Evidence for the existence of an atmospheric ‘Kingdom of life’ started to accumulate with the Ehrenberg’s treatise on *Passatstuab und Blutregen* in which he had presented an exhaustive account of his experimental results obtained in the period 1830-47 (Sreeramulu, 1970). The air around us incorporates with in it an imperceptible biomass of particulate materials of plant and animal origin. The identity behavior movements and endurance of the microbes in the air is covered by a branch of biology termed ‘Aerobiology’ (Gregory, 1973).

In the fullest sense it is the study of relationships between the atmosphere and the living entities (Dimmick and Akers 1969). The term ‘aerobiology” was coined by Fred C. Meier, in the 1930s, to describe a research project on microbial life in the upper air. Gregory (1952) has coined the term Air spora to the microbial population the air, where in the word spora is analogous to the words flora and fauna. The term referred above has been used extensively to cover the whole group of particles of biological origin, spores, pollen, hair, plant parts, algal filaments, bacteria, protozoa etc., whether dead or alive.

Scientific speculation about the occurrence of airborne microorganisms mostly dates from the time of Leeuwenhoek and is described in his letters to the
Royal society in 1680 (Dobell, 1932) while Gleditsch (1794) marveled at the prodigious quantities of perfectly organized particles in the air. Micheli (1729) first recorded the release into the air of a range of fungal spores but there were few detailed studies until the nineteenth century (Ainsworth, 1976). Ehrenberg (1849) was the first to provide evidence for the existence of the atmospheric kingdom of life. Pasteur (1861) demonstrated visually the existence of air spora and pointed out that the air spora must be measured while in suspension and not after deposition on surfaces.

Pasteur pointed out the necessity of volumetric techniques and extensive surveys to understand the effect of seasons and localities on the concentrations of spore types, especially during the outbreak of infectious diseases. Pasteur demonstrated that Microbes are normally abundant in the air. This had stimulated the medical men to speculate about the causes of epidemics of so-called "Zymotic diseases". Great interest in Aerobiology was generated during the 19th century as evidenced by the contributions of Maddox (1871), Blackley (1873) Cunningham (1873) Miquel (1883), Pouchet (1859), Robin (1871) and many other investigators. These workers have led to the conformation of air as a medium of transport of biological particles but the source of zymotic disease were traced to sources other than air (drinking water).

The realizations of the allergenic potentialities of pollen (Blackley 1873) and fungal spores (Cadham 1924; Feinberg 1935) and the role of air borne
spores in spread of plant diseases (Stakman and Christensen 19446); Mehta 1933, 1952) have led to renewed interest in aerobiology during this century.

The comity on apparatus in aerobiology (1941) made a remarkable review of early knowledge on aerobiology from which the contribution of Micheli has come to light. Later the subject has been reviewed by Molten (1942); Feinberg, Durham and Dragstedt (1946); werff (1958); Gregory (1961, 1973); Hide (1958) Edmonds (1979) and Lacey (1980).

Gregory (1961, 1973) in his book “Microbiology of the atmosphere” has given an excellent review on the historical background and also provided cumulative information on various aspects concerned with this growing field of science.

Aerobiological studies have been classified into two convenient groups: Extramural aerobiology deals with the distribution of organisms by the outside air and is of interest to workers in many fields; Intramural aerobiology, which is of interest to Medical man, begins with the problems of contagion of air borne infectious materials inside building and their behavior leading to spread of Epidemics. Aerobiology is discipline in its own right and a tool used in the service of a wide range of other disciplines. The discipline was established by a symposium on “Extra mural and Intra mural aerobiology” organized by the American Association for the advancement of science (Moulten, 1942).
Air sampling techniques

In order to study population of airborne particles and their dispersal, they must first be trapped, classified and counted. The components of air spora are very small and it is not possible to examine them in air borne state. Innumerable devices has been constructed to trap air spora and make them available for direct microscopic examination or for culturing, these methods are designated as visual and cultural techniques respectively.

The different devices are based on the principals of Sedimentation, impingement filtration, impaction, centrifugation and precipitation (thermal or electrostatic) (Hirst, 1973). Majority of the samplers in used has been constructed on the principle of Impaction.

The sampling methods have been subject of several reviews; “committee on apparatus in aerobiology” 1941, Sheldon et al 1967; May 1967; Akers and Won 1969; Davies 1971; Gregory 1973; South worth, 1974 Lacey 1981 and Dhingra and Sinclair (1985).

