High Molecular Weight PAHs in Microplastic Samples Collected Following the Sinking of the Container Ship X-Press Pearl

Douglas Stevens[1], Bryan James[2], Christopher Reddy[2], Robert Nelson[2], Frank Dorman[1]

[1]Waters Corporation
[2]Woods Hole Oceanographic Institution

X-Press Pearl Microplastics Spill

Waters™

npr WAMU 88.5

NEWS CULTURE MUSIC PODCASTS & SHOWS SEARCH

ENVIRONMENT

LISTEN & FOLLOW

Sri Lanka Faces An Environmental Disaster As A Ship Full Of Chemicals Starts Sinking

JUNE 2, 2021 · 2:08 PM ET

Laurel Wamsley

Smoke billows from the Singapore-registered container ship X-Press Pearl on Wednesday. The ship carries more than 80 containers of dangerous goods, including 25 tons of nitric acid.

Ishara S. Kodikara/AFP via Getty Images

ACS ENVIRONMENTAL Au

AN OPEN ACCESS JOURNAL OF THE AMERICAN CHEMICAL SOCIETY

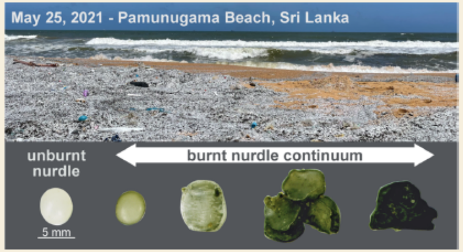
pubs.acs.org/environau Letter

The *M/V X-Press Pearl* Nurdle Spill: Contamination of Burnt Plastic and Unburnt Nurdles along Sri Lanka's Beaches

Asha de Vos,* Lihini Aluwihare, Sarah Youngs, Michelle H. DiBenedetto, Collin P. Ward, Anna P. M. Michel,* Beckett C. Colson, Michael G. Mazzotta, Anna N. Walsh, Robert K. Nelson, Christopher M. Reddy, and Bryan D. James

Cite This: *ACS Environ. Au* 2022, 2, 128–135 Read Online

ACCESS | Metrics & More | Article Recommendations | Supporting Information



ABSTRACT: In May 2021, the *M/V X-Press Pearl* cargo ship caught fire 18 km off the west coast of Sri Lanka and spilled ~1680 tons of spherical pieces of plastic or "nurdles" (~5 mm; white in color). Nurdles are the preproduction plastic used to manufacture a wide range of end products. Exposure to combustion, heat, and chemicals led to agglomeration, fragmentation, charring, and chemical modification of the plastic, creating an unprecedented complex spill of visibly burnt plastic and unburnt nurdles. These pieces span a continuum of colors, shapes, sizes, and densities with high variability that could impact cleanup efforts, alter transport in the ocean, and potentially affect wildlife. Visibly burnt plastic was 3-fold more chemically complex than visibly unburnt nurdles. This added chemical complexity included combustion-derived polycyclic aromatic hydrocarbons. A portion of the burnt material contained petroleum-derived biomarkers, indicating that it encountered some fossil-fuel products during the spill. The findings of this research highlight the added complexity caused by the fire and subsequent burning of plastic for cleanup operations, monitoring, and damage assessment and provides recommendations to further understand and combat the impacts of this and future spills.

KEYWORDS: *microplastic, pyroplastic, pollution, ship fire, contaminants, oil, maritime accident, citizen science*

Fate of the Ship and Nurdles

Waters™

ACS Environmental Au pubs.acs.org/environau Letter

Figure 1. Travel route[7] of the *M/V X-Press Pearl* leading up to the spill (A) and map of crowd-sourced nurdle sightings collated by Oceanswell[5] between May 29 to July 11, 2021 (B). Photographs of (C) the ship after sinking taken on July 10 (photo credit: Conor Bolas, ITOPF), of (D) burnt plastic and unburnt nurdles that washed ashore onto Pamunugama beach, and of (E) a handful of them both; photographs were taken on May 25. Full-sized photographs are available in Figures S1 and S2.

Spill Response: Characterization of Microplastics

Waters™

ACS ENVIRONMENTAL Au
AN OPEN ACCESS JOURNAL OF THE AMERICAN CHEMICAL SOCIETY

pubs.acs.org/environau

Divergent Forms of Pyroplas
X-Press Pearl Ship Fire

Bryan D. James,* Asha de Vos, Lihini I. Al
Anna P. M. Michel, Mark E. Hahn, and Ch

Cite This: *ACS Environ. Au* 2022, 2, 467–479

ACCESS | Metrics & More |

ABSTRACT: In late May 2021, the M/V *X-Press Pe*
ship caught fire while anchored 18 km off the coast of
Lanka and spilled upward of 70 billion pieces of plastic
(~1680 tons), littering the country's coastline.
combustion, heat, chemicals, and petroleum produc
apparent continuum of changes from no obvious effe
consistent with previous reports of melted and bu
(pyroplastic) found on beaches. At the middle of thi
nurdles were discolored but appeared to retain
morphology, resembling nurdles that had been weat
environment. We performed a detailed investigation o
and surface properties of discolored nurdles collected

