Aerobiology, aerodynamics and pollen sampling

Aerobiologia, aerodynamika oraz metody pobierania próbek pyłków

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Abstract

Aerobiology is the interdisciplinary science focused on the study of airborne organisms and biological materials.

Aerodynamics rules influence the transport of the pollens through the air and their eventual removal from the airflow. It depends on the various factors, such as pollen size, shape and weight and features of the air and weather.

The most commonly used pollen sampling methods are volumetric traps, rotorod samplers and cyclones.

Key words: *aerobiology, aerodynamics, pollen sampling.*

Streszczenie

Aerobiologia jest interdyscyplinarną nauką zajmującą się badaniem organizmów oraz biologicznych materiałów powietrznopochodnych.

Prawa aerodynamiki wpływają na przemieszczanie się pyłków w powietrzu oraz na ich ostateczne z niego usunięcie. Zjawiska te zależą od różnych czynników, między innymi od wielkości, kształtu, wagi pyłku oraz właściwości powietrza i pogody.

Najpowszechniej wykorzystywanymi metodami pobierania próbek pyłków są: pułapki objętościowe, rotametry oraz cyklony.

Słowa kluczowe: *aerobiologia, aerodynamika, metody pobierania próbek pyłków.*

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The Scope of Aerobiology

Aerobiology is the scientific discipline focused on the study of airborne organisms and biological materials, including their release to the air, their dispersion and transport, deposition or other removal from the air and their impacts on animal, plant and human systems. It is an interdisciplinary science with links to many other subject areas including Botany, Ecology, Meteorology, Agriculture and Allergology. Aerobiology also has many applications including crop pathology, biodeterioration and forensics.

This course focuses on pollen and spores but we need to be aware that aerobiological studies can include many other biological particles such as viruses, bacteria, faecal pellets from mites, urinary proteins from laboratory and farm animals and organic particles from industrial processes. Interest in Aerobiology is growing rapidly across a wide range of areas but is probably most noticeable in the field of Allergy.

Aerodynamics and Pollen Grains

Most pollen grains that are sampled in Aerobiology are from the wind pollinated (anemophilous) plants. These tend to produce pollen in vast amounts to increase the chances of some grains reaching the female flowers and to achieve pollination. During evolution the pollen from the wind pollinated plants has developed features and structures to assist its flight through the atmosphere. Some, such as grass pollen, are smooth, rounded and dry whereas others such as many of the conifers, have air sacs to aid buoyancy. In contrast many of the pollen grains of insect pollinated plants (entomophilous) have complex ornamentation and are often sticky which may assist them in adhering to insects. Pollen grains from anemophilous plants are mainly in the size range from 15 microns to 80 microns. Pollen grains from entomophilous types have a wider size range with some as small as 3 microns and some as large as 250 microns. Some of these may get airborne but if they do the grains would only usually be present in the air in small quantities. Also there are some species which disperse their pollen both on the wind and by insects.

In all these cases it is useful to know the basic aerodynamics that influence the transport of the grains through the air and their eventual removal from the airflow. A great deal of work has been done on aerodynamics. A lot of this is summarised in „The Bioaerosols Handbook", edited by Cox and Wathes (1995) and in „Methods in Aerobiology" edited by Mandrioli, Comtois and Levizzani (1998). In this course we are going to cover the main things that you need to know in the context of pollen sampling.

When the pollen is released from the plant it will take up the motion of the air flow. Even on calm days there is usually some air movement. The way the pollen is moved will depend on factors such as its size, shape and weight as well as features of the air and weather such as temperature, turbulence and precipitation. The time that the pollen remains in the air can differ from less than an hour to several days depending on the weather conditions etc.

Gravitational settling

All particles will be pulled down by the force of gravity at a velocity proportional to its mass. However other forces will also be operating. The molecules of the air will create some resistance to the fall. This is the **drag force** of the particle and is proportional to the square of the velocity of the particle, the air density and the cross sectional area of the particle. When the gravitational force is equal to the drag force the particle will be at its final or **terminal velocity**.

Stokes Law relates terminal velocity to particle size, mass, etc. It can be derived by equating acceleration due to gravity with drag force. For a spherical particle the terminal velocity v (cm/sec) is

$$V = \frac{\rho d^2 gC}{18\eta}$$

ρ is particle density g/cm^3
d is particle diameter cm
g is gravitational acceleration
η is air viscosity g/cm s^{-1}

This law can be applied to particles in the size range 1.6 to 70 microns. Very small particles slip between the air molecules. Particles larger than 70 microns produce small eddies. In both cases corrections have to be made.

The motion of the particle will differ with wind speed, eddies etc. In still air the speed of gravitational settling will be faster.

