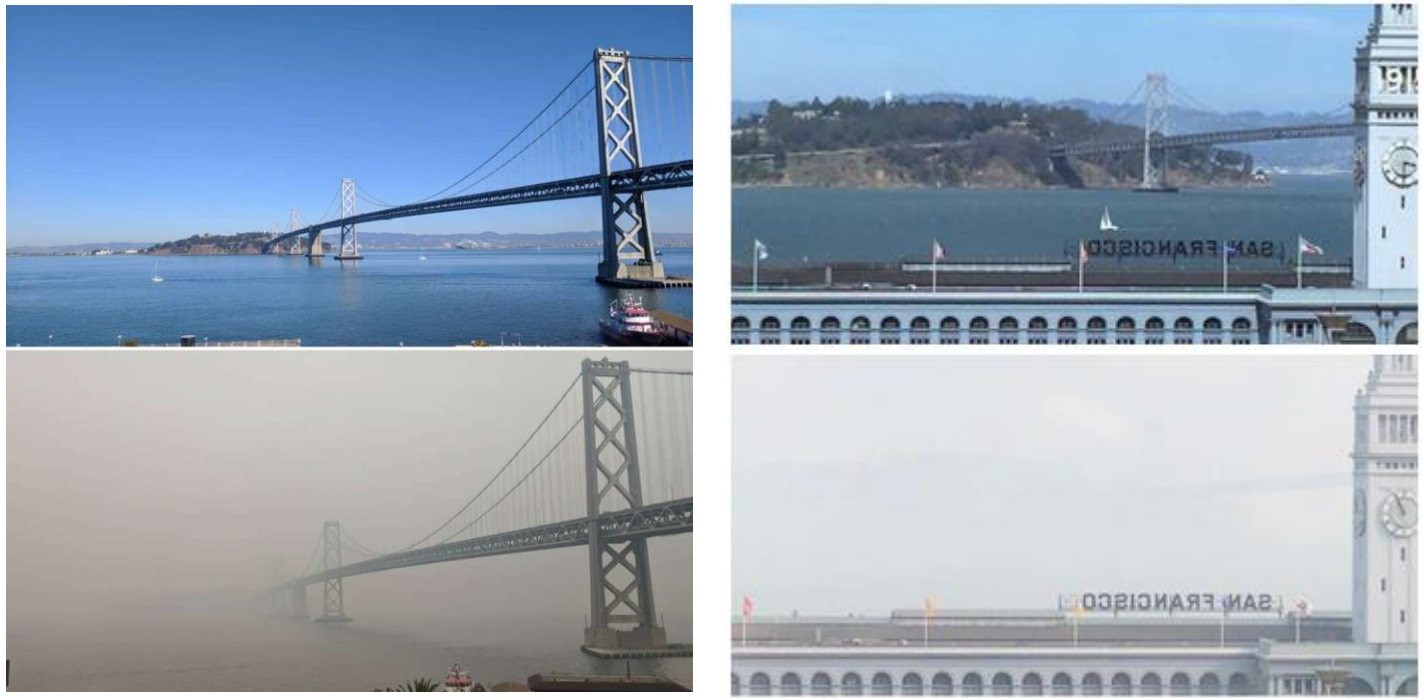
What else is in the Air?
Breathing for Two

CEED 4th Annual Environmental Health Summit - Session 6

Phoebe Stapleton

January 26, 2022

Air Pollution and Particulate Matter (PM) - Epidemiological Studies



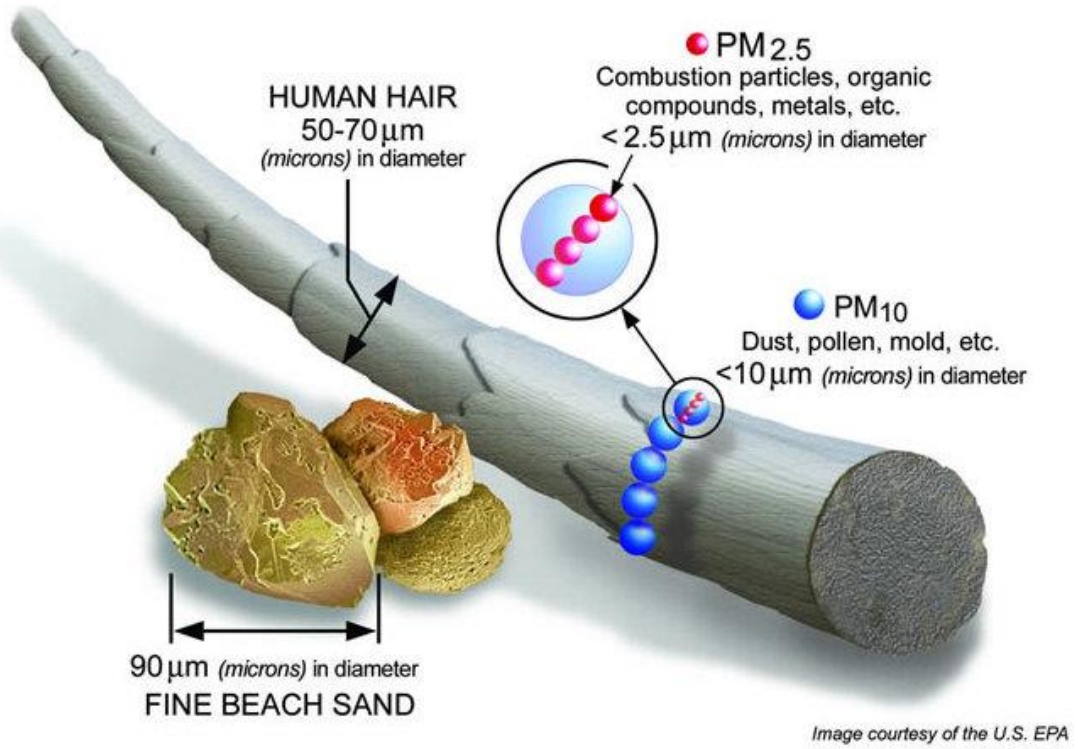
- Epidemiologic evidence of cardiovascular effects of particulate air pollution. [1]
- Increased incidence of myocardial infarction within 24 hours of inhaled particulate pollution. [2]
- Overall, exposure to fine and ultrafine particulate air pollution has adverse effects on cardiopulmonary health. [3,4]

San Francisco, Camp Fire wildfires, 2018

[1.] Dockery, EHP, 2001; [2.] Peters, Circulation, 2001;
[3.] Pope, Circ Research, 2015; [4.] Van Eeden, J Toxicol. Environ. Health A, 2002;

Particulate Matter (PM)

