Tail Pipe Emissions of Rapeseed Oil Based Fuels

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Rapeseed oil is used as transportation fuel in different ways. A very specific German way, which, however, could also be interesting for other countries, is the use of neat rapeseed oil in modified diesel engines. The other pathways are concerned with transesterified rapeseed oil, which means rapeseed oil methyl ester (RME). Here we know the neat application (B100), which was very common in Germany until a new taxation for biofuels became valid. Other forms are blends of the biofuel with fossil diesel fuel as B5 (5% RME in fossil diesel fuel), or B7 with a further addition of 3% hydrotreated vegetable oil. In the U.S., B20 is a common product, and for France B30 might become available, since the French car manufacturers announced to release their products for this fuel blend starting from the year 2009. For all of these fuels it is necessary to know their emissions behaviour concerning legally regulated and some important non-regulated tail pipe emissions compounds.

In the presentation, the formulated actual drafts for the forthcoming German regulations are discussed, after some remarks concerning the German legal framework during the most recent years and the German and European biodiesel production and consumption.

Furthermore, the instruments for quantitative analysis of the tail pipe emissions are described, as they are installed at the institute. An overview about the installations is provided in figure 1. Besides analyses for regulated compounds, the institute runs various classificators for particle size analysis, ranging in particle diameter from 10 nm to 10 µm (Berner impactor; electrical low-pressure impactor; scanning mobility particle sizer). Further analytical instruments are installed to detect aldehydes (HPLC); ozone precursors (GC-MS); nitrous oxide, methane, ammonia (FTIR); benzene (GC); and polycyclic aromatic hydrocarbons (HPLC). The latter is performed after sampling of particles and condensate in an intensive cooling-down and filtration procedure. The same sampling procedure is used to collect the material for mutagenicity testing, which is performed at the University of Bochum, Germany, by Ames tests using the bacterium Salmonella typhimurium. As engine test cycles, the ESC (European

Stationary Cycle) is applied to EURO III engines, and the ETC (European Transient Cycle) is used for EURO IV engines with exhaust gas aftertreatment. The latter was not considered for this presentation.

