IMPACT OF DIFFERENT VAPING MACHINES ON METAL CONTAMINATIONS OF E-CIGARETTE AEROSOLS

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1. Abstract

The presence of trace metals in e-liquids or aerosol of electronic cigarettes (e-cigarette) has been previously reported [1]. In a previous study, it was demonstrated that contaminations with tin, aluminum, copper, iron and nickel may occur from certain parts of a standard smoking machine [2]. Therefore, the risk of a possible transfer of trace metal from e-liquids or components of e-cigarette devices into aerosol needs to be carefully investigated.

For this purpose, rotary and linear smoking machines, as well as impingers and electrostatic precipitation trapping systems were studied.
For the quantification of trace metal concentration levels in aerosols, the fully validated method as presented during the CORESTA Smoke/Techno Study Group meeting 2015 [ST 10, CORESTA 2015] was applied. The measurements encompassed seven metals including aluminium, nickel, iron, chromium, copper, tin and silver and were performed with an Inductively Coupled Plasma - Optical Emission Spectrometer (ICP-OES).

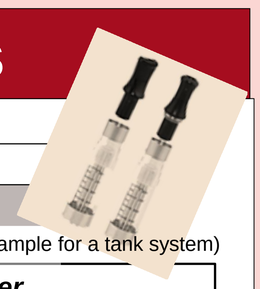
The aerosols were generated with clearomisers by applying vaping conditions according to the CORESTA Recommended Method (CRM 81).
The quantification was carried out using Yttrium as an internal standard. For the e-aerosol emissions, the limits of quantification (LOQ) ranged from 0.003 µg/10 puffs (copper, iron) to 0.04 µg/10 puffs (tin).

In this study, metal contaminations could be detected in aerosol and blank samples on a similar level when the investigated smoking machines were used.
The results obtained by the rotary and linear type devices and the different trapping systems are compared and discussed to reduce possible contamination sources.

2. Material and Methods

Table 1: sample investigated

Sample Description	Additional Information
e-cigarette	clearomizer (tank system)
Blank	Puffs without e- cigarettes


(Example for a tank system)

Trapping system: electrostatic

Particulate in the aerosol of 50 puffs is trapped by electrostatic precipitation coupled with an impinger (5 mL HNO_3)

Electrostatic precipitation is washed with 15 mL HNO_3

Impinger and wash solutions are combined (total 20 mL)

+ ISTD (internal standard)

Aliquot is analysed by ICP-OES

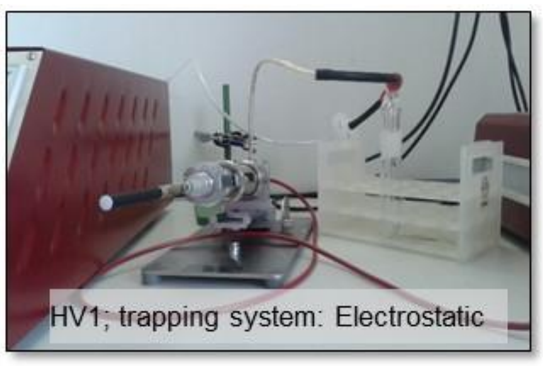
Trapping system: impinger

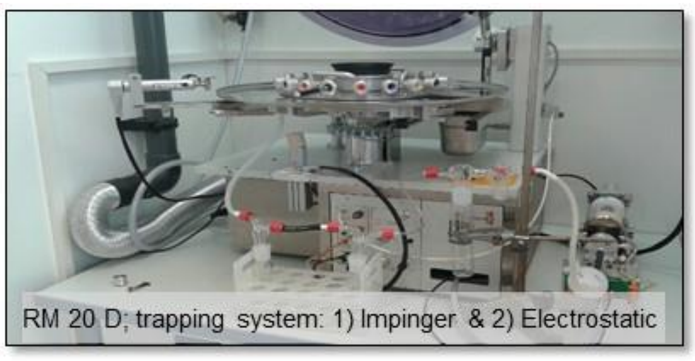
Particulate in the aerosol of 50 puffs is trapped by two impingers (each: 5 mL HNO_3)

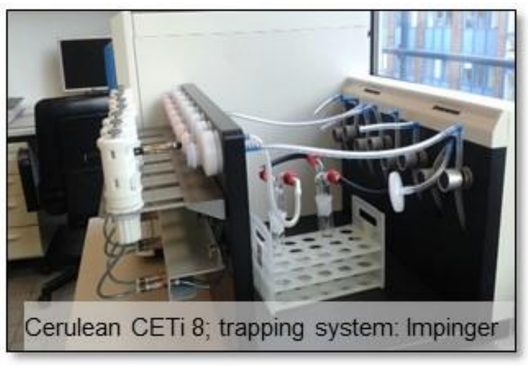
Impinger solutions are combined and filled up to 20 mL with HNO_3

