PVC ACADEMY
2024
Settima edizione

WEBINAR

PVC
PVC FORUM ITALIA

End of Waste Containing Lead, MCCPs and DEHP: Detection and Separation

Alessio Boscolo
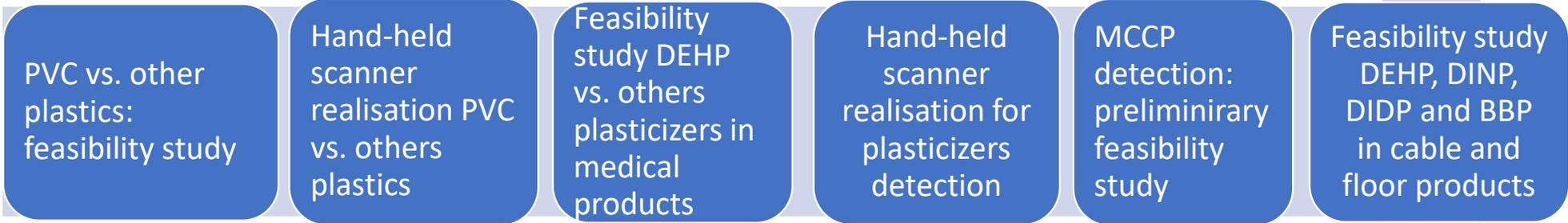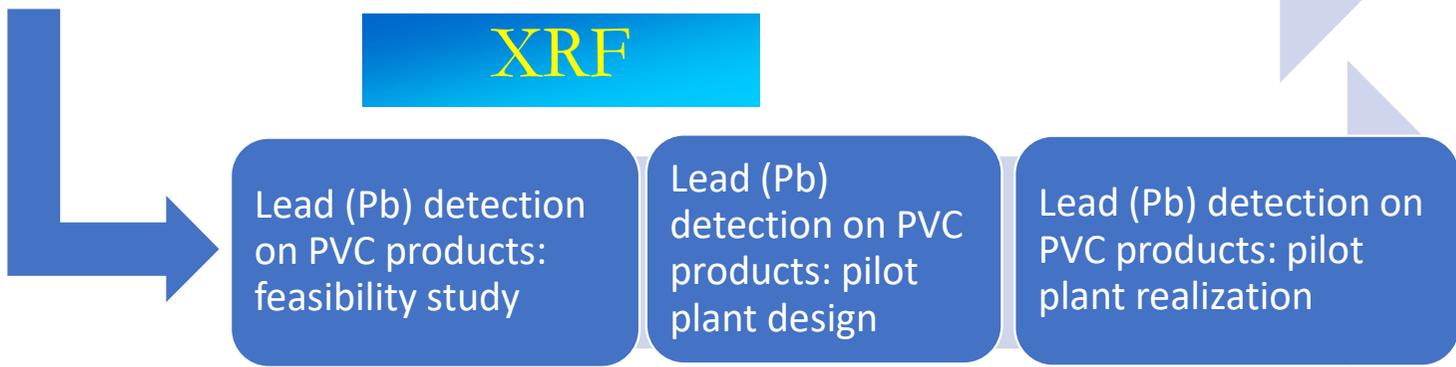
Researcher, Phoenix Optical Research and Technologies Srl

Chronicle

2020	2021	2022	2023	2024	...2025

NIR/SWIR

PVC vs. other plastics: feasibility study	Hand-held scanner realisation PVC vs. others plastics	Feasibility study DEHP vs. others plasticizers in medical products	Hand-held scanner realisation for plasticizers detection	MCCP detection: preliminirary feasibility study	Feasibility study DEHP, DINP, DIDP and BBP in cable and floor products

XRF

| Lead (Pb) detection on PVC products: feasibility study	Lead (Pb) detection on PVC products: pilot plant design	Lead (Pb) detection on PVC products: pilot plant realization

NIR/SWIR Techniques

Polymers typically absorb infrared (IR); absorption bands are typical and characterizing each molecule.

These absorption bands are typically confined to the spectral ranges that go from 1 to 2,5 µm (SWIR) or 3 to 5 µm (MIR)
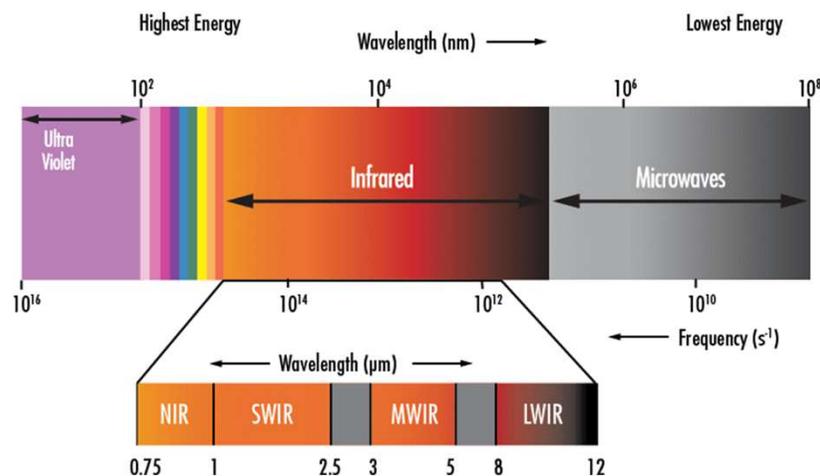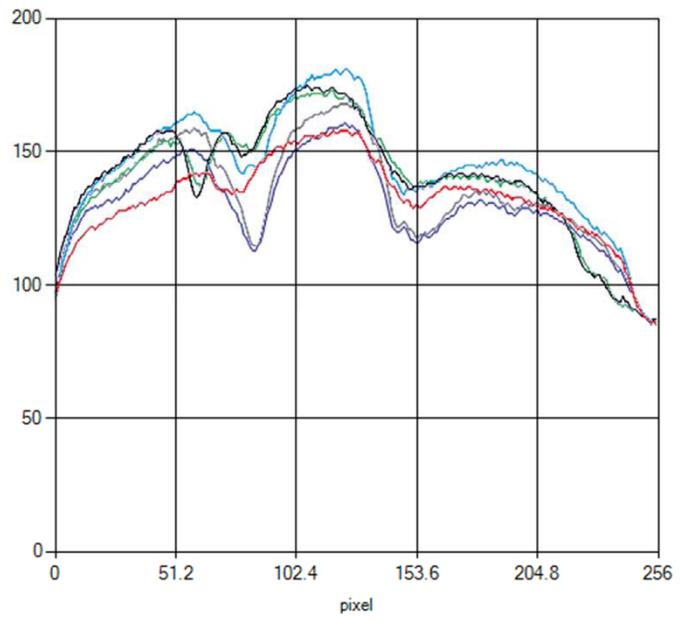

