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Sixteen-year reduction in levels of toxic PAHs in the Elbe River, Saxony

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Polycyclic aromatic hydrocarbons (PAHs) are a large group of toxic molecules produced by forest fires, industrial processes and the incomplete combustion of fossil fuels. The airborne particles containing these molecules are often washed into watercourses, where they can persist. This study uses long-term monitoring data from the Elbe river, Saxony, Germany, to show how changes in PAH sources affect both the concentrations of these chemicals and the corresponding environmental risks. The researchers suggest that controlling PAHs is the best prevention of harm to aquatic and human health.

Some PAHs are linked to cancer, birth defects and DNA mutations in humans. In the aquatic environment, PAH exposure has adverse influences on invertebrates and vertebrates. In addition, the related breakdown products of PAHs (daughter molecules) can be even more toxic. As PAHs and daughter molecules are known to cause environmental harm[1], listed as priority substances[2] by the European Water Framework Directive[3].

Research regarding toxic PAHs to date has not focused on the long-term trends of PAH exposure risk, in response to changes in sources of pollutants; largely because data has been lacking. This study, however, used extensive long-term monitoring data (2001–2016) for the Elbe River in Saxony, Germany. Saxony has undergone significant urbanisation and industrialisation, and the River Elbe has been exposed to pollution from, for example, municipal and industrial effluents. The researchers note that changes in sources of PAHs affect the concentrations of the pollutants in the river and have an effect on the corresponding environmental risks.

The potential sources of PAHs have changed over time in Saxony. Researchers examined this factor alongside concentration levels of the pollutants in the river, and assessed the health risks associated with PAH exposure. Data came from monitoring stations along the entire length of the Elbe River, throughout the state of Saxony, with monthly samples taken as part of the requirement of the EU Water Framework Directive.

To test the data, the researchers used Mann Kendall trend analysis (a method used to analyse data collected over time for consistently increasing or decreasing trends) , as it does not require a normal distribution, and outliers have less impact on the result. To assess the impacts of sample size and uncertainty in the trend analysis, they used the Monte Carlo Simulation (a technique used to understand the impact of risk and uncertainty). No detailed data was available on the composition of the main emission sources, so a positive matrix factorisation (PMF) receptor model was used to analyse the contributions of sources of the PAHs to the measured concentrations at the river sampling sites.

Ecological risk assessment posed by PAHs in surface waters was calculated by applying a risk quotient (RQ) approach using the maximum permissible concentrations (MPCs) and negligible concentrations (NCs) of the PAHs.

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Sixteen-year reduction in levels of toxic PAHs in the Elbe River, Saxony *(continued)*

In Saxony, almost 600 000 m3 of surface water is extracted for public drinking water and the river is also used for swimming. The researchers used human health risk assessment to identify the ways in which the public may come into contact with potentially polluted water was via skin contact or drinking the water intentionally or when swimming. Chronic daily intake (CDI) of PAHs was calculated following a method outlined by Sarria-Villa et al in their 2016 study[4], including body weight (for the German population), age, exposure duration/frequency to polluted water, skin adherence and skin/oral absorption factor. The cancer risks and hazard quotients from skin contact and drinking the potentially polluted water were calculated using data from the integrated risk information system (IRIS)5.

PAH concentrations (16 PAH chemicals) in the Elbe River during the 16-year study period — split into four time segments (2001–2004, 2005–2008, 2009–2012, 2013–2016) — decreased over time overall from 121.28 nanograms per litre (ngL-1) to 75.3 ngL-1. Within the study period, it was shown that the highest concentration of carcinogenic PAHs (7 PAH chemicals) was 40.51ngL-1 (2009–2012), while the lowest concentration of carcinogenic PAHs was 22.94 ngL-1 (2005–2008). This reduction in the sum of all the PAH's over the 16-year study period correlated with a decrease in coke oven use during this period from 26% at the start to 14% at the end. The main sources of PAHs increased in number over the study period with only three sources cited in 2001–2004 — coke, coal and vehicular emissions — which increased over time to include creosote and emissions from cement plants, with vehicular emissions being listed as either gasoline or diesel emissions from 2009 onwards.

The average PAHs in the Elbe River over the 16-year period were generally within the EU regulation safety value of 200ngL-1 for aquatic organisms. The mean PAH concentration was higher in winter than other seasons, potentially due to less discharge in the river during the winter, causing increased concentrations of PAHs as well as from increasing use of oil and coal for heating.

Over the 16-year period, the average PAH concentration of all the PAHs in the River Elbe was reduced by around 38%; however, some individual PAHs (CHR, BaA, BbF, BaP, and DBA) did not show any significant trend. PAH concentrations of IDP (from diesel engine emissions) and BgP (gasoline engine emissions) increased over the 16-year period.

By 2016 the composition of the PAHs found in the river had changed with 76% being of a higher molecular weight; (containing four or more benzene rings) these types of PAH pollutants were also the most carcinogenic. Over time, PAHs with a smaller molecular weight in the water samples decreased relative to the heavier weight molecules, which showed a rise of 12%. This may mean that sources releasing larger-weight PAH molecules remained constant during the 16-year time period. The main contributors of PAHs were vehicle emissions from petrol- and diesel- powered engines contributing approximately 42% of the total mass. Coal combustion made a lower but significant contribution (27% on average).

This study can assist policymakers in better understanding long-term PAH patterns and opportunities for mitigation measures as part of an integrated approach to reducing PAH levels in waterways. Swapping petroleum and coal for green energy sources would reduce PAHs in rivers, for example. The researchers suggest that regulation of PAHs could be adjusted to ensure it is appropriate in relation to the changing sources of this pollutant.

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1. Under the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH), the EU has regulated 8 PAHs for environmental reasons (e.g. presence in extender oils in tyres) and for human health concerns (e.g. presence in consumer goods – such as plastic and rubber parts, toys and childcare articles).

2. https://ec.europa.eu/environment/water/water-dangersub/pri_substances.htm

3. Directive 2000/60/EC : https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32000L0060

4. Sarria-Villa, R., Ocampo-Duque, W., Páez, M. and Schuhmacher, M. (2016). Presence of PAHs in water and sediments of the Colombian Cauca River during heavy rain episodes, and implications for risk assessment. Science of The Total Environment, 540: 455–465.

5. IRIS contains data in support of human health risk assessment and is compiled by the US Environmental Protection Agency.