Geof. Int., Vol. 26-3, 1987, pp. 359 - 373

ABUNDANCE AND HETEROGENEITY OF ALGAE IN THE MEXICO CITY ATMOSPHERE

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(Received: April 21, 1986)
(Accepted: July 7, 1986)

RESUMEN

En la atmósfera de la Ciudad de México se colectaron diez especies de algas, entre ellas se encuentran dos que no han sido reportadas con anterioridad, *Botryokoryne simplex* y *Chlorogloea microcystoides.*

Durante el muestreo, que abarcó julio y agosto de 1982 y de julio a diciembre de 1985, el 65% de las muestras fueron positivas. Se registraron cuentas tan bajas como de 0 a 23.3 algas m^{-3}, lo cual puede atribuirse al bajo índice de bochorno y a los vientos ligeros del norte. Con valores de humedad relativa arriba del 80% y por debajo del 30% se obtuvieron tubos de cultivo negativos.

Se revisaron las características alergénicas de la mayoría de los géneros de las algas aisladas, pero no existe información acerca del comportamiento de otras varias especies.

El presente estudio señala que deben medirse con precisión los parámetros meteorológicos en el sitio de muestreo para establecer las relaciones que existen entre la biota aérea y las condiciones ambientales. Asimismo, es necesario un mayor y más completo conocimiento de la composición de las algas subaéreas y del suelo, para poder describir adecuadamente la naturaleza de la biota en la atmósfera.

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ABSTRACT

Ten species of algae were collected from the Mexico City atmosphere, among them two species not previously reported: *Botryokorine simplex* and *Chlorogloea microcystoides.*

65% of the samples taken from July to August 1982 and July to December 1985, were positive. Counts as low as 0-23.3 algae m^{-3} were recorded which could be due to a low sultriness index and light and northerly winds. With humidity values over 80% and under 30% negative culture tubes were obtained.

The allergenic characteristics of most of the algae genera isolated have been checked, but there is no information about the characteristics of several other species.

The present paper indicates that very precise meteorological parameters must be measured at the sampling site before valid relationships between aerial biota and environmental conditions can be determined. A more complete understanding of the soil and subaerial algal composition is needed before the nature of the biota in the atmosphere could be adequately described.

INTRODUCTION

Aerobiological research has provided information on the ecology of microorganisms since the presence of some of them in the atmosphere was not yet recognized.

Several authors have found that great numbers of these organisms are able to thrive in this gaseous, adverse environment for considerable length of time (Gregory, 1945; Pady, 1957; Jones and Cookson, 1983).

Algae (Chlorophyta, Cyanophyta and Chrysophyta) commonly quoted as organisms restricted to soil and water, at present are definitely known to comprise a portion of the microflora (Ehrenberg, 1844; Salisbury, 1866; Schlichting, 1964; Smith, 1973).

The specific composition of the airborne algal flora is dependent upon the proximity to various soil-based populations of algae and upon meteorological conditions (Schlichting, 1976).

The fact that algae found in the air we breath represent a health risk, as the size of many of them is of the order 1-40 *u*m which makes it possible for them to be inhaled and retained within the respiratory tract, thus causing hypersensitivity reactions due to their high protein content considered as a source of antigen. Several species of Chlorophyta and Cyanophyta are known to cause skin and bonchial mucose membrane sensitivity (Cohen and Rief 1953; Bernstein and Safferman, 1966; Mittal *et al.*, 1979).

Only preliminary research on airborne organisms has been conducted in Mexico (González y Orozco, 1943; Rivera *et al.*, 1986). Consequently an investigation was undertaken in order to isolate and identify the airborne algae present in an urban area and to find out whether they might be a contributing factor to inhalant allergenic sensitivity.

MATERIAL AND METHODS

Thirty one samples of airborne algae were taken during the months of July through September 1982 and from July through December 1985, at the campus of the National University of Mexico, southwest of downtown Mexico City and surrounded by a residential area with heavy traffic in and around the campus. The University City is 2 270 m above sea level. In spite of its low latitude within the tropics, Mexico City, because of its great altitude, has a temperate subhumid climate, with one rainy season in summer; mean annual temperature of 15°C and yearly mean maxima of 22°C.