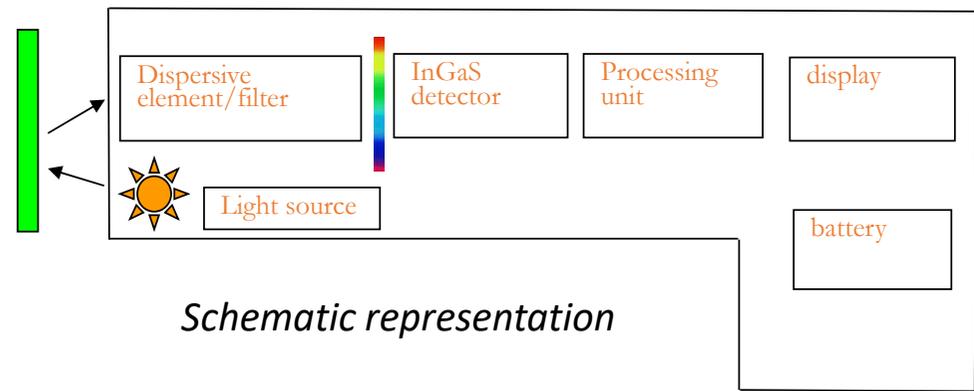Electromagnetic spectrum
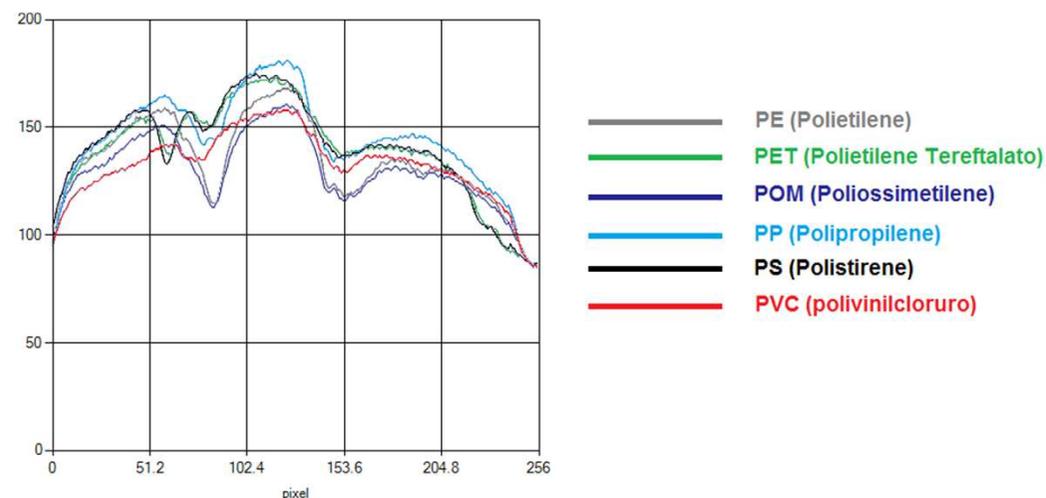
Some polymers spectra

PVC vs other plastics

Reflectance spectra of some plastics widely used in industry.

———	PE (Polietilene)
———	PET (Polietilene Tereftalato)
———	POM (Poliossimetilene)
———	PP (Polipropilene)
———	PS (Polistirene)
———	PVC (polivinilcloruro)

Dispersive element/filter — InGaS detector — Processing unit — display

Light source

battery

Schematic representation

Plasticizers identification in medical products

Spectra of some PVC samples with different plasticizer inside

| PRODUCT CODE	PLASTICISER
XTS-M-T 7505 N	TOTM
XTS-M-T 7505 N	TOTM
XTS-M-S-T 8015 N	TOTM
XTS-M-T 8401 T01	TOTM
XTS-M-T 8207 T04C	TOTM
XTS-M-T 8401 N	TOTM
XTS-Z 5601 T230	DEHT/DOTP
XTS-Z 6515 T	DEHT/DOTP
XTS 6014 T230	DEHT/DOTP
XTS-M-D 7401 N	DINCH
XTS-M-D 7401 N	DINCH
XTS-M-D 7401 N	DINCH
XTS-M-D 7401 N	DINCH
XTS-M 7101 N	DEHP/DOP
XTS-M 6001 N	DEHP/DPO+DOA
XTS-M 6102 N	DEHP/DOP
XTS-M 7101 N	DEHP/DOP
XTS-M 7101 N	DEHP/DOP
XTS-M 7400 N	DEHP/DOP
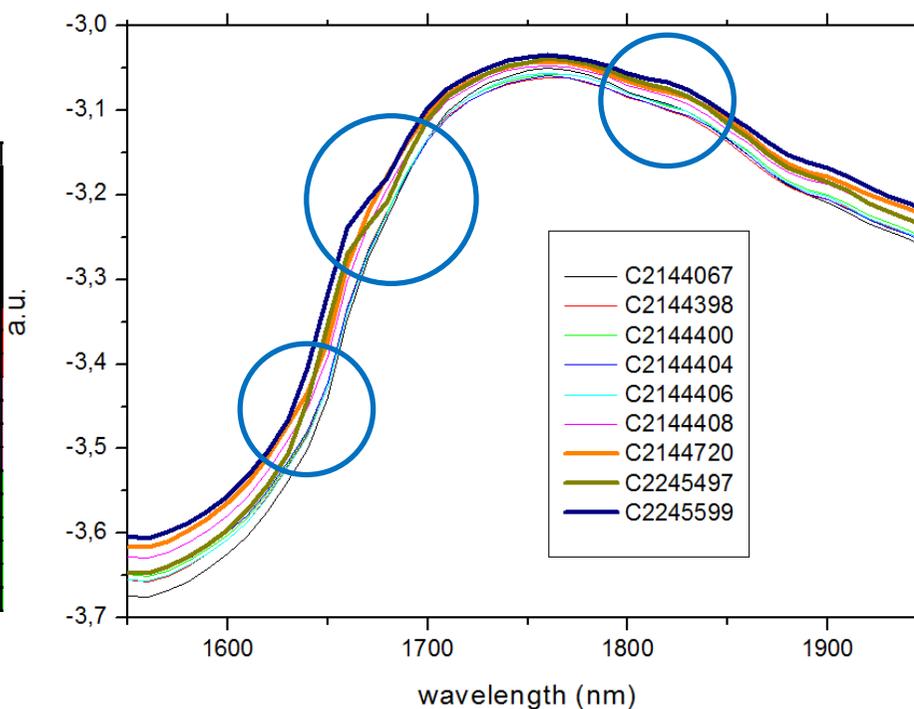
The results of the NIR/SWIR measurements in reflection show differences in the responses of the plastic samples such as to allow the material to be uniquely identified.