ACS ENVIRONMENTAL Au
AN OPEN ACCESS JOURNAL OF THE AMERICAN CHEMICAL SOCIETY

pubs.acs.org/environau Article

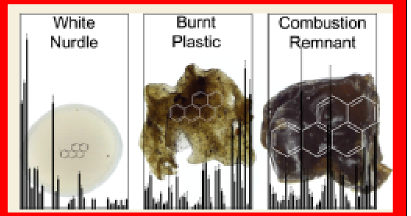
Fire and Oil Led to Complex Mixtures of PAHs on Burnt and Unburnt Plastic during the M/V *X-Press Pearl* Disaster

Bryan D. James,* Christopher M. Reddy, Mark E. Hahn, Robert K. Nelson, Asha de Vos,*
Lihini I. Aluwihare, Terry L. Wade, Anthony H. Knap, and Gopal Bera

Cite This: https://doi.org/10.1021/acsenvironau.3c00011 Read Online

ACCESS | Metrics & More | Article Recommendations | Supporting Information

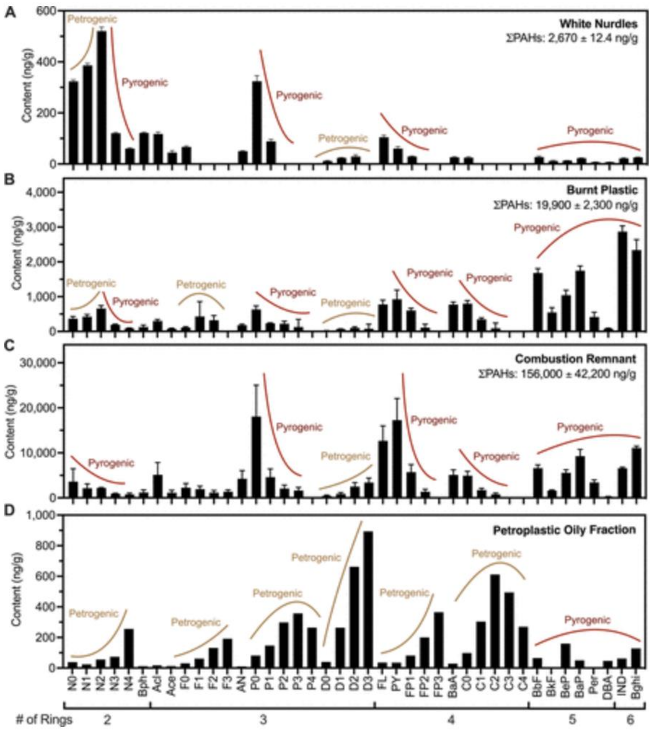
ABSTRACT: In May 2021, the M/V *X-Press Pearl* container ship burned for 2 weeks,
leading to the largest maritime spill of resin pellets (nurdles). The disaster was exacerbated by
the leakage of other cargo and the ship's underway fuel. This disaster affords the unique
opportunity to study a time-stamped, geolocated release of plastic under real-world
conditions. Field samples collected from beaches in Sri Lanka nearest to the ship comprised
nurdles exposed to heat and combustion, burnt plastic pieces (pyroplastic), and oil-plastic
agglomerates (petroplastic). An unresolved question is whether the 1600+ tons of spilled and



Differentiating Pyrogenic and Petrogenic PAHs

Waters™

Figure 2



White nurdles

Burnt nurdles

Combustion Remnant

Why Look for More Than the US EPA 16 PAHs?

Waters™

Environmental Pollution 224 (2017) 796–809

Contents lists available at ScienceDirect

Environmental Pollution

journal homepage: www.elsevier.com/locate/envpol

ELSEVIER

Invited paper

Source-oriented risk assessment of inhalation exposure to ambient polycyclic aromatic hydrocarbons and contributions of non-priority isomers in urban Nanjing, a megacity located in Yangtze River Delta, China ☆

Shaojie Zhuo [a], Guofeng Shen [a, d, *], Ying Zhu [b], Wei Du [a], Xuelian Pan [a], Tongchao Li [a], Yang Han [a], Bengang Li [a], Junfeng Liu [a], Hefa Cheng [a], Baoshan Xing [c], Shu Tao [a]

[a] *College of Urban and Environmental Sciences, Peking University, Beijing 100871, China*
[b] *Lancaster Environment Centre, Lancaster University, Lancaster LA1 4YQ, United Kingdom*
[c] *Stockbridge School of Agriculture, University of Massachusetts, Amherst, MA 01003, United States*
[d] *Jiangsu Key Laboratory of Environmental Engineering, Jiangsu Provincial Academy of Environmental Sciences, Nanjing 210036, China*

"…inclusion of non-priority PAHs could be valuable for both PAH source apportionment and health risk assessment."

Why Look for HMW PAHs? Toxicity

Waters™

Environment International 177 (2023) 107991

Contents lists available at ScienceDirect

ELSEVIER

Environment International

journal homepage: www.elsevier.com/locate/envint

Full length article

Evaluation of the cancer risk from PAHs by inhalation: Are current methods fit for purpose?

