Environmental degradation and pigments influence on plastics waste determined by Raman Spectroscopy: sorting algorithm and plastic Raman database

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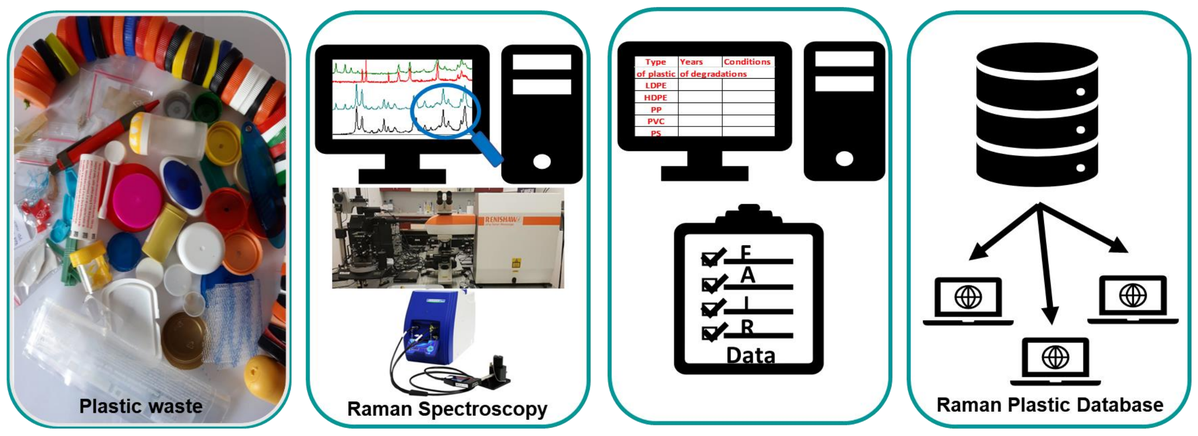
Background and aim

Globally, plastic pollution became one of the most pressing environmental issues being a high concern in many research sectors. Recycling including the sorting process is an important step in transition toward circular economy. Among the challenges posed by macro- and microplastics from environment, one is to collect and sort them at feasible costs for reuse purpose.

Commercial plastic waste appears much more complex and the characteristic polymer Raman signal can be altered on one hand due to natural factors such as long term solar atmospheric or seawater exposure, biofilm deposition or other aggressive agents and, on other hand, due to intrinsic factors such as pigments, fillers or other blends components. To date, little is known regarding Raman spectral feature of long term (years) aged polymers.

Thus, we aimed to determine the molecular changes related to aging and pigments of a high stock of plastic degraded for years in environment. More than a Raman spectral characterization of plastics waste, a sorting algorithm and a plastic Raman database were proposed to support an efficient and a proper plastic waste management based on Raman sorting technique.

Materials and Methods



Results and Discussions

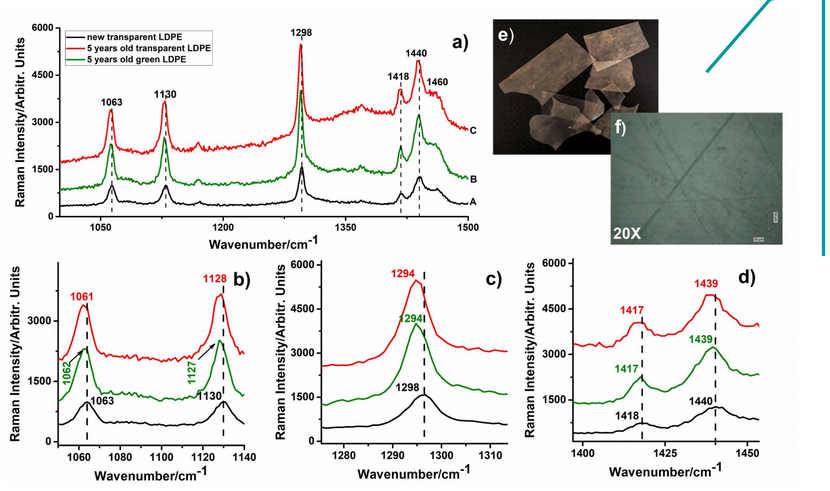


Fig.1. Raw Raman spectra of low-density polyethylene (LDPE) samples degraded by long term of sun exposure: new transparent LDPE (A), 5 years old green LDPE (B) and 5 years old transparent LDPE (C).

