

To study distribution of algae in and around Delhi aerobiological surveys were undertaken for two consecutive years (September, 1972, to August, 1974). The surveys were accomplished by (a) slide exposure method and (b) culture plate exposure method. A total of 850 slides were exposed using Durham's gravity sampling device. Of these, 560 slides were exposed during 1973 (272 slides at two meter and 288 at ten meter height) and the rest (290 slides) were exposed during 1974 at ten meter height. A total of 858 culture plates were exposed (276 for one hour and 282 for two hours) during 1973 and the rest (300 culture plates) were exposed during 1974 at ten meter height for two hours duration only. Air was found to be rich in algae flora during the months of September to November. The dominant forms of algae present were all blue greens. This might be due to the relative greater resistance of blue green algae to unfavorable conditions.

STUDIES ON ALLERGENIC ALGAE OF DELHI AREA: BOTANICAL ASPECTS

ARUN MITTAL, Ph.D., M.K. AGARWAL, Ph.D.,
and D.N. SHIVPURI, M.D.

VERY FEW STUDIES have been published on the presence of algae in the air and their possible role in causing respiratory allergic disorders.^{1,6} In India, although systemic and comprehensive botanical and clinical investigations on pollen, fungi, insects and dusts have been reported,^{7,13} the role of airborne algae was never investigated in this country. We have published preliminary studies on the presence of algae.^{14,15} This paper, however, presents the first comprehensive report from India on the prevalence of various algae spores in Delhi atmosphere for two consecutive years by simultaneous daily exposure of slides and culture plates.

Materials and Methods

To study distribution of airborne algae in and around Delhi aerobiological surveys were undertaken. The surveys were accomplished by the following two methods:

A. Slide Exposure Method

Slides thinly smeared with glycerine jelly (without

phenol) were exposed to the atmosphere in a gravity spore trap at the height of ten meters and two meters from ground level for 24 hours on all working days from September, 1972, to August, 1973 to see if there was any difference in the total algae trapped at two different heights. For the subsequent year, i.e., September, 1973, to August, 1974, the slides were exposed at the ten meter height only. The exposed slides were then aseptically transferred to a conical flask (250 ml capacity) containing 100 ml of sterile Fogg's medium with nitrogen. These flasks were then incubated at 27°C under continuous illumination for algae growth.

During the two consecutive years of air sampling 850 slides were exposed using Durham's Gravity slide sampling device. Of these, 560 slides were exposed during 1973 (272 slides at two meter and 288 at ten meter height) and the rest (290 slides) were exposed during 1974 at ten meter height.

The number of days on which an alga was trapped and its preponderance in the cultures were taken as parameter for its distribution in the air.

B. Culture Plate Exposure

In an attempt to find the number of viable airborne algae, culture plate exposure studies were also undertaken. Petri dishes containing 20 ml of sterilized Fogg's medium with nitrogen were solidified by adding

Doctor Mittal is Research Officer, National Allergy Centre, New Delhi, India.

Doctor Agarwal is Junior Research Officer, Department of Respiratory Allergy and Applied Immunology, V.P. Chest Institute, Delhi University, Delhi, India.

Doctor Shivpuri is Director, National Allergy Centre, New Delhi, India.
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1.5% agar and were exposed for one hour and two hours, starting at 11:00 a.m. This was done to find out if exposure time has an effect on the type and number of algae trapped.

During the year 1973 a total of 858 culture plates were exposed (276 for one hour and 282 for two hours), whereas in 1974, 300 culture plates were exposed for

two hours duration. The exposed culture plates were then incubated in a culture chamber at $27^{\circ}\text{C} \pm 1^{\circ}\text{C}$ under continuous illumination. The culture plates were examined daily for growth of algae, identification and their isolation. The different algae forms developed in slide cultures and exposed culture plates were identified.¹⁶⁻¹⁸ After identification they were isolated by

Table I. Viable Algae Identified from Air of Delhi During This Study.

