Integrated air quality monitoring technology for high-volume, low-cost measurements of indoor air quality

Douglas Booker

NAQTS

UKIEG Conference 2018 - Ventilation, Indoor Air Quality and Health, 17th May 2018

Background

National Air Quality Testing Services (NAQTS) is a social business that is passionate about improving the quality of life. We seek to improve awareness of indoor air quality through widespread public and commercial monitoring using our holistic, high-quality, air pollution monitoring technology.

Our technology incorporates the latest developments in low-cost sensor technologies, alongside a regulatory grade Condensation Particle Counter, Thermal Desorption tubes, and other environmental measurements, the NAQTS V1000 is a portable air quality monitoring station designed to be easy-to-use for high-volume, lower-cost air quality measurements.

Based in UK (Lancaster University Environment Centre and Cardiff), and in Ann Arbor, Michigan, USA.

Lancaster University

Co-located with Lancaster Environment Centre (LEC) one of the largest multi-disciplinary environment centres in the world

It combines an academic university department with a number of businesses

PhD Projects

1. Energy Efficiency & IAQ
2. Particulate Matter Mitigation
3. IAQ & Environmental Justice

Technology

PN - CPC with 20:1 pre-dilution (IPA, d_{50} 15nm)

CO, NO_2 - Multiple Electrochemical and Metal Oxide sensors

VOCs - Electrochemical, Metal Oxide and Thermal desorption tubes for GC-MS Analysis.

CO_2 - NDIR

T, P, RH – BME280
Noise – dBA
Location – GPS
Vibration – 3D accelerometer and 3D Gyro
Web GUI with SQL Database

Metrology

PN Calibration in accordance with ISO 27891


CERTIFICATE OF CALIBRATION

ISSUED BY Ricardo-AEA Ltd trading as Ricardo Energy & Environment

DATE OF ISSUE 15/02/2018 CERTIFICATE NUMBER PMC328

ilac-MRA UKAS CALIBRATION 0401

Ricardo Energy & Environment
Particle Measurement Centre
Unit 2 Ludbridge Mill
Reading Road, East Hendred
Wantage, Oxfordshire
OX12 8LN, UK

Page 1 of 4 pages
Approved Signatory
Name
Signature

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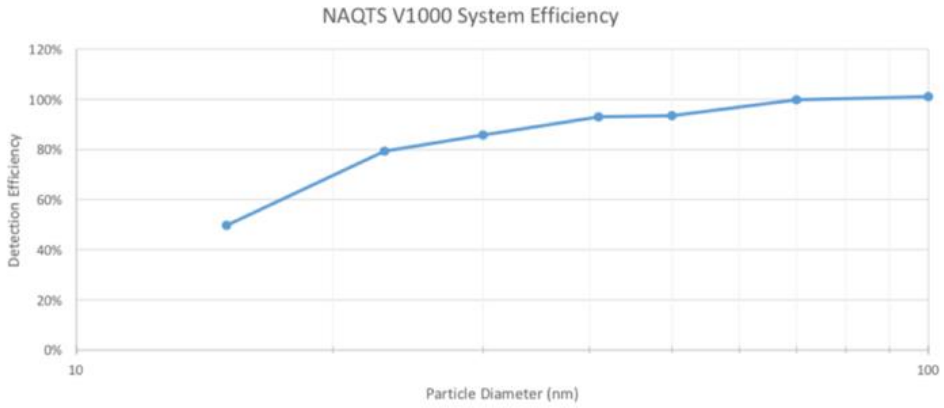
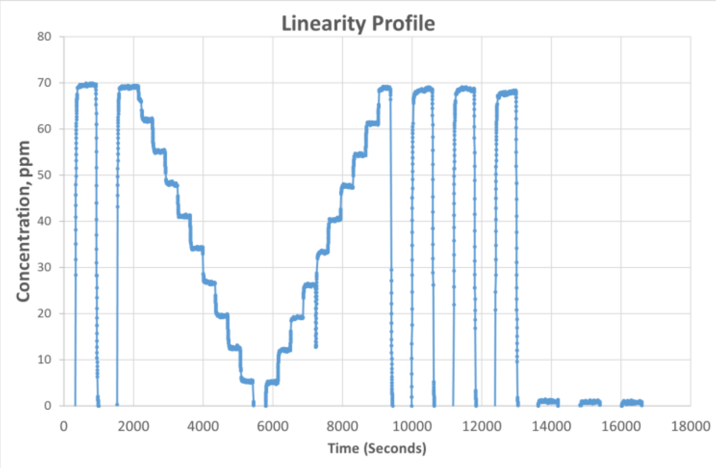
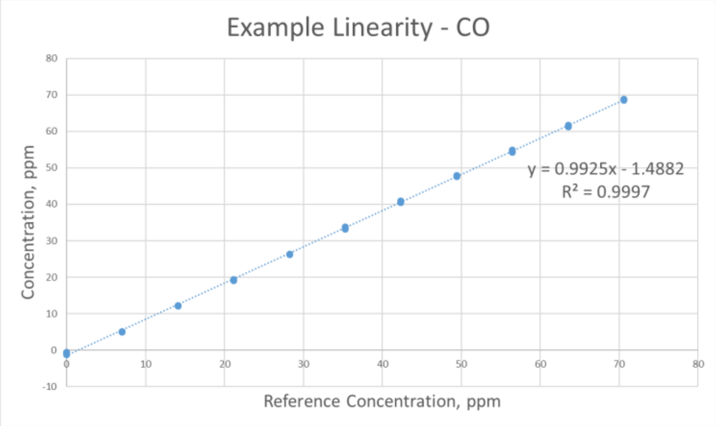
Customer : To: National Air Quality Testing Services Ltd
Address : Lancaster Environment Centre, Lancaster University, LA1 4YQ



Gas calibration (Zero/span linearity)





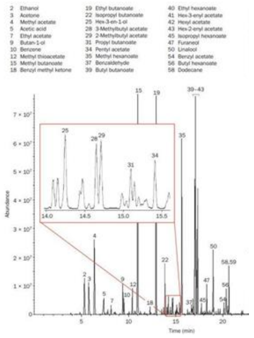
Applications

INSIDE:OUTSIDE SCHOOLS IN THE BRUSSELS AREA

Capturing real-time pollution levels during school drop off/pick up times, as well as levels of student exposure in the classroom

VOC SPECIATION

Real – time VOCS / thermal desorption results



V1000 accommodates 4 Active TD tubes that can be configured to sample on events, or on a timer basis

BENCHMARKING VEHICLES "COMFORT"

Air Quality, Noise, and Vibration

Data on in-cabin comfort from 100s of vehicles

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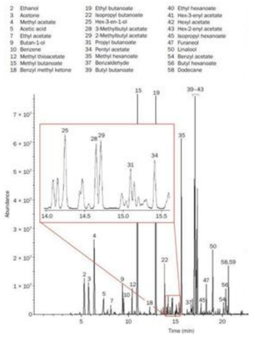


BENCHMARKING VEHICLES "COMFORT"
Air Quality, Noise, and Vibration

Data on in-cabin comfort from 100s of vehicles

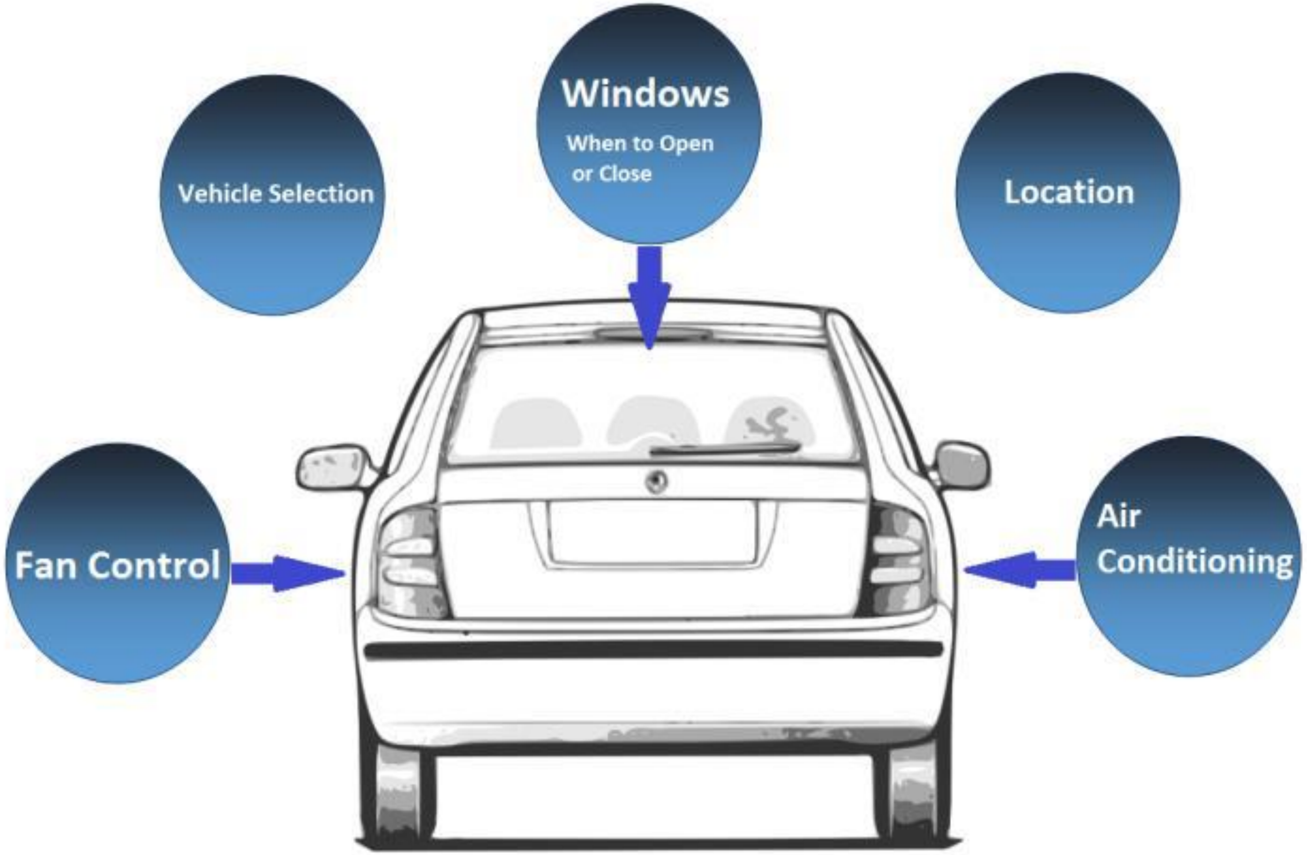
Vehicle Interior Air Quality

101 minutes per day in vehicles (Dong et al. 2004)

Immediate proximity to significant pollutant sources (other vehicles), plus in urban areas, high outdoor concentrations

The challenges for Vehicle Interior Air Quality (VIAQ) are similar to IAQ

Studies are done jointly with Emissions Analytics.



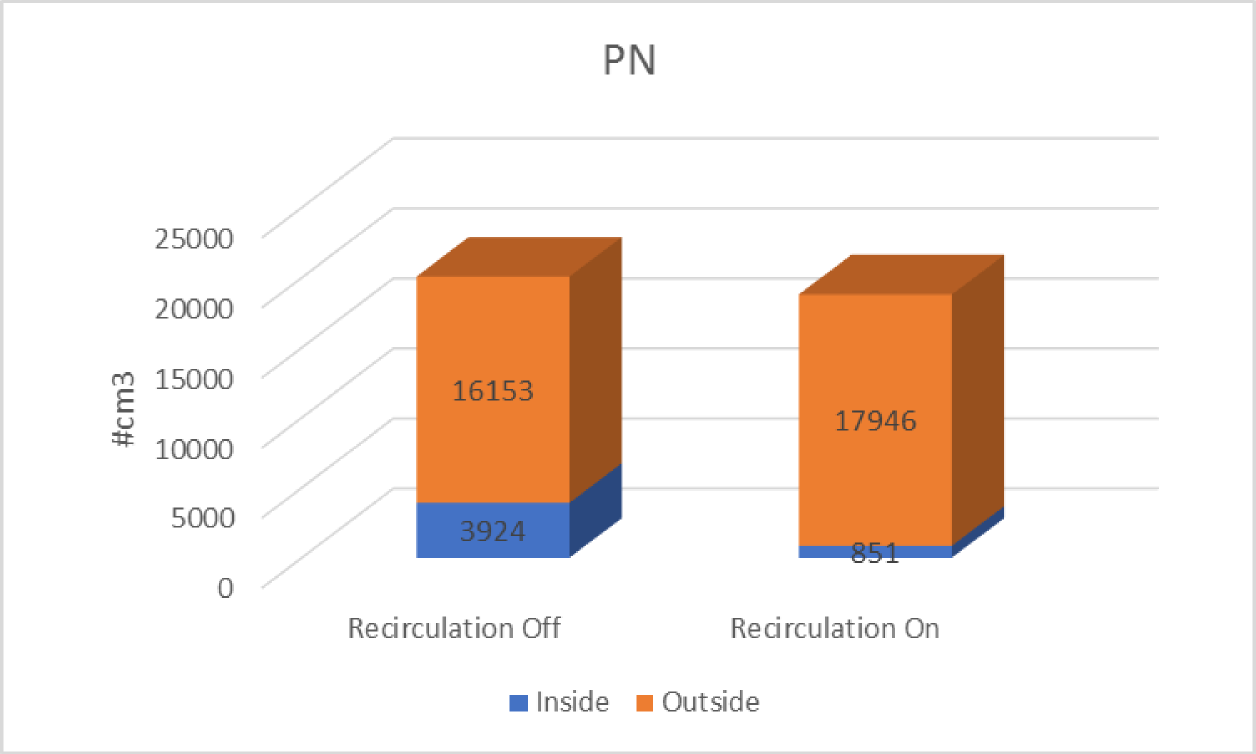
Dong, L.; Block, G.; Mandel, S. Activities contributing to total energy expenditure in the Unites States: Results from the NHAPS study. Int. J. Behavioral Nutrition Phys. Activity 1, 4 (2004)
Müller, D; Klingelhöfer, D; Uibel , s; Groneberg, D.A. Car indoor air pollution - analysis of potential sources. *Journal of Occupational Medicine and Toxicology* 6, no. 33 (2011): 1-7.

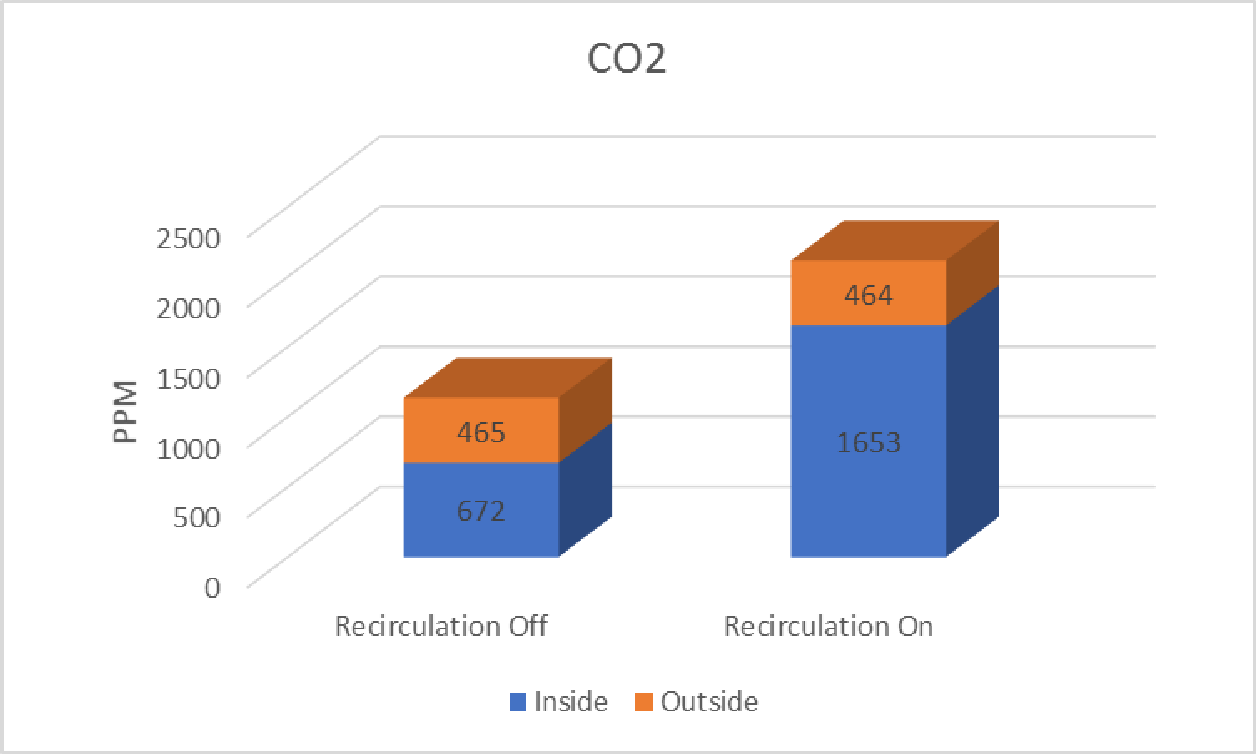
Q1: How much ambient air pollution is coming into the vehicle?

