EUROPEAN TYRE & RUBBER
manufacturers'association

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EVALUATION OF AIRBORNE TYRE AND ROAD WEAR PARTICLES (TRWP)

DATA GENERATED UNDER THE TYRE WORK PROGRAMME OF WBCSD

PRESENTATION TO UNECE PMP IWG

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8 JANUARY 2014

WBCSD - Tyre Industry Project (TIP)

- Project management by the World Business Council for Sustainable Development
- Technical expertise provided by ChemRisk, LLC, scientific consulting firm, bringing expertise in the areas of toxicology and industrial hygiene services, as well as in ecological risk assessment
- With the support of the 11 most important tyre producers and the comments on the vision and strategic direction of independent experts (Assurance Group).

Goal : Anticipate the potential long term environmental and health issues relating to tyre materials, **Tyre & Road Wear Particles**, end of life tyres and recycling management

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Tyre & Road Wear Particles (TRWP)

Outline

- Generation, characterization of TRWP and airborne TRWP sampling in lab
- Marker for TRWP and environmental global sampling study for airborne TRWP
- Toxicity study on TRWP Intratracheal Instillation test an Inhalation tests
- Overall conclusions

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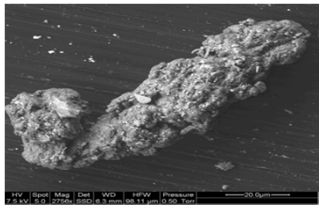
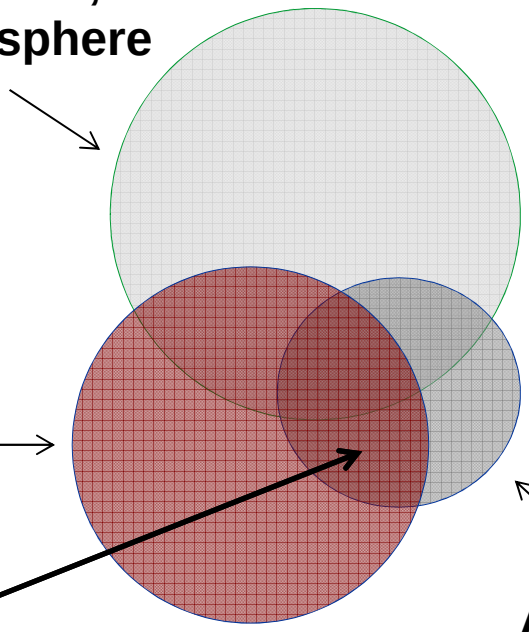
Types of Particles



C: from environmental "dust", brakes, fuels, and the atmosphere

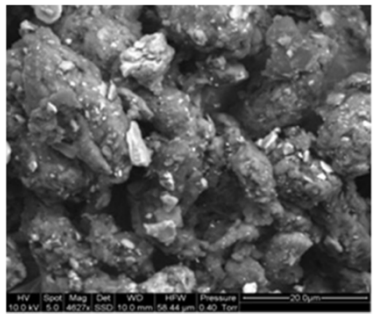


RP (A+B+C)
= All particles on the road
= Roadway Particles

B: from pavement

A: from tire

TRWP (A+B)
= Particles from wear
= Tyre & Road Wear Particles



TP (A)
= Particles from tyre
= Tyre Particles

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Collections system for TRWP

- For any characterization (physical, chemical and toxicological) particles representative of the real wear have to be collected.
- To be representative particles have to be generated from the interaction of tyres and road surface.
- Particles obtained for example by grinding of rubber pieces are not representative and results obtained by these particles cannot be extrapolated to real on road use of tyres.
- **Since recently it is possible to collect particles representative of on road use of tyres by in-door techniques.**

Marisa L and All, Physical and chemical characterization of tire-related particles : Comparison of particles generated using different methodologies , Science of the Total Environment 408 (2010) 652-659