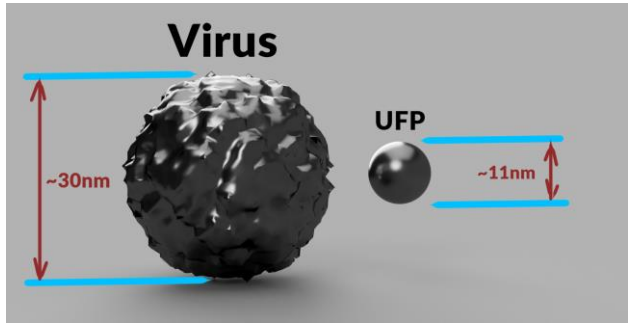
- Particulate Matter – term for solid particles and liquid droplets in the air



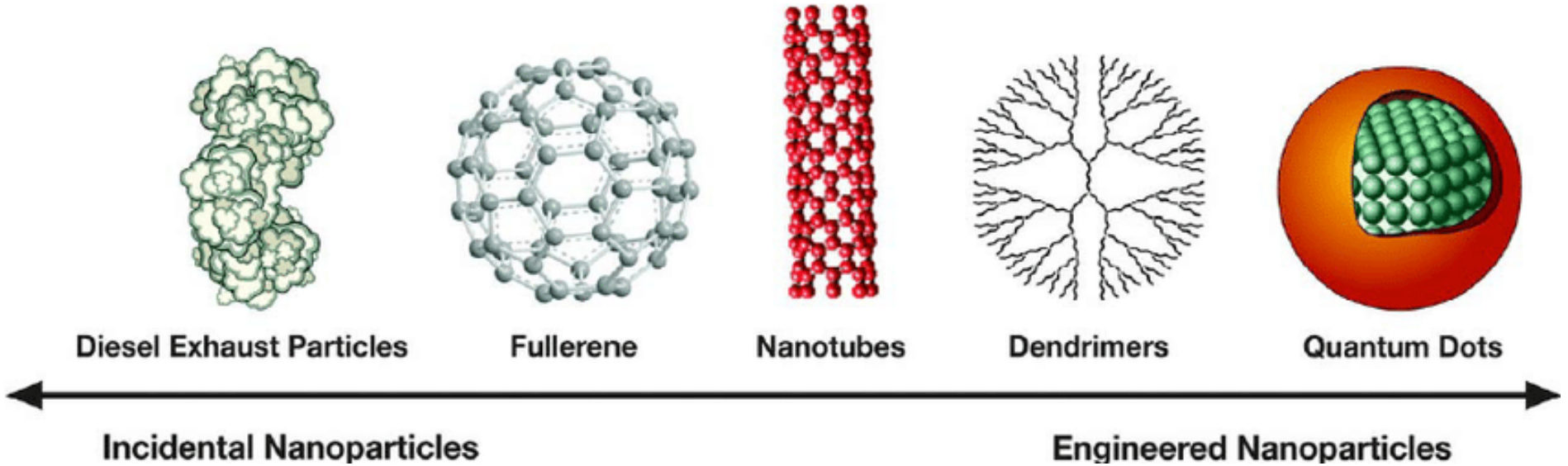
PM_{10}: <10µm diameter
(Times New Roman 40)

$PM_{2.5}$: <2.5µm diameter
(Times New Roman 5)

$PM_{0.1}$: <0.1µm diameter
(Times New Roman 2)

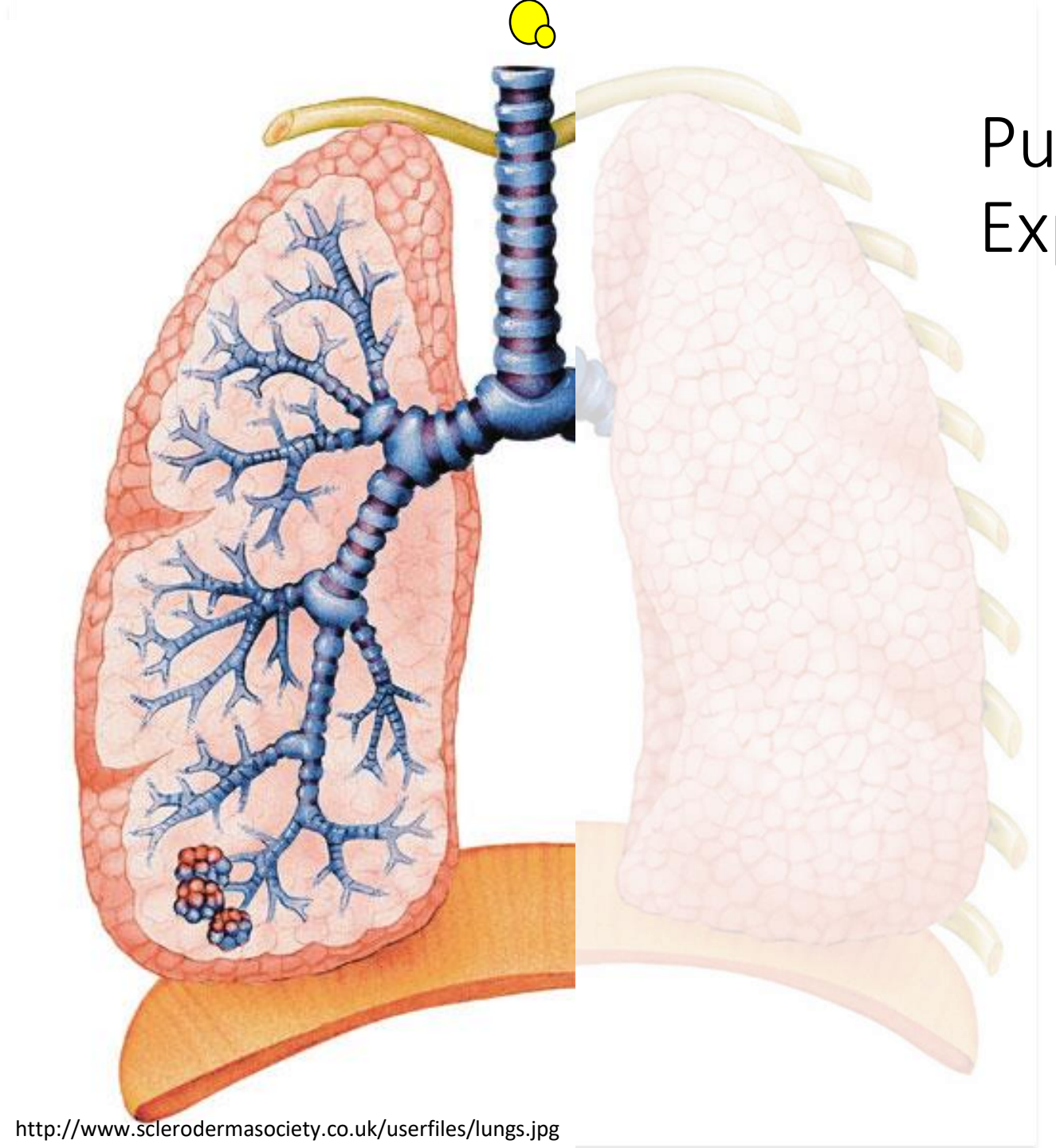


Diesel Exhaust/Ultrafine Particles/Nanoparticles



- Previously identified as “ultrafine” size, studies demonstrated higher inflammatory, reactive stress, and toxicity potential than larger counterparts. [1,2]

