Researchers discover potentially harmful nanoparticles produced through burning coal

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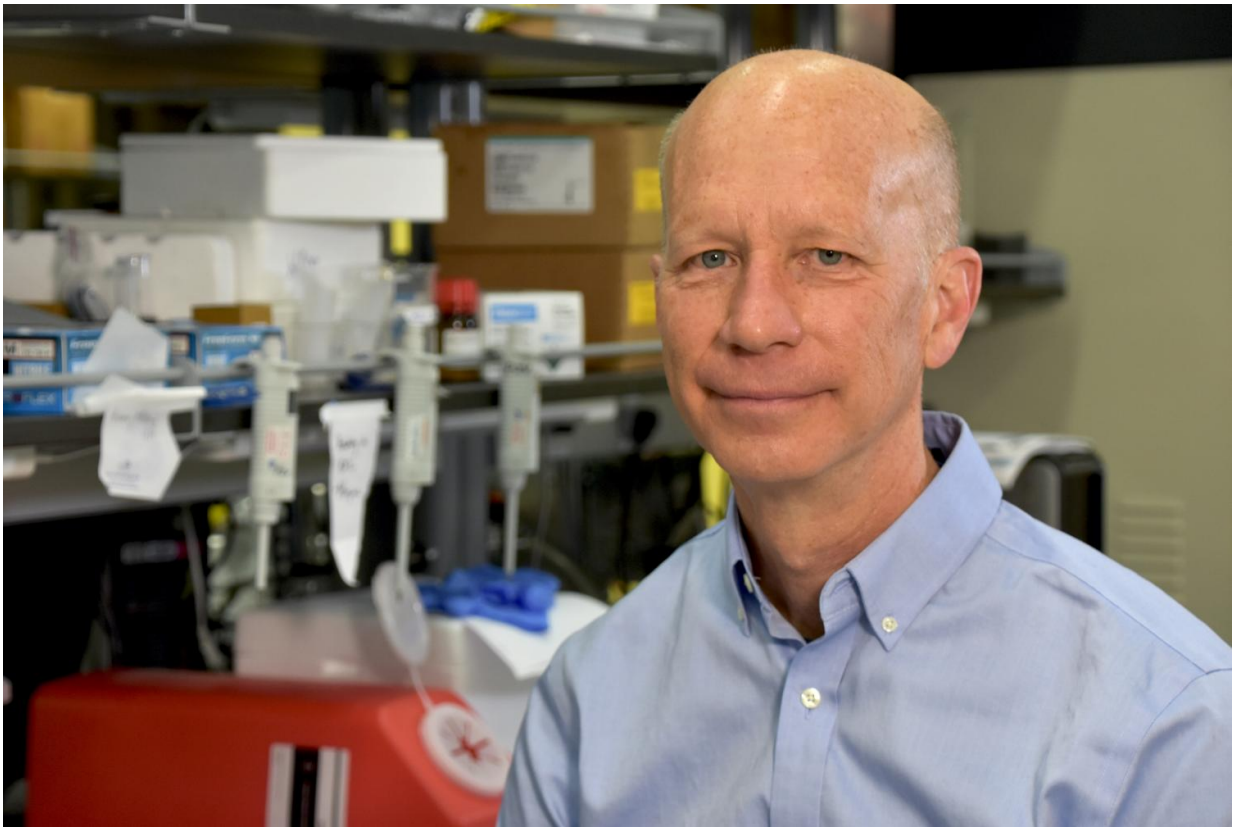

Michael F. Hochella Jr. is a University Distinguished Professor of Geosciences with the Virginia Tech College of Science. Credit: Virginia Tech

Environmental scientists led by the Virginia Tech College of Science have discovered that the burning of coal produces incredibly small

particles of a highly unusual form of titanium oxide.

When inhaled, these nanoparticles can enter the lungs and potentially the bloodstream.

The particulates—known as titanium suboxide nanoparticles—are unintentionally produced as coal is burned, creating these tiniest of particles, as small as 100 millionths of a meter, said the Virginia Tech-led team. When the particles are introduced into the air—unless captured by high-tech particle traps—they can float away from power plant stacks and travel on air currents locally, regionally, and even globally.

As an example of this, these nanoparticles were found on city streets, sidewalks, and in standing water in Shanghai, China.