The effects of precipitation

Two main processes can remove the pollen from the air during the formation and process of precipitation. The first of these is rainout, which is when small particles are absorbed into cloud droplets or ice crystals in clouds. The second is washout which is when precipitation (rain drops, snow flakes, hail etc.) hits particles and either absorbs them or impacts them. Typically even a slight rainfall will remove a lot of the pollen from the air.

Impaction

Pollen grains and other particles may impact on obstacles in the air flow such as buildings and trees. The amount of pollen impacted will depend on factors such as the size, shape and orientation of the obstacles, the wind speed and the features of the pollen, especially its mass. All particles have an inertia of motion in that they tend to carry on moving in the same direction unless there is sufficient force in the air flow to divert their course. This means that particles may keep on moving towards an obstacle and impact on it even though the general air flow is diverted. This principle is also important in pollen sampling with the Hirst type volumetric trap.

Pollen Sampling

As with all environmental sampling the first step is to decide what we need to know. From this we can decide what to sample, where and how to do it, what the sampling time or interval should be and so on. The approach to sampling will be different for various situations and problems. For example studying pollen dispersal from a crop will require a different approach to studying general seasonal variations in pollen in the air at a site or studying occupational exposure to pollen.

Most routine pollen sampling is done to provide daily average counts as part of pollen monitoring networks. This information is then used together with other information such as weather forecasts and phenology to provide pollen forecasts. It is also used as a data base for analysis of patterns and trends in pollen counts in relation to weather factors and land use as well as in studies of allergy and clinical trials.

Volumetric traps

Most routine monitoring of pollen for daily average counts is done with volumetric traps of the Hirst design (Hirst 1952). This trap has been adopted for most pollen sampling networks in Europe and is used increasingly in other parts of the world including USA. The trap sucks in air at a rate of 10 l/min through a critical orifice which is kept facing the air flow by a wind vane and is protected from rain by a shield. The flow is designed to be isokinetic but this may not always be so, e.g. in strong winds and in rapid changes of wind speed. The air passes over a drum which rotates at 2 mm per hour (thus giving 48 mm for a day). The drum carries a tape with an adhesive surface coating such as silicone oil or Vaseline with paraffin wax. Particles in the air flow impact on the tape due to inertia of momentum. As the drum rotates a time related sample is left on the tape. The drums can carry enough tape for a week. The tape can be removed, mounted on a slide and examined under a microscope. Alternatively the traps can have a daily head which carried a slide. This passes over the inlet at the same speed as the drum. The Hirst type trap was designed for capturing pollen and is not efficient at capturing small particles (below 3 microns). Experiments have demonstrated that the efficiency of the trap at capturing pollen ranges from 68 to 85% being close to 70% in a wind speed of 6 ms^{-1} when it is theoretically sampling isokinetically.

The traps are usually sited on exposed roof tops away from local sources of pollen in order to sample from a mixed air flow without bias. It is important to avoid obstructions or other potential problems such as places near the edge of the roof with updraughts. A site survey should be conducted to note local vegetation, buildings and topography as these may influence the results.

Other types of sampler

There are numerous other types of sampling devices for collecting pollen from the air. These are described in detail in the references given at the end of this paper. Descriptions of a few of the most frequently used ones are included here to give you an idea of the range.

Rotorod samplers

These have two small square rods which are held vertically, one on each end of an arm which rotates at 2500 rpm. Particles in the air adhere to the leading edge of the rod which has strips coated with a sticky substance such as Vaseline. The strips can be removed for analysis. All models are very small and can be battery operated which make them very useful for field work. They can be mounted onto masts easily for taking vertical measurements. However they do not give time related samples, only a total sample for the duration of operation. This can be related to air volume by calculating the amount of air the arms have passed through. They can get overloaded with pollen making analysis difficult. The rotorod samplers are used extensively in the USA for routine pollen monitoring,

The Cour sampler

This is a filter mechanism consisting of a metal support with a tail vane and two filter holders (400 cm^2). If an anemometer is nearby it is possible to get an estimate of the volume of air that has gone though the filters. The Cour trap is used in several regions of the Mediterranean. The filters which are changed weekly consists of five layers of hydrophilic cotton gauze which has been immersed in a silicon and a thinner solution. This helps capture the particles and also hinders bacterial and fungal growth. The advantage of the system is that it is cheap and does not need power. However it gives only weekly samples and analysis is laborious.

Cyclones

These suck air into a reverse cyclone flow and particles fall into a collecting pot such as an eppendorf tube. The sample can then be mounted on a slide for microscopic inspection or be analysed imunologically for allergens. Cyclones can be various sizes and can have various suction rates.

The cyclones can be very efficient at collecting very small particles and have been used successfully for assessing allergen loads (Emberlin J 1995). However in polluted air they may get overloaded with particles.

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