Larson, Biology of Reproduction, 2014
[1.] Stone, IEEE Trans Nanobioscience, 2007
[2.] Nurkiewicz, Part Fibre Toxicol, 2008



http://www.sclerodermasociety.co.uk/userfiles/lungs.jpg

Pulmonary Nanoparticle Exposure

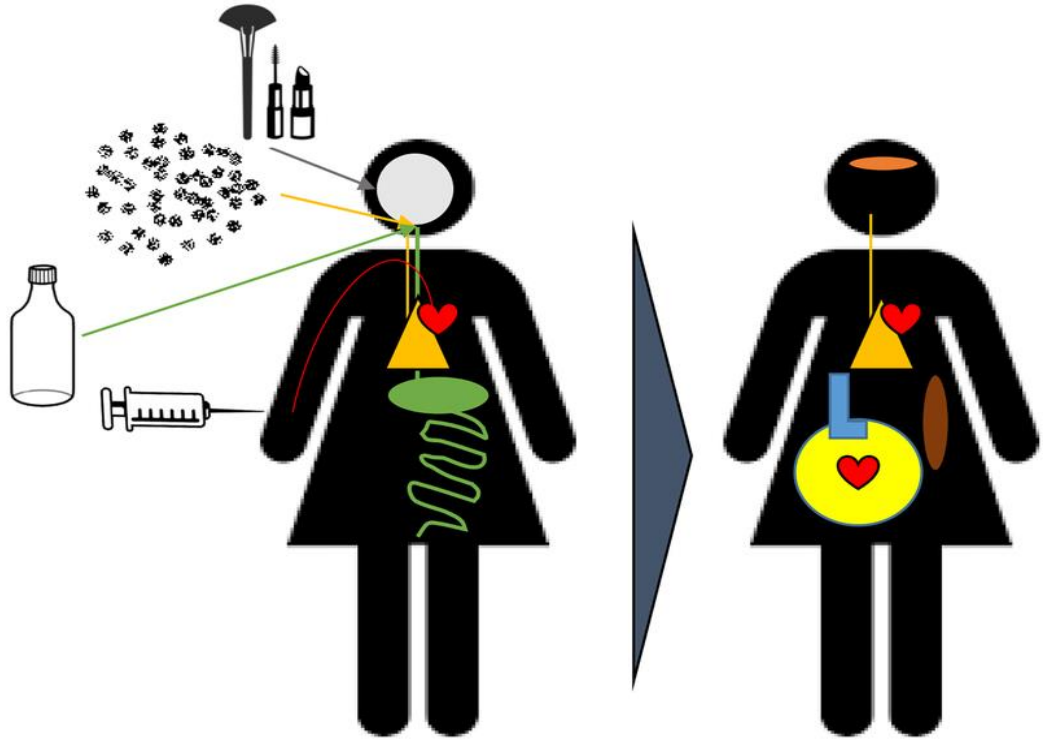
- Pulmonary particle retention[1]
- Pulmonary inflammation following exposure[2]
- Particle translocation from the lungs to systemic organs[3]

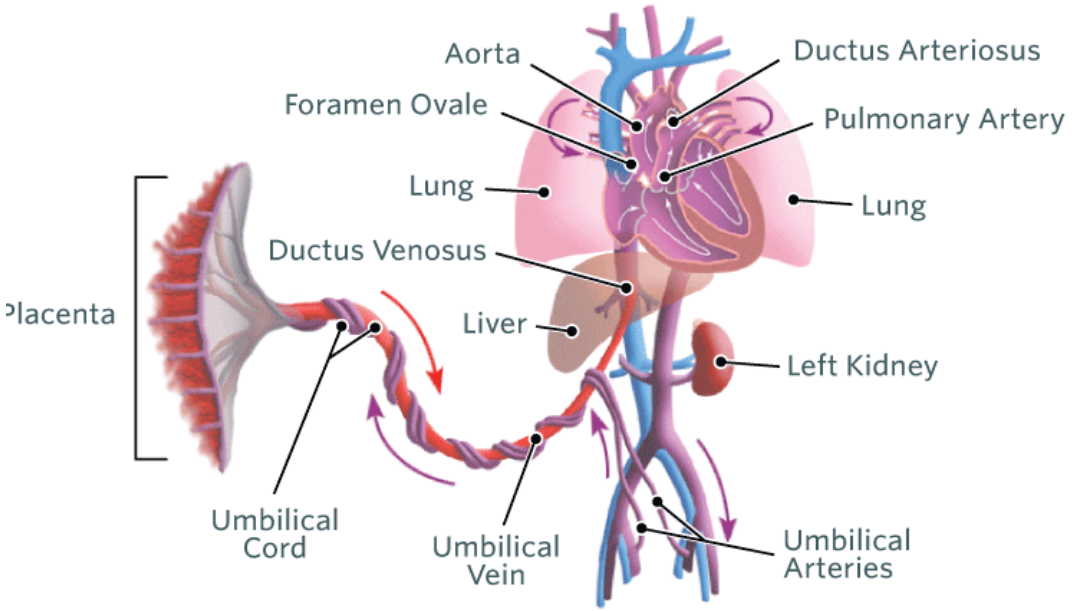
Animation – Dr. Cody Nichols

[1]Husain et al. 2013
[2]Baisch et al. 2014
[3]Elder et al. 2006

Maternal-Fetal Model

- Complex and widely understudied model
  - Maternal Health
  - Placental Barrier
  - Fetal/Progeny Health
  - Hormonal variation
  - Physiological disparities (normal)
  - Developmental Onset of Health and Disease (DOHAD)
    - Progeny Health