Simultaneous measurements of inside and outside the vehicle

Immediate proximity to significant pollutant sources (other vehicles), plus in urban areas, high outdoor concentrations

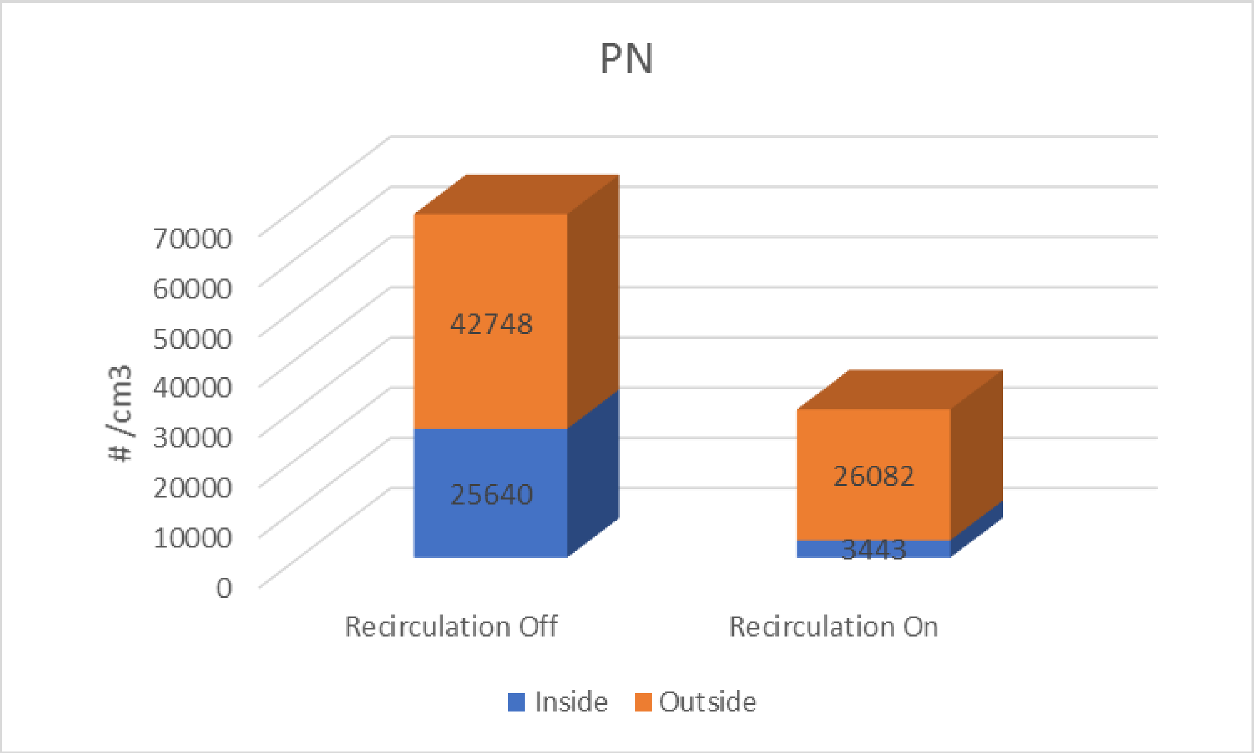
German Sedan

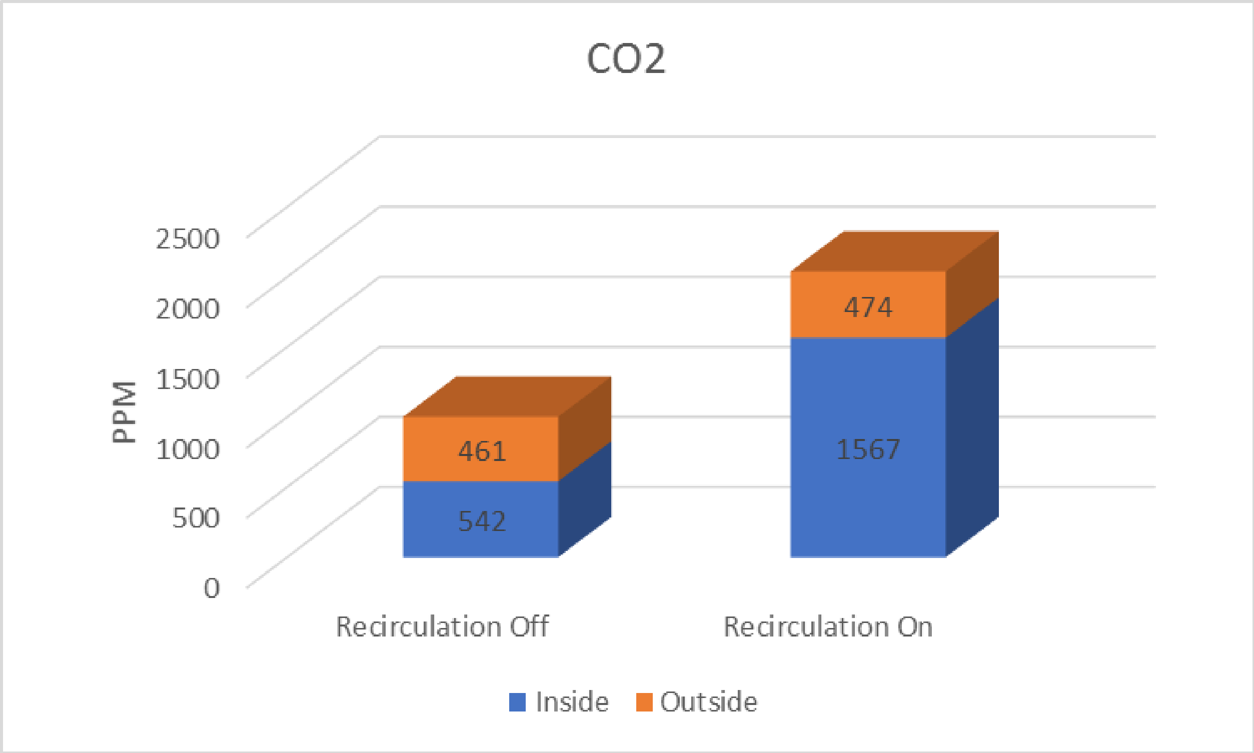




	INGRESS RATIO	STUFFINESS FACTOR
Recirculation Off	24%	1.4
Recirculation On	5%	3.6

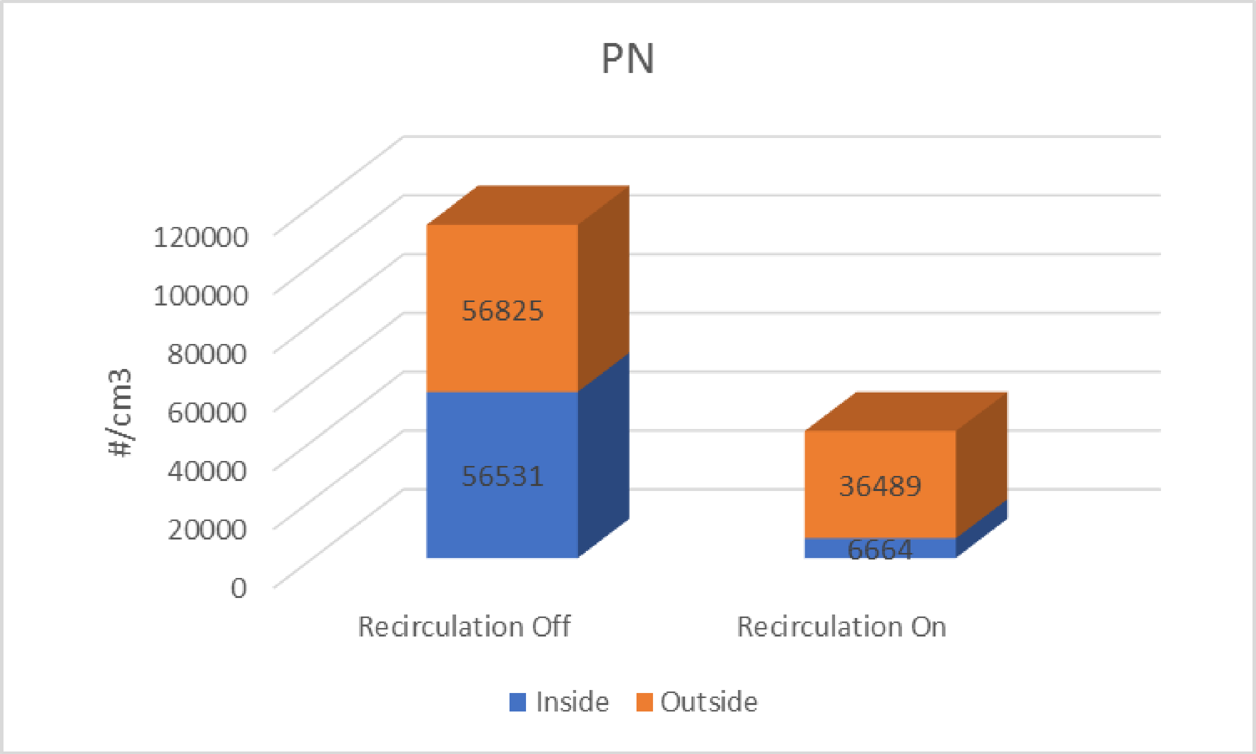
American Hatchback

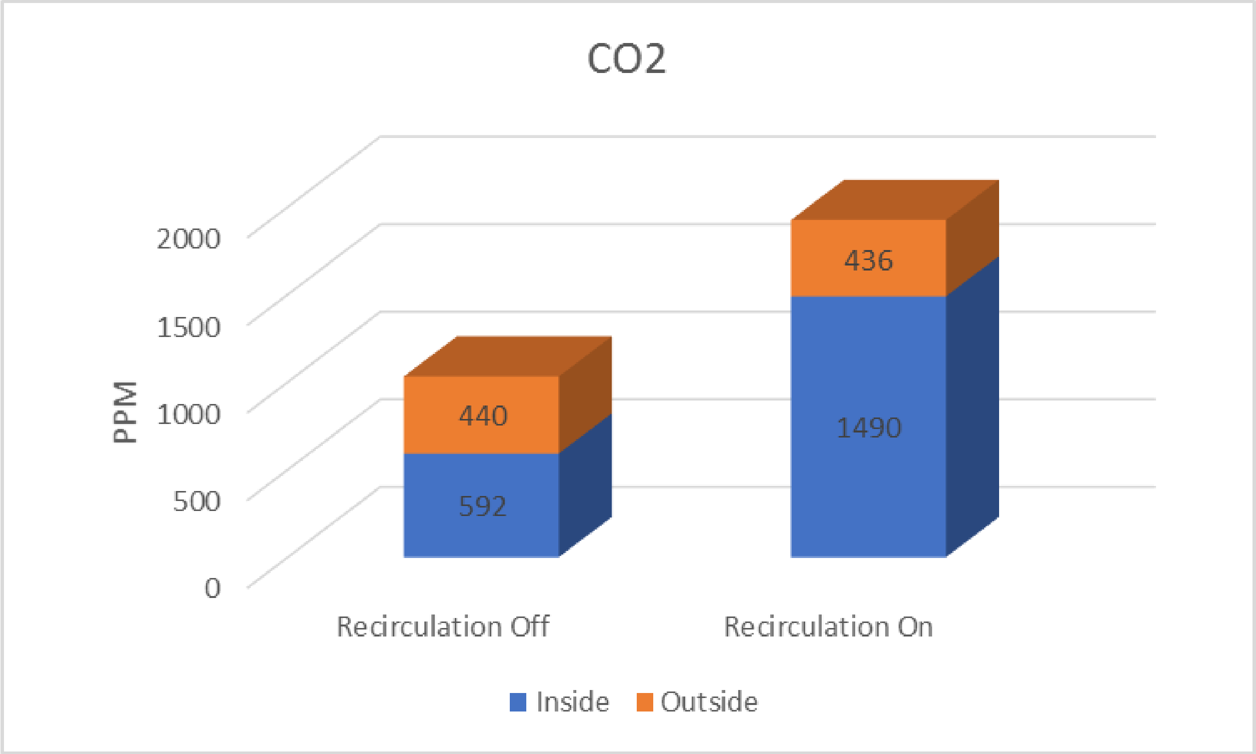




	INGRESS RATIO	STUFFINESS FACTOR
Recirculation Off	60%	1.2
Recirculation On	13%	3.3

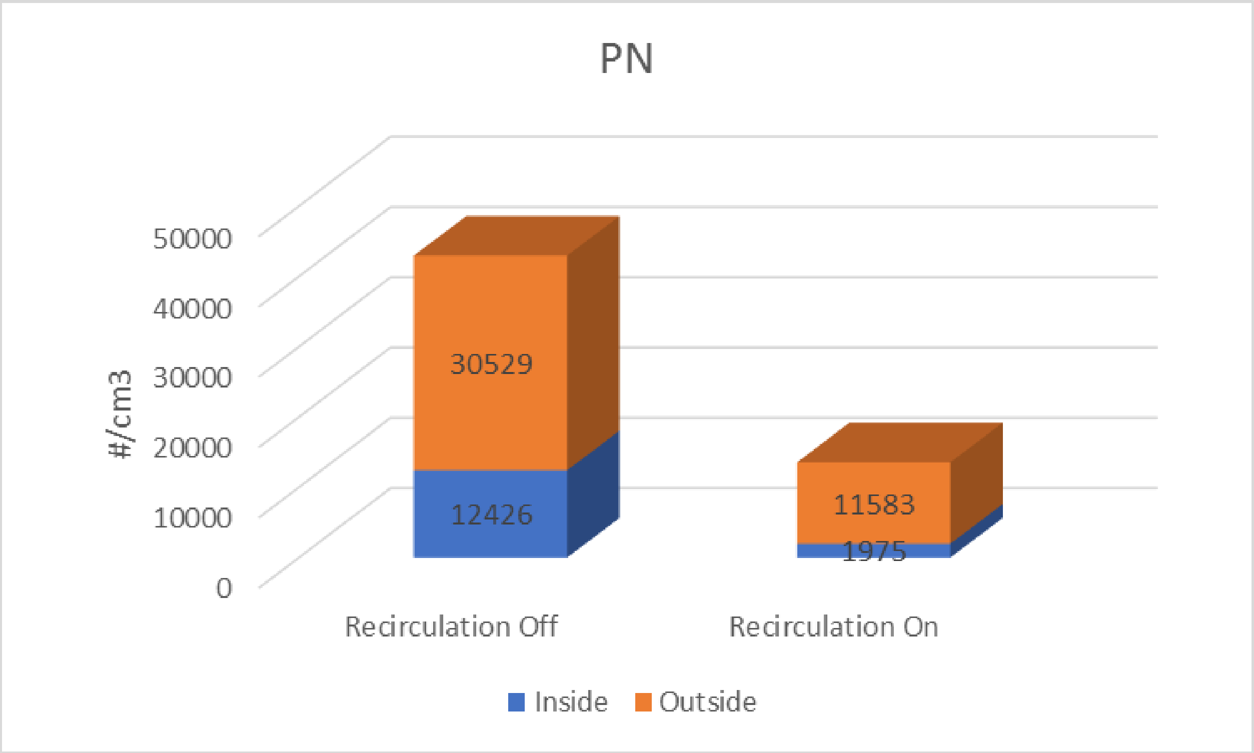
Japanese Crossover

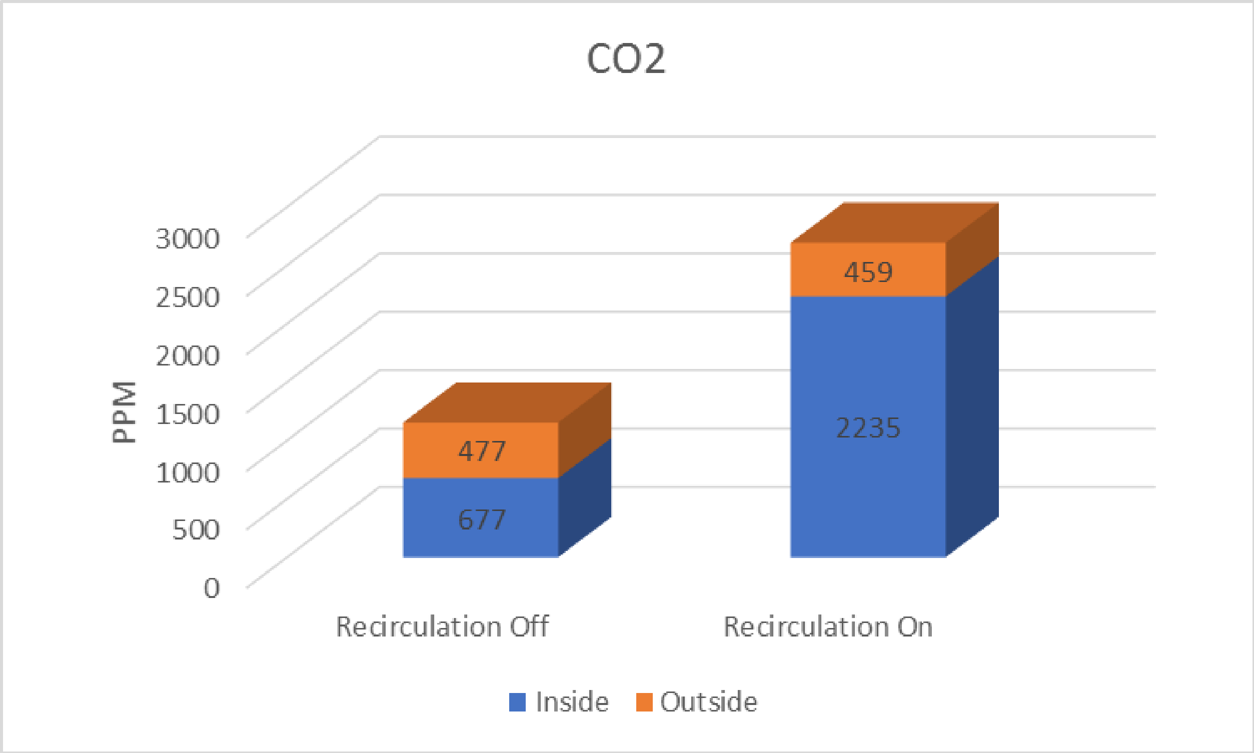




	INGRESS RATIO	STUFFINESS FACTOR
Recirculation Off	99%	1.3
Recirculation On	18%	3.4