Software development
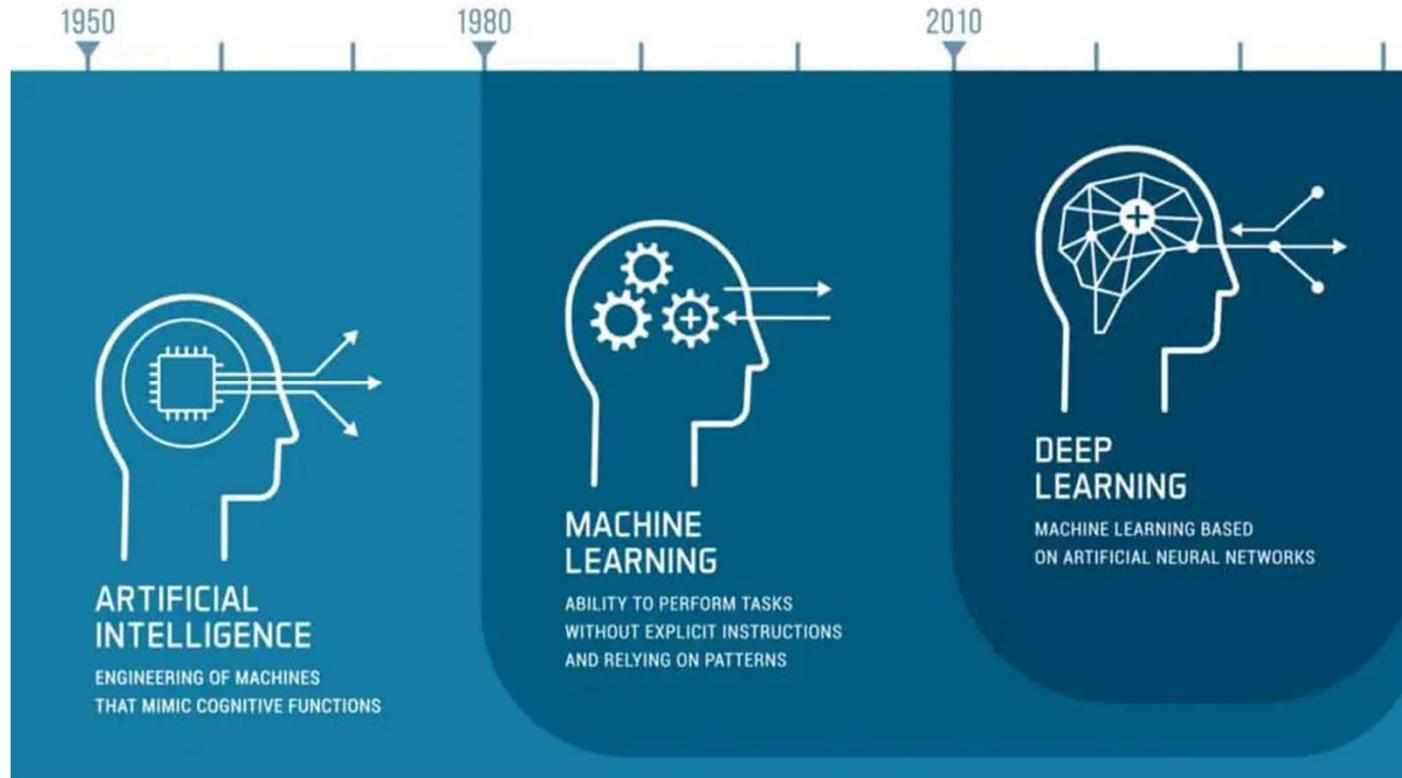
As in previous projects, we decide to use a new category of algorithms that give good results in similar thematics, i.e. **Machine Learning**.