Stapleton, 2019; Campagnolo, 2017; Hougaard, 2015

Epidemiological Evidence

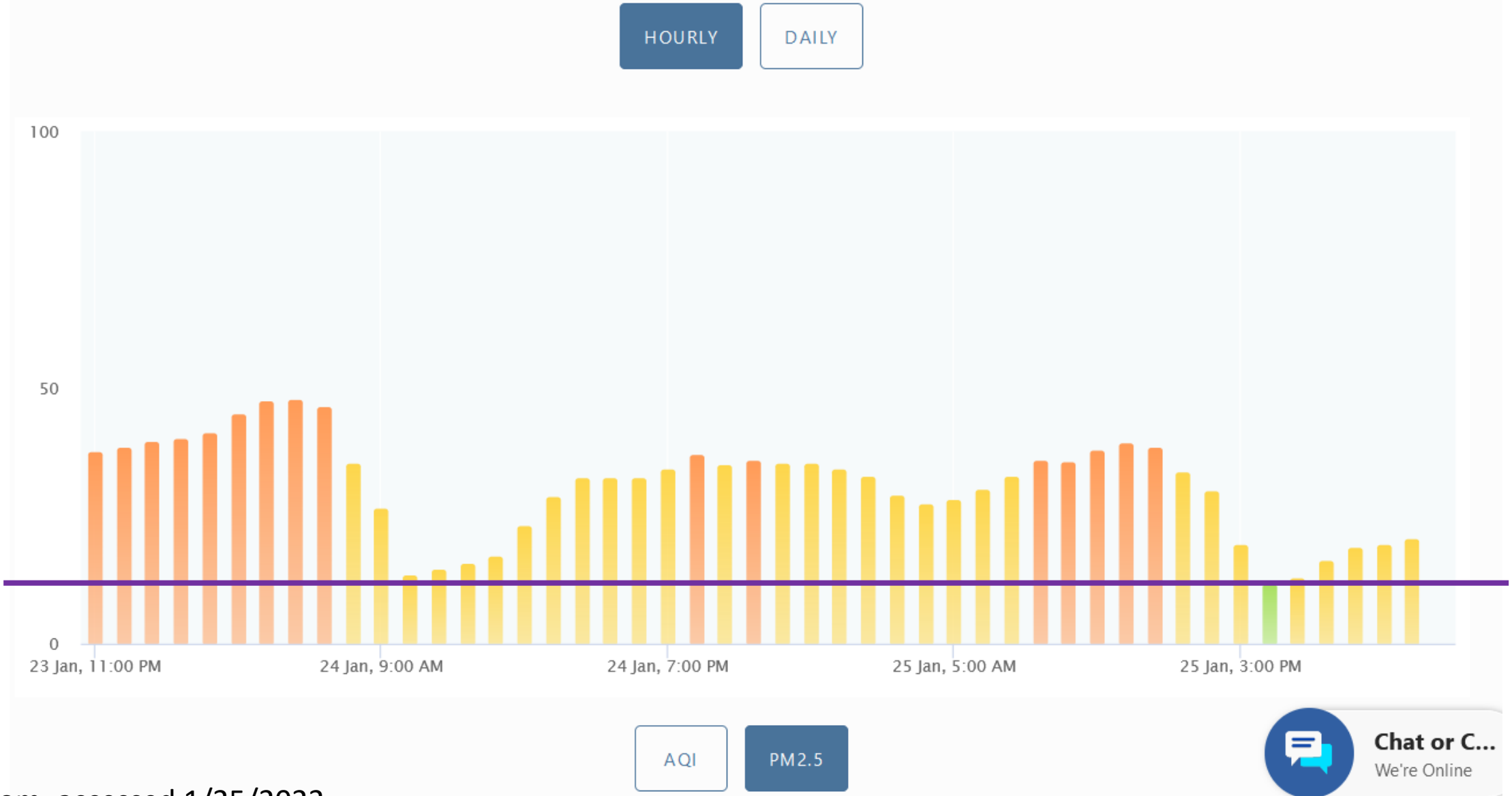
- In Ohio, exposure to high levels of $PM_{2.5}$ in the 3rd trimester increased risk of stillbirth by 42%. “High” is identified as approximately 16.5 µg/m^3 or 135% of US EPA air quality standard of 12 µg/m^3. (DeFranco, 2015)

- Exposure the PM during pregnancy has been associated with increased risk of small for gestational age. (Tapia, 2020)

- Increased risk of asthma and respiratory infections in infants and children. (Jung, 2019; Goshen, 2020)

HISTORICAL

Historic air quality graph: East Jersey Street, Elizabeth



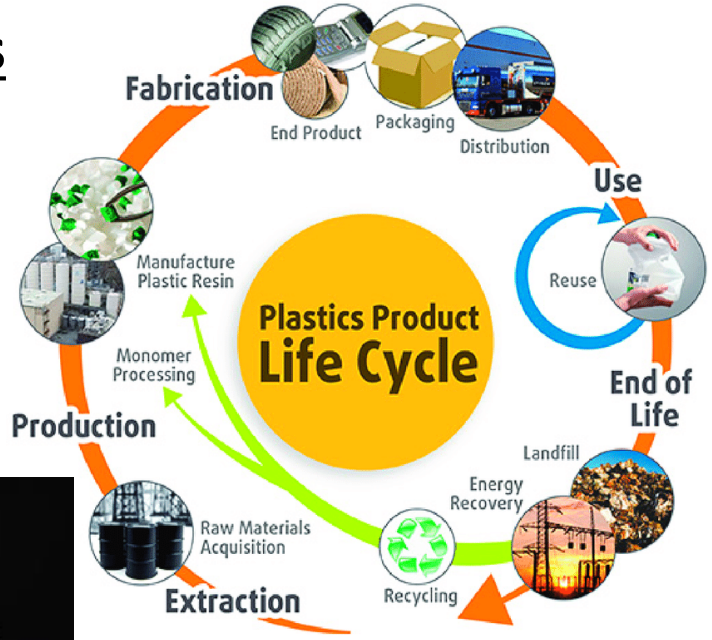
iQAir.com, accessed 1/25/2022

Our Studies in Laboratory Models

Nanosized Metals – Titanium Dioxide

Low reactivity surrogate for the particles in diesel exhaust.