I. Class Chlorophyceae	g) Family Oscillatoriaceae
A. Order Volvocales	9. <i>Lyngbya borgerti</i>
a) Family Chlamydomonadaceae	10. <i>Lyngbya cryptovaginata</i>
1. <i>Chlamydomonas polyphyrenoides</i>	11. <i>Lyngbya major</i>
B. Order Chlorococcales	12. <i>Oscillatoria simplicissima</i>
b) Family Chlorococcaceae	13. <i>Phormidium anqustissimum</i>
2. <i>Chlorococcum humicola</i>	14. <i>Phormidium bohneri</i>
c) Family Chlorellaceae	15. <i>Spirulina major</i>
3. <i>Chlorella pyrenoidosa</i>	h) Family Nostocaceae
d) Family Coelastraceae	16. <i>Anabaena anomala</i>
4. <i>Scenedesmus bijuga</i>	17. <i>Anabaena fertilissima</i>
II. Class Cyanophyceae	18. <i>Anabaenopsis circularis</i>
C. Order Chroococcales	19. <i>Nostoc commune</i>
e) Family Chroococcaceae	i) Family Rivulariaceae
5. <i>Aphanocapsa pulchra</i>	20. <i>Calothrix fusca</i>
6. <i>Aphanothece naegeli</i>	j) Family Scytonemataceae
7. <i>Gleocapsa decorticans</i>	21. <i>Plectonema notatum</i>
D. Order Pleurocapsales	22. <i>Scytonema bohneri</i>
f) Family Pleurocapsaceae	23. <i>Scytonema rivulare</i>
8. <i>Myxosarcina spectabilis</i>	F. Order Stigonematales
E. Order Nostocales	k) Family Stigonemataceae
	24. <i>Westiellopsis prolifica</i>

Table II. Algae Forms Cultured from Air Exposed Slides at the Height of Ten Meters and Two Meters for 12 Months (from September, 1972, to August, 1973).

S.No.	Algae forms	Height	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Frequency %
		(Meter)													
1.	<i>Phormidium</i> spp	10 M.	10	8	9	13	11	6	12	13	6	7	5	7	37.0
		2 M.	11	7	7	16	9	6	14	12	5	8	4	6	38.6
2.	<i>Chlorococcum</i> spp	10 M.	12	9	12	15	9	9	6	7	4	2	1	1	30.1
		2 M.	14	14	14	12	7	6	10	10	5	7	3	4	38.9
3.	<i>Oscillatoria</i> spp	10 M.	4	4	2	2	2	4	4	2	2	1	1	1	10.0
		2 M.	6	5	1	2	3	3	5	4	1	-	-	-	11.0
4.	<i>Lyngbya</i> spp	10 M.	8	2	2	1	1	1	1	1	-	-	1	-	6.2
		2 M.	8	1	1	1	-	-	-	-	-	-	1	-	4.4
5.	<i>Anabaena</i> spp	10 M.	4	1	1	1	2	-	4	2	-	1	-	-	5.5
		2 M.	4	3	2	6	2	4	2	-	-	-	2	-	9.2
6.	<i>Chlorella</i> spp	10 M.	1	2	-	1	1	2	4	4	1	-	-	-	5.5
		2 M.	2	4	2	-	1	2	3	4	2	1	3	1	9.2
7.	<i>Myxosarcina</i> spp	10 M.	1	2	3	1	-	1	1	1	1	1	2	1	5.2
		2 M.	-	4	-	1	1	-	2	1	-	-	-	-	3.3
8.	<i>Scytonema</i> spp	10 M.	-	1	5	2	1	-	2	1	-	-	1	-	4.5
		2 M.	-	2	-	1	1	-	1	1	1	-	-	-	2.5
9.	<i>Westiellopsis</i> spp	10 M.	2	2	1	1	1	1	-	-	4	-	-	-	3.8
		2 M.	2	3	1	3	4	1	1	2	1	1	-	-	6.9
10.	<i>Scenedesmus</i> spp	10 M.	1	3	3	-	1	-	3	-	-	-	-	-	3.8
		2 M.	1	2	3	2	1	-	1	-	1	-	-	-	4.0
11.	<i>Nostoc</i> spp	10 M.	-	2	1	1	-	-	1	-	-	-	-	-	1.7
		2 M.	-	2	1	1	-	1	2	1	-	-	-	-	2.9
12.	<i>Aphanothece</i> spp	10 M.	1	1	1	-	1	-	1	-	-	-	-	-	1.7
		2 M.	1	3	1	-	-	-	1	-	-	-	-	-	2.2
13.	<i>Plectonema</i> spp	10 M.	1	1	-	-	-	1	-	-	-	-	-	1	1.4
		2 M.	1	1	-	-	1	-	1	-	-	-	-	-	1.5
14.	<i>Aphanocapsa</i> spp	10 M.	1	-	-	1	-	-	-	-	-	-	-	-	0.6
		2 M.	1	-	-	-	-	-	-	-	-	-	-	-	0.3
15.	<i>Gleocapsa</i> spp	10 M.	-	1	-	-	-	-	-	-	-	-	-	-	0.3
		2 M.	-	-	-	1	1	-	-	-	-	1	-	-	1.5
	Algae forms	10 M.	50.0	56.0	41.6	47.8	41.6	36.3	44.0	32.0	24.0	20.8	25.0	20.8	-
	trapped %	2 M.	45.8	52.0	50.0	55.0	45.8	35.0	48.0	37.5	29.1	22.7	22.7	13.6	-