Air from 4 m above the ground was drawn through a bubble flask containing 50 ml of BBM (Bold's Basal Medium) at a rate of 15 L min^{-1}. A total of 0.9 m^3 of air was sampled at each time (Schlichting, 1961).

For the algae counts a 10 ml sample aliquot was filtered through a membrane millipore filter (0.45 μm pore size) and after culturing in agar plates at 20-30°C, a 16 h-light period per 24 h and 350 foot candle light intensi ' over 15 days was applied (Schlichting, 1961; Stein, 1973).

One half of each filter sample was cultured in liquid medium (BBM) at the same conditions mentioned above, but this time for over a 90 day period. After isolation made by streaking technics on agar tubes, the algae were identified by inspection of the cultures (Gommont, 1901; Gardner, 1927; Geitler, 1932; Starr, 1955; Skuja, 1956; Desikachary, 1959; Uherkovich, 1966; Fott and Novakova, 1969; Archibald and Bold, 1970; Bourrelly, 1970, 1972; Ettl, 1976; Bold and Wynne, 1978). Weather conditions of wind speed, wind direction, temperature, humidity and sky were continuously measured and recorded during the sampling period at the sampling site.

RESULTS

Eleven species of algae were collected from 31 samples (Table 1). Out of 31 culture tubes, 20 were found to be positive. As a rule, the number of algae was low, but through October to December, their number increased.

TABLE 1. ALGAE COUNTS AND SIGNIFICANT PARAMETERS MEASURED DURING SAMPLING PERIOD.

Date of Sample	Sky* Condition	Temperature °C	Relative Humidity (%)	Viable Organisms	Organisms Nr/m³
20/7/82	C	24.0	31	Botryokoryne simplex	1.1
21/7/82	C	23.8	44	Plectonema gracillimum	1.1
24/7/85	C	23.3	34	Chlorella saccharophila	2.3
25/7/85	C	22.3	33		0.0
28/7/82	C	23.3	28	Chlamydomonas agloeformis	1.1
3/8/82	C	22.0	63	Chlorogloea microcystoides	1.1
11/8/82	C	22.5	49	Chlorella saccharophila	1.1
				Scenedesmus acutus	1.1
				Botryokoryne simplex	1.1
11/8/85	Cl	20.1	59	Scenedesmus acutus	1.2
12/8/85	C	15.2	90		0.0
13/8/85	C	15.4	72		0.0
14/8/85	Cl	12.2	82		0.0
4/9/85	Cl	21.7	52	Chlorococcum diplobionticum	1.2
5/9/85	C	18.1	62	Chlorella luteoviridis	1.2
9/10/85	C	24.0	45	Botryokoryne simplex	0.7
				Hormidium subtile	1.5
14/10/85	C	23.5	40		0.0
16/10/85	Cl	17.8	50		0.0
25/10/85	C	20.2	42	Plectonema gracillimum	1.1
				Chlorella vulgaris	2.2
				Scenedesmus acutus	1.1
26/10/85	C	20.5	35	Scenedesmus acutus	1.1
11/11/85	C	18.4	40	Chlorogloea microcystoides	1.1
				Unidentificated filament	1.1
				Chlorella luteoviridis	1.1
12/11/85	Cl	9.2	88	Chlorococcum sp.	1.1
13/11/85	Cl	17.3	62	Chroococcus sp.	1.1
				Chlorella luteoviridis	1.1
				Botryokoryne simplex	1.1
14/11/85	C	21.2	34	Hormidium subtile	1.1
17/11/85	C	22.0	28		0.0
18/11/85	C	22.0	27		0.0
19/11/85	Cl	19.7	44		0.0
20/11/85	Cl	21.8	33		0.0
21/11/85	Cl	20.0	37	Scenedesmus acutus	16.6
				Hormidium subtile	3.3
				Botryokoryne simplex	3.3
22/11/85	Cl	21.4	36	Botryokoryne simplex	3.3
2/12/85	C	18.8	40	Scenedesmus acutus	1.1
3/12/85	C	16.8	45	Chlorophyta unidentificated	4.4
5/12/85	C	14.9	58		0.0

C: CLOUDY

Cl: CLEAR

The algae *Botryokoryne, Scenedesmus* and *Chlorella* were the most common airborne organisms, but the second was the most abundant during the sampling period.

