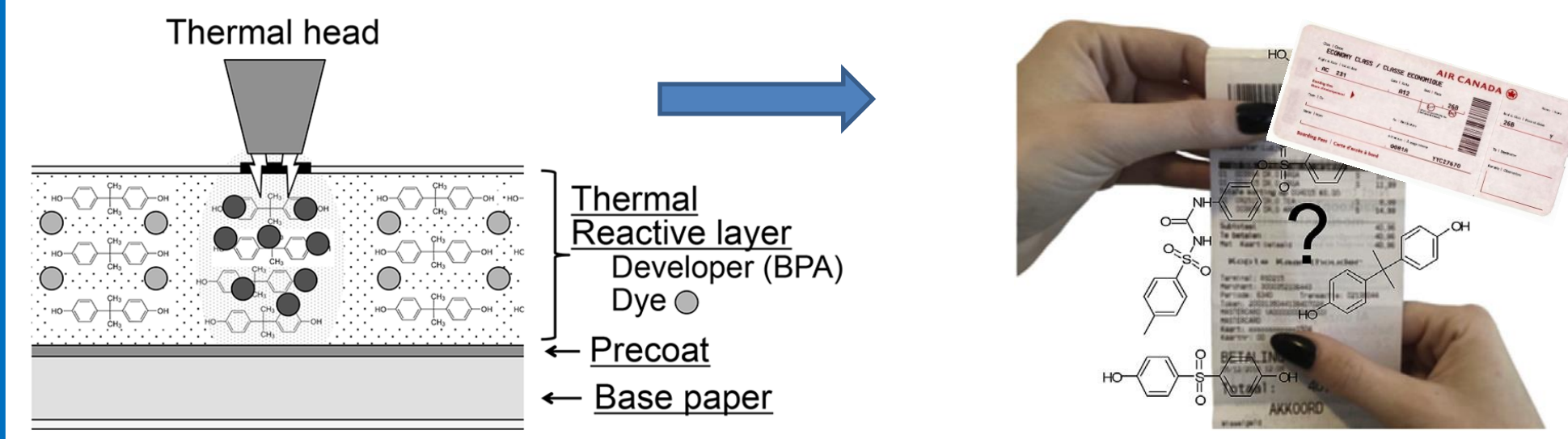


## Introduction

- Thermal paper is used for sale receipts, public transport tickets and luggage labels.
- The paper consists of two layers: a) base paper and b) thermosensitive layer where color is generated by the reversible interaction of the developer with the thermochromic dye.
- Bisphenol A (BPA) is commonly used as a color developer, despite it is a well-known endocrine disrupter.
- BPA is present on the printing surface in its unbound non-polymerized form, so can be easily transferred to the skin.
- Thermal paper is considered as the second source of exposure to BPA since daily most adults come in contact with it.
- Concern of BPA toxicity is leading to industry to look for BPA replacements in thermal paper. BPS and Pergafast 201 are some of the proposed alternative as color developers.
- There is a lack of toxicity data of these substitutes but their structural similarity suggests the potential to exert similar toxicological effects in humans than BPA.
- The European Commission has adopted in 2016 a regulation to limit BPA in thermal paper to 0.02 wt% by 2020. Thus, a gradual BPA replacement from the industry in thermal paper is expected.