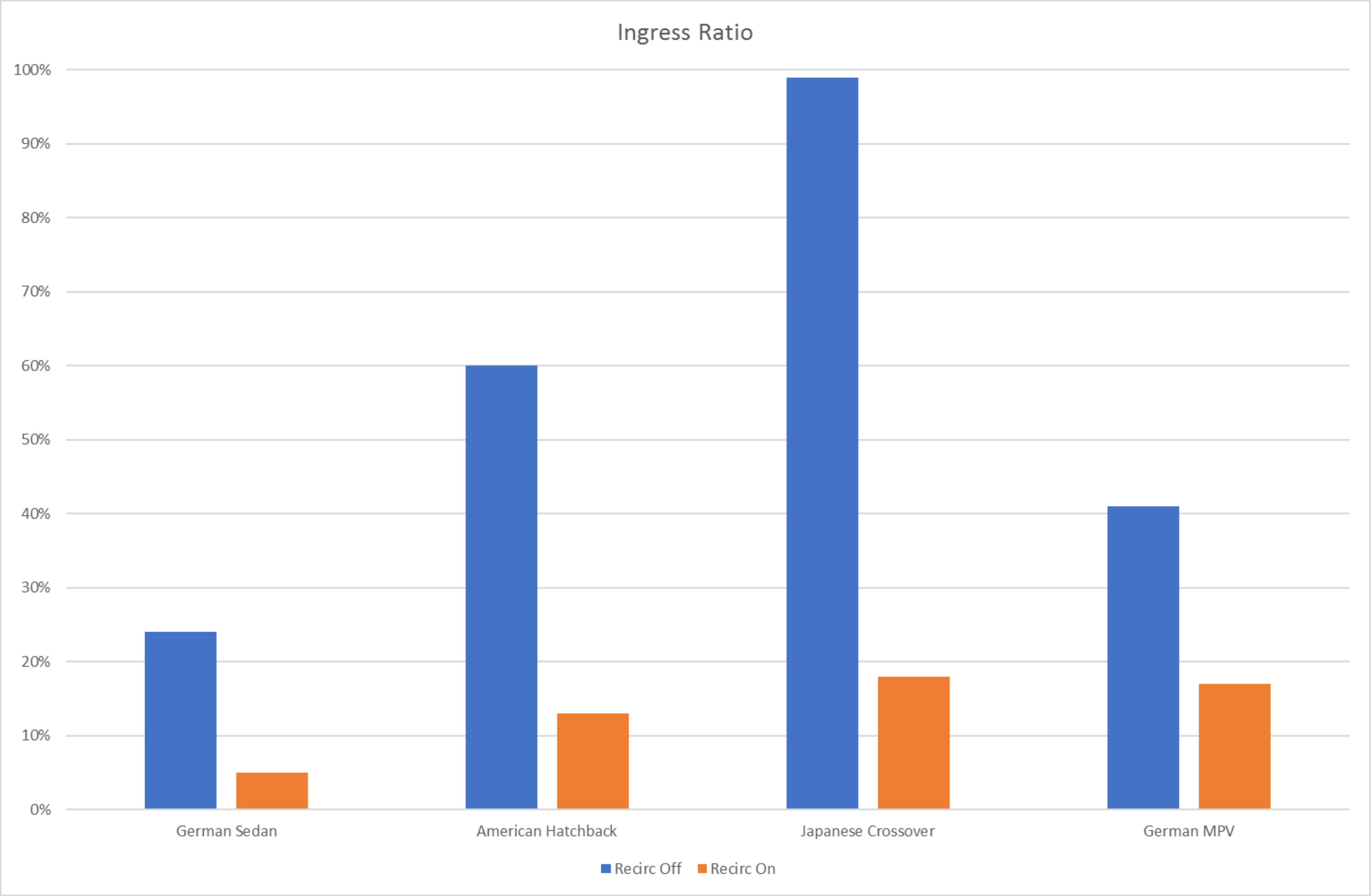
German MPV





	INGRESS RATIO	STUFFINESS FACTOR
Recirculation Off	41%	1.4
Recirculation On	17%	4.97

Ultrafine Particles – Ingress Ratio



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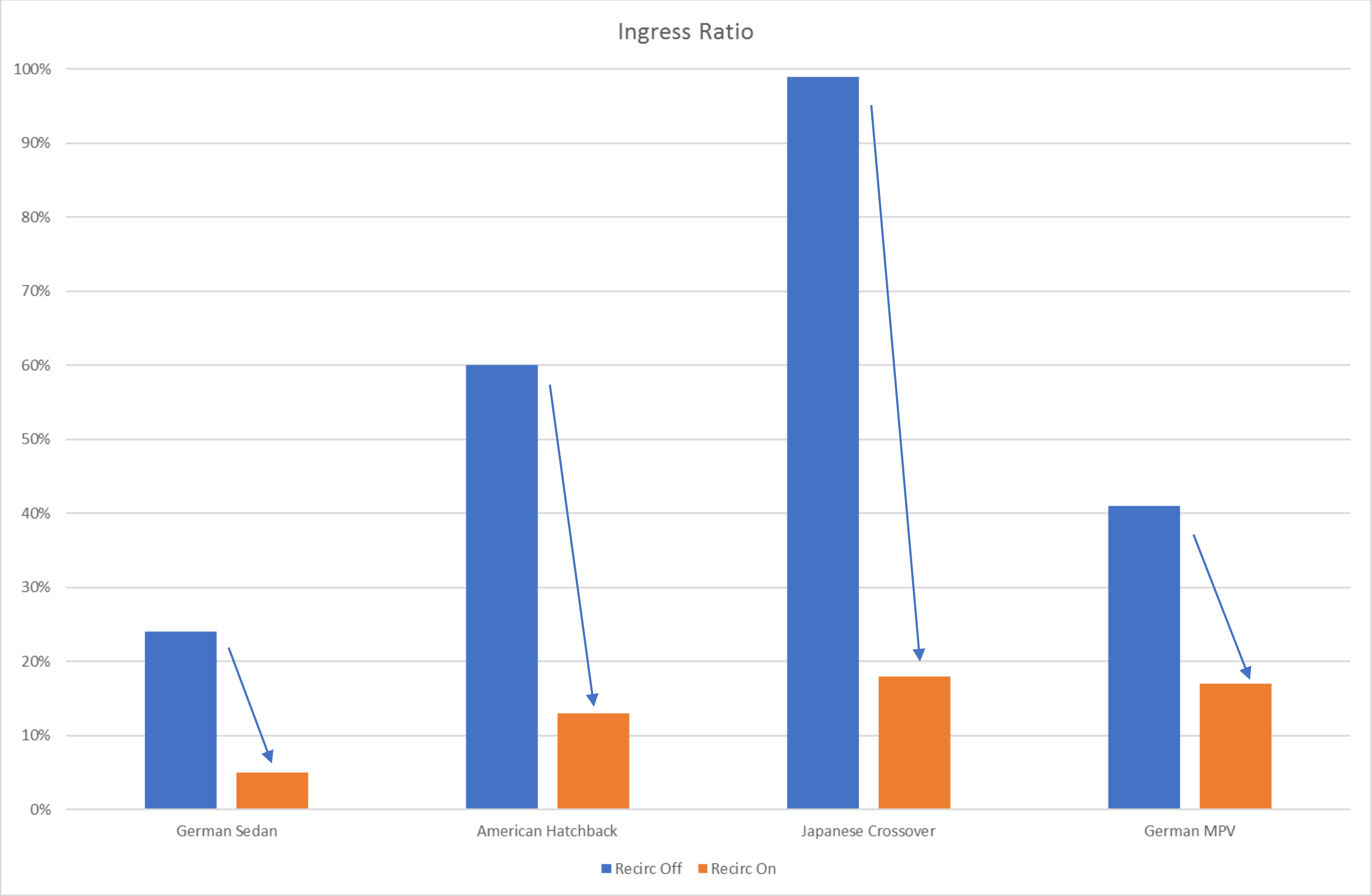
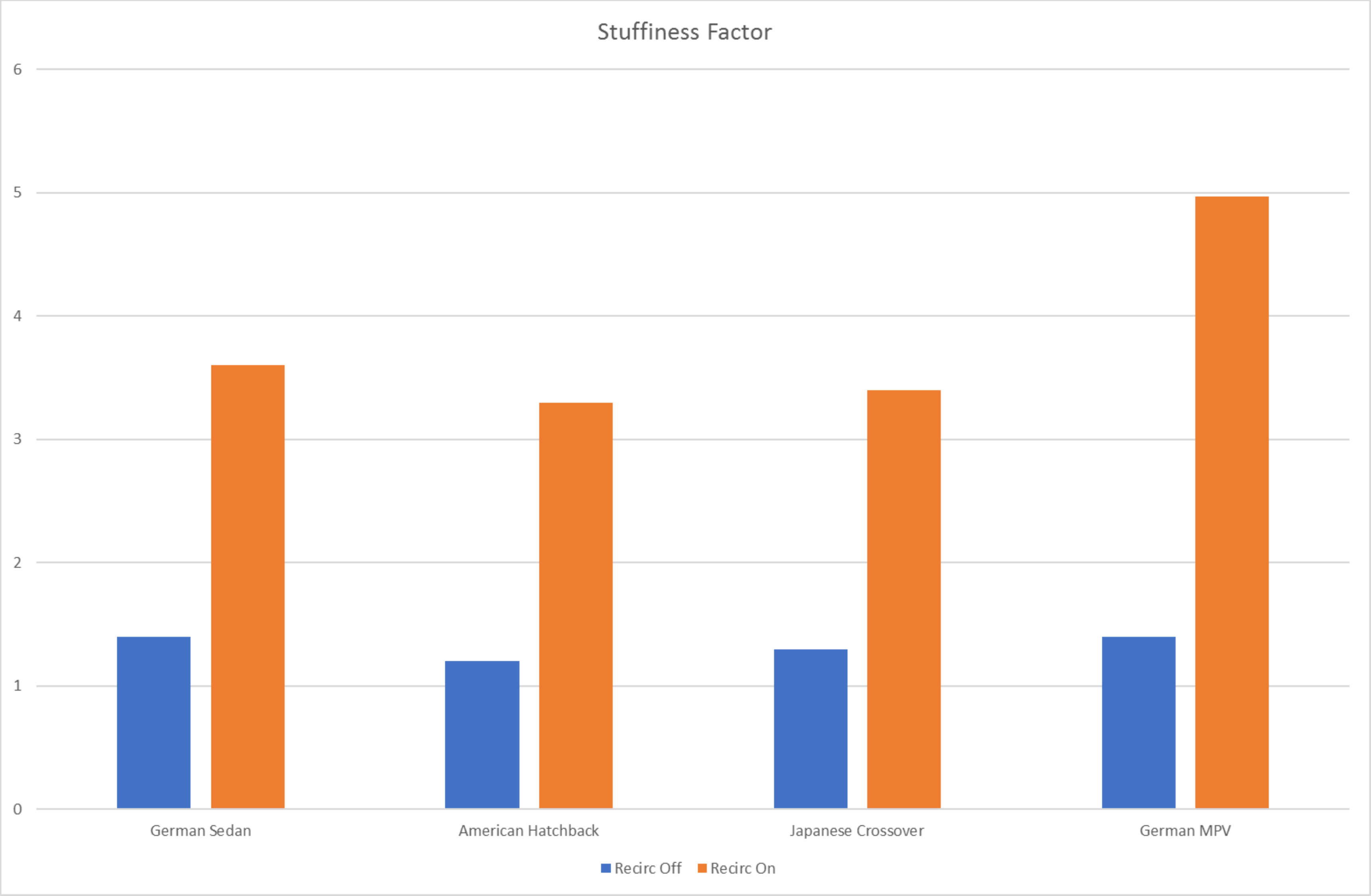


The data from these four vehicles shows the **heterogeneity of Ingress Ratios**

24-99% with recirculation mode off

5-17% with recirculation mode on

CO2 – Stuffiness Factor



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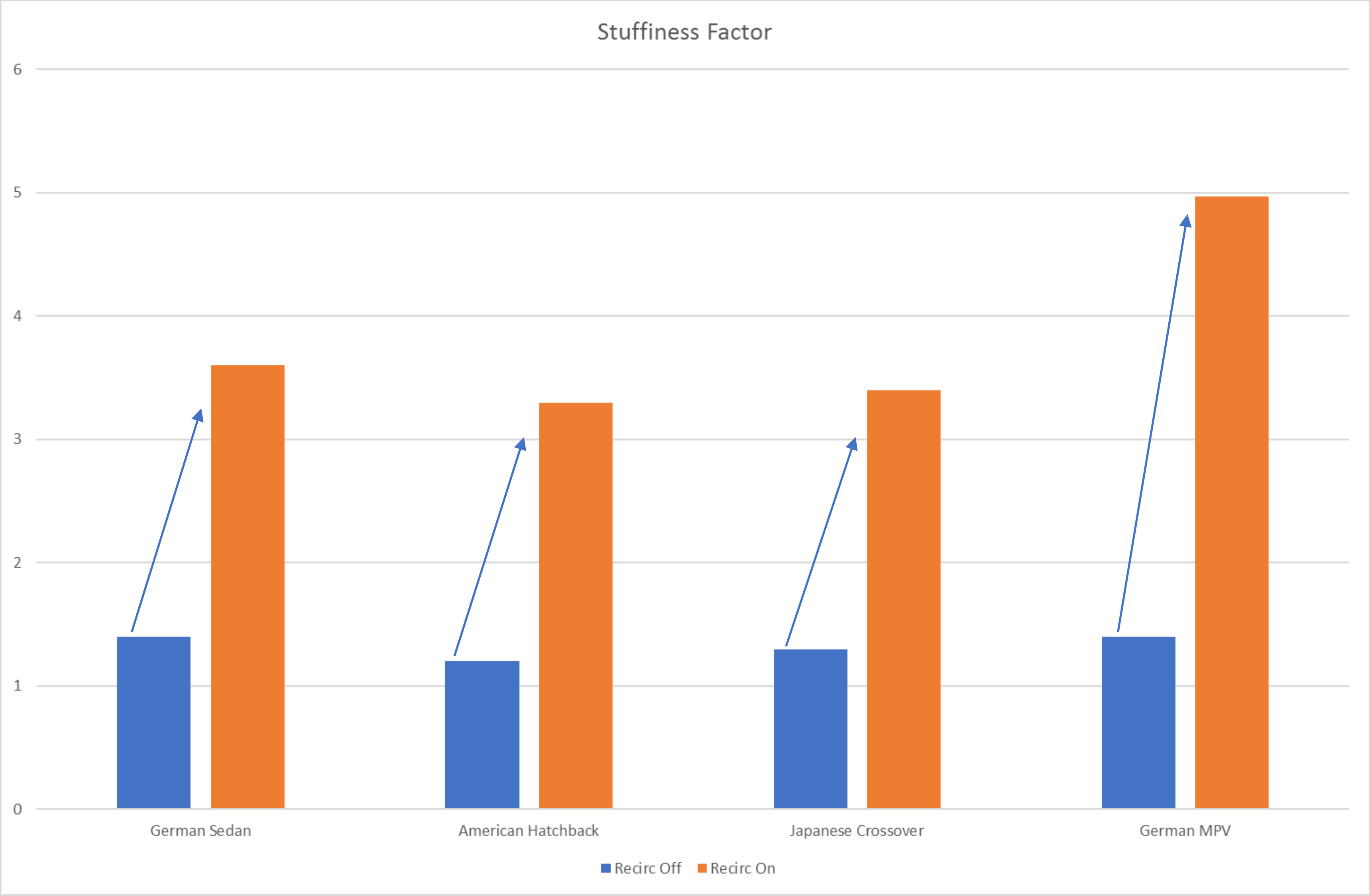


An **inherent tradeoff** between protecting passengers from ambient ingress, and adequate ventilation

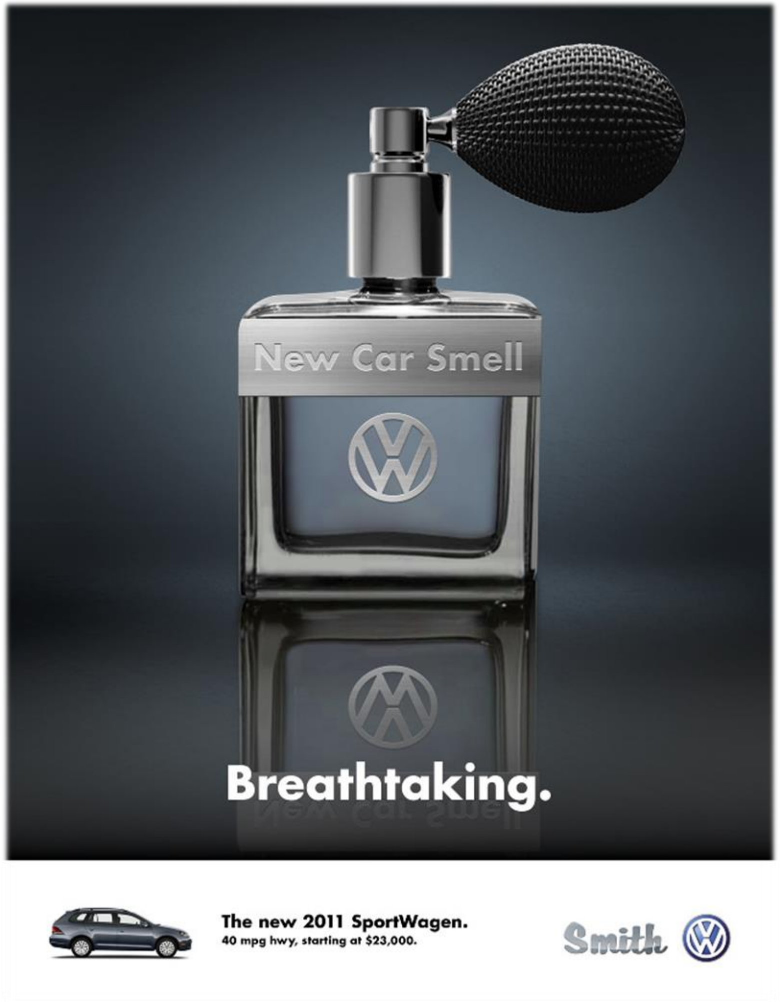
Huge influence of passenger habit on dose. By driver education, and automation of HVAC controls, exposure to PN can be reduced significantly

Q2: What are the in-vehicle sources of air pollution?

