



Changing climate and its effect on Cyanobacteria

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General Note

Article is recommended to print as color version in recycled paper. *Save Trees, Save Climate.*

ABSTRACT

Cyanobacteria are the most primitive life form on earth, play major role in scavenging volume of carbon dioxide and produces maximum oxygen in the atmosphere and metabolites through photosynthetic process. Summer month and elevated water temperature for longer period in combination with pollutants and liquid waste discharge created suitable environmental condition for growth of cyanobacteria. During the survey, altogether 105 cyanobacteria comprising 93 species, 09 variety and 03 forms were identified in samples collected from 55 water bodies of Maldah District. Out of 93 species, 37 species have been scrutinised for properties of benefit and nuisance. *Oscillatoria* was recorded most dominant genus followed by *Anabaena* and *Microcystis*. Property-wise maximum 24 species were recorded as indicators of pollution followed by 14 species for antibiotic, medicines, vitamins, etc., 10 species for lipid and 4 species for protein and for other beneficial properties like carbohydrates and bio-fertilizer & land reclamation recorded in 3 species and metal removal and indicator of clean water and taste and odor recorded in 2 species. However, as 13

species were recorded under the category toxin necessary precautionary measures have been suggested for preventing from any deleterious impacts likely to cause due to toxins of varying nature as reported for its production by the bloom forming species. Overall, as compared to the beneficial properties, nuisance species were evaluated 22.89% only. Hence, keeping in view of 77.10% species of beneficial properties as recorded may help in betterment of mankind in future.

1. INTRODUCTION

Cyanobacteria are prokaryotic, unicellular to filamentous, ranging from 0.5 μm to 60.0 μm , among most capable to form sheath to bind other cells or filaments into colonies and attribute as flattened, cubed, spherical, sub-spherical, rounded or elongated shapes and obtain energy through photosynthesis. Most filamentous thallus contains heterocysts, found with or without trichome or hormogones, endospore and pseudo-parenchyma. The pigments in combination with phycobilin and chlorophyll produces characteristic blue-green colour from which common name "blue-green algae" has been derived and called in early days belonging to the class Myxophyceae and or Cyanophyceae. However, as per its prokaryotic nature they are also called as blue-green bacteria or Cyanobacteria or Cyanoprokaryota. They are ubiquitous in nature and found distributed all over land and water system often in such an environment where there is no other vegetation possibly due to their adaptive capability to extreme adverse environmental conditions with respect to different environmental factors like temperature (Thomas and Gonzalves, 1965a, b, c, d, e, f, g and Vasishta, 1968), pH (Prasad *et al.*, 1978), salinity (Singh *et al.*, 2009), availability of nutrients and pollution load (Palmer, 1980; Kant, 1983; Sengar and Sharma, 1987; Tripathi, 1989; Shaji and Patel, 1991, 1992; Suthar and Prasad, 1992; Kohli *et al.*, 1994; Sinha, 2001 and Gupta and Shukla, 2002), etc.

They are first primitive form of life on earth, may have been emerged / originated during 3.5 billion years ago (Cassidy, 2009), predominant during Precambrian era (Schopf, 1975, 1994, 1996) and during early days (during 2.4 billion years ago) produced about 90% of oxygen in the Earth's atmosphere using carbon dioxide through the process of photosynthesis. Hence, they are considered important components of the aquatic ecosystem and act as an architect of earth's atmosphere as they are founder of the aquatic food-chain. However, its growth and or formation of blooms in water depends on the availability of different suitable environmental conditions in combination with light (solar energy), temperature, total solids including suspended and dissolved solids, turbidity and transparency, pH, flow and stable conditions, dissolved oxygen, nutrients like nitrogen, phosphorous, etc. as well as organic substances. Simple changes in any of the above environmental factor in water body directly or indirectly may cause great variation in its species diversity and abundance (Lois, 1976 and Puttaiah *et al.*, 1985; Gupta, 2015) and bloom formation due to eutrophication (Hallegraeff, 1993; Gupta and Kumar 2005). However, now, scientists believe that high temperature possibly due to global warming and alteration in climate change along elevated high water temperature for longer period may cause more and frequent bloom formation.

