Chemical profile and toxicity of leachates from different types of tires

Norwegian Institute for Water Research

MicroLEACH

Elisabeth S. Rødland, Ana C. Almeida, Maria Christou, Sebastian Küehr, Jan Thomas Rundberget, Tânia Gomes

BACKGROUND

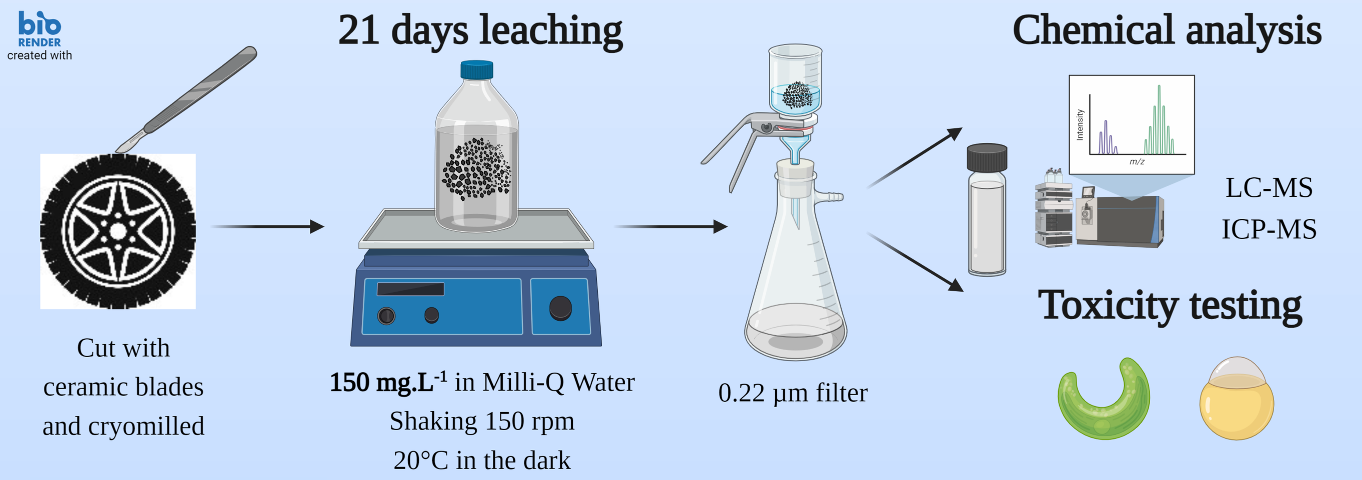
The negative impact from tire wear particles released into the environment has recently gained more attention, as new studies related to their chemical content, leaching capabilities and effects on organisms have been published. Studies demonstrated that tires contain a wide range of compounds, including rubbers and natural rubber, metals and organic compounds. Although several studies have investigated the chemical content of tires and their toxic implications on different organisms, most studies use crumb rubber material from scrap tires or a mixture of tire materials. These mixtures allow the investigation on the levels and effects across a range of tires in a sample, which is environmentally relevant, however, it makes it difficult to evaluate the variation between seasonality, brand and models of different tire types. Our main aim was to investigate the toxicity of leachates from 4 tires (winter studded, winter non-studded, summer, truck) in the freshwater microalgae *Raphidocelis subcapitata* and zebrafish embryos *Danio rerio* and understand if their chemical composition affected the organisms differently.

APPROACH

LEACHATES PREPARATION AND CHARACTERIZATION

Table 1 – Tires used from different brands commonly used in Norway and their seasonality.

