Clouds of desert dust and microbiology: a mechanism of global dispersion

Huge numbers of microbes are carried in the atmosphere in dust clouds. **Dale Griffin** explores the impact of this phenomenon on global ecology.

Although desert soils and sediments in Earth's atmosphere are derived from arid regions around the globe, the majority of 'desert dust' originates from two locations, the Sahara and Sahel regions of Africa, and the deserts of Asia. In the months from June through October, dust originating from Africa routinely impacts the Caribbean and Central and North America. In the remaining months, the African dust storms typically impact South America, Europe and the Middle East. Dust storms originating in the Asian deserts usually occur from February through to April of each year, and although the Asian deserts are smaller than the Sahara and the dust season only 3 months long, the larger Asian dust events are capable of global dispersion in the Northern Hemisphere.

The current estimate of the quantity of soil moving some distance in Earth's atmosphere each year is approximately 3 billion metric tons (Fig. 1). If that 3-billion-ton estimate was converted into 1964 Volkswagen Beetles (based on weight and dimensions), there would be enough Beetles to create a 42-km-tall tower with a base area equivalent to the walled city of Chester, UK. From a microbiology perspective, there is an additional piece of trivia – the 3-billion-ton estimate converts to 3×10^{15} g. At a conservative estimate of 10,000 bacteria per gram of arid soil (microbial ecology studies have shown that actual concentrations range from 10^6 to 10^9), the bacteria would form a 38-cell-wide bridge between Earth and Jupiter if placed end to end (assuming an average bacteria size of 0·75 µm). This conservative estimate is based on bacterial species alone and does not include the fungi and viruses also known to inhabit soils. Even more interesting than these bits of trivia are the questions that arise from such a large quantity of dust and dust-borne micro-organisms moving through the atmosphere. Are there any benefits to dust movement? What influence does this process have on global microbial ecology issues? Can dust-borne pathogenic micro-organisms survive long-range atmospheric transport and cause infection in downwind ecosystems? These are questions with global implications, questions that are being addressed by surprisingly few.