Effects of sun exposure:

→ modifications of the physical properties of plastic samples

→ band shifts, relative intensity change

→ red shift of 1-4 cm^{-1} for the characteristic bands of polyethylene (PE) (Fig.1.)→ morphological changes

→ Changes in crystallinity, higher background

Effects of pigments:

→ Intrinsic factors, especially the presence of pigments, lead to the appearance of additional bands in Raman signals which are specific to the pigments present in the polymer structure.

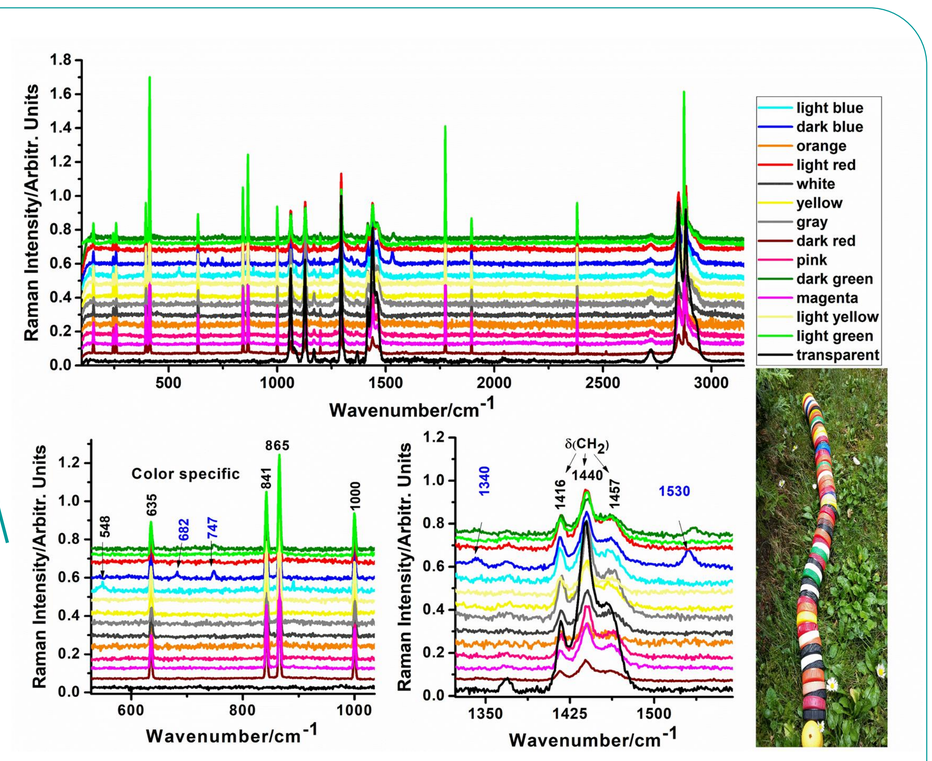


Fig.3. Normalized Raman spectra of various colored high-density polyethylene (HDPE) largely used as beverage bottle caps.