Algae were more often found on cloudy days under relative humidities from 30 to 60% and air temperatures from 9.2 to 23.8°C. Most of the algae found were associated with a sultriness index of 150 to 350 mb°C. However, the prevailing values of this index were smaller than 200. A slight influence of the sultriness index on the ratio of positive to negative culture tubes was also detected whereas negative culture tubes decreased as the sultriness index increased beyond the 200 mb°C curve (Fig. 1).

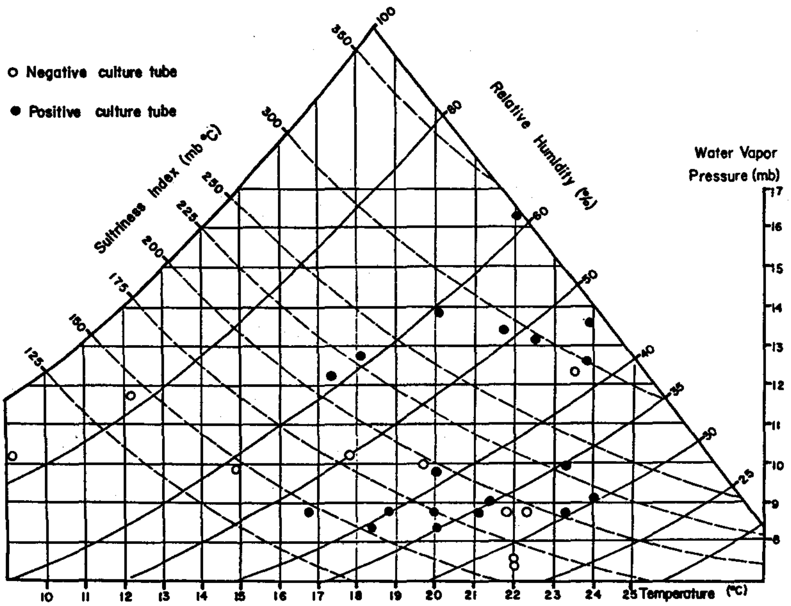

Fig. 1. Distribution of positive and negative culture tubes on a psychrometric chart.

Figure 2 shows the direct relationship between wind speed and the number of organisms; in other words, as the wind speed increased, the number of organisms increased. Algae were more often found when wind blew from a northerly direction and only occasionally when it came from a southerly direction.

Most algae were clasified as unicellular Chlorophyta and Cyanophyta (Table 2). Only two different species of filamentous algae were collected. The size of all of them was variable, mostly within 1 to 40 μm (Figs. 3-4). Although soil algae were most prevalent in the atmosphere, viable microalgae both from subaerial and water surfaces were also detected. Table 2 refers to allergenic algae.

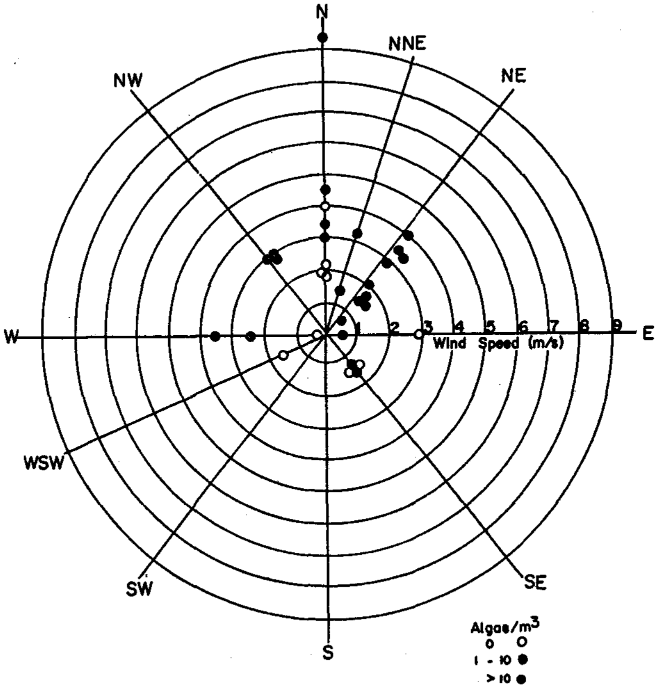

Fig. 2. Relationship between wind speed and direction to number of airborne algae.

