NANYANG TECHNOLOGICAL UNIVERSITY SINGAPORE | Nanyang Environment and Water Research Institute

ENVIRONMENTAL IMPACTS & POTENTIAL SOLUTIONS OF TIRE WEAR PARTICLES

Introduction:

Tire wear particles (TWPs) are estimated to contribute approximately 1,327,000 tonnes per year of emissions across Europe. Car tires are composed of both natural and synthetic rubber, combined with a wide range of chemical additives—including fillers, reinforcing agents, processing aids, accelerators, retarders, adhesives, and activators. These additives are typically not chemically bonded to the rubber matrix, allowing them to migrate to the surface over time.

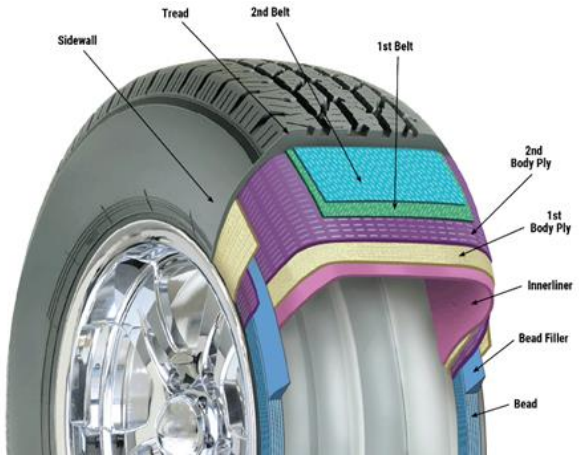
As a result, both tires and TWPs are recognized as sources of soluble organic pollutants due to the leaching of these additives. While microparticles tend to settle in sediments and are generally removed during drinking water treatment processes, soluble organic compounds—especially those that are highly polar and persistent—are more mobile in aquatic environments and harder to eliminate, posing risks to ecosystems and human health.

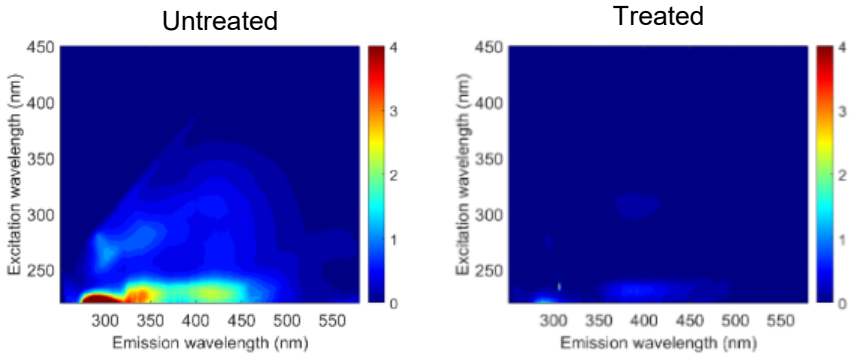
Similarly, leachates from plastics are now considered an emerging environmental concern. The hazards associated with tire leachates gained attention following the discovery of 6PPD-quinone, a toxic oxidation product of 6PPD (N-phenyl-N'-(1,3-dimethylbutyl)-p-phenylenediamine), a common rubber additive. This compound has been implicated in mass die-offs of Coho salmon in the Pacific Northwest.