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On-road Collection System

The reference to validate in door collection

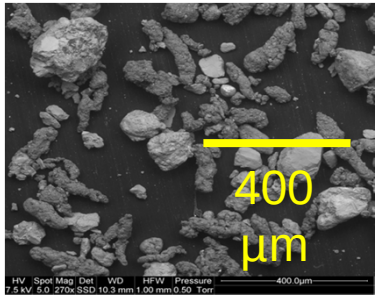
BASt In-door Collection Method

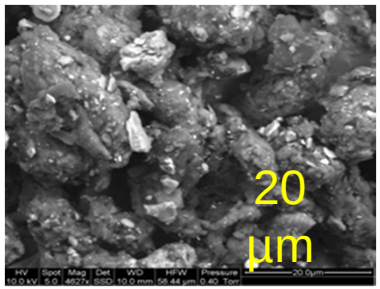
- Standard “Driving” Conditions During Collection:
  - asphalt pavement;
  - 183km at varying speeds up to 150 km/h
    - 2% @ 0-30 km/h
    - 7.4% @ 30-50 km/h
    - 25.2% @ 50 – 80 km/h
    - 34.2% @ 80 – 120 km/h
    - 30.6% @ 120 – 150 km/h
  - Variations in acceleration and deceleration
  - Cornering

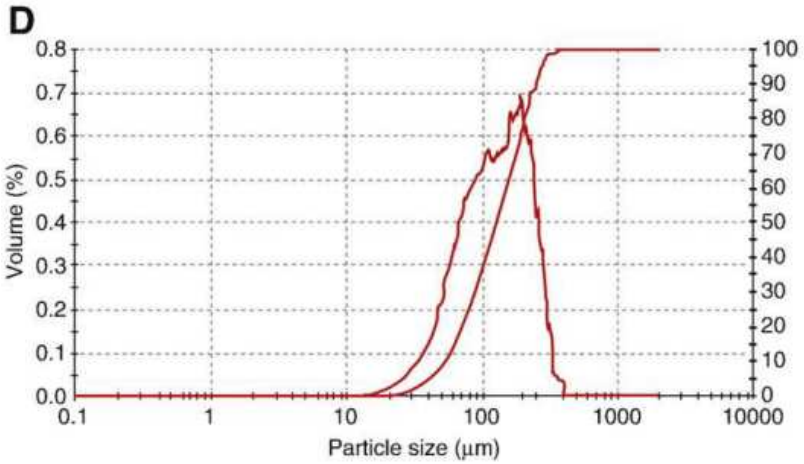
Chemical and Physical Analysis of TRWP

Physical Properties

- Size Distribution (by Vol. of particles)
  - **Asphalt: 4 -350 µm with median of 105 µm**
  - **Concrete: 1-149 µm with median of 77 µm**







Transmission optical microscopy - probability distribution and cumulative distribution (asphalt)

Chemical Composition

- TRWP is a mix of tyre tread, and road surface and dust.
- Contribution from tyre is 'diluted' (~50%) with road minerals and organics.

General composition analysis of particles as determined by thermogravimetric analysis.

Chemical family	RP	TWP	TP
Plasticizers and oils	13	10	19
Polymers	23	16	46
Carbon blacks	11	13	19
Minerals	53	61	16

Values are expressed in percent by mass.

Kreider et al. 2010

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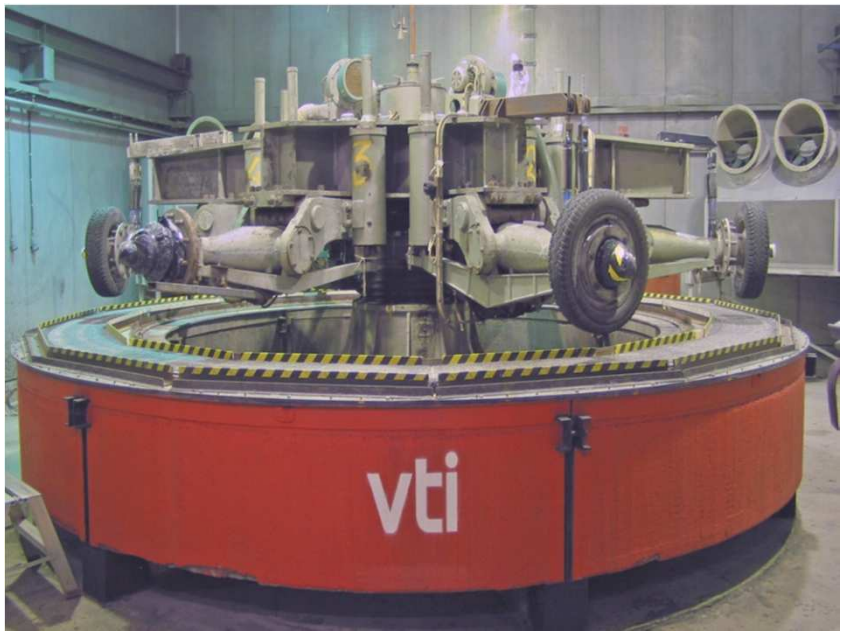
VTI In-door Collection Method