TABLE 2. OCURRENCE AND ALLERGENICITY OF ALGAE COLLECTED IN THE MEXICO CITY ATMOSPHERE.

Taxa	% Frequency	Ocurrence	Allergenicity
Cyanophyta			
Chlorogloea microcystoides GEITLER,1925	6.4	soil,pools[1]	------
Plectonema gracillimum (ZOPF) HANSGIRG,1885	6.4	subaerial (window glass)[2], soil	------
Chlorophyta			
Botryokoryne simplex REISIGL,1964	19.2	soil[3]	------
Chlamydomonas agloëformis PASCHER,1927	3.2	peat bogs[4]	genus[10]
Chlorella luteoviridis CHODAT,1912	9.6	pools,peat bogs[5]	
Chlorella vulgaris BEIJERINCK,1890	3.2	water,soil,subaerial surfaces[5]	specie[9,10,11]
Chlorella saccharophila (KRÜGER) MIGULA,1907	3.2	pools, soil, epiphytic,[5]	genus[9,10,11]
Chlorococcum diplobionticum HERNDON,1958	3.2	soil[6]	genus[9,10,11]
Chlorococcum ellipsoideum DEADSON and BOLD,1960	6.4	soil[6]	genus[9,10,11]
Hormidium subtile (KÜTZ) Heering	9.6	lentic waters,epiphytic, soil[7]	genus[12]
Scenedesmus acutus MEYEN,1829	19.2	water[8]	genus[9,10,11]

(1) Desikachary 1959
(2) Geitler 1932
(3) Bourrelly 1970
(4) Ettl 1976
(5) Fott and Novakova 1969
(6) Archibald and Bold 1970
(7) Skuja 1956
(8) Uherkovich 1966
9. Bernstein and Safferman 1966
10. Bernstein and Safferman 1970
11. Bernstein and Safferman 1973
12. McElhenny *et al* 1962