Nanosized Plastics

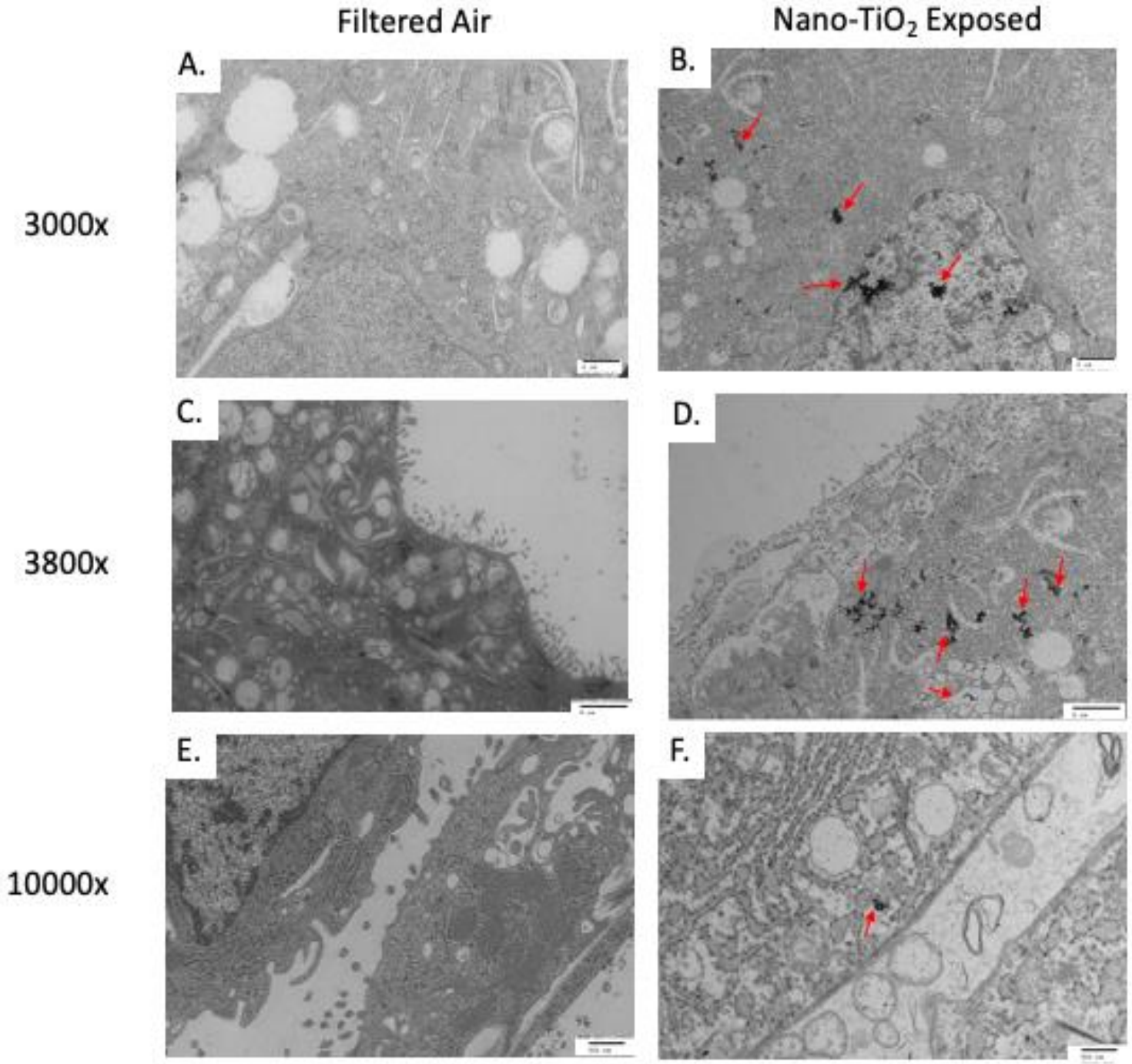


Particle Translocation – Metals

Organ	Expected exposure order (highest to lowest Ti concentration)	Actual exposure order (highest to lowest Ti concentration)	Actual % of Nano-TiO2	Coresponding Ti (ppb)
Maternal Liver	1	1	19.24	104.39
Maternal Kidney	2	15	2.33	12.67
Uterus	3	9	5.02	27.25
Placenta Decidua	4	4	6.87	37.27
Placenta Labyrinth	5	8	5.03	27.27
Maternal Spleen	6	10	4.95	26.83
Maternal Aorta	7	6	6.39	34.66
Maternal Whole Blood	8	13	3.84	20.83
Maternal Heart	9	7	5.87	31.84
Maternal Pancreas	10	12	3.90	21.14
Ovaries	11	11	4.69	25.44
Umbilical	12	5	6.65	36.10
Fetal Liver	13	14	3.02	16.36
Fetal Whole Blood	14	2	12.93	70.14
Fetal Heart	15	3	9.28	50.38
Total Ti (ppb)				**542.59**

D'Errico, Placenta, 2022 (in revision)