The *Machine Learning* is a subset of artificial intelligence focusing on a specific goal: setting computers up **to be able to perform tasks without the need for explicit programming**
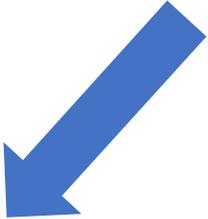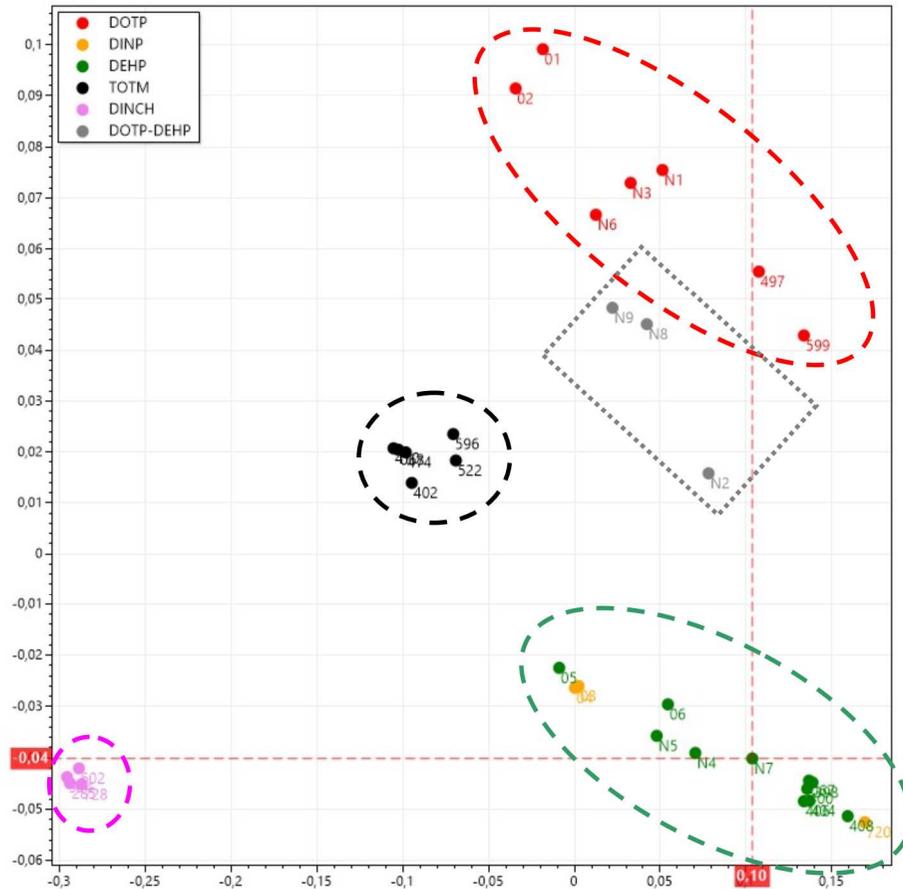
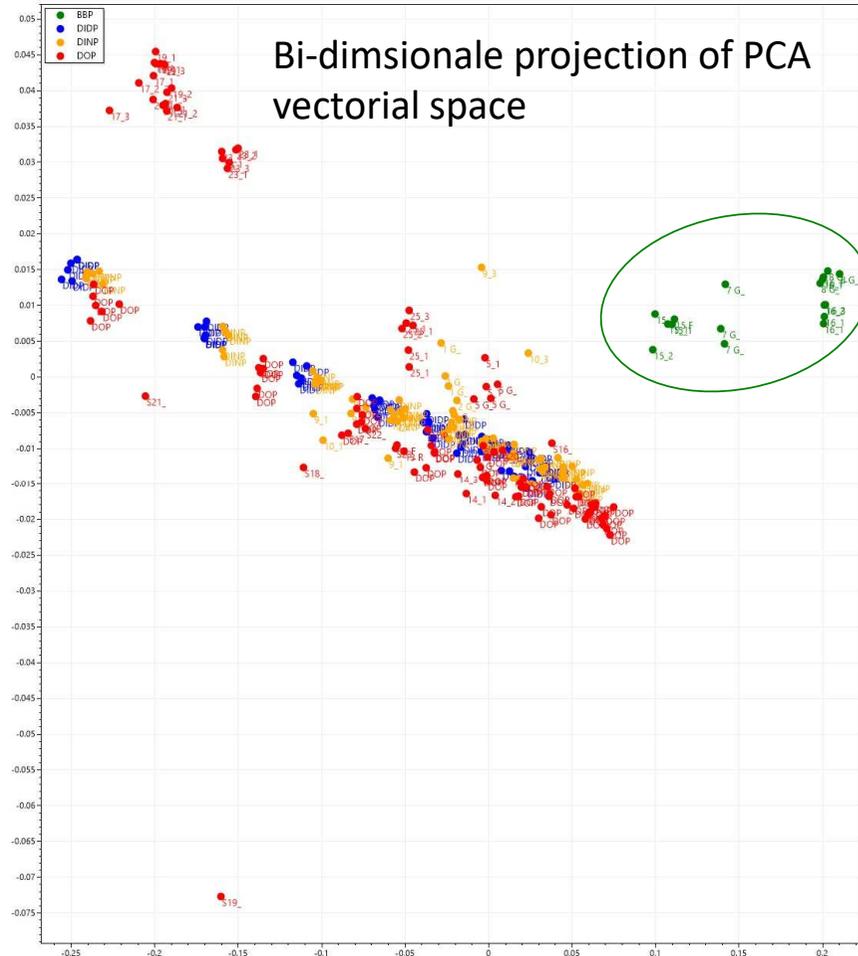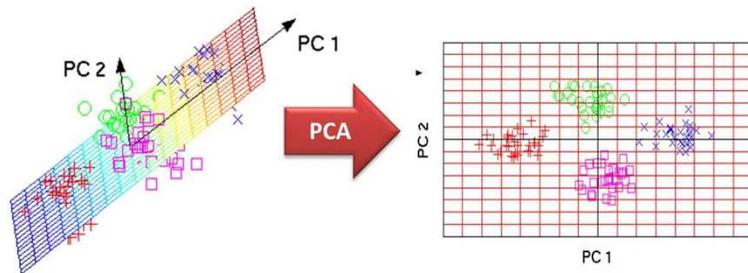| SAMPLE #	PRODUCT CODE	PLASTICISER	%
2144522	XTS-M-T 7505 N	TOTM	37%
2144596	XTS-M-T 7505 N	TOTM	37%
2144063	XTS-M-S-T 8015 N	TOTM	30%
2144474	XTS-M-T 8401 T01	TOTM	30%
2144402	XTS-M-T 8207 T04C	TOTM	32%
2144470	XTS-M-T 8401 N	TOTM	30%
2245599	XTS-Z 5601 T230	DEHT/DOTP	44%
2245497	XTS-Z 6515 T	DEHT/DOTP	39%
2144720	XTS 6014 T230	DEHT/DOTP	41%
2245285	XTS-M-D 7401 N	DINCH	33%
2144728	XTS-M-D 7401 N	DINCH	33%
2144602	XTS-M-D 7401 N	DINCH	33%
2144594	XTS-M-D 7401 N	DINCH	33%
2144406	XTS-M 7101 N	DEHP/DOP	34%
2144398	XTS-M 6001 N	DEHP/DPO+DOA	36% + 5%
2144408	XTS-M 6102 N	DEHP/DOP	40%
2144400	XTS-M 7101 N	DEHP/DOP	34%
2144404	XTS-M 7101 N	DEHP/DOP	34%
2144067	XTS-M 7400 N	DEHP/DOP	33%
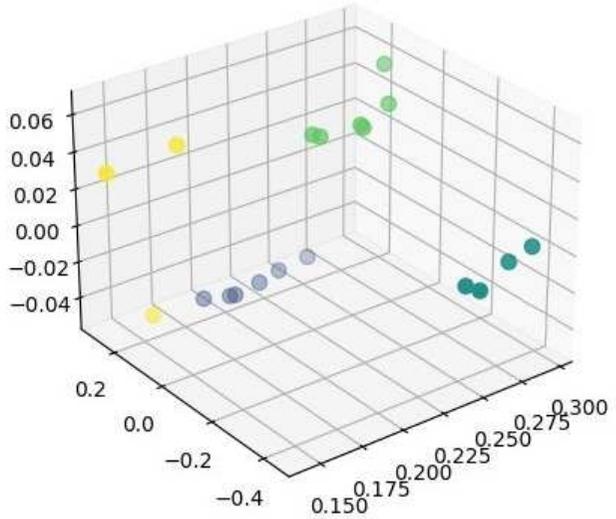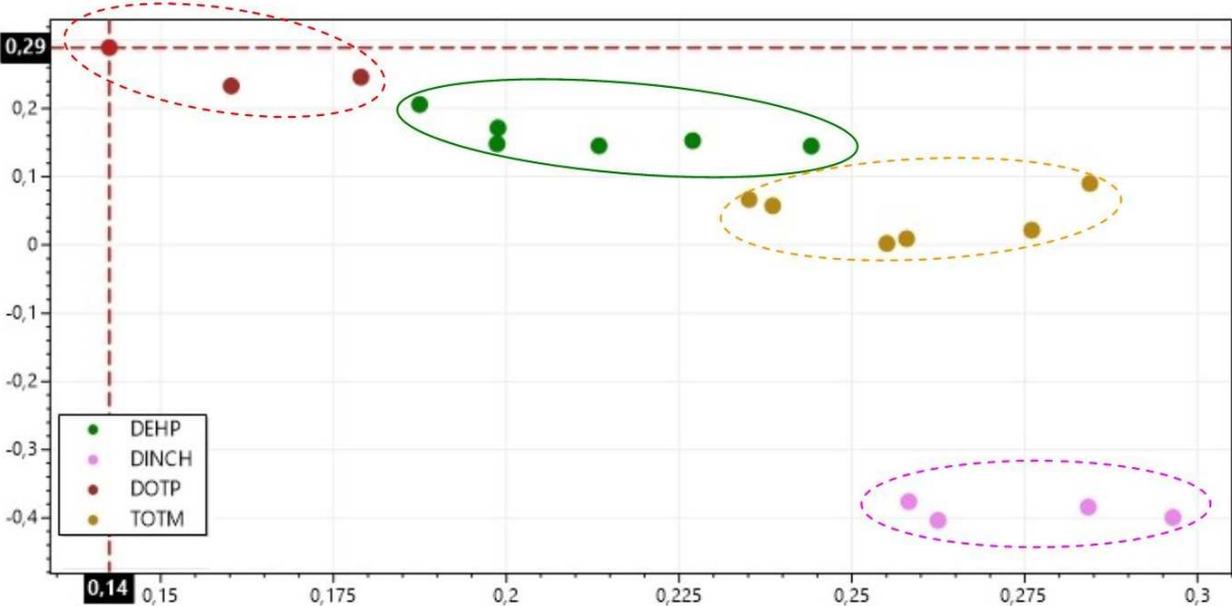
Plasticizers identification in medical products