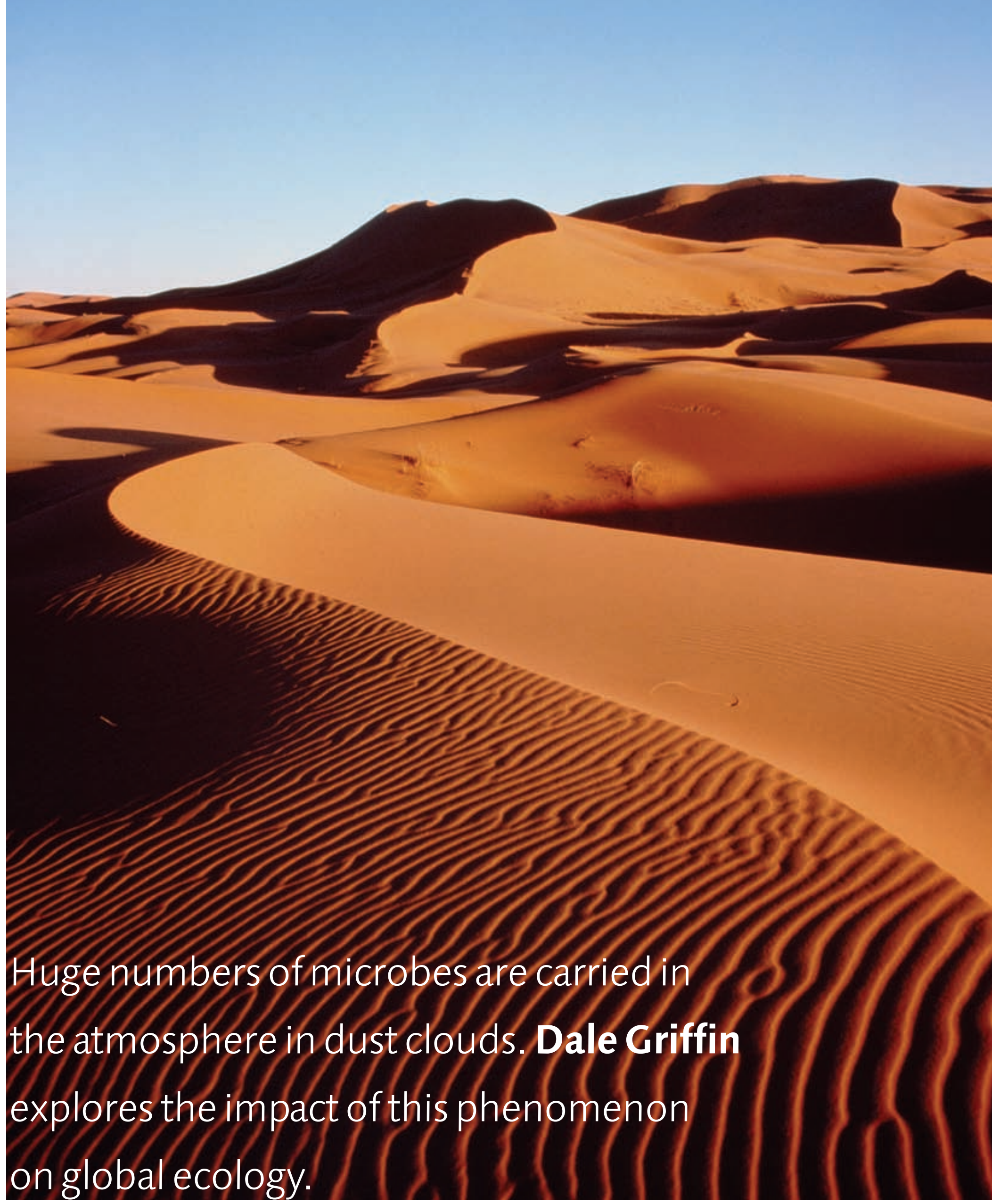
Benefits

Plant life in both terrestrial and aquatic ecosystems has evolved to take advantage of the nutrient-rich particles (iron, phosphate and organic detritus) in clouds of desert dust. Research has shown that plant life in the upper canopy of the Amazon rain forest derives nutrients from African dust. Rain forests located on the northern Hawaiian Island chain are believed to obtain a significant fraction of their nutrient budget from Asian desert dust. Increases in marine biomass have been documented following deposition of desert dust in our oceans. African dust deposition in the Caribbean, through time, provided the clays in Bahamian soils that enabled pre-Columbian Indians to produce pottery from an otherwise clay-limited soil. Clearly, the global movement of dust has benefitted both ecosystems and humanity.

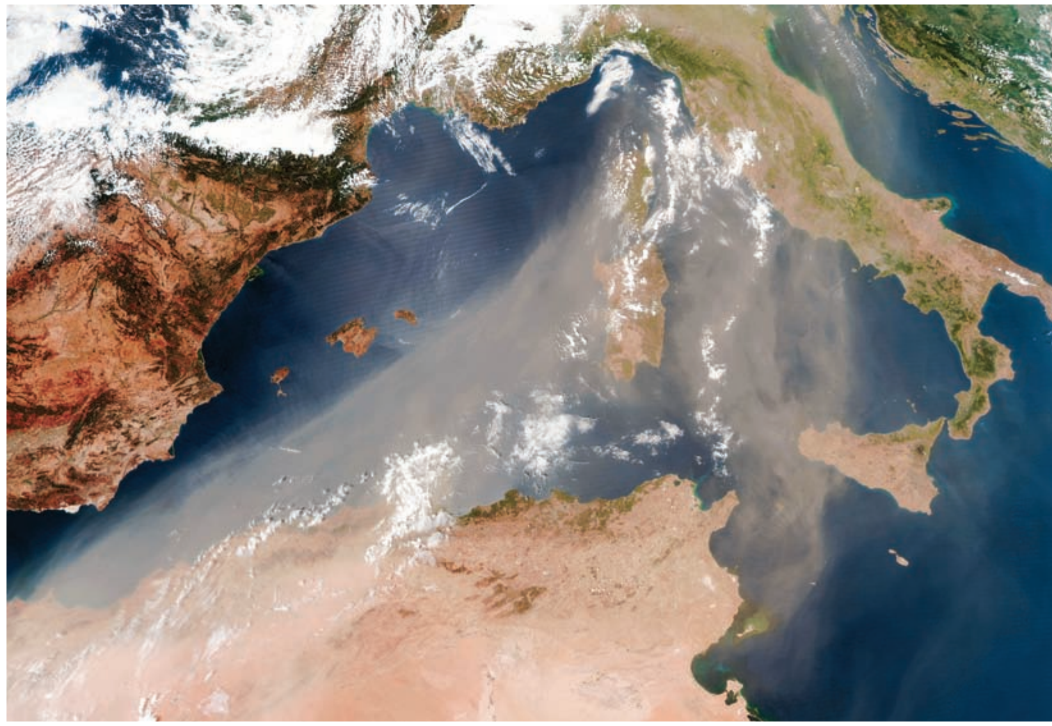
Microbial ecology

Whereas far too few microbiologists study dust-borne microbiology, the field has at times in the past sparked interest. In the early 1800s, C.G. Ehrenberg identified 'infusoria' in samples of African dust collected aboard *HMS Beagle* by Charles Darwin while traversing the coast of north-western Africa. Research in the 1970s by Russian scientists using rockets to collect high-altitude microbiological samples noted that greater numbers of cultivable micro-organisms were present when dust was in the atmosphere.