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sub-culturing them on tube slants containing nutrient media.

Fogg's medium with nitrogen was prepared with the following dehydrated materials: potassium nitrate, 0.25 g, magnesium sulphate 0.20 g, potassium dihydrogen phosphate 0.20 g, calcium chloride 0.10 g, FeEDTA 1 ml, A, micro-nutrient solution 1 ml and dissolved in 1 litre of distilled water. The pH was adjusted to 7.5.

For the preparation of FeEDTA, 26.1 g of ethylene

diamine tetracetic acid was dissolved in 268 ml of 1 normal potassium hydroxide solution. To this 24.9 g of ferrous sulphate was added and the volume made up to one litre. This was aerated overnight and again the volume was made up to one litre.

The stock solution of micronutrients contained in one litre was ammonium molybdate 0.018 g, manganese chloride 1.810 g, boric acid 2.900 g, copper sulphate 0.080 g and zinc chloride 0.110 g.

Table III. Algae Forms Cultured from Air Exposed Slides at Ten Meters Height for 12 Months (September, 1973, to August, 1974).

Algae Forms	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Frequency%
1. <i>Phormidium</i> spp	7	8	6	10	8	12	10	12	11	13	13	15	42.9
2. <i>Chlorococcum</i> spp	6	6	6	6	7	8	7	10	6	6	10	8	29.6
3. <i>Oscillatoria</i> spp	2	2	2	6	4	6	6	4	4	6	4	6	18.5
4. <i>Chlorella</i> spp	2	2	3	4	4	5	6	6	4	5	2	4	16.2
5. <i>Scytonema</i> spp	2	1	2	2	1	-	2	-	2	4	-	4	6.8
6. <i>Nostoc</i> spp	1	2	2	-	-	-	-	-	2	2	2	-	4.5
7. <i>Westiellopsis</i> spp	-	2	2	1	2	-	-	2	2	-	2	1	4.5
8. <i>Lyngbya</i> spp	2	2	-	-	-	-	-	-	2	4	-	2	4.1
9. <i>Myxosarcina</i> spp	1	1	1	-	2	-	-	1	2	2	-	-	3.4
10. <i>Anabaena</i> spp	1	1	2	1	-	-	-	-	1	2	-	-	2.7
11. <i>Spirulina</i> spp	2	2	-	-	-	1	-	-	-	2	-	-	2.4
12. <i>Anabaenopsis</i> spp	-	2	1	-	-	1	-	-	-	-	-	-	1.4
13. <i>Calothrix</i> spp	-	-	2	1	-	-	-	-	-	-	-	-	1.0
14. <i>Aphanothece</i> spp	1	1	-	-	-	-	-	-	-	-	-	-	0.6
15. <i>Chlamydomonas</i> spp	-	-	1	-	-	-	-	-	-	-	-	-	0.3
Algae Forms trapped (%)	45.8	52.0	50.0	36.0	29.1	22.7	24.0	24.0	40.0	41.6	25.0	25.0	-

Table IV. Algae Forms Encountered on Culture Plates Exposed for One Hour and Two Hours at Ten Meters Height for 12 Months (from September, 1972, to August, 1973).