Plasticisers detection: DEHP, DINP, DIDP and BBP in cable and floor products

Bi-dimsionale projection of PCA vectorial space

Dimensionality Reduction
& Principal Component Analysis

Three-dimesional projection of PCA vectorial space
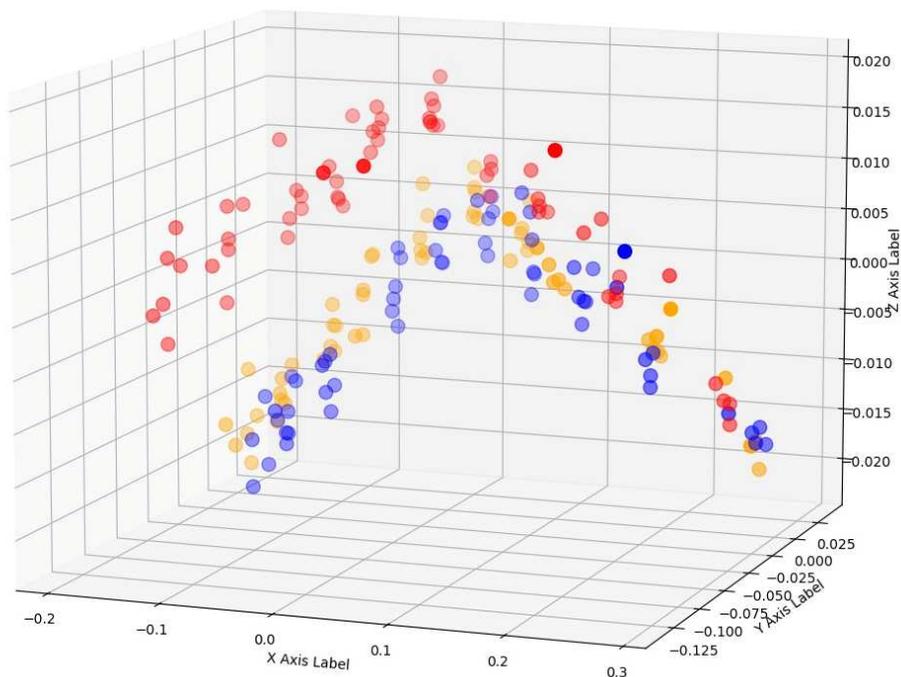
CONFIANCE	50%	60%	70%
SAMPLES	262	262	262
NO	7	15	24
%NO	2,7%	5,7%	9,2%

