CHAPTER II

REVIEW OF LITERATURE
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The term aerobiology was first coined by Fred. C Meier of U.S.A. during 1930's to describe research on microbial life in the upper air. However, the presence of microbes in the atmosphere was detected by the experiments of earlier workers such as Micheli (1729), Pouchet (1860) and microscopical and cultural demonstrations of Pasteur (1861). Later on the information on the airspora was added by Ehrenberg in Germany (1849), Blackley in England (1873), Cunningham in Calcutta (1873) and Miquel in Paris (1883). Gregory (1925) used the term airspora to describe the study of population of airborne pollen grains, fungal spores and bacteria. Nilsson (1975) included viruses and abiotic particulate matter along with organic and inorganic components of the atmosphere. Edmonds (1979) defined aerobiology as an interdisciplinary study of biological components of the atmospheric interactions and deposition and on how they affect plants, animal and human health and it also deals with the allergenic properties of various bioparticles such as pollen and spores.

Aerobiological studies started with the mycological studies to find out the fungal pathogens and then slowly it turned into routine aerobiological survey to find out
the effect of these airborne particles on human health.

In the following pages review of Literature on different aspects such as work on outdoor pollen and fungal spores in India and abroad has been dealt with under separate headings. Main emphasis has been given to the aerobiological studies conducted outdoors, comparative aerobiological surveys at various sites on diurnal periodicities.

1) AEROBIOLOGICAL STUDIES OUTSIDE INDIA

Leeuwenhock was the first to observe microscopically and describe the micro-organisms in the 17th century. For about two decades till the middle of the nineteenth century the concept that microbes arose from organic matter prevailed. Pasteur (1861) conclusively proved that air was the inoculum for microbial growth. Pasteur also found that airborne microbes decreased with height above the sea level and also trapped the microbes from the air over the city of Paris by using a gun cotton filter.

Hesse (1884, 1888) conducted spore trapping experiments in Berlin using Koch's nutrient gelatin. Similar spore trapping methods were employed by Frankland (1886, 1887) and Frankland and Hart (1887) in London.

From 1940's aerobiological survey was conducted
extensively and continuously over long periods in Britain especially at Cardiff and Rothamsted Experimental stations, Harpenden.

Hyde and Williams (1944) conducted a one year pollen survey at Cardiff and reported pollen of Graminaeae, Betula, Urtica, Plantago and Ulmus to be the most dominant.

Wodehouse (1945), in his book 'Hayfever plants' identified and discussed the botany of hayfever plants of U.S.A. and reviewed all pollen surveys conducted in U.S.A.

Newman (1948) collected pollen and fungal spores on sticky microscopic slides at about 4000 feet while flying over Tasmania sea of Australia. Pady et al., (1948) exposed the nutrient plates during flights over the arctic and sub-arctic Canada and found Hormodendrum to the most dominant.

Nilsby (1949) studied the airborne mould spores content and found a pronounced seasonal variation with mould spores, with peaks during June to October. The most prevalent spore type was Hormodendrum (68%).

Flensborg and Samse-Jensen (1950) in Copenhagen, also reported similar findings.

Hyde (1950 a, 1950 b) studied the main course of
pollen incidence to be pre-determined to some extent by the weather during the year and also during the preceding year.

Gregory (1951) studied the deposition of spores on sticky glass cylinders. He found the cylinders with a diameter of 0.53 cm to be quite efficient and selected them for spore trapping experiments at Rothamsted.

Griffith (1951), in the aeromycological investigation of Savannah area by nutrient plates, found Aspergillus, Alternaria and Hormodendrum to be dominating spores and in greatest concentration during the months of April to November.

Polunin (1951) exposed fifty slides from aircraft and trapped pollen grains and fungal spores of Pteridophytes and Uredospores.

Gregory (1952) sampled Cladosporium, Ustilago, Erysiphe and Basidiospores from the atmosphere of England with Cascade impactor, 2 meters above the ground.

Gregory and Hirst (1952) observed the concentration of basidiospores to rise upto 30,000 spores per cubic meter on days during wet period using Hirst's volumetric spore trap.

Gregory and Hirst (1952) described the construction,
procedure, working and efficiency of an automatic volumetric spore trap. This device - 'Hirst - volumetric spore trap' had a vaseline coated microscope slide moving at 2 mm/hr. and had an orifice through which air was sucked in at the rate of 10 litres/minute.

Hyde (1952) conducted a daily census of atmospheric pollen for six years between 1943 - 1948 at Cardiff.

Kelly and Pady (1953) exposed agar plates and silicone coated slides from aircrafts and obtained Cladosporium, Alternaria, Penicillium and Streptomyces as principal type of fungi of the air over the non-arctic regions of Canada. Pady and Kelly (1953 a, 1953 b) used different air samplers to monitor spores and correlated spores with air masses.

Richards (1954) found higher concentration of mould spores during the months of June to September in Cardiff. Cladosporium constituted 38% of the total catch. He also discussed the seasonal periodicities exhibited by 11 predominant genera. Alvarez and Castro (1955) observed that Hormodendrum, Aspergillus were principal airborne moulds in Havana, Cuba. Cammack (1955) found that in the wet season numbers of Puccinia polyspora were higher than those of dry season and that of Cladosporium concentrations were high in both the seasons whereas Nigrospora sphaerica
was higher in dry season in Nigeria.

In Britain, Hyde (1956) carried out aeropalynological work at 9 stations from 1943 - 1955 and he discussed year to year variation, phenological variations and also day to day variations in pollen incidence.

Gregory and Hirst (1957) studied the fungal spore composition and compared the spore incidence at 2 meters above ground level and at 25 meters above the ground level at Rothamsted. The two traps were separated by a horizontal distance of 100 yards. The average spore concentration of 12 common groups measured at 25 meters was 81.5% of that measured at 2 meters.

Sreeramulu (1958) demonstrated a 4-5 times increase in the atmospheric concentration of Cladosporium, Epicoccum and Alternaria after mowing grass.


