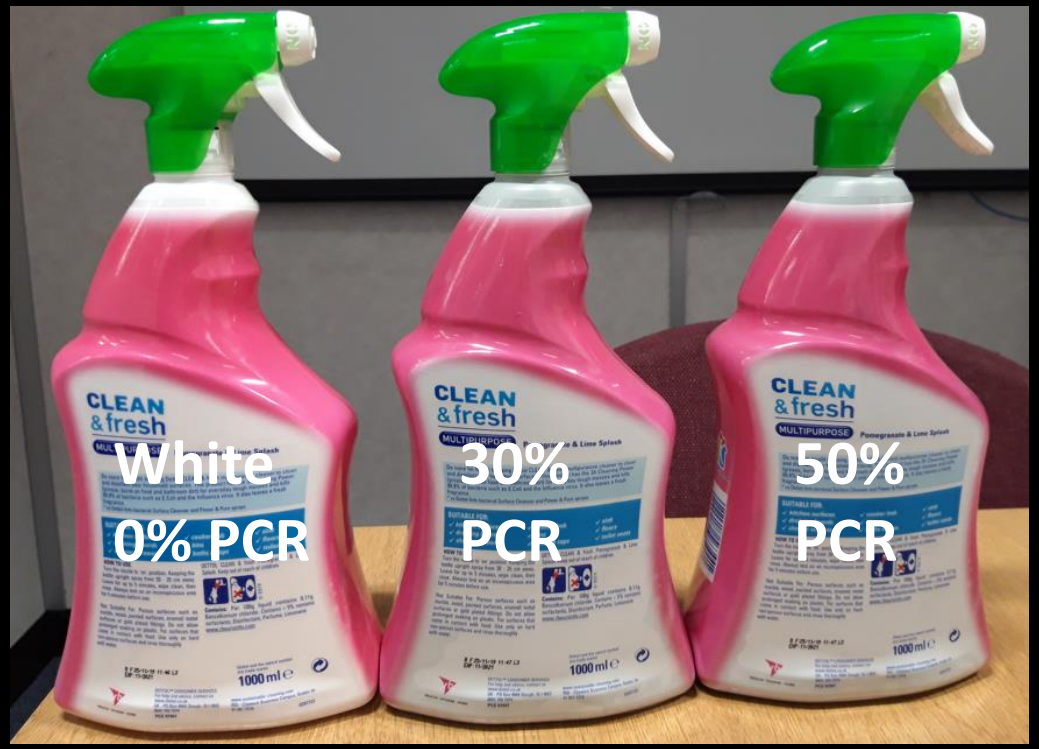
CIRCULAR RECYCLED PLASTICS – QUALITY ATTRIBUTES

- Recycled Plastics are made from mixtures of grades
- Properties (processing and mechanical) are an average of the inputs so they don't line up exactly with virgin grades
- 100% rPlastic DOES NOT equal 100% virgin Plastic
- Blending with an appropriate grade of virgin polymer will allow re-alignment of the properties close the standard virgin grade.
- Blending minimises colour variation and processing variation
- Manufacturing is more stable when recycled content is spread over more packaging than concentrated into fewer products

30% recycled content in 100% of packages is better than 100% recycled content in 30% of packages



CIRCULAR ECONOMY PACKAGING
– self-coloured bottles could be the norm



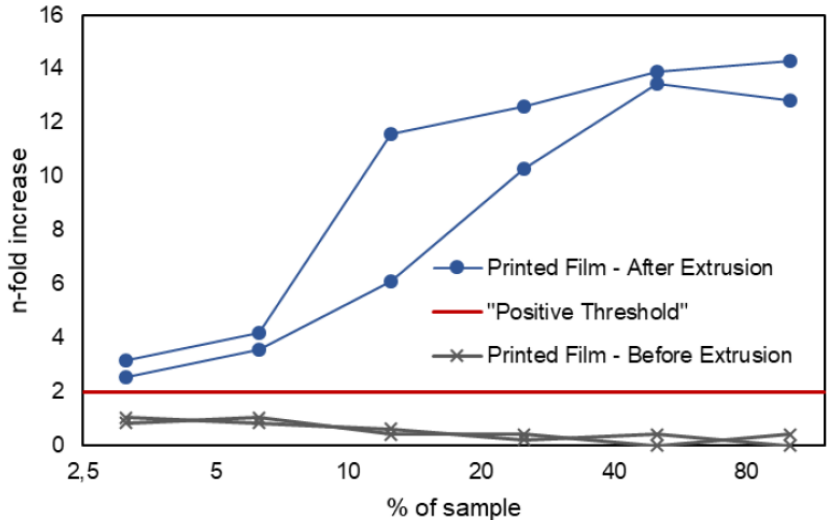
It is possible to use sleeves to deliver the important marketing and consumer advice on “grey” packaging with little visible change to the appearance.

Principles of Food Grade Recycling of plastics packaging

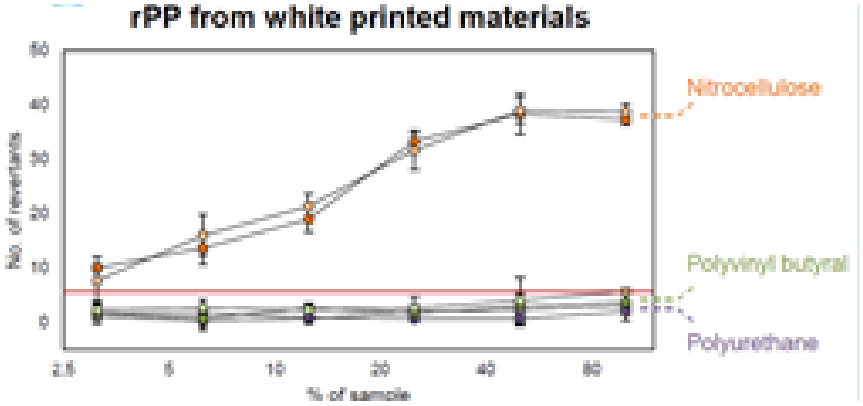
- The plastic resin has been manufactured to food grade specifications for all monomers and additives
- Ideally the package has been used for food applications.
- The package about to be recycled has not been contaminated by abnormal use by consumers
- The recycling process has powerful decontamination steps to remove ALL migrating molecules (to at least over 95% depending on packaging)
- The recycling process is being used on a commercial basis preferably on a large scale
- The package is designed to be recycled