The spore traps that are in use for the past one and half a century could be classified into four groups on the basis of air sampling principles.

Gravity traps:

Here spores are allowed to settle on the adhesive trapping surface under the influence of gravity .the gravity slide has been used widely as the routine
method for investigating the pollen and spore content of the air since the period of Blackley (1873) and later extensively in hay fever studies in Europe (Hyde, 1952a,b, 1956), (Durham, 1944) and elsewhere.

The deposition on the slide is greatly influenced by atmospheric turbulence, wind velocity and size of the spore, but not by gravity as erroneously understood (Gregory and Stedman, 1953). In fact the cover used in the equipment such as Durham shelter to protect the slide from rain, dew etc hinders the sedimentation of spores from layers above it. Much of catch is due to the impaction as proved by the deposition of spores even on the under the surface of horizontally placed slides (Gregory and Stedman, 1953). The highly selective nature of horizontally slides was demonstrated experimentally (Ogden and Raynor 1960) their work revealed that night dispersed spores are seldom caught on the adhesive surfaces of gravity slides.

HOSPITALS

The fungal flora of the air of hospital wards was investigated by Noble and Clayton (1963) with special emphasis on fungi, which grew at 37°C. They isolated 22 genera on a total of 78 days of sampling and reached peak incidence in the autumn and winter months; no other fungal species were recorded at 37°C with such regularity. *Aspergillus niger* was present an 32 of the 78 days although never in such larger number, as was *Aspergillus fumigatus*. Among
other fungi, *Aspergillus flavus*, *A. niger*, *Monilia sitophila*, *Paecilomyces*, *Penicillium*, *Rhizopus* and *Syncephalastrum* were recorded with some regularity. Genera such as *Cladosporium*, *Isaria*, *Aureobasidium*, *Stysanus*, *Trichophyton* were isolated from samples incubated only at 20-25 °C but not recovered at 37°C.

The predominance of species of *Aspergillus* and *Penicillium* in the air of a large Hospital was reported by Alteras and Lehrer (1977). These two genera accounted for 32.2% of all the isolates. Following these in orders of frequency were *Alternaria* and *Hormodendrum Cladosporium*, *Rhizopus*, *Cephalosporium* and *Pullularia* comprising 28.4% of all the fungi isolated. The other genera of the fungi viz., *Mucor*, *Phoma*, *Verticillium*, *Trichoderma*, *Helminthosporium*, *Scopulariopsis*, *Paecilomyces*, *Fusarium* etc., were isolated either sporadically or rarely. The departments mostly affected were the Oto-Rhino-Laryngology and some of the internal medicine. No fungi were recorded in the burns department. Five and four strains of *Geotrichum candidum* and *Candida albicans* respectively isolated from the bathroom and patients in the Paediatric and Orthopedicts departments. Three strains of *Trichophyton mentagrophytes* were found in the atmosphere of the Urology department.

The airborne *Aspergillus fumigatus* levels outside and with in the University Hospital in Michigan was estimated by Solmon et al., (1978). The predominant fungi recorded were *Aspergillus fumigatus*, *A. niger*,
Paecilomyces sp. and Mucor spp. In contrast to earlier reports, levels of a Aspergillus fumigatus were low through out the year and did not show any abundance in fall winter as reported from London. The contribution of Aspergillus and Penicillium was only 8% and 2% respectively to the total in Hospital near Mysore (Jayaprakash, 1980) where Cladosporium (65%) was the largest contributor. Chaubal and Kotmire (1985) also reported Cladosporium as dominant in the Hospital premises at Kolhapur accounting for 18% of the total incidence. Cladosporium sp., Aspergillus niger, Alternaria sp., Penicillium citrinum, A. versicolor and Penicillium oxalicum were found to be dominant in the air of Delhi hospital (Singh et al, 1994). From among the spores of fungi isolated from a hospital ward spores belonging to species of Aspergillus, Alternaria and Curvularia were reported to show maximum number of positive skin reaction among allergy patients (Tilak et al, 1980/81). Cladosporium, Aspergillus, Fusarium, Penicillium, Aureobasidium, Curvularia and Nigrospora were reported to be most frequent in the air and floor at the Hospital clinics of the Federal University of Minas Gerais Belo Horizonte Brazil (Silva et al, 1983). The largest numbers of fungi were found during the morning in the air. The occurrence of predominant fungi in the indoor and outdoor air was found to seasonal. (Qiao et al, 1986). They found large numbers of Alternaria, Cladosporium, Ustilago, Puccinia, Penicillium, Aspergillus and Rhodotorula in the hospital environment.
Streifel et al. (1987) studied in-Hospital sources of airborne *Penicillium* spores. Air samples taken from corridors of a bone marrow transplant section revealed a marked increase in airborne thermo tolerant *Penicillium* spores. Simultaneous culture of outside air showed lower spore counts, which were unchanged before during and after the corridor outbursts establishing that the source was within the Hospital. The in hospital source was ultimately traced to rotting Cabinet wood enclosing a sink with leaking pipes in the medication room. It produced approximately $5.5 \times 10^5$ thermo tolerant *Penicillium*, CFU/hour. In a patient room supplied by corridor air, an in room recirculating high efficiency particular air filter reduced the mean thermo tolerant *Penicillium* count to 2.2 CFU/m$^3$. Fungal contamination of a unit of Medical oncology in the Hospital of Tours (France) was traced to windows especially during renovation work. From their on fungal air counts. Arlet et al (1989) observed that bacterial contamination was least in Laminar airflow rooms and reduced in ultra clean air rooms in comparison with congenital room.