Emecz (1962) studied the fluctuation of four meteorological factors, air temperature, light intensity, relative humidity and wind in relation to anthesis of grasses.
Hirst and Stedman (1963) explained large increase in the concentration of some dry airborne spores with the onset of rain by the "tap and puff" mechanism. Rain-drops disperse dry spores by mechanical striking and by creating radial air movements.

Adams (1964) gave the results of a four year survey of fungal spores over Cardiff by using Hirst's volumetric trap. 93% of the total catch was represented by Cladosporium, hyaline basidiospores, hyaline ascospores, Sporobolomyces, coloured basidiospores, coloured ascospores and Ustilago.

Basset (1964) conducted the survey at 19 sites in Manitoba and Sasktchewan in Canada from 1950 - 1962 by gravity method. Main pollen recorded were Populus spp., Acer negundo, ragweed, Salsola pestifer and Artemesia spp.

Gregory and Lacey (1964) discovered the significant amounts of spores of Pithomyces chartarum, a species which was known only from warm climates. The source of these species was found to be the mowed grass, Holcus lanatus. Rees (1964) studied the airspora of a site in Brisbane for a year and found that pollen of Cupressaceae was the most common among the pollen grains and hyaline basidiospores constituted the highest among the fungal spores.

Hansen and Dahl (1965) did the long term studies on the atmospheric pollen (1951 - 1963) at Minneapolis.
and showed that pollen of Urticales, *Ambrosia* and *Quercus*
were found abundantly.

Derrick (1966) studied airborne pollen and spores in Melbourne using gravity method. Grass and *Plantago*
species were major contributors to pollen cloud. He reported pollen of *Acacia*, *Casuarina*, *Chenopodium*,
*Cupressus*, *Pinus*, *Betula*, *Alnus*, *Quercus*, *Myrtaceae*. Spores were represented by *Cladosporium*, *Alternaria*,
*Stemphylium*, *Puccinia*, *Penicillium* and *Epicroccum*.

Fulton and Mitchell (1966) studied the airspora of marine influenced air mass and a land air mass at 690 meters over San Antonio, Texas using aircrafts.

Al-Doory (1967) identified 80 fungal genera from the atmosphere of San Antonio, Texas of which *Hormodendrum*
and *Alternaria* accounted for major percentage of the catch.

Burleigh et al., (1967) constructed a volumetric spore trap for use in an aircraft in U.S.A. to study the dissemination of cereal rust spores. They showed that the rust spore concentration in aircraft reflected rust severity.

Hirst and Hurst (1967) discussed the various aspects of aerobiological research like distant dispersal, vertical profile studies, temperature inversion effects, air
trajectories and effect of meteorological factors etc.

Hirst et al., (1967) studied airspora at high altitudes to find out the vertical spore profiles over the land. Ogden and Raynor (1967) devised the intermittent rotoslide sampler which collected pollen on the edge of two microscopic slides in metal holders which were rotated by a small electric motor.

Kramer and Pady (1968) studied the viability of airborne spores and found out that the average viability of all spores is 40%. Alternaria was found to be very resistant and it retained its viability for a very long time.

Davies (1969 a) studied spore concentration at Ahmedi and recorded Cladosporium with its seasonal maxima in November and Ustilago as the most common type. Other types recorded were Aspergillaceae, Botrytis, Chaetomium, Curvularia, Epicoccum, rust spores and Trichotheicum.

Newmark (1970) reviewed aerobiological surveys done all over the World and discussed new developments in the field of aerobiology.

Harvey (1970) studied spore productivity in 6 species of Cladosporium and reported that more spores were released in wet air than in dry air, while numbers were intermediate with humid air.
Raynor and Ogden (1970) made an intermittent rotoslide sampler and determined its efficiency. Raynor and Hayes (1970) developed a method by which ragweed pollen concentration in the air could be predicted. These predictions were made by referring to the mean annual concentration curve of earlier years, concentration of the current year and the weather forecast.

Ado et al., (1971) studied the atmospheric pollen content of three different climatic zones in the U.S.S.R.

Hyde (1972) studied the modern trends in aerobiological research and general British airspora, its particular source, its composition and phenology.

Villaveces (1972) studied the airspora at Ventura in California and reported Juniper-Cypress-redwood, pine-spruce-deodar-cedar and birch-Casuarina to be dominant among pollen and Alternaria, Hormodendrum, Helminthosporium and Epicoccum to be dominant among the fungal spores.

Stix (1973) reported Cladosporium, Ustilago, ascospores and basidiospores from the atmosphere of Darmstadt and other places in West Germany.

Eversmeyer et al., (1973) studied the vertical dispersal and dissemination of wheat pathogens at four heights above ground level.
Collins-William et al., (1973) investigated the pollen of pine, birch, oak, maple, elm and poplar to be most important airborne pollen grains in the air of Toronto, Canada.

Gregory (1973) published the second edition of his classical book - 'Microbiology of the atmosphere' (1st ed. 1961) which dealt in various aspects of aerobiological research.

Hirst (1973) studied the spore transport and vertical profile of airspora. Kapyla and Koivikko (1973) reported pollen counts in Finland and Koivikko (1973) gave the history of aerobiology in Finland. Nilsson (1973) gave the history of aerobiology in Sweden.


Kapyla and Koivikko (1975) reported Pinus pollen to be the most dominant followed by Gramineae, Artemisia, Urtica, Betula, and Quercus at Turku, Finland.

Batchelder (1977) showed that Rotorod sampler had better capability of collecting the airborne particles in comparison to Rotoslide, Anderson and Durham devices.

Janzon et al., (1977) studied the incidence of Alnus pollen between 1973 - 76 and related the differences in the catches to temperature incidence and phenology of
the most important trees in Finland.

Makinlen (1977) discussed correlation of pollen count and meteorological data by regression analysis. Tkachyk and Khan (1977) found that *Hormodendrum* and *Rhodotorula* were commonest among the moulds in the air of Edmonton.