The cyanobacterial blooms keep floating on surface of water due to presence of gas vesicles in which air is remain trapped and provide buoyancy (Walsby, 1994; Oliver, 1994; Walsby *et al.*, 1987), coats stagnant water bodies and reservoirs in hot summer months keep thrive in changing climate and trigger more sickness by excretion of secondary metabolites (diverse type of toxins) as a result of 40 to 50 bloom forming species are linked to digestive system, neurological, liver diseases in aquatic and terrestrial fauna including humans when they come in contact or use and even they may also kill (Komárek and Anagnostidis, 1999, 2005; Kumar and Gopal, 2003; Gupta and Kumar, 2005 and Gupta and Husain, 2007). This is one of the worldwide problems due to increased concentration of nutrients in water and subsequent impacts on living beings, most government and NGO's have taken initiatives for R & D research, formulation of regulation and awareness programme to mitigate the problem for the betterment of the mankind.

Keeping these in view, different habitats and diverse type of freshwater bodies of Maldah District were surveyed for identification of nuisance causing species for alarming early warning to prevent from its impacts, utilization for welfare of mankind and further research/reference.

2. MATERIAL AND METHODS

Maldah District is situated in West Bengal between 24°41'20" and 25°32'08" N. Lat. and 87°45'50" and 88°28'10" E. Long., extends over 3733.17 km² with total population 32,90,468 as per Census, 2001 (BAES, 2005). During the survey all administrative blocks of Maldah District namely Ratua-I, Ratua-II, Harishchandrapur-I, Harishchandrapur-II, Chanchal-I, Chanchal-II, Manikchak, Gazol, Habibpur, Bamangola, Old Maldah, English Bazar and Kaliachak were visited and samples were sampled from 55 water bodies (places) comprising 32 bils (Amkhaki, Liltua, Barabilla, Singera, Ghogha, Chakla, Bochamari, Ashi Dob, Makaiya, Hazartakia, Janipurkur,

Adhsoi, Manna, Dekul, Meetna, Singar, Sanak, Singer, Kendha, Kuchla, Bhatia, Chand, Tarkeshwar, Nawabganj, Balotuli, Jalsukha, Laxmipur, Chattara, Garhal, Adhsoi, Pulintola and Madhaipur); 9 ponds / pukurs (Bhadobartola, Damua, Shivrampalli, Rohni, Meenatulla, Jorkuppa, Kuppa, Samda and Salamidarwaza); 7 dighis (Raikhan, Thinnagar, Kalua, Paradhala, Sukan, Bara and Chota Sagar); 5 sites in rivers like Ganga (Mahadhap and Gopalpur); Kalindri (Bhaluka), Fulhar (Sankatala Ghat; Mahananda (Alal Bridge) and Tangan (Madhaipur) and 2 jhils (Bochahi and Mahadhap).

Atmospheric and water temperature were measured by thermometer graduated up to 110 °C and pH of water was recorded on the spot using high quality BDH pH paper strips (APHA, 1998). About area and depth of water bodies, data were recorded from official record of the concerned departments. Cyanoprokaryotes samples were sampled randomly by towing Phytoplankton Net to a distance of 1.0 m to 5.0 m depending up on depth of water bodies and were preserved by adding 2 to 3 drops of 4% formalin solution in 15.0 ml screw cap Borosil glass specimen vials to avoid any chemical reaction. Specimen vials were further marked by glass marker about sample number, location, type of water bodies and date of collection. Specimens were observed under Leica DM 2500 Microscope with annotation using Leica QWin V 3.2 Image Processing and Analysis Software and photomicrographs were taken by DFC 500 digital camera for necessary parameters like shape and size required were measured and taken into account for identification. Specimens were identified by consulting standard books and monograph of Geitler (1932), Fritsch (1935), Tiffany and Britton (1952), Desikachary (1959, 1972), Palmer (1980), Prescott (1982), Kant and Gupta (1998) and Komárek (2005).

3. RESULTS AND DISCUSSIONS

Maximum numbers of water bodies were surveyed in Ratua followed by English Bazar, Old Maldah, Harishchandrapur and Chanchal blocks while one each water body was surveyed in Bamongola and Kaliachak blocks. Most of water bodies like jhils of Rambari, Gopalpur and Hilsamari have been engulfed by river Ganga due to changes in its discharge. Some of water bodies have either been dried and or are on the verge of drying as water depth ranged maximum from 1.0 m to 3.0 m. All water bodies are receiving nutrients by surface runoff from nearby agricultural fields and domestic wastewaters from local inhabitant which entail cyanobacteria to occur low to high density with diversity in its species composition in water depending upon concentration of nutrients, kind of pollutants, physico-chemical characteristics of water and current, interferences of aqua and pisci-culture practice, cultivation of Makhana, etc.