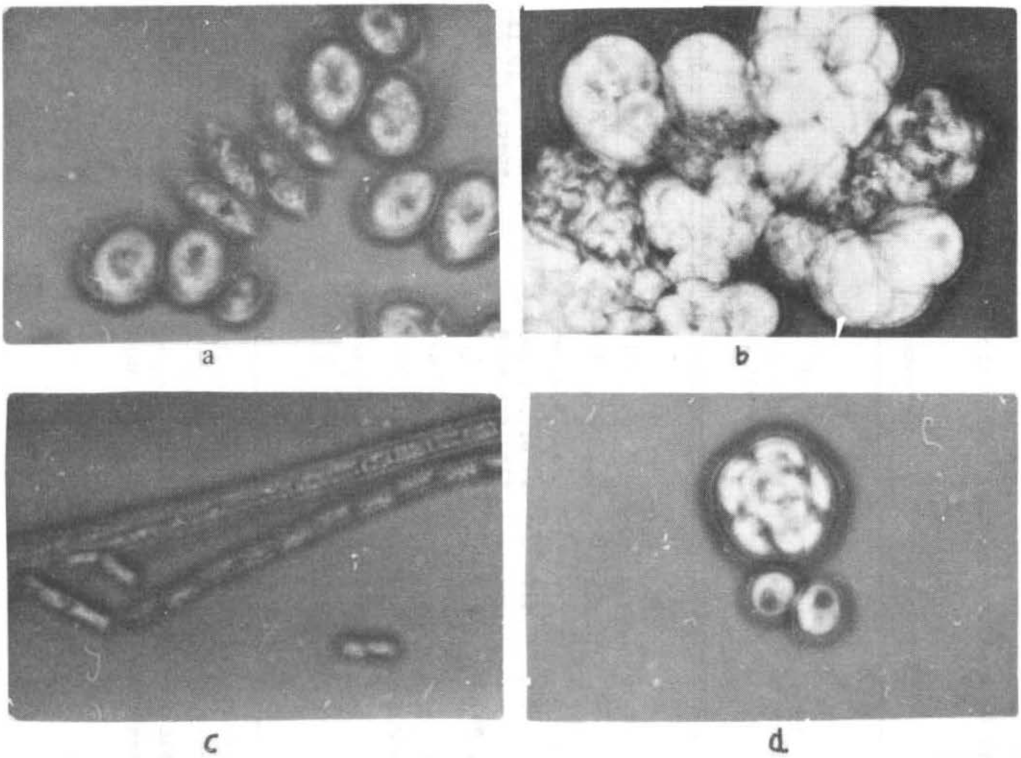

Fig. 3. Photomicrographs (X 2 000) of different airborne algae: a. *Scenedesmus acutus;* b. *Botryokoryne simplex;* c. *Hormidium subtile;* d. *Chlorella vulgaris.*

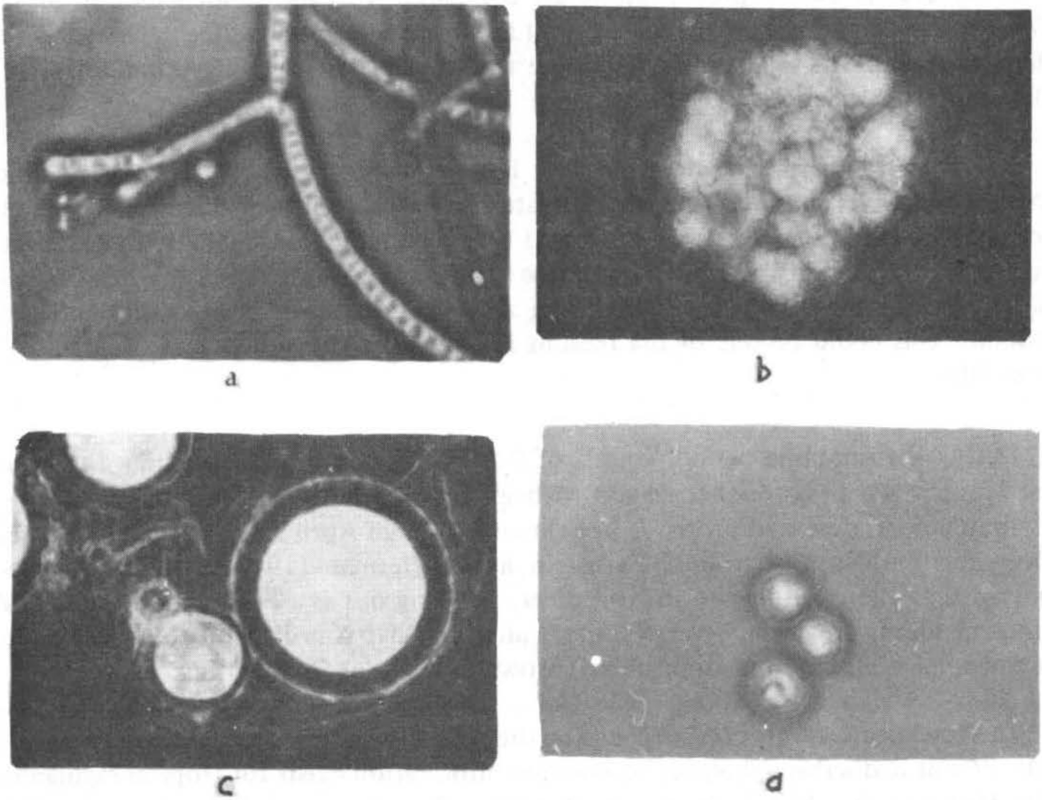

Fig. 4. Photomicrographs of different airborne algae: a. *Plectonema gracillimum* (X 2 000); b. *Chlorogloea microcystoides* (X 320); c. *Chlorococcum diplobionticum* (X 2 000); d. *Chlorella sacharophila* (X 2 000).