Bringfelt (1978) analysed the data collected for seven years (1970 – 76) at four sites. The daily counts were correlated against weather data by a number of multiple regression calculations made with a standard method for computer, called stepwise regression.

Airspora studies by Hariri et al., (1978) showed the seasonal variations in atmospheric fungi in Ahwaz, Iran. Fungal spores which showed monthly variations were *Cladosporium*, *Alternaria*, *Geotrichum*, *Penicillium*, *Aspergillus*, *Mucor* etc.
Shafiee and Rahmani (1978) identified 22 different genera of fungal spores from the atmosphere of Tehran. The common spores isolated were yeasts, *Penicillium*, *Rhodotorula*, *Aspergillus*, *Stemphylium* and *Alternaria*.

Lewis and Vinay (1979) in North-American states reported the presence of significant quantities of airborne pollen from entomophilous plants. *Acacia*, *Brassica*, *Citrus*, *Ligustrum*, *Olea* were the principal entomophilous genera which contributed the pollen to the air.

Chen and Huang (1980) identified atmospheric pollen grains and fern spores of Taipei, Taiwan. Fern spores formed a significant percentage (10.2%) of the airspora. The important fern spores reported were *Alsophila*, *Dicranopteris*, and *Nephrolepis*. It was also reported that the pollen and spores increase with increase in temperature and lower humidity.

Ikuse et al., (1980) studied the seasonal fluctuations of the airborne pollen of *Cryptomeria japonica* which is an important agent of pollinosis at Chiba Prefecture, Japan.

Mc Donald and O' Driscoll (1980) compared the pollen and spore counts at Galway, Ireland for the years 1977 - 78. There was a large difference in catch between the years which was mainly attributed to the differing wind
direction. Solomon and Hayes (1980) analysed aero-palynological data from 1943 to 1975 at Tucson, Arizona and discussed how the introduction of exotic ornamental plants over the years had changed the atmospheric pollen content.

Larsen (1981) found that Cladosporium (68.9%), Alternaria (9.4%), Penicillium (6%), Aspergillus (2.5%) and Botrytis (0.9%) comprised 87.6% of the fungi collected from Copenhagen atmosphere during a three year survey. He observed the pronounced seasonal periodicity in Cladosporium and Alternaria, whereas Penicillium and Aspergillus seemed to be independent of seasonal changes though their concentration tend to increase during winter months. Pereira and Ferrand (1981) sampled the air for the presence of airborne pollen especially ragweed and mold spores in the New York city.

Bringfelt et al., (1982) recorded daily pollen counts of Stockholm for 1970 - 76 and presented some statistical models for the prediction of the start and intensity of pollen season.


Bonny and Allen (1983) compared the pollen catches
from Tauber traps and simple jar traps under varying meteorological conditions and found the average pollen catch to be consistently higher in Tauber traps. Frenguelli et al., (1983) studied the airborne pollen grains of Ascoli Piceno in Italy during the years 1981 - 1982. Lower counts recorded during 1981 which were attributed to the climatic conditions during that year unfavourable for the production of dispersal of pollen.

D'Amato et al., (1984) reported dominant spore types to be Cladosporium (73.90%) followed by basidiospores (11.73%) and Alternaria (3.25%) in Naples. Rubulis (1984) constructed the spore calendars of the cities of Stockholm and Eskilstuna. Solomon (1984) discussed the various aspects of aerobiology including the biology of pollen, dispersion, pollen structural features in identification, monitoring approaches etc.

Donini et al., (1985) in their study demonstrated a correlation between aeropalynological, meteorological and clinical data during 1984 in Paris.

Dhorranintrina et al., (1987) reported the higher incidence of fern spores in the atmosphere in various provinces of Thailand.

El-Ghazaly et al., (1987) conducted a survey of the atmospheric pollen in Alexandria, Egypt. Hurtado and
Riegler-Golihman (1987) made a four year study of the airspora of suburban Caracas, Venezuela and found approximately sixty different pollen, 4 fern spores and 250 fungal spore types.

Mandrioli (1987) discussed the effect of climatic factors on the flowering process and on airborne pollen.

**Comparative Studies of the airspora at different sites**

The effect of specific ecogeographical condition on the air has been extensively studied.

Miquel (1883) conducted a survey of the Parc Montsouris about 5 km south of the centre of Paris and the densely populated city. At the Parc Montsouris bacteria were nearly three times as numerous in summer as in winter, but moulds fluctuated rather less. Near the Hotel de Ville in the centre of Paris, bacteria showed little seasonal variation.

In England, Hamilton (1959) made a comparative study of airborne pollen and spores by simultaneous sampling of an urban site (London) and a rural site (Rothamsted Experimental station) 22 miles away from each other using Hirst trap. He found that the airspora in the city was less than half of those in the country. The quantitative variation of airborne pollen in the rural and the urban sites were explained due to the proximity and strength
of sources and the other factors such as height of the spore trap from the ground level.

Lacey (1962) studied the summer airspora of two contrasting adjacent sites and reported that the ecology of an area had a major influence on its airspora through the local flora and microclimate and it was reported that the spore catch near the stream was 2.5 times more than the adjacent exposed site at Berkshire, England.

Barkai-Golan and Glazer (1962) studied the two ecologically contrasting sites in Israel and reported a qualitatively similar but lower catch at the site surrounded by arid and desert region.

Davies (1969 b) concluded that the widely differing climate and topography of Davos (a small town in the Alps) and London (a large city on the plains of England) were responsible for difference in the seasons, peak occurrence and dispersal of aeroallergens.

Solomon et al., (1969) have shown the effect of suburbanisation which results in numerical decrease in the herb pollen concentration.

Hyde (1969) found higher concentration of Cladosporium over a rural area, while Penicillium occured more frequently in urban area.
Long and Kramer (1972) made a comparative assessment of airspora at two contrasting ecological sites in Kansas and observed higher number of spores during dry periods at an exposed Prairie hill top site indicating transport from remote sources, while the woodland ravine site recorded a higher catch during periods favourable for growth and sporulation of fungi.