Noel J. Aquilina [a], Roy M. Harrison [b,c,*]

[a] *Department of Chemistry, Faculty of Science, University of Malta, Msida MSD 2080, Malta*
[b] *Division of Environmental Health and Risk Management and National Centre for Atmospheric Science, School of Geography, Earth and Environmental Sciences, University of Birmingham, Birmingham B15 2TT, United Kingdom*

[Aquilina "Evaluation of the cancer risk from PAHs by inhalation: Are current methods fit for purpose? Env.Intl. (2023)]

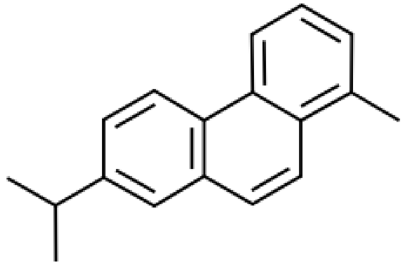
Why Look for HMW PAHs? Source Apportionment

Waters™

nature

Explore content ⌄ About the journal ⌄ Publish with us ⌄

nature > letters > article



Letter | Published: 08 December 1983

Retene—a molecular marker of wood combustion in ambient air

Thomas Ramdahl

Nature **306**, 580–582 (1983) | Cite this article

Adapting for HWM PAHs – GC-APCI

Waters™

GC/MS Conditions:

Column: Rxi-5HT 15m x 0.25mm x 0.10 µm (Restek)

Temp Program: 31 min runtime

Carrier Gas: **Nitrogen**

Injection: Split 10:1, SSL at 380°C, 100% graphite o-ring, 4 mm straight liner with wool, graphite ferrules on head and tail of column, high temp BTO septum

Mass Spectrometer: Xevo™ TQ Absolute tandem quadrupole system

Ionization: GC-APCI+ , dry source, charge exchange

Corona current: 2.0 µA

Cone gas: 270 L/hr (N_2)

Make up gas: 350 L/hr (N_2)

Aux Gas: 200 L/hr (N_2)

CID Gas: 0.40 mL/min (N_2)

Ramp (°C/min)	Temp °C	Hold (min)
Initial	40	0.5
14	160	0
22	395	11

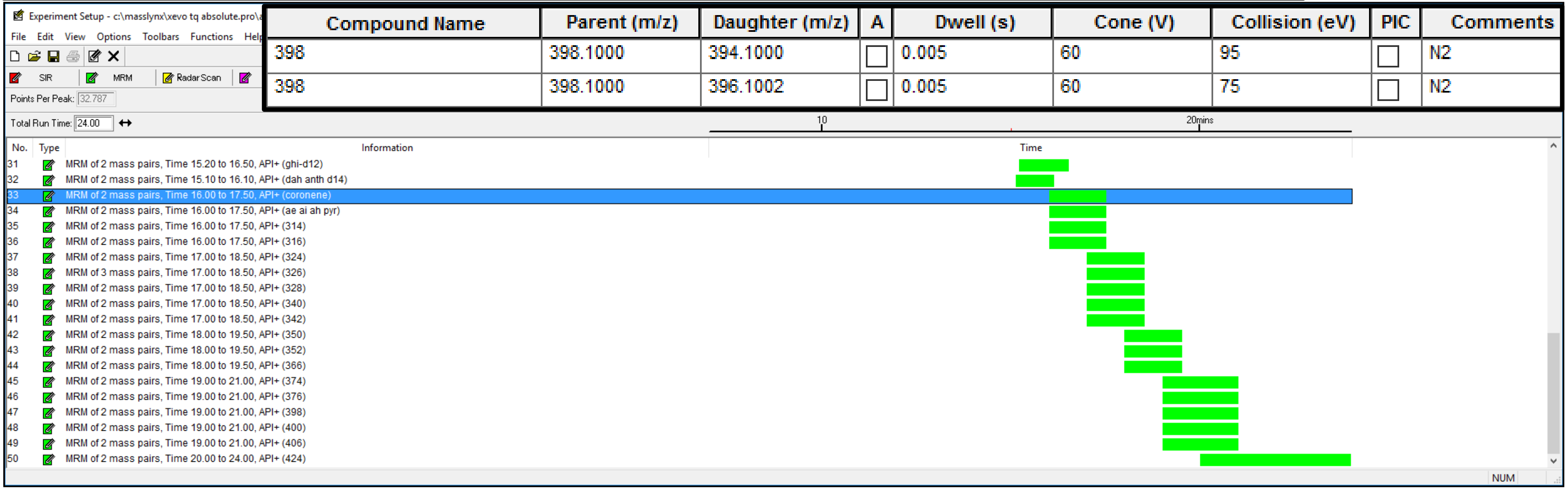
Ramp (mL/min per min)	Flow (mL/min)	Hold (min)
Initial	0.60	0
0.015	0.90	0
0.150	3.0	0

