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DEVELOPMENT AND EVALUATION OF STANDARDIZED METHODS: ASSESSMENT OF THE CONTRIBUTION OF MATERIALS EMISSIONS TO INDOOR AIR POLLUTION BY ORGANIC COMPOUNDS IN PASSENGER CARS

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ABSTRACT

Indoor air pollution is becoming a factor of rising public interest. This pollution does not only concern rooms in housing accommodation but is also of interest in vehicles such as in cars. The amount of polymer materials that is being used in the inside construction of a car has grown considerably in recent years. Nearly all plastics contain low molecular weight substances, which are highly volatile and may contribute to the indoor air pollution in cars. In a research project standardized methods to detect these emissions have to be developed and evaluated. Hereby the part of the TÜV Norddeutschland is to measure the indoor air pollution in passenger cars. The point of main effort for the Institute of Polymer Testing and Polymer Science (IKP) is to detect the emission sources. These results may contribute to improve better materials with lower emissions.

The tests will start off by measuring the emissions of complete components from the inside of a vehicle. In order to perform these tests a component measuring chamber for defined testing conditions (temperature, humitidy, etc.) was developed and constructed by the IKP and Heraeus Vötsch in Balingen. After this the materials used in these parts will be analyzed by the IKP evaporation tube.

At both institutes a possible standardized testing cycle and the testing facilities have been fixed. Starting from February 1993, six brand-new passenger cars will be tested.

INTRODUCTION

Indoor air pollution due to formaldehyde emissions from the inside decoration (wood, textiles) is well known. Until now the central point of view has been the formaldehyde pollution, especially from particle boards (1, 2, 3, 4, 5, 6). With the increasing use of plastics in housing accomodation as well as in the inside of cars and the increased sensibility of the population to the fact of indoor air pollution, emissions originating from plastics are also of interest (7, 8).

Nearly all plastics contain additives such as plasticizers or other processing agents. In addition, some polymers may have large amounts of low molecular weight substances that show high volatility, for instance monomeric compounds, solutes or catalysts.

Most of these low molecular weight substances are highly volatile and may contribute to these emissions. Some of these emitted substances precipitate on the windscreen leading to cloudiness and thus to a loss of clear sight.

METHODS

The TÜV Norddeutschland has completed his experimental arrangement to study the indoor air pollution in cars under defined temperatures and air exchange rates.

The tests at the IKP will start off by measuring the emissions of complete components from the inside of a vehicle. In order to perform these tests a component measuring chamber for defined testing conditions (temperature, humitidy, etc.) was developed and constructed by the IKP and Heraeus Vötsch in Balingen. The developed chamber allows measurements with a carrier gas flow to get defined air exchanges in order to determine emission rates and to measure without air exchanges to find out equilibrium concentrations. To realize conditions of use the chamber can be air-conditioned from 10 °C to 130 °C.

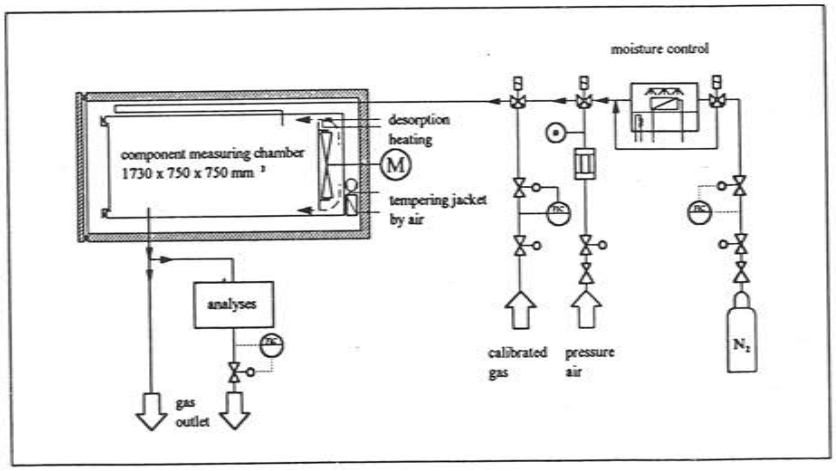

Fig. 1. Flow sheet of the component measuring chamber.

The well mixed chamber air guarantees homogeneous conditions in concentrations and temperatures inside the chamber (continous stirred tank-reactor). Consequently a taken sample of this air represents the concentrations in the chamber.

The purpose of the chamber was to proof possible outgassing products down to a very low level. So all parts of the chamber that are in contact with the testing room atmosphere are free from emissions or have low emission potential. To avoid memory effects (errors due to preceding measurements) there was paid attention to sufficient possibilities for cleaning the chamber.

To make final analyses air samples will be taken from the component measuring chamber. The applied analytical procedures are gaschromatography with mass detector (GC/MS) and high-pressure liquid chromatography (HPLC/UV).

Equation 1 describes how to determine the emission rate per component with the results from a measurement with defined air exchange

$$\dot{m}_E = c_\infty \cdot \dot{V} \qquad (1)$$

with
$\dot{m}_E$ = emission rate per component [g/s], c_∞= steady-state concentration [g/m³], and
$\dot{V}$ = carrier gas flow [m³/s].

For this computation base the outgassing process is modelled like in fig. 2 shown.