Volatile Organic Compounds (VOCs), responsible for the “new car smell”, can be emitted from an array of interior parts and components: the dashboard, interior panels, flooring materials, and many others.

Within the confined space of a vehicle, VOCs emitted from these components may reach levels that are potentially harmful to human occupants, causing symptoms such as nausea, allergies, fatigue, stinging eyes, and headaches.

Beyond affecting drivers’ and passengers’ well-being and comfort, such symptoms may have also consequences on safe driving



Experimental Set-Up (Static Baseline)

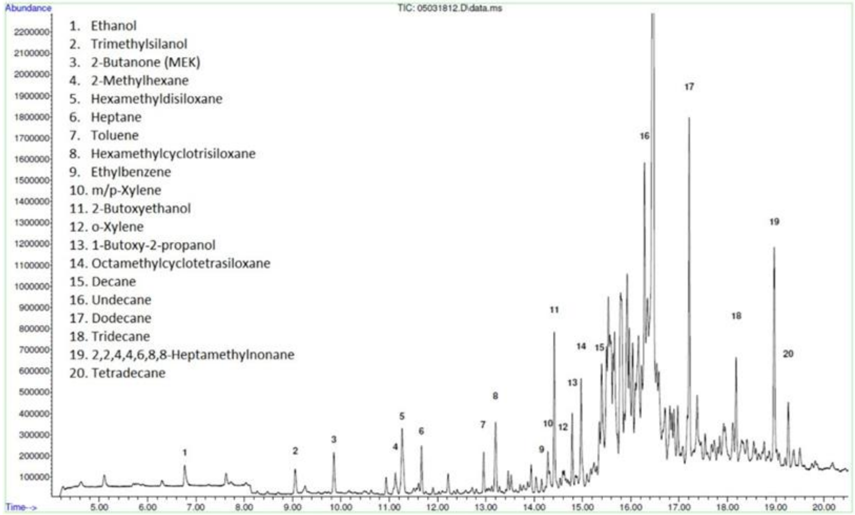
Hydrophobic TnxTA/Cg1

Integrated into NAQTS V1000

Tested inside Emissions Analytics' Stokenchurch Emissions Lab

Thermal Desorption

Agilent GC-MS, samples run on full scan mode



Top 20 peaks, Semi-quantitative (spiked with d8-Toluene, d6-benzene and d4-dichlorobenzene)

Experimental Set-Up (Real World Driving)

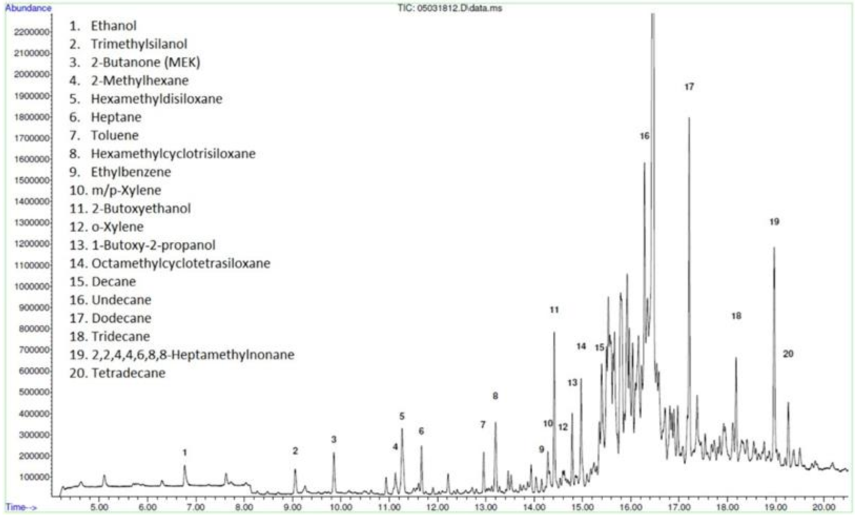
Hydrophobic TnxTA/Cg1

Integrated into NAQTS V1000

Tested dynamically on RDE-type route (Geofencing – Urban, Rural, Highway etc.) at same time as indoor-outdoor research to see VOCs ingress

Thermal Desorption

Agilent GC-MS, samples run on full scan mode



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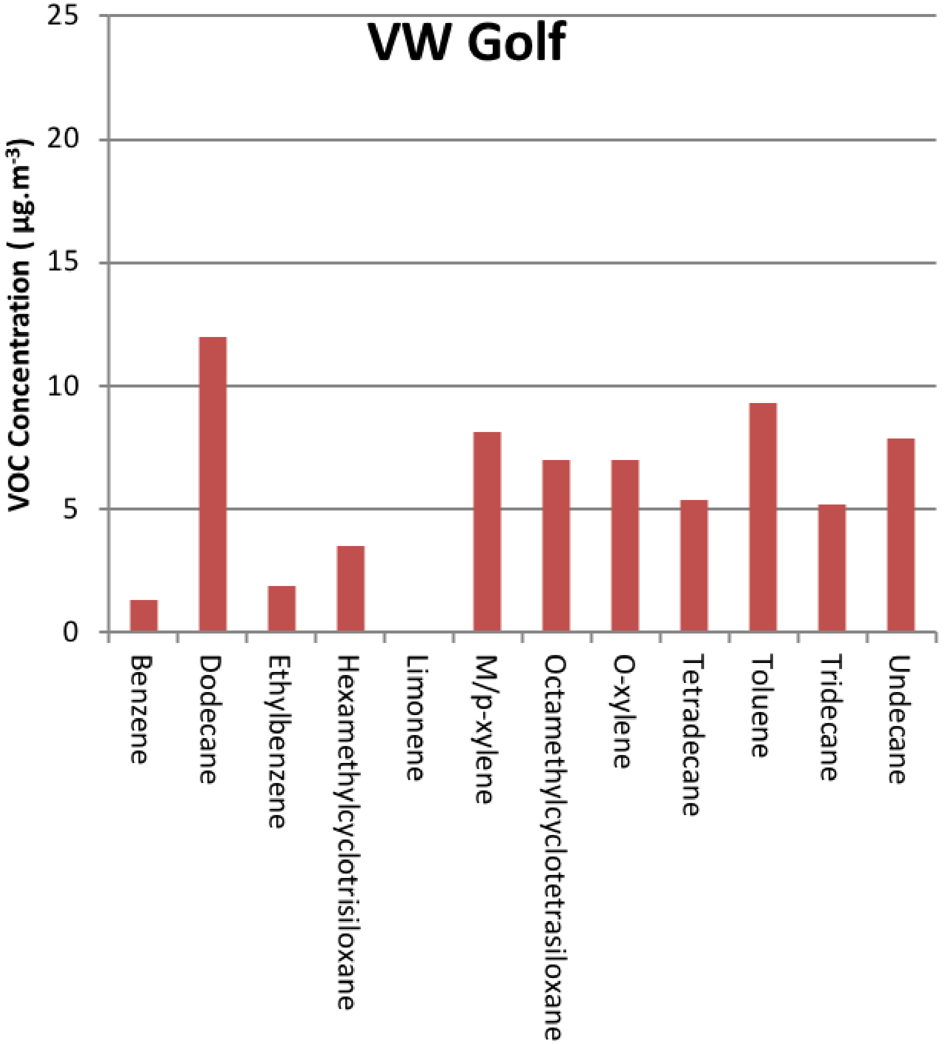
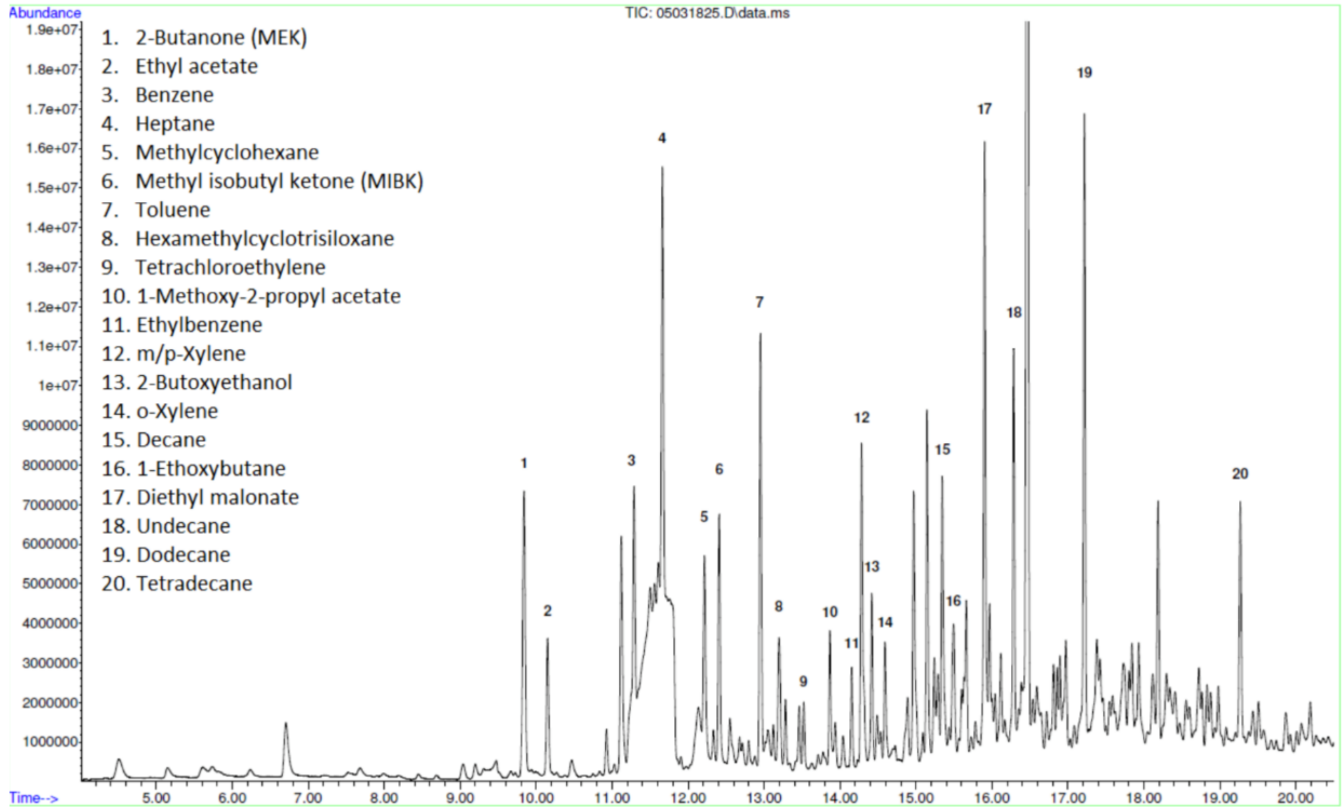
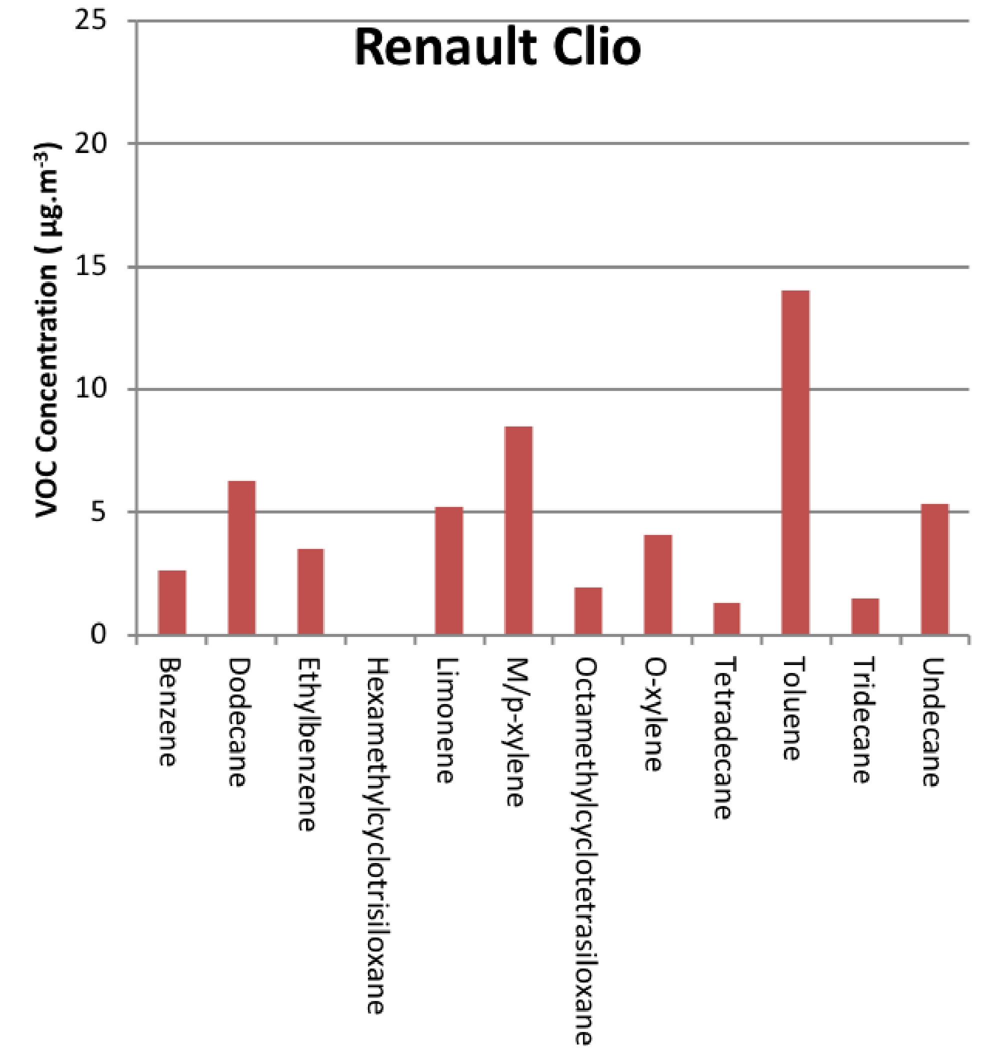
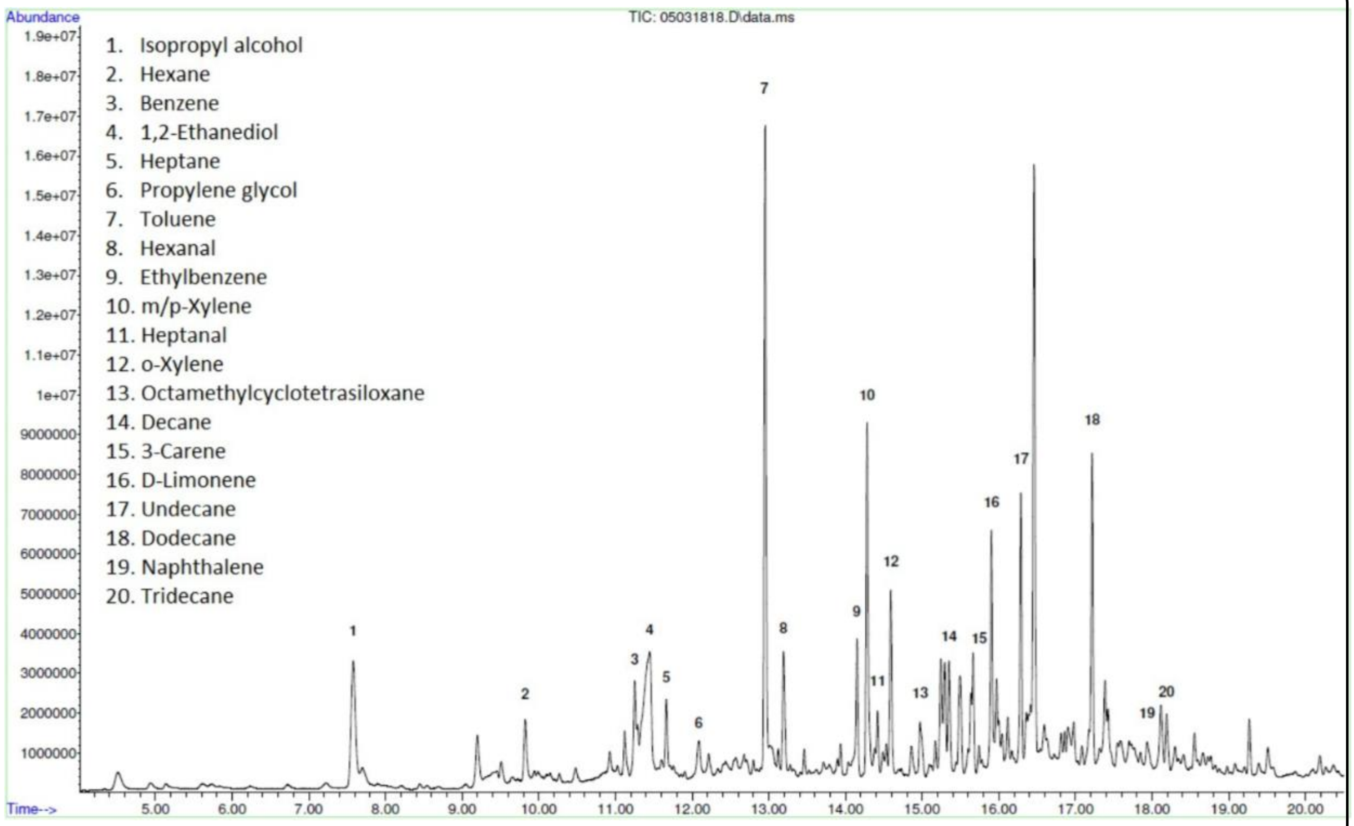
VW Golf (2011)


VW Golf
VOC Concentration (µg.m^{-3})
25
20
15
10
5
0
Benzene
Dodecane
Ethylbenzene
Hexamethylcyclotrisiloxane
Limonene
M/p-xylene
Octamethylcyclotetrasiloxane
O-xylene
Tetradecane
Toluene
Tridecane
Undecane