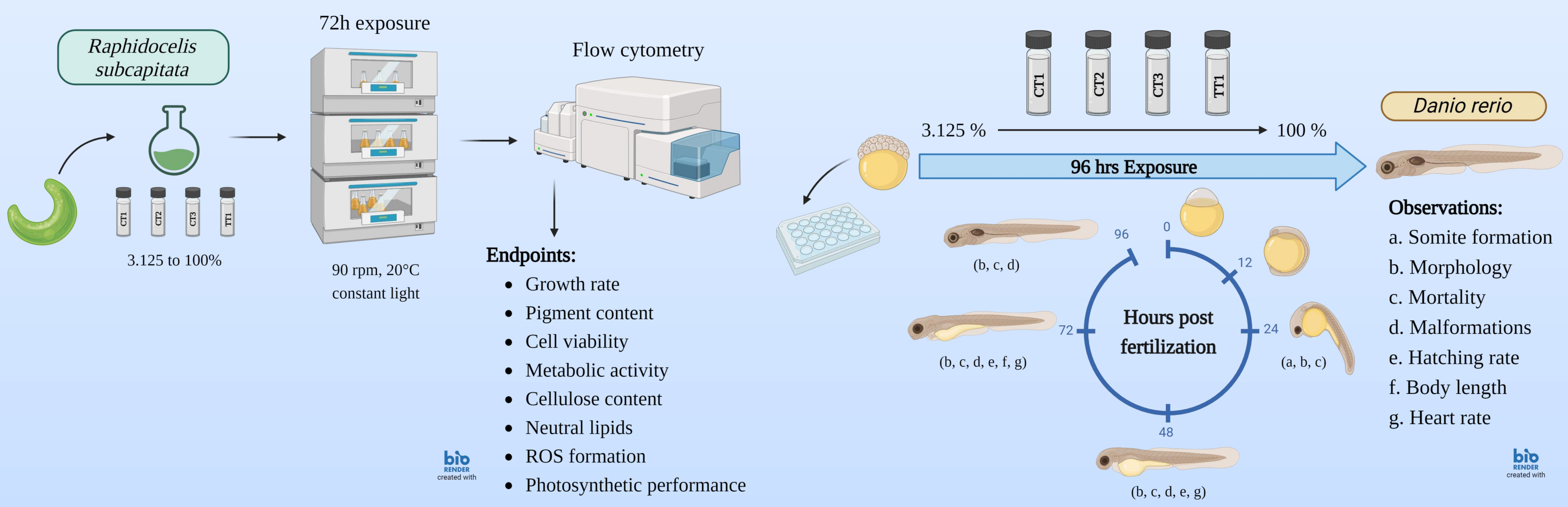
Tire sample	Brand	Season/type	Vehicle type
CT1	Brand 1	Winter studded	Personal vehicle
CT2	Brand 2	Winter non-studded	Personal vehicle
CT3	Brand 3	Summer	Personal vehicle
TT1	Brand 1	Winter non-studded	Heavy vehicle



