

Carcinogenic soot particles from petrol engines

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What we blow out when we floor the throttle

Empa researchers studied exhaust emissions from seven gasoline cars and one diesel, six of which were built between 2012 and 2016. Alarming substances came to light in the gas chromatograph, a fine, analytical instrument. As the dynamometer revealed, most of these substances are produced when the vehicle accelerates.

Soot particles
The nanoparticles, which initially have a diameter of 15 to 20 nanometers (thirtieths of a millimeter), congregate to form larger particles measuring 80 to 100 nanometers, and penetrate the alveoli of the lung (the lungs can only remove particles that are larger than 200 nanometers). Chemical pollutants accumulate on the surface of the soot particles, which transport them into the lungs and thus into the bloodstream – like a Trojan horse.
→ Euro 6 permits 6 billion particles / km for direct-injection gasoline cars and 600 billion particles / km for diesel vehicles. For gasoline cars with intake manifold injection, there are no emission limits at all.

Carbon monoxide (CO)
The gas is poisonous as it binds to hemoglobin and thus interferes with oxygen transport in the blood. CO poisoning is fatal within a short period of time. In January, six teenagers died in Germany using a gasoline power generator in a summerhouse.
→ Euro 6 permits 1,000 mg CO / km for gasoline cars and 500 mg / km for diesel.

Nitric oxides (NO and NO₂)
In air NO rapidly oxidizes to form NO₂, a poisonous gas with a pungent odor that irritates the throat and dissolves readily in water to form nitric acid. Above 21 degrees Celsius, it transforms into N₂O₅, a corrosive and highly oxidizing gas.
→ Euro 6 permits 60 mg NO + NO₂ / km for gasoline cars and 80 mg / km for diesel.

Formaldehyde (CH₂O)
Formaldehyde can cause allergies and skin, respiratory tract or eye irritations. In concentrations of 30mg/m³ and above, it can be life-threatening. In case of chronic exposure, it is carcinogenic and affects the memory, ability to concentrate and sleep.
→ Euro 6 does not specify any limits.

Benzene (C₆H₆)
Its breakdown in the body produces toxins that can trigger cell mutations (cancer). Its long-term intake can harm the liver organs and bone marrow, which causes anemia. In humans and animals, benzene accumulates in the brain, bone marrow and fatty tissue.
→ Euro 6 does not specify any limits.

Dinitropyrene (C₁₂H₆N₂O₄)
Dinitropyrene is produced in the hot exhaust tract in diesel engines through the reaction between pyrene and NO₂. 1,3-, 1,6- and 1,8-dinitropyrenes are particularly mutagenic and trigger malignant tumors in many organs in various lab animals.
→ Euro 6 does not specify any limits.

Benzo(a)pyrene (C₂₀H₁₂)
Benzo(a)pyrene is one of the strongest known carcinogenic substances. It is found in cigarette smoke and causes lung cancer. Benzo(a)pyrene is converted chemically in the body. The metabolic product reacts with DNA, which can prevent cell division or cause mutations.
→ Euro 6 does not specify any limits.

Credit: Empa

A new study led by Empa scientists finds that some direct-injection gasoline engines emit just as many soot particles as unfiltered diesel cars

did in the past. Particle filters can remedy this.

Worldwide, three new cars roll off the line every second – that's 73 cars and 18 million utility vehicles per year. Most run on gasoline. In industrialized nations, the trend is moving towards so-called downsizing engines: smaller but with direct gasoline injection and turbocharging. This technology is more environmentally friendly and saves fuel, according to manufacturers. Experts estimate that by 2020, 50 million of these direct-injection gasoline engines will be running on the roads across Europe, and researchers are now studying the cocktail of exhaust emissions from these engines.

Researchers of the GasOMeP project, along with collaborators, selected seven direct-injection gasoline cars, including a Mitsubishi Carisma (2001 model, exhaust emission standard Euro 3). The other vehicles were all built between 2010 (VW Golf, Euro 4) and 2016 (Citroën C4, Euro 6b). By way of comparison, a current Peugeot 4008 (2013, Euro 5b) with a diesel engine and a particle filter was also included. All the vehicles were tested based on the WLTP cycle (Worldwide Light-Duty Vehicles Test Procedure), which will be mandatory for newly licensed models as of September 2017 (see p. 10).

The results were sobering: Every single one of the tested gasoline cars emitted 10 to 100 times more fine [soot particles](#) than the diesel Peugeot. Under the microscope, the [particles](#) from the gasoline engines were similar in size to the soot particles that had given diesel a bad name: primary particles measuring 10 to 20 nanometers in size, which congregate into particle agglomerates measuring 80 to 100 nanometers before leaving the exhaust. "Once inhaled, these particles remain in the body forever," explains Norbert Heeb. The evidence shows that they can penetrate the membrane of human alveoli in the lungs and thus get into the bloodstream.

However, the particles are not the only problem, as Heeb is well aware: "Liquid or solid chemical toxins from the combustion process, including polycyclic aromatic compounds, accumulate on the surface of the particles, which can then smuggle these substances into the bloodstream – like a Trojan horse."

Maria Munoz, a colleague of Heeb's from Empa's Advanced Analytical Technologies lab, took a closer look at the exhaust emissions from the vehicles tested in the GasOMeP project – and discovered benzo(a)pyrene, a known carcinogenic substance also found in cigarette smoke.

The World Health Organization (WHO) considers even the tiniest dose of benzo(a)pyrene harmful. The EU settled on an air limit of one nanogram per cubic meter. Levels in [exhaust emissions](#) were found to be as much as 1,700 times above this limit. Or to put it another way, one cubic meter of exhaust gas transforms up to 1,700 cubic meters of clean air into a mixture deemed carcinogenic according to the EU standard.

Once again, the diesel [vehicle](#) with particle filter fared much better. In the test, the Peugeot emitted only 45 nanograms of carcinogenic substances – six times less than the best one of the analyzed [gasoline cars](#).

Researchers push for action

The results of the GasOMeP project were presented during a conference held at the Empa Academy in late March. The researchers concluded that particle filters used for diesel vehicles should now also be mandatory for gasoline vehicles.

"At the moment, they don't incorporate the best available technology,"

says Heeb. "New exhaust emission technologies launched on the market usually take around 13 years to become fully effective. Only then will nine out of 10 cars from the vehicle stock be replaced. So the sooner particle filters are made mandatory for [gasoline](#) vehicles, the better it will be for everyone's health."

Provided by Swiss Federal Laboratories for Materials Science and Technology

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