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Behaviour of PFAS in Waste Incineration Plants – Results of a Full-Scale Test at the Thermal Waste Treatment Plant in Schweinfurt (GKS)

This topic is addressed in two scientific studies. The first study was conducted at KIT using a pilot-scale facility and published in *Chemosphere* in 2024 [1]. The second one expands and validates these findings in a full-scale thermal waste treatment (TWT) plant in Schweinfurt in 2025 with a throughput of 190,000 t per year.

The results from the KIT pilot study show a high fluorine-related degradation rate during the incineration of fluoropolymers of above 99.99 % regardless of the increase in combustion temperature, which was raised from 860 °C to 1095 °C during the trials. All potential emission pathways (wastewater, solid residues and flue gas) had been taken into account.

In the investigations performed at the TWT plant in Schweinfurt, which is equipped with a grate furnace and a wet flue gas cleaning system (thermal capacity approx. 21 MW and mass flow around 8 Mg/h per line), the PFAS concentration in the waste was gradually increased using the following scenarios (see Fig. 1):

I. Combustion of municipal solid waste (MSW = household waste and household-type commercial waste) = reference scenario I.

II. Co-incineration of PFAS-contaminated soil (compost and sewage sludge), added to the waste of scenario I.

III. Spiking of PFAS into the waste from scenario I (substantial over-dosing of PFAS).

All ingoing and outgoing material streams were sampled and analysed for PFAS. This included the waste, the scrubber process water, the bottom ash, all residues from the flue gas cleaning (FGC) and the stack flue gas. 6 different methods (OTM 45, DIN EN 1948, variations of both) were applied in parallel for the gas measurements.

For a better understanding of the PFAS behaviour in the process, combustion air from the waste bunker, ambient air, internal wastewater streams of the scrubber and all other operating resources (e. g. activated lignite, limestone, binding agent) were examined for PFAS. All subsequent results refer, by way of example, to a minimum of 22 polar and semi-volatile PFAS and partly up to 73 different PFAS-species.

The combustion conditions in the furnace ranged between approximately 900 °C and 1100 °C in the different combustion zones for all scenarios, meeting the regulatory requirements for thermal waste treatment, including a minimum temperature of 850 °C for 2 seconds in the first pass.

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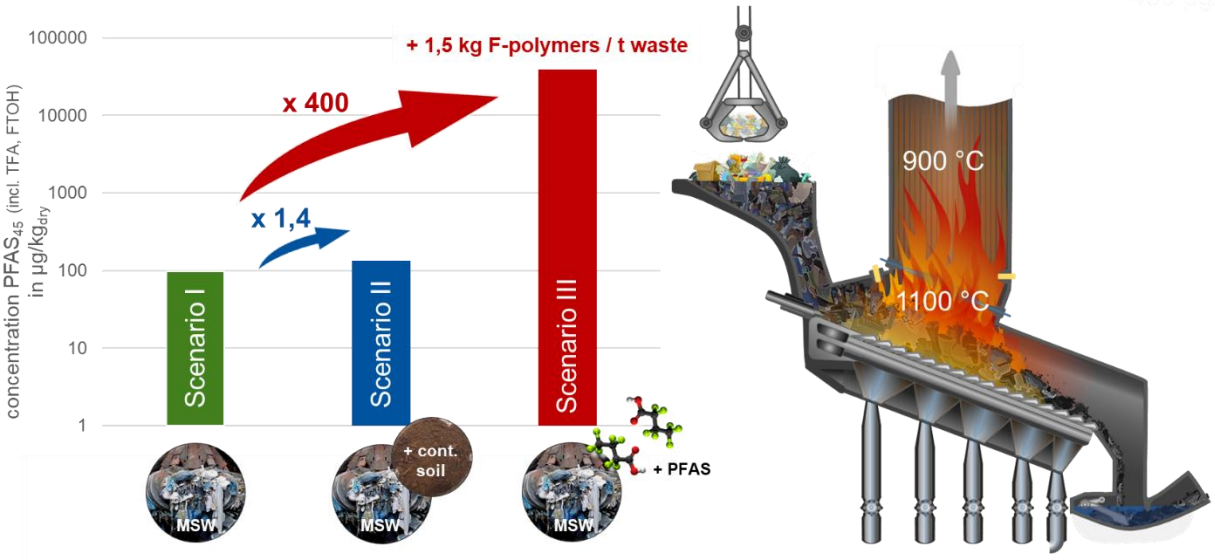

Figure1: PFAS-input for the different scenarios of the GKS campaign

For scenario II and III no significant increase in the PFAS concentration was observed at the stack relative to the reference scenario I. The sum of PFAS remained below 1 ng/m³$_{STP}$ (median of the 6 applied methods) for all scenarios. Analyses of up to 73 PFAS in selected samples revealed no significant increase in PFAS concentrations in comparison to the 22 PFAS that were analysed as a minimum requirement for all methods. Only in scenario III, tetrafluoromethane (CF_4) was detected at 0.7 mg/m³$_{STP}$, representing a “product of incomplete combustion” (PIC). No other PICs were detected (neither with OTM 50 nor with FTIR).

PFAS concentrations in the operating resources ranged from 1.4 µg/kg in the activated lignite to 2.2 µg/l in the process water. The process water originates from the river Main and therefore contains background trifluoroacetic acid (TFA) pollution. Within the FGC system, TFA introduced to the scrubber via river water is captured in the filter ash, which consequently represents a sink.

