EFFECTS OF EXTENDED LOW-LOAD OPERATION OF A NON-DPF DIESEL ENGINE ON THE RELATIVE TOXICITY OF ITS EMISSIONS

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BACKGROUND: Engine operating conditions common in congested urban areas are outside of the currently used standardized test cycles. Problematic operating modes might be extended idling and creep, dynamic/transient operation and full-power accelerations. These operating modes may lead to higher and more toxic emissions. For toxicity evaluation of particulate engine emissions, focus should be on the realistic urban driving conditions. The focus of this work is on the effects of extended operation of truck engines at low load, typical for severe congestion, on exhaust emissions.

AIM: To assess the impact of operating mode and fuel type (diesel vs. biodiesel) on the toxicity of organic extracts of diesel engine emissions.

CONCLUSIONS: 1) The most sensitive toxicity marker is DNA adduct analysis – both in cell-free and human lung cell model (A549). Highest adduct levels were detected for full-load immediately after an extended low-load period (deposit burn-off) on diesel fuel.
2) The results of oxidative damage of biomolecules and micronucleus test did not indicate clear toxic effects of EOMs.

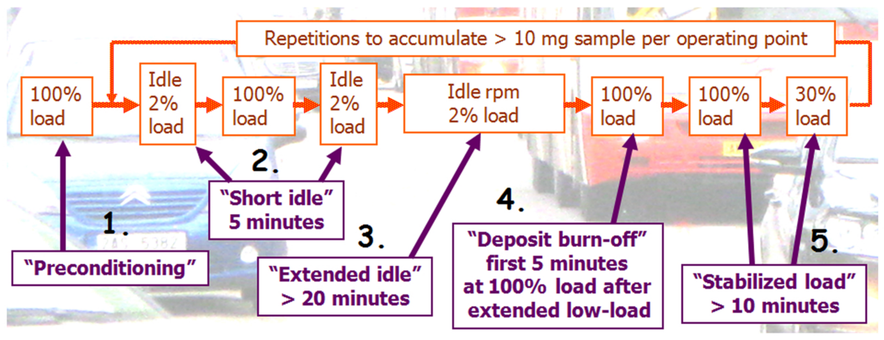
METHODS

1. SAMPLING

a) Engine

Type of engine: diesel Zetor 1505, turbocharged, 4.16 liter, 90kW
Fuels: on-road diesel (EN 590), 100% biodiesel (FAME)
Operating modes:
- engine coupled to dynamometer and operated at steady-state conditions selected to represent different phases of engine operation during the transit traffic congestion:
  - 100 rpm above idle, 2% load (870 rpm, 10 Nm) - corresponds to low-speed "creep"
  - intermediate rpm, 30% load (1500 rpm, 150 Nm) - corresponds to "highway cruise"
  - intermediate rpm, 100% load (1500 rpm, 500 Nm) - corresponds to hill climb / acceleration

To collect the sample of emission particles in sufficient quantities for various toxicity tests, laboratory operations in each operating mode ran in different time intervals.



	Operating mode	Engine speed [rpm]	Engine torque [Nm] and load
1	Stabilized full load	1500	500 (100%)
2	Short idle (5 minutes)	870	10 (2%)
3	Extended idle (? 20 minutes)	870	10 (2%)
4	Deposit burn-off (first 5 minutes at 100% load after extended idle)	1500	500 (100%)
5	Stabilized 30 % load (cruise) (? 10 minutes)	1500	150 (30%)

b) Sampling equipment
atmospheric high-volume samplers (EcoTech 3000, 8"x10" filters)
filter: PTFE filter (TX40HI20WW, Pall)

c) EOM extraction
1.Extraction by dichlormethane
2. Evaporation under a stream of nitrogen with 1,2-propanediol as a keeper
3. Re-dissolution in dimethylsulfoxide (DMSO)

Filter
↓
2 m³ EOM/ µl DMSO

↓

2. TOXICITY TESTS

1) Acellular assays (calf thymus DNA ± rat liver microsomal S9 fraction)
- incubation at 37°C for 24 hours

- DNA adducts (by ^{32}P-postlabelling)
- 8-oxo-dG

2) Cellular assays (model of human lung epithelial cells - A 549 cells)

a) Cytotoxicity – test WST-1 cell proliferation test (Roche)
- doses of 1 and 10 dm³ of undiluted emissions were tested
- incubation for 24 hours

b) Genotoxicity - DNA adducts (by ^{32}P-postlabelling)
- micronucleus test

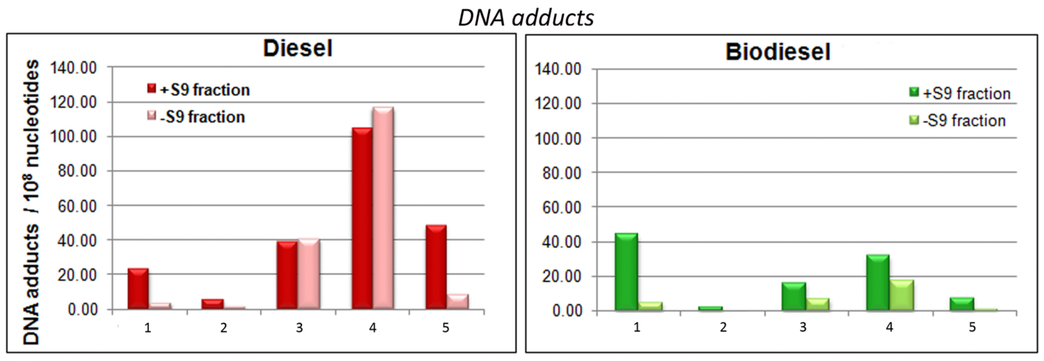
c) Oxidative damage - oxidative damage of proteins: carbonyl groups
- oxidative damage of lipids: 8-isoprostane