INKS

- Concerns around recycling plastics with inks still present
- Original inks could be safe
- Degradation of inks – potentially harmful

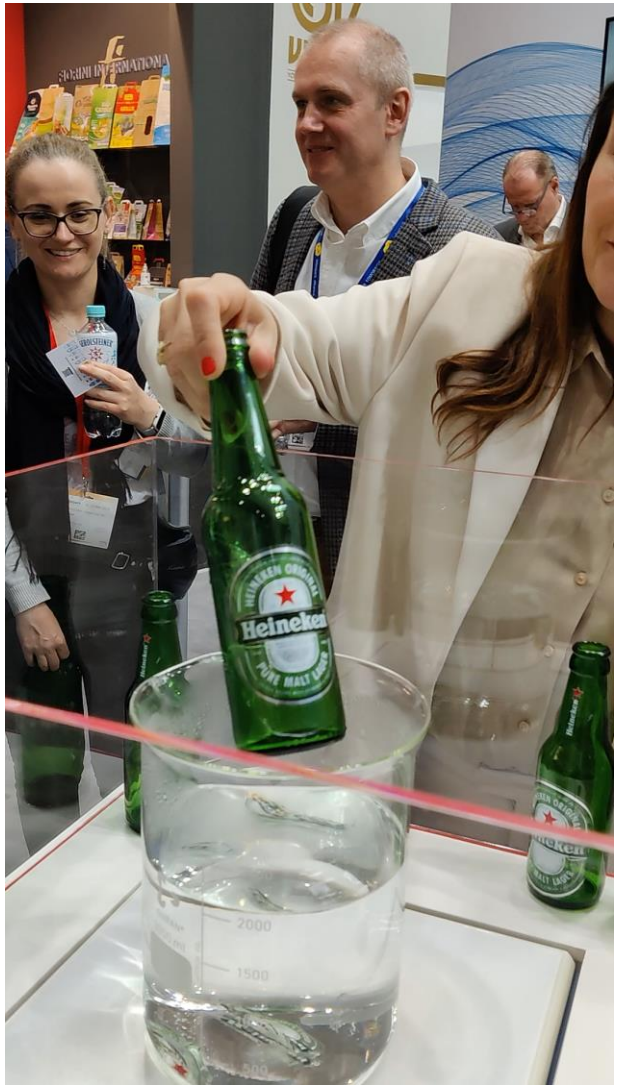


- PolyCycle/Migratox/SafeCycle – Ames Testing shows some recyclates genotoxic activity
- Investigations pointing to Nitrocellulose based inks
- Ames activity increases with processing temperature



Adhesives

- Adhesives with phthalate plasticisers
  - Many endocrine disrupting / toxic to reproduction
  - Conflicts - some permitted use with FDA indirect use but excluded from 10/2011
  - MEHP / BEHP / DOTP frequently observed in labels
  - Some alternatives available i.e. adipates (see 10/2011)
- Label removal
  - One long term study finds an average of 2.2 % of HDPE flakes with labels attached after conventional hotwash process
  - Poor delamination = carry over of glues and inks
  - Glues causing gels and black speck impurities
  - Label carry over causing issues with genotoxic activity and circularity
- Should stay with the label when they peel off
- Ideally do not leach plasticisers



Design to Recycle: NextCycle IML from MCC Verstraete

- Removable IMLs - Verstraete's NextCycle IML
- Fully printed (non-bleeding inks) without adhesives.
- These labels are designed to be removed prior to extrusion at the grinding steps or air elutriation stage and separated from the rigid flakes

IML and Print removal: Mechanical Cleaning during wet washing

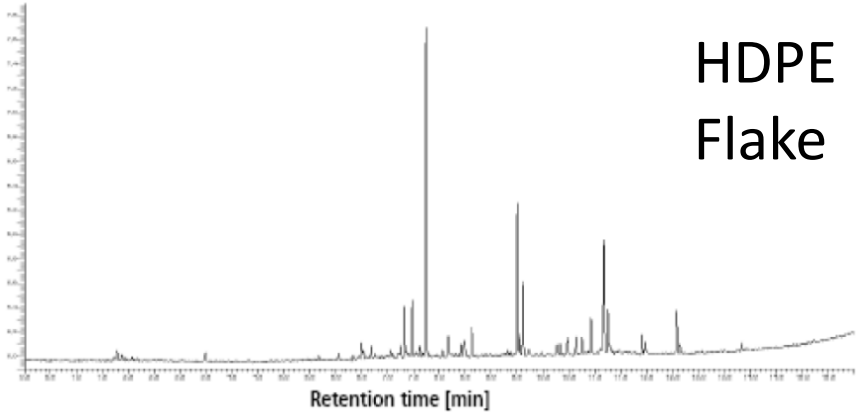
Recycling with IML labels left on

Recycling with IML labels removed through innovative recycling approach

Food Grade HDPE needs to be >99% prior food grade input materials

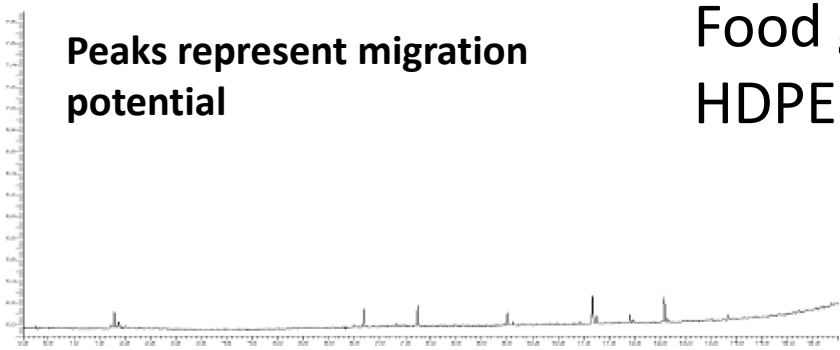
Milk bottles to recycled content Milk bottles
USFDA approved – Not yet EFSA approved after 32 billion bottles with >30% rHDPE content