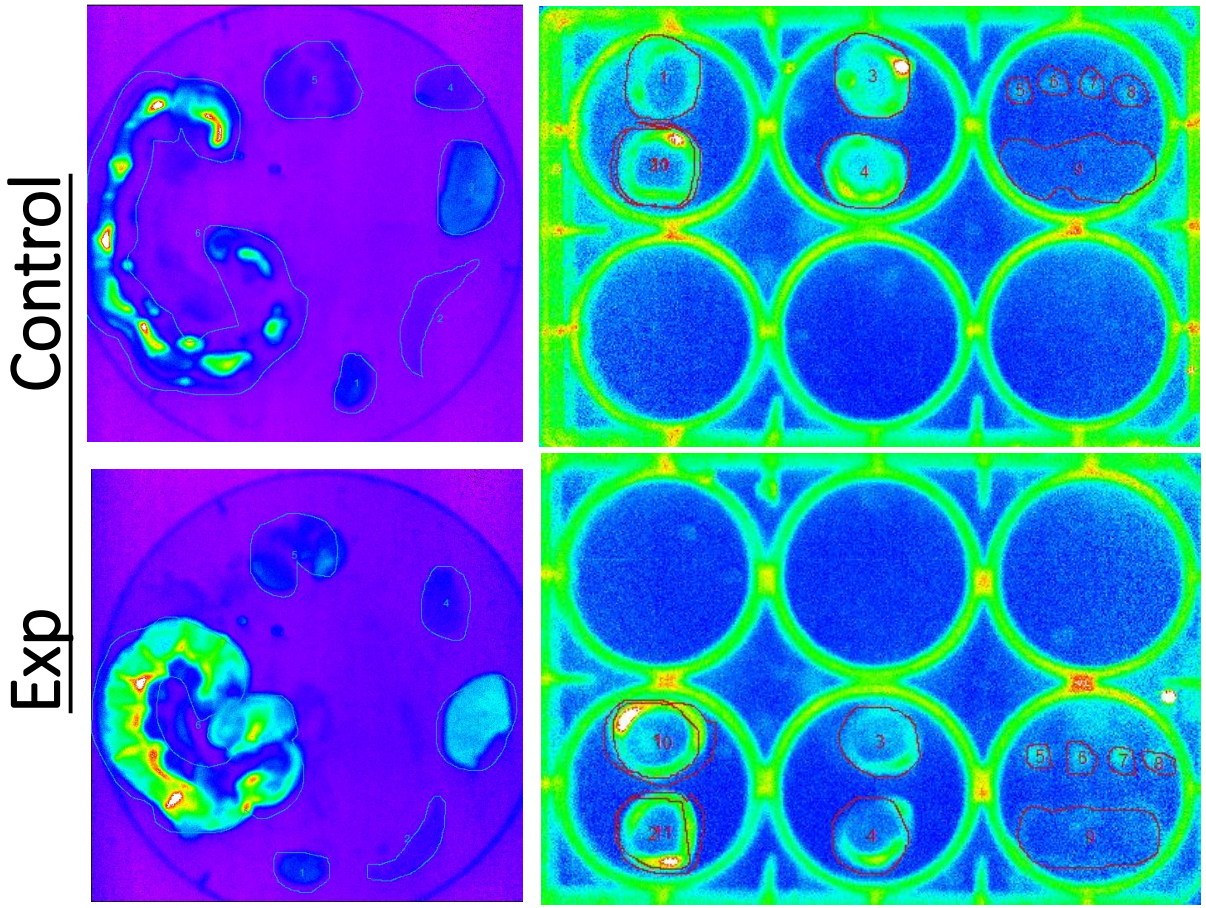
Particle Translocation – Metals

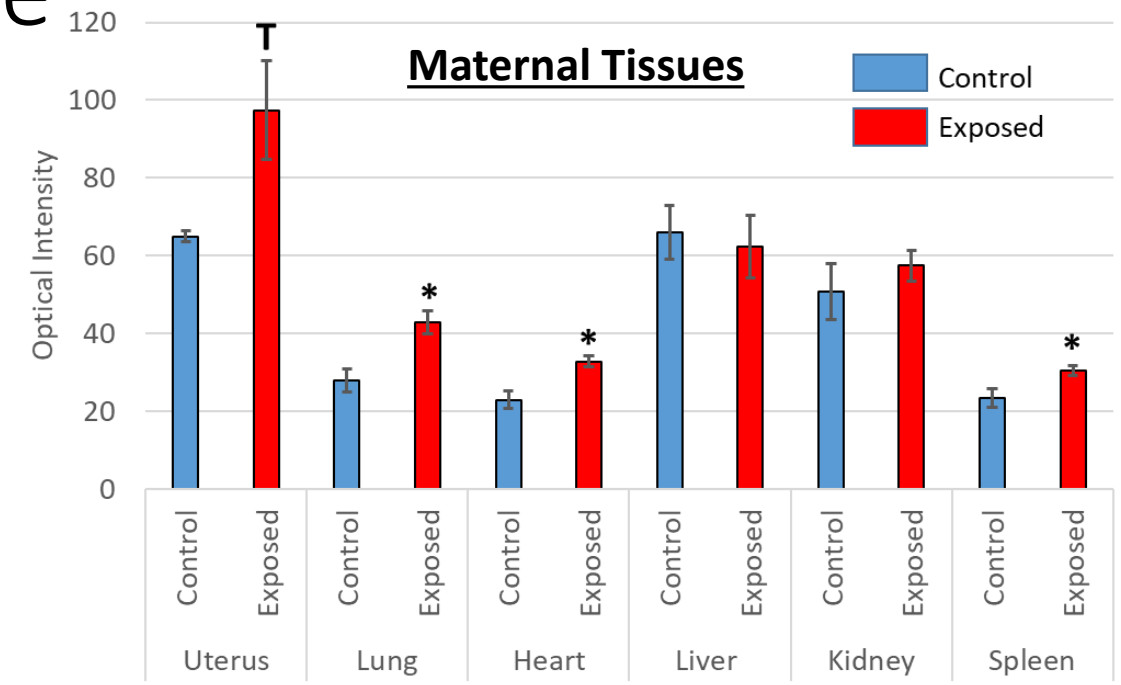


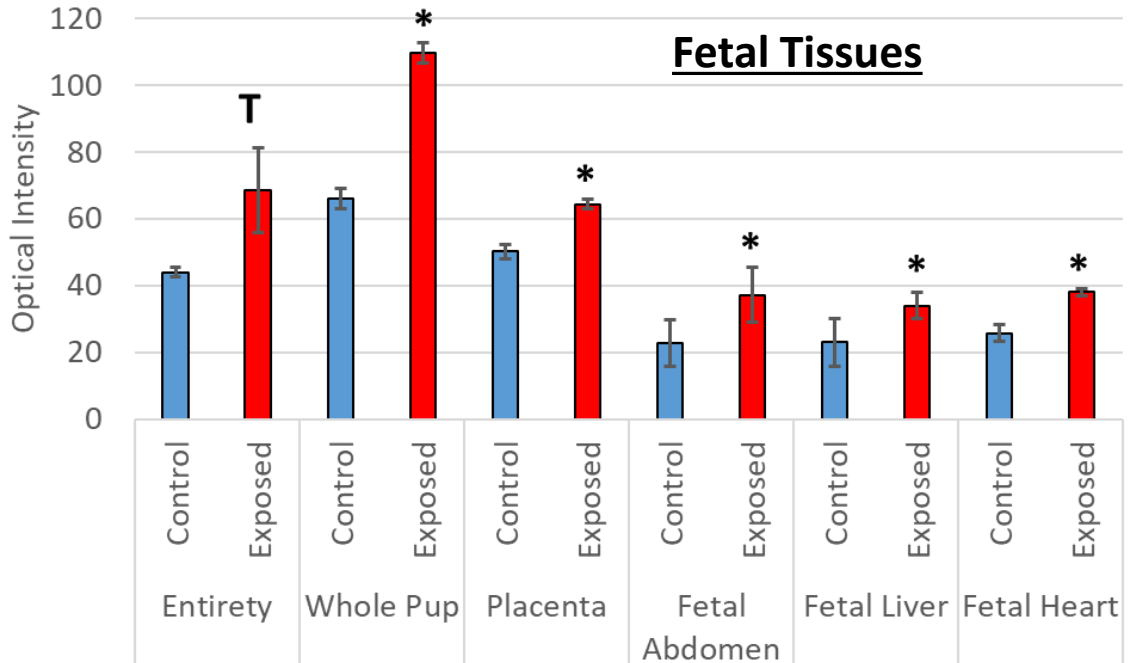
D'Errico, Placenta, 2022 (in revision)