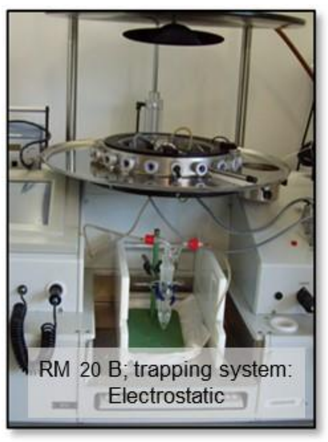
Smoking regime (CRM 81): puff volume: 55 mL; puff frequency: 30 sec; puff duration: 3 sec; profile: square shape [3]

3. Results and Discussion

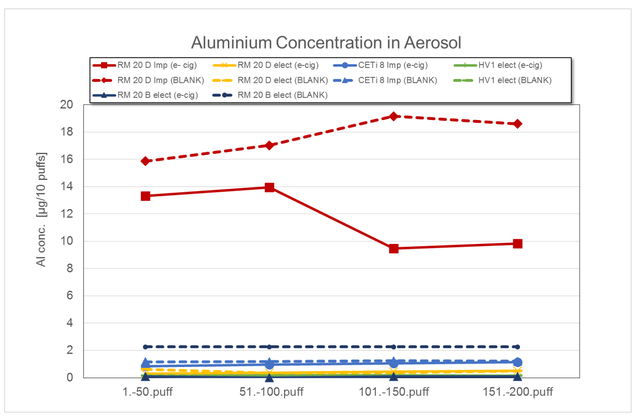

HV1; trapping system: Electrostatic

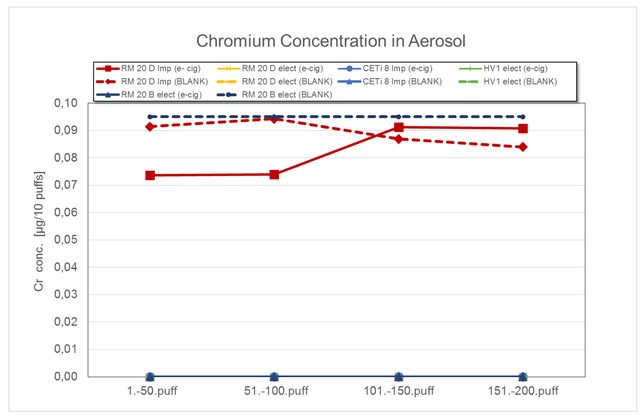

RM 20 D; trapping system: 1) Impinger & 2) Electrostatic

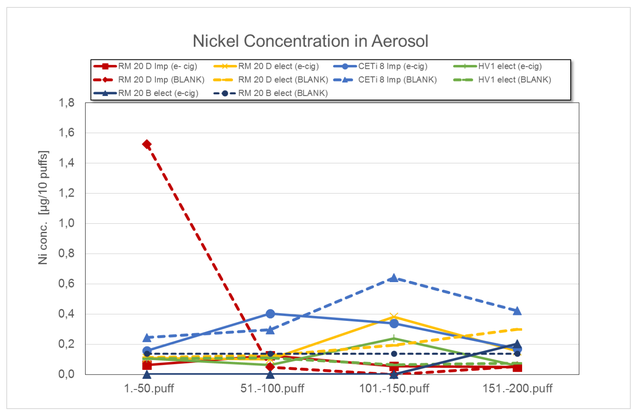

Cerulean CETi 8; trapping system: Impinger

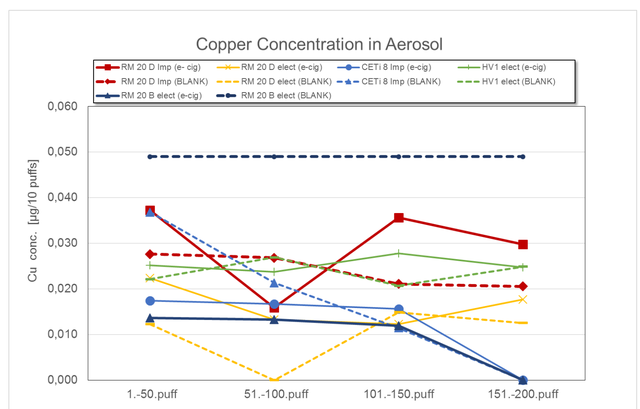

RM 20 B; trapping system: Electrostatic

The e-cigarette was tested on four different smoking machines coupled with different trapping systems: Borgwaldt HV1 electrostatic precipitation, Borgwaldt RM 20D electrostatic precipitation and impinger, resp., Cerulean CETi8 impinger, and Burghart RM 20B electrostatic precipitation. (see pictures above)
On 5 different days, 200 blank-puffs and 200 sample puffs in 50 puff steps were performed by applying each experimental set up (different smoking machine and/or different trapping system). Furthermore, 200 blank-puffs were taken once every day.
The mean values of the investigated metals obtained by vaping the e- cigarette and the Blank samples are shown in the figures on the right.
Results of the quantified metals are summarized in table 2. (Tin and silver are not listed in the table, due to the fact that both metals are not detectable in the samples.)