Streifel et al., (1989) studied the control of airborne fungal spores in the University hospital designed to maximize the air quality protection of severely compromised patients. The results showed the areas with the greatest control of personal and air changes to have the lowest airborne concentration of fungi and the smallest particles. Larger indoor airborne ranking indicated highest levels depending on local human activity, air change rates or filtration efficiency. A
low spore concentration was reported in Hospital units receiving filtered air compared with control environment (Singh et al 1994). But in naturally ventilated hospitals the spore concentration was similar to that of outside air.

Iwen et al. (1994) monitored the fungal spores in protective environments during Hospital construction and correlated with an outbreak of invasive Aspergillosis (IA) in University Medical centers special care unit (consisting of single patient rooms with HEPA filtration under positive pressure) in Omaha, Nebraska, USA. They reported that 5 patients developed IA due to *Aspergillus fumigatus* (2), *Aspergillus* (1) and *Aspergillus* sp.(2). They also reported increasing spore count in room adjacent to construction area.

The levels of airborne fungal spores in Hospital wards and a diet kitchen were carried out in UK hospital by Aidoo et al (1985) using 4 different media. Sabouraud medium showed relatively lower fungal counts when compared with other 3 media. Fungi accounted for approximately 68% of the viable counts and the predominant genera were *Aspergillus, Penicillium, Fusarium, Rhizopus, Candida, Rhodotorula* and *Pichia (Hansenula)*. Spore counts were higher in the wards than in the diet kitchen and the spore counts were higher in Warmer months than in colder months.

Variation in Bacterial concentration in different units of the same Hospital in UAE were reported by Jaffal et al (1997) while the fungal
contamination was similar in most wards with *Aspergillus* species. Being more predominant. The intensive care unit and operating theatre had low counts and significantly more human related than environmental microorganisms.

Hospenthal et al (1998) conducted air samplings in rooms and corridors of Oncology ward of national institute of Clinical center, Bethesda, USA to assess the concentration of viable *Aspergillus* conidia to correlate with the incidence of invasive Aspergillosis. *Aspergillus fumigatus* and *A. flavus* were recorded at the mean of 1.83 CFU/ m³. Individual samplings yield 11.6 CFU/ m³. The other *Aspergillus* species were recovered at a mean do 2.38 CFU/m³ and maximum of 32.6 CFU/ m³. A seasonal pattern was not observed in the overall incidence of Aspergillosis or concentration of air borne conidia.

