ISSN: 2287-688X

Annals of
Plant Sciences
Volume 10, Issue 8 (2021) pp. 4268-4279

Research Article

Impact of Seasonal Variation on the Distribution Pattern of Coccoid and Filamentous Cyanophycean Aero-Algae from Nagpur, India

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Abstract: Investigation was carried out at Nagpur for a year to understand the aero algal flora and its distribution pattern by exposing slides daily using stationary Lakhanpal and Nair sampler. Slides were exposed at a height of 35'11". After every fortnight, two slide were exposed and strip from second slide is used for culturing. From 365 slides obtained, total 943 algal forms were encountered. From the exposed slides 253 aero-algal forms were identified upto generic level and from the cultures 50 aero-algal forms were identified upto generic level. Cyanophyta (905) was found to be the most dominant group, followed by Bacillariophyta (22), Chlorophyta(14) & Euglenophyta(2) respectively. Out of various genera recorded, Lyngbya, Phormidium, Chroococcus, Gleocapsa, Merismopedia, Euglena & Chlorella were found to be dominant. Maximum total number of algal forms (297) were recorded in the autumn season of October while minimum total number of algal forms (17) were recorded in the rainy season of July. The aero-algal calendar prepared during investigation period indicates the presence of aero-algal forms throughout the year. Filamentous cyanophycean forms were found to be dominant during December-February while the coccoid cyanophycean forms were dominant during October-November. During rest of the months both the forms are more or less in equal proportion. The metrological parameter like humidity, temperature, rainfall and wind velocity influences the abundance or otherwise for the presence of algal components in the air. It is further observed that ,it is not only the climatic conditions which play a vital role in the distribution of aero-algal forms but seasonal variation has a more clear impact on the distribution and occurrence percentage of algal aerosols.

Keywords: Aero-algae, Seasonal variation, Nagpur, Allergenic forms, Natural incubation, Aerosols

Introduction

Importance of air pollutants and its impact on human health has been address from time to time, which emphasis purely on gaseous pollutants. But after covid – 19 pandemic, it has become need of time to expand the spectra of aero-pollutants and include bio-pollutants monitoring on daily basis.

Algae form one of such biological pollutants, which needs to get monitored on daily basisas it has huge varied habitats available (terrestrial and sub-aerial sources) to get itself easily metamorphosis into algal aerosols. Genitsaris *et al.* (2011) by comparing 353 morphological literature on aerobiological studies have quoted that 38 aero-algae are reported to be allergenic and 14 aero-algae are known toxic producers creating a threat to human health. The presence of algal in the air was first reported by Ehrenberg (1844); Salisbury (1866)

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DOI: http://dx.doi.org/10.21746/aps.2021.10.8.1

by exposing glass plates identified disease producing algoid organisms and classified them as palmellae. Molisch (1920), who coined the terms "aeroplankton" reported dust rains containing diatoms. Katharina *et al.* (2008) had develop a biomonitoring system involveing aero-terrestrial algae for the detection of airborne pollutants from Leipzig, Germany. Thomas *et al.* (2009) have reported aero-algal flora from marine environment from New England, USA coast. Guadalupe *et al.* (2009) has emphasis on the significance of wind velocity in the form of turbulent kinetic energy responsible for the dispersal of the aero-algal forms. Genitsaris *et al.* (2011) have reported 63 algal forms from the air of the Meditereanean city of Thessaloniki. Wan-Loy *et al.* (2011, 2013) have reported 14 cyanophycean forms from the indoor environment in Kuala, Lumpur, Malaysia. They have also indicated the importance of crowded area as an important factor contributing for the aero-algal diversity. Smith (2012) has reported 25 aero-algal forms from North Carolina. Schlichting (2012) has reported total 187 algae and protozoa from the atmosphere in Michigan, Texas and North Carolina and co-relate its significance to mankind in the form of causes for allergies, origin of hurricanes, clogging of air filters. Sylvie *et al.* (2016) had provided a comparative model related with the dispersal of aero-algal forms.Sing *et al.* (2018) have isolated 192 algal colonies and identified 31 algal forms from Honolulu, Hawai, USA.

In India, research work on Aerophycology in particular, is of very recent origin. The first reference to air-borne algae was reported by Talade (1969) from Parabhani. Using vertical cylinder traps, Ramalingam (1971), observed a number of air-borne algae at Mysore; Mittal *et al.* (1973, 1974, 1979) using culture plates have recorded more than 30 algal forms from Delhi's metropolitan area. Singh (1985) reported the dominance of cyanophycean members from the atmosphere of Bandals. Verma (1992, 1996) reported the dominance of cyanophycean algae in the air of Jabalpur. Sharma *et al* (2006, 2008, 2010) have reported 34 aero-algal genera from Varanasi and discussed on various factors responsible for the distribution of aero-algal forms and also reported aero-algal diversity at human breathing level by sampling at 2.5 m heights. They have also tested allergenic potential of two most commonly occurred cyanonophyta, *Phormidium fragile* and *Nostoc muscorum*. Gupta *et al.* (2008) have reported the survival rate of certain soil blue–green algae against varied seasonal and atmospheric condition and further reported the survival of *Lyngbya* throughout the year.