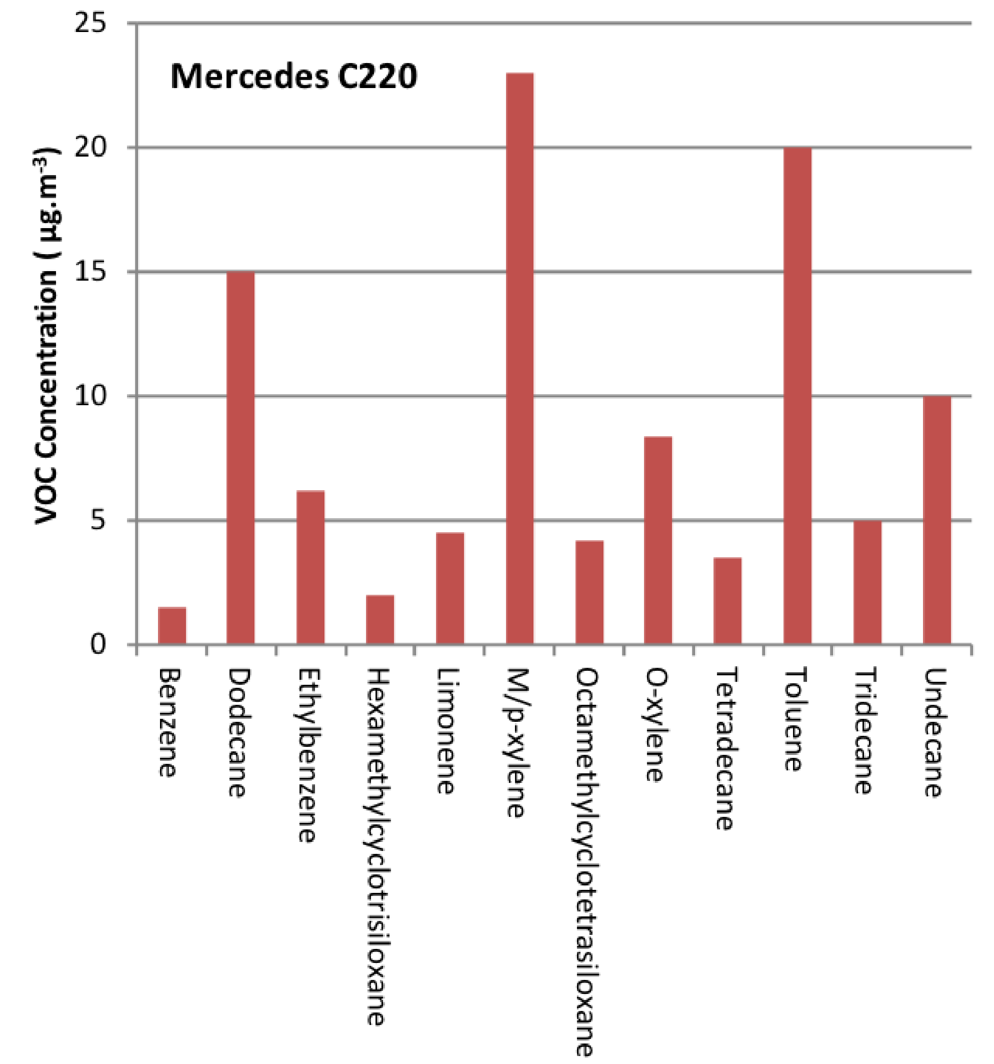

Abundance
TIC: 05031825.D\data.ms
1. 2-Butanone (MEK)
2. Ethyl acetate
3. Benzene
4. Heptane
5. Methylcyclohexane
6. Methyl isobutyl ketone (MIBK)
7. Toluene
8. Hexamethylcyclotrisiloxane
9. Tetrachloroethylene
10. 1-Methoxy-2-propyl acetate
11. Ethylbenzene
12. m/p-Xylene
13. 2-Butoxyethanol
14. o-Xylene
15. Decane
16. 1-Ethoxybutane
17. Diethyl malonate
18. Undecane
19. Dodecane
20. Tetradecane
Time-->

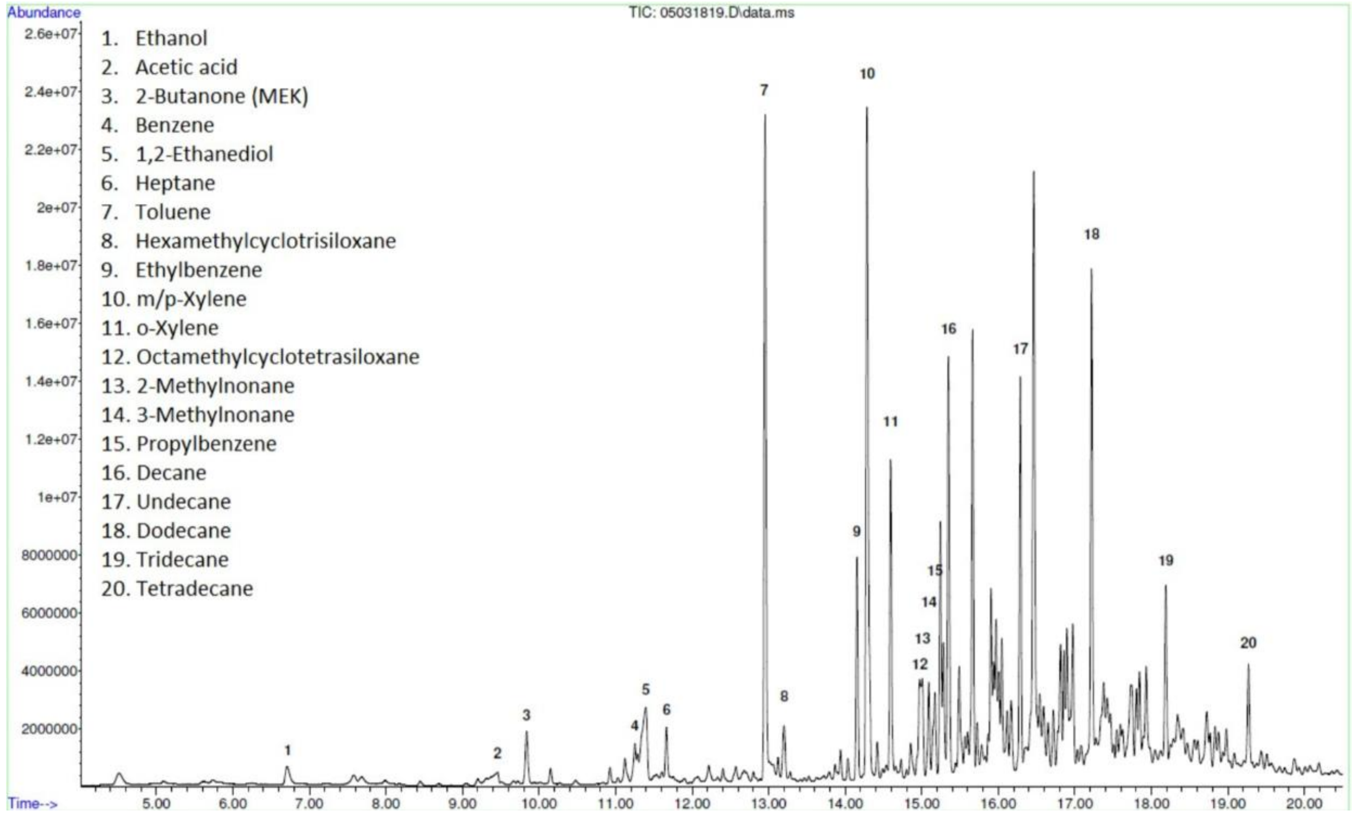
Renault Clio (2016)



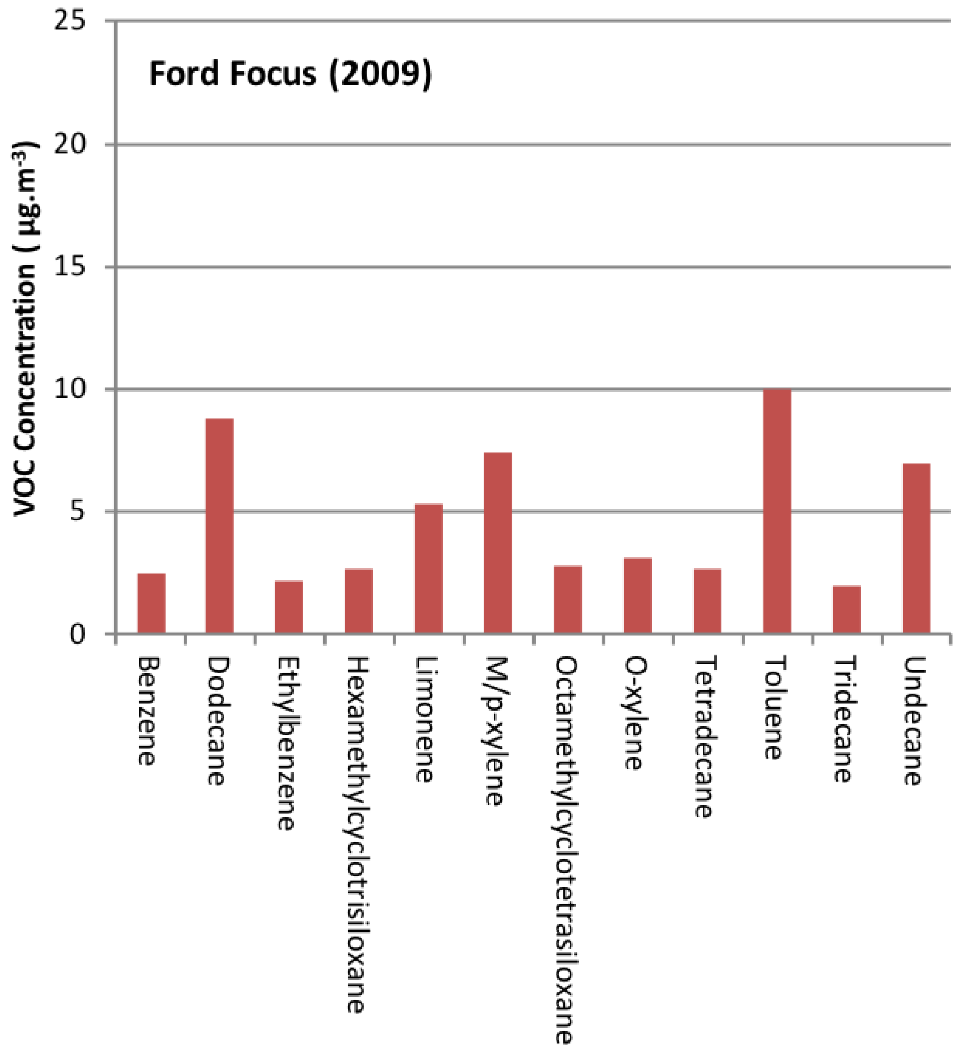


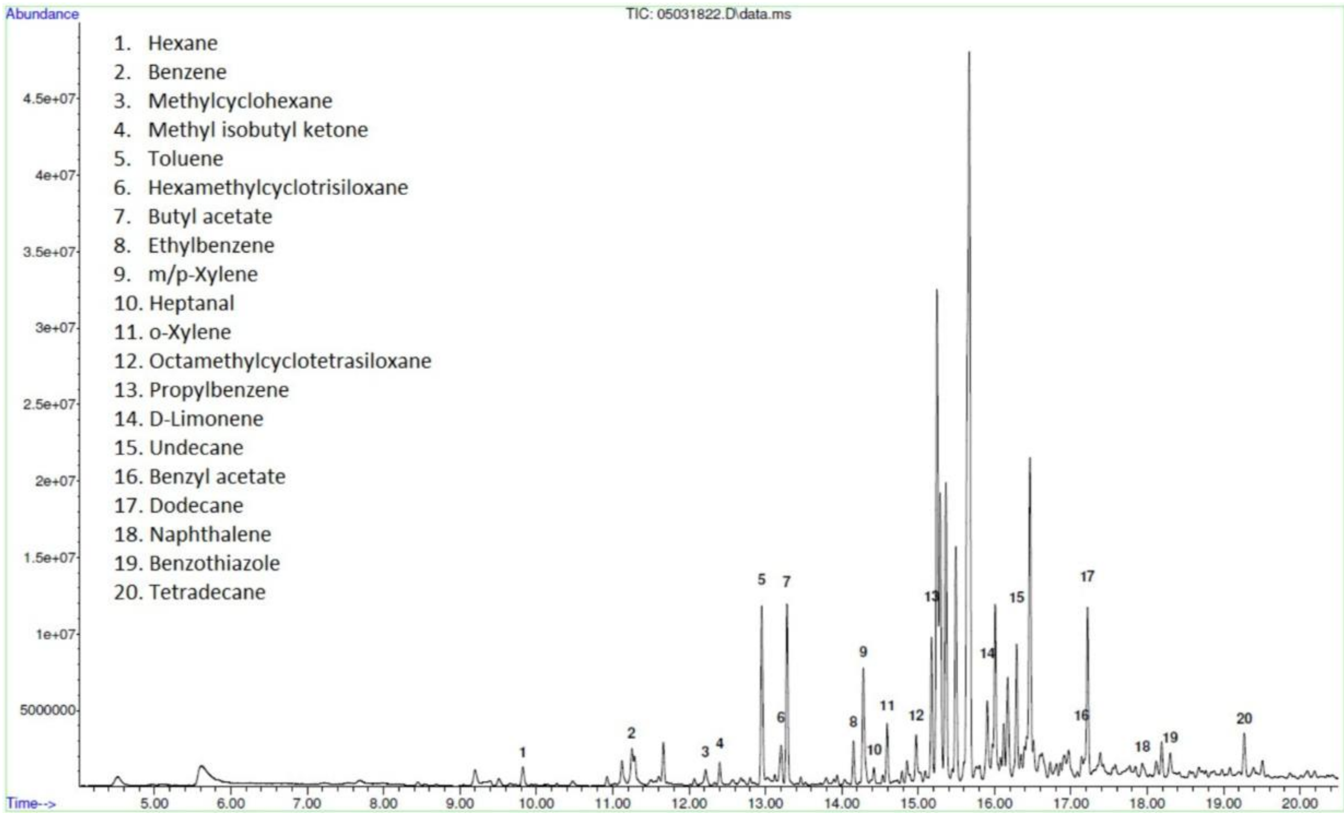
Mercedes C220 (2005)





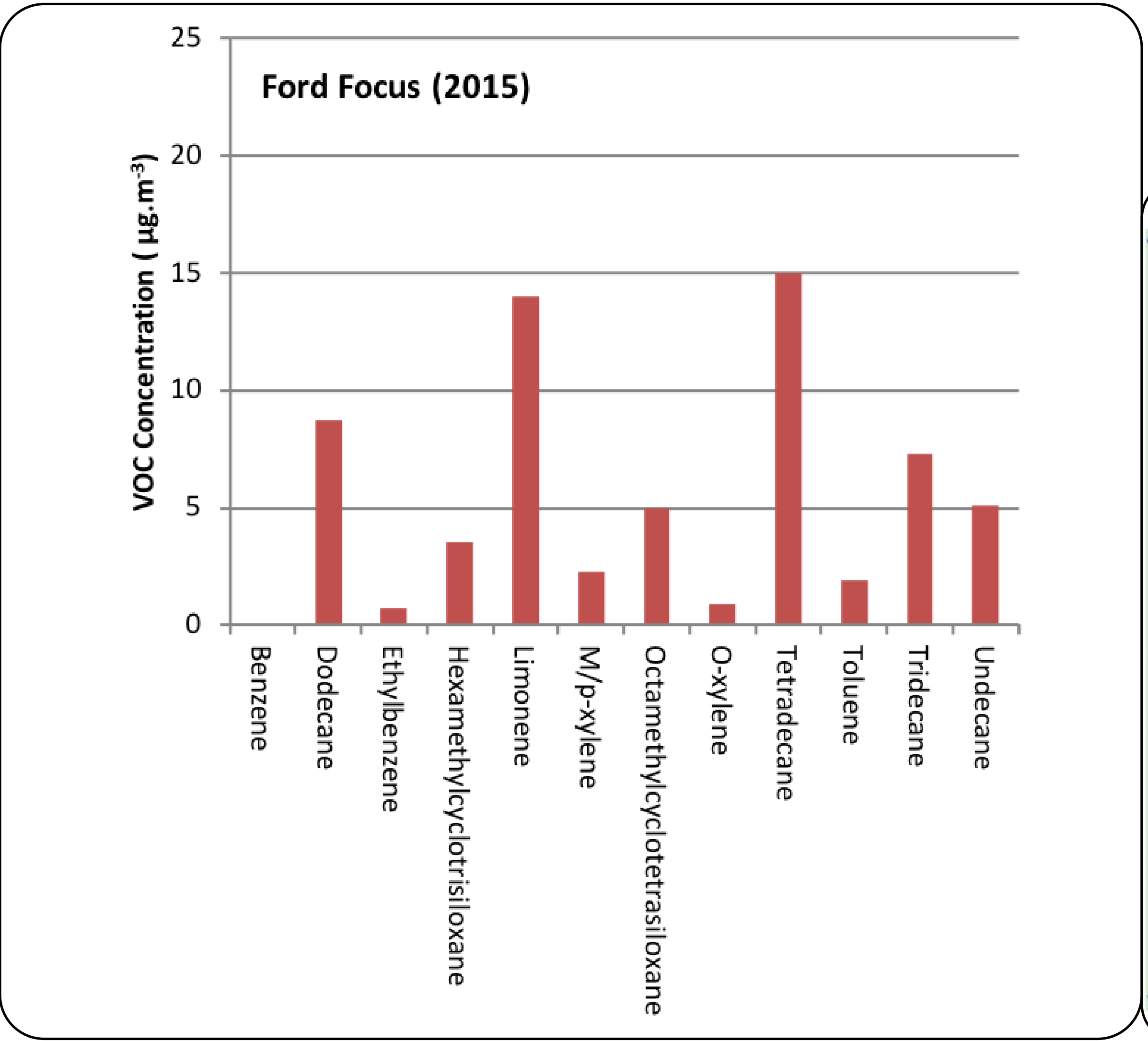
Ford Focus (2009)