## Aims

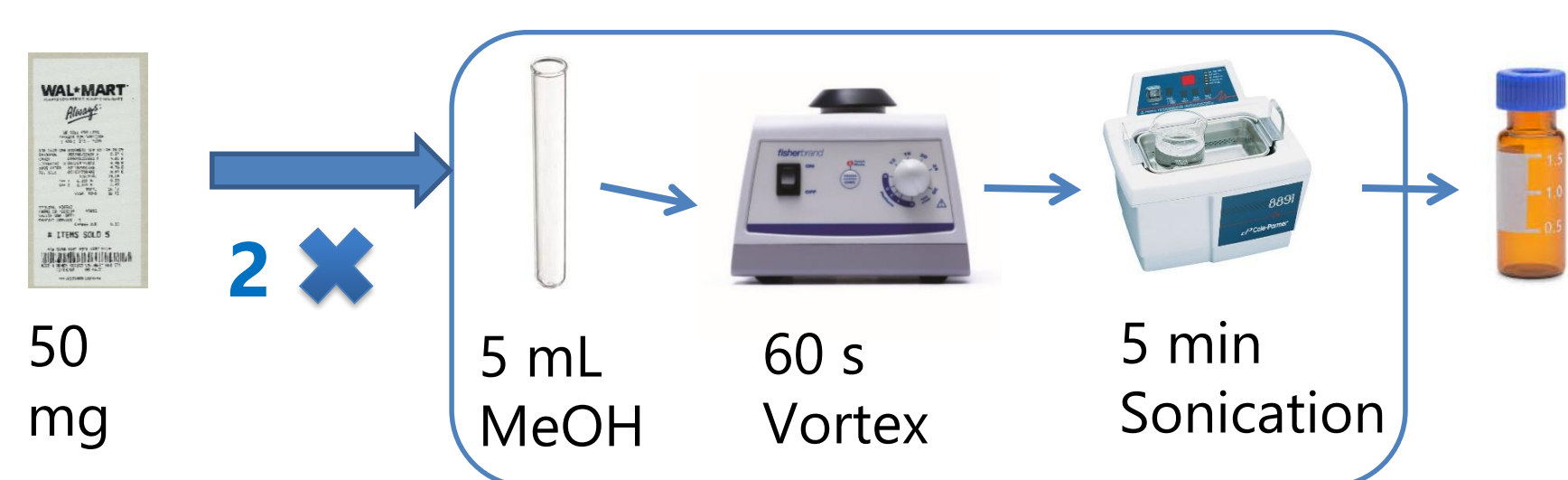
- Investigate the current use of BPA as color developer in the worldwide.
- Identify currently used alternative developers by LC-HRMS.