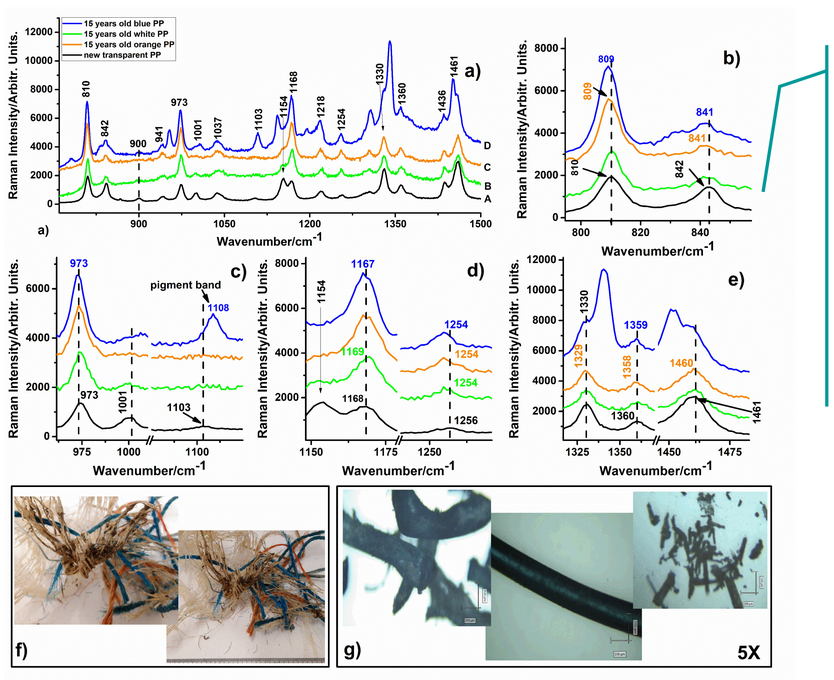


Fig.2. Raw Raman spectra of polypropylene (PP) samples degraded in marine environment: new transparent PP (A), 15 years old white PP (B), 15 years old orange PP (C) and 15 years old blue PP (D);

Effects of sea water exposure:

→ modifications of the physical properties of plastic samples

→ band shifts, relative intensity change

→ red shift of 1-2 cm^{-1} for the characteristic bands of polypropylene (PP) (Fig.2.)→ morphological changes

→ Higher background due to dirt accumulation

Database access
https://ramanplasticdatabase.ro/

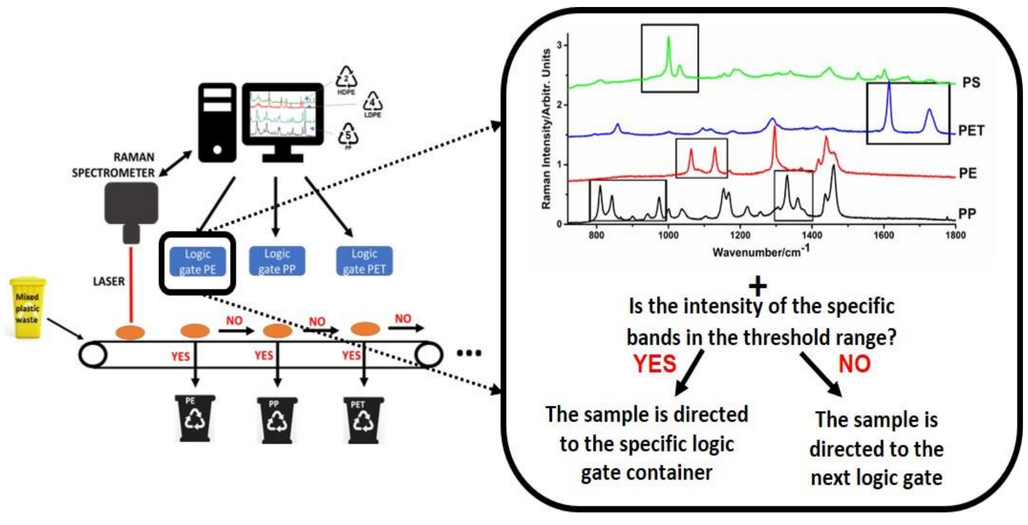


Fig.4. Scheme of the plastic sorting process based on Raman Spectroscopy

Conclusions

→ The study showed the extrinsic and intrinsic factors influence on Raman signals of degraded plastic samples.

→ Extrinsic factors led to deterioration of the physical properties of degraded samples, band shifts, relative intensity change and modification of crystallinity.

→ Intrinsic factors, especially the presence of pigments led to the appearance of additional bands in Raman signals which are specific to the pigments present in polymer structure.

→ A sorting methodology based on Raman characteristic signal of plastic waste was proposed.

→ A plastic Raman database was created and it contains data about degraded plastics waste and all the data complies with the FAIR principle.

Acknowledgments

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References

[1] Horodytska O., Cabanes A., Fullana A., Plastic Waste Management: Current Status and Weaknesses. *Springer* (2019); 18.
[2] Christopher J. R., Plastic Pollution and Potential Solutions. *Science Progress* (2018); **101**, 53.
[3] Marica I., Aluaș M., Cinta Pînzaru S., The Management and Stewardship of Medical Plastic Waste using Raman Spectroscopy to Sustain Circular Economy (*2019) EHB*, Iasi, Romania, pp 1-4.
[4] Chamas A. Monn H. et al., Degradation Rates of Plastics in the Environment. *ACS Sustainable Chem. Eng.* (2020); **8**, 3494-3511.
[5] Kawazumi, H., et al., 2014. High-performance recycling system for waste plastics using raman identification, in: Progress in Sustainable Energy Technologies Vol II: Creating Sustainable Development.