Identification and characterization of quaternary ammonium compounds in Flemish indoor dust by ion-mobility high resolution mass spectrometry

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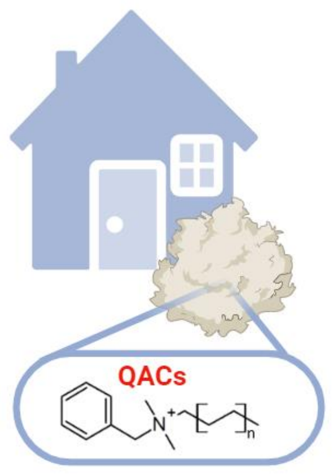
INTRODUCTION

Quaternary ammonium compounds (QACs), used as disinfectants and surfactants, are considered contaminants of emerging concern (CECs)[1]. Significantly higher QAC levels have been reported in dust and human blood samples collected during the **COVID-19 pandemic** compared to pre-pandemic time points[2,3]. However, information on the occurrence and identity of many QACs in environmental matrices is still lacking.

Ion mobility mass spectrometry (IM-MS)-derived **collision cross section (CCS)** values can serve as a valuable additional identification parameter within suspect screening studies of CECs. For a limited number of QACs, CCS values and CCS-*m/z* trendlines have been reported in the past[4].

This study describes a (semi-quantitative) targeted and suspect screening approach for QACs in Flemish indoor dust samples. To increase identification confidence, CCS values of suspect QACs were matched with **CCS-*m/z* trendlines** of known QACs. Additionally, **estimated daily intakes (EDIs)** were calculated based on semi-quantified concentration to estimate potential human exposure and associated health risks.



METHODS

Database compilation - DTIMS

21 QACs from three classes

→ C_8-C_{18} DDAC (n = 6)

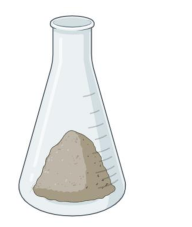
→ C_6-C_{18} BAC (n = 7)

→ C_8-C_{22} ATMAC (n = 8)

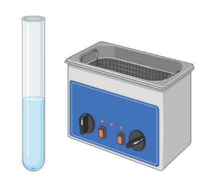
→ Implementation in previous database[5]

→ Characterization of **CCS-*m/z* trendlines**

Sample analysis



Dust samples from Belgium (n = 46)



Sonication assisted extraction (MeOH)

QA measures:
- 4 procedural blanks
- Spiked QC samples
- Labelled IS

LC/ESI-IM-HRMS

Column: Phenomenex Luna C18 100Å, 100 x 2.1 mm, 2.6 µm

(A) H_2O:ACN (80:20; v/v) + 0.1% acetic acid

(B) ACN:H_2O (95:5; v/v) + 5 mM NH_4OAc

(C) IPA + 0.1 % formic acid

Acquisition Modes (ESI+):

QTOF only (CE 10/20/40 eV)

All Ions Fragmentation (AIF) IM-MS

Mass range: *m/z* 100-1700

Semi-quantification

Calibration curves of 21 targeted QACs:

→ Based on rel. area and response factor (R_f) of calibrant

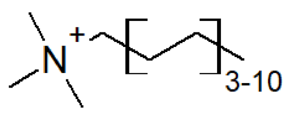
$$Conc._{QAC} = \frac{A_{QAC}/A_{IS}}{R_f}$$

→ Calibrant selected aiming at maximal structural similarity between calibrant and suspect compound

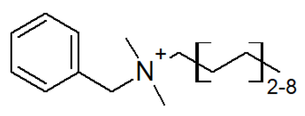
Data analysis

Target screening

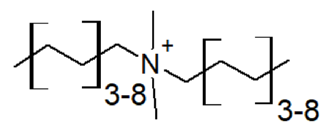
- Target list (n = 21)
- Characteristic fragmentation pattern
- Match based on
  - ➢ Fragm. spectra
  - ➢ *m/z*
  - ➢ CCS values
  - ➢ RT
  - ➢ Isotopic pattern



ATMACs (n = 8)