Acquisition Scheme: MRM Method Development

Waters™

Compound Name	Parent (m/z)	Daughter (m/z)	A	Dwell (s)	Cone (V)	Collision (eV)	PIC	Comments
coronene	300.0500	296.0500	☐	0.002	50	100	☐	N2
coronene	300.0500	298.0500	☐	0.002	50	75	☐	N2

Compound Name	Parent (m/z)	Daughter (m/z)	A	Dwell (s)	Cone (V)	Collision (eV)	PIC	Comments
398	398.1000	394.1000	☐	0.005	60	95	☐	N2
398	398.1000	396.1002	☐	0.005	60	75	☐	N2



Pseudo-MRM for EI GC/MS of PAHs

Waters™

Microchemical Journal 129 (2016) 194–199

Contents lists available at ScienceDirect

Microchemical Journal

journal homepage: www.elsevier.com/locate/microc

ELSEVIER

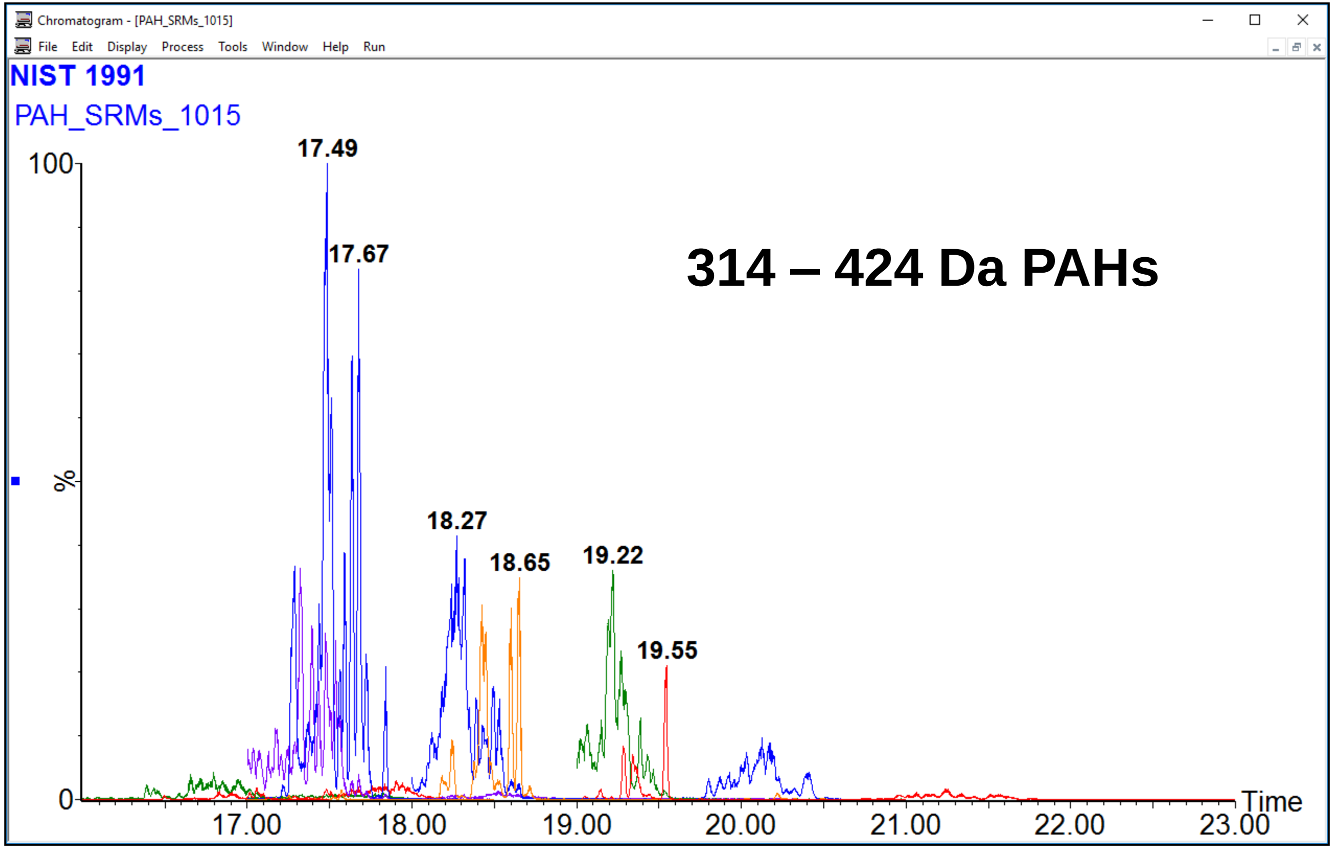
Analysis of polycyclic aromatic hydrocarbons in cigarette samples using gel permeation chromatography clean-up by gas chromatography–tandem mass spectrometry

Wenliu Lian [a,b], Fenglian Ren [a,*], Liyun Tang [b], Daozhu Dong [b]

[a] *Central South University, School of Chemistry and Chemical Engineering, No. 932 South Lushan Road, Changsha 410083, China*
[b] *China Tobacco Hunan Industrial Co., Ltd., Technology and Research Center, No. 386 Laodong Road, Changsha 410014, China*