- Provide meaningful information about industry strategy for BPA replacement in thermal paper.



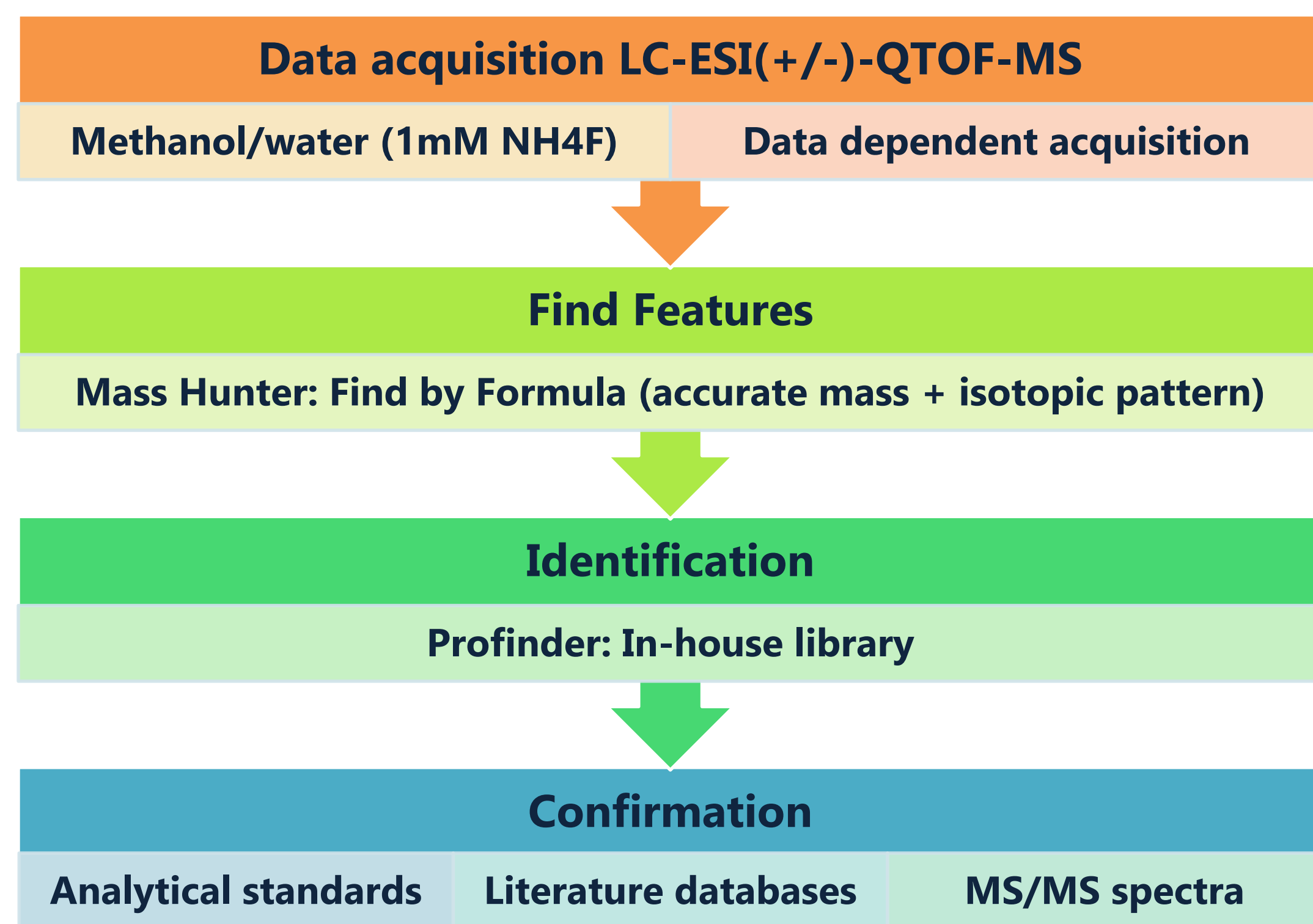
## Suspect-screening developers in thermal paper