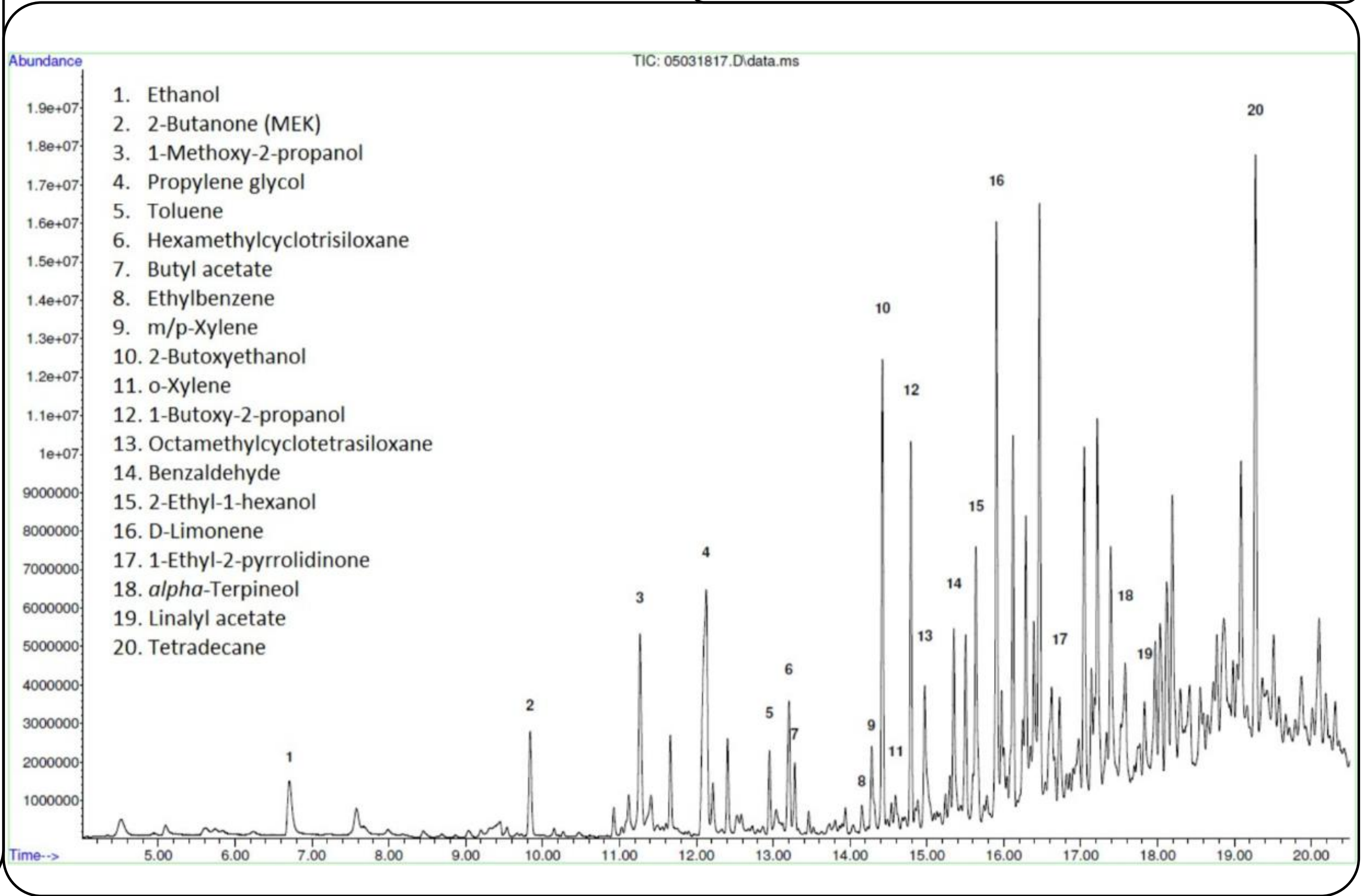




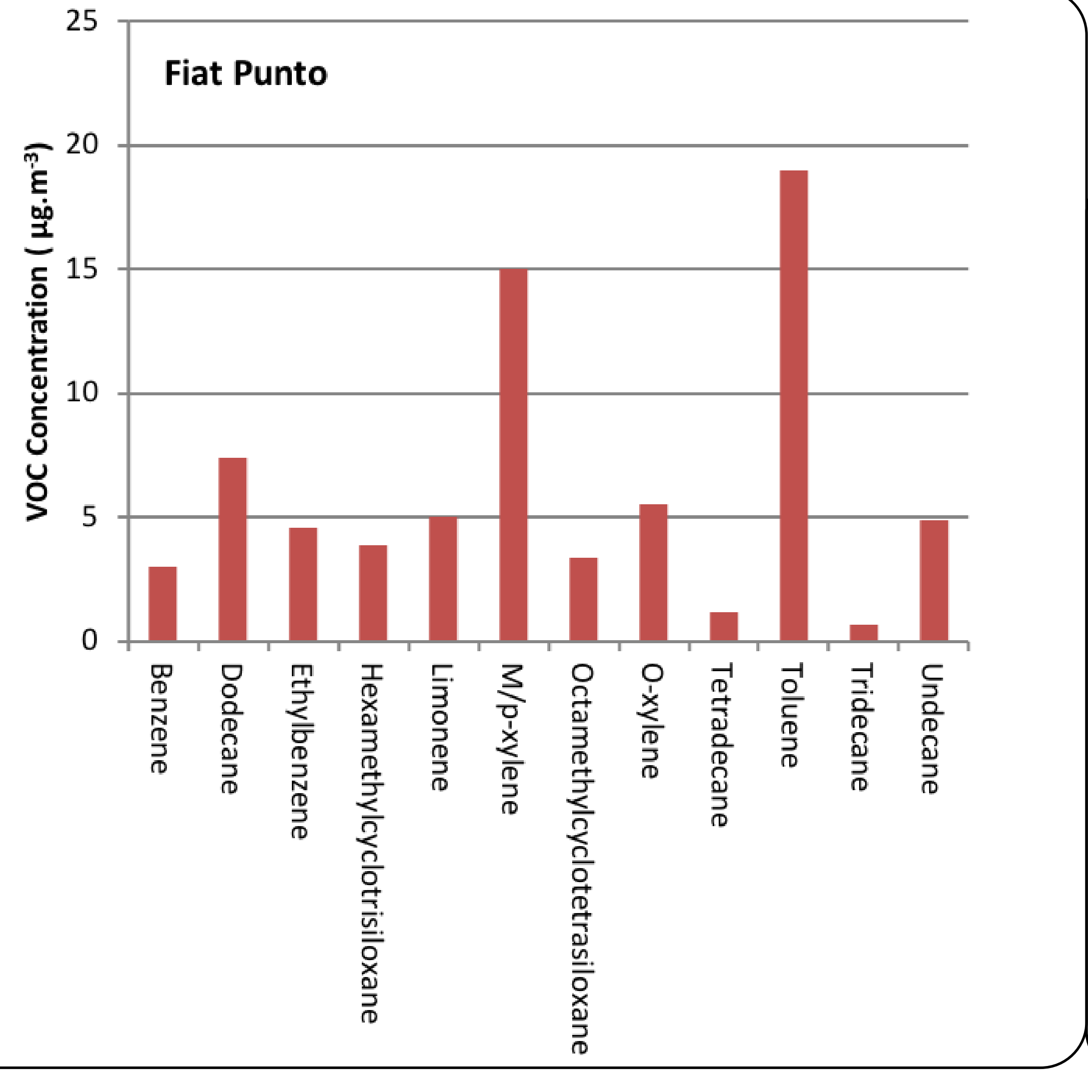
EMISSIONS ANALYTICS NAQTS

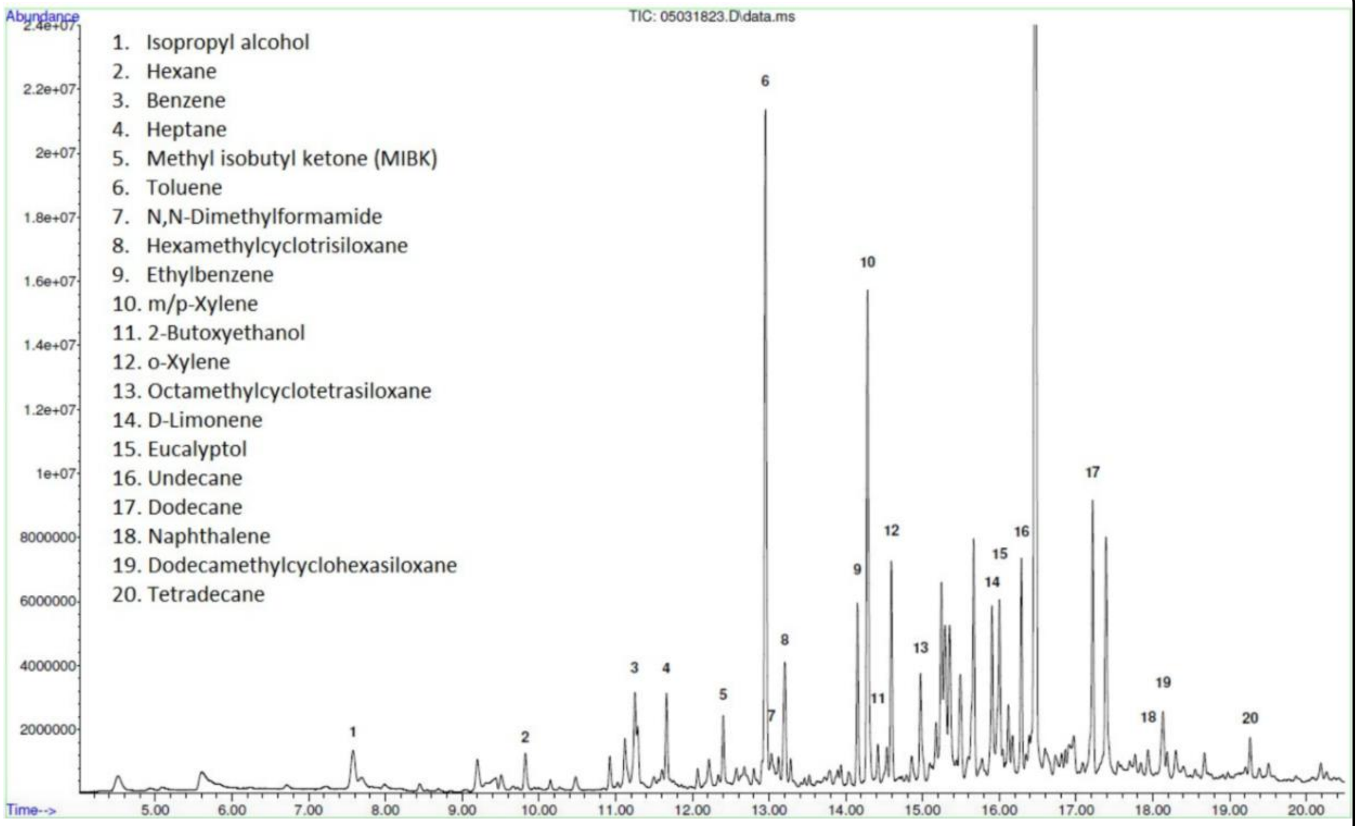
Ford Focus (2015)



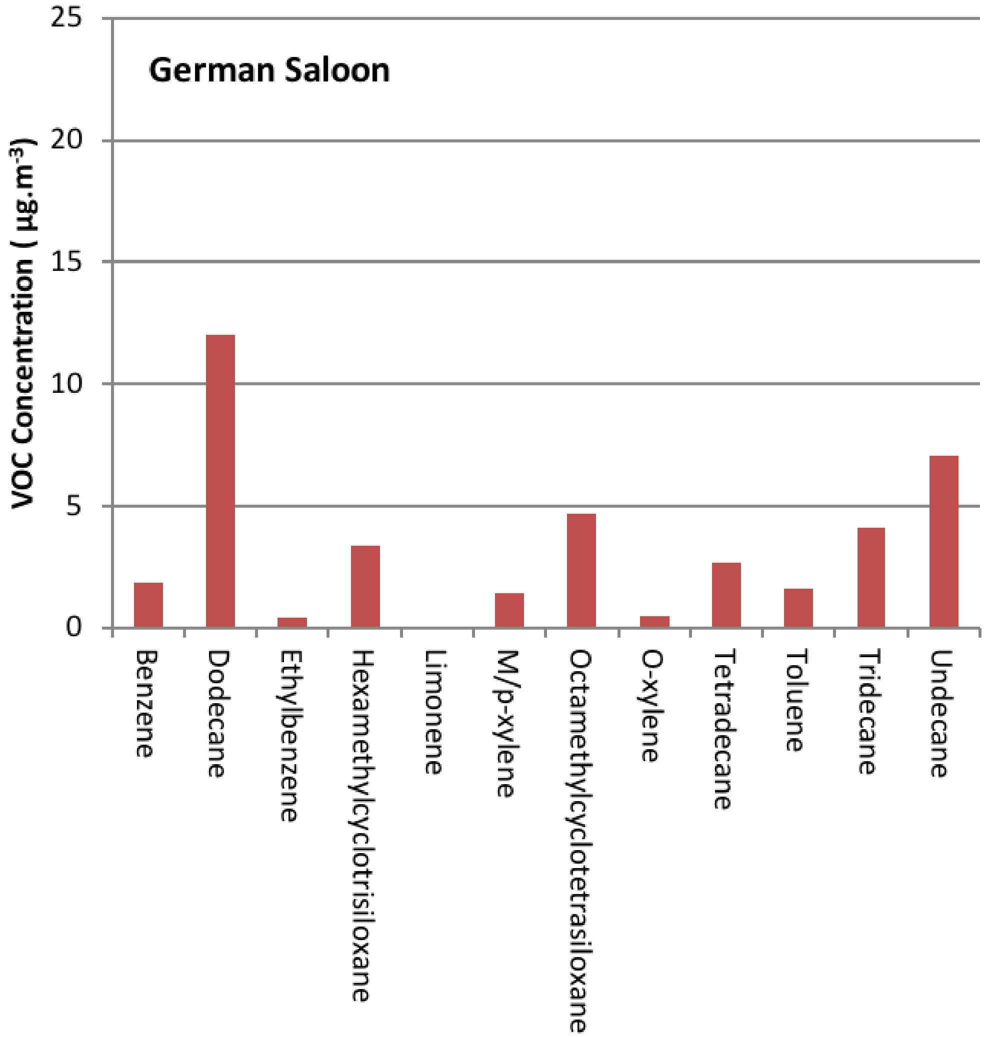


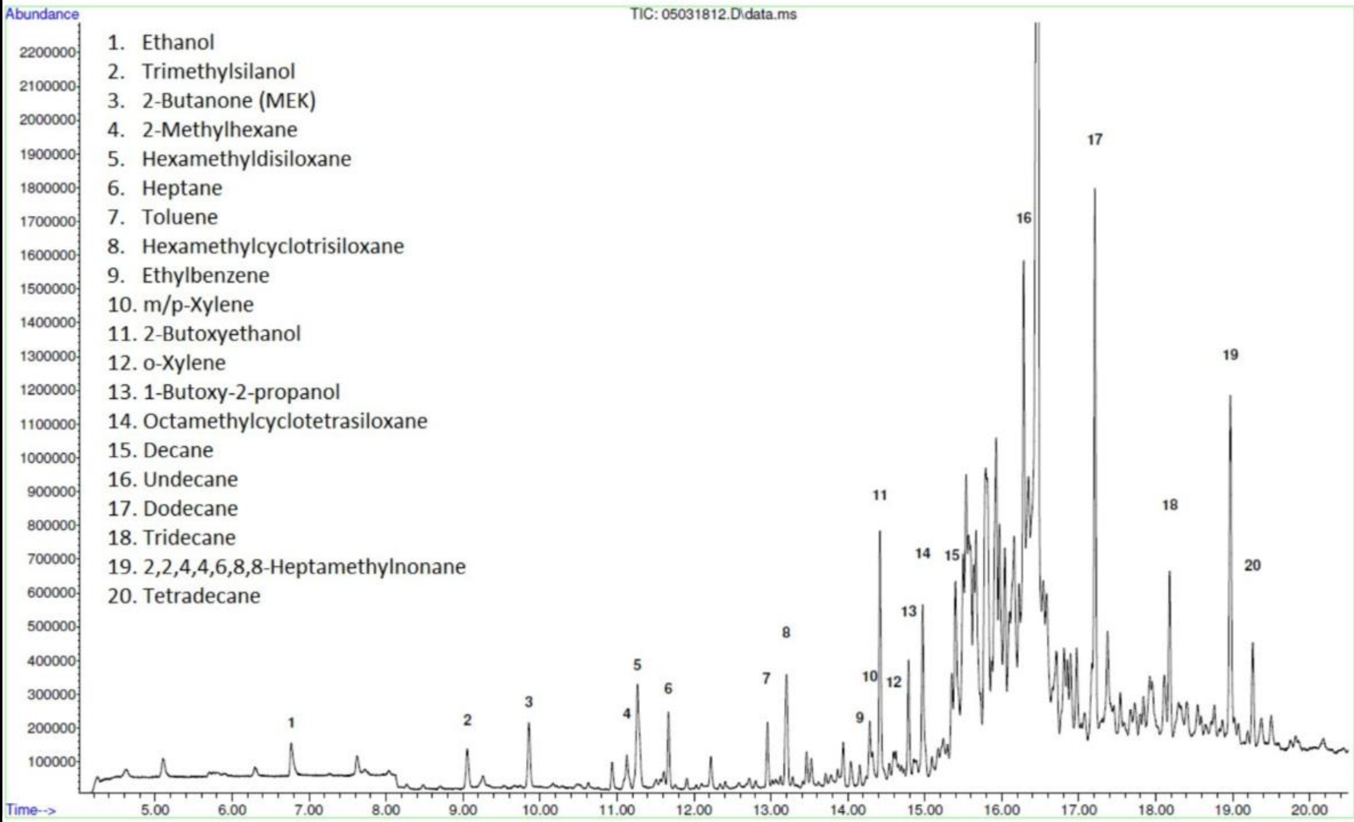
Fiat Punto (2008)



