New multinebulizer for spectrochemical analysis: wear metals determination in used lubricating oils by on-line Standard Dilution Analysis (SDA) using Inductively Coupled Plasma Optical Emission Spectrometry (ICP OES)†

Miriam García, Miguel Ángel Aguirre* and Antonio Canals*

[1]Department of Analytical Chemistry and Food Science and University Institute of Materials, Faculty of Science, University of Alicante, P.O. Box 99, 03080 Alicante, Spain

†Electronic supplementary information (ESI) available: Further experimental results.

*Corresponding authors: aguirre.pastor@ua.es (M.A. Aguirre) and a.canals@ua.es (A. Canals).

1.1. Application of the Eco-Scale

Nowadays, there is an standard method of wear metal analysis described in the ASTM-5185.[1] This method is quite away of the principles of Green Analytical Chemistry,[2] mainly because it uses big amounts of organic solvents (*e.g.*, xylene and kerosene). Our proposed method is more eco-friendly as little volume of aqueous standards are used, reducing the use of organic solvents and human intervention, among other features. In order to evaluate the greenness of both analytical methodologies, a comprehensive approach called analytical Eco-Scale is used.[3] This tool is based on assigning penalty points to parameters of an analytical process that are not in agreement with the ideal green analysis. An ideal process has a score of 100 in the Eco-Scale and then for each of the parameters that differs from the ideal value, penalty points are assigned, lowering the total score. The higher the score, the greener and more economical is. Following this criteria, chemical processes are classified according their Eco-Scale Score as: excellent (>75), acceptable (50-75) and inadequate (<50). Table S1 shows the analytical Eco-Scale total score for both analytical methodologies. According to the comparison of scores, the proposed methodology is greener than the standard method and is even close to be classified as excellent, something tricky when working with a sample with an organic matrix itself.

References

1 ASTM International, *D5185-18, Standard Test Method for multielement determination of used and unused lubricating oils and base oils by Inductively Coupled Plasma Atomic Emission Spectrometry (ICP-AES)*, United States, 2018.

2 M. Koel, Do we need Green Analytical Chemistry?, *Green Chem.*, 2016, **18**, 923–931.

3 A. Gałuszka, P. Konieczka and Z. M. Migaszewski, Analytical Eco-Scale for assessing the greenness of analytical procedures, *Trends Anal. Chem.*, 2012, **37**, 61–72.

Table S1. Comparison of Penalty Points (PP) and Analytical Eco-Scale Score for different methodologies of wear metals determination in lubricating oils

ASTM method		**Multinebulizer/SDA/ICP OES**	
	PP		**PP**
Reagents	26	*Reagents*	17
Waste	15	*Waste*	9
Energy	1	*Energy*	1
Occupational hazard	3	*Occupational hazard*	3
Total	45	Total	30
Eco-Scale Score	**55**	**Eco-Scale Score**	**70**