GC/MS Analysis of HDPE

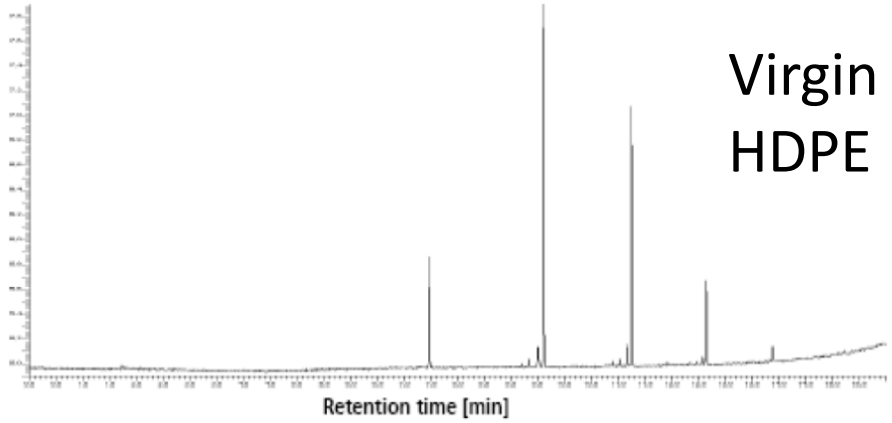


HDPE Flake

Peaks represent migration potential



Food grade HDPE pellet



Virgin HDPE

CASE STUDY: Competitive INTELLIGENT SORTING into food use packaging

Globally, Near Infra Red (NIR) and visible signatures are used to identify the polymer type and colour at very high speeds.

No markers are needed for sorting into polymer types such as PET, HDPE, PP, LLDPE etc

The important technologies of marker sorting (Spectroscopic, Neural network (Artificial Intelligence) and Digital product markings will deliver more precise separation for recycling.

No.1 Priority is FOOD-GRADE Prior Use

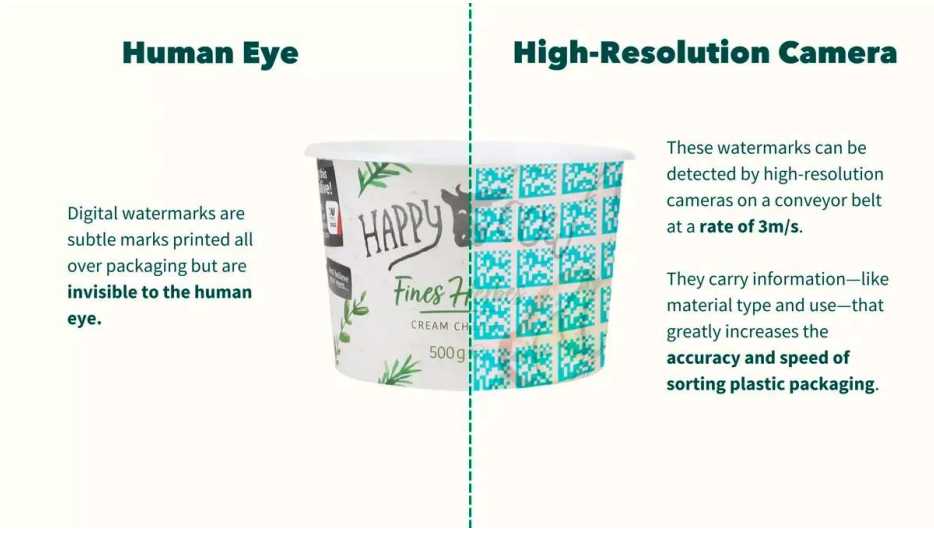
No.2 Priority is Non-Food Grade Prior Use

No.3 Priority is Toxic products

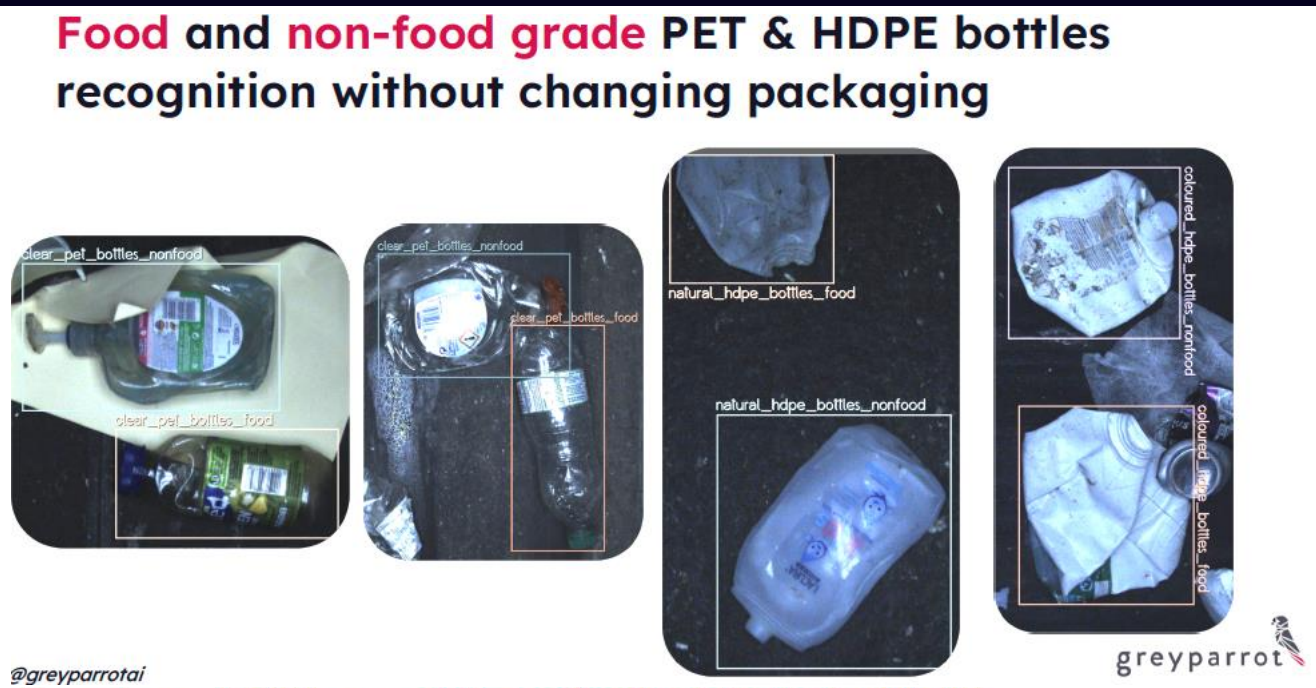
No.4 Priority is Difficult to Recycle packaging