The atmospheric and water temperature during survey were ranged from 21 °C to 31 °C and 20 °C to 27 °C respectively during winter season and from 28 °C to 36 °C and 26 °C to 35 °C respectively during summer season. pH of water of different water bodies ranged from 5.0 to 8.0 in winter and 6.0 to 8.5 during summer season depicted in Table 1. As per recorded atmospheric and water temperature during the survey there is an increase in difference in temperatures ranging from 7 °C to 5 °C and 6 °C to 8 °C during winter and summer season respectively. Summer month and elevated water temperature in combination with pollutants and liquid discharges created suitable environmental condition for growth of cyanobacteria.

Table 1 general features of water bodies surveyed in Maldah district, West Bengal

S. No.	Name of Water Bodies	Environmental Factors							
		During Summer		Temperature (°C)				pH	
				Atmospheric		Water			
		Area of Water bodies (in hec.)	Depth of Water (in m)	Win.	Sum.	Win.	Sum.	Win.	Sum.
I	Bils								
1.	Amkhaki (Kanchan Nagar, Ratua-I)	-	-	25.0	36.0	21.0	35.0	6.5	7.0
2.	Liltua (Kanchan Nagar, Ratua-I)	0.65	1.0	25.0	34.0	22.0	33.0	5.5	6.5
3.	Makaiya (Bhaluka, Ratua-I)	-	-	28.0	35.0	25.0	34.0	7.5	7.0
4.	Barabilla (Arai Danga, Ratua-II)	10.19	3.0	25.0	31.0	23.0	29.0	6.5	6.5

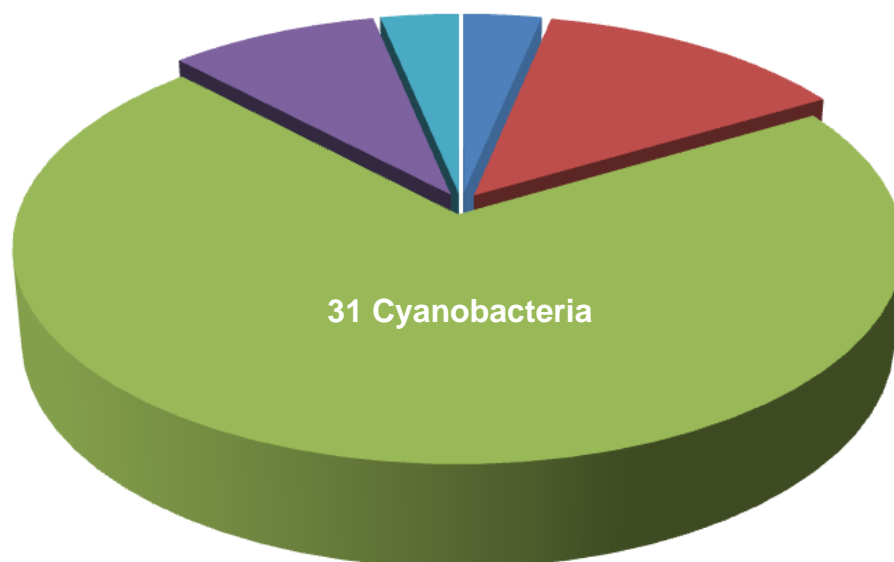
5.	Garhal (Haripur, Chanchal-I)	-	-	28.0	-	24.0	-	6.5	-
6.	Singera (Ganga Devi, Chanchal-II)	-	-	27.0	30.0	25.0	28.0	6.8	6.5
7.	Ghogha (Ganga Devi, Chanchal-II)	1.0	1.0	28.0	30.0	25.0	29.0	6.5	7.0
8.	Chakla (Ganga Devi, Chanchal-II)	-	-	28.0	31.0	25.5	30.0	6.5	6.8
9.	Bochamari (Bowalia, Chanchal-II)	-	-	29.0	33.0	24.0	32.0	6.5	7.0
10.	Hazartakia (Mobarakpur Gram, Harishchandrapur-I)	9.0	2.2	29.0	34.0	26.0	32.0	6.5	7.0
11.	Adhsoi (Pachla, Harishchandrapur-I)	-	-	25.0	36.0	23.0	34.0	6.5	6.0
12.	Janipukur (Serpur, Harishchandrapur-I)	-	-	30.0	35.0	27.0	34.0	7.5	6.0
13.	Ashi Doab (Uttar Harishchandrapur, Harishchandrapur-I)	-	-	-	30.0	-	29.0	-	6.8
14.	Manna (Bhaluka, Harishchandrapur-II)	5.0	1.5	27.0	33.0	26.0	32.0	7.0	7.5
15.	Dhekul (Khidirpur, Harishchandrapur-II)	8.0	2.0	28.0	36.0	26.0	34.0	6.5	7.5
16.	Meetna (Barnali, Harishchandrapur-II)	1.5	1.05	24.0	33.0	23.0	32.0	6.5	7.0
17.	Singsar (Chandipur, Harishchandrapur-II)	-	-	26.0	34.0	24.5	32.0	6.0	6.8
18.	Sanak (Chandipur, Harishchandrapur-II)	3.25	1.5	26.0	33.0	24.0	32.0	6.0	6.0
19.	Pulintola (Chandipur, Manikchak)	30.50	3.0	27.0	-	23.0	-	7.2	-
20.	Kuchla (Eklakhi, Gajol)	-	-	26.0	31.0	24.0	29.0	6.5	7.0
21.	Batia (Bilhatia, Gajol)	8.0	1.5	26.0	34.0	23.0	32.0	7.2	7.0
22.	Singer (Saluka, Gajol)	-	-	30.0	34.0	23.0	33.0	7.0	6.5
23.	Kendha (Saluka, Gajol)	-	-	31.0	34.0	27.0	32.0	6.0	6.5
24.	Chand (Jagarnathpur Gram, Habibpur)	-	-	30.0	31.0	27.0	29.5	6.0	6.5
25.	Madhaipur (Madhaipur, Old Maldah)	-	-	27.0	-	25.0	-	5.0	-
26.	Nawabganj (Nawabgan, Old Maldah)	-	-	23.0	33.0	22.0	32.0	6.0	6.5