- Thermal papers (n=308) such as payment receipts, tickets from public transport, boarding passes and cinemas were collected from Europe, Asia, North America and Oceania.

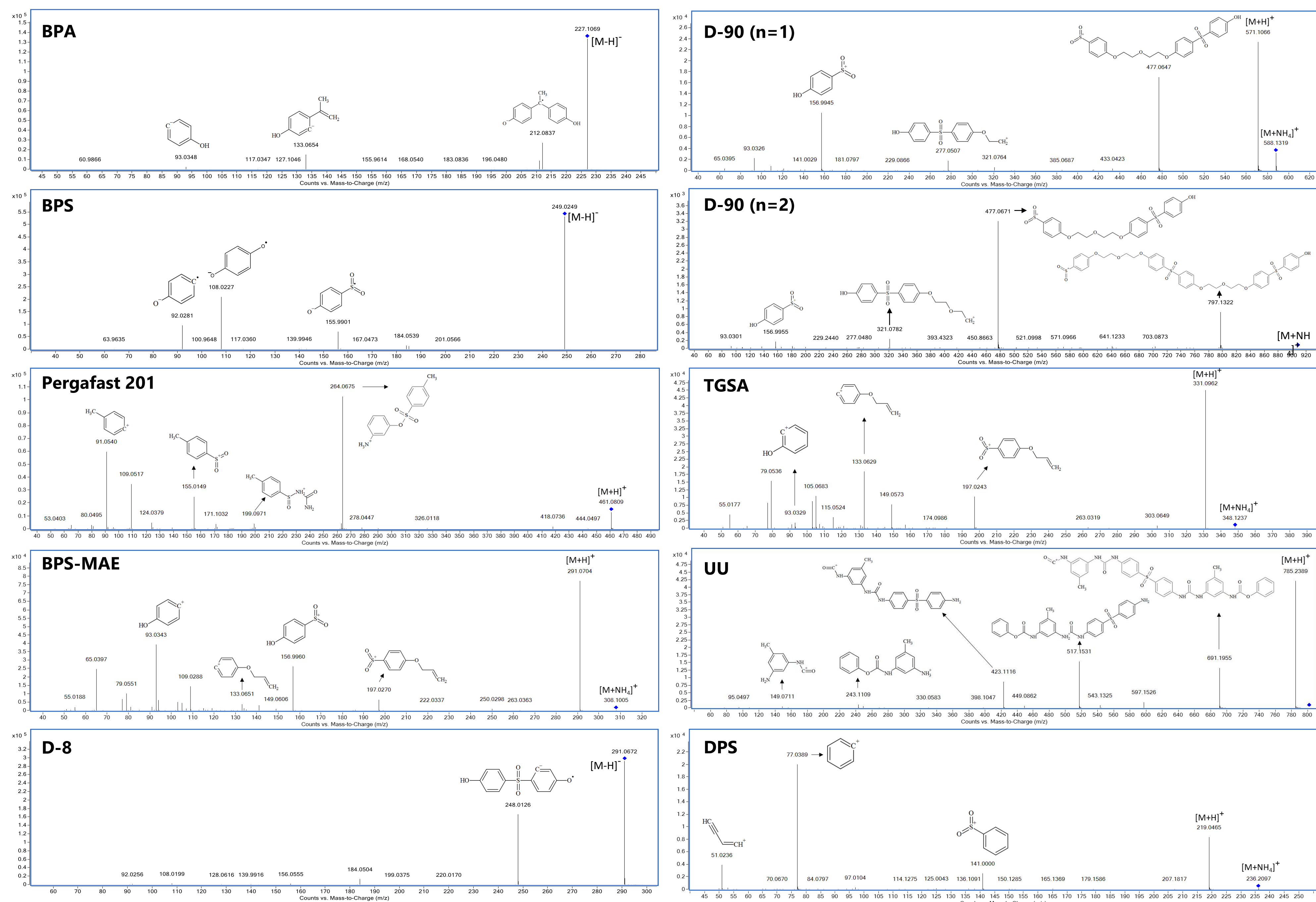
## Sample preparation



## Screening workflow

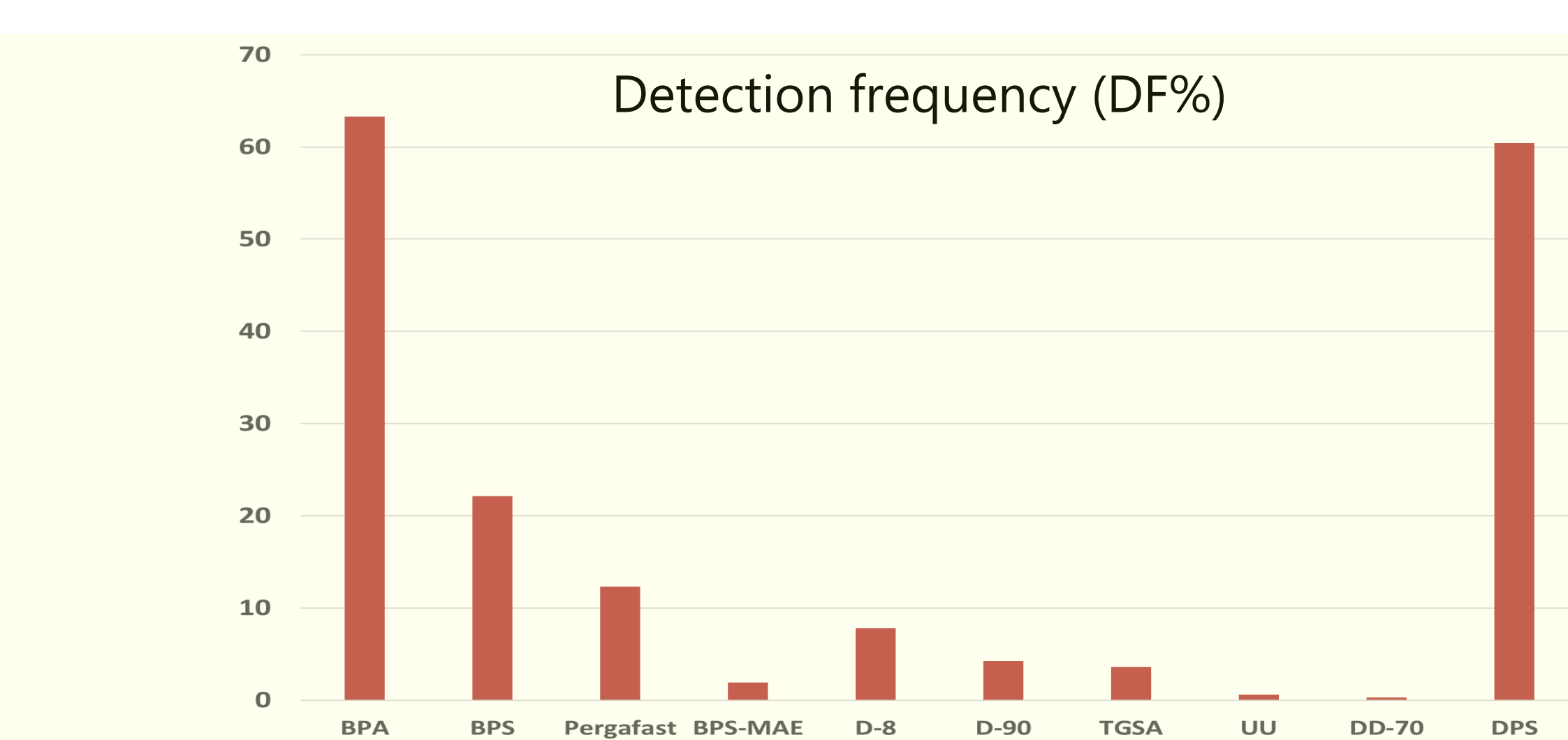