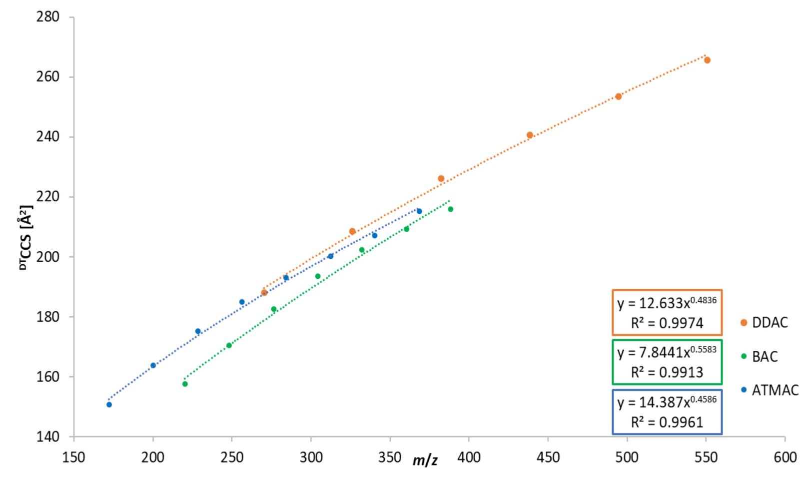
BACs (n = 7)



DDACs (n = 6)

Suspect screening

- Suspect list (n = 370)
- Known and predicted QACs
- Match based on
  - ➢ Exact mass
  - ➢ Fragm. spectra
- Comparison of CCS values with established CCS-*m/z* trendlines
- Characteristic fragments



EDI calculation

$$EDI\ [mg/kg\ (bw)/day] = \frac{C \times I \times F}{BW}$$

C = Semi-quant. concentration [µg/g dust]

I = Ingestion [60 mg/day (toddlers) / 100 mg/day (adults) for the 95th percentile exposure scenario)

F = Fraction of time spent at home [0.6/0.91 (adults/toddlers)] and in public spaces [0.18]

BW = body weight [72 kg/12 kg (adults/toddlers)]

Unequivocal identification | **Tentative match[6]; novel compounds** | **Risk assessment**

RESULTS AND DISCUSSION

Database compilation

- Good correlations observed for each QAC class (power model; Fig.1)
- QACs were clearly distinct from other compound classes[5]
- Increase in CCS value with increasing chain lengths

→ Potential use of CCS-*m/z* trendlines as **additional identification parameter**