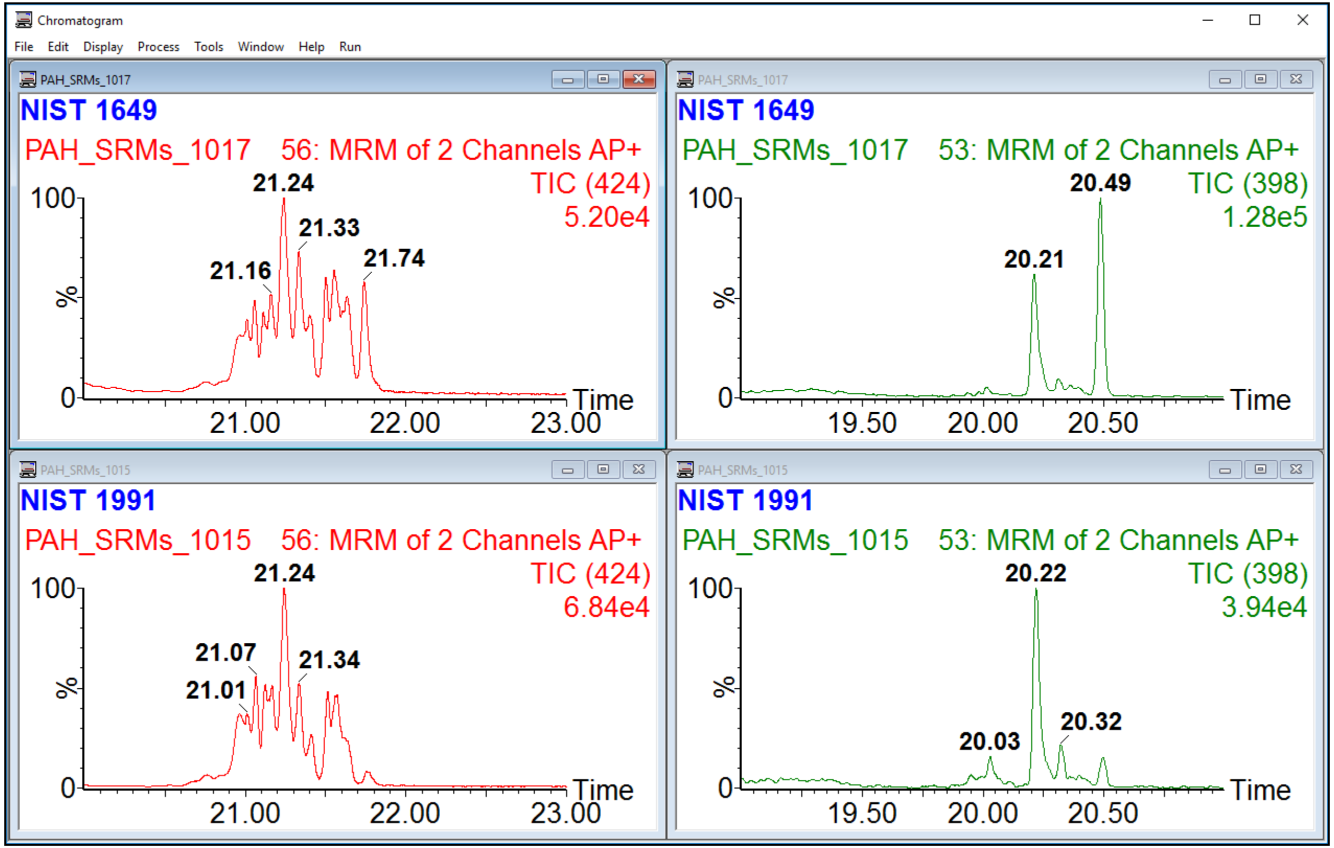
[Lian (2016) Analysis of polycyclic aromatic hydrocarbons…)]