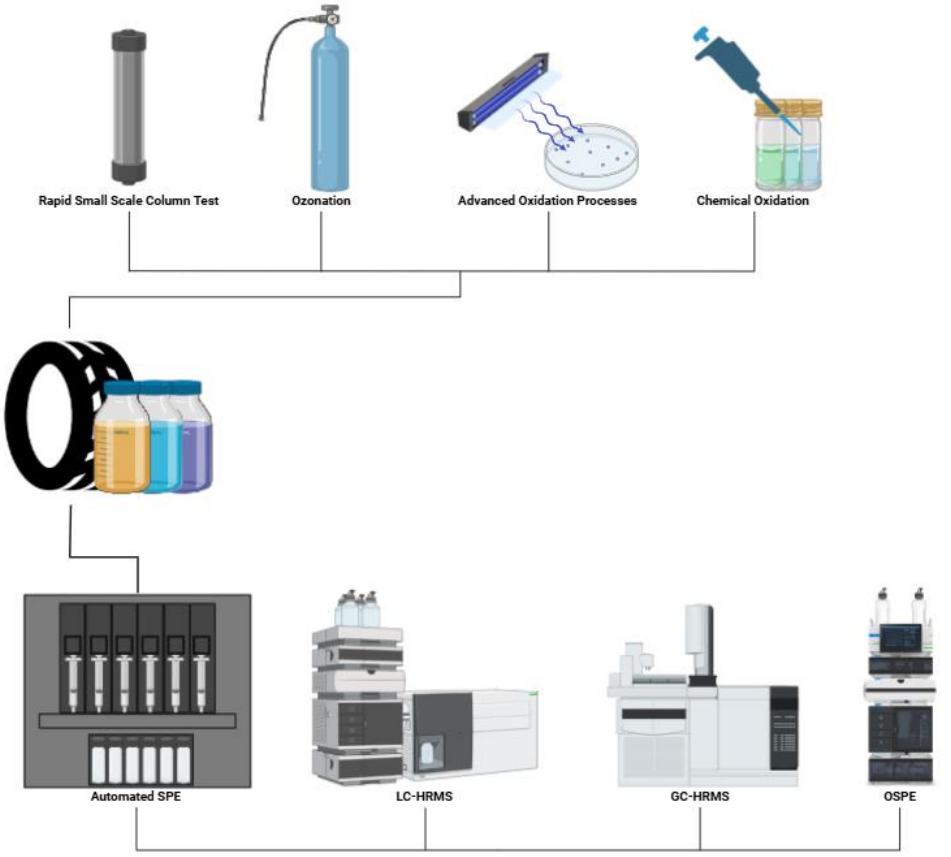
Characterization Experiments:

Leachate samples from tire wear particles (TWPs) were prepared following a standardized protocol and initially analysed for their dissolved organic carbon (DOC) and dissolved organic nitrogen (DON) concentrations. To visualize compositional changes throughout various treatment stages, fluorescence spectroscopy was performed using excitation-emission matrices (EEMs). The leachates were characterized before and after different treatment strategies

A highly sensitive analytical method was developed using liquid chromatography coupled with tandem mass spectrometry (LC-MS/MS), incorporating both QqQ and QTOF detectors. This approach enables detection at parts-per-trillion levels, facilitating the tracking of individual TWP additives and transformation products. Additionally, it allows for the identification of novel reaction products, contingent upon the availability of reference standards.



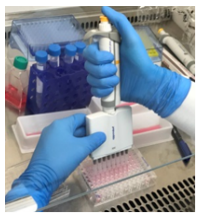




Biological Testing Experiments:

A range of biological and toxicological assays encompasses three primary categories:
(i) cell-based screening assays assessing cytotoxicity and employing fluorescent gene reporter cell lines;
(ii) zebrafish embryo assays to evaluate developmental toxicity; and
(iii) downstream molecular analyses, including gene marker profiling, mitochondrial stress evaluation, and multiplexed molecular characterization of peptides and nucleic acids.

Native cells/ Fluorescent reporters



- HepG2 (cytotoxicity)
- GR reporter (glucocorticoids)
- ER reporter (estrogenic compounds)
- Oxidative Stress response

Reporter Signals

Multi-mode Plate reader
Absorbance, fluorescence signals and imaging

Real-time cell analyzer
Impedance-based & Imaging analysis

Molecular analyses (DNA/RNA/Peptides)

Real-time PCR & Digital PCR
5-channel, flexible format

Associate Professor
Richard D. Webster