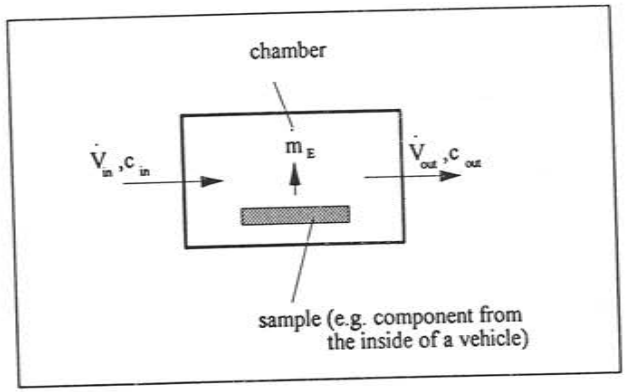

Fig. 2. Modell for the outgassing process.

Hence the mass balance for the component measuring chamber follows

$$V\frac{dc(t)}{dt} = (\dot{V}_{in}\cdot c_{in} - \dot{V}_{out}\cdot c_{out}(t)) + \dot{m}_E \qquad (2)$$

with V = volume of the chamber [m³], c(t) = the concentration in the chamber at time t [g/s], $\dot{V}_{in}$= $\dot{V}_{out}$= $\dot{V}$ = carrier gas flow [m³/s], c_{in} = concentration at the chamber inlet [g/m³], $c_{out}(t)$ = concentration at the chamber outlet at time t [g/m³].

On the assumption that the chamber is gastight, the gas volume of the emission flow is neglectable, the solution of the differential equation is:

$$c_{out}(t) = \frac{\dot{m}_E}{\dot{V}}\left(1 - e^{-\frac{t}{V/\dot{V}}}\right) \qquad (3)$$

After a certain period of time the chamber walls are saturated and there is no more adsorption, so the emission rate per component results as described in equation 1.

If there can be detected any outgassing substances, the chamber measurements will be followed by subsequent measurements. These tests will be carried out with an evaporation tube, which has been developed by the IKP.

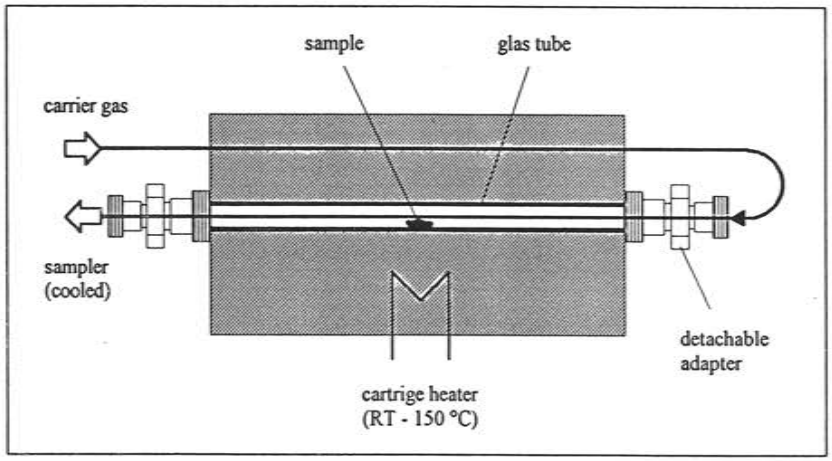

Fig. 3. IKP evaporation tube.

This evaporation tube (Fig. 3) consists of a tempered aluminum block (30 °C - 150 °C) assimilating a tube of glas (D_i = 6/7/9 mm) to pick up the sample (ca. 0,5 g). The sample tube is admited by a carrier gas flow (nitrogene; 200 ml/min) to transport the pollution loaded gas to a sampling tube (e. g. charcoal-tube) for ad-/absorbing the volatile substances. The final analyses are identical with the chamber analyses with GC/MS and HPLC/UV.

RESULTS

Experiments with and without air exchange in the chamber were made with a thermoforming sheet to fix a possible standardized testing cycle.

After nearly one week an equilibrium concentration was found with a chamber temperature of 45 °C. The period of time to reach the equilibrium concentration of course depends on the chamber loading. If there is a test with air exchange the period of time to reach a steady-state concentration is depended on the carrier gas flow.

As shown in table 1 the concentration reached by measurements without air exchange are several times higher than with air exchange ($\dot{V}$ = 10 l/min).

Table 1. Concentration comparison: with air exchange - without air exchange.

experiment	MEK-conc. [µg/m³]	Toluene-conc. [µg/m³]	Cyclohexane-conc. [µg/m³]
saturating conc. from the pure substance at 45 °C	844.000	344.000	74.000
without air exchange	40.030	45.810	12.660
with air exchange, $\dot{V}$ = 10 l/min	1.010	1.910	480
comparison without/with air exchange	40	24	26

DISCUSSION

By these tests a standardized testing cycle has been defined for measuring emissions of complete components.

To proof whether a toxical or irritable substance is present the cycle will start off by a test without air exchange in the chamber at 65 °C. Afterwards tests will follow with air exchange at different temperatures (23 °C, 45 °C, 65 °C). With these results the emission rate of single substances per component will be determined like described in equation 1. These results show the influence of single volatile substances to the indoor air pollution in passenger cars.

The tests will be followed by the subsequent measurements of the materials used in these parts by the IKP evaporation tube.

After a cycle it will be known whether there are critical substances in the indoor air of a passenger car which originate from the inside construction of the car. By this the sources of these emissions are detected. Next the reduction of the emissions by modifying the components in which the respective materials are detected has to be started.

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