Nanoplastic Translocation to the Fetal Compartment

- *In Vivo* Translocation (Optical Imaging)





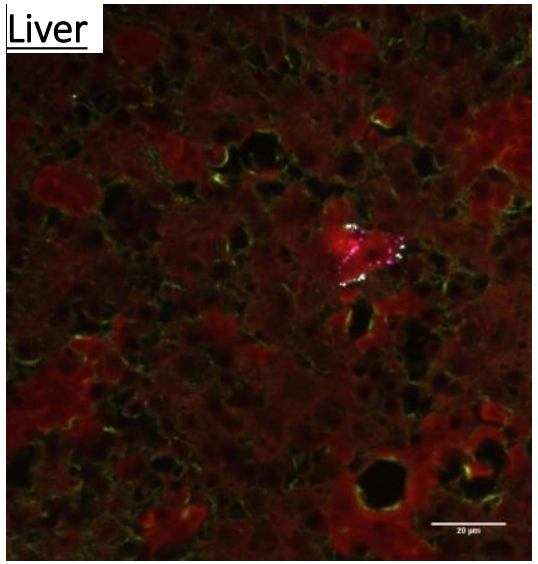


Fournier, 2020

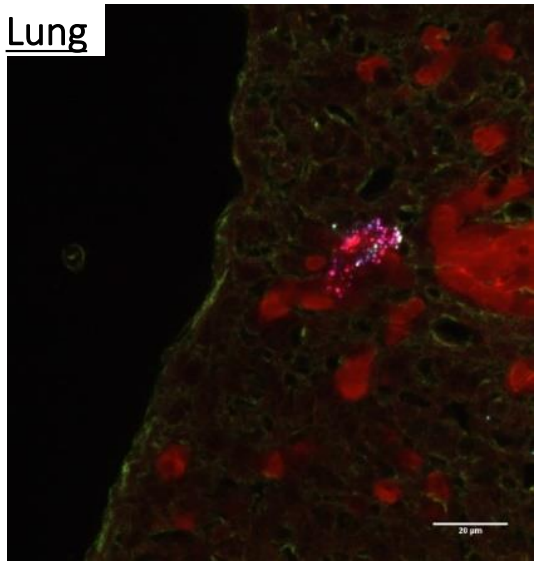
Nanoplastic Translocation to the Fetal Compartment

(Dark-Field Microscopy)

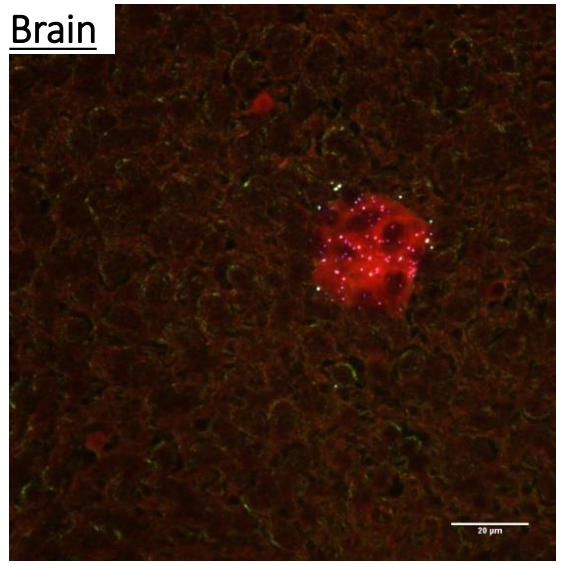
Liver



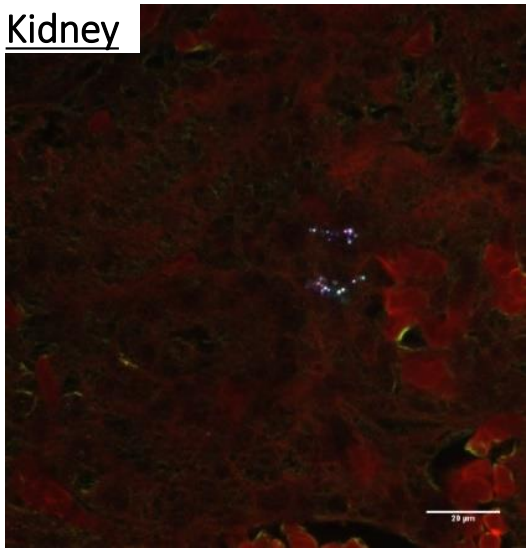
Lung



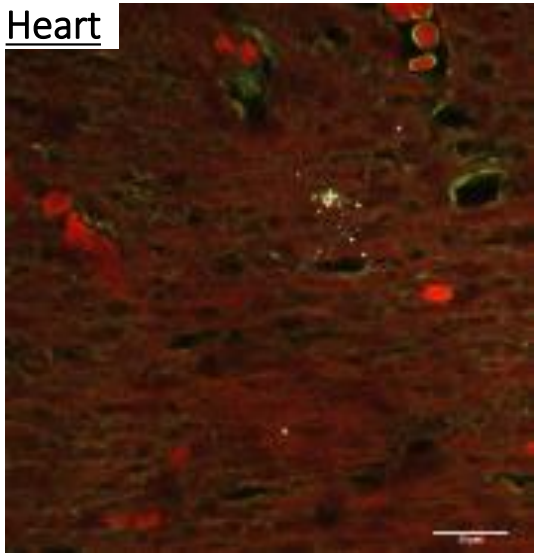
Brain

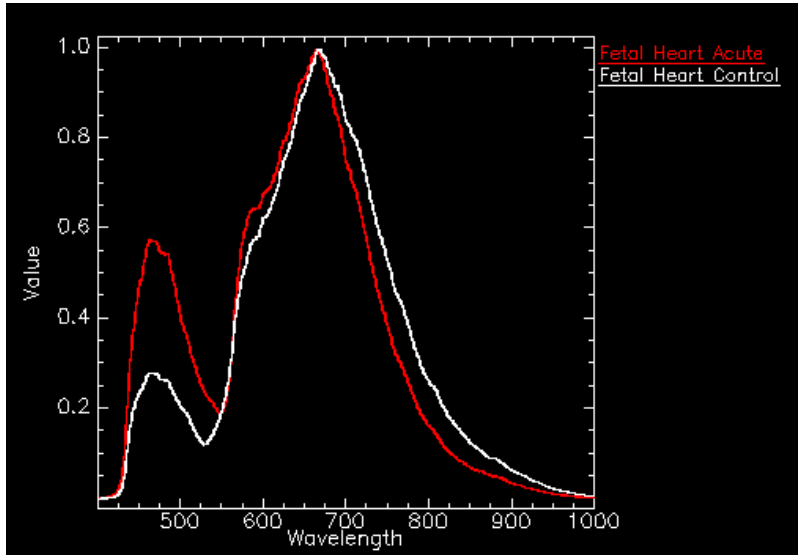


Kidney



Heart





Fournier, Particle and Fibre, 2020

Microplastic particle migration to the human placenta after **real-world** exposure