27.	Tarkeshwar (Nawabgan, Old Maldah)	-	-	24.0	33.0	23.0	32.0	6.0	6.0
28.	Balotuli (Jatra Danga, Old Maldah)	-	-	28.5	30.0	25.5	29.5	7.5	6.0
29.	Jalsukha (Kajigram, English Bazar)	-	-	27.0	33.0	25.0	30.0	6.5	6.8
30.	Beachcol (Kamlabari, English Bazar)	-	-	Dry	Dry	Dry	Dry	Dry	Dry
31.	Chattara (Uttar Ramchandrapur, English Bazar)	-	-	24.0	32.0	22.0	31.0	7.0	7.6
32.	Lakshmipur (Lakshmipur, English Bazar)	-	-	25.0	33.0	20.5	31.0	6.5	7.0
II	Ponds								
1.	Bhadobartola	-	-	29.0	36.0	27.0	35.0	8.0	8.5
2.	Damua (Konar, Harishchandrapur-I)	-	-	28.0	29.0	26.0	28.0	6.5	6.5
3.	Jorkuppa (Karmanigram, English Bazar)	-	-	24.0	30.0	21.0	32.0	6.5	7.0
4.	Kuppa (Karmanigram, English Bazar)	-	-	27.0	32.0	24.5	30.0	6.5	7.0
5.	Samda (Samda, English Bazar)	-	-	26.5	32.0	24.0	31.0	6.8	7.0
6.	Salami Darwaza (Maldah Fort, Kaliachak-I)	-	-	28.0	34.0	24.0	33.0	7.0	7.5
7.	Shivrampalli (Mangalbari, Old Maldah)	-	-	27.0	34.0	24.0	33.0	7.0	7.5
8.	Rohini (Jatra Danga, Old Maldah)	-	-	28.0	35.0	26.0	34.0	7.0	7.5
9.	Meenatula (Mohamadpur, Old Maldah)	-	-	28.0	34.0	25.0	33.0	7.5	7.8
III	Dighis								
1.	Raikha (Eklakhi, Gajol)	-	-	27.0	34.0	25.0	33.0	6.0	6.5
2.	Thinnagar (Daulatipur, Bamongola)	-	-	25.0	32.0	24.0	31.0	6.0	6.5
3.	Paradhala (Paradhala, Old Maldah)	-	-	26.0	35.0	24.0	34.0	6.5	7.5
4.	Sukan (Sukan, Old Maldah)	-	-	30.0	36.0	26.0	33.0	6.5	7.5
5.	Kalua (Narayanpur, Old Maldah)	-	-	25.0	35.0	23.0	34.0	7.0	6.5