OK	255	247	238
%OK	97,3%	94,3%	90,8%

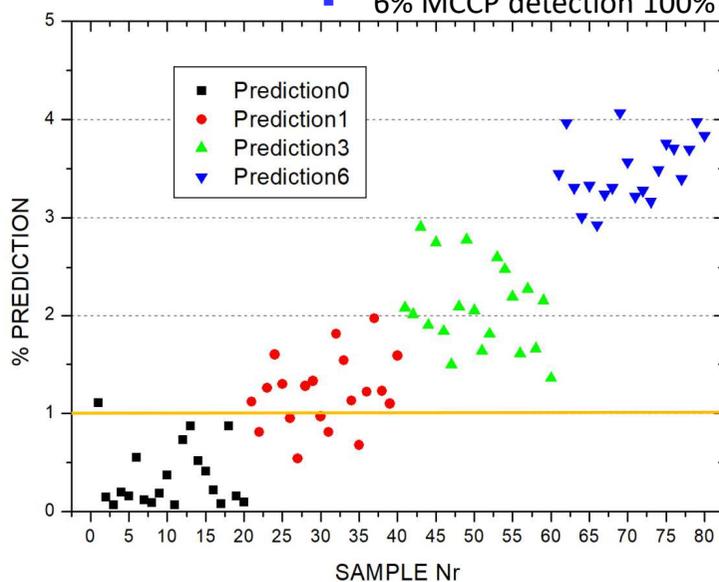PCA distribution vs. %percentage content of plasticizer
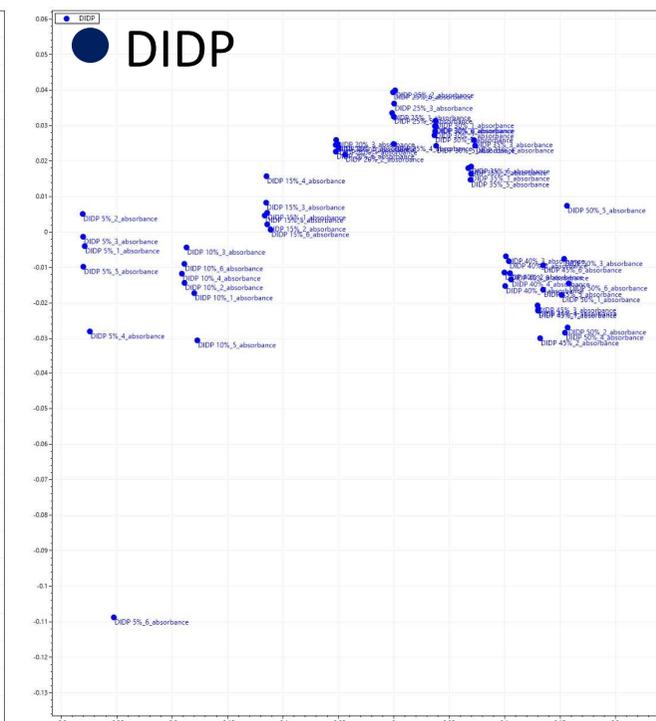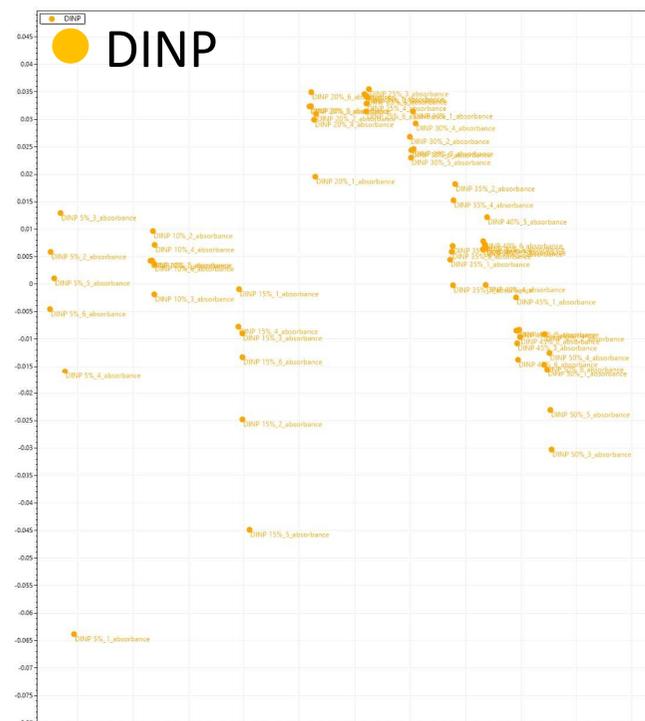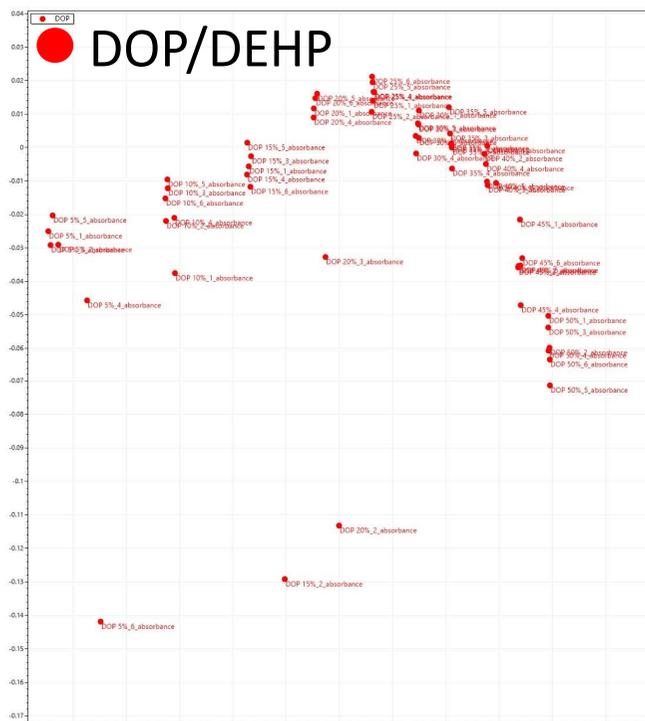
PVC with MCCP detection and different plasticizers – DINP and DOP

Samples with MCCP & DOP

Setting 1% as the minimum detection threshold, we have respectively:

- 0% MCCP detection 95%
- 1% MCCP detection 70%
- 3% MCCP detection 100%
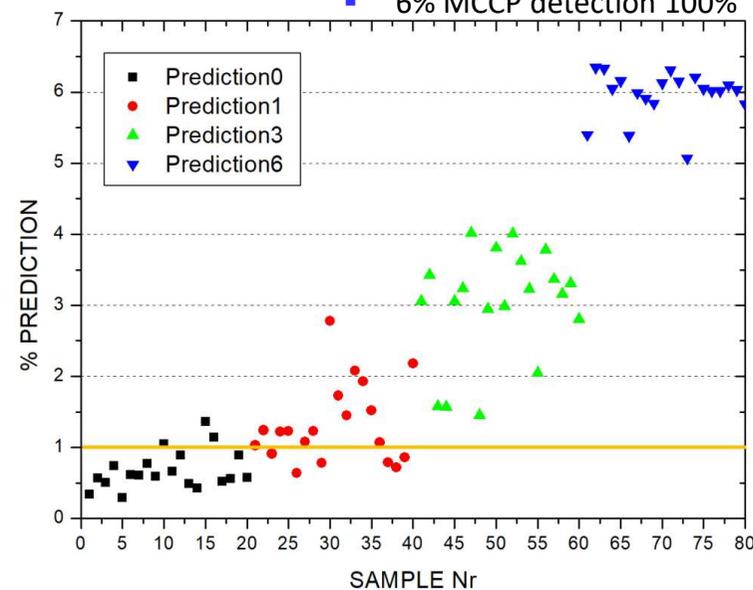- 6% MCCP detection 100%
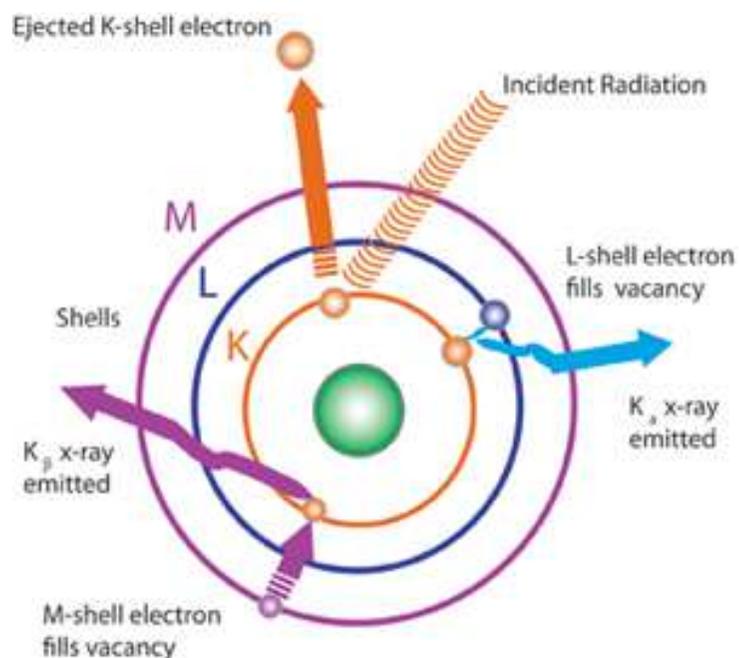

