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Microbiological aerosols in the atmosphere:

how they get there, what happens to them and how they may affect us

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Huge strides have been and are still being made in the control, and sometimes the elimination of infectious diseases. However, even in the developed world, we can still be very seriously affected by epidemics both of human and animal diseases. The recent outbreak of foot and mouth disease and the projections of the likely consequences of a new flu strain arising from the bird-flu epidemic illustrate how vulnerable we still are.

Micro-organisms have evolved many ways of moving between hosts and so enabling their reproduction. When they also evolve means to overcome the hosts defence mechanisms and the transport between hosts goes unchecked it can lead to epidemics or pandemics of the disease. Many disease-causing organisms, particularly those that infect the upper respiratory tract, induce sneezing and coughing in the host which generates an aerosol of the disease-causing organism. The particles may remain in airborne suspension for hours or even days and may travel considerable distances before they become non-infective. There is strong evidence that the initial spread of the most recent outbreak of foot and mouth disease in the UK was caused by an aerosol of the infection being carried many miles down a valley to infect a flock of sheep.

Sneezing is one way that micro-organisms move between hosts . Photo courtesy of Andrew Davidhazy/RIT ©

If we want to develop tools to help us control outbreaks of potentially fatal diseases, such as new strains of flu, it is important to understand how microbiological aerosols are generated and transported. We also need to develop techniques that can be used to detect potentially pathogenic organisms in the presence of the highly variable atmospheric aerosol that is certain to contain a wide selection of innocuous biological materials.

Atmospheric aerosols

The air we breathe is an aerosol. The concentration of particles varies enormously with location, altitude and weather conditions but even "clean" air will normally contain billions of particles in every cubic metre. The majority are very tiny indeed, typically some tens of nanometres in diameter, but there will be a significant number (perhaps 10^5 or 10^6 per cubic metre) that have micrometre dimensions and of these a significant proportion will be of biological origin.

The atmosphere acts, like the oceans, as a global medium of transport for a wide range of different materials. This enables the living world to function by distributing the components vital to maintain ecosystems and diluting or enabling the destruction of waste products. Many living systems use the atmosphere as their means of propagation, perhaps the most obvious example being plant pollens and fungal spores that are wind disseminated.

Bacteria and viruses can also use the atmosphere to propagate. An infected host can be induced, by a variety of mechanisms to release the organisms into the atmosphere. Once airborne these can be inhaled by a new host where they will deposit in the airways to begin a new infection cycle. Of course most of the bacteria and viruses in the atmosphere are non-pathogenic and we all inhale many thousands of organisms daily without any ill effects.

Microbiological aerosols in the atmosphere: *continued*

The primary destructive agent is the ultra-violet component of sunlight, which, with long exposure, is effective in killing most living cells. Other factors include humidity and a variety of gaseous materials commonly found in the atmosphere. However, there are a number of factors that may act to protect disease-causing organisms even when the particles are exposed to destructive agents. Organisms are often emitted in clumps containing tens or even hundreds of units and in such cases those organisms at the centre of the clump will be protected and so may remain viable for much longer periods. Similarly mucous from the respiratory tract can act as a very effective protective barrier for the organisms inside it.

We all know that many infectious diseases spread more effectively in winter when nights are longer and the intensity of UV radiation, even in daylight, is much reduced. Also in indoor environments such as hospitals and large public spaces the UV component of the light is very low and so, even relatively delicate organisms may have long lifetimes in these environments.

Detection of airborne micro-organisms

In many cases individuals infected with a disease become effective transmitters before their symptoms are fully developed and recognised. This makes the control of epidemics, particularly in our modern mobile society, extremely difficult. To detect when someone is beginning to emit disease organisms is difficult, costly and, in most cases impractical and so, in general, we just have to accept the consequences and treat the disease in the recipients. However, we are now faced with the prospect of some very serious diseases such as new strains of flu, to which people will have no resistance, or infections such as MRSA that are very difficult to treat. Epidemics of such diseases have the potential to kill millions.