## MS/MS Spectra Identified Developers & Sensitizer

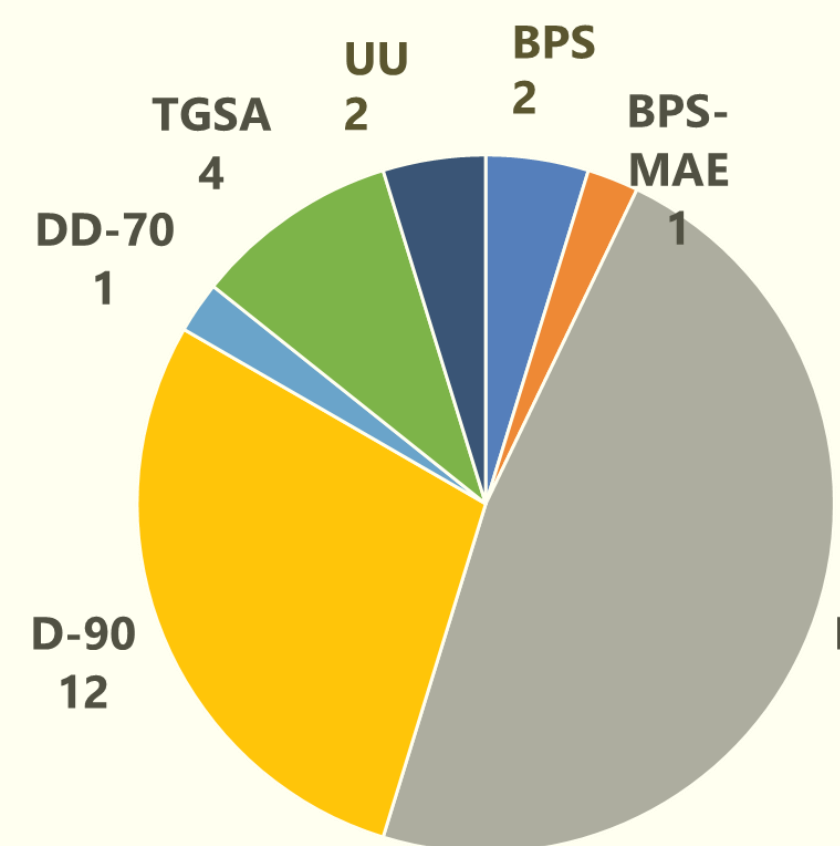


MS/MS spectra acquired for the 9 identified developers, except D-70, and the sensitizer DPS.

## Results & Discussion



Despite BPA is globally the most frequently used main developer, exits a clear trend of BPA replacement with alternative developers, such as BPS or Pergafast 201.