Digital watermarks Filigrade and Digimark

Fluorescent markers on labels



CASE STUDY: Artificial Intelligence (e.g. Grey Parrot) SORTING for plastics packaging



CASE STUDY: Removing and controlling colour to boost recycling

- Pigments are possibly the most contentious yet easily reversible element of today's packaging.
- Imagine defining product categories by the colour of their plastic containers instead of by a wide range of brand cues.
- Only a small range of colours would be acceptable
- All food products contained in natural or white packaging,
- non-food sector in pastel colours – thereby using smaller concentrations of pigments
- hazardous products in black plastic.
- Sorting by transparent/pastel/black colouration of packaging is very simply achieved by the use of well-established, accurate and relatively low-cost automatic sorting technology using the visible light spectrum and cameras for detection.

Sorting based on colour could separate food grade items (Natural or white) and reject toxic products (black)

Questions & Answers

Please feel free to add your questions in the Q & A box.

REPAK
Business *funding* recycling

10 Minute Break

REPAK
Business *funding* recycling

POLYPROPYLENE

Growth of the "do everything" plastic

2018

56MMT

USD$ 97 Billion

+50% GLOBAL GROWTH

2025

83MMT

USD$ 147 Billion

Europe

10MMT

2018

NEXTLOOPP Project

48 participants in PP supply chain

Highest stiffness to weight ratio, insoluble, strong, super-tough, transparent, fibres, sheet, mouldings, furniture, appliances, automotive, packaging.

NEXTLOOPP CLOSING THE LOOP ON FOOD GRADE PP

NEXTLOOPP UNIQUE TECHNOLOGIES

PolyPrism

Sorting food-grade packaging

PPristine

Decontamination technology

Our unique technology has taken 8 years of intense research and commercial trials to achieve and is now **plug and play ready for use**.

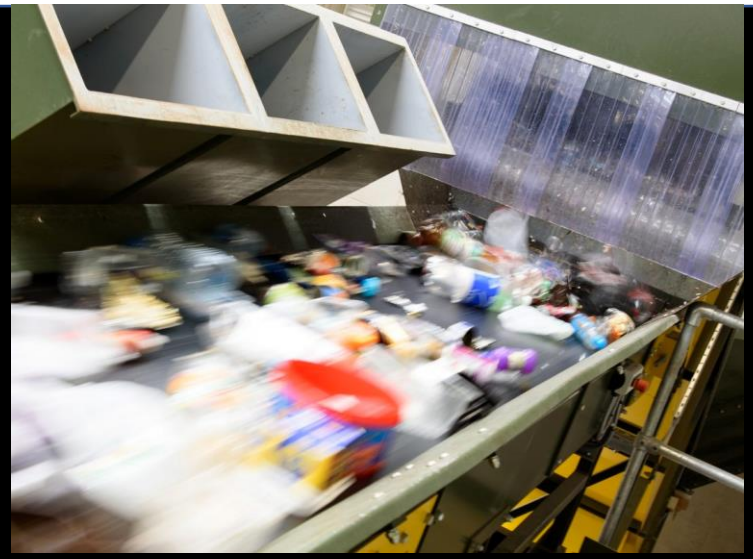
This technology has been designed to be implemented **with current technologies, staffing and infrastructure**.

Sorting with markers requires only one layer of ink on a label and UV light

Mechanical recycling offers the most cost and carbon efficient option for recycling plastics

NEXTLOOPP
CLOSING THE LOOP ON FOOD GRADE PP


NEXTLOOPP
CLOSING THE LOOP ON FOOD GRADE PP



PACKAGING EUROPE

NEXTLOOPP unveils results of tracer-based sorting trials

21 OCTOBER 2021

NEXTLOOPP the PP recycling project led by Nextek Limited, has announced that its trial to sort food-grade plastic packaging waste using a label marker achieved 99.9% sorting purity at maximum production speed.

NEXTLOOPP's PolyPRISM™ 'plug-and-play' marker system was used on TOMRA's sorting equipment, enabling it to be validated at the test site.

The technology can identify variations – such as between a milk bottle and a bleach bottle – in plastic packaging at a maximum production speed of more than two tonnes per hour.

‘BRAND QR CODES’ AND ‘RECYCLING QR CODES’ ON LABELS

iPhone recognition of UV visible QR code at HY pigment concentration 0.35% w/w

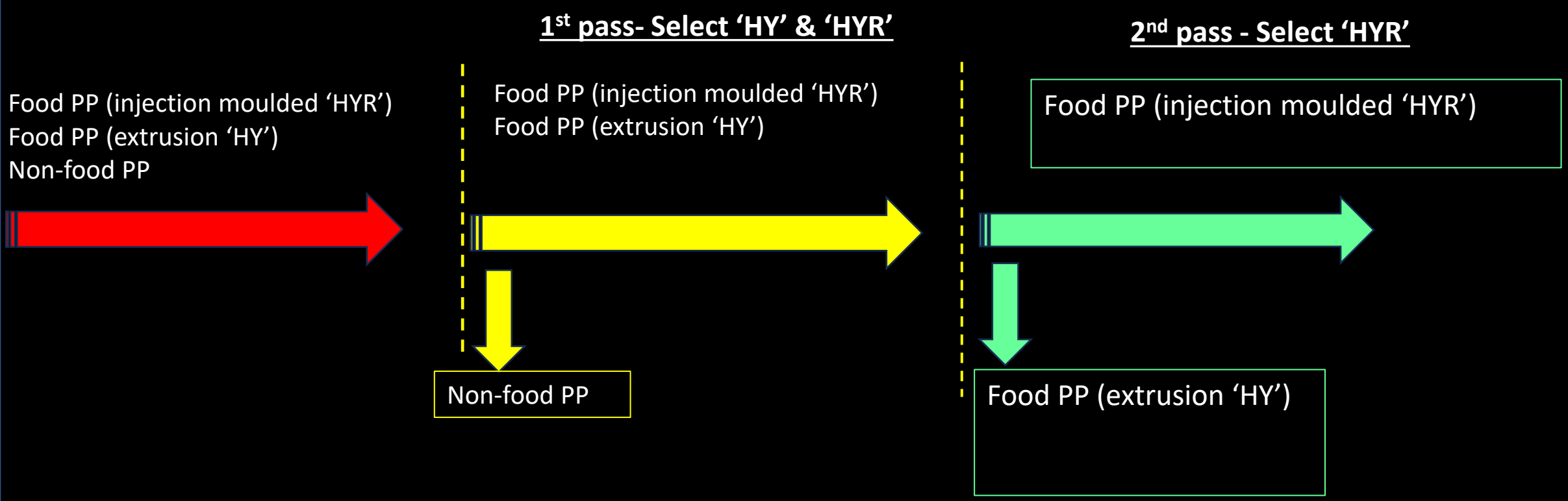
‘Brand QR code’