Bozilova and Yankova((1974) surveyed airborne pollen at 3 sites in Bulgaria.

Leuschner (1974 b) made a comparative study of Davos and Basel, the two places differing markedly in climatic conditions due to their heights over mean sea level, showed a qualitative and quantitative differences of pollen at two localities.

Fuckerieder (1976) determined the grass pollen content of 13 central European sampling sites between 1967 and 1974 using Hirst volumetric spore trap. Quantitative differences were noticed in grass pollen content at different sites. Pollen of Poaceae represented one third of the total airborne pollen and the time of maximum pollen content varied. In the main season, grass pollen was in peak concentration for 27 - 50 days, the shortest period was seen in rural areas and longest in mountains.
In Scotland various pollen seasons set in later than in Southern Britain (Hyde, 1950 a, b; Hyde and Williams, 1959; Davies, 1965). Similar quantitative and qualitative differences in the pollen of plain and mountain was made by Michel et al., (1976).

Brown and Jackson (1978 a) operated simultaneously eight identical volumetric spore traps within a 60 km radius of Derby and illustrated the need for setting up different samplers to get truely representative aero-palynological data of the area as a whole.

Brown and Jackson (1978 b) compared the airspora of three sites situated in the east coast, west coast, and Derby in Britain. Airspora was less richer at the coastal sites than in Derby and fewer pollen and spores were encountered on the west coast.

Yankova (1978) after 2 to 8 years aeropalynological survey in 20 localities in Bulgaria reported about the atmospheric distribution of grass pollen grains.

Lejoly - Gabriel and Leuschner (1983) compared the airborne pollen at Louvain - La - Neuve, Belgium and Basel, Switzerland. The principal arboreal pollen recorded from both the stations were Taxus, Betula, Alnus, Pinus, Quercus and Fraxinus and main non arboreal pollen types trapped were Poaceae, Urticales, Mercuriales, Plantago and Rumex.
Basal with its greater abundance of anemophilous plants recorded three times higher the amount of airborne pollen as compared to the stations at Belgium.

El-Ghazaly et al., (1984) surveyed pollen types at two sites in Stockholm region for four consecutive years. A total of 32 pollen types were recorded of which *Betula, * *rus,* Poaceae were the dominant types.

Larsson et al., (1984) assessed the pollen catches of two Burkard spore traps operated at the same site 3 meters apart at Eskilstuna and also compared the pollen incidence with two other localities in Central Sweden, namely Stockholm & Huddinge.

Studies on diurnal periodicity

The first systematic study of the microbial content of the air was made by Pierre Miquel (1899). He sampled atmospheric moulds and bacteria and proved that they exhibited a diurnal periodicity in their occurrence. He studied airborne microbes in relation to season, weather, geographic location, in the air at the high altitudes over the Alps - overseas during voyages and also estimated the microorganisms brought down by rain. His observations were recorded in reports from the observatories Montsouris, Paris (1878-99).

Hyde and Williams (1945) in their studies at Cardiff observed a diurnal variation in grass pollen which they
correlated closely both in frequency and amplitude with bright sunshine.

Gregory and Hirst (1952) recorded the diurnal periodicity in the emission of basidiospores and the effect of rainfall in their incidence over a potato field using Hirst trap.

Hamilton (1959) studied the airspora of an urban site in London and a rural site (Rothamsted Experimental Station) 22 miles from London. Many spores exhibited a diurnal periodicity and the incidence of many pollen and spore types correlated significantly with individual meteorological factors.

Composition of the diurnal periodicity of airspora at a Jamaican banana plantation was studied by Meredith (1961, 1962) who recognised three categories of fungi. Group I and II consisted typical airspora; Group I (Dieghtoniella, Nigrospora, Cordana, Corynespora, Zygosporium and Zygophiala) had a peak at 0900 hrs; Group II (Cladosporium, Alternaria, Curvularia, Pithomyces, Periconiella, Memnomiella, Ustilago and others) exhibited a peak between 0900 hrs and 1400 hrs; Group III characterised by spores of damp weather (Ascospores, Basidiospores and splash dispersal spores) attained their peaks between midnight and 0600 hrs.
Pady, Kramer and Wiley (1962) in Kansas reported night time peaks for basidiospores, 1-celled and two celled hyaline spores, *Fusarium*, yeast and hyphal fragments. There was no definite peak evident for *Cladosporium*, *Alternaria*, *Cercospora* and rust.

Hyde (1969) reviewed the general outdoor Britain airspora with reference to circadian periodicity and other aspects.

Ogden and Hayes (1969) determined circadian periodicity of *Amrosia*, *Phelum*, *Zea* and *Ricinus* which exhibited a characteristic day time pattern of pollen emission.

Haard and Kramer (1970) from Kansas reported that the discharge of basidiospores in 19 genera of Hymenomycetes was primarily at night, the peak spore production period was coincident with the time of maximum relative humidity.

Lawrence and Meredith (1970) found the airborne conidia of *Cercospora beticola* over a plot of *Beta vulgaris* to exhibit a well defined diurnal periodicity with a peak at 1000 hrs.

Ingold (1971) described the daytime and nocturnal rhythms of spore discharge in a number of fungi.

Long and Kramer (1972) studied two contrasting sites at Kansas and indicated a distinct daytime maxima in *Cladosporium*, *Alternaria* and night-time maxima in ascospores and basidiospores.
Hyde (1973) discussed the diurnal periodicity of pollen grains and fungal spores outdoors and indoors.

Ayanru's (1978) at Nigeria revealed that peak concentration of Cladosporium and Drechslera sp. occurred between 0700 and 1100 hrs; Cercospora sp. and Fusarium sp. between 1200 and 1600 hrs; Yeasts, Sporobolomyces sp. and Geotrichum sp. between 0100 and 0700 hrs.