In Maharashtra, the first aerophycological report, was from Talade (1969) from Parabhani. Tilak and Vishwe (1978) have reported algae flora of Aurangabad. Balkrishna and Gunale (1980) reported dominence of blue-green in the aero-algae of Poona. Pandkar (2011) has reported high aero-algal diversity from Pune. Marathe and Reddy (1980) by exposing Petriplates reported 21 algae types from the atmosphere of Nagpur. Anis (1988) and Javed (1990) has reported aero algal forms from Aurangabad.

From Nagpur the first aero-algal report was from Marathe *et al.* (1980). After a gap of decade's Pandkar *et al.* (2010) reported aero-algal flora from vegetable and fish market, Nagpur. Pandkar (2011, 2013) has emphasis on the effect of manipulated environmental condition on the occurrence of aero-algal forms and introduce an innovative method of natural incubation during culturing. The climate of Nagpur is near about dry, which is suitable for better algal dispersal. But little attention has been paid to the spread and dispersal of air-borne algae.

In the present paper, results obtained by daily sampling of Nagpur atmosphere (Bajaj Nagar) for a year by using Lakhanpal & Nair (1958) air samples & cultures obtained from exposed slides are reported. Effect of metrological parameters and seasonal variation on the distribution pattern of aero-algal forms with reference to coccoid and filamentous cyanophycean aero-algal forms has been discussed.

Material and methods

A) *Stationary sampling and daily slide preparation*
Daily sampling was carried out at Bajaj Nagar Terrace of 'Sfurti' building from October 1994 to September 1995 using Lakhanpal & Nair sampler (1958). Slides were exposed at a height of 35'11" (including the height of aeroscope). Slide with cellotape in the center and coated with petroleum jelly was exposed daily for 24 hours. This slide was then mounted using glycerin jelly under 20 X 40 mm or 20 X 60 mm cover glass at the sampling site to avoid contamination. This slides were directly scanned for the presence of aero-algal forms.

B) *Culturing and Inoculation*
For culturing two slides were exposed after every fortnight. Cellotape strip from 2nd slide is inoculated into sterile test tube containing B.G 11 medium at the sampling site to avoid contamination during transportation to the laboratory.

C) *Incubation*
An innovative method has been developed for incubation. The mean minimum temperature of Nagpur being around 18^{o}c to 20^{o}c, incubation is done under natural condition. For this, wooden racks (120 X 90 cm) each accommodating 80 test tubes were fixed on the frame of the north side- window and the cultures were allowed to grow under natural conditions. After 3–4 weeks, algal growth has been observed.

D) *Semi-permanent slide preparation*
Semi-permanent slides were prepared from the cultures obtained using glycerin as mounting medium.

E) Identification
The algal genera were identified visually on the basis of comparative morphological features with standard available literature and monograph.

Results and Discussion

Out of 365 slides exposed, 103 were recorded negative, probably due to rain disturbances and winds. Total 943 aero-algal forms were recorded during one year period, out of which 943 aero-algal forms were identified upto class level, 300 aero-algal forms were identified upto generic level and only 177 aero-algal forms were identified upto species level (Table 2). Cyanophyta was found to be dominant phyla (905), followed by Bacillariophyta (22), Chlorophyta (14) and Euglenophyta (2) respectively (Table 1) (Graph 1).