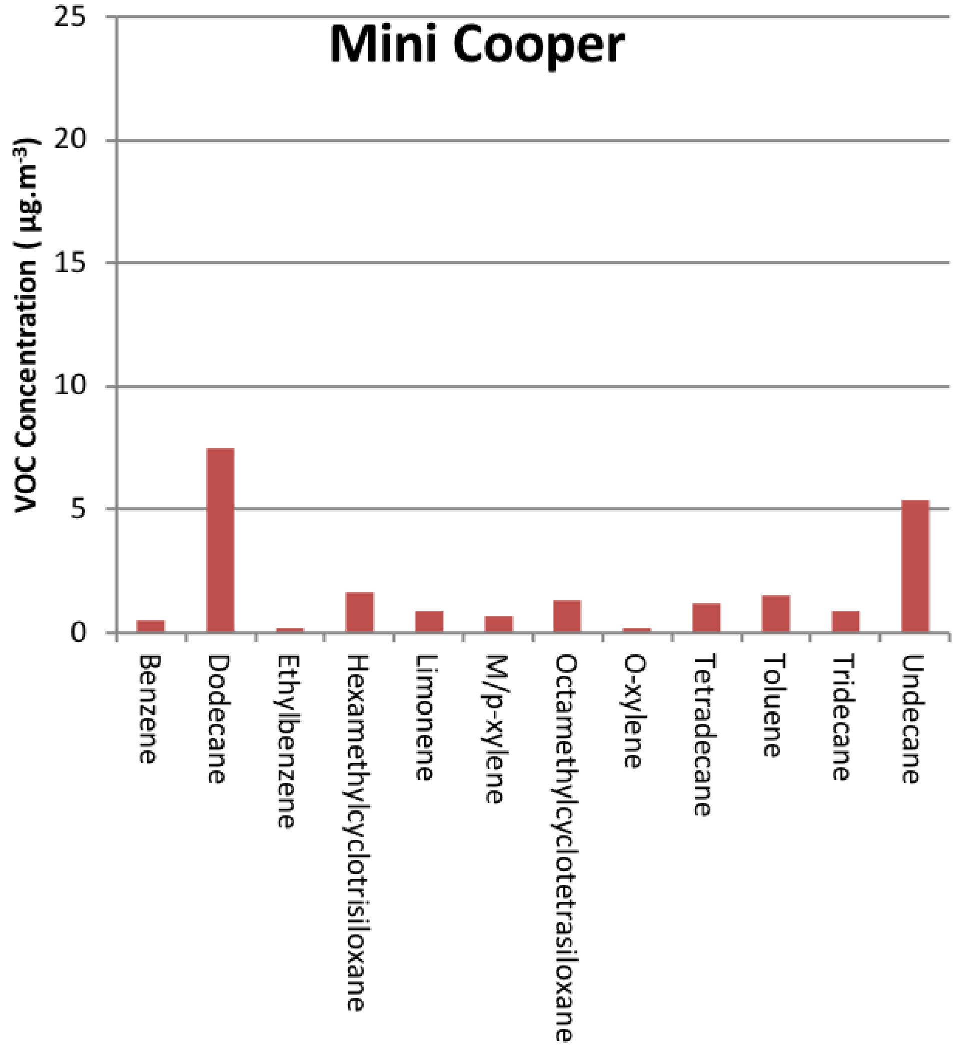


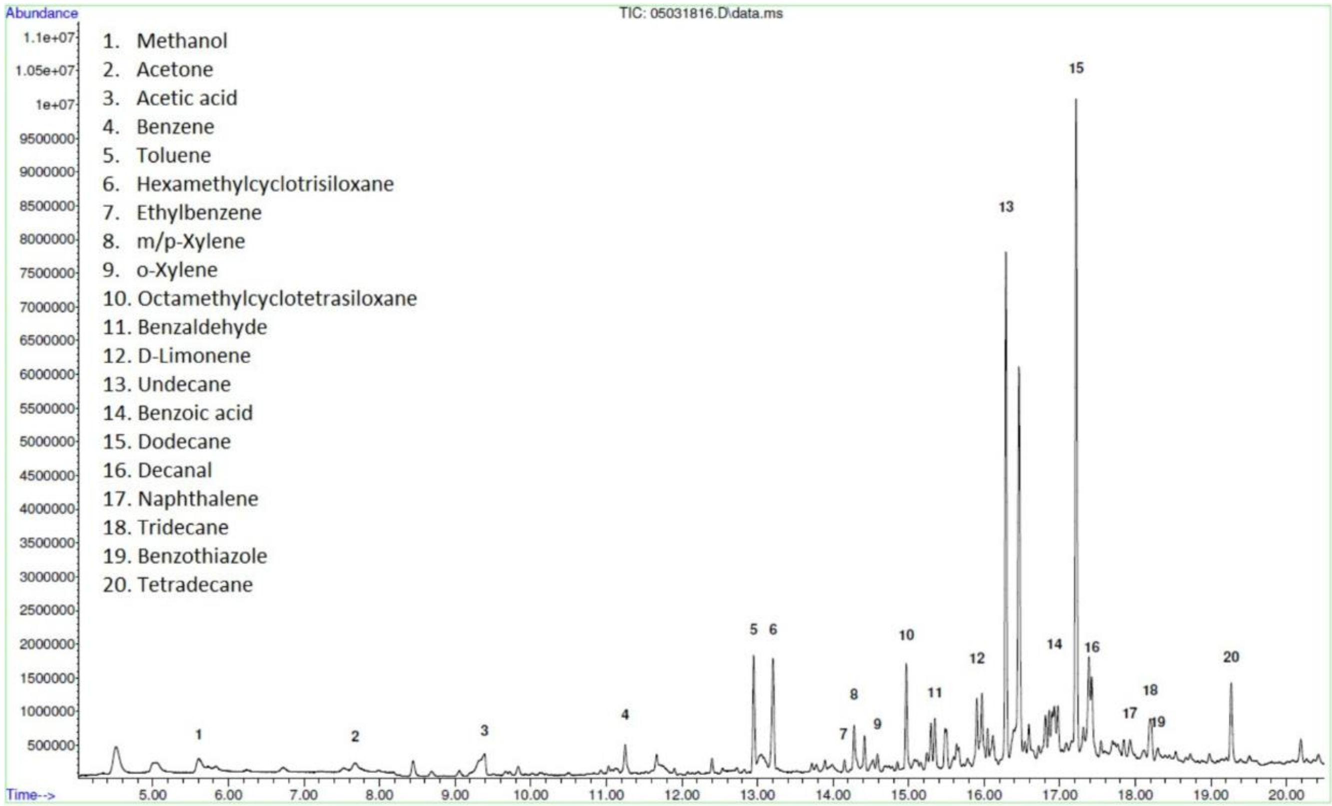
German Saloon (2017)



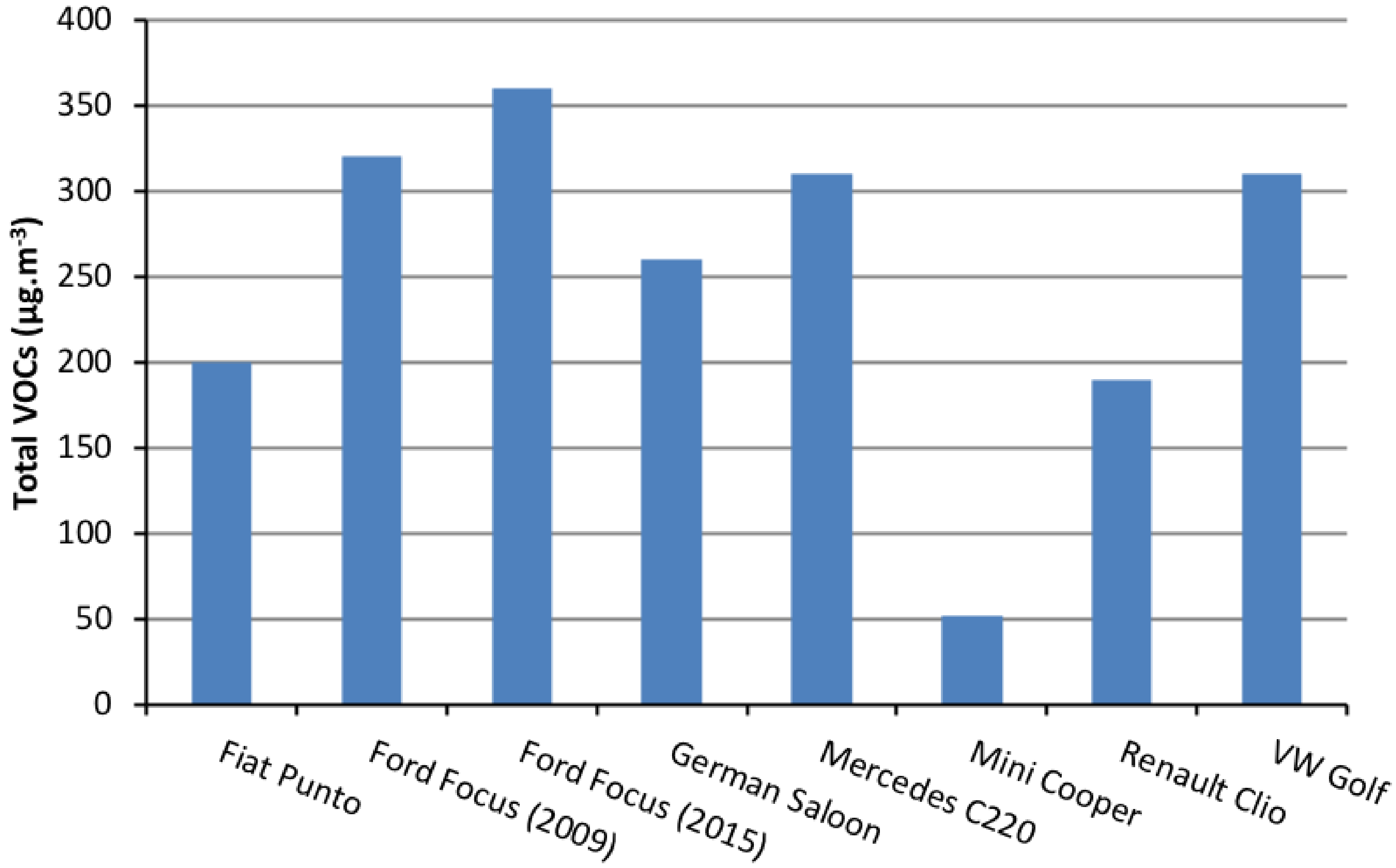


Mini Cooper (2006)





Comparisons - TVOCs



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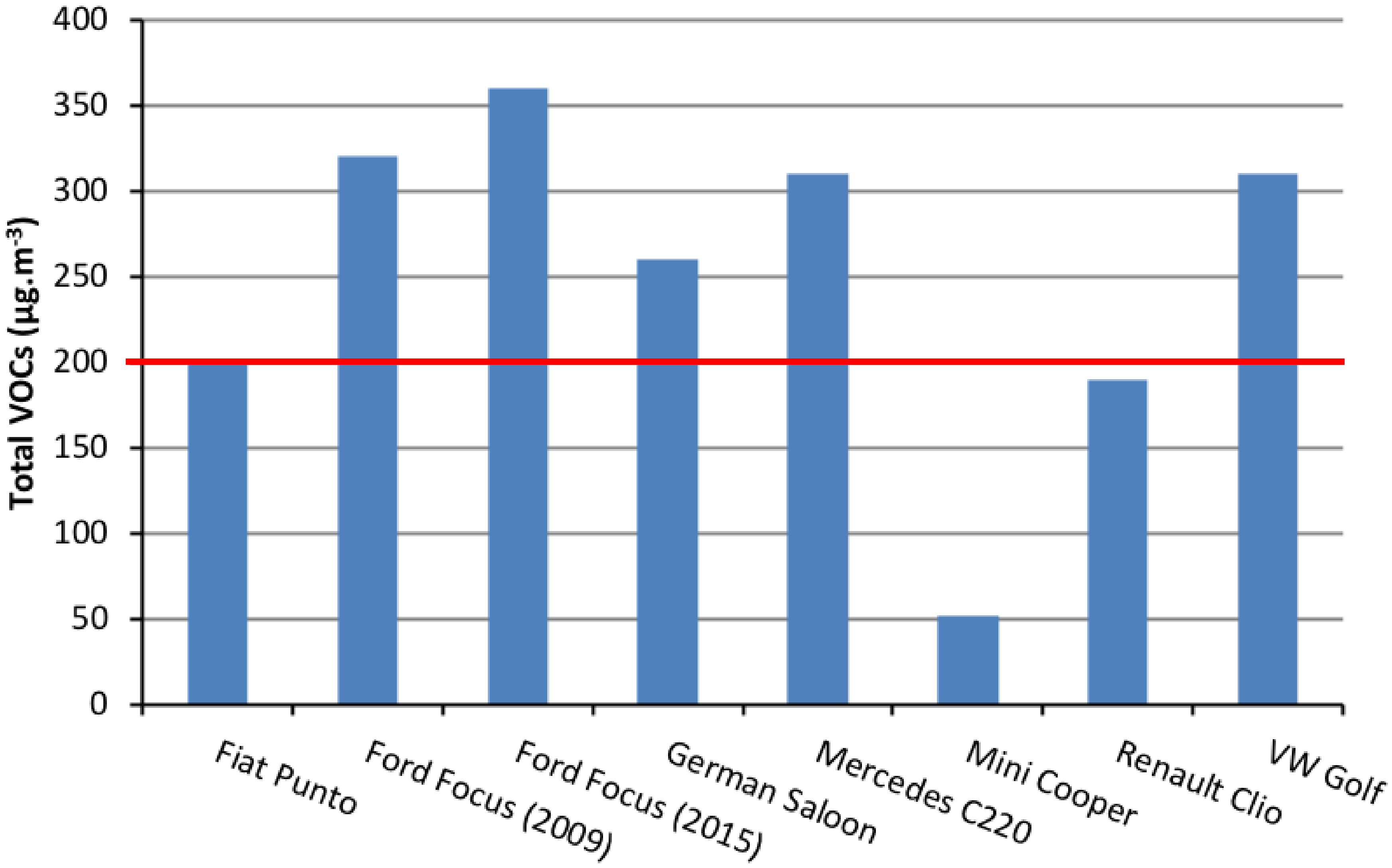
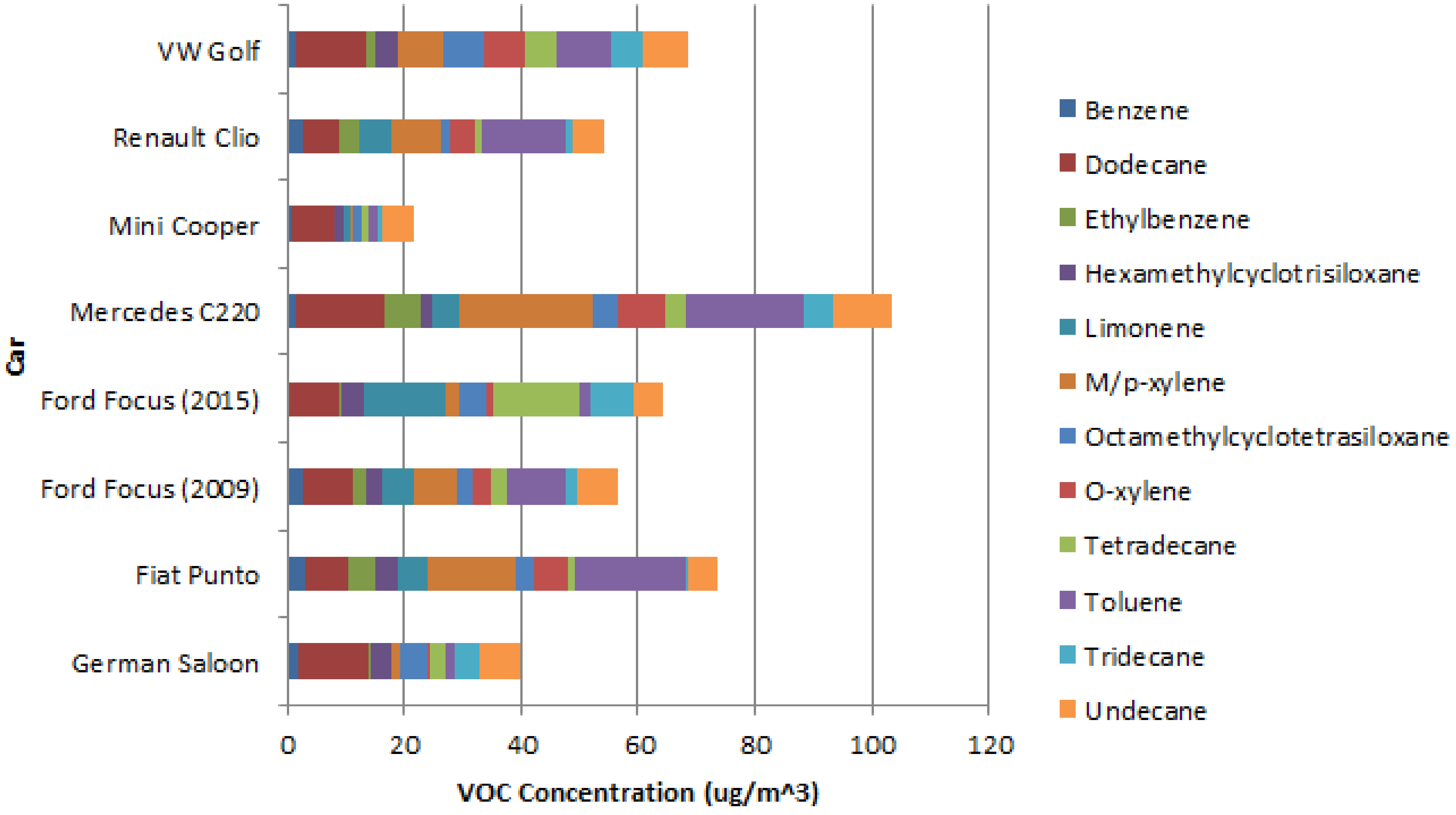