Makinen and Rantio-Lehtimaki (1979) found that in Turku, double maxima was exhibited by Cladosporium (before and after noon) and smut spores (morning and evening) while basidiospores and hyaline ascospores had peak concentration at night and Penicillium with a slight peak in the afternoon.

11) AEROBIOLOGICAL STUDIES DONE IN INDIA

Aerobiological studies in India started with Cunningham (1873) with his study of the airborne microorganisms of Calcutta jail.

Ranjan et al., (1952) isolated 58 species of fungi from the air of Kanpur during the period 1945 - 46.

Sanghvi, Sethi and Kasliwal (1957) from S.M.S. Hospital, Jaipur constructed a pollination calendar for 58 entomophilous and 62 anemophilous plant species. These
studies were conducted by Durham's sampler and showed a maximum tree pollen occurrence between April to June; grass pollen between September to November, when it constituted 70% of the catch and weed pollen occurred evenly throughout the year.

Kalra and Dumbrey (1957) did aerobiological studies of Army Medical College campus, Poona. They found *Holoptelea, Pithecellobium, Acacia, Delonix* and *Tridax* to be the most common pollen and *Helminthosporium, Alternaria*, smut and rust, the dominant fungal spores. Grasses were the major contributors to the airspora.

Lakhanpal and Nair (1958) found February - April to be the high pollen seasons of Lucknow and *Holoptelea* (42.55%) was the dominant type of pollen. Other types were *Ailanthus* (22.30%), *Gramineae* (9.7%), *Morus* (6.15%).

Shivpuri, Viswanathan and Dua (1960 a) compiled a pollination calendar of Delhi to correlate pollen season with increase in allergy incidence. In the second part of their study, Shivpuri, Viswanathan and Dua (1960 b) reported the commonly occurring atmospheric pollen to be *Gramineae, Ailanthus, Ricinus, Amaranth - Chenopod, Dodonaea, Salvadoria, Putranjiva, Xanthium* and *Cyperaceae*.

Volumetric studies on the airspora were started for the first time in India by Sreeramulu and Seshavataram
(1962) who investigated the relative abundance, the
diurnal periodicity and seasonal periodicity of 20 air-
borne spore types over the paddy field at Pentapadu by
employing Hirst spore trap. Cladosporium (29.6%) and
basidiospores (24.95%) were the chief contributors while
septate fusiform spores (14.44%), Aspergillus (5.95%),
Podaxis (5.35%) and Nigrospora (4.48%) also formed
significant components of the airspora.

Nair and Kaul (1963) designed an air sampler which
consisted of an anemometer assembly coupled with a clock
machine and an adhesive coated tape driven at a constant
rate.

Chaubal and Deodikar (1964) reported 20 monocotyle-
donous and 21 dicotyledonous pollen from the air of Poona.

Baruah and Chetia (1966) reported the predominant
pollen at Gauhati which included Gramineae (66.5%),
Cyperaceae (14.10%), Amaranth - Chenopod (10.8%), and
Polygonaceae (2.5%).

Ramalingam (1966 - 67) based on two year volumetric
survey of air over paddy fields recorded grass pollen in
large numbers. He found that the ratio between the fungal
spores and pollen was 400 : 1 but pollen contributed
higher volume of 19.5%. 
Sreeramulu (1967) reviewed all the aerobiological work carried out in India which included the history of aerobiology, aeropalynological survey, aeromycological survey and intramural studies.

Tilak and Srinivasulu (1967) found that Curvularia (40.17%), Helminthosporium sp. (19.36%), Basidiospores (10.90%), and Alternaria (10.42%) were dominant types in Aurangabad.

Ramalingam (1968) constructed a simple device to expose an adhesive coated glass cylinder of 0.53 cm diameter in a vertical position for sampling air.

Agarwal et al., (1969) and Mukherji et al., (1969) carried out aeromycological surveys at Delhi. The peak periods of fungal concentration were during the period September to November and February to April.

Mishra and Srivastava (1970) investigated the aeromycoflora of a lake and an adjacent field at Gorakhpur. Sreeramulu (1970) reviewed the work done in fungal spore and pollen contents of the air within and above crop fields in India.

Tilak and Kulkarni (1970) designed a new volumetric sampler for continuous air sampling for 8 days.

Singh and Shivpuri (1971) recorded 38 types of
pollen grains, 20 of which were anemophilous and 18 entomophilous. Individually the grass pollen topped the list. There were about nearly 100 species of grass in Delhi of which Cynodon, Pennisetum and Cenchrus are dominant genera. With regard to anemophilous weeds, Amaranthaceae and Chenopodiaceae ranked first in numerical abundance with Amaranthus and Chenopodium being the most common. Next place was taken by Xanthium. In Delhi atmosphere, pollen of grasses accounted to 19.5%, weeds to 38.07% and tree pollen to 29.11%. These studies were conducted by gravity slides.

Ramalingam (1971) found Cladosporium (49.8%), smut spores (3.7%) and 'aspergilli' (3.6%) to be the dominant components of the airspora at Mysore. Pollen contributed 4% to the airspora. The high incidence of smut spores and Epicoccum conidia was pointed out as a characteristic feature.

Tilak and Srinivasulu (1971) identified the various ascospores in the airspora of Aurangabad.

Aeropalynological studies of Calcutta and surrounding areas (Falta and Kalyani) were taken up by Chanda and his co-workers (Chanda and Mandal, 1977, 1978; Chanda, Mandal and Lahiri, 1978; Mandal, Chanda and Mukherjee, 1977; Mandal and Chanda, 1979, 1981). Pollination calendars of Calcutta, Falta and Kalyani were prepared (Chanda 1973;
Chanda and Mandal, 1977, 1981; Mandal, Chanda and Mukherjee, 1977). Chanda, Mandal and Lahiri (1978) reported the occurrence of pollen of grass (39%), Arecaceae (3%) and Euphorbiaceae (3%) over Calcutta. Grass pollen was also the major constituent of the air-spores at Falta (Chanda, 1973; Chanda, Mandal and Lahiri, 1978).