DISCUSSION

The results of this study on airborne algae in Mexico City point out to the existence of a low diversity (ten species) in comparison with the 230 species of microalgae recorded from air samples throughout the world (Schlichting, 1976). However, two genera not previously reported in the air were found: *Botryokoryne* and *Chlorogloea* belonging to Ulothricales and Chroococcales respectively. Both being unicellular, their source is the soil as a common habitat. The former presents cells with an approximate diameter less than 19 μm while the cells of the latter are even smaller (5 μm). Many single celled organisms were found more often than other types as they are lighter and more apt to become airborne. All the algae found were classified either as Chlorophyta (87%), or Cyanophyta.

If the results of the present study are compared with the incidence of airborne *Chlorella* and *Scenedesmus* in the existent literature, it seems possible to characterize them as ubiquitous so that they could be used as standard types for comparison of algae counts throughout the world.

Several researchers have reported that both at very low (<20%) and very high (>80%) relative humidity the survival rate of microorganisms decrease (Ehresman and Hatch 1976; Smith, 1973; Riley and Kaufman, 1972). On the other hand, at high relative humidity values, an increase of the microorganisms mass occurs, because of their higroscopicity, thus giving a faster deposition rate of them on the ground. This could be one of the reasons for their absence at high (>80%) relative humidity.

During the sampling period, counts of 0-23.3 algae per m^3 were found; the highest number was in November, in accordance with Smith (1973), who found the largest number of algae and protozoa in February through April and November through December, in North Carolina. Bernstein and Safferman (1972a, 1972b) also reported that allergies increase in November, pointing out as a cause the increment of airborne algae. However, several authors mention that it is difficult to establish the seasonality of algae in the atmosphere (Brown *et al.*, 1964; Schlichting, 1974).

The low algae counts recorded during the present research could be due to a scarcity of soil and subaerial algae; however,no information exists for tropical highlands like Mexico City. Also, this scarcity of viable airborne algae could be due to the following three combined effects: light winds, a low sultriness index and high levels of air pollution.

A direct relationship between wind speed and algae counts was observed in the United States by Pady and Kelly (1953); Schlichting (1974) and Singh (1981). Another factor which could account for the lack of injection of algae into the atmosphere by thermals is a low sultriness index. This environmental factor had an average value of 150.9 mb°C. It has been observed that this index increase as much as ten times at sea level in Southern Mexico (Rosas *et al.*, unpublished M.S.) where the algae counts were even 100 times higher.

Air pollution is important on the viability of airborne microorganisms (Druet and Packman, 1968; Druet and May, 1968). Although information does exist on the high levels of pollutants in the Mexico City atmosphere (Bravo, 1973; Báez *et al.*, 1984), no pollution levels in the air were simultaneously measured.

Among the recorded algae the soil-borne ones were more abundant, because in urban areas the ground is the main source of airborne algae (Brown and Bold, 1964; Schlichting, 1972).

Airborne algae may cause respiratory disorders (Salisbury, 1866) and both respiratory and dermatological allergies (McGovern *et al.*, 1965, 1966). The size of the algal cells is also important, because of the size-dependence depth of the respiratory tract where the reaction takes place, primarily at the bronchial level, with sympthoms suggesting either asthma or pulmonary diseases with various types of response within the alveoli (Chapman, 1984). This makes one believe that most of the collected algae could reach those places.

Furthermore, one must suppose that these algae represent a health risk because of their high protein content (Chlorophyta 24% and Cyanophyta 44%) (Fogg and Stewart, 1955).

The algae here reported have been tested for both skin and bronchial mucous membrane sensitivity, but its identification has been made only at the genus level. It is not known whether the diverse species behave in the same way, as is the case for both *Chlorella* and *Chlorococcum* which have been tested at the genus level. However, several species of these organisms have been reported in home dust (Bernstein and Safferman, 1970; Mittal *et al.*, 1979).

Up to the present, research on *Plectonema, Chlorogloea* and *Botryokoryne* has not been done, so it would be interesting to carry out a research in atopical children to test their allergenic potential.

ACKNOWLEDGEMENTS

The authors are grateful to A. Yela, A. Rodríguez, J. L. Godínez and F. Graffé for their collaboration during this study, to M. Cruz for the final review of the manuscript. Also to A. Mota for the meteorological data.

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