TOXICITY TESTING

Microalgae growth inhibition test – ISO 8692

Zebrafish embryo toxicity test (FET) – OECD 236



RESULTS

TOXICITY TESTING

Microalgae growth inhibition test

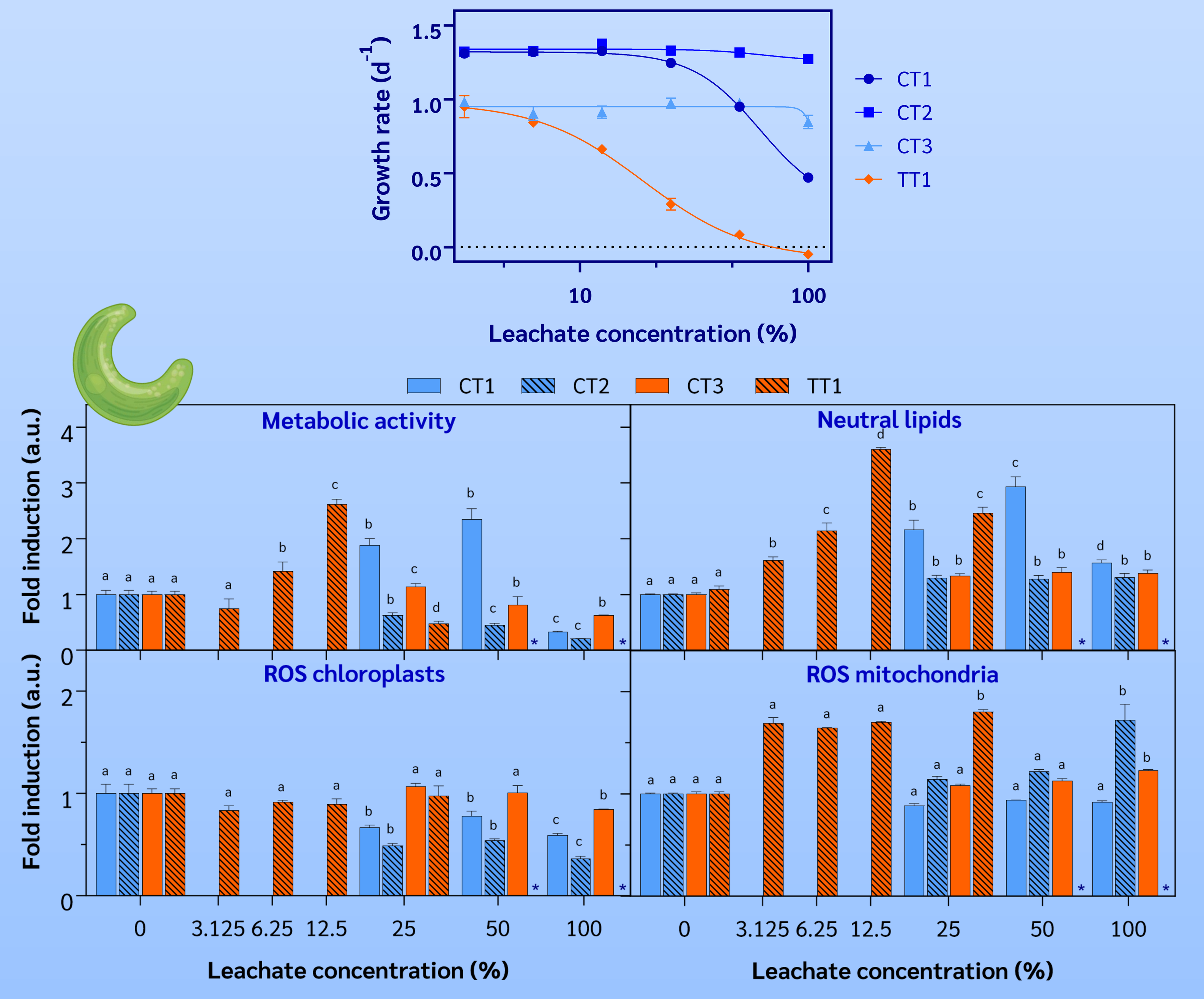


Figure 1 – Effects of the tire leachates on the freshwater algae *Raphidocelis subcapitata* exposed for 72 hours. *Not analysed due to mortality of microalgae cells. Different letters indicate significant differences between concentrations ($p < 0.05$).

Zebrafish embryo toxicity test

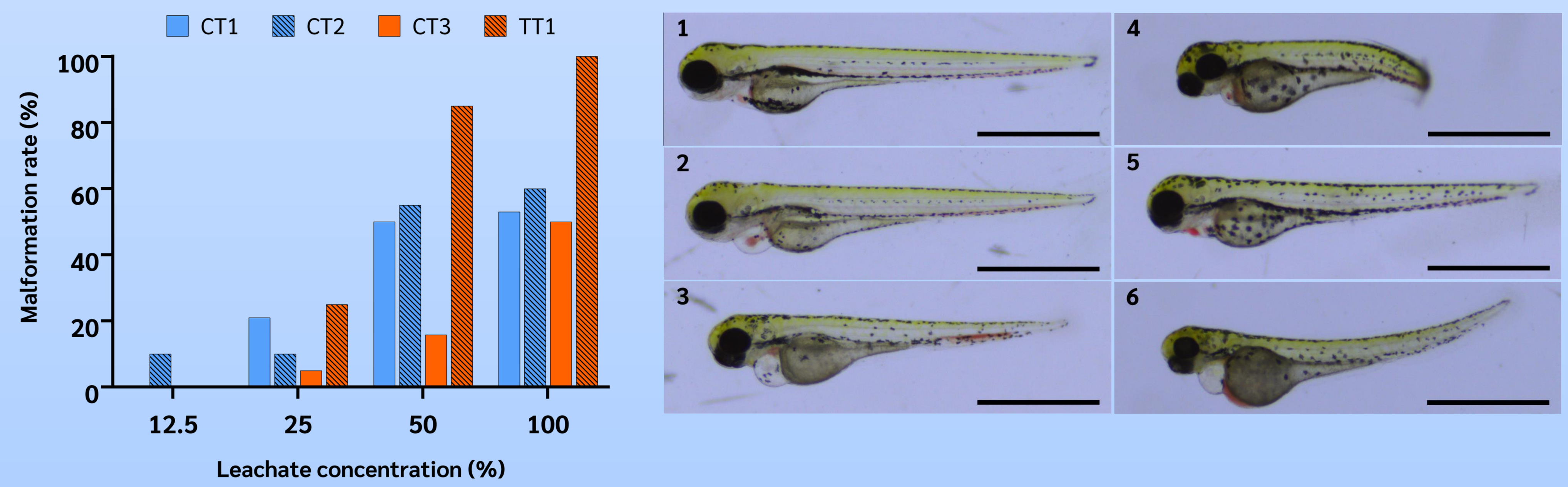


Figure 2 – A) Effect of the tire leachates on malformation rate in zebrafish larvae at 96 hours post fertilisation (hpf). B) Zebrafish larvae at 96 hpf from the control (1) and exposed to tire leachates showing pericardial and yolk sac oedemas, haemorrhage and spinal deformities: (2) CT1 50%; (3) CT2 50%; (4-5) TT1 50% and (6) TT1 100%. Scale bars are 1 mm.