Vishnu - Mittre and Khandelwal (1973) recorded 48 pollen types and 18 fungal spore types from Lucknow atmosphere. Grass pollen were dominant (34.6%) followed by Holoptelea (13.0%), Syzygium (12.7%), Amaranth - Chenopod (8.6%), Azadirachta (3.6%), Ailanthus (2.4%), Casuarina (2.14%) & Ricinus (2.2%) which were the major types. Among the spore types Alternaria (35.8%), Helminthosporium (12.8%), Uredospore (12.1%), Aspergillus (6.7%), Cladosporium (5.0%), Nigrospora (4.9%) and other types were recorded.

Subba Reddi (1974 a) recognised two categories of plants based on their pollination period at Visakhapatnam;
1) The compact flowering type with distinct and definite flowering period eg: Holoptelea
2) Diffused flowering type with particular peak as exemplified by Cocos and inters etc.

Tilak (1974) conducted aeromycological surveys at Aurangabad and Parbhani.
Deshpande and Chitaley (1976) carried out aeropaly-nological survey at Nagpur at heights of 1, 15 and 40 meters. The pollen catches decreased with increasing height. The observation revealed 26 pollen types of which 1/3 of pollen were of grasses followed by trees (29.3%) and the two principal pollen seasons recognised were August to November dominated by weed and grass pollen and January to May dominated by trees and grass pollen. Grasses, Amaranthaceae, Chenopodiaceae, Ailanthus Papilionaceae, Caesalpinaceae and Dodonaeas, were the major types. Grass dominated the air throught the year except during January when Dodonaeas pollen outnumbered them.

Rati and Ramalingam (1976) operated an Anderson Sampler for a period of two years to collect data on the airborne fungi at Mysore.

Mandal et al., (1977) constructed a pollination calendar of the plants growing in Kalyani, West Bengal. Menon et al., (1977) described the biology of the plant Prosopis juliflora and its peak incidence in the air at Delhi. Patil and Srivastava (1977) estimated the average total pollen production per flower of Peltophorum pterocarpum to be 11,30,800.

Subba Reddi and Janaki Bai (1977) studied spore
deposition gradient both in the horizontal and vertical directions by releasing a mixture of Lycopodium (32 μ) and Podaxis (14 x 11 μ) spores from a point of source. The number of spores decreased with increasing distance from the source and gradient of both spore types were similar inspite of their size difference, showing that size of the spore and velocity of its fall do not effect the spore deposition gradient over short distances.

Chanda et al., (1978) surveyed the atmosphere of Calcutta for pollen and found the pollen of grasses to be the most dominant.

Gaur (1978) reported 38 types of pollen from Meerut. Major types were Gramineae (22.43%), Myrtaceae (14.72%), Chenopod - Amaranth (12.14%), Moraceae (15.50%), Cyperaceae (1.77%).

Tripathi et al., (1978 a, b) carried out the aeropalynological and botanical survey of Bhopal and compiled a pollination calendar of Bhopal comprising of 91 species belonging to 25 trees, 12 shrubs and 54 herbs. Airspora survey recorded 72 pollen types of which Gramineae, Holoptelea and Eucalyptus were predominant.

Asthma Research Society (1979) published a report on Aeropalynological and Allergy survey of Bangalore for the period of 1976 - 78 at 6 centres with Durham sampler
and 5 centres during 1977 - 78 and identified nearly 113 types of fungal spores and about 74 pollen types. Dominant pollen were Cassia, Parthenium, Grass, Chenopod-Amaranth, Delonix - Peltophorum and cyperaceae and among the fungal spores were Alternaria, Helminthosporium, Curvularia and other types.

Mandal and Chanda (1979) identified Poaceae (Wild) 16.72%, Poaceae (cultivated) 13.24%, Asteraceae 8.76%, Arecaceae 8.45% and Amaranthaceae 7.03% to be dominant airborne pollen of Kalyani.

Singh, A.B. and his co-workers carried out aeropaly-nological studies at Delhi (Singh, A.B., Babu and Shivpuri, 1979; Singh, A.B. and Babu, 1980 a, 1980 b, 1981, 1982; Singh, A.B. et al., 1983; Singh, A.B. 1984). Pollination calendar of 110 probable allergenic plants were prepared and their atmospheric pollen incidence was studied.

Bora and Baruah (1980) prepared a pollination and pollen calendar of Guwahati for the year 1977. Grass pollen was maximum (61.83%) in the atmosphere.

Chaubal (1980), Gaur and Bhati (1980) also reported grass pollen to be the highest at Kolhapur and Modinagar respectively.

Sullia and Khan (1980) studied the airspora of a
marke in Bangalore to investigate the market diseases of fruits and vegetable. 'Aspergilli' and 'Penicillia' accounted for nearly 70% of the market airspora.

Tilak and Vishwe (1980) reported pollen of Gramineae (80.64%), Cyperaceae (5.01%) and *Parthenium* (2.32%) to constitute the major part of the airspora of Augangabad.

A pollination calendar for potentially allergenic plants were prepared for Vijayawada (Appanna, 1980), Kurukshetra (Lamba and Madan, 1980) and Kanpur (Shukla and Misa, 1980).


Kundu et al., (1981) prepared a pollination calendar of Darjeeling. The common trees were *Betula*, *Alnus*, *Quercus* etc.

Seetharamaiah et al., (1981) conducted an atmospheric survey of pollen of *Parthenium hysterophorus* which constituted 40% of the total pollen at Bangalore. Talde and Gaikwad (1981) reviewed work on aerobiology carried out in Maharashtra.

Chaubal and Kotmire (1982) reported the pollen of grasses, *Parthenium*, *Amaranthus - Chenopodium*, *Cyperus* to be the most dominant and among Fungi *Cladosporium*, Smut spores, Uredospores, *Alternaria*, *Curvularia*, *Torula* and *Nigrospora* to be most dominant in the atmosphere of Kolhapur.