SRM NIST 1991: Mixed Coal Tar/Petroleum Extract



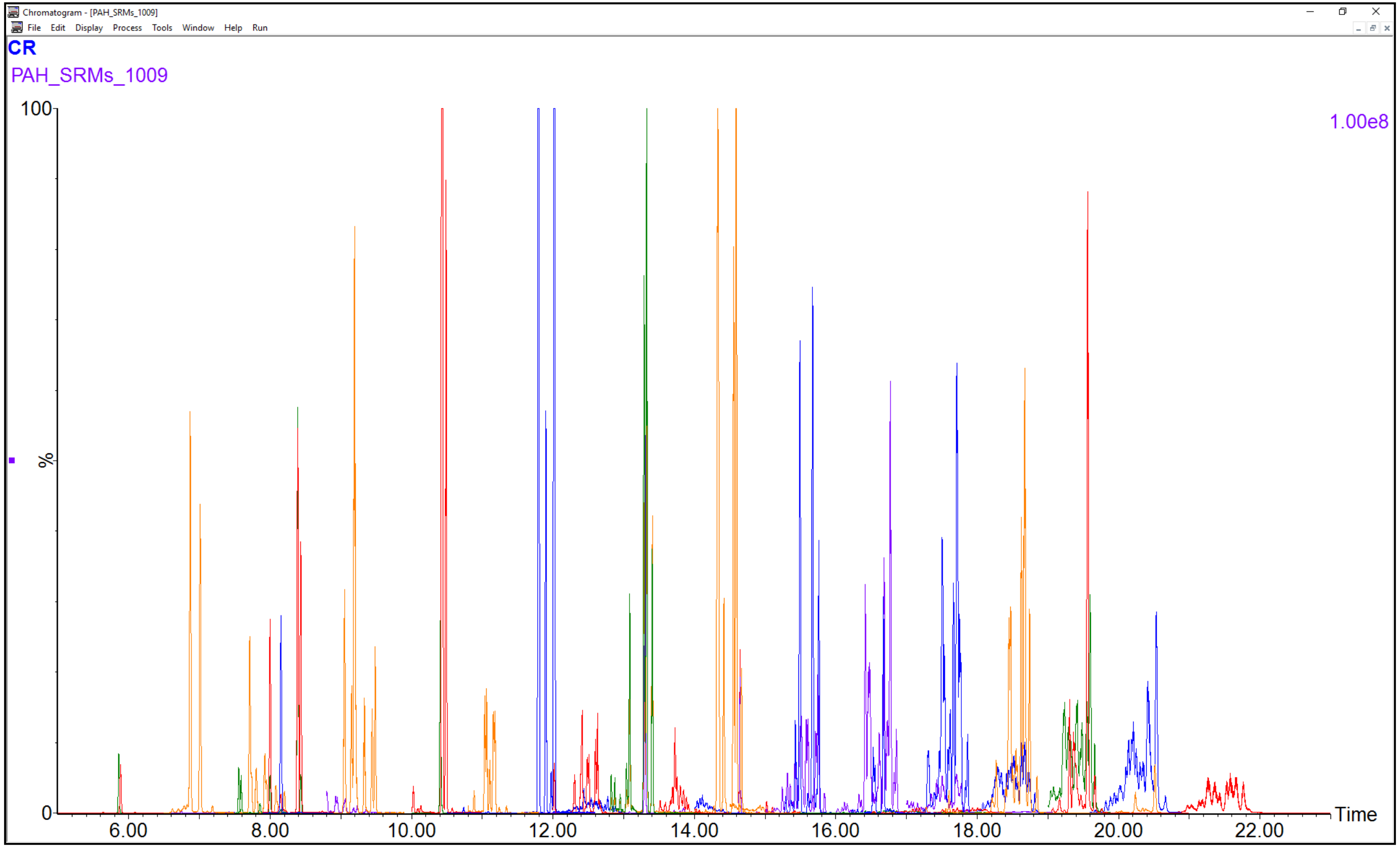
Comparing NIST SRM 1649 (Urban Dust) and 1991