Table 1-Aero-algal calendar of Bajaj Nagar from Nagpur

S. No	Algal Forms	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
A	**Cyanophyta**	**297**	**83**	**46**	**89**	**85**	**88**	**46**	**58**	**54**	**10**	**31**	**18**	**905**
	Coccoid - Cyanophyta	207	45	13	27	25	44	21	28	28	6	21	9	475
	Filamentous - Cyanophyta	90	38	33	62	60	44	25	30	26	4	10	9	431
1.	*Lyngbya*	2	2	5	11	17	29	16	11	7	2	1	3	106
2.	*Phormidium*	22	3	3	6	2	3	5	4	2	1	2	1	54
3.	*Chroococcus*	7	2	1	1	3	4	10	5	3	1	7	2	46
4.	*Gloeocapsa*	14	----	----	----	----	2	2	2	---	1	2	----	23
5.	*Merismopedia*	1	3		1		2		6	4	2	2	1	22
6.	*Aphanocapsa*	1	----	----	1	1	----	1	---	---	---	1	----	5
7.	*Anabaena*	1	2	----	----	----	----	----	---	---	---	----	----	3
8.	*Scytonema*	1	----	----	----	----	----	----	---	2	---	----	----	3
9.	*Microcystis*	----	1	1	----	----	----	----	---	---	---	----	----	2
10.	*Johannesbaptistia*	----	----	----	----	----	----	----	1	---	---	----	1	2
11.	*Nostoc*	----	----	----	----	----	----	----	1	---	---	----	1	2
12.	*Chamaesiphon*	1	----	----	----	----	----	----	---	---	---	----	----	1
13.	*Spirulina*	1	----	----	----	----	----	----	---	---	---	----	----	1
14.	*Schizothrix*	1	----	----	----	----	----	----	---	---	---	----	----	1
15.	*Pseudanabaena*	----	----	----	----	----	----	1	---	---	---	----	----	1
16.	*Microcoleus*	----	----	----	----	----	----	----	---	1	---	----	----	1
17.	*Oscillatoria*	----	----	----	----	----	----	----	---	---	---	1	----	1
18.	*Nodullaria*	----	----	----	----	----	----	----	---	---	---	1	----	1
19.	*Aphanotheca*	----	----	----	----	----	----	----	---	---	---	1	----	1
20	*Mastigocladus*	----	----	----	----	----	----	----	---	---	---	1	----	1
21.	*Plectonema*	----	----	----	----	----	----	----	---	---	---	1	----	1
22.	*Dermocarpa*	----	----	----	----	----	----	----	---	---	---	----	1	1
B	**CHLOROPHYTA**	----	----	**1**	**2**	**1**	**1**	**2**	**1**	---	--	**2**	**4**	**14**
1.	*Chlorella*	----	----	1	----	----	1	----	---	---	---	2	----	4
2.	*Trebouxia*	----	----	----	1	----	----	----	---	---	---	1	----	2
3.	*Chlorococcum*	----	----	----	----	----	----	1	---	---	---	1	----	2
4.	*Pleurococcus*	----	----	----	----	----	----	1	--	---	---	----	----	1
5.	*Trentipholia*	----	----	----	----	----	----	----	1	---	---	----	----	1
6.	*Stichococcus*	----	----	----	----	----	----	----	---	---	---	1	----	1
C	**BACILLARIOPHYTA**	----	----	**2**	**3**	----	**2**	----	---	---	**7**	**6**	**2**	**22**
1.	*Pinnularia*	----	----	----	----	----	1	----	---	---	---	1	2	4
2.	*Navicula*	----	----	----	----	----	----	----	---	---	4	----	----	4
3.	*Cymbella*	----	----	----	----	----	1	----	---	---	---	----	----	1
4.	*Fragilaria*	----	----	----	----	----	----	----	---	---	---	1	----	1
D	**EUGLENOPHYTA**	----	----	----	----	----	----	----	---	---	---	----	**2**	**2**
1.	*Euglena*	----	----	----	----	----	----	----	---	---	---	----	2	2
Total forms recorded		**297**	**83**	**49**	**94**	**86**	**91**	**48**	**59**	**54**	**17**	**39**	**26**	**943**
No. of positive samples		32	26	22	29	26	30	23	28	17	13	20	14	280