**VEGETABLE MARKETS:**

*Penicillium digitatum* and *P. italicum* were reported to be most abundant in the air of mechanized packinghouses of Citrus in Israel (Barkai-Golan, 1961). Of these two fungi, *P. digitatum* was more frequent. The no. of *P. italicum* spores had increased towards the end of the season and became almost equal to that of *P. digitatum* or in some instances even surpassed them. Their numbers were much less in places further away from packing houses. Other parasitic fungi such as *Fusarium, Trichoderma, Collectotrichum* and *Diplodia* were found only in small quantities. The predominant saprophytic fungus recorded
was *Cladosporium*. The number of colonies recorded was much lower at the end of packing season than that obtained during the season. Barkai-Golan (1966) observed that air also contributes in the contamination of fruits in addition to the surfaces of the conveyor belts, sorting containers and packer's hands. In a later study, he (Barkai-Golan 1980) found *A. niger* as a predominant in the air of fruit storing rooms accounting at 77% of the total *Aspergilli*. Sullia and Khan (1980) reported *Aspergillus* and *Penicillium* contributed 70% of the air flora in the market and showed the relationship between the air mycoflora of the particular market and the occurrence of market diseases of vegetables and fruits. Similar study was conducted by Singh and Mishra (1984). The presence of air borne fungal spores in fruit shop and the incidence of fruit rots were studied by Sumboli and Badyal (1991).

Jayaprakash (1980) studied the air borne fungi in fruit market in Mysore and observed that the contribution of *Cladosporium* (41%) was high followed by *Aspergillus* (26.5%) and *Penicillium* (9.7%). The abundance of *Cladosporium* followed by *Aspergilli* in vegetable market was reported by Shashidhar and Reddy (1989). A reverse situation was reported from Jabalpur (Verma *et al*, 1984). They recorded more *Aspergilli* followed by *Cladosporium, Nigrospora* and *Curvularia*. Similar observations were reported by Ghani (1996), Kakde and Saoji (1996), Rajukar and Talde (1996) and Bharathi *et al* (1997). From a study of the incidence of *Fusarium* in the air fruit and
Vegetable Market, Meshram et al (1989) observed the abundance of Fusarium moniliforme from among the 20 species isolated.

BUS STAND AREA:

In the past no research work was carried out in this area even though it is highly polluted with vehicles' smoke and dust disturbed by the people and vehicles movement. That is why this new area was chosen by the author for the assessment of fungal propagules present in the air.

SOLID WASTE DUMPING SITES:

Pohjola et al (1977) investigated the air spora of a Garbage disposal plant where workers were complaining of allergy and skin diseases. With in the plant they recorded Aspergillus and Penicillium spore types in concentration, which were 100-6000 times greater than that of out door air. Wide variations were noticed in the air spora based on the nature of the garbage handled. They suggested the compulsory use of the facemasks by workers at least in the dumping room where very high concentration of mould prevails. The generation, behavior and applications of the air borne microorganisms in the refused disposal facilities were studied by Higgins et al (1987). Jager et.al. (1984) studied the air borne microorganisms at different working places at composting facilities in Germany. Vander werf (1996) studied the air borne...
dust, bacteria, fungi, viable thermophilic fungi, *Aspergillus fumigatus*, Gram-
bacteria and endodoxins at Samio Ontario leaf and yard waste composting
facility in Ontario. Siboe et al (1996) studied the air borne fungal spores from
garbage dumpings in urban centers of Africa and they correlated with
respiratory diseases. Udayprakash and Vittal (1996) isolated 30 species in the
air of Garbage dumping site, *Cladosporium cladosporoides* being dominant
with 40% of its contribution to the total followed by *Aspergillus fumigatus*, *A.
flavus*, *A. niger* and *Penicillium citrinum*. Udayprakash and Vittal (1997)
reported *Aspergillus fumigatus* (687.1 CFU/m3) as dominant followed by
*Mucor pusillus* (164.1 cfu/m3) and *Thermomyces lanuginosus* (77 CFU/m3) in
their survey of thermophilic and thermo tolerant fungi at garbage dumping site
in Madras.

Reinthaler et al (1998) conducted a survey air borne molds in a large
composting plant in Austria and observed a highest median value of $1.4 \times 10^5$
CFU/m3 for molds and for Aspergillus fumigatus it was $1.7 \times 10^4$ CFU/m3.

Fischer et al (1998a) studied the secondary metabolites in the working
places in a compost facility in Germany. *Aspergillus candidus*, *A. nidulans*,
*Penicillium brevicompactum*, *Paecilomyces variotii* and *A. fumigatus* were
recorded frequently. The microbial volatile organic compounds (MVOC) were
also studied. The toxigenic effects of the molds in addition to pathogenic and
allergenic effect were studied by Fischer et al (1998b).
Lacey et al. (1990) suggested emission of large numbers of microorganisms when handling freshly made compost. A fumigatus was sometimes abundant especially in domestic compost presenting a risk of Asthma, Alveolites, and infection.

