Distribution and Diversity of Cyanobacteria of Industrial Effluents in Chhattisgarh State

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Received: 06.08.2017 **Accepted: 15.08.2017**

ABSTRACT

During the study of cyanobacterial biodiversity in industrial effluent, the effluents of three different industries such as Paper mill, Sugar mill and Fertilizer factory were assessed. The physico-chemical properties of all the effluents were observed more or less similar. Totally 39 strains of cyanobacteria were identified under present investigation, distributed in these different effluents. The maximum numbers of cyanobacteria (35 strains) were recorded from sugar mill followed by the effluents of paper mill (30 strains) and fertilizer factory (27 strains). Out of total 18 strains of cyanobacteria were observed in common to all the effluents, whereas, *Oscillatoria* with 07 species was found as abundant, followed by *Phormidium* (04 species), *Lyngbya* (03 species), *Microcystis* (03 species), *Aphanocapsa* (02 species) and *Synechococcus* with single species. The abundance of cyanobacteria in these effluents was due to favourable contents of oxidizable organic matter, rich calcium and abundant nutrients such as nitrates and phosphates with less dissolved oxygen. Indicator species from each effluent and their immense value for the future pollution abatement programs have also been discussed.

Keywords: *Cyanobacteria, Industrial effluents, Biodiversity*

INTRODUCTION

Cyanobacteria are a diverse group of prokaryotes that occupy a broad range of ecological niches by virtue of their age, having first appeared some 2.5 billion years ago. They belong to the most archaic organism on the earth. The Proterozoic era is sometimes called the "Age of cyanobacteria", because at that time cyanobacteria dominated the biota (Vanden hoek *et al*., 1993). As autotrophic prokaryotes, cyanobacteria are common inheritance of water logged area throughout the world and very significant due to nitrogen fixing ability of its heterocystous forms in nature. However certain non-heterocystous forms of cyanobacteria can dominant phytoplankton within water reservoirs. They show high flexibility and adapt themselves to varied environment because of their tropic independence to carbon in a number of cases. However, specific algae grow in specific environment and therefore their distribution pattern, ecology, periodicity, qualitative and quantitative occurrence differs widely. The abundance and composition of blue green algal population in surface waters of ponds and lakes have been discussed in many works and a conflicting general impression exists. It is said that they flourish well either in nutrient rich and warm water or at times in water with apparently low nutrient concentrations, subjected to higher temperature and bright light conditions. (Fogg, 1975; Mohapatra and Mohanty, 1992; Dwivedi and Pandey, 2002; Jafari and Gunale, 2006). In addition, pH, carbon dioxide, organic matter, alkalinity, nitrates and phosphates are factors important in determining the distribution of cyanobacteria. Cyanobacteria are also capable of abating various kinds of pollutants and have advantages as potential biodegradation organism (Boominathan, 2005).

Several reports are now available on the occurrence of algae in polluted waters (Tarar *et al*., 1990; Dwivedi and Pandey, 2002; Barinova, 2006; Raut *et al.,* 2010). However, the diversity in physical, chemical and biological characteristics of industrial effluents is so great that each waste water habitat requires a separate study. Knowledge of the physical, chemical and biological characteristics of an industrial waste is a preliminary and essential requirement for any attempt at chemical/ or biological treatment of waste. Hence, the present study was aimed to assess the physicochemical characteristics and cyanobacterial diversity of three different industrial effluents such as paper mill, fertilizer factory and sugar mill.

MATERIALS AND METHODS

For the study of cyanobacterial diversity, samples (both effluent and cyanobacteria) were collected from three different industrial areas such as paper mill- Orion paper & Industries limited Bilaspur, Chhattisgarh India. Fertilizer factory – BEC fertilizers Bilaspur, Chhattisgarh, India and Sugar mill – Bhoramdeo Sahakari Shakkar Karkhana Maryadit Kabirdham, Chhattisgarh, India. Effluent samples and cyanobacteria were collected in large sterilized container and zipped polythene bags respectively. Physico-chemical character of effluents was carried out according to standard methods (APHA, 1995). Standard microbiological methods were followed for the isolation of cyanobacteria. Cyanobacterial samples were microscopically observed and stored in bottles treated with 10% HCL. It is then cloned for laboratory culture intensively under sterile condition using Chu-10, BG-11 & BG-110 medium by standard procedure adopted after Vaishampayan, A. (1991). The inoculated plates were incubated in culture room maintained at 25 $\pm 2^{o}C$ fitted with cool white fluorescent tube emitting 2500 lux for 18 hours a day. The isolated cyanobacteria were identified with the help of classical manuals of Desikachary (1959) and Anand (1989).