Method for airborne TRWP evaluation now existing :
Julie Panko and All, Physico-Chemical analysis of airborne tire wear particles , Eurotox, 2009

Real Time Monitors	Low Pressure Impactor	PM10
Scanning Mobility Particle Sizer (SMPS) (7 -300 nm)	12-stage cascade impactor → APS (0.04 – 10 µm)	<10 µm
Aerodynamic Particle Sizer (APS) (0.5 – 10 µm)	Elemental analysis by particle induced x-ray emission (PIXE)	Elemental analysis by scanning electron microscopy – energy dispersive spectroscopy (SEM-EDS)

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Airborne TRWP Evaluation - Results

APS: Overall low airborne PM10 concentration of 10 µg/m^3
Bi-modal particle size distribution in the PM10 (Peaks at 1 um and 5-8 µm)

SMPS: Particle Number (PN) concentration in ultra-fine range was similar to that of background in the chamber (1000-2000#/cm^3)

- Peak in the # of particles generated between 10-100 nm
- Results similar to other VTI studies which showed no nano-particles arising from the tyre tread

Elemental composition by Particle Induced X-ray Emission (PIXE)

- Pavement wear particles dominated the coarse fraction 2.5 µm – 10 µm
- Tyre wear particles were found mostly in size fractions less than 5 µm
- **TRWP had a relative contribution of 8.5% by mass of the total PM10 fraction (i.e. 91.5% of the PM10 mass is from the pavement)**

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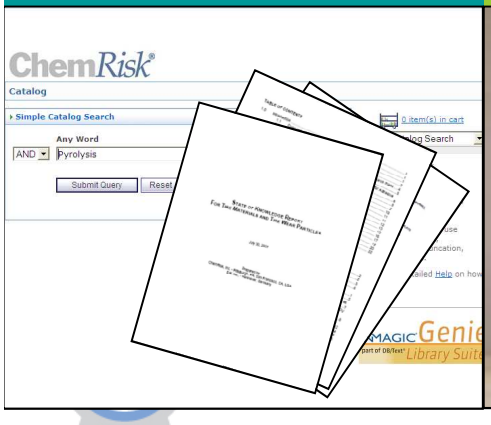
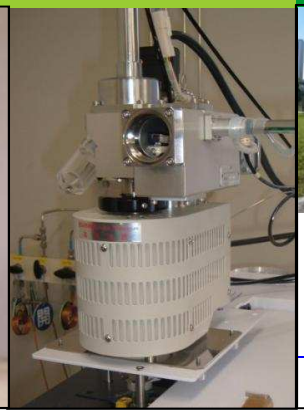
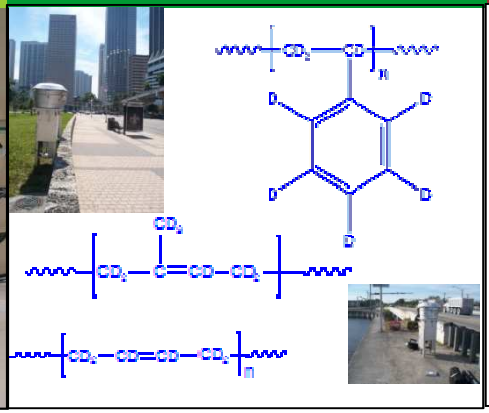
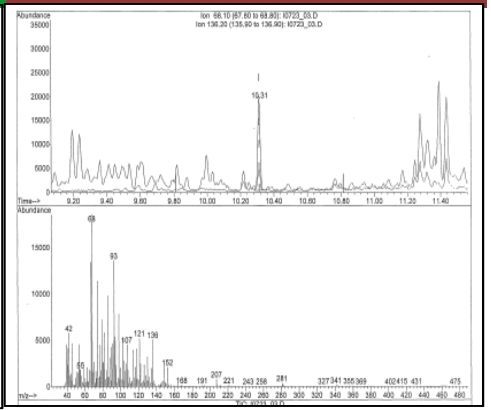
Timeline of Pyrolysis Marker Development and Verification

2007-2008	2009	2010	2011
Literature Review *State of Knowledge Assessment*	**Method Comparison** *Organic Zinc Extraction versus External Standard Pyr-GC/MS*	**Method Selection and Refinement** *New Internal Standard Pyr-GC/MS Method*	**Method Finalization** *Detection Limit Study Completed with Int. Std.*

