

Dirty smoke from ships found to degrade air quality in coastal cities

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Ah, nothing like breathing clean coastal air, right? Think again. Chemists at UC San Diego have measured for the first time the impact that dirty smoke from ships cruising at sea and generating electricity in port can have on the air quality of coastal cities.

The scientists report in this week's early online edition of the journal *Proceedings of the National Academy of Sciences* that the impact of dirty smoke from ships burning high-sulfur fuel can be substantial, on some days accounting for nearly one-half of the fine, sulfur-rich particulate matter in the air known to be hazardous to human health.

Their results have particular significance for the state of California, which will require, beginning next July, that all tankers, cargo and cruise ships sailing into a California port switch to more expensive, cleaner-burning fuels when they come within 24 miles of the coast. Similar international rules requiring clean-burning ship fuels are set to take effect in 2015.

While those regulations are intended to minimize the potential hazards dirty ship smoke may pose to human health and the environment—which some researchers have estimated may be responsible for as many as 60,000 deaths worldwide and a cost to the U.S. economy of \$500 million a year—no one knows the actual impact of ship smoke. The reason is that air quality experts have been unable to quantify the specific contribution of ship smoke to the air pollution of coastal cities—until now.

"This is the first study that shows the contribution of ships to fine particulates in the atmosphere," said Mark Thiemens, Dean of the Division of Physical Sciences and a professor of chemistry and biochemistry at UCSD who headed the research team. "Ships are really unregulated when it comes to air pollution standards. What we wanted to find out was the contribution of ships to the air pollution in San Diego. And what we found was a surprise, because no one expected that the contribution from ships of solid sulfur-rich particles called primary sulfate would be so high."

Primary sulfate, or SO_4 , is produced when ships burn a cheap, sulfur-rich fuel called "bunker oil." Most of the sulfur emitted by ships burning bunker oil is released as sulfur dioxide, or SO_2 , a gaseous pollutant which is eventually converted to sulfate in the atmosphere. But although SO_4 may be a smaller component in ship emissions, the scientists say, these primary sulfate particulates are particularly harmful to humans, because they are especially fine microscopic particles, less than 1.5 microns or millionth of a meter in size. As a result, they can travel extremely long distances because they stay in the atmosphere for longer periods and, unlike bigger dust grains and particles that are removed by the body when breathed, remain in the lungs.

"The importance of primary sulfate is usually ignored in assessments of the impact of ship emissions on air quality because less than 7 percent of all sulfur emitted by ships is found in primary sulfate particles," said Gerardo Dominguez, a postdoctoral researcher at UCSD and the first author of the paper. "But our results suggest that this component of ship emissions is important and should not be ignored in the future. Knowing how much sulfate from ships is in the air will also allow us to better understand what happens to the other 93 percent of sulfur emitted by ships."

Working with Thiemens, Dominguez developed a chemical

fingerprinting technique that allowed the scientists to distinguish primary sulfate from ship smoke from the tailpipe emissions of trucks, cars and other sources. This was done using an oxygen-isotope technique developed by Thiemens that allows scientists to determine the signature of sulfate molecules made in the atmosphere. The researchers discovered that primary sulfates from ship engines incorporated molecular oxygen (the type we breathe in to live) and are easily distinguished from primary sulfates from car and truck diesel emissions.

Sampling air at the end of the pier at the UC San Diego's Scripps Institution of Oceanography in La Jolla, the scientists found that the smoke from ships contributed as much as 44 percent of the sulfate found in fine particulate matter in the atmosphere of coastal California. On the days when the proportion of ship sulfate approached one-half of the fine particulate matter, the scientists determined from wind direction and speed calculations that ships burning high sulfur fuel in the Los Angeles, Long Beach and San Diego ports were a major influence.

"We found that in San Diego, the Port of Los Angeles can be a significant influence on air quality because these fine particulates can travel so far," said Dominguez.

The researchers said the chemical fingerprinting techniques they developed in their study for ship primary sulfur emissions should assist the California Air Resources Board as well as regulators in other states and countries monitor the impacts of ships off their coasts as new restrictions on bunker oil burning by ships are implemented.

"This will tell us whether California's new regulation requiring cleaner burning fuel 24 miles off the coast is having the effect it's intended to have," said Thiemens. "And because a large part of the world's population live in major cities with shipping ports—such as New York City, San Francisco, Hong Kong, Houston, and Singapore—and global

shipping is expected to increase in the decades to come, this should help policy makers around the world make more informed decisions about improving the health of their citizens."

Source: University of California - San Diego

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