In contrast to the KIT pilot study, the fluorine load in municipal waste cannot be quantified exactly at the full-scale TWT plant due to unknown fluoropolymer concentrations in the waste under normal operation. Therefore, the fluorine-related degradation rate is calculated as the difference between the PFAS-spiking scenario III and the reference scenario I, expressed as the **Total Delta Destruction Rate** (**TD²R**):

$$\mathbf{TD^2R} = 1 - \frac{\sum \dot{m}_{\mathrm{F\ from\ PFAS\ out,Scenario\ Spiking}} - \sum \dot{m}_{\mathrm{F\ from\ PFAS\ out,Scenario\ Ref}}}{\sum \dot{m}_{\mathrm{F\ from\ PFAS\ in,additional\ spiked\ PFAS}}}$$

Applying this approach results in a **TD²R > 99.9999 wt.-%** excluding CF_4. When CF_4 concentrations from the PFAS overdosing in scenario III is included, the TD²R decreases to 99.7%. CF_4 is considered inert and non-toxic [2, 3], though it is relevant for climate.

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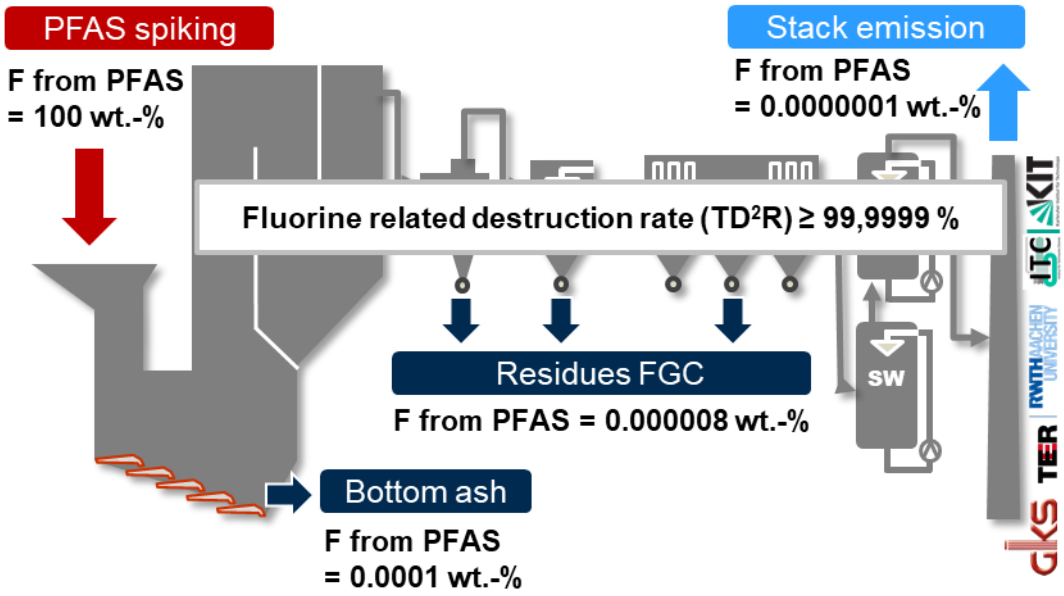

Figure 2: Fluorine (F) related transfer coefficients and destruction rate of PFAS added to a TWT plant

The transfer coefficient is determined analogously by evaluating PFAS-derived fluorine in each outgoing material stream and calculating the difference between scenario III and scenario I (see Figure 2). Of the total fluorine from the PFAS added to the waste, only 0.000108 wt.-% is found in the residues, which, apart from bottom ash, are disposed of in deep underground repositories.

Excluding CF_4, merely 0.0000001 wt.-% fluorine of the added PFAS enter the flue gas, resulting in a **Stack Delta Destruction Rate (SD²R) > 99.9999999 wt.-%**.

This extensive and unprecedented full-scale study confirms the results of the KIT study. Thermal waste treatment plants act as sinks for PFAS, achieving fluorine-related destruction rates of > 99.9999 wt.-%. Additionally, it was shown by comparison of 6 different sampling methods that the cooled probe method (DIN EN 1948) is at least comparable to the OTM 45 method for flue gases of combustion processes. Transfer of the results to other TWT has to be proven.

While the removal in TWT is obviously a reliable sink for PFAS, no statements can be made on basis of this study referred to PFAS in production, usage and other processes (i.e. landfilling, recycling).

References:

[1] Gehrmann et al.: Mineralization of fluoropolymers from combustion in a pilot plant under representative European municipal and hazardous waste combustor conditions. In: Chemosphere, Vol. 365, Oct. 2024, 143403 (https://doi.org/10.1016/j.chemosphere.2024.143403)

[2] Makowski et al.: Saftey evaluation of carbon tetrafluoride as an inert hyperbaric breathing gas in Sprague-Dawley rats. In: Toxicology and Applied Pharmacology, Vol, 444, 1 June 2022, 116023 (https://doi.org/10.1016/j.taap.2022.116023)

[3] International Chemical Safety Cards (ICSC) 0575 - TETRAFLUOROMETHANE (https://chemicalsafety.ilo.org/dyn/icsc/showcard.display?p_lang=en&p_card_id=0575&p_version=2)