Janaki Bai and Subba Reddi (1982) studied the prevalence of the flowering of plants, their pollen productivity and also pollen load in the air. Most prevalent pollen in the air were those of grasses (37%) followed by *Casuarina* (13%).

Jayaprakash Narayana et al., (1982) found the spores of *Aspergilli*, *Penicillia*, *Fusaria*, *Zygomyces*, *Alternaria* and *Cladosporium* to be the most dominant in the vegetable market of Bangalore.

Singh, A.B. and Babu (1982) trapped 86 pollen types
from the atmosphere of Delhi and showed their seasonal year to year and site to site variation in quality and quantity.

Vittal and Ponnuwamy (1982) isolated 48 species belonging to 23 fungal genera from the atmosphere of Madras.

Janaki Bai and Subba Reddi (1983) prepared a key for the identification of airborne pollen types. Kulkarni and Tilak (1983) reported 18 ascospore types from the air over sugarcane fields at Aurangabad.


Tilak (1984) reviewed several reports of aeropalynological survey in India and showed that the entomophilous pollen also becomes airborne in significant number.

Tilak and Babu (1984) monitored fungal pathogens over a bajra field for two crop seasons by using volumetric sampler.

Bhat and Rajasab (1985) carried out a one year aeropalynological survey at Gulbarga and reported that *Parthenium*, Poaceae and other types such as *Cassia auriculata*.
Cassia siamea, Mimusops elengi, Cyperaceae, Argemone mexicana, Prosopis spicigera were reported in lower percentage.

Kumar (1985) identified the airborne pollen and spores in Bareilly. Wadhwani and Mehrotra (1985), and Wadhwani and Srivastava (1985) conducted aeromycological investigations of some crop fields and vegetable market of Lucknow respectively.

Wadhwani et al., (1986) isolated 30 species of Aspergillus along with 140 other fungi from the air of Lucknow.

Singh, A.B. (1987) gave the salient features of various pollen surveys conducted in India and listed the dominant airborne pollen types from different regions in India.

Bhat and Rajasab (1988) carried out a survey of pollen grains and fungal spores for the period of two years and reported 21 pollen grains and 32 fungal spore types.

Tilak and Rao (1988) studied the atmospheric concentration of Ganoderma at Aurangabad and reported the maximum concentration of Ganoderma during different months and also studied the relationship between this basidiospore concentration and meteorological factors.
Jain and Mishra (1988) studied the airborne pollen grains, fungal spores and other biocomponents at Gwalior.

Comparative studies of the airspora at different sites.

In a two year comparative study of atmospheric pollen at Anakapalle (Rural) and Visakhapatnam (urban) area, Subba Reddi (1970) recorded 38 pollen types from 2 sites using vertical cylinders as spore traps. The total catch at the urban site was 50% lower than that of the rural site due to the abundance of the grass pollen at the rural site. At both the places the maximum concentration of anemophilous tree pollen was found in February and to some extent in April. The grass pollen incidence was greater in the air in the period of July-August, weed pollen during August to September. Anemophilous pollen catch was only 2.7% of the total catch at Visakhapatnam and 1.6% at Anakapalle. Casuarina pollen was found to be dominant at both the sites. Major part of weed pollen was contributed by Cyperaceae, Amaranthaceae, Chenopodiaceae with former as predominant at Anakapalle, tree and grass pollen were of equal importance at Visakhapatnam and Anakapalle.

Bajaj (1978) carried out a survey of fungal spores for two successive years at an agricultural farm and a residential locality at Nagpur. Spore incidence was also correlated with weather factors.
Bhattacharya et al., (1981) reported the difference in the airspora between 3 locations in West Bengal which were widely due to different surroundings. However, grass pollen showed overall dominance at all the centres.

Gaur and Bhati (1980) and Gaur and Kasana (1981) conducted studies on an Industrial area and in a rural area in Modinagar and showed that the Industrial area was low both in quality and quantity of the catch but with similar composition.

Kumar (1984) made comparative studies of the aerial pollen flora of 8 places in the Gangetic region of Northern India and found Azadirachta, Cannabis, Chenopodium, Cyperus, Holoptelea, Morus, Ricinus, Rumex and Xanthium to be common airborne pollen.

Singh, B.P. et al., (1981) reported that the pollen of Gramineae, Leguminoseae and Compositeae were common to 18 centres in India and Myrtaceae, Amaranth - Chenopod, Cyperaceae, Euphorbiaceae, Meliaceae, Palmae were found in majority of them.

Kumar (1984) compared the aerial flora of Barielly with Delhi, Meerut, Modinagar, Lucknow, Gorakhpur, Varanasi and Gwalior and found that Cyperaceae, Poaceae, Azadirachta Cannabis, Chenopodium, Morus, Ricinus were common to all the cities.
Bhat and Rajasab (1985) studied the incidence of airborne pollen at University College and Government College of Gulbarga. The pollen of herbs and grasses accounted for 95% of the total pollen count in the campus and 74% in the College area, while trees and shrubs pollen accounted for only 5% and 26% in the respective areas. *Parthenium* and *Cassia* sp. were dominant types reported from both the centres.

Sinha and Mishra (1988) did the quantitative analysis of pollen grains at the rural site and reported that pollen of Poaceae dominated all the other types of pollen.

**Studies on diurnal periodicity.**

On the basis of data collected from a two year volumetric survey of air over paddy fields near Visakapatnam in 1961-62. Ramalingam (1966) reported that there was a forenoon pattern observed for pollen with their peak concentration around 1000 hrs while very low concentrations were observed in the afternoon hours and night.

Subba Reddi (1970) found high concentration of pollen between 0800 and 1600 hrs, peak occurrence for pollen of Myrtaceae were recorded at 0700 hrs, Cyperaceae and Grass at 0800 hrs, Amaranthus - Chenopod at 0900 hrs.
Borassus and Phyllanthus at 1000 hrs, Casuarina and Oryza at 1100 hrs and Dodonaea at 1200 hrs.