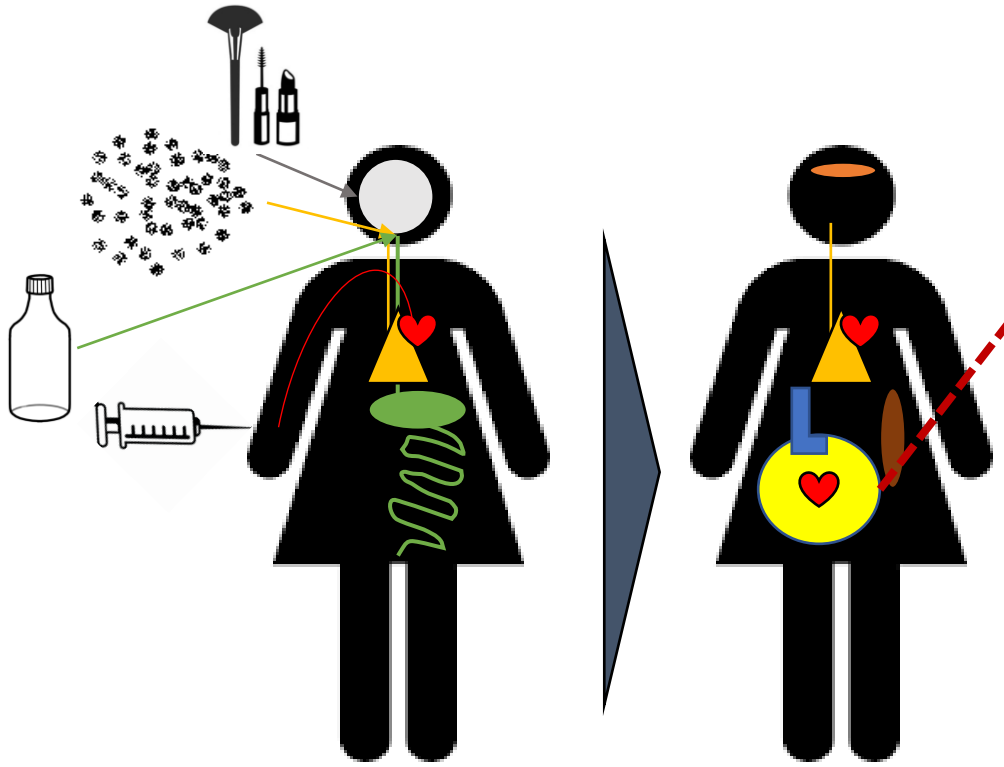


Figure 2

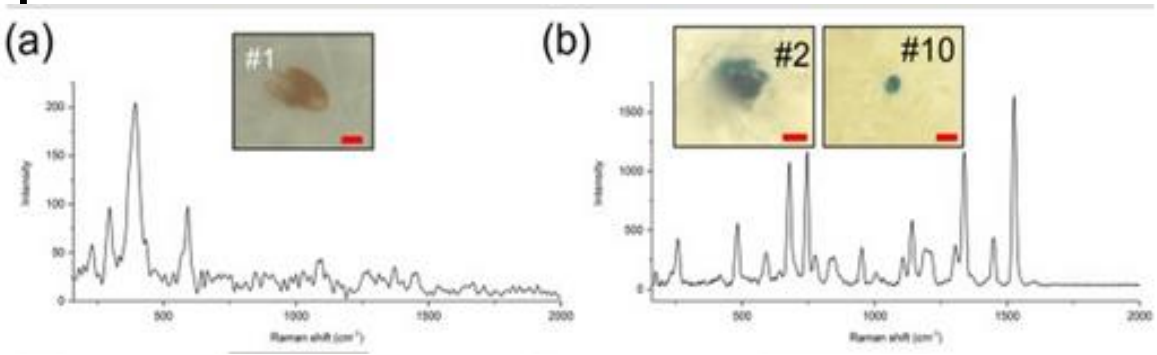


Table 1

Particle	Placenta Portion	Microparticles				
		Size	Color	Polymer matrix	Pigment	
					Generic name	Molecular formula and IUPAC name
#1	FS	~10 μm	Orange	n.d.	Iron hydroxide oxide yellow (Pigment Yellow 43; C.I. Constitution 77492)	FeO(OH) iron(III) oxide hydroxide
#2	CAM	~10 μm	Blue	Polypropylene	Copper phthalocyanine (Pigment Blue 15; C.I. Constitution 74160)	$C_{32}H_{16}CuN_8$ (29H,31H-phthalocyaninato(2 –)-N29,N30,N31,

Ragusa, 2020, Environment International; Stapleton, 2019, AIMS Environmental S

What We Know

- Particles are in our air.
- Our laboratory animals are small for gestational age. *(Stapleton, 2013; Fournier, 2019)*
- Impaired uteroplacental blood flow after exposure. *(Stapleton, 2013; D'Errico 2019)*
- Particles or metal ions can translocate from the lungs to the placenta and the fetus within 24-hours. *(D'Errico 2019; Fournier, 2020; D'Errico, in Revision)*
- Prenatal exposure impacts offspring cardiovascular health. *(Stapleton, 2013; Stapleton, 2015; Fournier, 2019; Fournier, 2021)*

Needs/Solutions

- Understanding of local pollution levels – access, community partners, teamwork.
- Implementation of reduction programs.

- Understanding of the biological effects.
  - ➢ Know particles are getting in – and around – what are the local effects?
    - ❑ Maternal Effects
    - ❑ Placental Effects
    - ❑ Fetal Effects
  - ➢ Strategies to create an intervention/mitigate the biological outcome.

Thank you and Acknowledgements

Stapleton Laboratory

Jeanine D'Errico, Graduate Student
Chelsea Cary, Graduate Student
Talia Seymore, Graduate Student
Jarett Reyes George, SURF Student

Rutgers Molecular Imaging Facility
Ed Yurkow, PhD
Derek Adler, MS

Rutgers Research Pathology Services
Mike Goedken, DMV, PhD
Marianne Polunas, PhD

Cytoviva, Inc

National Institute of Environmental Health Sciences
Your Environment. Your Health.

NIH-R01-ES031285; R00-ES024783 (PAS); T32-ES007148; P30-ES005022; R25-ES020721