At a number of different locations, including Bamako in Mali, Erdemli in Turkey, the tropical mid-Atlantic Ocean, and the US Virgin Islands, our research groups have found elevated concentrations of very diverse populations of bacteria and fungi when



▲ Sand dunes in the Sahara desert, photographed in Morocco. *Noboru Komine / Science Photo Library*



▶ Fig. 1. Terra satellite image of a dust plume crossing the Mediterranean sea. Sand and dust from North Africa and the Sahara has blown north towards Italy in a large plume. This image was taken on 16 July 2003 by NASA's Moderate Resolution Imaging Spectroradiometer (MODIS). *NASA / Science Photo Library* desert dust is in the atmosphere. During dust events in Bamako, Mali, the bacterial and fungal colony-forming units (c.f.u.) averaged 6,655 (m air)$^{-3}$ (Fig. 2). Ninety-seven percent of the c.f.u. were bacteria. In the US Virgin Islands, during dust events, those concentrations dropped to 10^4 m^{-3} (72 % bacteria), indicating a die-off of over 90 % due to the stresses of atmospheric transport. At the Turkey research site, c.f.u. were dominated by fungi (93 % of isolates), and we believe this is due to differences in source regions of dust (dust impacting the Mediterranean region typically originates from the northern Sahara, whereas the dust moving across the Atlantic typically originates from the southern Sahara/Sahel). Numerous isolates collected over a site in the tropical mid-Atlantic Ocean were genetically (16S rDNA sequences) similar to various Mali isolates. Other research groups conducting microbial surveys during Asian dust events in South Korea have documented elevated concentrations of diverse fungal populations in a number of independent studies.

It is obvious that despite the physical stresses of atmospheric transport (UV-induced DNA damage, desiccation, temperature, etc.), many species of fungi and bacteria are capable of surviving long-range atmospheric transport.

Dust-borne pathogens

One of the best examples of dust-borne pathogens is the small outbreaks of coccidiomycosis (caused by the fungal pathogen *Coccidioides immitis*) that occur annually in the Americas following dust events. One of the first links to be made between long-range transport of desert dust and ecosystem health was the isolation and identification of a terrestrial fungus (*Aspergillus sydowii*) as the causative agent of a Caribbean-wide sea fan disease from atmospheric samples collected in the US Virgin Islands. An outbreak of aspergillosis in caged desert locusts was documented following a dust event in Bikaner, India. Of those dust-associated isolates we have identified using DNA sequencing of the ribosomal gene, ~20 % are species known to cause disease in a broad range of plant and animal life and ~10 % are known opportunistic human pathogens. Although dose is certainly an issue when determining risk from exposure, it should not be surprising that dust-borne pathogenic species capable of surviving atmospheric transport are capable of causing disease in downwind ecosystems.

The implications of the global dispersion of dust-borne micro-organisms are what make this field so interesting. Do dust-borne micro-organisms influence regional microbial ecology in downwind environments? How do fate and survival issues change with location, distance, and season? What is the true risk of infection from dust-borne pathogens? This article is but a brief synopsis of what dust-associated microbiology has shown us and where it is leading us. Hopefully, this wide-open field will attract other microbiologists in our quest to understand its regional and global implications.

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Further reading

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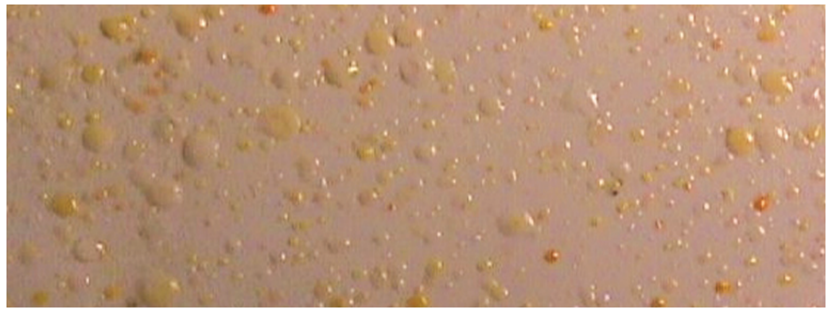

▶ Fig. 2. Atmospheric sample taken during a dust event in Mali, Africa, showing heavy growth of bacteria and fungi. The volume of air filtered was ~75 litres. *Dale Griffin*