S.No. Algae forms	Hours of exposure	1972												1973												Fre- quen- cy %
		Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	
1. <i>Phormidium</i> spp	1 Hr.	4	4	4	9	13	4	8	6	3	1	6	4	23.9												
	2 Hrs.	3	3	5	10	14	3	7	4	4	2	7	2	22.7												
2. <i>Chlorococcum</i> spp	1 Hr.	1	2	1	2	2	2	1	4	5	1	2	2	9.0												
	2 Hrs.	1	2	1	2	1	1	1	3	3	-	1	-	5.7												
3. <i>Chlorella</i> spp	1 Hr.	-	3	-	-	2	1	1	5	4	1	2	1	7.2												
	2 Hrs.	-	1	-	1	4	1	3	4	3	1	1	-	6.7												
4. <i>Anabaena</i> spp	1 Hr.	3	2	1	3	1	1	2	-	1	-	-	-	5.0												
	2 Hrs.	3	1	1	2	1	-	2	1	-	1	1	-	4.6												
5. <i>Oscillatoria</i> spp	1 Hr.	3	2	1	1	1	-	1	2	1	-	-	-	4.3												
	2 Hrs.	1	1	1	2	2	1	-	-	1	-	-	-	3.6												
6. <i>Scytonema</i> spp	1 Hr.	-	1	1	-	3	2	-	-	-	-	-	-	3.9												
	2 Hrs.	-	1	-	1	4	1	3	1	1	-	4	-	5.7												
7. <i>Lyngbya</i> spp	1 Hr.	4	1	-	3	-	-	-	-	-	-	-	-	2.9												
	2 Hrs.	4	-	-	2	-	-	-	-	-	-	-	1	2.5												
8. <i>Nostoc</i> spp	1 Hr.	-	1	2	-	1	1	-	-	-	-	-	-	1.8												
	2 Hrs.	-	1	2	-	1	-	-	-	-	-	2	-	2.1												
9. <i>Myxosarcina</i> spp	1 Hr.	-	-	-	-	2	-	1	-	-	-	1	1	1.8												
	2 Hrs.	-	1	-	1	-	-	1	-	1	-	2	-	2.1												
10. <i>Westiellopsis</i> spp	1 Hr.	-	-	-	1	1	-	1	-	1	-	-	-	1.4												
	2 Hrs.	-	-	-	1	-	1	1	-	-	-	-	-	1.0												
Algae forms trapped (%)	1 Hr.	20.8	34.8	28.6	25.0	36.0	30.0	31.8	16.6	30.0	12.5	20.0	20.8	-												
	2 Hrs.	20.8	34.8	20.0	37.5	28.0	27.1	31.8	20.8	30.0	12.5	32.0	8.3	-												

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Table V. Algae Forms Encountered on Culture Plates Exposed for Two Hours at Ten Meters Height for 12 Months (September, 1973, to August, 1974).

Algae Forms	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Frequency %
1. <i>Phormidium</i> spp	6	4	8	7	6	4	9	5	6	9	14	15	31.0
2. <i>Chlorococcum</i> spp	5	2	2	4	4	4	3	2	3	3	4	4	13.3
3. <i>Chlorella</i> spp	3	2	2	1	-	2	2	2	2	3	4	4	9.0
4. <i>Oscillatoria</i> spp	-	1	3	-	-	2	4	3	2	3	-	4	7.3
5. <i>Nostoc</i> spp	2	2	2	2	2	-	2	2	-	3	2	-	6.3
6. <i>Lyngbya</i> spp	1	1	2	1	1	1	-	-	-	2	4	2	4.6
7. <i>Westiellopsis</i> spp	2	-	2	1	1	-	-	-	-	2	3	2	4.3
8. <i>Anabaena</i> spp	1	1	-	-	-	-	-	2	-	-	1	-	1.6
9. <i>Scytonema</i> spp	2	1	2	-	-	-	-	-	-	-	-	-	1.6
10. <i>Myxosarcina</i> spp	-	1	-	-	1	-	-	-	-	-	-	-	0.6
Algae forms trapped (%)	32.0	36.0	32.0	24.0	24.0	16.6	20.0	24.0	16.0	28.0	26.9	24.0	-

Results

Results of the aerobiological studies made through slide exposure and culture plate exposure are summarized in Tables I, II, III, IV and V.