Multi-national bodies such as the World Health Organisation and the European Union are beginning to consider what tools are available to help combat the potential threat. One of the areas that they are looking at is the work that has been done for the military to develop rapid detection systems for biological weapons. Of course it would still be impractical to monitor all individuals but it may be possible to detect significant changes in the biological content of the atmosphere in places such as airports or hospitals where there may be a very high throughput of infected individuals. Instruments such as the VeroTect, which was developed by Biral for the armed forces, could potentially be adapted to this role. To assist in this Biral, together with other manufacturers and research groups, is actively participating in EU working groups that are examining the problems and attempting to formulate solutions and strategies.

For more information on the Verotect please contact Biral.

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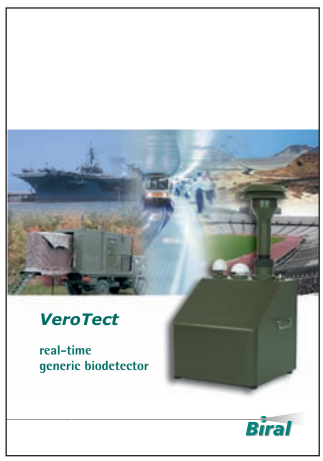
Verotect biodetector



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Generation of microbiological aerosols

All aerosols of micro-organisms are generated by some type of disruptive process. This may be by the break-up of sheets or columns of liquid suspensions or by air movement lifting deposited particles and separating them into single units. An example from the natural world of the break-up of liquid suspensions to generate a potentially infectious aerosol is sneezing. A sneeze is caused by a rapid muscular spasm that expels air at high velocity through the nose where the shear forces tear the mucous from the nasal hairs and lining, breaking up the ligaments into droplets. The greater the energy input to the process the smaller will be the droplets that are produced.

At the other end of the energy scale is the dispersion of pollens and spores. Here the plants have evolved complex strategies that use the geometry of the pollen grains, coating of the grain and the lining of the pollen sac to overcome the effect of the Van der Waals forces that hold small particles to both surfaces and to each other. So pollens and spores are effectively dispersed, even in very light winds.

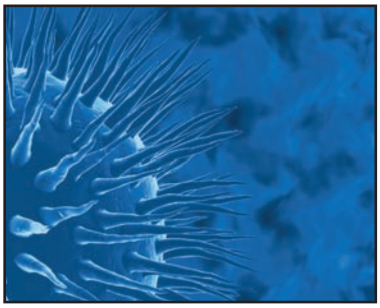

Image of a virus

Dispersion

An aerosol, being a quasi-stable suspension of particles in air, will act in many ways just like one of the gaseous components of the atmosphere. So wherever the wind blows or convection currents move the air then the particles will be carried with it. However, there are some important differences in the way that particles behave as compared to gaseous components of the atmosphere and these can be of particular significance in the case of micro-organisms.

Diffusion – When a source of gas is added to the atmosphere it will dilute very rapidly as the molecules diffuse through the other gaseous components. When a source of particles enters the atmosphere they will also diffuse, due to Brownian motion, but very much more slowly and with a diffusion coefficient that is a function of particle size. So for micro-organisms, which are relatively large particles, their diffusion coefficient will be many orders of magnitude smaller than that of a gas molecule. This can be important in the spread of disease as, if there is little turbulent mixing, the cloud may take a long time to disperse.

Deposition - Particles unlike gas molecules do fall through the atmosphere under the influence of gravity, the rate of fall being, once again, a function of their size:
As can be seen from the table, the velocity of fall is extremely slow, even for particles larger than a micrometre and so the effects of convection and Brownian motion can result in particles being kept in semi-permanent suspension.

Particle Size (micron)	Velocity of Fall (mm s^{-1})
0.1	0.00085
1.0	0.035
5.0	0.78
10.0	3.0

Impaction - When the wind carries particles among solid objects, particles can be deposited due to their greater inertia carrying them to the surface of a body as the air flows around it. This is the principal mechanism by which airborne pollen grains reach their target.

Survival of micro-organisms in the atmosphere

Micro-organisms can remain in suspension in the atmosphere almost indefinitely but this is a challenging environment and for many species their lifetime in it can be very limited unless they are protected in some way. Clearly some organisms have evolved to survive in the atmosphere. Pollens and spores are obvious examples, but also some bacteria such as the bacilli have evolved techniques by which they form spores that are highly resistant to environmental attack.

continued overleaf

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