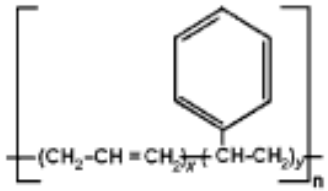
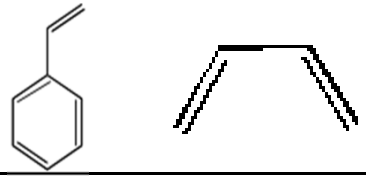
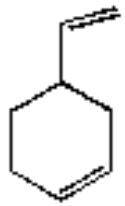
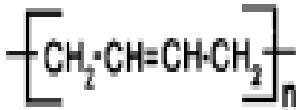
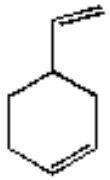
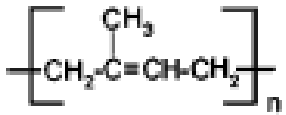
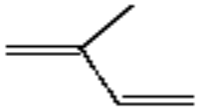
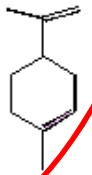








Final Pyrolysis Marker Selection (2010)

Polymer	Monomer	Dimer
SBR 	Styrene Butadiene 	Vinylcyclohexene (butadiene dimer 
BR 	Butadiene 	Vinylcyclohexene (butadiene dimer) 
NR 	Isoprene 	Dipentene (isoprene dimer) 

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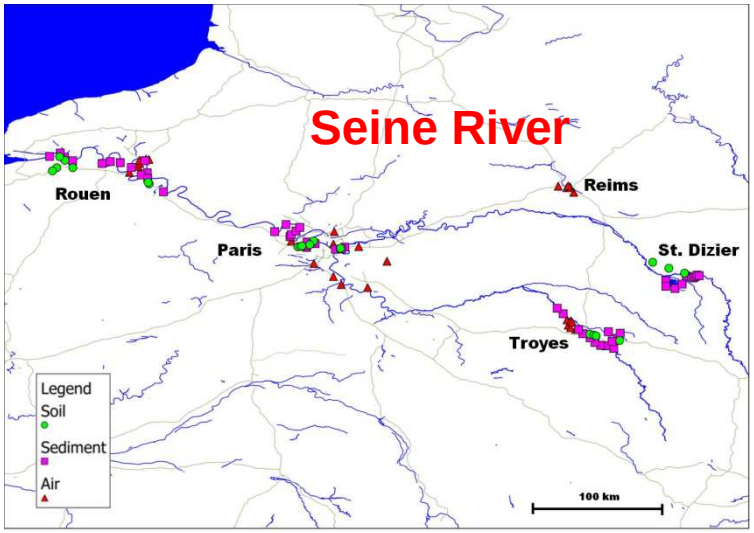
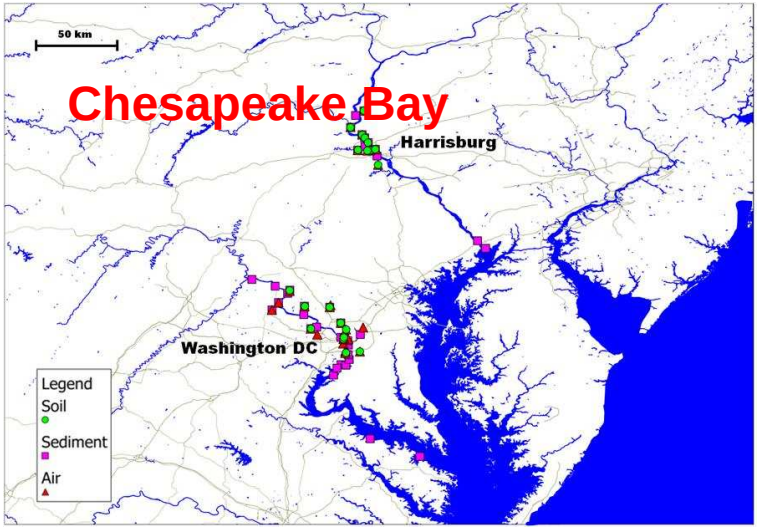
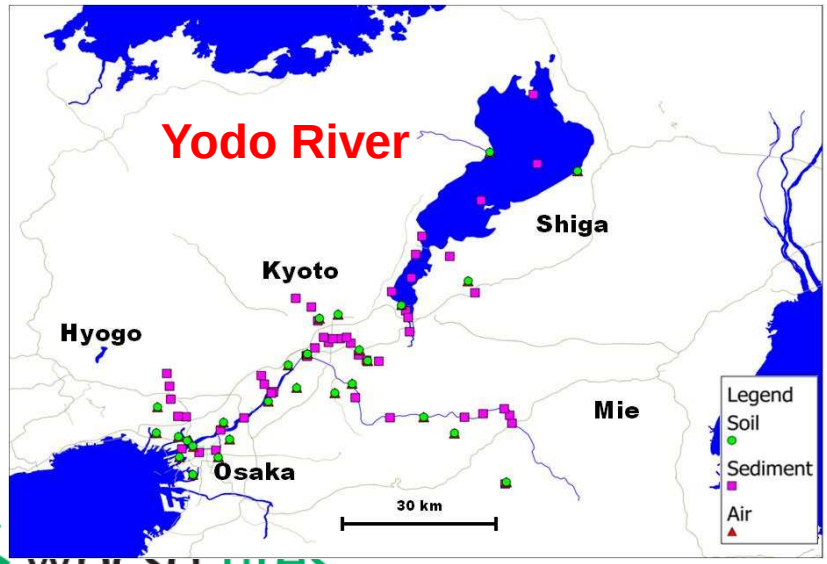
From fall 2010 to summer 2011, global air sampling field work in Europe, the US and Japan