RESULTS AND DISCUSSION

Through proper collection and careful identification 39 strains of cyanobacteria, distributed in such three different source of industrial effluent were recorded and categorized on the basis of their thallus organization and presence of heterocyst (Table 1) sugar mill recorded the maximum number of species (35) followed by paper mill (30) and Fertilizer factory (27). Form the analysis of all the identified samples Heterocystous forms were identified in all the three effluents samples. *Anabaena anomala, Anabaena cariabilis, Anabaena oryzae, Anabaena spherical, Calothrix elenkinii, Nostoc calcicol, Nostoc carneum, Nostoc ellipsosporum, Nostoc hatei, Nostoc muscorum and Nostoc spongiaeforme,* were found in paper mill. *Anabaena anomala, Anabaena cariabilis, Anabaena oryzae, Calothrix elenkinii, Nostoc carneum, Nostoc ellipsosporum, Nostoc hatei, Nostoc muscorum, Nostoc spongiaeforme, Aulosira prolifica, Cylindrospermum indentatum, Gloetrichia echinulata, Rivularia aquatic* and *Scytonema bohneri* were found in fertilizer factory and *Anabaena anomala, Anabaena cariabilis, Anabaena oryzae, Calothrix elenkinii, Nostoc carneum, Nostoc ellipsosporum, Nostoc hatei, Nostoc muscorum, Nostoc spongiaeforme, Cylindrospermum indentatum, Scytonema bohneri, Sytonema stuposum, Anabaena spherical* and *Nostoc calsicola* were found in sugar mill. Physico-chemical characteristics of different industrial effluents were analysed and observed data have been mentioned in Table 2 and monthly occurrence of Cyanobacterial species has been incorporated in Table 3 and 4.

Table 1
Occurrence of Cyanobacterial flora in different industrial effluents
[+ (Observe), - (Not observed)]

Nature	Thallus	Cyanobacterial Strains	Industrial effluents		
			Paper Mill	Fertilizer Factory	Sugar Mill
Non-Heterocystous	Unicellular	1. *Aphanocapsa crasa*	+	+	+
Non-Heterocystous	Unicellular	2. *Aphanocapsa grevillei*	+	+	+
Non-Heterocystous	Unicellular	3. *Aphanocapsa microscopic*	+	+	+
Non-Heterocystous	Unicellular	4. *Aphanothece saxicola*	+	-	+
Non-Heterocystous	Unicellular	5. *Chroococcus micrococcus*	-	+	+
Non-Heterocystous	Unicellular	6. *Synechocystis aquatilis*	-	+	+
Non-Heterocystous	Colonial	7. *Microcystis aeriginosa*	+	+	+
Non-Heterocystous	Colonial	8. *Microcystis orrissica*	+	-	+
Non-Heterocystous	Colonial	9. *Microcystis robusta*	+	-	+
Non-Heterocystous	Colonial	10. *Gleocapsa luteo-fusca*	+	+	-
Non-Heterocystous	Filamentous	11. *Lyngbya bergei*	+	+	+
Non-Heterocystous	Filamentous	12. *Lyngbya allorgei*	+	-	+
Non-Heterocystous	Filamentous	13. *Lyngbya infixa*	-	+	+
Non-Heterocystous	Filamentous	14. *Oscillatoria animalis*	+	+	+
Non-Heterocystous	Filamentous	15. *Oscillatoria brevies*	+	+	+
Non-Heterocystous	Filamentous	16. *Oscillatoria chlorine*	+	-	+
Non-Heterocystous	Filamentous	17. *Oscillatoria curviceps*	+	-	+
Non-Heterocystous	Filamentous	18. *Oscillatoria ornate*	+	+	+
Non-Heterocystous	Filamentous	19. *Oscillatoria princeps*	+	+	+
Non-Heterocystous	Filamentous	20. *Oscillatoria splendid*	+	-	+
Non-Heterocystous	Filamentous	21. *Phormidium bohneri*	+	-	+
Non-Heterocystous	Filamentous	22. *Phormidium retzii*	+	+	+
Heterocystous	Filamentous	23. *Aulosira prolifica*	-	+	-
Heterocystous	Filamentous	24. *Anabaena anomala*	+	+	+
Heterocystous	Filamentous	25. *Anabaena cariabilis*	+	+	+
Heterocystous	Filamentous	26. *Anabaena oryzae*	+	+	+
Heterocystous	Filamentous	27. *Anabaena spherical*	+	-	+
Heterocystous	Filamentous	28. *Calothrix elenkinii*	+	+	+
Heterocystous	Filamentous	29. *Cylendrospermum indentatum*	-	+	+
Heterocystous	Filamentous	30. *Gloeotrichia echinulata*	-	+	-
Heterocystous	Filamentous	31. *Nostoc calcicola*	+	-	+
Heterocystous	Filamentous	32. *Nostoc carneum*	+	+	+
Heterocystous	Filamentous	33. *Nostoc ellipsosporum*	+	+	+
Heterocystous	Filamentous	34. *Nostoc hatei*	+	+	+
Heterocystous	Filamentous	35. *Nostoc muscorum*	+	+	+
Heterocystous	Filamentous	36. *Nostoc spongiaeforme*	+	+	+
Heterocystous	Filamentous	37. *Rivularia aquatic*	-	+	-
Heterocystous	Filamentous	38. *Scytonema bohneri*	-	+	+
Heterocystous	Filamentous	39. *Scytonema stuposum*	-	-	+