AIR BORNE THERMOPHILIC AND THERMOTOLERANT FUNGI:

Cooney and Emerson (1966) defined a thermophilic fungus as one that has a maximum temperature for growth at or above 50°C and a minimum temperature for growth at or above 20°C. They are found in nature where organic materials (Damphay, leak mould, composting materials, straw and dung of animals) decomposed at elevated temperature.

Studies on air borne thermophilic fungi are very few when compared with Mesophiles. Lacey and Lacey (1964) reported the presence of spores of thermophilic moulds in the atmosphere of farm building. Later, Fergus (1964) investigated the presence of thermophilic and thermotolerant fungi in the air of a room in which the trays of mushroom compost or dumped during spawning. He isolated the thermotolerant fungus, Aspergillus fumigatus using Anderson sampler.

Evans (1972) studied the thermophilic fungi from the air over the roof of Keele biology Department at the proximity from the coal spoil tips by exposure plate method. Among 2500 isolates, A. fumigatus comprised 50%.
The fungi, *Thermomyces lanuginosus* and *Mucor pusillus* also contributed substantially to the total. *Absidia corymbifera, A. ramose, Emercilla nidulana, Thielavia thermophile, Penicillium pieceum* were common members. *Paecilomyces varioti, Sporotrichum thermophile and Thermoidea sulfureum* were sporadic in their seasonal occurrence.

Hudson (1973) surveyed the thermophilus and thermotolerant fungi in the air at Cambridge using Anderson sampler for one-year period. Twelve species were isolated and among them *A. fumigatus* constituted nearly 69%. *Talaromyces thermophile, Thermomyces lanuginoses and Mucor pusillus* were found frequent.

Thakur (1977) reported *Mucor pusillus* and *Torula thermophila* as the most commonly isolated species from the atmosphere of a cattle form near Bombay. The species isolated were *Mucor pusillus, Thermoascus aurantiacus, Talaromyces dupontii, T. emersonii, Chaetomium thermophile, Humicola grisea, H. insolens, Torula thermophil, Sporotrichum thermophile* and the *A. fumigatus*. Nine species of thermophilic fungi viz., *A. fumigatus, A. nidulans, A. niger, Chaetomium thermophile, Malbranchia pulchell, Melanocarpus albomyces, Rhizopus arrhizus* and *Thermoascus aurantiacus* were isolated Rippon et al., (1980) from the air near thermal effluent of nuclear power generating reactor in Illinois, U.S.A. In their studies on air borne thermophilic fungi at Qena, Abdelfattah and Swelim (1982) isolated only *Aspergillus* with *A*.
fumigatus as dominant. Jones and Cookson (1983) studied the air borne thermophilic fungi near a suburb of Washington (DC) using Anderson microbial sampler.

Deshmukh and shukla (1984) isolated 9 species including A. fumigatus, Mucor pusillus, and Thermoascus aurantiacus from air of Sagar (M.P). Sandhu and Singh (1985) isolated 29 species of Thermophilus fungi from the atmosphere of Amritsar, India. Aspergillus fumigatus, Thermomyces lanuginosus, Mucor pusillus and Chaetomium thermophile were the commonest one.

Vidya (2000) studied the airborne thermophilic fungal spores from Bangalore and isolated six genera. The genera encountered were Aspergillus fumigatus (47%), Mucor pusillus (32.3%) Humicola grisey (5.5%), Chaetomium thermophile (3.1%), Torula thermophila (1.3%) and Sporotrichum thermophile (0.6%).

SEASONAL VARIATIONS IN THE OCCURRENCE OF FUNGAL AIRSPORA

Spore concentrations measured in the atmosphere are the result of a wide range of complexity interrelated environmental and biological factors. Mishra and Kamal(1971) carried out the research work on Seasonal variation in the
total airspora, of the year 1967, at the Gorakhpur University. Lyon et.al. (1984) explained variations of air spora in the atmosphere due to weather conditions.

N.B. Devy and N.I. Singh (2001) demonstrated the variations in the occurrence of fungal air spores over a potato field. A.D. Dhimdhime et.al. (2001) demonstrated seasonal variations in different seasons on sunflower fields. N.K. Udayaprakash has proved with his experiments that the fungal spores show their variation according to season and also location.