Table 2-Aero-algal flora of Bajaj Nagar from Nagpur

SR NO	GENUS	SPECIES	TOTAL	SR NO	GENUS	SPECIES	TOTAL
A	CYANOPHYTA		905	10(3)	*Phormidium*	*subincrustatum*	5
1	*Anabaena*	----------	3	10(4)	--- ,, ---	*rotheanum*	2
2	*Chroococcus*		46	10(5)	--- ,, ---	*mucosum*	2
2(1)	--- ,, ---	*minutus*	13	10(6)	--- ,, ---	*cebennense*	2
2(2)	--- ,, ---	*minor*	18	10(7)	--- ,, ---	*jadinianum*	2
2(3)	--- ,, ---	*multicoloratus*	1	10(8)	--- ,, ---	*anomela*	2
2(4)	--- ,, ---	*indicus*	1	10(9)	--- ,, ---	*corium*	1
3	*Chamaesiphon*	*fuscus*	1	10(10)	--- ,, ---	*favosum*	1
4	*Gloeocapsa*		23	10(11)	--- ,, ---	*foveolarum*	4
4(1)	--- ,, ---	*aeruginosa*	1	10(12)	--- ,, ---	*jenkelianum*	1
4(2)	--- ,, ---	*rupestris*	2	11	*Schizothrix*	*lamyi*	1
4(3)	--- ,, ---	*stegophila*	1	12	*Spirulina*	----------	1
4(4)	--- ,, ---	*nigrescens*	2	13	*Scytonema*		3
4(5)	--- ,, ---	*polydermatica*	1	13(1)	--- ,, ---	*cincinnatum*	1
4(6)	--- ,, ---	*decorticans*	1	13(2)	--- ,, ---	*schmidtii*	1
5	*Lyngbya*		106	14	*Aphanocapsa*		5
5(1)	--- ,, ---	*aerugineo*	19	14(1)	--- ,, ---	*biformis*	3
5(2)	--- ,, ---	*baculum*	7	14(2)	--- ,, ---	*grevillei*	2
5(3)	--- ,, ---	*gracilis*	17	15	*Microcystis*	*stagnalis*	2
5(4)	--- ,, ---	*martensiana*	5	16	*Aphanotheca*	*pallida*	1
5(5)	--- ,, ---	*allorgei*	2	17	*Dermocarpa*	*flahaultii*	1
5(6)	--- ,, ---	*spiralis*	2	18	*Pseudanabaena*	*schmidlei*	1
5(7)	--- ,, ---	*cryptovaginata*	1	19	*Johannesbaptistia*	*pellucida*	2
5(8)	--- ,, ---	*corticicola*	1	20	*Nostoc*		2
5(9)	--- ,, ---	*kashyapii*	2	20(1)	--- ,, ---	*muscorum*	1
5(10)	--- ,, ---	*putcalis*	1	20(2)	--- ,, ---	*paludosum*	1
5(11)	--- ,, ---	*major*	1	21	*Plectonema*	*tomasinianum*	1
5(12)	--- ,, ---	*hieronymusii*	1	22	*Mastigocladus*	*laminosus*	1
5(13)	--- ,, ---	*subtilis*	1	B	CHLOROPHYTA		14
5(14)	--- ,, ---	*palmarum*	1	1	*Chlorella*	----------	4
5(15)	--- ,, ---	*aureofulva*	1	2	*Chlorococcum*	----------	1
5(16)	--- ,, ---	*mesotricha*	1	3	*Pleurococcus*	----------	1
5(17)	--- ,, ---	*digueti*	1	4	*Stichococcus*	*bacillaris*	1
6	*Merismopedia*		22	5	*Trebouxia*	----------	2
6(1)	--- ,, ---	*tenuissima*	4	6	*Trentipholia*	----------	1
6(2)	--- ,, ---	*punctate*	11	C	BACILLARIOPHYTA		22
6(3)	--- ,, ---	*convolute*	2	1	*Cymbella*	----------	1
7	*Microcoleus*	*sociatus*	1	2	*Fragilaria*	----------	1
8	*Nodularia*	*spumigena*	1	3	*Navicula*	----------	1
9	*Oscillatoria*	*annae*	1	4	*Pinnularia*	----------	6
10	*Phormidium*		54	D	EUGLENOPHYTA		2
10(1)	--- ,, ---	*angustissimum*	3	1	*Euglena*	*acus*	2
10(2)	--- ,, ---	*retzii*	5				

Table 3-Comparative account of aero-algal forms recorded by two different methods, keeping sampling site, time and sampler as constant factor

Sr.No.	Algae Form	Slides	Culture
A	**Cyanophyta**	241	38
1	*Aphanocapsa*	--	05
2	*Aphanotheca*	--	01
3	*Anabaena*	03	--
4	*Chroococcus*	40	06
5	*Chamesiphon*	01	--
6	*Dermocarpon*	--	01
7	*Gloeocapsa*	21	02
8	*Johannesbaptistia*	--	02
9	*Lyngbya*	104	02
10	*Merismopedia*	18	04
11	*Microcoleus*	01	--
12	*Microcystis*	--	02
13	*Mastigocladus*	--	01
14	*Nodularia*	01	--
15	*Nostoc*	--	02
16	*Oscillatoria*	01	
17	*Phormidium*	46	08
18	*Pseudanabaena*	--	01
19	*Plectonema*	--	01
20	*Spirulina*	01	--
21	*Scytonema*	03	--
22	*Schizothrix*	01	--
B	**Chlorophyta**	03	**9**
1	*Chlorella*	02	02
2	*Chlorococcum*	--	02
3	*Pleurococcus*	--	02
4	*Stichococcus*	--	01
5	*Trebouxia*	--	02
6	*Trentipholia*	01	--
C	**Bacillariophyta**	07	**03**
1	*Cymbella*	--	01
2	*Fragilaria*	01	--
3	*Navicula*	04	--
4	*Pinnularia*	02	02
D	**Euglenophyta**	**02**	--
1	*Euglena*	02	--

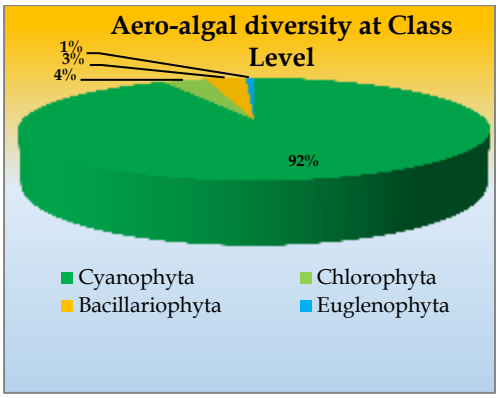
Total Thirty three aero-algal genera belonging to phyla Cyanophyta, Chlorophyta, Bacillariophyta and Euglenophyta respectively were recorded from Bajaj Nagar Slides and Bajaj Nagar Culture (Table 3).