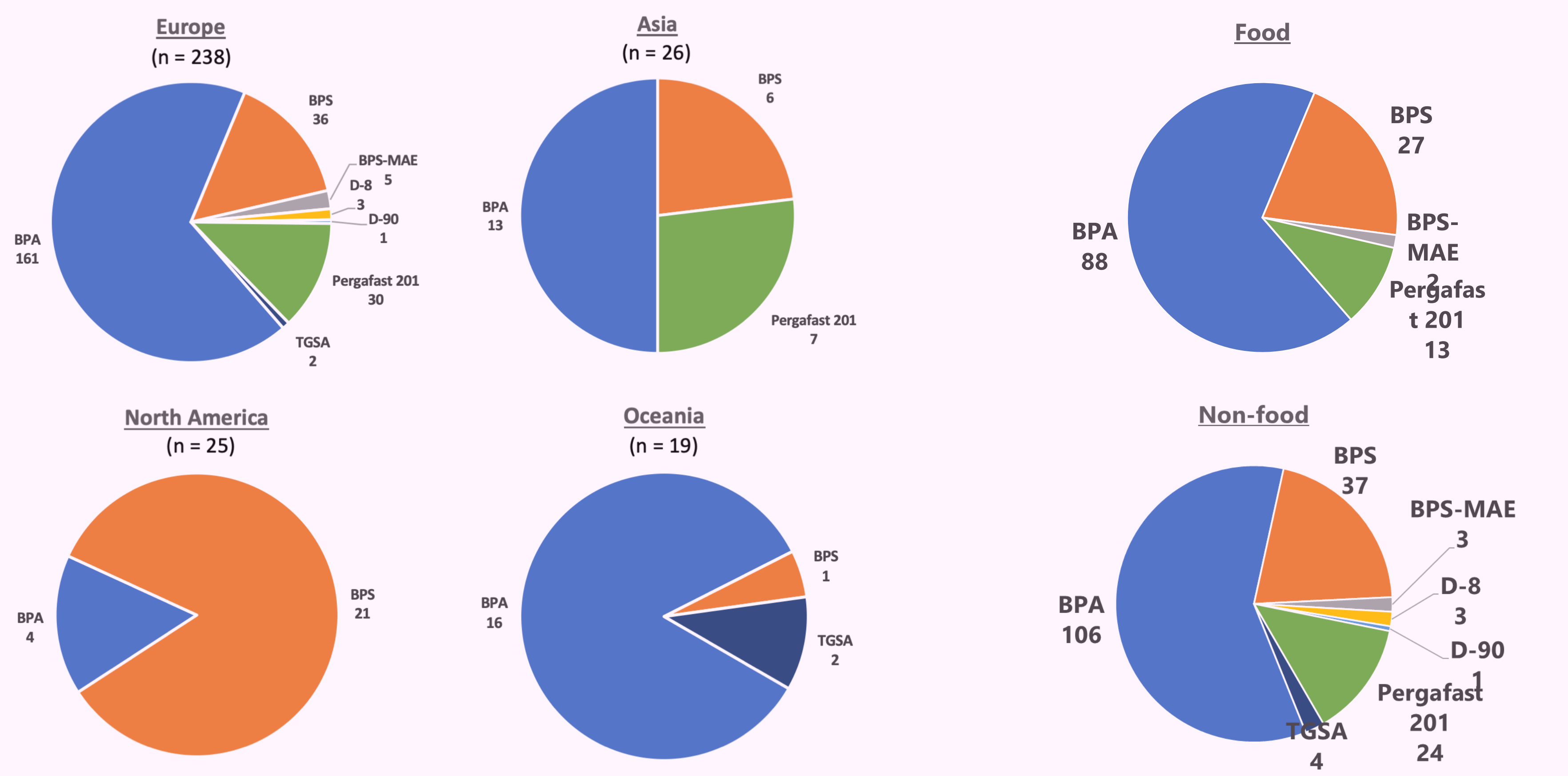


In 42 out of all samples, a secondary developer was detected. D-8 is the main secondary developer founded in thermal paper, with BPA or BPS as primary developer.

## Statistical analysis

Statistical analyses (ANOVA, Student t-test and Pearson correlation) were performed to evaluate the use of BPA as main developer between continents, countries and point-of-sales.

- In Europe, Asia and Oceania, BPA is still the main color developer, followed by BPS. No statistical difference were founded between Europe and Asia for the use of BPA. However, in North America BPS has become a major developer.
- Regarding to point-of-sale origin, Student t-test revealed a significant lower use of BPA as developer in thermal paper related to food.



## Conclusions

- 9 developers identified: BPA, BPS, Pergafast 201, BPS-MAE, D-8, D-90, TGSA, UU, DD-70.
- BPA was most frequently detected, followed by BPS and Pergafast 201. Despite the lack of specific legislation, it is clear that alternative developers are currently globally in use for the manufacturing of thermal paper.
- Detection of BPA showed a statistically significant difference between continents and point-of sale origin.
- The sensitizer DPS was for the first time reported in combination with other developers than BPS.

## Acknowledgements

P. Vervliet and C. Gys acknowledge PhD fellowships from the Research Foundation Flanders (FWO) through projects G089016N and G0E5216N.  
N. Caballero-Casero acknowledges a post-doc fellowship from the University of Antwerp (BOF funds).