Health Effects

- <200 µg/m³ - No irritation or discomfort
- 200-3000 µg/m³ - Irritation and discomfort possible
- 3000-25000 µg/m³- Discomfort expected and headache possible
- >25000 µg/m³ - toxic

Comparisons II- Speciation



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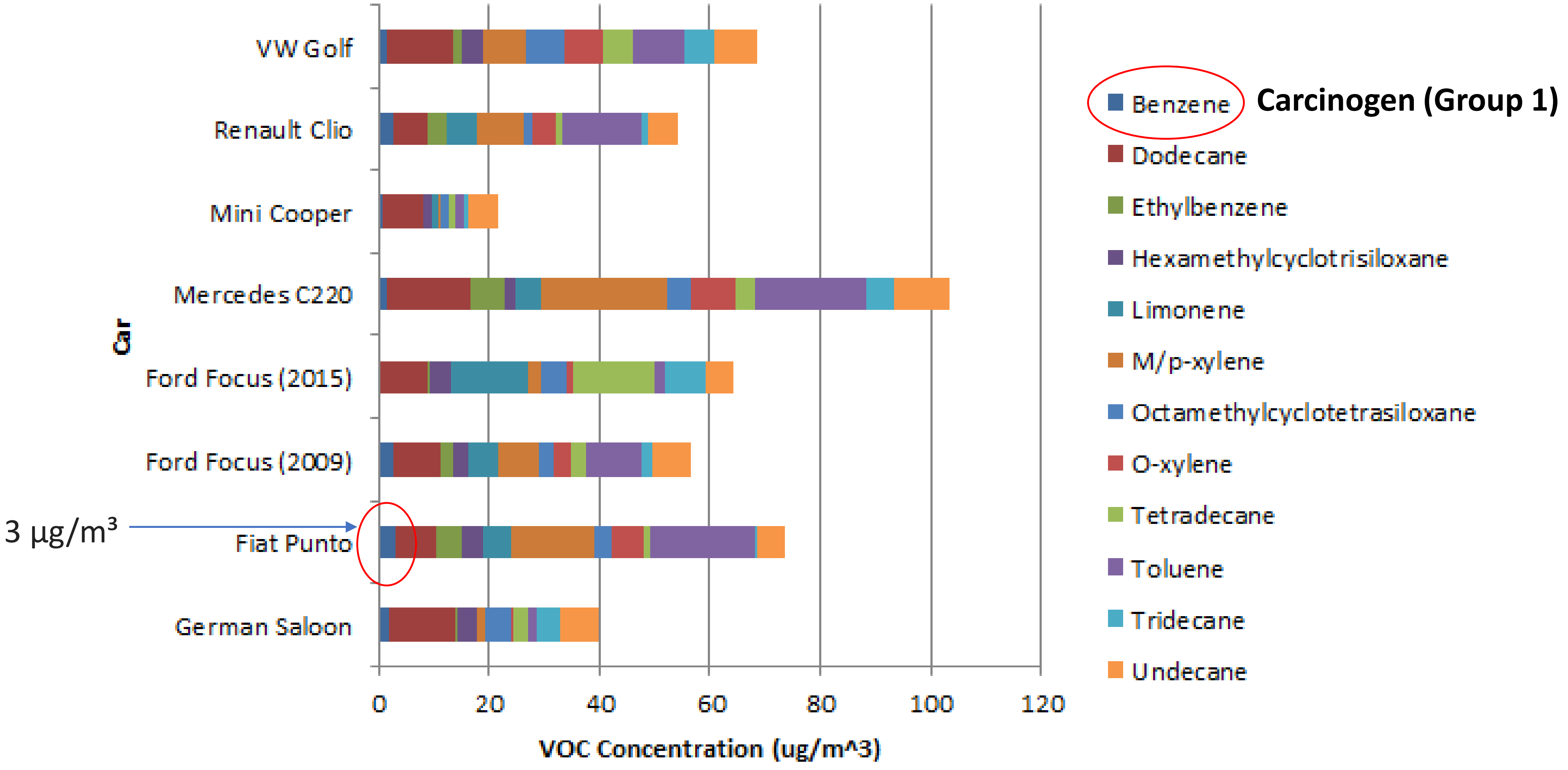

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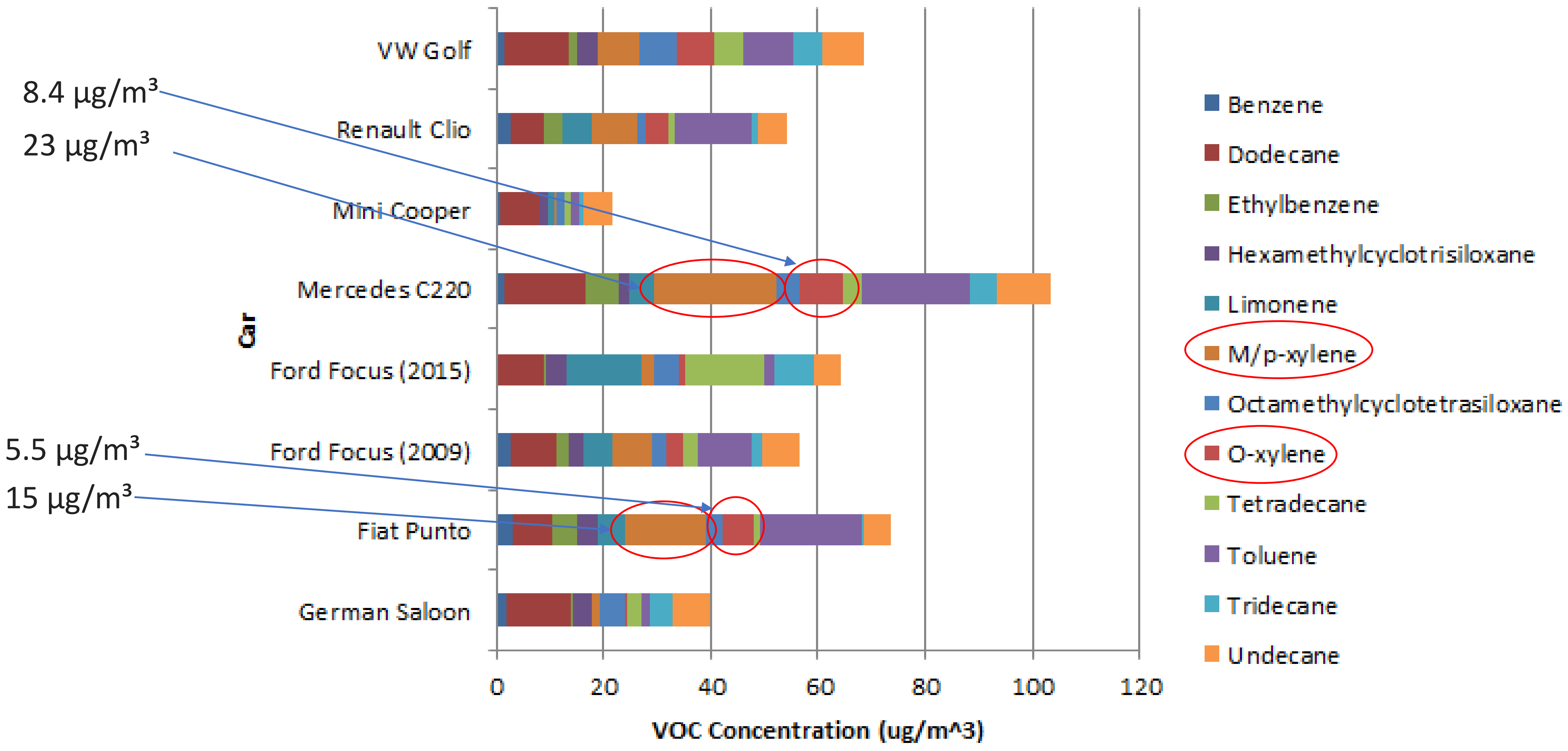

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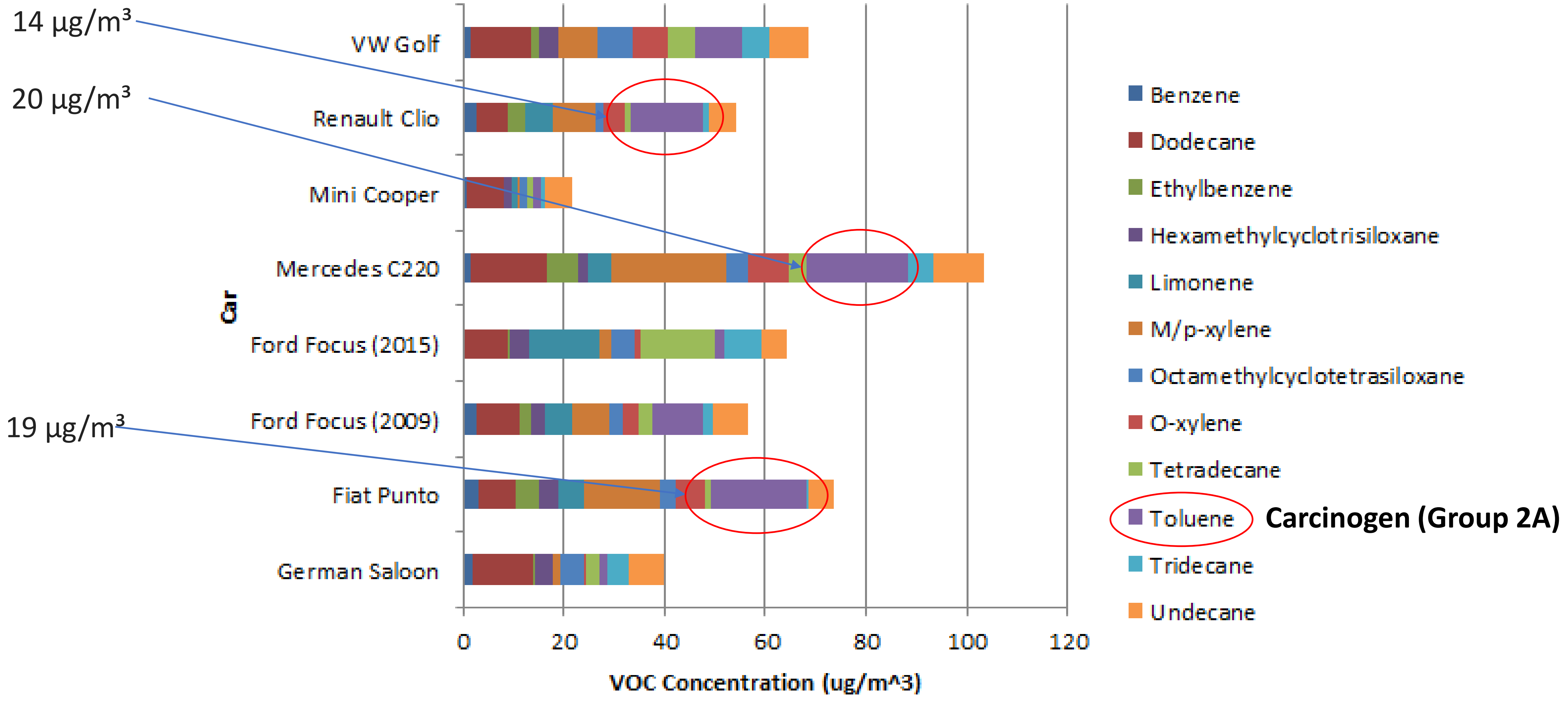
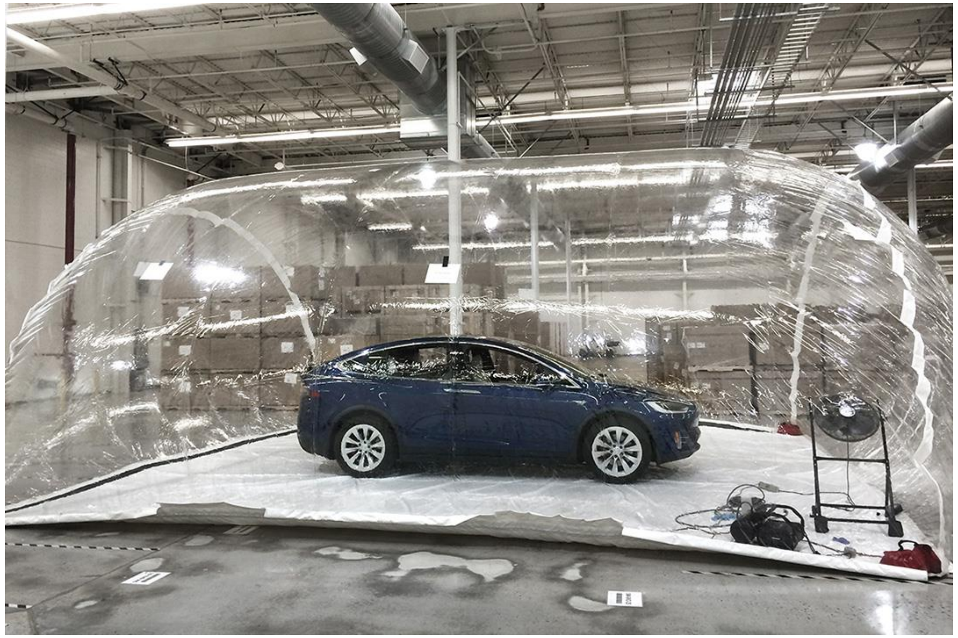
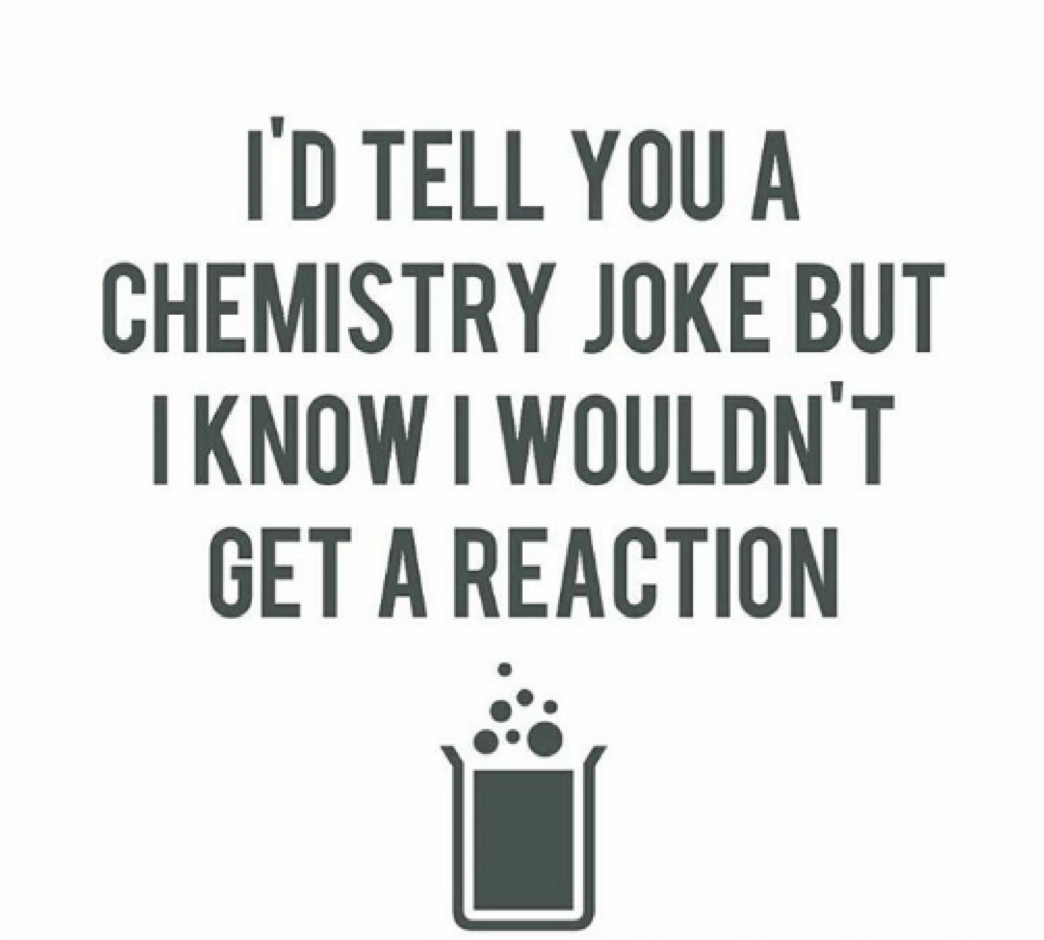


How do you communicate these results to the general public?

Vehicle manufacturers beginning to differentiate themselves based on VIAQ, we need more independent research to inform the consumer.



"You can literally survive a military grade bio attack by sitting in your car" - TESLA



Complicated subject matter + general public aversion to analytical chemistry

Conclusions

This case study represents a small data set, however, Emissions Analytics are using NAQTS' air quality monitoring technology to gather data on Ingress & Stuffiness for 100s of vehicles per year. Moreover, this will be extended to include other pollutants (NO2, CO, VOCs).

The NAQTS V1000 is a holistic, portable air quality monitoring station designed to be easy-to-use for high-volume, lower-cost air quality measurements

Any questions?

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www.naqts.com