Prizes to drive brand loyalty
Social media engagement
Customer service information
Customer feedback
Food recipes
Food track and trace
Food nutritional value
Food allergy information
Supply chain transparency
Sustainability and disclosures

‘Recycling QR code’

Polymer traceability
Recycled content and verification
Polymer properties eg MFI
Approval for contact with food

SEPARATING FOOD GRADE INJECTION MOULDED PP AND EXTRUSION GRADE PP USING UV VISIBLE MARKERS



HY AND HYR LABELLED PP PACKS VIEWED UNDER UV 365NM

98% SEPARATION
INJECTION-MOULDED AND EXTRUSION GRADE PP

Without UV
zero packs selected
(Control test)

With UV - select ‘HY and HYR’
(All selected- 100% yield)

With UV – select INJ packs
(Yield 97%, purity 97%)
Extrusion packs not selected
(Yield 98%, purity 98%)

Decontamination efficiency

Decontamination efficiency achieved by NEXTLOOPP PPristine technology.

Process	Toluene (mg/kg)		Chlorobenzene (mg/kg)		Phenyl-cyclohexane (mg/kg)		Benzophenone (mg/kg)		Hexyl salicylate (mg/kg)		Isopropyl myristate (mg/kg)	
M Wt	92.1	Decon (%)	112.5	Decon (%)	160	Decon (%)	182.2	Decon (%)	222.3	Decon (%)	270.4	Decon (%)
Control*	1049	~	1151	~	970	~	720	~	962	~	843	~
NEXTLOOPP PPristine	<0.5	100%	<0.5	100%	1.7	99.8%	9.0	98.8%	22	97.7%	41	95.1%

Where 'Control' refers to measured concentration of surrogates in challenge test flake prior to any processing.

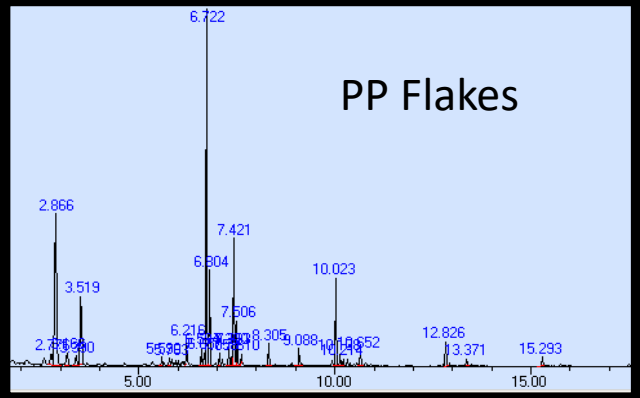
Characterisation of the recycled plastic

Physical/mechanical characterisation

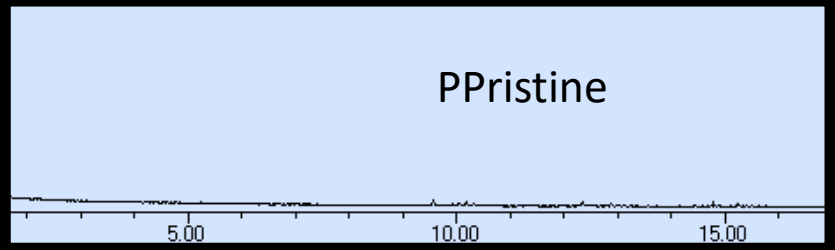
Property	Natural	White	Grey
Pellets per 5 g	147	136	174
Tensile stress at yield (MPa)	30.5	28.5	28.0
Tensile strain at yield (%)	9.0	6.3	6.1
Tensile modulus (MPa)	1,183	1,255	1,248
Flexural modulus (MPa)	1,379	1,426	1,376
Izod impact, notched, 23 °C (kJ/m^2)	5.1	5.7	5.4
Izod impact, notched, -20 °C (kJ/m^2)	3.0	3.6	3.5
Melt flow rate (g/10min)	14.1	20.2	27.3

Characterisation of the recycled plastic

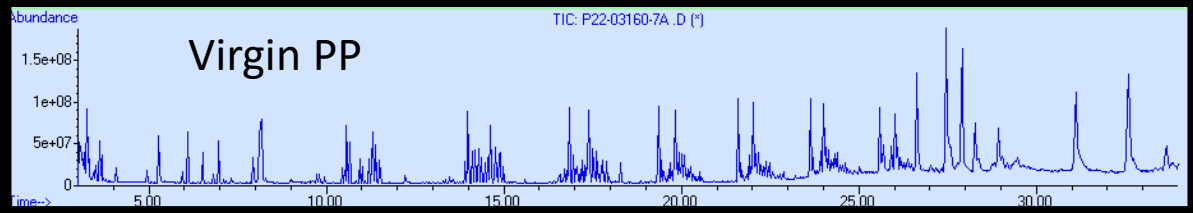
Headspace characterisation (120 C 60mins)