Shenoi and Ramalingam (1975) have shown a post dusk pattern of circadian periodicity of smut spores, insect scales and others.

Tilak and Kulkarni (1975) recorded Rhizopus spores over sugarcane fields. They were the wet spore group and exhibited day spora in diurnal periodicity with peak at forenoon.

Rati and Ramalingam (1976) studied the circadian variation in Aspergillus spores at Mysore. Aspergillus exhibited a double peak pattern with peaks at 0800 hrs and 1800 - 0200 hrs.

Gaur (1978) found predominance of Gramineae, Myrtaceae, Chenopod - Amaranth, Moraceae, Cannabis and Palmae pollen during his two year investigation of Meerut atmosphere, where he reported 35 types. Maximum pollen concentrations were observed between 1000 to 1400 hrs.

Singh and Babu (1980) conducted volumetric sampling of the air with the sampler devised by Tilak and Kulkarni (1970) and identified 58 different pollen types. They determined the diurnal periodicity for total pollen and six dominant allergens of Delhi area. The pollen of Delhi exhibited early morning pattern.
Dixit and Gupta (1981) studied seasonal and diurnal census of airspora over barley fields at Agra and recorded 70 micro-organisms of which fungi constituted 81.11%. He reported that maximum fungal spores were recorded either during afternoon or noon.

Vittal and Krishnamoorthy (1981) studied the airspora of an agricultural farm and recorded 22 spore types including Cladosporium (72.9%), Nigrospora (7.6%), Fusarium (6.3%) and other types. He studied the circadian periodicity for these spore types. He observed three patterns of periodicities namely night pattern, post dawn pattern and mid-day pattern.

Gaur and Kala (1984) in Srinagar observed a forenoon pattern in Celtis and Cupressus, afternoon pattern in Melia, Morus, Pinus; night pattern in Betula; double peak pattern in Emblica, Rumex, Quercus and irregular pattern in Carex, Juglans and some Graminaceous pollen.

Bhat and Rajasab (1986) observed peak concentration of grass pollen at 1000 hrs, Parthenium, Amaranth - Chenopod and Cyperaceae at 1200 hrs, Xanthium, Helianthus at 1400 hrs, Acacia nilotica, Cassia auriculata, Eucalyptus, Tridax and Argemone exhibited a double peak pattern. Dubey and Rai (1988) studied the circadian periodicities of 12 fungal spore types in a hospital ward and from
outside environment.

Vittal and Krishnamoorthi (1988) studied the circadian periodicities of 10 fungal spore types common in the atmosphere of Madras and showed post dawn pattern for *Nigrospora*, mid-day pattern for *Alternaria*, *Drechslera*, *Curvularia* and *Torula*, double peak pattern for *Cladosporium* and *Periconia* and night pattern for *Ganoderma*, *Coprinus* and *Leptosphaeria*.

iii) **AEROBIOLOGICAL STUDIES IN BANGALORE.**

Agashe and Vinay (1975) initiated aerobiological investigations in Bangalore and further conducted extensive work on various aspects of aerobiology. Pollen morphological investigations of some of the common plant species of Bangalore were conducted to aid in identification of airborne pollen (Agashe and Vinay, 1975; Vinay and Agashe, 1979; Agashe and Nagalakshmana, 1985).

In preliminary airspora survey by Agashe and Vinay (1980) various pollen and fungal spores were trapped using Durham's gravity sampler. Later systematic daily census of airborne pollen and fungal spores were conducted by employing modified vertical cylinder sampler (Ramalingam, 1986) and also clinical studies were undertaken to determine airborne pollen and fungal aeroallergens (Agashe and
Anand 1982; Anand et al., 1981; Agashe et al., 1983 a, b; Agashe and Anand 1984; Agashe, 1979; Agashe and Anand 1985). These studies revealed predominance of pollen grains of Parthenium, Casuarina, Amaranthus, Grass, Ricinus, Peltophorum, Eucalyptus, and Cassia in the atmosphere. Among the fungal spores Alternaria, Cladosporium, Helminthosporium, Curvularia, Nigrospora and smut spores were recorded in abundance. The relationship between atmospheric pollen counts and the individual meteorological variables were statistically correlated by Agashe and El-Fadil (1989). Among the major types studied pollen of Cocos nucifera showed highest co-efficient variation followed by Cyperaceae, Holoptelea integrifolia and Pongamia species and Typha angustata showed positive correlation with temperature, Parthenium hysterophorus with relative humidity and Casuarina equisetifolia and Holoptelea integrifolia with radiation factor.

On the basis of clinical studies (Agashe and Anand, 1982; Anand and Agashe, 1984; Anand et al., 1981) reported Albizzia lebbeck, Cassia occidentalis, Cassia siamea, Parthenium hysterophorus, Artemisia scoparia, Ageratum conyzoides and Amaranthus species as most important allergic airborne pollen.

Aeropalynological allergy survey in Bangalore was
conducted by Asthma Research Society (1979) by employing gravity sampler. They reported Cassia, Parthenium, Delonix, Peltophorum, Mimosa, Amaranth - Chenopod, Cyperaceae and Grass pollen among others as dominant types. Aspergillus, Helminthosporium, Curvularia, Alternaria and smut spores were the most common among fungi. Other studies in Bangalore include atmospheric survey of airspora, with emphasis on Parthenium pollen by Seetharamiah et al., (1981). The study of airspora of Bangalore market area with relation to the spoilage of fruits and vegetable have been investigated by Sullia and Khan (1980) and Jayaprakash Narayana et al., (1982) by culture plate technique. They showed species of Aspergillus, Penicillium, Phoma and Trichoderma as airborne pathogenic forms.

Agashe and Abraham (1988) constructed a pollen calendar showing the count and relative abundance of 12 major types present in the airspora of Bangalore.