Samples with MCCP & DINP

Setting 1% as the minimum detection threshold, we have respectively:

- 0% MCCP detection 85%
- 1% MCCP detection 70%
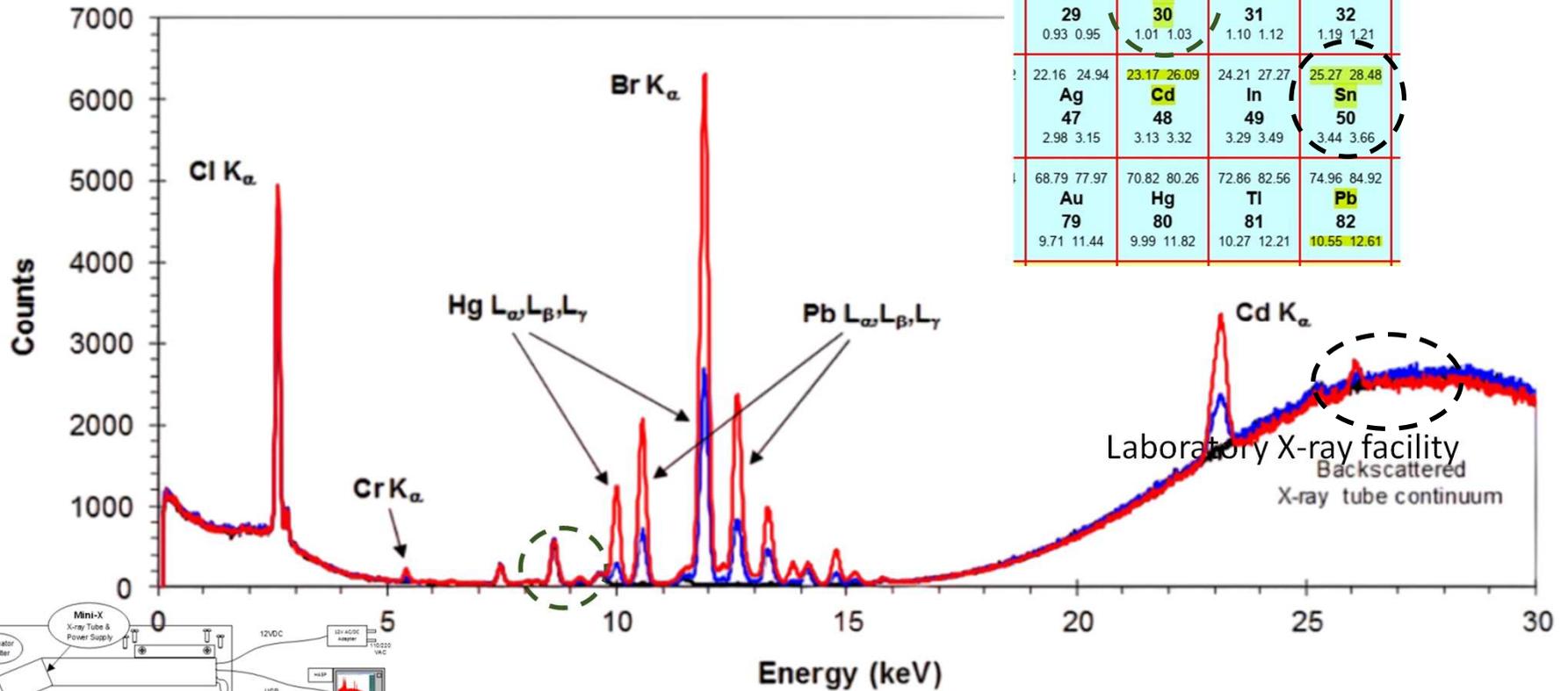- 3% MCCP detection 100%
- 6% MCCP detection 100%

PVC with MCCP detection and different plasticizers – DINP and DOP

- Fluorescent X-rays are produced by exposing a sample to an X-ray source that has an excitation energy similar to, but greater than, the binding energy of the inner-shell electrons of the elements in the sample.

- Some of the source X-rays will be scattered, but a portion will be absorbed by the elements in the sample.

- Because of their higher energy level, they will cause ejection of the inner-shell electrons. The electron vacancies that result will be filled by electrons cascading in from outer electron shells;

- however, since electrons in outer shells have higher energy states than the inner-shell electrons they are replacing, the outer shell electrons must give off energy as they cascade down.