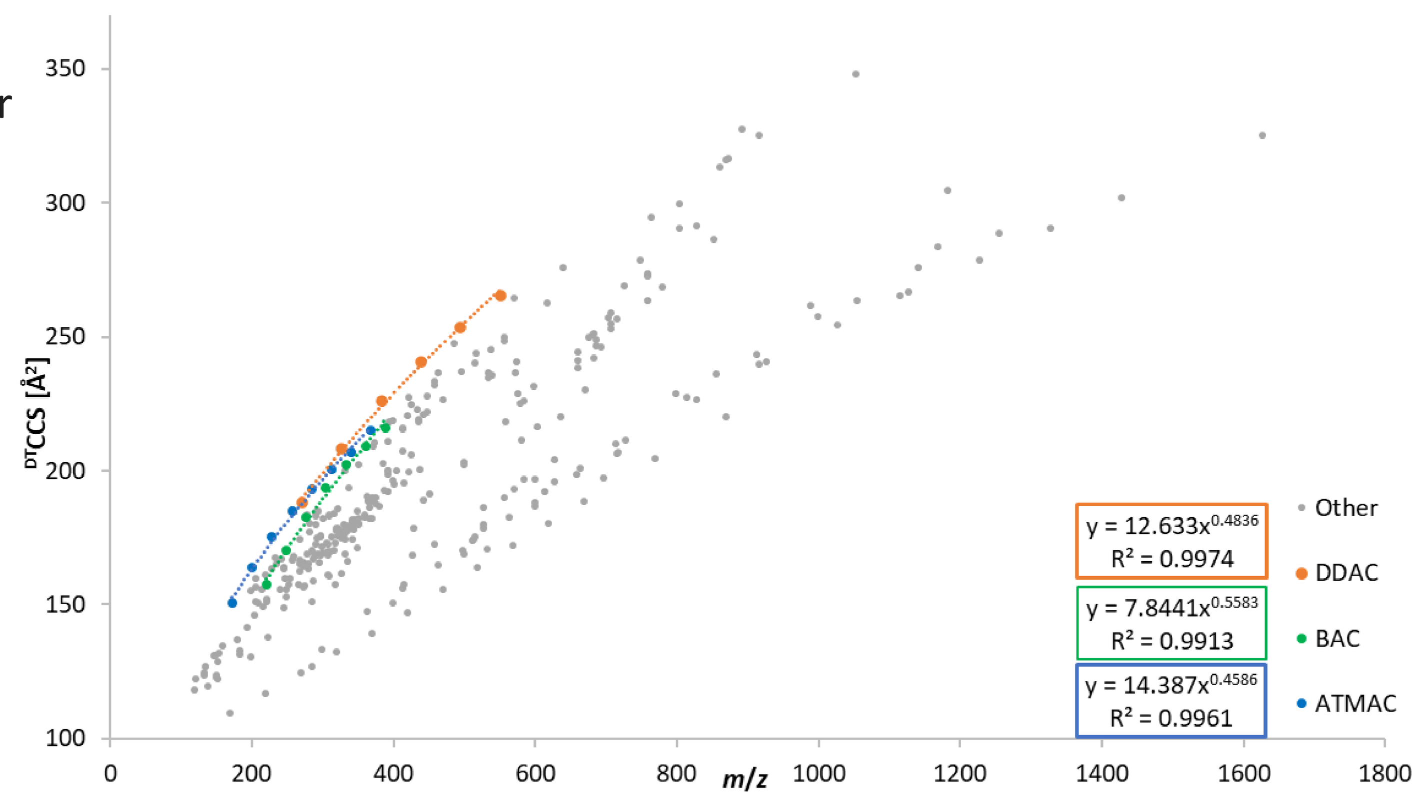


Fig. 1. CCS-*m/z* trendlines observed for the three QAC classes in comparison to previously established CCS database[5] (grey dots).

Target screening

- All 21 targeted QACs detected in house dust samples with confidence level 1 or 2[6] (Table 1)
- Fifteen QACs detected with DFs > 90 %
- Individual QACs with max. concentrations up to 32.2 µg/g dust
- Median ΣQAC concentration of 13.1 µg/g dust

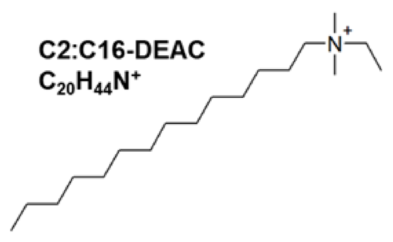
Table 1. Semi-quant. median, min. and max. concentrations of most abundant QAC homologues of each class and summed semi-quant. median, min. and max. concentrations for each QAC class. DF: Detection frequency.

Compound	DF [%]	Median [µg/g]	Min [µg/g]	Max [µg/g]
C22-ATMAC	100	1.5	0.1	7.3
C12-BAC	100	3.0	0.5	28.4
C10:C10-DDAC	100	1.9	0.2	9.5
ΣATMAC		4.5	0.3	15.5
ΣBAC		5.8	1.0	70.6
ΣDDAC		3.4	0.9	55.7
ΣQAC		14.7	2.8	103.7

Suspect screening

- 17 suspect compounds identified with confidence levels (CL) 2 or 3 (Table 2)
- Newly identified class of **dimethyl ethyl alkyl ammonium compounds (DEACs)**
- DDACs with mixed chain lengths identified
- CCS values of matched suspects plotted with CCS-*m/z* trendlines of the three target QAC classes (Fig. 2)

C2:C16-DEAC
$C_{20}H_{44}N^+$



CCS-*m/z* trendlines as a valuable additional identification tool

Table 2. Representative selection of suspect QACs identified in dust samples. For each suspect, IM-MS derived CCS values were acquired and matched with previously established trendlines (Fig. 2). APE: absolute percent error; CCS: collision cross section; SD: standard deviation; CL: Level of identification confidence.

Nr.	Compound	DF [%]	x̅ APE [ppm]	x̅ CCS [Å²]	SD [Å²]	CL
1	C2:C14-DEAC	100	0.88	187.23	0.55	3
2	C14:C16/C12:C18-DDAC	100	0.85	246.42	0.89	3
3	C16:C18-DDAC	100	0.82	259.73	0.80	3
4	C13-BAC	52.2	2.68	196.63	0.63	3
5	1-Hexadecyl-pyridinium	56.5	3.14	192.06	0.71	3
6	Benzethonium	26.1	2.12	207.66	0.56	3

