Detection and Quantification of the Emission of Formic acid and Acetic acid under in-situ Storage and Display Environmental Conditions in Museum

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Introduction

- Pungent smell discovered from the region with newly built wooden showcases
- Preliminary analysis of different gaseous pollutants in collection stores
- Various direct-read instrument available for different gaseous pollutants, but not for organic acids
- Pilot project to develop a suitable method to quantify amount of formic acid and acetic acid under in-situ conditions in museum
- Sampling with sorbents, followed by instrumental analysis with Ion

The Concerns

Demanding Detection Limit Required

Major Indoor-Generated Pollutants in Museums		Suggested Pollutant Limits: Sensitive Materials	Suggested Pollutant Limits: General Collections	Action Limits: High	Action Limits: Extremely High
Hydrogen sulfide, H_2S		<0.010	<0.100	0.4 to 1.4	2.0 to 20
Organic acids	Acetic acid,[j] CH_3COOH	<5	224 40 to 280	200 to 480	600 to 1000
Organic acids	Formic acid,[k] HCOOH	<5	42 to 78	104 to 260	260 to 780

Vulnerable to Analytical Column Cloggage

- Incomplete filtration due to product defect
- Introduction of insoluble particles due to human error
- Precipitation of impurities inside column

Retention Time Required

- Acetate: 3.6 – 8.8 minutes
- Formate: 4.3 – 9.4 minutes

Our Method

Passive Sampler

Radiello®(Triethylamine)

Ion Chromatograpy-Conductivity Detector

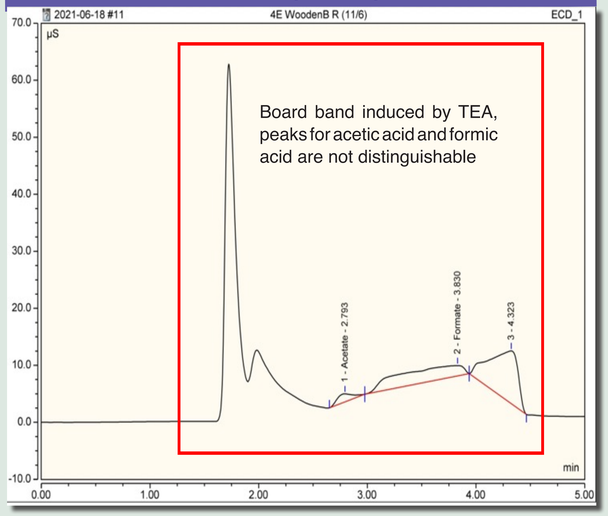
- IC-CD Model: Dionex ICS-1100
- Mobile phase: 0.4mM NaOH
- Column: Dionex™ IonPac™ AS11-HC
- Mode: Isocratic
- Flow rate: 1.0 mL/min
- Injection Volume: 25 µL

Method Development / Modification

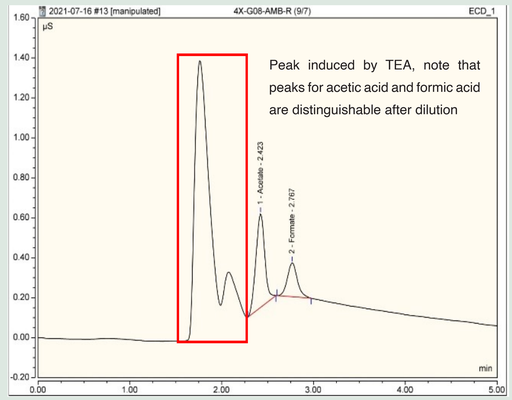
NaOH (AS11-HC) vs. NaHCO3/Na2CO3 (AS-23)

Parameter	AS11-HC	AS-23
Matrix Interference	Yes (TEA)	No
Internal Pressure (psi) (at flow-rate 1mL/min)	Lower (1360 – 1400 psi)	Higher (2000 psi)
Ease of Operation	Easier	More difficult
Risk for Column Cloggage	Lower	Higher
Robustness	Better	

Matrix Interference by Triethylamine (TEA)



Real Sample Analysis: Museum Wooden Showcase



Used for more than 20-year-old wooden showcase in museum was selected for analysis with the newly-developed method.

Result Table for the Wooden Showcase Sample

Wooden Showcase Sample	Acetic Acid (ppb)			Formic Acid (ppb)			Mean (ppb)		RSD(%)	
Trial	Right	Middle	Left	Right	Middle	Left	Acetic Acid	Formic Acid	Acetic Acid	Formic Acid
1st	1003.07	1009.04	1030.54	277.14	258.01	255.95	1014.22	263.70	1.42	4.43
2nd	1084.05	1073.88	1143.13	280.69	262.48	254.89	1100.36	266.02	3.40	4.99
3rd	1004.65	1055.43	1079.56	256.09	247.72	239.21	1046.55	238.74	3.65	4.99
Mean	1030.59	1046.12	1084.41	269.91	252.02	246.53	1014.22	263.70		
RSD (%)	4.49	3.19	5.21	5.82	5.72	6.25	4.44	6.59		

- Due to the protonation of TEA by NaOH
- Solved by matrix dilution (DI Water) and long exposure of sampler (1 week)

Case Study: Museum Cabinets

Summary of Results for Metal Store

Description	Mean Acetic Acid (ppb)	Mean Formic Acid (ppb)
Ambient	5.35	< 5
Metal Cabinet	6.61	< 5
Wooden Cabinet 1	23.64	10.11
Wooden Cabinet 2	33.71	13.23

Result Discussion

- Metal artefacts are known to be extremely vulnerable to attack by organic acids
- More gaseous organic acids were detected in wooden cabinets than metal cabinet and ambient environment, wide usage of metal cabinets therefore justified
- Acidic acid detected in ambient environment was probably due to contamination by exterior surfaces of the wooden cabinets

Possible Way Forward

Quantification of Damage Induced by Organic Acids

- To quantify and estimate how such high amount of gaseous organic acids can induce damage on artefacts
- To provide objective comparison and gain cooperation and resonance with collection and venue management staff

Establishment of Mitigation Plans and Verification

- To explore and establish ways to mitigate the emission of gaseous organic acids
- To verify and quantify the effectiveness

Promotion to Other Museums in Hong Kong

- To promote the importance of organic acids analysis
- To enlarge the project scale to exhibition galleries and other museums/archives

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