RESULTS

1) ACELLULAR ASSAYS (ct DNA)

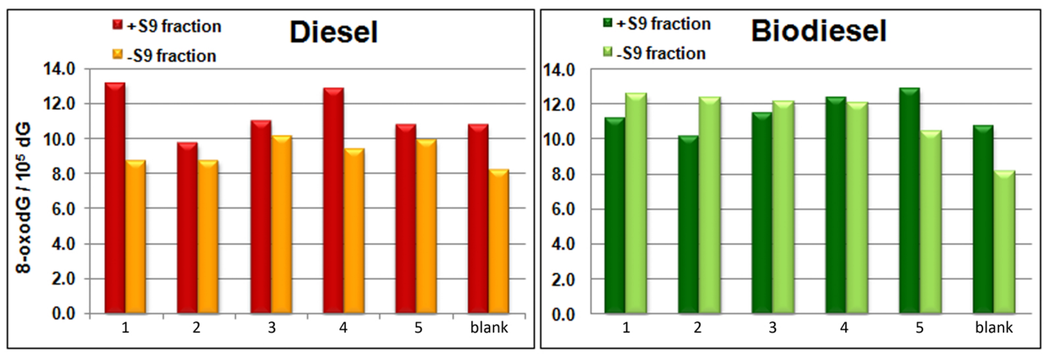
concentration 10 dm³ emissions/ml

DNA adducts



The results suggest that highest genotoxicity is induced by operating mode 1500/500 (deposit burn-off), particularly for diesel.
For biodiesel is genotoxicity substantially lower.

8-oxodG

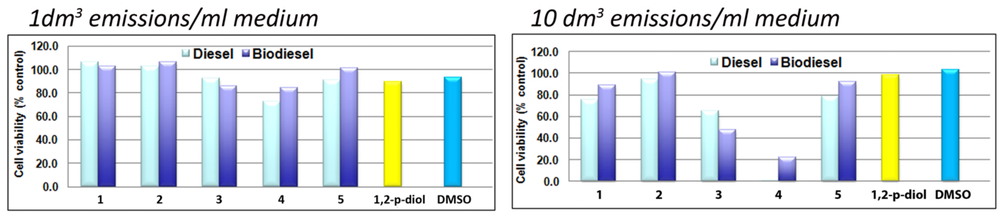


No significant DNA oxidative damage was observed for all operating conditions for both diesel and biodiesel.

2) CELLULAR ASSAYS (HUMAN LUNG CELLS A549)

a) Cytotoxicity

1dm³ emissions/ml medium *10 dm³ emissions/ml medium*

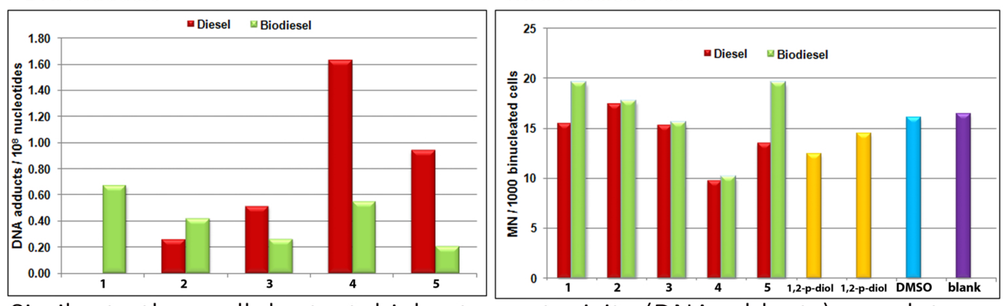


Significant cytotoxicity was observed for higher dose of 10 dm³ of the undiluted emissions.
All toxicity tests were performed at the subtoxic dose of 1 dm³.

b) Genotoxicity

concentration 1 dm³ emissions/ml culture medium

DNA adducts *Micronucleus test*

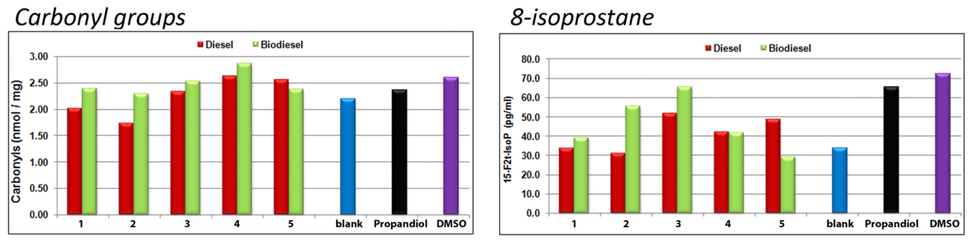


Similar to the acellular test, highest genotoxicity (DNA adducts) was detected for engine operating mode 1500/500 (deposit burn-off).
Higher DNA adducts were induced by diesel compared to biodiesel.
No significant genotoxicity was observed by micronucleus test.

c) Oxidative damage

concentration 1 dm³ emissions/ml culture medium

Carbonyl groups *8-isoprostane*



No signifiant induction of the oxidative damage of proteins and lipids in A549 was observed at any operating mode for diesel and biodiesel.

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