- The energy is given off in the form of X-rays, and the phenomenon is referred to as X-ray fluorescence.
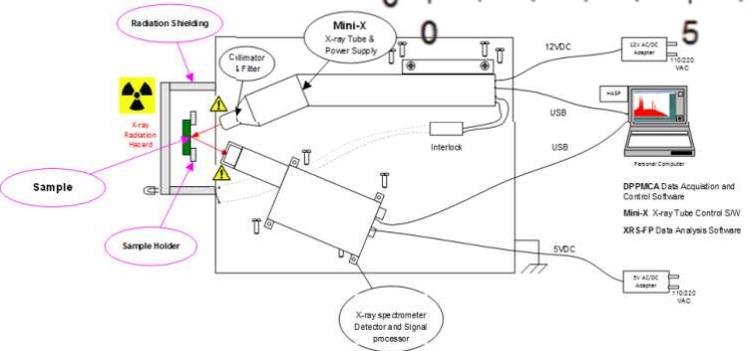
Pb detection: from laboratory to production plant

Example of the spectra measured from PVC samples: blank, low levels of the RoHS elements and a standard with high levels of the RoHS elements [source: Amptek Inc]

Laboratory X-ray facility

Schematic diagram of a production machine with XRF technology
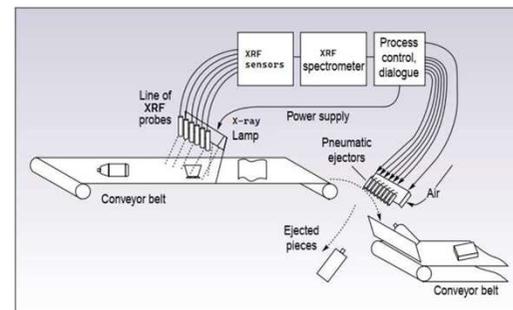
Future: to add NIR technology
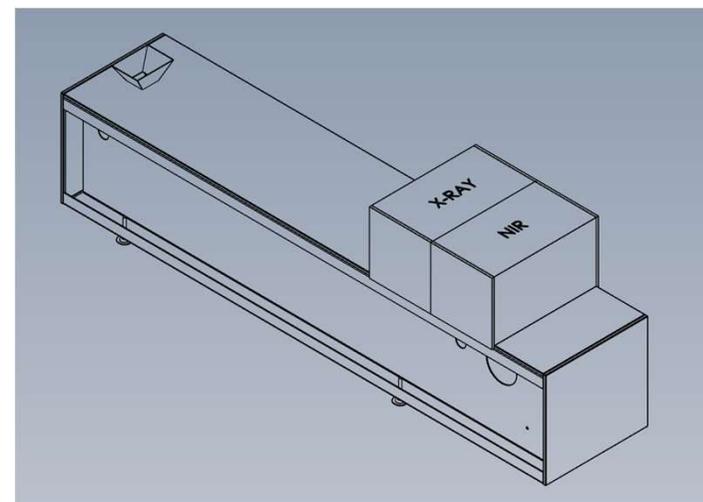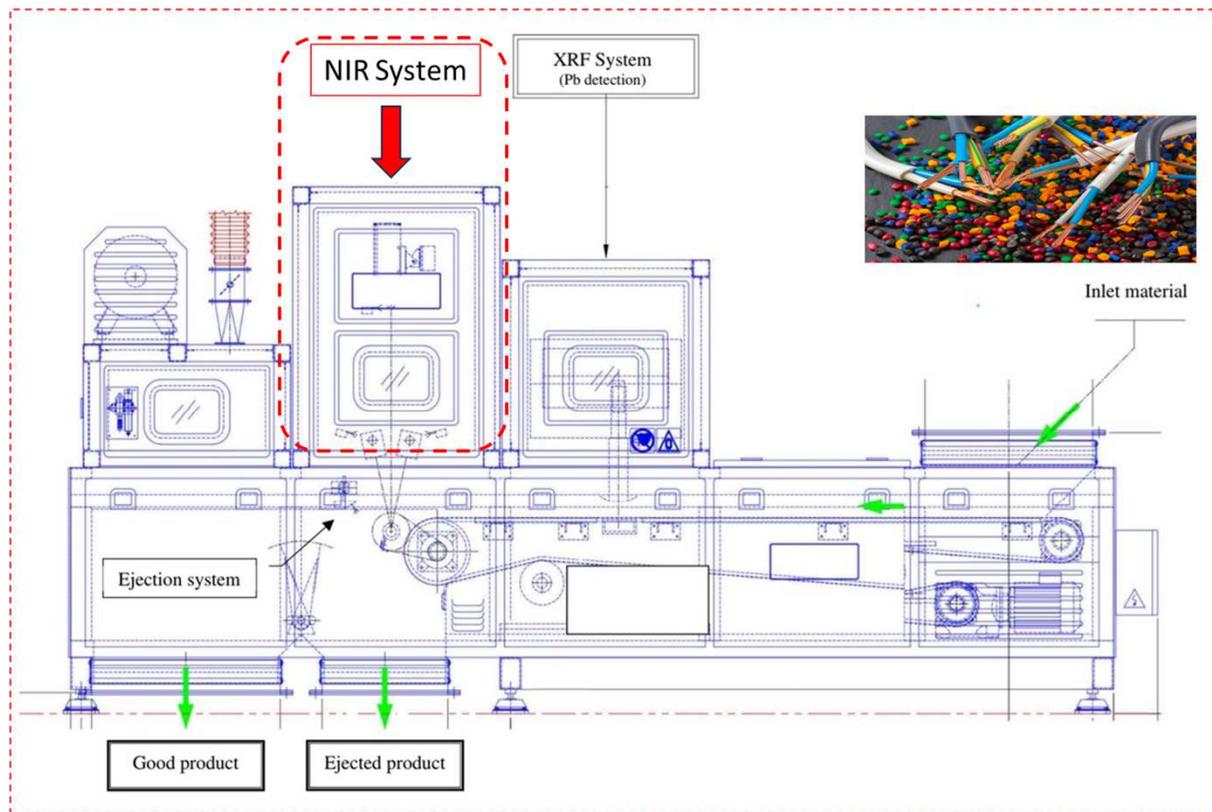
The future developments

Next future

- *Feasibility study for the detection of DEHP/DOP, DOTP, DINCH and DINP plasticizers in PVC **black** samples using MIR spectral region*

- *Development of a Laboratory Scanner for the sorting of plasticizers inside PVC products with a **quantification** of them*

- *Assembling and test of the XRF pilot plant*

Mid-term future

- *Development of a on-line machine for the detection and sorting of Pb and Cd inside PVC products*

- *Development of a on-line machine for the detection and sorting of plasticizers and MCCP inside PVC products*

Thank you

- 🌐 **www.phoenix-rto.it**

- ✉️ **phoenix@phoenix-rto.it**

- **Via Svizzera, 6 – 35127 Padova - Italy**

- 🔗 **Alessio Boscolo**

- **+39 0497625256**