6.	Bara Sagar (Kamlabari, English Bazar)	-	-	27.0	31.0	25.0	30.0	6.0	7.2
7.	Chotta Sagar (Nadirkhani, English Bazar)	-	-	27.0	33.0	23.0	32.0	6.5	6.5
IV	Rivers								
1.	Ganga* (Mahadhap, Ratua-II)	-	-	26.0	-	25.0	-	7.0	-
2.	Ganga** (Gopalpur, Manikchak)	-	-	21.0	32.0	20.0	31.0	6.5	7.0
3.	Kalindari (Bhaluka, Harishchandrapur-II)	-	-	26.0	33.0	23.0	32.0	7.2	6.5
4.	Fulhar (Sankatala Ghat, Manikchak)	-	-	26.5	31.5	23.0	30.0	6.8	6.5
5.	Mahananda (Alal Bridge, Gajol)	-	-	27.0	28.0	23.0	26.0	7.2	6.5
6.	Tangan (Madhaipur, Old Maldah)	-	-	Dry	Dry	Dry	Dry	Dry	Dry
V	Jhils								
1.	Bochahi (Kanchan Nagar, Ratua-I)	0.7	1.0	26.0	33.0	24.0	32.0	6.5	7.0
2.	Mahadhap (Mahadhap, Ratua-II)	-	-	25.0	-	24.0	-	6.5	-

Sum. = Summer; Win. = Winter; * = Rambari Jhil and ** = Gopalpur and Hilsamari Jhils have been engulfed by river Ganga.