Air was found to be rich in algae flora from September to November. Another peak, although of less magnitude, was observed during May and June. *Phormidium angustissimum*, *Oscillatoria simplicissima* and *Chlorococcum humicola* were in the air round the year, followed by *Chlorella pyrenoidosa*, *Anabaena fertilissima*, *Lyngbya major*, *Scytonema bohneri* and *Westiellopsis prolifica*. It was interesting to note that a dry climate increased the incidence of air-borne algae. Similar results were obtained by culture plate exposure.

The monthly variation in spore counts, with respect to rainfall, temperature and relative humidity during the two consecutive years (September 1972 to August 1974) at ten meter height is given in Table VI.

Discussion

The dominant algae present in air were mostly blue greens. This might be due to the relatively greater resistance of blue green algae to unfavorable conditions.

There was no statistically significant difference in culture plates exposed at ten meter for one hour and ten culture plates exposed at ten meter for one hour and two hours duration during 1973. Therefore, in the following year the slides were exposed for 24 hours at ten meters and the culture plates were exposed for two hours each day at the height of ten meters only.

During the rainy season (July to mid-September), although the algae growth on land is profuse, the incidence of airborne algae becomes limited because of high humidity and the rain washing out the air. Towards the end of the rainy season in mid-September, during which land is covered with a profuse growth of algae, the environmental conditions become favorable. Humidity and temperature decrease and the rains also

Table VI. Monthly Variation in Percentage of Algae Forms Trapped at Ten Meters Height with Respect to Temperature, Relative Humidity and Rainfall.

Months	Mean temperature (°C)	Relative humidity %	Rainfall (mms)	Algae forms Trapped %
Sept. '72	28.6	54.0	036.0	50.0
Oct.	25.8	57.0	032.6	56.0
Nov.	21.3	55.0	100.1	41.6
Dec.	16.2	66.0	Nil	47.8
Jan. '73	14.3	59.5	029.3	41.6
Feb.	19.1	57.5	007.0	36.3
Mar.	22.4	40.5	000.8	44.0
Apr.	30.1	26.5	Nil	32.0
May	33.7	31.5	015.9	24.0
June	34.2	48.5	015.5	20.8
July	31.5	67.5	140.3	25.0
Aug.	29.4	80.0	340.9	20.8
Sept.	29.8	70.0	067.0	45.8
Oct.	26.2	56.0	043.3	52.0
Nov.	20.3	50.0	Nil	50.0
Dec.	13.9	69.0	008.0	36.0
Jan. '74	14.0	54.0	Nil	29.1
Feb.	15.6	49.0	000.2	22.7
Mar.	24.0	42.0	004.0	24.0
Apr.	30.5	28.0	Nil	24.0
May	32.9	31.0	005.0	40.0
June	33.3	40.0	021.0	41.6
July	30.3	75.0	375.4	25.0
Aug.	30.5	70.0	102.4	25.0

Courtesy Meteorological Department, Ministry of Tourism and Civil Aviation, Lodhi Road, New Delhi.

stop. The soil starts drying up. All these factors help in enriching the air with algae and there is an increased incidence of airborne algae ranging from 41-56% during the period from September to November.

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Requests for reprints should be addressed to:
Dr. Arun Mittal
National Allergy Centre
A-10, Pamposh Enclave
New Delhi-110048
India

"It has been made a subject for remark that writers on Natural History, Physics, Physiology, and Chemistry are usually men of mild and equable character and of a happy disposition; while writers on Law and Politics, and even on Moral Philosophy, are of a dismal and melancholy temper. The reason is not far to seek: the former consider Nature and survey the work of the great Being, while the latter observe Society and meditate upon the works of man. Their studies are bound to affect them differently."

Chamfort