Analyzing Chemicals and Genes Yields Novel Insight into PAH Behavior

A new NIEHS Superfund Research Program-funded study revealed how polycyclic aromatic hydrocarbons (PAHs) breakdown and transform in the presence of ultraviolet A (UVA) light and titanium dioxide nanoparticle pollutants. Their findings have important implications for PAH cleanup, which may not consider how PAHs transform in diverse environments.

PAHs are a large class of environmental pollutants that occur naturally in coal, crude oil, and gasoline, and are produced when fuel, garbage, or other materials are burned. PAHs can contaminate water, air, and soil. Many factors influence how they move and change in the environment. One important factor is exposure to UV light, which breaks down and changes PAHs in a process called phototransformation. The presence of other pollutants can also have an effect on PAH transformation.

Staci Simonich, Ph.D., of the Oregon State University SRP Center, and collaborators funded by the European Union Horizon 2020, sought to explore how two PAHs, anthracene (ANT) and phenanthrene (PHE), behave in water in the presence of titanium dioxide nanoparticles using a combination of advanced analytical chemistry and gene expression analyses. These nanoparticles are found in consumer products, like sunblock, and used to clean up after pollution events, such as oil spills in water.

The team performed detailed chemical analyses using gas chromatography−mass spectrometry on UVA-exposed ANT and PHE in the presence or absence of titanium dioxide nanoparticles to understand their effect on PAH phototransformation under realistic conditions.

Titanium dioxide nanoparticles enhanced phototransformation of PHE, and the team discovered diverse byproducts for both PAHs in the presence of UVA. In addition to identifying distinct chemicals smaller in size than the original PAHs, the researchers also found larger compounds. According to the authors, UVA causes PAHs to dissociate, recombine, and rearrange over time.

Their analyses also revealed two breakdown products common to both ANT and PHE, regardless of whether nanoparticles were present or not, representing promising environmental indicators of ANT and PHE pollution, and potentially other PAHs within this large class of chemicals. According to the team, environmental indicators of PAHs would help researchers better understand the environmental impacts, human health implications, and distribution of PAH pollution in aquatic environments.

Since many PAHs degrade into more environmentally mobile and toxic compounds, they evaluated the capacity for ANT and PHE to generate reactive oxygen species, which are molecules that can lead to increased toxicity. Both ANT and PHE created more reactive oxygen species in the presence of UVA light, but titanium dioxide nanoparticles suppressed this increase for PHE. The researchers attribute these differences to adsorption to the nanoparticles and capacity to absorb UVA wavelengths.

To explore the interplay between phototransformation and how PAHs may change in the body over time, the team carried out similar experiments with larval zebrafish. They looked at expression profiles of genes that encode for enzymes involved in PAH metabolism. This information can be used to determine which PAHs and byproducts are bioavailable, or capable of being absorbed into the body where they can be processed or stored and potentially cause harm to an organism.

Changes in gene expression showed that titanium dioxide nanoparticles reduced the bioavailability of ANT to zebrafish. However, in combination with UVA, the nanoparticles catalyzed the formation of more bioavailable PAH byproducts. PHE was readily bioavailable and transformed by the larval zebrafish regardless of nanoparticles being present. Expression of all genes were reduced under UVA, which the authors attribute to phototransformation being favored over changes within the body for PHE.

By combining multiple analytical chemistry and gene expression analyses, the team revealed new insights into distinct interactions between PAHs, UVA light, and titanium dioxide nanoparticles over time that affect how PAHs move and change in water under realistic conditions. Their unique approach also demonstrated the need to consider diverse PAH byproducts during environmental cleanup activities, particularly when titanium dioxide nanoparticles are involved.

If you'd like to learn more about this research, visit the Superfund Research Program website at niehs.nih.gov/srp. From there, click on the Research Brief title under the banner, and refer to the additional information listed under the research brief. If you have any questions or comments about this month's podcast, send an email to srpinfo@niehs.nih.gov.

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