Table 2
Physico-chemical Characteristics of effluent collected from paper mill, fertilizer factory and sugar mill.

Parameters	Sampling Sites		
	Paper mill	Fertilizer factory	Sugar mill
Temperature (°C)	32	29	30
pH	7.9	8.9	6.4
Turbidity	24.67	18.61	39.56
Electric conductivity	0.99	0.83	0.62
Total Alkalinity	247.9	208.1	161.1
Total Acidity	25.2	31.9	40.6
DO	0.90	Nil	1.26
BOD	277.1	885.4	315
COD	650.3	512.1	570
Chloride	541.1	590.9	205.0
Total Hardness	270.8	232.4	183.7
Calcium	100.2	89.5	105
Magnesium	41.5	29.7	99
Nitrate Nitrogen	63.7	49.7	134
Nitrite Nitrogen	56.2	39.2	64
Phosphate	33.4	3.9	20.4
TDS	2404.4	1862.3	1150.3
TSS	658.4	421.9	365.8

Except Temperature, pH and Electric conductivity all values are expressed in mgl^{-1}

Table 3
Monthly variation and occurrence of cyanobacterial strains in different effluents

Months	Paper mill		Fertilizer factory		Sugar mill	
	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17
July	2, 3, 9, 10, 21, 22	2, 3, 10, 21, 22	10, 11, 15	2, 10, 15, 22	2, 6, 13, 18, 21	3, 11, 12, 21, 31
August	1, 2, 11	4, 10, 11, 12	11, 14, 22	1, 10, 14, 22	11, 12, 13, 21, 22	11, 12, 14, 19, 22
September	11, 14, 15, 16, 24, 25, 31	1, 2, 15, 22, 24, 27, 31, 32, 33, 34	1, 2, 7, 15, 24, 25, 33, 35, 36	1, 2, 7, 24, 29, 32, 36	2, 3, 13, 20, 27, 34, 35, 36	1, 2, 7, 13, 24, 25, 36
October	4, 8, 11, 16, 24, 25, 31, 33	1, 2, 8, 11, 22, 24, 27, 28, 31, 34	7, 11, 15, 23, 25, 26, 28, 36, 37	7, 11, 22, 23, 26, 28, 29, 32, 36	7, 8, 13, 20, 22, 32, 24, 27	8, 11, 14, 13, 22, 24, 29, 34, 36, 38
November	4, 8, 11, 15, 22, 24, 25, 36	1, 3, 7, 16, 22, 24, 26, 31	1, 3, 7, 14, 23, 26, 30, 32	1, 2, 5, 22, 24, 30, 36	1, 2, 7, 14, 18, 24, 27, 32, 35	1, 2, 7, 14, 22, 24, 26, 35, 36, 38
December	7, 9, 11, 18, 19, 20, 26	1, 2, 7, 9, 18, 19, 22, 24, 27	3, 10, 14, 22, 26, 32, 33, 34	1, 6, 7, 14, 22, 26, 33, 36, 37	1, 2, 5, 11, 22, 25, 26, 34, 35, 36	2, 3, 7, 14, 25, 28, 33, 34, 36, 39
January	1,2, 8, 11, 17, 24, 25, 31	1, 3, 4, 10, 24, 25, 32	1, 2, 7, 13, 24, 25, 28, 33, 37	1, 3, 11, 14, 24, 25, 28, 34, 35	3, 4, 7, 17, 24, 29, 31, 39	1, 4, 7, 17, 24, 25, 32
February	3, 4, 12, 14, 26, 31, 36	2, 3, 10, 14, 17, 27, 31, 34	3, 5, 12, 18, 19, 25, 32, 33, 36	1, 2, 18, 19, 25, 28, 32, 35	1, 3, 7, 20, 26, 36	4, 8, 11, 16, 26, 28, 33, 34
March	7, 12, 14, 22, 26, 33, 34	1, 9, 12, 22, 25, 33	1, 2, 7	6, 7, 13, 22	1, 3, 16, 20, 27	4, 5, 8, 13, 17, 21, 27
April	1, 3, 7, 14, 21, 22	3, 4, 7, 20, 22, 25	1, 7, 13	2, 7, 14	1, 2, 7, 17	1, 6, 7, 13, 19,
May	1, 3, 8, 17, 22, 26	1, 2, 7, 17, 21, 22	1, 2, 14, 22	1, 10,	2, 7, 8, 21, 22	1, 2,7, 8, 21, 22
June	7, 9, 20, 21	3, 9, 12, 20, 21	7, 14, 22	2, 3, 21, 22	6, 7, 9, 20, 31	2, 7, 12, 20, 34