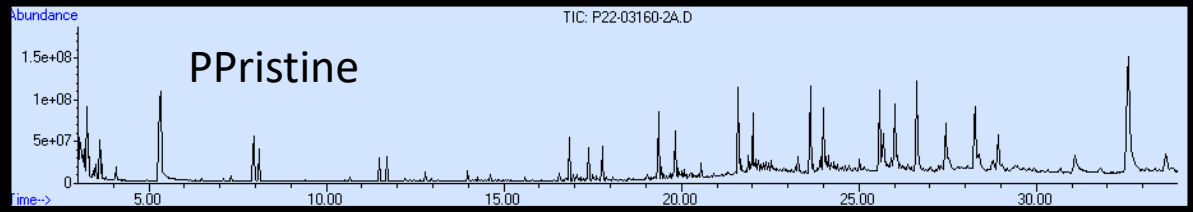
NEXTLOOPP



Extraction characterisation (THF 60 C 3 days)



NEXTLOOPP



GCMS to identify and semi-quantify NIAS

Characterisation of the recycled plastic

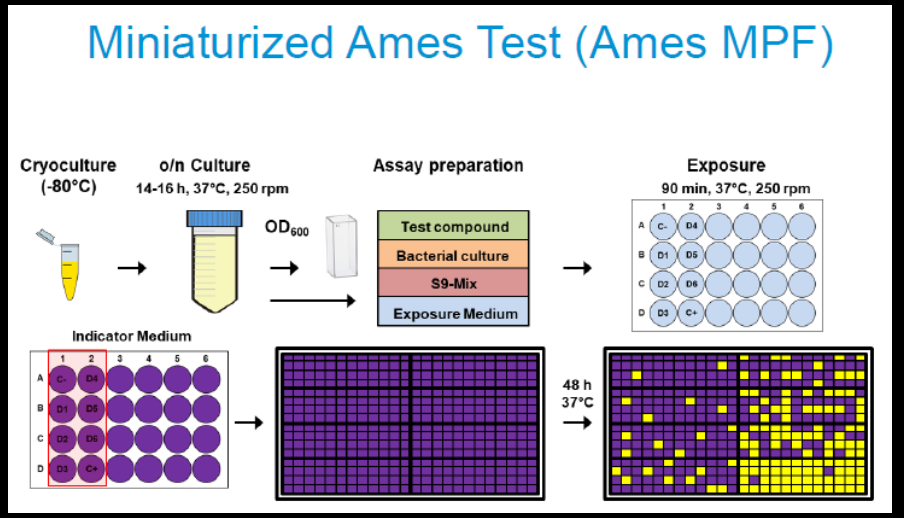
Overall Migration

40 C 10 days

Sample name	3% Acetic acid overall migration mg/dm²	10% Ethanol overall migration mg/dm²	Olive oil overall migration mg/dm²
PPristine Natural	1.38	1.30	6.54
PPristine White	2.49	1.09	9.66
PPristine Colour	3.47	1.45	8.70
PPristine IM	0.78	1.04	6.58
PPristine INRT	2.67	1.46	6.59

Ames Testing (PolyCycle Migratox Project)

95% Ethanol, 60 C, 10 days migration



Strain (Enzyme)	PPristine Natural Result (LOD) µg/L	PPristine INRT Result (LOD) µg/L
TA98 (- S9)	< LOD (23)	< LOD (25)
TA98 (+ S9)	< LOD (0.9)	< LOD (1.0)
TA100 (- S9)	< LOD (1.8)	< LOD (1.9)
TA100 (+ S9)	< LOD (3.7)	< LOD (4.1)

Intended applications

Is water/milk model appropriate for PP?

- Trays for chilled meats
- Pots for chilled pasta sauces which may be microwaved
- Pots for porridge and noodle which are dry and cooked with boiling water
- Caps and closures for containers
- Liners to store powdered infant milk
- Pots for yogurts
- Trays for microwavable meals
- Pots for butters
- Tubs for ice cream
- Tubs for wrapped confectionary

Some PP used to store food long term at room temperature and consumed by toddlers i.e. jelly

Toddler scenario proposed, 125 g / 12 kg toddler / day ≈ 11 g / kg bw / day

Three essential stages in Food Grade PP recycling

A. Sorting into PP is the first step

B. Sorting into Food Grade PP is next

C. Extrusion and decontamination rate > 95% - 100%

Input for Food Grade PP needs to be >95% prior food grade

NEXTLOOPP RESINS

rPP MATERIAL

NEXTLOOPP PPRISTINE™ NATURAL FG IM

NEXTLOOPP PPRISTINE™ NATURAL FG

NEXTLOOPP PPRISTINE™ WHITE FG

NEXTLOOPP PPRISTINE™ COLOUR FG

NEXTLOOPP PPRISTINE™ NATURAL INRT

NEXTLOOPP PPRISTINE™ WHITE INRT

NEXTLOOPP PPRISTINE™ COLOUR INRT

NEXTLOOPP PPRISTINE™ MIXED INRT

EFSA/USFDA/FSA SUBMISSION UPDATE

- FDA submitted
- FSA submitted
- EFSA registration as novel tech application

Dear Mr. Kosior:

Attached is an acknowledgement letter for your recent submission to the U.S. Food and Drug Administration. Your request will be assigned to a Regulatory Review Officer for review and response.

Regards,

Center for Food Safety and Applied Nutrition
Office of Food Additive Safety
U.S. Food and Drug Administration
Tel: 240-402-1175
sylvia.dodson-proctor@fda.hhs.gov

FDA U.S. FOOD & DRUG ADMINISTRATION

Asiantaeth Safonau Bwyd
food.gov.uk
Food Standards Agency

Food Standards Scotland
foodstandards.gov.scot

Dear Paul Marshall,

Your application for approval of PPristine was received on 07/11/2022 and has been assigned the following application number RP 1793. We shall now check the information you have provided to ensure that it complies with the requirements of Article 9(1)(a) of retained Regulation (EC) No 1935/2004 on materials and articles intended to come into contact with food.

COMMERCIALISATION TRIALS with project participants

CO_{TOO}CLEAN

Cleaning Plastic Film To Food-Grade Standards using super critical CO_2

Creating food-grade destinations for films.

Alliance Prize
Solutions to Address Flexible Plastics in Household Waste
NY Stock Exchange
29th November 2022

COTOOCLEAN Project Partners

- **Four key innovation partners** providing plastics recycling, process development and material science expertise
- **Four commercial partners** to exploit the technology across the flexible film supply chain for successful commercialisation.