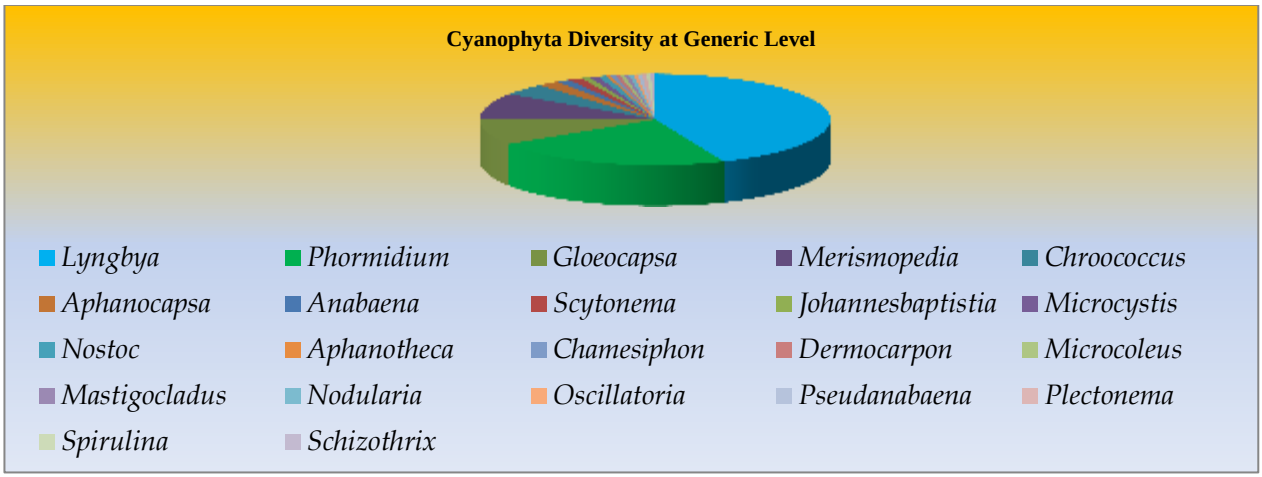
Out of which forms like Aphanocapsa, Microcystis, Aphanotheca, Dermocarpon, Pseudanabaena, Johannesbaptistia, Nostoc, Plectonema, Mastigocladus, Chlorococcum, Pleurococcus, Stichococcus, Trebouxia and Cymbella were recorded in cultures only. Similarly Chamesiphon, Microcoleus, Nodularia, Oscillatoria, Spirulina, Scytonema, Schizothrix, Trentipholia, Fragilaria, Navicula & Euglena were recorded from exposed slides only. Some forms like Anabaena, Chroococcus, Gloeocapsa, Lyngbya, Merismopedia, Phormidium, Chlorella and Pinnularia were recorded in both exposed slides and cultures (Table 3).

Algal forms reported to be allergenic to human beings such as Microcystis, Anabaena, Nostoc, Oscillatoria, Goyal (1976), Lyngbya, Phormidium, Anabaena, Scytonema, Chlorella, Chlorococcum. Mittal *et al.* (1979) Microcoleus, Fragilaria , Aphanotheca Tilak (1992), Phormidium and Nostoc Sharma and Rai (2008) have been recorded from the Nagpur atmosphere.

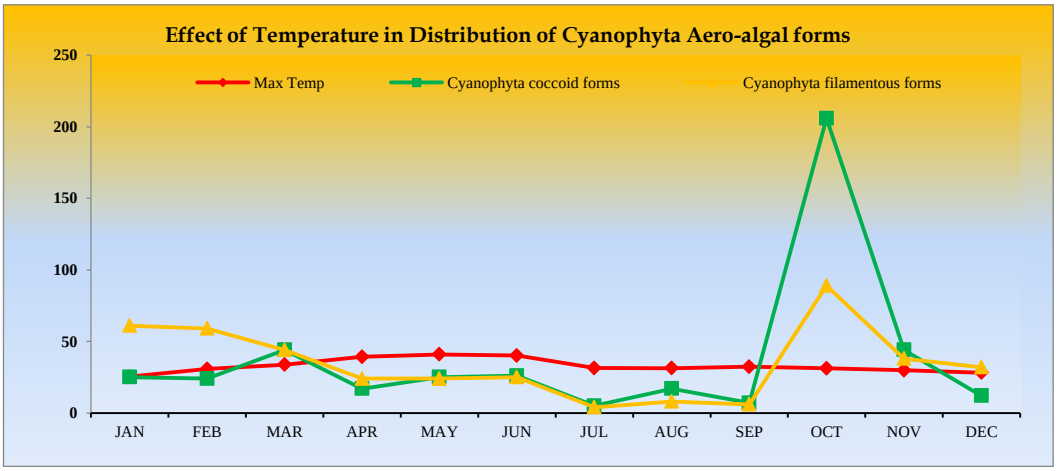
Out of various genera recorded Lyngbya (104), Phormidium (46) and Chroococcus (40) were found to be dominant one (Graph 2) recorded almost throughout the sampling period (Table 1), out of which two forms *i.e.* Lyngbya and Phormidium are reported as allergenic aero-algae (Mittal *et al.* 1979; Sharma and Rai, 2008)