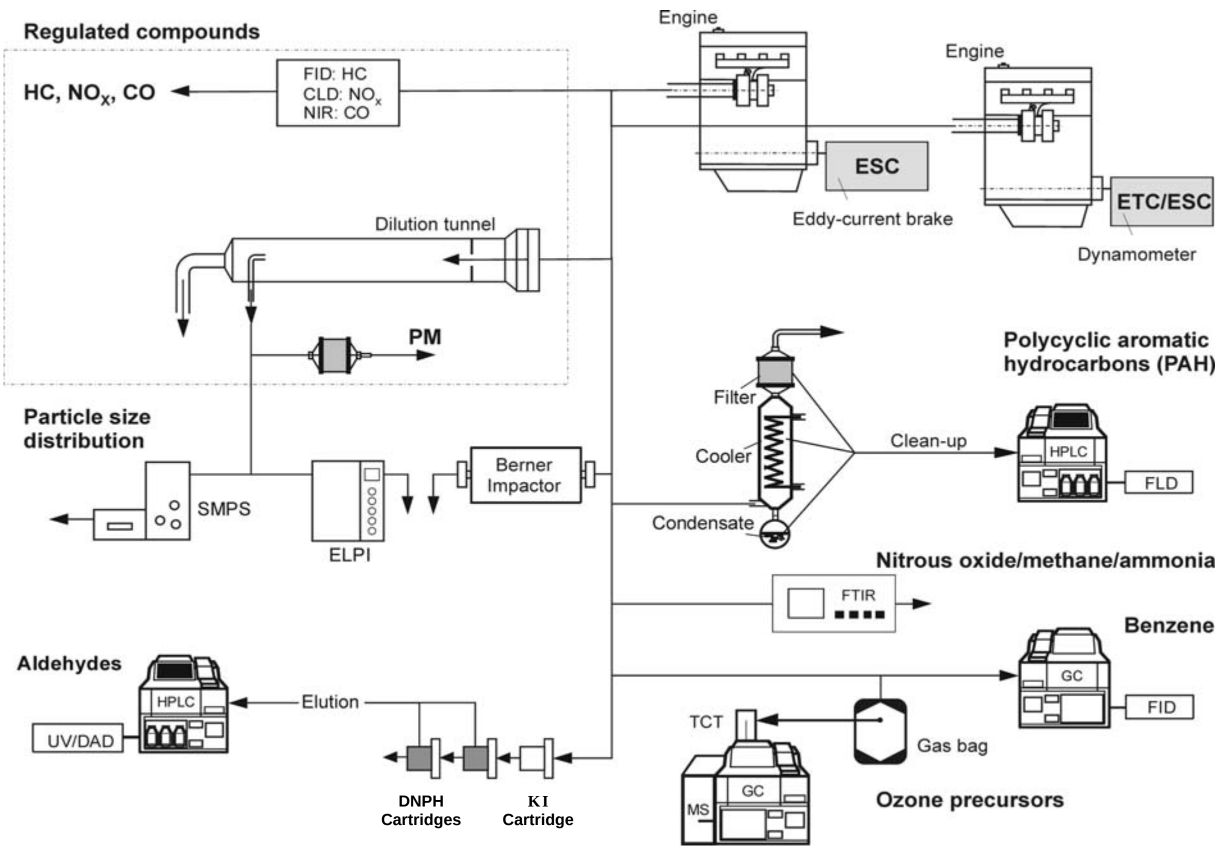

Figure 1: Analytical equipment for tail pipe emissions analysis, used at the vTI

The main emphasis of this contribution, however, is the presentation of results for determination of the regulated emissions concerning CO, HC, NO_X, and PM as well as the mutagenic potency of the exhaust gases. It is shown that some effects do not vary in linear dependence of the blend composition. Various fuels and blends were tested in a Mercedes Benz 6-cylinder diesel engine OM 906 LA (EURO III). These fuels were: Reference diesel fuel (DF); rapeseed oil methyl ester (RME); Shell middle distillate (GtL); cold pressed rapeseed oil (VO); refined and flow improved vegetable oil (VO_{mod}). For all of these, the HC emissions were very well below the regulated limit, which also holds true for the CO emissions. For the NO_X emissions, however, GtL showed the lowest emissions, and the three biofuels exhibited emissions that were higher than the regulated limit. The biggest differences could be observed for the mutagenic potency of the exhaust gas. Here the VO showed a 10-

fold higher mutagenicity, compared to RME, GtL, and DF, while the VO_{mod} even exhibited a 30-fold higher mutagenicity, cf. figure 2.

Other fuels considered were Shell V-Power (VP) and its competitor, Aral Ultimate (Ult). Furthermore, blends of these two "modern" products with 20% RME were investigated (B20-VP; B20-Ult), in order to try some blends with high biogenic content. In this case, the neat components did not show any unexpected behaviour. For the blends, the results concerning the regulated compounds were as expected for blends, which means, almost linear interpolations of the neat components' behaviour. For the mutagenic potency, however, an unexpected nonlinear behaviour occurred: the blends B20-VP and B20-Ult showed definitely higher mutagenicity than each of their neat ingredients.

This was also tested with a blend from DF and RME (B20). Again, this blend resulted in higher mutagenic potency than DF and RME as neat components. During these tests, GtL fuels proved to cause relatively low mutagenicity, cf. figure 3.

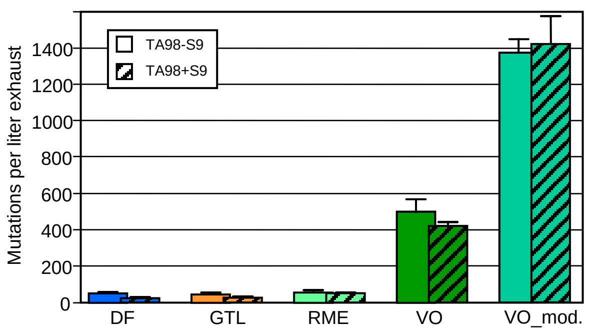

Figure 2: Specific mutagenicity of tail pipe emissions; in particular: vegetable oil as fuel

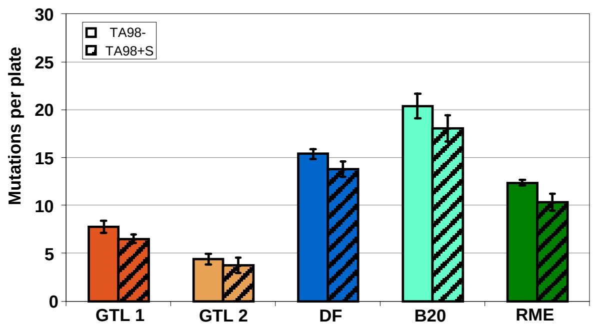

Figure 3: Mutagenicity of tail pipe emissions; in particular: B20 blend and GtL fuels

The mechanisms leading to these effects could not yet be revealed yet. However, the blend results correspond nicely to the findings of Fang and McCormick (2006), who found the highest formation of sediments for the B20 blend, compared to other blends and to the neat components DF and methyl ester (there, SME was used).

References

Fang, H.L., McCormick, R.L.: Spectroscopic Study of Biodiesel Degradation Pathways. Society of Automotive Engineers, Paper 2006-01-3300, 14 p, 2006.

Krahl, J., Munack, A., Ruschel, Y., Schröder, O., Bünger, J.: Exhaust Gas Emissions and Mutagenic Effects of Diesel Fuel, Biodiesel and Biodiesel Blends. Society of Automotive Engineers, Paper 2008-01-2508, 7 p, 2008.