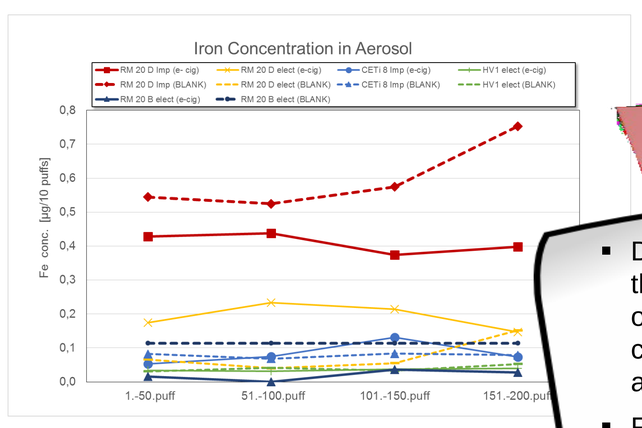


Table 2: summary of metal results [µg/10 puffs]:

Smoking machine / trapping			Al	Ni	Fe	Cr	Cu
RM 20B / electrostatic	blank	min	<0.067	< 0.044	0.014	< 0.027	< 0.011
		max	32.74	0.519	1.09	0.095	0.124
	e-cigarette	min	< 0.067	< 0.044	< 0.011	< 0.027	< 0.011
		max	0.136	0.373	0.052	< 0.027	0.023
RM 20D / electrostatic	blank	min	0.026*	< 0.044	< 0.011	< 0.027	< 0.011
		max	1.34	0.317	0.182	< 0.027	0.015
	e-cigarette	min	<0.067	< 0.044	< 0.011	< 0.027	< 0.011
		max	1.87	0.536	0.866	< 0.027	0.022
RM 20D / impinger	blank	min	<0.067	< 0.044	< 0.011	< 0.027	< 0.011
		max	46.49	2.94	1.33	0.106	0.030
	e-cigarette	min	0.112	< 0.044	< LOQ	< 0.027	< 0.011
		max	38.43	0.126	1.14	0.095	0.037
CETI8 / impinger	blank	min	0.049*	< 0.044	0.009*	< 0.027	< 0.011
		max	1.94	2.56	0.169	< 0.027	0.037
	e-cigarette	min	0.188	< 0.044	0.023	< 0.027	< 0.011
		max	3.27	0.905	0.500	< 0.027	0.017
HV1 / electrostatic	blank	min	<0.067	< 0.044	0.007*	< 0.027	< 0.011
		max	0.290	0.157	0.105	< 0.027	0.046
	e-cigarette	min	<0.067	< 0.044	0.016	< 0.027	< 0.011
		max	0.289	0.558	0.065	< 0.027	0.049

* Results are below LOQ (calculated for 50 puffs), but in these cases, 200 blank puffs were trapped (LOQ calculated for 200 puffs: Al: <0.017; Fe:<0.003)

4. Conclusion

- Due to the metal concentration detected in the blank and e-cigarette samples, a transfer of aluminium, nickel, iron chromium and copper from e-cigarette device into e-cigarette aerosol could not be accurately quantified.
- For the different smoking devices, similar metal contamination could be observed
- To determine and evaluate possible metal contamination in e-cigarette aerosols, a “clean experimental set up” is essential.
- The issues raised by this study are relevant to the development of standard methodology for measuring metals in EVP aerosol.

Outcome of the study:

The metal analysis encompassing aluminum, nickel, iron, chromium, copper, tin and silver was performed by investigating e-aerosols, which were generated with different types of smoking machines, including rotary and linear. Neither in the aerosol nor in the blank samples obtained from same vaping runs, tin and silver could be detected. But, trace levels of aluminum, nickel, iron, chromium, and copper were found as contaminations in aerosol and blank samples on comparable levels. However, a significant reduction of metal contaminants by using one of the both smoking machine types –rotary or linear- could not be observed.

Acknowledgement:
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References

[1] M. Williams, A. Villarreal, K. Bozhilov, S. Lin, P. Talbot; PLOS ONE; Volume 8; Issue 3, **2013**
[2] Otte S., Nowak S., Intorp M.; *Method Development and Validation: Quantification of Metals in Liquids and Aerosol of e-cigarettes*; CORESTA Congress Presentation ST 10; **2015**
[3] CORESTA recommended method 81*: Routine Analytical Machine for E-Cigarette Aerosol,* **2015**

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