Graph 1

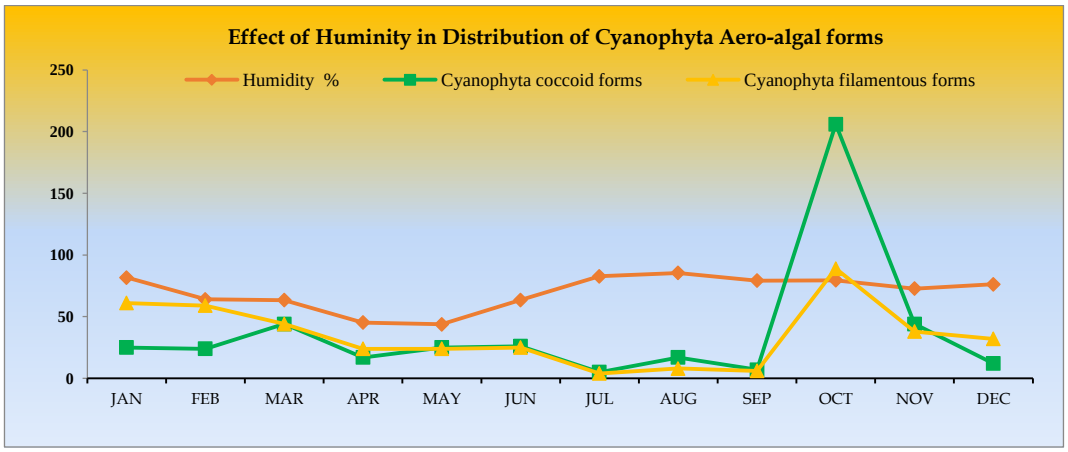




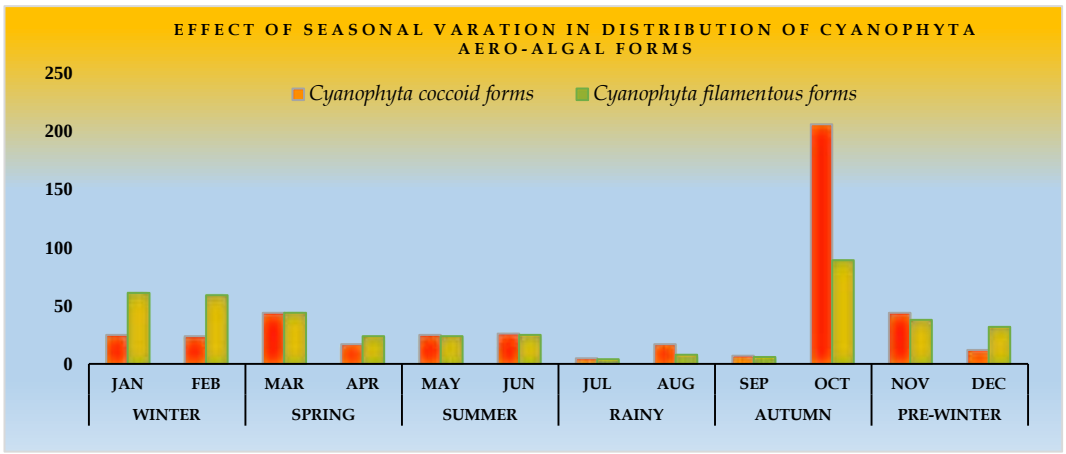
Graph 2



Graph 3



Graph 4



Graph 5

It is evident from the observations, cyanophyta aero-algal forms were found to be dominant ones, indicating their high survival rates during unfavourable conditions (Graph 1) (Gupta & Agrawal (2008), Evelyn et al. (2011)). Some diversity in the aero-algal flora of exposed slides and cultures, were also observed (Table 3). This probably indicates that some forms in the air might be in spore form and these minute spores are normally not reported during slide scanning. This can be due to aero-algal forms undergoing spore formation to overcome the unfavourable period, which is difficult to identify from the

direct slide scanning. Similarly all forms from air might not be viable to be obtained during culturing.

Maximum total number of algal forms (297) were recorded in the autumn season (October) while minimum total number of forms (17) were recorded in the rainy season (July) (Table 1). Lowest count of July was probably due to rains, where most of the slides and also algae of the atmosphere were washed away by rains showing minimum positive samples collected. During winter and spring season (November, January, February & March) recorded average numbers of forms (Graph 5) (Sharma *et al.* 2006).

Again it was found that coccoid cyanophyta forms were dominant during October-November while filamentous cyanophyta forms were dominant during December-February. During rest of the months both coccoid & filamentous forms were almost in equal proportion (Graph 5).