Waters™

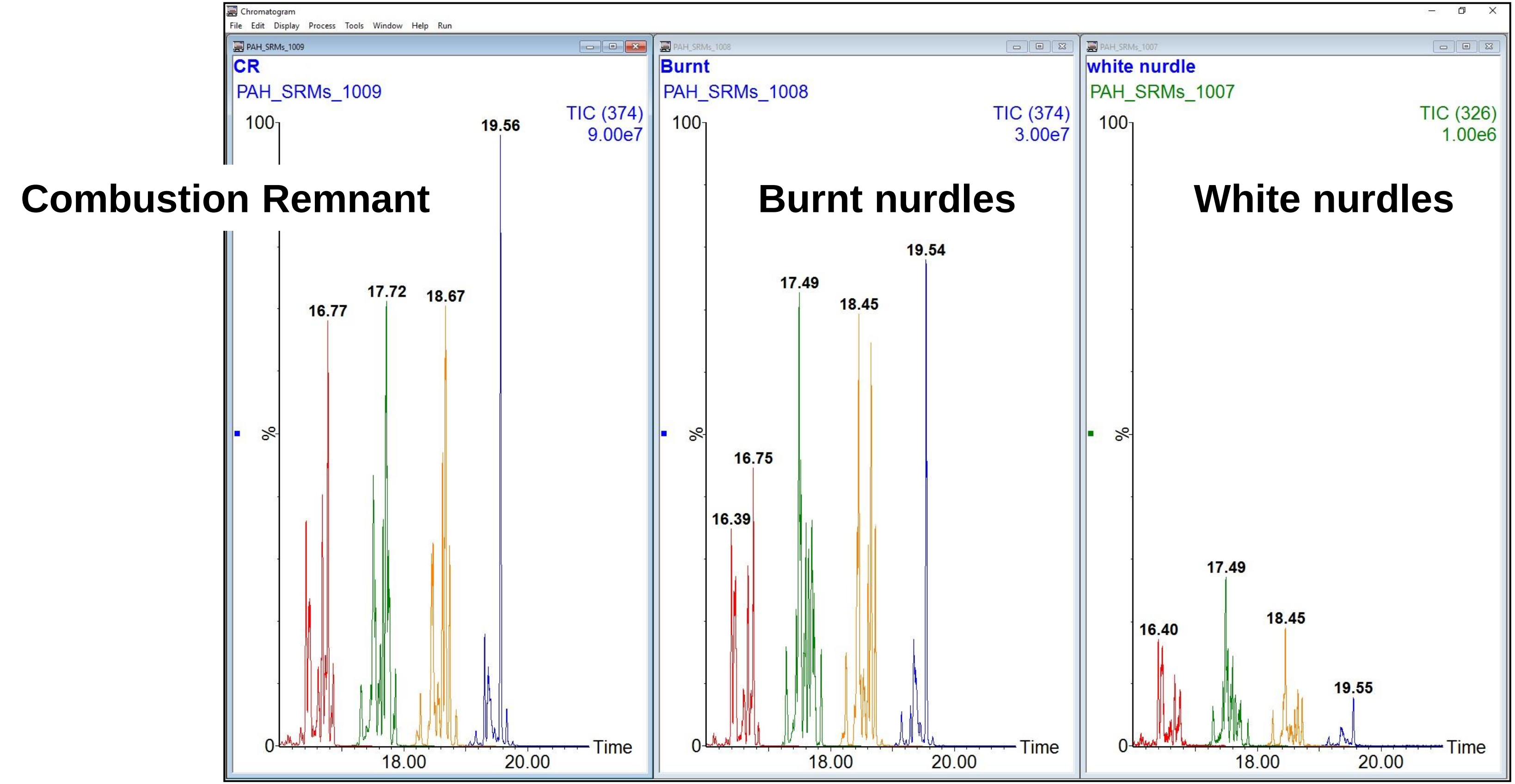


Combustion Remnant Extract

Waters™

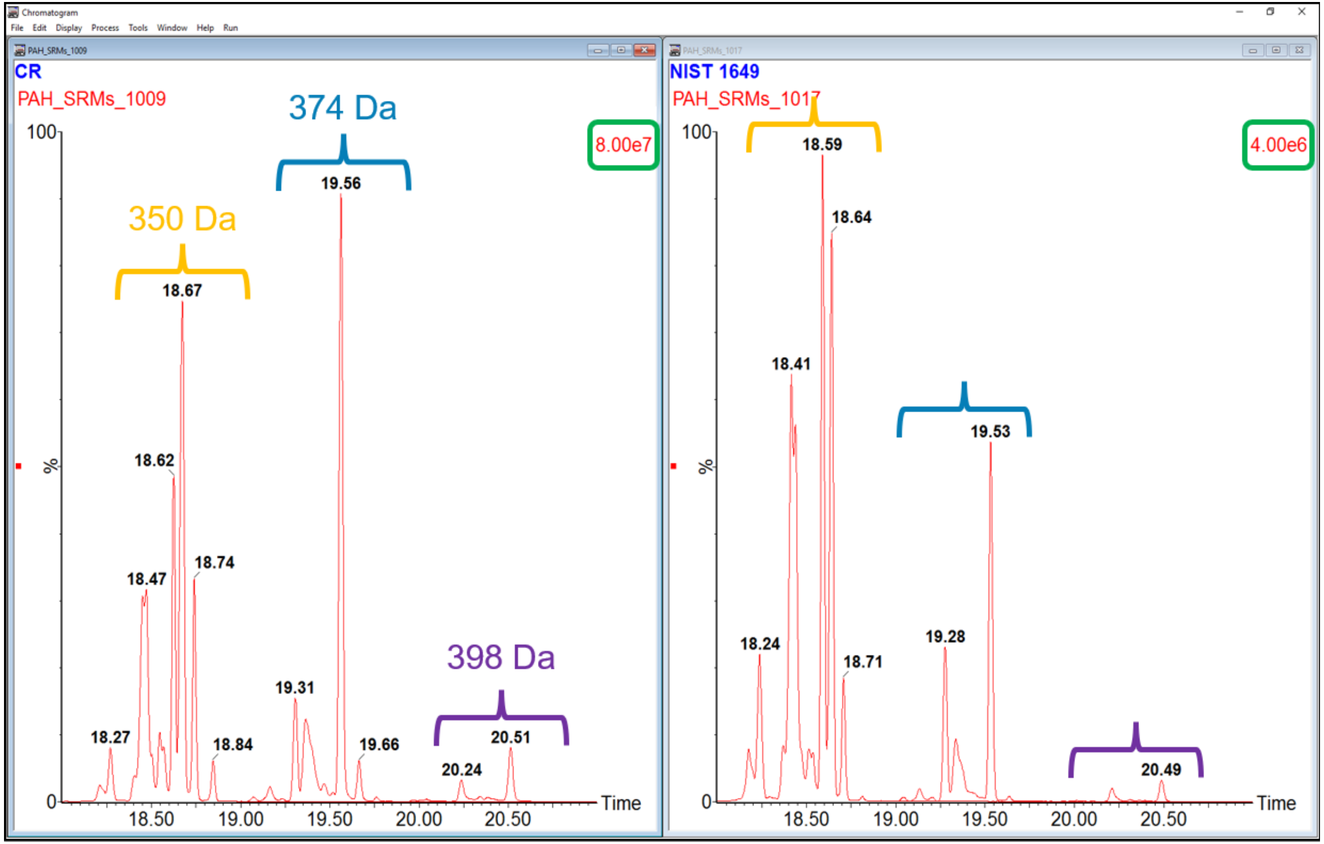


Comparing HMW PAH Profiles of Different MPs

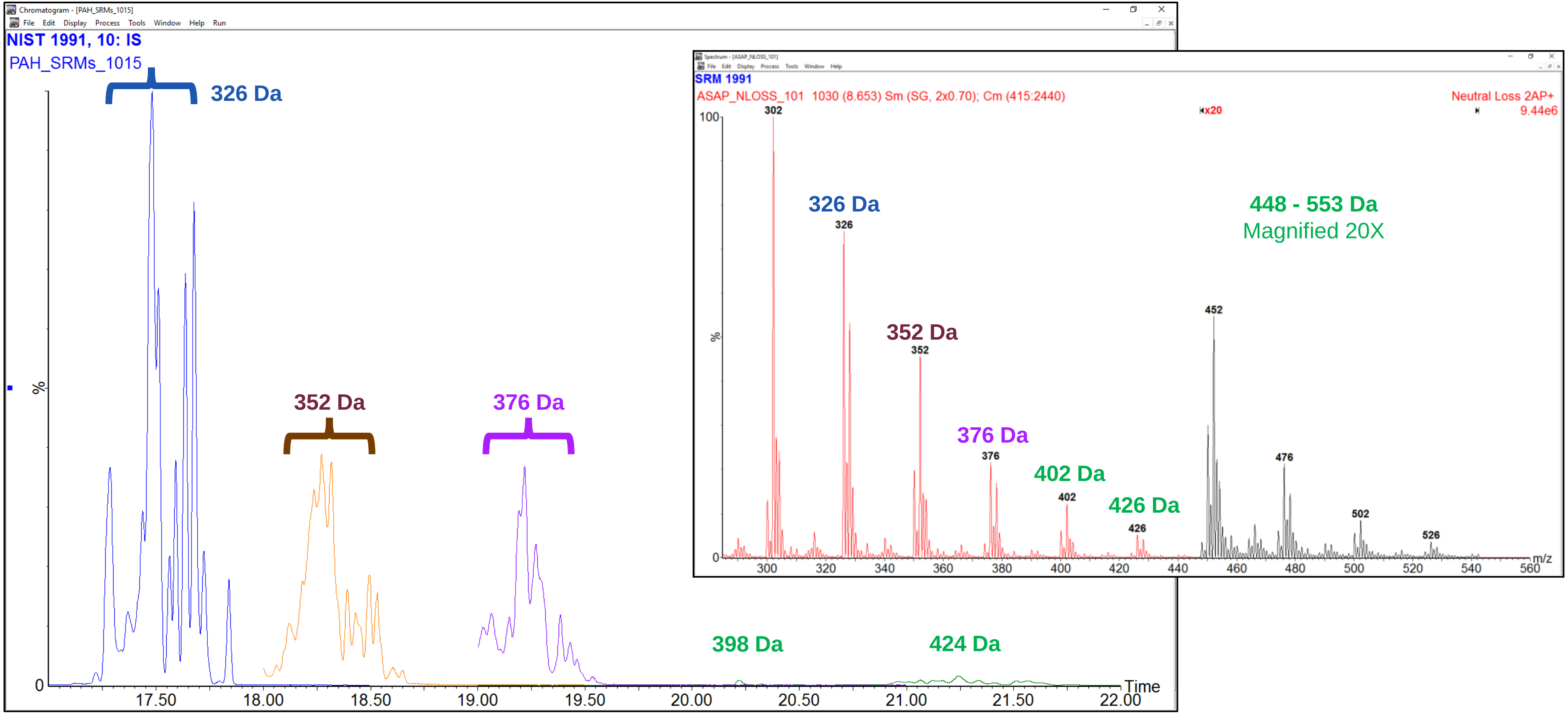


Comparing MP with NIST 1649 (Urban Dust)

Waters™



MRM Chromatogram v. NLoss Direct Probe Spectrum



Conclusions

Waters™

- Analysis of an expanded range of HMW PAHs in unfractionated extracts of MPs was achieved using a standard GC-APCI QqQ configuration combined with a simple, generic microextraction
- Charge transfer, atmospheric pressure chemical ionization facilitated the implementation of a class-specific MRM acquisition scheme
- Only minor modification to the original GC method required
- Nitrogen carrier gas achieved elution of HWM PAHs with symmetric, narrow peaks through the use of flow programming

- Further investigation of HMW PAHs for potential source markers and toxic compounds is enabled with this approach

Acknowledgements

Waters™

- Stephanie Crombie
- Daniel Furlong

Government of Canada / Gouvernement du Canada

Environment and Climate Change Canada

Thank you for your attention!

Environmental Measurement Symposium

a combined meeting of the Forum on Environmental Accreditation and the National Environmental Monitoring Conference