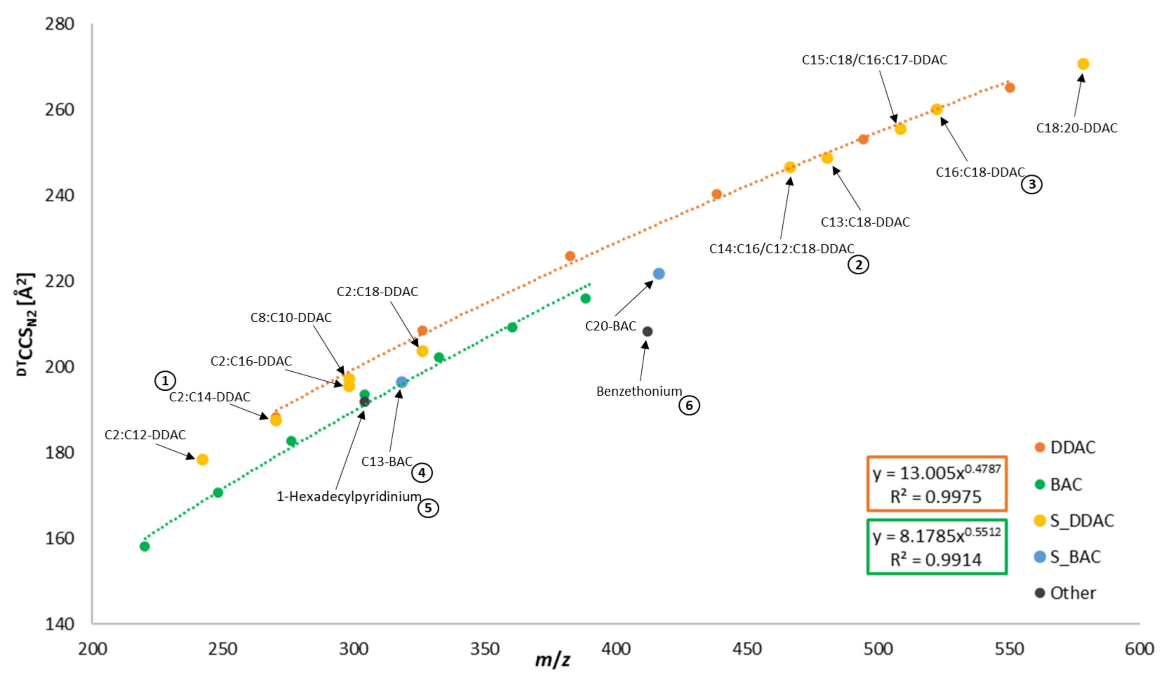


Fig. 2. Combined plot of CCS-*m/z* trendlines of two target QAC classes (BAC: green; DDAC: orange) and CCS values measured for matched suspects (S_DDAC/S_BAC/Other). The numbers indicated for a selection of suspect compounds correspond to the data in Table 2.

Estimated Daily Intakes

- All **EDIs** calculated from (summed) concentrations of targeted QAC classes clearly below **acceptable daily intake** proposed by EFSA (Fig. 3)
- **No indications for potential health risks**
- Suspect or yet unknown QACs and other exposure routes not considered

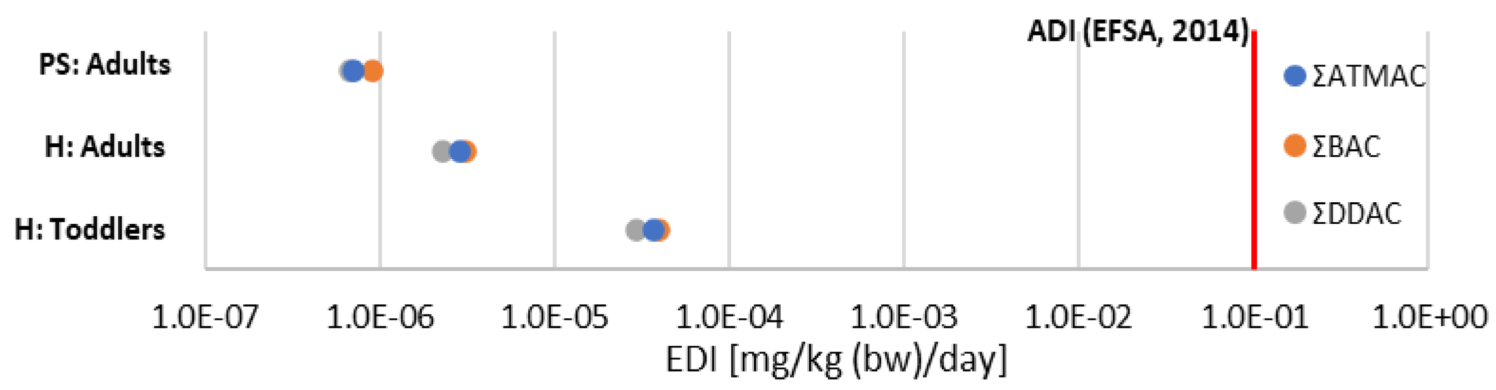


Fig. 3. EDIs calculated from semi-quant. concentration of three targeted QAC classes in comparison to ADI established by (EFSA, 2014). For adults, samples from homes (H) and public spaces (PS) were considered.

CONCLUSIONS

- **Ubiquitous occurrence** of known and novel QACs in indoor dust
- **17 novel QACs** identified
- Established **CCS-*m/z* trendlines** as valuable additional identification parameter
- EDIs **do not suggest potential health risk** for sampled population

LITERATURE

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