The observations clearly indicate that the environmental parameters like temperature, humidity, wind velocity & rainfall play a desire role in the occurrence and distribution of air borne algal forms (Paul (2012), Pandkar (2013)) but does not show any direct co-relation with the occurrence percentage of aero-algal forms (Graph 3 & Graph 4). This has led to further studies indicating that it is not only the climatic conditions which play a vital role in the distribution of aero-algal forms but seasonal variation has a more clear impact on the distribution and occurrence percentage of aero-algal forms (Graph 5) (Sharma *et al.* (2006). Cyanophyta was further differentiated into filamentous and coccoid forms and its co-relation with seasonal variation has been studied.

It was found that in winter season (January – February) cyanophyta filamentous forms was found to be dominant compare to cyanophyta coccoid forms. On the onset of spring there is decline in filamentous forms and a gradual drift of coccoid forms. During summer season, both the forms are more or less in equal proportion with steady graph till the onset of rainy season where there is sudden decline in aero-algal counts. Autumn season (September – October) shows a sudden rise in peak of algal occurrence followed by a sharp decline in pre-winter season (Graph 5).

The autumn season also called as leaf fall season leads to exposure of varied terrestrial and sub-aerial habitat such as soil, wall, building roof, bark crevices ~~etc.~~ to high temperature followed by high wind velocity, the condition pre-requist for the formation of algal aerosols its dispersal resulting into high aero-algal counts (Sharma *et al.* (2006), Katharina *et al.* (2008), Gupta & Agrawal (2008)). The least aero-algal count encounter in rainy season is due to wash away of aero-algal forms along with water droplets, which get settle down and result in increasing the ground, terrestrial and sub-aerial algal flora.

CONCLUSION

Out of 365 slides exposed, 103 were recorded negative, probably due to rain disturbances and winds. Total 943 aero-algal forms were recorded during one year period, out of which 943 aero-algal forms were identified upto class level, 300 aero-algal forms were identified upto generic level and only 177 aero-algal forms were identified upto species level. Cyanophyta was found to be dominant phyla (905), followed by Bacillariophyta (22), Chlorophyta (14) and Euglenophyta (2) respectively.

Some diversity in the aero-algal flora of exposed slides and cultures, were also observed. Maximum number of aero-algal forms were recorded in autumn season (297) while minimum number of aero-algal forms

were recorded in rainy season (17). Forms such as Lyngbya and Phormidium reported to be highly allergenic algae has been encountered almost throughout the sampling period.

These investigation provide the variety of algal forms in the air, of which some are potential allergens. Instead of board casting only gaseous pollutants on daily basis, it is the need of hours to report bio-allergens also on daily basis for the benefit of public health.
Hence it is necessary to pursue further research with such aero-algal allergens which will help to minimized allergy patients count.

Acknowledgments
I would like to thanks Dr Mohan Z. Patel, for his constant moral and financial support provided during this work.

References

1. Balakrishnan, M. S., and V. R. Gunale. "Cyanophycean air pollutants: A possible cause of inhalant allergy." *Indian Journal of Air Pollution Control* 3 (1980): 9-17.
2. Ehrenberg, G.C. "Beitricht user dies Zoo Bekanntmachung geeigenten Verhand lungo der Konig" *Press. Akad. Wiss* (1844): Print.
3. Hui-ping, E., Wan-Loy, C. and Ambu, S "Occurrence of airborne algae within the township of Bukit Jalil in Kuala Lumpur, Malaysia". *Grana* 50. 3 (2011): 217-227 Online.
4. Eyal, R., Belkin, N., Paytan, A. & Herut, B. "The relationship between Air- Mass Trajectories and the Abundance of Dust-Borne Prokaryotes at the SE Mediterranean Sea". *Atmosphere* 10.5 (2019): 280. Online.
5. Freystein, K., Salisch. M. and Reisser, W. "Algal biofilms on tree bark to monitor airborne pollutants". *Biologia* 6316 (2008): 866-872. Online
6. Genitsaris. S, Kormas K. A & Moustaka-Gouni. M. "Airborne algae and cyanobacteria: Occurrence and related health effects". *Frontiers in Bioscience 1.3* (2011): 772-787. Online.
7. Guadalupe, R.O and Jorge, C. "Aeroalgae: Response to some aerobiological questionns", *Grana* 32.1 (2009): 48-56. Online.
8. Gupta, S. and Agarwal S.C "Vegetative survival of some wall and soil blue-green algae under stress conditions". *Folia Microbiology (Praha)* 53 (2008): 3343-3350. Online.
9. Hans, W. S., Wade. R. and Alison, R. S . "Diurnal patterns of airborne algae in the Hawaiian Islands: A preliminary study". *Aerobiologia* 34 (2018): x363-373.xOnline.
10. Javeed, I. H. "Aerobiological investigate-ons at Aurangabad" *Ph.D. Thesis, Marathwada University, Aurangabad* (1990). Print.
11. Marathe, K. and Reddy, K.V.S. "Advances in pollen spore research V-VII" *ed. P.K. K. Nair* (1980): 177-184. Print
12. Mittal, A., Agarwal, M.K. and Shivpuri, D.N. "Studies on the prevalent algal forms of Delhi atmosphere". *Aspects of Allergy and Appied Im*munology 7 (1974): 52-62. Print.
13. Mittal, A., Agarwal, M.K., and Shivpuri, D.N. "Respiratory allergy to algae clinical aspects". *Annals of Allergy* 42 (1979): 253 - 256. Print.
14. Mittal, A., Agarwal SK Goyal, and D. N. Shivpuri. "Preliminary studies on the allergenic algae of Delhi Metropolitan area." *Botanical aspects. Aspects of allergy and applied Immunology* 5 (1973): 41-50.