Sampling Locations

- Unice KM, and All, evaluation of tire and road wear particles in the Seine River Watershed, Society of Environmental Toxicology and Chemistry/SETAC, May 2012
- Chemrisk LLC – TRWP Global Sampling Project October 11, 2011

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Results from Global Air Sampling PM10

Watershed	Area (n)	Median Distance to Road [Range] (m)	Average PM10 (µg/m³)	TRWP Det. Freq.	Avg (µg/m³) TRWP	Max (µg/m³) TRWP	% Contribution to PM10 (Average) TRWP
Seine (France)	Troyes (6)	5 [3-100]	26	83%	**0.70**	**1.34**	**2.80**
	Reims (6)	5 (5-10)	10	67%	**0.17**	**0.70**	**1.74**
	Paris (9)	20 (5-300)	48	78%	**0.05**	**0.11**	**0.14**
	Rouen (6)	30 (20-150)	20	50%	**0.17**	**0.86**	**0.86**
Chesapeake (USA)	Harrisburg (9)	7 (3-89)	15	78%	**0.13**	**0.32**	**0.94**
	Washington, D.C. (4)	15 (3-46)	23	100%	**0.24**	**0.48**	**1.04**
	Maryland (7)	21 (8-46)	16	71%	**0.12**	**0.26**	**0.72**
	Virginia (7)	15 (1-229)	14	86%	**0.10**	**0.16**	**0.84**
Yodo (Japan)	Shiga (4)	5 (2-10)	49	100%	**0.18**	**0.32**	**0.38**
	Kyoto/Mie (10)	4 [1-10]	24	70%	**0.09**	**0.22**	**0.50**
	Hyogo (3)	3 [2-5]	35	33%	**0.06**	**0.09**	**0.18**
	Osaka (10)	5 [2-10]	33	70%	**0.09**	**0.15**	**0.38**
Seine	*All (27)*	20 [3-300]	28	70%	**0.24**	**1.34**	**1.24**
Chesapeake	*All (27)*	15 [1-229]	16	81%	**0.14**	**0.48**	**0.88**
Yodo	*All (27)*	5 [1-10]	32	70%	**0.10**	**0.32**	**0.40**
All	*All (81)*	**8 [1-300]**	**25**	**74%**	**0.16**	**1.34**	**0.84**

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Field collected PM10 samples contained TRWP at concentrations generally < 1 µg/m³ , TRWP contribute to ~ 1% in global field evaluation