Table 4
Monthly occurrence of Cyanobacterial strains in different effluents

Months	No. of Cyanobacterial strains different effluents		
	Paper mill	Fertilizer factory	Sugar mill
July	06	05	09
August	06	05	07
September	14	11	12
October	14	12	14
November	14	13	14
December	13	13	13
January	10	15	11
February	12	13	12
March	10	05	11
April	08	06	08
May	09	05	08
June	06	05	08
Nature wise			
Non-Heterocystous	19	15	21
Heterocystous	11	13	14

The abundance of cyanobacteria is attributed to favourable contents of oxidizable organic matter and less dissolved oxygen (Table 2) that observation supports Boominathan (2005) and Vijaykumar *et al.* (2005). Observations of Kannan (2006) and Kling *et al.*, (2012) suggest that cyanophyceae grow luxuriantly with great variety and abundance in in ponds rich in calcium. The present data in all the three effluents also showed that calcium is possibly one of the factors (Table 2). Whether it plays its role individually or in combination with other factor complexes can only be understood by culture studies. Besides calcium, high amounts of oxidizable organic matter, traces of dissolved oxygen, considerable amounts of nitrate and phosphates in all the effluents investigated were probably the factors favouring the growth of cyanobacteria as suggested Nazneem (1980), Venu *et al.* (1984), Boominathan (2005), Murugesan (2005) and Vijayakumar *et al.* (2005). Venkateswarlu (1976), Mohapatra & Mohanty (1992) and Subramaniyan *et al.*, (2007) reported that hgh values of BOD, COD, phosphates and nitrates with very low DO Favoured the growth of cyanobacteria than any other algae. Their finding were supported by the observations of Boominathan (2005), Vijayakumar *et al.* (2005) and Jegnathan (2006) in paper mill, sugar mill and fertilizer factory respectively. In the present study also, all the effluents showed a considerable amount of nitrates and phosphates, with increased level of BOD and COD along with very low DO level. This could be the reason for the flourishing growth of cyanobacteria in the effluents investigated. Moreover, Stewart and Parson (1970) observed rapid growth of cyanobacteria in the microaerophilic conditions. Fogg *et al.* (1973) inferred that the correlation between abundance of planktonic cyanobacteria and high concentration of dissolved organic matter may be due to the depletion of oxygen. Rai and Kumar (1976b) reported that the genus *Oscillatoria* has been found to be very tolerant to pollution which frequently inhabits the polluted water. Similarly, Singh and Saxena (1969) found Oscillatoria and *Phormidium* were the most dominant genera in sewage. Present study also confirmed their observation as *Oscillatoria, Phormidium, Aphanocapsa* along with *Nostoc,* were found dominating all the effluents studied (Table 3). Pannington *et al.* (2001), Barinova (2006) and Raut *et al*., (2010) have emphasized the use of algae as reliable indicators of pollution.

There are certain members of cyanobacteria which are tolerant to organic pollution and resist environmental stress caused by the pollutants. Such species can be used as 'Marker species' or indicators of particular habitat (Prasad and Saxena, 1980, Izaguirre *et al.,* 2007). Indicator species are of immense value for the future pollution abatement programmes. Out of the indicator species observed in different effluents, *Oscillatoria and Phormidium* were found in more percentage (Table 4) and thus considered as the indicators of the effluents analysed. Compared to other species they were seen growing and multiplying profusely. Their higher representation indicates their capacity to thrive in this type of manmade habitat.

CONCLUSION

On the basis of present findings and the forgoing discussion, it may be concluded that physico-chemical characters together with biological monitoring provided converging lines of evidence for evaluation of polluted habitats in this case as in some other studies (Eaton *et al*., 2005; Vijaykumar *et al*., 2005 and Raut *et al.,* 2010).

ACKNOWLEDGEMENTS

Author is thankful to the Principal, Govt. E. Raghavendra Rao Postgraduate Science College, Bilaspur (C.G.) for providing research facilities and encouragement to carry out the present investigation.

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