Our joint vision is to deliver a revolutionary commercial process that can efficiently and effectively clean and decontaminate post-consumer polyolefin films to a food-grade material.

The global market size for food flexibles is vast at 21.7 Million tpa (AMI 2022)

At 25% PCR content = 4.4 Million tpa – many opportunities for global recycling enterprises.

COTOOCLEAN Decontamination of Plastic Films

COTOOCLEAN Decontamination using supercritical CO_2 as an extraction solvent

Decontaminates LLDPE, HDPE & PP films >99% of oils and chemical contamination in USFDA and EFSA challenge tests

CO_2e savings of 65% compared to virgin PE (1.3t/t vPE)

Deodorises films – no smell

De-inks with green co-solvents - improves colour and quality

De-lamination & de-metallise multi layer films – boosts yields

No water

No drying

No toxic or corrosive chemicals – CO_2 and green solvents

No diluted residues or wastes

Our Approach- % Decontamination Rates

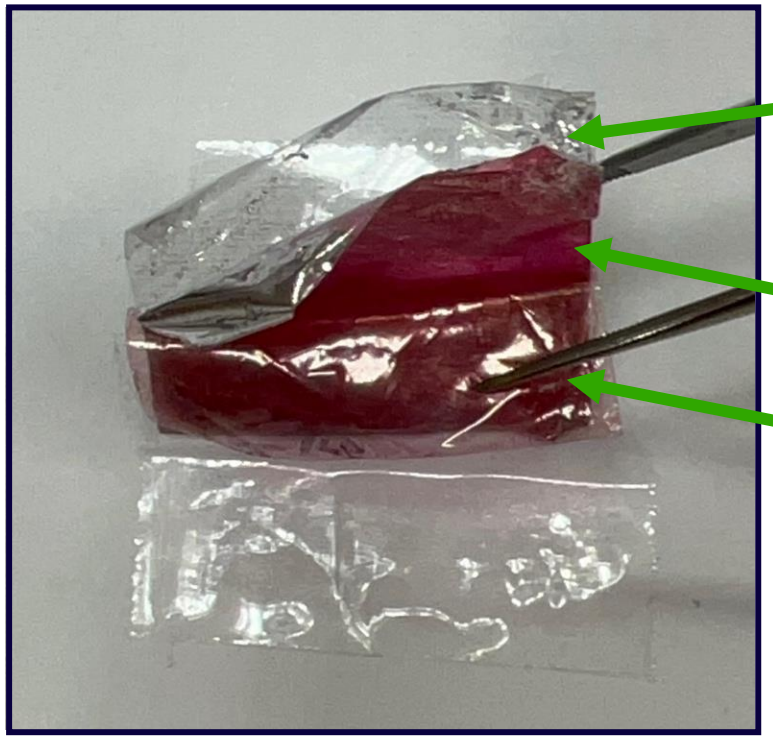
-Based on EFSA “Challenge test” method for food grade recycled polymers.

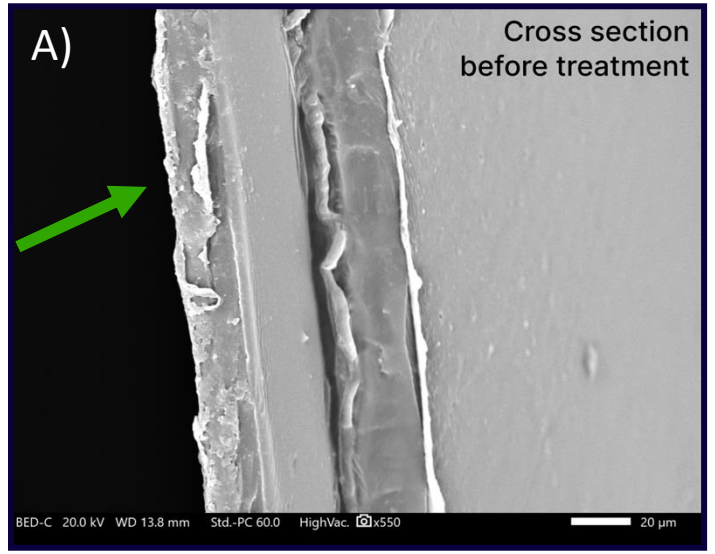
Contaminant	LDPE			PP			HDPE		
	Initial (ppm)	Final (ppm)	% removed	Initial (ppm)	Final (ppm)	% removed	Initial (ppm)	Final (ppm)	% removed
Toluene	73	0	100.00%	188	0	100.00%	42	0	100.00%
Chlorobenzene	201	0	100.00%	507	0	100.00%	85	0	100.00%
Limonene	980	<10	99.00%	1549	0	100.00%	368	0	100.00%
Phenylcyclohexane	2242	38	98.30%	2366	7	99.70%	729	7	99.10%
Hexyl Salicylate	3584	11	99.70%	2725	26	99.10%	1046	21	98.00%
Benzophenone	2755	<10	99.60%	2202	3	99.90%	800	1	99.90%
Isopropyl Myristate	3926	9	99.80%	2703	27	99.00%	1056	17	98.40%

COTOOCLEAN Delamination of multilayer films

The images shown demonstrate the delamination of a 3-layer metallised multilayer films after treatment.

SEM Images (A and B) of 3-layer metallised film before and after treatment.
The top layer of clear PP is indicated by the green arrows.





