Tire Abrasion in the Environment

Sampling basket reveals hot spots

According to a study by the Fraunhofer Institute for Environmental, Safety, and Energy Technology in Oberhausen, Germany, 110,000 tons of tire abrasion are created each year in Germany alone. The study states that this abrasion causes one third of all annual microplastics emissions in Germany and can make its way into the environment through precipitation. Researchers at the Technical University (TU) of Berlin are working on identifying and quantifying how these particles enter into the aquatic environment. As part of the project *RAU (Tire abrasion in the environment)* funded by the German Federal Ministry of Education and Research (BMBF), they spent three-and-a-half years investigating what happens to tire particles during the usage phase of tires together with partners from industry, municipalities, and research. The aim of the project is to develop a catalog of measures to reduce entry at so-called hot spots – sites with particularly high load. The GKD Group (GKD), leading international technical weavers based in Düren, Germany, developed the sampling basket, a central element to the success of the project.

The RAU project was conducted under the leadership of Daniel Venghaus, scientific employee in the department of urban water management headed by Professor Matthias Barjenbruch, at TU Berlin from August 2017 to January 2021. The project plan outlined four key areas for compiling the planned catalog of measures: developing a sampling system, analysis concepts and systems, laboratory trials for particle description, and in situ measurements. The polymer SBR BR was selected as the leading particle, as this marker for tires can be used to calculate the majority of tire abrasion and thereby the quantities entering into the environment. For mass-related analysis, GC/MS (gas chromatography/mass spectrometry) pyrolysis was used in the project. This method can determine the leading particle qualitatively and quantitatively and thereby determine the tire abrasion in the environmental sample.

Development without preliminary data

The researchers set GKD the task of developing a sampling basket that can be used without alterations in the shaft of any drain that conforms to DIN standards. This basket had to be designed in such a way that it can sample the entire volumetric flow of an average rain event and separate out the particles. In addition, GKD had to make sure that it was possible to configure the filter cascade flexibly to suit the site and to integrate the necessary measuring technology. The solution GKD proposed was a filter cascade consisting of sieve pans commonly used in solids analysis which was integrated into a basket structure similar to conventional leaf collecting baskets. This resulted in a basket of modular design made up of six sieve pans with different pore sizes. "Initially, we assumed that the basket would be of a much more complex design," explains Daniel Venghaus. He adds: "We thought of creating a special structure with mesh arranged at an incline in order to create an environment in which the particles are rinsed off individually and the filter doesn't become blocked." The design consisting of standard elements developed by GKD also impressed in the subsequent sample fractionation: To do this, the filter cascade was removed completely from the basket and placed into a common vibrator tower. As Daniel Venghaus sees it, this system is one of a kind, "as it enables fractionation according to DIN standards in just one process step." However, the design of the basket and the filter cascade posed a particular challenge for the engineering and filtration experts from GKD: All preliminary data such as type, concentration, quantities, sizes, size distribution, or number of particles was unknown. The developers also had no information about environmental conditions or loss of pressure. Without this input data, the filter experts were only able to simulate conceivable flow behavior in the construction of the basket and calculate mesh-specific flow rates for different ponding depths. On this basis, a prototype of the sampling basket was built at GKD's in-house filter production site and incorporated directly into Daniel Venghaus' ongoing tests. The actual development and continuous optimization based on factual measured data took place live at the test bench of TU Berlin and in situ. For use on the street, however, it had to be ensured that the basket had a sufficiently high flow rate to prevent overflowing drains from endangering road safety.

First tests of the basket performance at the test bench

The test bench at TU Berlin has a drain shaft made of acrylic glass. It quickly became apparent that the principle hydraulic design of the basket was right. Extensive tests examined the basket's performance in detail to make it possible to determine the sequence of meshes in the filter cascade and identify weaknesses in the design under load. Initially, air cushions that formed automatically in the basket prevented the flow. In longer test series, the filter experts from GKD developed a deaeration system together with the researchers at the TU. They discovered that it wasn't just the sieve pan with the finest filter that required lateral deaeration via silicon ventilation hoses, but that all the other sieve pans had to be ventilated individually in this way. The original specification from the researchers at the TU stipulated a fine mesh with a pore size of ten micrometers or smaller. From the previous OEMP project (*Optimized materials and processes for the removal of microplastics from the water cycle*), Daniel Venghaus knew about the optimized dutch weaves with a pore size of six micrometers (ODW 6) that GKD had developed here. On the test bench, however, the first tests conducted with sweepings showed that this fine filtration mesh became blocked relatively quickly in the sampling basket. Even changing the feed –

