

Up in the Air: The Emerging Science of Dust and Sandstorm Microbes

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On October 13, 2017, a sandstorm blew off the west coast of Africa, creating a plume of dust that stretched thousands of miles across the Atlantic Ocean and reached the Caribbean five days later. Each year, up to five billion tons of dust is ejected into the earth's atmosphere, mostly from large deserts like the Sahara in Africa and the Gobi in Asia. Such dust plumes affect all regions of the planet, with some individual plumes even circling the globe.

In an expanding field of environmental microbiology, researchers have begun investigating the microscopic travelers that hitch rides on these dust plumes and transit the globe. Because of their origins in harsh desert climates, these bacteria, archaea, microbial eukaryotes (including fungi), and viruses may be especially good at surviving extreme conditions and adapting to new environments. As researchers in this emerging field, Hayedeh Behzad, Katsuhiko Mineta, and Takashi Gojobori of the King Abdullah University of Science and Technology (KAUST) in Saudi Arabia provide an overview of current knowledge and highlight the potential impacts on human and ecosystem health in a new review in *Genome Biology and Evolution*, "Global Ramifications of Dust and Sandstorm Microbiota" (Behzad et al. 2018). One thing that is clear is that, for a field of study still in its infancy, its potential ramifications are massive.

Behzad and colleagues detail several studies that indicate that dust and sandstorms may enable the spread of disease-causing microbes. For example, the fungal agents that cause valley fever can be found in desert soils, and epidemics in the southern United States appear to be correlated with the intensification of sandstorms (Tong et al. 2017). Perhaps more surprisingly, increased incidence of Kawasaki disease, a serious heart condition, in Japanese and U.S. children may be associated with a fungus found in winds originating from China (Rodo et al. 2014). Cases of measles (Ma et al. 2017), pulmonary tuberculosis (Wang et al. 2016), and influenza (Chen et al. 2010) may also be linked to the occurrence of dust and sandstorms. Finally, in a study suggesting just how

far-reaching this phenomenon may be, several genetic sequences potentially belonging to meningitis pathogens were found in Saharan dust deposits within snow packs in the Swiss Alps (Meola et al. 2015).

As further detailed in the review by Behzad and colleagues, dust and sandstorm-derived microorganisms also have the potential to significantly affect the ecosystems to which these microbes are transported. Deposits of such microbes could impact the ecosystem services provided by microbial communities, affecting nutrient cycling and food chains. Notably, Saharan-derived dust samples in the Caribbean were found to contain *Aspergillus sydowii*, a fungus that infects corals and may be partially responsible for the declining health of the Caribbean coral reef (Garrison et al. 2003). In addition, pathogens carried by sandstorms may infect agricultural crops, with major implications for the global economy.

Teruya Maki at Kanazawa University in Japan, author of several studies on sandstorm-derived microbes, agrees with Behzad, Mineta, and Gojobori regarding the potential risks of these organisms: "Although the microbial communities associated with dust events are mainly composed of nonharmful populations...there is the possibility of pandemics [caused by] the spread of pathogens after the deposition of dust particles." Maki, who discovered a link between Japanese outbreaks of foot-and-mouth disease and Chinese sandstorms (Maki et al. 2012), believes the review by Behzad et al. provides important information regarding the potential risks of such microbes to the general public. However, Maki also points out that among dust and sandstorm microbes, there may be species that provide benefits to humans as well. As an example, Maki's research team has made a fermented food called natto using bacteria isolated from the air at 3,000 m, which is currently sold under the name "Sky Natto" in Japan.

The potential impacts of dust and sandstorm microbes make research in this field critical. Located at KAUST and surrounded by some of the largest deserts in the world, Behzad, Mineta, and Gojobori are well situated to investigate

these microorganisms using cutting-edge technology. “Our laboratory is examining the potential impact of sandstorms on human health and the environment using metagenomic approaches,” notes Behzad on behalf of all three of the authors, an endeavor made possible by the state-of-the-art facilities at KAUST. While the majority of the current knowledge on this topic is derived from culture-based approaches, such technology has the potential to shed light on the ~90% of environmental microbes that cannot currently be cultured.

In addition to advances in metagenomics, the authors anticipate that future research will benefit from improvements in culturing techniques and air sample collection. In particular, Behzad notes, “I would hope that within a decade or two, we would have sufficient tools necessary to explore airborne microbiomes at all levels of the atmosphere, not just when deposited on the surface.” Most importantly, however, Behzad, Mineta, and Gojobori believe that the establishment of large-scale, multidisciplinary collaborations across different laboratories will be key for unraveling the mysteries of this global phenomenon. “Unification of standardized methodological frameworks across different laboratories could facilitate reproducibility and comparison of data between different research communities. Such unified frameworks require considerable investments of time and resources to develop and perfect, but when used by the wider research community, they could help complete gaps in our current understanding of sandstorm-derived microbiota.”

Importantly, Behzad et al. point out that the study of these microbes and their impacts is especially urgent given the predicted increase in dust and sandstorm-related activity in the future due to global climate change. The authors note that over the past two decades, the number and intensity of the

sandstorms in the region surrounding KAUST have been on the rise. Thus, a better understanding of the risks and effects of desertification may help to develop control measures or protective policies. Microbes are “necessary building blocks of living ecosystems,” concludes Behzad. “Studying them helps us unlock their potential and understand their influence on us. Studies of airborne microbiota enable us to monitor our environment for potential risks to human and ecosystem health.”

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