15. Molish, H. "Popular biologische Vortsage XIII. Biol. Atmospherschem Staubes", *Jena* (1920): 280. Print.

16. Jogita, P. "Preliminary Study of Allergic Algae from Air at Human Breathing Level from Nagpur". *Biosciences, Biotechnology Research Asia.* 08.1 (2011): 159-164. Print. Online.

17. Jogita, P. "Effect of humidity on the occurrence of aero-algal forms". *The Botanique* 17.2 (2013): 112-115. Print.

18. Jogita, P. and J. L. Tarar . "Air Borne Algal Pollutants From Vegetable and a Fish Market At Nagpur". *The Botanique* 14.1 (2010): 22-27. Print.

19. Jogita, P. "Presence of High Algal Diversity in Pune Air". *International Conference on Biodiversity and its cons*ervation PD 7 (2011):1-10. Print.

20. Ramalingam, A. "Airspora of Mysore". *Proc. Acad. Sci.* Ind 74.B (1971): 227-240. Print.

21. Sabina, A. "Studies in some allergens" at *Aurangabad University, Aurangabad* (1988): Print.

22. Salisbury, S.H. "On the cause of intermittent & remittant fevers with investigations which tend to prove that these affections are caused by certain species of Palmella". *Americal Journal Medical Sciences* 51 (1866): 51 - 75. Print.

23. Schlichting, H.E. Jr. (2012). "The importance of airborne algae and Protozoa". *Journal of the air pollution control association* 19. 12 (2012): 946-951. Online.

24. Sharma, N. K., Raj, A.K. & Singh, S. "Meterological factors affecting the diversity of airborne algae in an urban atmosphere". *Ecography* 29.5 (2006): 766-772. Online.

25. Sharma, N. K., Singh, S. & Rai, A. K. "Diversity and Seasonal Variation of viable algal particles in the atmosphere of a subtropical city in India". *Environ Res* 102.3 (2006): 252-259. Online.

26. Sharma, N.K. & Rai, A.K. "Allergenicity of airborne cyanobacteria Phormidium fragile and Nostoc muscorum". *Ecotoxicol Environ Saf* 69.1 (2008): 158-162. Online.

27. Naveen, S. & Singh, S. "Differential Aerosolization of Algae and Cyanobacterial particals in the Atmosphere". *Indian Journal of Microbiology* 50.4 (2010): 468-473. Online.

28. Singh, A. "Algal aeroflora from the Banaras", *Ph.D. Thesis, Banaras University* (1985): Print.

29. Smith, P. "The effect of some air pollutants and meterological conditions on airborne algae and protozoa". *Journal of the air pollution control association* 23.10 (2012): 876-880. Online.

30. Sylvie,V.M., Tesson, C.A. S., Šantl-Temkiv. T. and Löndahl. J. "Airborne Microalgae: Insights, Opportunities and Challenges". *Applied and Environmental Microbiology* 82.7 (2016): Online.

31. Talde, U.K. "Airspora of Parbhani". *Indian Journal of Microbiology* 9 (1969): 55-58. Print.

32. Thomas F.L & Patrick. M. E. "Airborne algae and cyanobacteria", *Grana* 28.1(2009): 63-66. Online.

33. Tilak, S. T. "Aerophycology". *Indian Journal Aerobiology, Spl vol* (1992):11-22. Print.

34. Tilak S.T. and Vishwe,, D.B. "Report on airborne algae from Aurangabad". *Proc. 6th Ind. Sci. Cong. Part III* (1978): 25. Print
35. Verma, K.S. (1992). "Aerophycology at Jabalpur - A Preliminary Study". Indian Journal *Applied and pure Biology* 7.1(1992): 61-64. Print.
36. Verma, K. "Air-borne algae". *8th National Conference on impact of Airborne Microbes* (1996): 16 -18. Print
37. Wan –Loy, C., Tneh, S.Y. and Ambu, S. "A survey of airborne algae and cyano-bacteria within the indoor environment of an office building in Kuala Lumpur, Malaysia", *Grana* 52.3 (2013): 207-220. Online

Cite this article as:
Jogita T. P. Impact of Seasonal Variation on the Distribution Pattern of Coccoid and Filamentous Cyanophycean Aero-Algae from Nagpur, India. *Annals of Plant Sciences*.10.8 (2021) pp. 4269-4281.
DOI: http://dx.doi.org/10.21746/aps.2021.10.8.1

Source of support: Nil; **Conflict of interest:** Nil