inclined filters to achieve cross forces – was unable to prevent the cascade from blocking quickly. Ultrasonic vibrations applied to the outside of the screen frames also failed to achieve the necessary success in preliminary tests. Plus, it was not possible for this procedure to be implemented in a standard shaft. Nevertheless, to optimize the flow rate, the use of optimized dutch weaves with pore sizes of 10 and 20 micrometers was tested. On the test bench they worked well or even very well, yet in the subsequent in situ tests the results could not be replicated. The large number of particles from undefined solids made it harder to keep the mesh open with increasing separation rates. "When it comes to road runoff, the finest screen determines the entire flow," explains Daniel Venghaus. The breakthrough finally came in the form of the innovative three-dimensional Porometric mesh with a pore size of 20 micrometers that had been developed in parallel by GKD: Its significantly higher dirt-holding capacity and better flow characteristics enabled the smooth functioning that was required. For Daniel Venghaus, the excellent cleaning characteristics of this mesh were another important advantage, as the materials cleaned off it were his test material. Before the first use in situ, however, three further critical optimizations were made at the TU test bench: The connection developed by GKD between the sampling basket and the connected measuring technology for particulate sampling was integrated. It was also necessary to eliminate leaks on the head of the basket where the drip edge meets the concrete ring and on the O-seal gaskets of the sieve pans. By testing various sealing materials, GKD identified suitable silicon seals and professionally installed them on the basket. In addition, the tensioning device on the sieve pans was reworked: Additional safety pins prevented the filter cascade from slipping down in the shaft.

Unexpected challenges in practical test

During the first in situ use of the optimized prototype, however, the researchers and developers found themselves confronted with an unexpected problem: The sampling basket built to DIN standards didn't fit in the drains. "This is the reality of mechanical engineering," recalls Daniel Venghaus. "The street shafts were not built to a precision of tenths of a millimeter, but with tolerances of up to a centimeter." To ensure that the sampling basket could be used universally as required, the diameter of the filter therefore had to be reduced from 315 to 305 millimeters. GKD also added a level gauge to the head of the basket. It alerts to the threat of flooding, thereby improving both road safety and the validity of sampling. Yet the real challenge for Daniel Venghaus' team and GKD again lay in determining a mesh sequence in the filter cascade which ensures blockage-free flow with the required fractionation. The undefined and permanently changing particulate load from the road runoff meant that the filtration rates determined at the test bench became blocked unexpectedly quickly in practice. The use of Porometric mesh led to significant progress here. However, coarse particulate material such as leaves still regularly led to blockages, as even one single leaf on the upper sieve blocked a large filtration surface. Again, the filtration experts from GKD ultimately found the decisive solution: A pleated mesh disc of the same pore size was placed onto each filter. Its three-dimensional structure allows it to act as a preliminary filter which retains the coarse material. Since then, the particulate material to be sampled has been flowing through the filter cascade without any issues, even in situ. This cascade is formed by six sieve pans with mesh apertures that can be selected flexibly in the sizes 1,000, 500, 250, 125, 63, and 20 micrometers. The in situ tests gave the largest particulate load at 125 and 63 micrometers, which is why these pore sizes were sometimes used double. This possibility highlighted the importance of the system's modularity. At the same time, however, it became apparent that the filter cakes produced retained finer particles than defined by the apertures. That's why Daniel Venghaus no longer talks of fractionated sampling, but rather defined particulate sampling. The actual fractionation of the sample takes place subsequently when the filter cascade is placed on the vibrator tower.

Representative road margins

The in situ samples were taken at twelve different measuring points – ten of them in cities, two outside of cities on the autobahn and at an airport. This revealed curves and traffic lights to be so-called hot spots with an increased volume of tire abrasion. These sites are to undergo more intensive investigation in a follow-on project. The RAU project also showed that – measured from the curbside – a 1.6-meter-wide margin is representative for the accumulated particulate material and thus also for tire abrasion on the entire road. As a general rule, the hand sweeping method proved to work well for collecting dry samples, while the sampling basket is the method of choice for wet environmental samples. The original idea of using the basket as a filter, however, proved not to be viable in practice due to the undefined quantities and composition of particulate matter. Nevertheless, Daniel Venghaus feels that the sampling basket fulfilled the goal of the project "very well". His reasoning: "GKD managed to find the suitable meshes, including fine mesh, and combined them with standard discs in a standard filter frame to form a functioning filter cascade." The sampling basket thus made it possible to identify hot spots for tire abrasion and install targeted avoidance strategies by combining different measures. The sampling basket is particularly good at taking samples from the most frequently occurring low-rainfall events, which worked to only a limited extent with conventional samplers due to the low water flow. The sampling basket enables this by allowing a filter cake to build up without impeding the runoff of the water that comes later. With heavy rainfall, however, it is only possible to sample an initial period before blockage occurs. Yet Daniel Venghaus thinks that this short period could be sufficient to determine the contaminant potential. However, researchers still need to find out how long the water actually pollutes during heavy rain. The Berlin researcher's appraisal of the basket's performance is accordingly positive: "The aim was to develop a sampling basket that works in situ down to 20 micrometers under all relevant framework parameters, such as weather, flow rate, and defined pore sizes. The result is a sampling basket that minimizes sampling errors, records all external parameters to describe the event, and samples an entire rainfall event from the first second onward. Systems that have usually been used to date have only been able to pull partial samples." With the addition of a special pump module for sampling the fluid phase, the filtration experts from GKD expanded this broad performance spectrum again during the course of the project with a key element. In addition to the defined particulate sampling, this now makes it possible to take a representative partial sample of the separated particulate material and extrapolate this data for the entire flow volume. This interaction between the sampling basket and fluid phase rounds out the overall picture of the materials gathered. For Daniel Venghaus, this was further confirmation of the special quality of the cooperation with the filtration experts: "With GKD we had a partner on site with us who provided a suitable technical mesh and defined the requirements for understanding and mastering filtration in practice in these challenging and undefined circumstances."

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