The findings are published in the latest issue of *Nature Communications* under team leader Michael F. Hochella Jr., University Distinguished Professor of Geosciences with the College of Science, and Yi Yang, a professor at East China Normal University in Shanghai. Other study participants include Duke University, the University of Kentucky, and Laurentian University in Canada.

"The problem with these nanoparticles is that there is no easy or practical way to prevent their formation during coal burning," Hochella said, adding that in nations with strong environmental regulations, such as the United States, most of the nanoparticles would be caught by particle traps. Not so in Africa, China, or India, where regulations are lax or nonexistent, with coal ash and smoke entering the open air.

"Due to advanced technology used at U.S.-based coal burning power plants, mandated by the Clean Air Act and the Environmental Protection Agency, most of these nanoparticles and other tiny particles are removed before the final emission of the plant's exhaust gases," Hochella said.

"But in countries where the particles from the coal burning are not nearly so efficiently removed, or removed at all, these titanium suboxide nanoparticles and many other particle types are emitted into the atmosphere, in part resulting in hazy skies that plague many countries, especially in China and India."

Hochella and his team found these previously unknown nanoparticles not only in coal ash from around the world and in the gaseous waste emissions of coal plants, but on city streets, in soils and storm water ponds, and at wastewater treatment plants.

"I could not believe what I have found at the beginning, because they had been reported so extremely rarely in the natural environment," said Yang, who once worked as a visiting professor in Virginia Tech's Department of Geosciences with Hochella. "It took me several months to confirm their occurrence in coal ash samples."

The newly found titanium suboxide—called Magnéli phases—was once thought rare, found only sparingly on Earth in some meteorites, from a small area of rock formations in western Greenland, and occasionally in moon rocks. The findings by Hochella and his team indicate that these nanoparticles are in fact widespread globally. They are only now being studied for the first time in natural environments using powerful electron microscopes.

Why did the discovery occur now? According to the report, nearly all coal contains traces of the minerals rutile and/or anatase, both "normal," naturally occurring, and relatively inert titanium oxides, especially in the absence of light. When those minerals are burned in the presence of coal, research found they easily and quickly converted to these unusual titanium suboxide nanoparticles. The nanoparticles then become entrained in the gases that leave the power plant.

When inhaled, the nanoparticles enter deep into the lungs, potentially all the way into the air sacs that move oxygen into our bloodstream during the normal breathing process. While human lung toxicity of these particles is not yet known, a preliminary biotoxicity test by Hochella and Richard Di Giulio, professor of environmental toxicology, and Jessica Brandt, a doctoral candidate, both at Duke University, indicates that the particles do indeed have toxicity potential.

According to the team, further study is clearly needed, especially biotoxicity testing directly relevant to the human lung. Partnering with coal-power plants either in the United States or China would be ideal, said Yang.

More troubling, the study shows that titanium suboxide nanoparticles are biologically active in the dark, making the particles highly suspect. Exact human health effects are yet unknown.

"Future studies will need to very carefully investigate and access the toxicity of titanium suboxide nanoparticles in the human lung, and this could take years, a sobering thought considering its potential danger," Hochella said.

As the titanium suboxide nanoparticle itself is produced incidentally, Hochella and his team came across the nanoparticle by accident while studying a 2014 coal ash spill in the Dan River, North Carolina. During the study of the downstream movement of toxic metals in the ash in the Dan River, the team discovered and recognized the presence of small amounts of the highly unusual titanium suboxide.

The group later produced the titanium suboxide nanoparticles when burning coal in a lab simulation.

This new potential air pollution health hazard builds on already

established findings from the World Health Organization. It estimates that 3.3 million premature deaths occur worldwide per year due to polluted air, Hochella said. In China, 1.6 million premature deaths are estimated annually due to cardiovascular and respiratory injury from air pollution. Most Chinese megacities top 100 severely hazy days each year with particle concentrations two to four times higher than WHO guidelines, Yang said.

Direct health effects on humans is only one factor. Findings of thousands of scientists have determined that the biggest driver of warming of the planet and the resulting climate change is industrial-scale coal burning. The impact of titanium suboxide nanoparticles found in the atmosphere, in addition to greenhouse gases, on animals, water, and plants is not yet known.

More information: Yi Yang et al, Discovery and ramifications of incidental Magnéli phase generation and release from industrial coal-burning, *Nature Communications* (2017). DOI: 10.1038/s41467-017-00276-2

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