CHEMICAL ANALYSIS

Table 2 – Chemical characterization of car tire leachates (100%) in Milli-Q water using LC-MS and ICP-MS analysis.

Tire sample	Zn ($\mu g.L^{-1}$)	6PPD ($ng.mL^{-1}$)	6PPD-Q ($ng.mL^{-1}$)	DPPD ($ng.mL^{-1}$)	HMMM ($ng.mL^{-1}$)	DPG ($ng.mL^{-1}$)	TMQ ($ng.mL^{-1}$)	PhBT ($ng.mL^{-1}$)	SBR ($\mu g.mg^{-1}$)
CT1	121.9 ± 2.3	1.0 ± 0.1	2.8 ± 0.4	3.4 ± 0.3	25.8 ± 2.2	31.9 ± 4.9	24.0 ± 5.2	<LOD	232 ± 28.6
CT2	29.4 ± 1.2	10.6 ± 0.3	3.6 ± 0.4	3.0 ± 0.1	176.5 ± 16.3	41.1 ± 10.7	36.1 ± 4.5	8.1 ± 0.2	187 ± 12.1
CT3	18.0 ± 1.3	3.2 ± 0.1	2.3 ± 0.6	<LOD	19.9 ± 0.1	2080 ± 308	13.7 ± 0.7	24.1 ± 0.8	265 ± 11.5
TT1	352.2 ± 6.4	7.3 ± 0.4	0.9 ± 0.4	<LOD	<LOD	51.2 ± 37.0	12.4 ± 0.9	<LOD	425 ± 38.8

Zn – Zinc; 6PPD – N1-(4-Methylpentan-2-yl)-N4-phenylbenzene-1,4-diamine; 6PPD Q – 6 PPD quinone - 2-((4-Methylpentan-2-yl)amino)-5-(phenylamino)cyclohexa-2,5-diene-1,4-dione; DPPD – Diphenyl-p-phenylenediamine; HMMM – Hexamethoxymethylmelamine; DPG – Dipropylene glycol; TMQ - poly(1,2-dihydro-2,2,4-trimethyl-quinoline) – rubber antioxidant; PhBT – 2-phenylamino-5-(2-hydroxybenzono)-1,3,4-thiadiazole; SBR – Styrene-butadiene rubber.

OVERVIEW

- **Chemical analysis:**
  - Variation in chemical composition explained by tire brand (60%), vehicle type (32%) and seasonality (27%) (Redundancy analysis (RDA), all significant ($p<0.05$)).
  - SBR levels explained 39% (RDA, p<0.05) of the variation in chemical composition. Significant correlation ($p<0.05$) observed for SBR~Zn (RDA 45%, positive) and SBR~6PPD-Q (86%, negative).
- **Toxicity testing:**
  - TT1 most toxic to *R. subcapitata* (EC_{50}=18.9%), followed by CT1 (EC_{50}= 61.5%). CT2 & CT3 with low to no toxicity (EC_{50}>100%).
  - ROS formation, metabolic activity, cellulose & neutral lipid content most affected sub-lethal parameters in microalgae ➔ tire specific trends.
  - A small effect in survival and hatching rate in zebrafish embryos ➔ TT1 with highest effects, followed by CT2, CT1 and CT3.
  - Embryos showed different types of malformations ➔ pericardial and yolk sac oedemas, hemorrhages and spinal deformities, more evident in TT1.

CONCLUSIONS

- The different responses in microalgae and zebrafish suggest a correlation with the chemical profile of the leachates produced from the 4 different tires.
- Our results demonstrate the importance of assessing the chemical profiles and toxicity of individual tires, as well as in mixtures ➔ particularly important to understand the impact from tires and their leachates in different environmental compartments.

esr@niva.no

Affiliation: Norwegian Institute for Water Research (NIVA).

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