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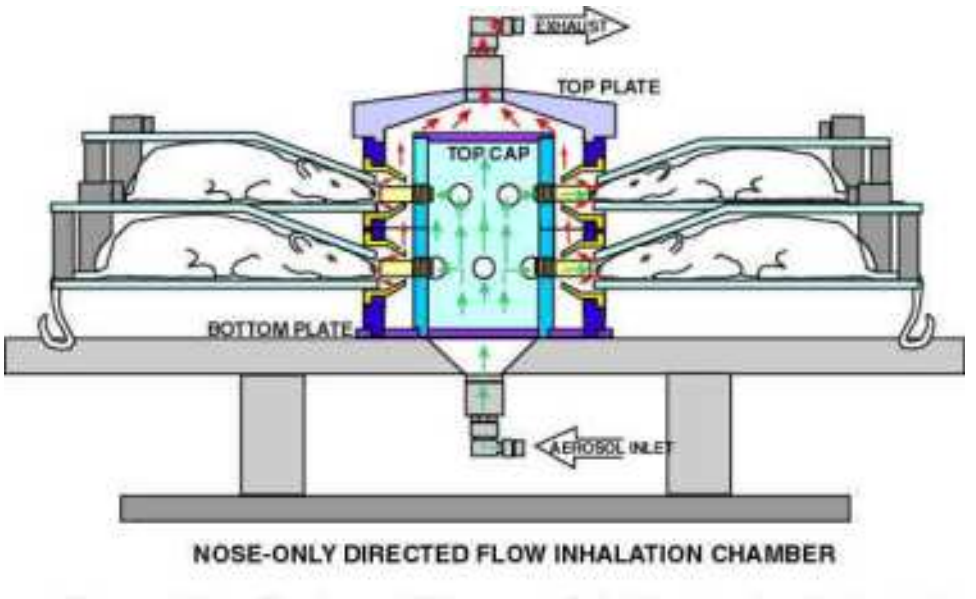
Design of TRWP Inhalation Tests

- Air concentration of TRWP monitored real-time and by gravimetric analysis following study completion
- Particle size distribution is monitored real-time to ensure particles can be inhaled by rats



NOSE-ONLY DIRECTED FLOW INHALATION CHAMBER

- **Expose rats to TWRP (separated to PM10 fraction) at four concentrations:**
  - **0, 10, 40, 100 µg/m³**
- **Expose rats in sub-chronic scenario**
  - **6 hours/day**
  - **28 days**

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Toxicity Studies - Conclusions

- **Results of both instillation and inhalation studies provide a similar conclusion; TRWP is unlikely to cause adverse cardiopulmonary effects**
- Instillation study indicated that TRWP and TP are less toxic than silica or diesel exhaust and behave similarly to inert particles (titanium dioxide)
- Histopathology seen in instillation study was not seen with inhalation
- Inhalation study identified a **NOAEL** (no observable adverse effect level) **of 112 µg/m^3** of TRWP to be used to compare to detected airborne concentrations of TRWP from global sampling.

- Kreider ML and ALL, Effect of Intratracheal Instillation of Tire and Road Wear Particles and Tread Particles on Inflammation and Cytotoxicity in Rat Lung : A Comparative Toxicity Study , SOT, 2009)
- Kreider ML and Panko JM, Effect of Sub acute Inhalation Exposure to Tire and Road Wear Particles in Rats, Eurotox, June 2012

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TRWP Program Overall Conclusions 1/2

Knowledge on TRWP was significantly improved during the last four years :

- Techniques to collect particles representative of on real road use of tyres are now existing
- Analytic techniques are now in place for the characterization of TRWP, and results are available
- Techniques for measurement of contribution of TRWP to PM10 in air, soil and sediment pollution are in place, efficiency is demonstrated and results available
- Evaluation of level of TRWP toxicity and also ecotoxicity are now possible and results available
- On going WBCSD TIRES work: measurement of contribution of TRWP to atmospheric PM 2.5 pollution (results expected for end 2014, report publication 2015)

New technologies issued from these studies are now to be proposed to ISO

Publications are available on :
http://www.wbcsd.org/Pages/EDocument/EDocumentDetails.aspx?ID=54&NoSearchContextKey=true

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TRWP Program Overall Conclusions 2/2

By applying the new techniques, clear results were obtained :

- Tyre wear generates a broad distribution of TRWP
  - Composed of tyre tread, road surface and road dust
  - Size range from 1-350 µm (median ~80 – 100 µm)
- The majority (>99%) of TRWP is sedimentary in nature and will be transported to roadside run-off
- The smallest size fraction of TRWP (~1 µm) is detectable in PM10, however this contributes
  - ~10% of PM10 in lab evaluation
  - ~1% of PM10 in global field evaluation
- Field collected PM10 samples contained TRWP at concentrations generally < 1 µg/m^3
- Inhalation toxicity studies identify a no adverse effect of 112 µg/m^3 for TRWP.

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