CO$_{TOO}$CLEAN De-Inking and Oil removal

De-Inking

BEFORE

Crisp pack, reverse print outer layer

Crisp pack, reverse print mid layer

Surface printed bread bag

AFTER

Oil Removal

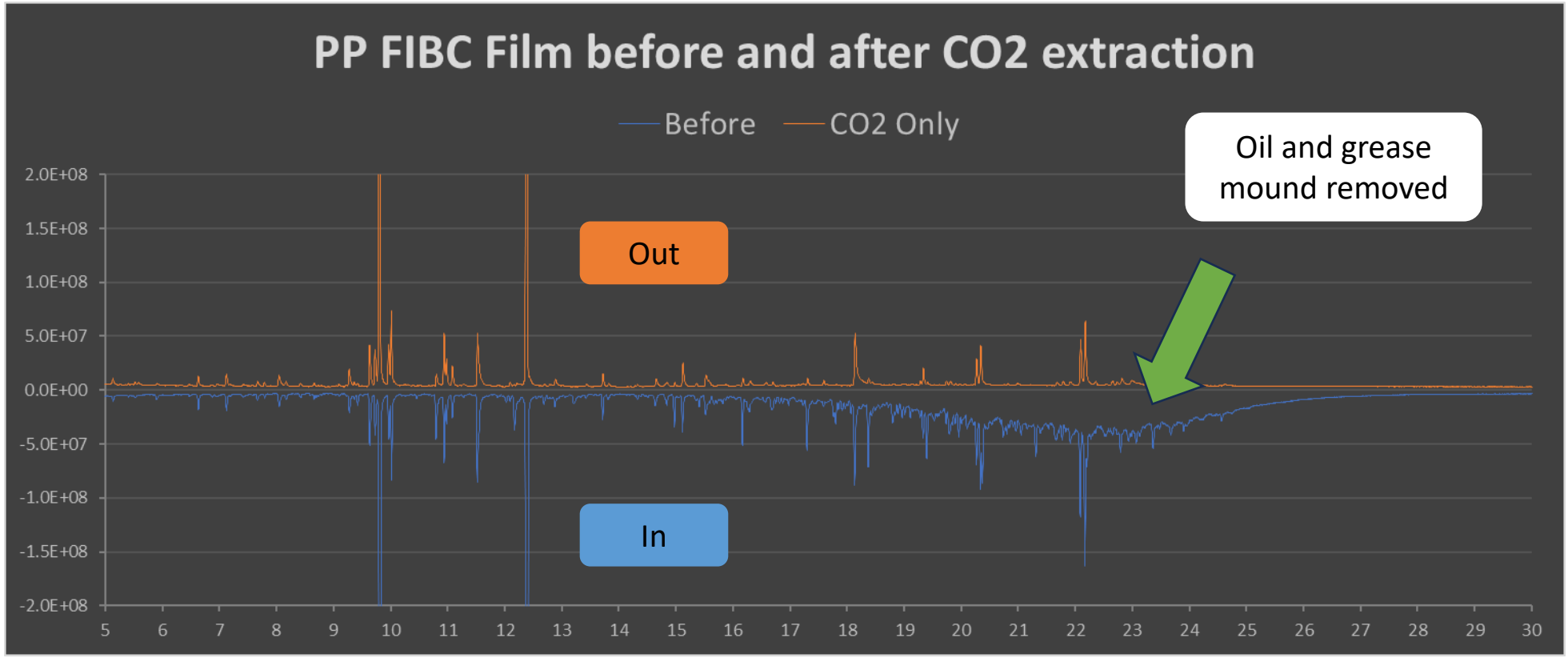
BEFORE

Oil saturated film sample, simulation of surface contamination from food.

AFTER

After CO_2 cleaning >99% oil was removed.

COtooCLEAN decontamination of PP films



GC/MS headspace traces before and after COtooCLEAN treatment

Substance	Removal
Hexadecane	94%
Heptadecane	97%
Octadecane	99%
Nonadecane	100%

CO$_{TOO}$CLEAN Future Steps

1. Design and build of pilot Plant

- Based on the success of the Innovate UK fund project

2. Large Scale conversion

- Scaled production starting with mono polyolefin films (both food and non-food)

3. Submission of FG Dossiers

- EFSA novel technology (1616/2022) and USFDA

Many challenges remain

- Sorting food grade from non-food grade packaging to implement food-grade recycling technologies
- Recovery of plastics from waste before landfill
- High performance plastics properties in closed loops in existing and new applications

How do we accelerate a Circular Economy for Plastics?

1. Infrastructure

- Create greater MRF resources to sort Recyclables and Post-Consumer Household "Waste"

2. Recycled Content in Packaging

- Every product should be designed to be circular
- Recycled plastics should be manufactured locally NOT imported or exported

3. Innovation in the Circular Economy

Many challenges remain for innovation

- Sorting food grade from non-food grade packaging to implement food-grade recycling technologies
- Recovery of plastics from waste before landfill
- High performance plastics properties in closed loops in existing and new applications

What will help to Make a Difference

- A shared vision in Chemical-Waste-Recycling Industry Associations and buy-in by Brands and Convertors
- Big recycling operations for high quality plastics in every major population centre
- Research that focuses on greater efficiency and participation in the circular economy
- Large Petro-chemical operations that scale up "Chemical Recycling" for difficult-to-recycle plastics.
- Bans on oxo-degradable plastics that distract or damage circularity
- Government taxes on packaging without recycled content to stimulate the timelines

Questions & Answers

Please feel free to add your questions in the Q & A box.

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Summary – Sorcha Kavanagh

2 Repak Working Groups

1. Natural caps for the Dairy Industry
2. Increasing the availability of food grade recycled content

Food Safety
AUTHORITY OF IRELAND

TEAM GREEN
PLASTIC
PLEDGE

OBJECTIVE 1: **TO PREVENT**	Prioritise the prevention of plastic packaging waste by **minimising avoidable single use packaging and promoting packaging reuse** where possible.
OBJECTIVE 2: **TO SUPPORT**	**Support Ireland to deliver** the Circular Economy **Package plastic recycling targets of 50%** of **all plastic packaging by 2025** and **55% by 2030,** as set by the European Commission.
OBJECTIVE 3: **TO SIMPLIFY**	Reduce complexity within the plastic packaging supply chain by **simplifying polymer usage** and **eliminating non-recyclable components** in all plastic packaging **by 2030.**
OBJECTIVE 4: **TO INCREASE**	Help to build a circular economy for used plastic packaging in Ireland and Europe by **increasing the use of plastic packaging with recycled content.**
OBJECTIVE 5: **TO REDUCE**	Ensure our **approach** to plastic packaging reduction is aligned to Ireland's **goal of a 50% reduction in food waste by 2030** as set out in Ireland's food waste charter.

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Resources which will be available for you following the webinar

- Ed’s slides
- FSAI Slides - Plastic Recycling Regulation 2022/1616
- Packaging Design Guide
- Post webinar survey – Future Speakers and topics

Thank You.

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