NOSTOCALES



CHROOCOCCALES

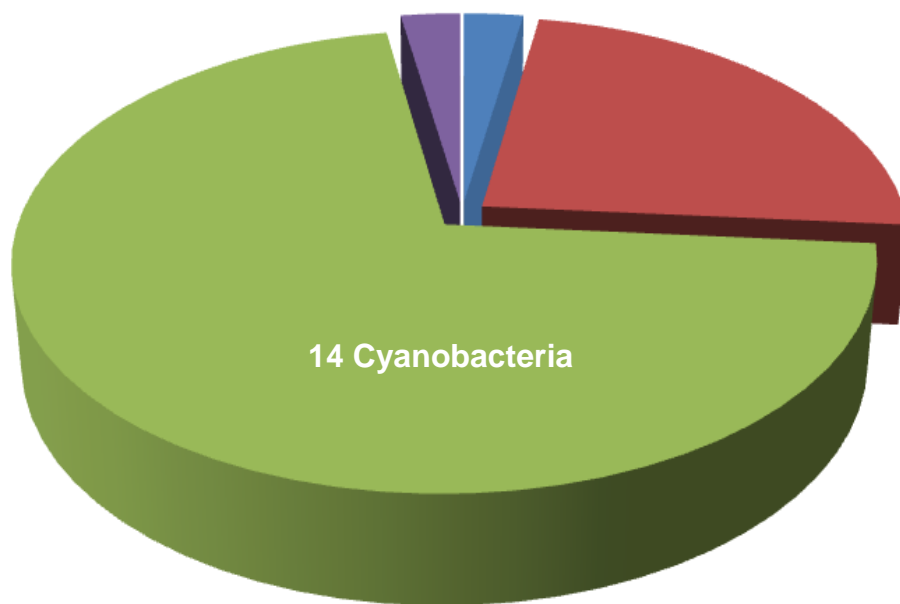


Figure 1 Order-wise number of Cyanoprokaryotes identified

During survey, altogether 105 cyanobacteria comprising 93 species, 09 variety and 03 forms belonging to 22 genera of 05 Family were identified. Order-wise number of cyanobacteria have been depicted in Fig. 1. So far species dominance is concerned, maximum 31 cyanobacteria comprising 25 species with 4 var. and 2 f. species were recorded for genus *Oscillatoria* (*O. acuta* Bürhl & Biswas, *O. agardhii* Gomont, *O. amoena* (Kütz.) Gomont, *O. amphibia* C.Agardh ex Gomont, *O. amphigranulata* Goor, *O. angusta* Koppe, *O. chalybea* G.Mertens ex Gomont, *O. formosa* Bory ex Gomont, *O. geitleriana* Elenkin, *O. geminata* Menegh. ex Gomont, *O. limnetica* Lemmerm., *O. limosa* C.Agardh ex Gomont, *O. minnesotensis* Tilden, *O. okenii* C.Agardh ex Gomont, *O. princeps* Vaucher ex Gomont, *O. prolifica* Gomont, *O. proteus* Skuja, *O. quadripunctulata* Brühl & Biswas, *O. raoi* DeToni, *O. redekei* Goor, *O. rubescens* DC. ex Gomont, *O. splendida* Grev. ex Gomont, *O. subbrevis* Schmidle, *O. tenuis* C.Agardh ex Gomont and *O. willei* N.L.Gardner; *O. ornata* var. *crassa* C.B.Rao, *O. pseudogeminata* var. *unigranulata* Biswas, *O. tenuis* var. *natans* Gomont and *O. tenuis* var. *tergestina* Rabenh. ex Gomont and *O. formosa* f. *loktakensis* Brühl & Biswas and *O. perornata* f. *attenuata* Skuja) followed by 14 cyanobacteria comprising 13 species with 1 f. species for genus *Anabaena* (*A. affinis* Lemmerm., *A. ambigua* C.B.Rao, *A. anomala* F.E.Fritsch, *A. aphanizomenoides* Forti, *A. azollae* Strasb., *A. constricta* (Szafer) Geitler, *A. fertilissima* C.B.Rao, *A. flos-aquae* Bréb. ex Bornet & Flahault, *A. inaequalis* (Kütz.) Bornet & Flahault, *A. iyengarii* Bharadwaja, *A. oryzae* F.E.Fritsch, *A. planctonica* Brunth., *A. volzii* Lemmerm and *A. vaginicola* f. *fertilissima* B.N.Prasad), 11 species for genus *Microcystis* (*M. aeruginosa* (Kütz.) Kütz., *M. flos-aquae* (Wittr.) Kirchn., *M. ichthyoblabe* Kütz., *M. novacekii* (Komárek) Compère, *M. panniformis* Komárek, *M. protocystis* Crow, *M. pseudofilamentosa* Crow, *M. robusta* (H.W.Clark) Nygaard, *M. stagnalis* Lemmerm., *M. viridis* (A.Braun) Lemmerm. and *M. wesenbergii* (Komárek) Komárek) were recorded. These species along with others were abundantly developed in mass and strongly predominating over other species in community and frequently-appearing in majority of the samples.

Almost all cyanobacteria are having economic importance including scavenging carbon dioxide up to 71%, releases oxygen and store metabolites, remove pollutants and balance the aquatic ecosystem in many ways. Among many species are capable to form and bear beneficial properties which help in socio-economic development, good health, monitoring of resources, etc. However, a few species also occur in water bodies which causes nuisance as they clog filter beds, disrupt drinking water supply as well as also form blooms in water and produces varying range of toxins which have deleterious effect on living beings even causing death too. So, attempt have been made and scrutinized 37 such species which have been recorded during the survey keeping in view of their

beneficial properties like source of protein, carbohydrates, lipids, antibiotic, medicines, vitamins, etc., bio-fertilizer & reclamation of land, metal removal and as indicator of clean water, taste and odor, pollution including industrial wastewater as reported by Palmer (1980), Becker (1994), Brettum and Andersen (2005), Ray (2006) and Subramaniyan *et. al* (2007) and depicted in Table 2. Out of listed 37 species, *Microcystis aeruginosa* (Kütz.) Kütz., *Nostoc calcicola* Bréb. ex Bornet & Flahault and *N. linckia* Bornet ex Bornet & Flahault recorded for 5 properties ; *Anabaena planctonica* Brunth., *Nostoc ellipsosporum* Rabenh. ex Bornet & Flahault, *Oscillatoria amoena* (Kütz.) Gomont, *O. rubescens* DC. ex Gomont and *O. tenuis* C.Agardh ex Gomont recorded for 4 properties and *Anabaena flos-aquae* Bréb. ex Bornet & Flahault, *Oscillatoria princeps* Vaucher ex Gomont, *O. splendida* Grev. ex Gomont, *Phormidium tenue* (Menegh.) Gomont and *Synechocystis pevalekii* Erceg. recorded for 3 properties. Fifteen species were recorded for 1 property followed by 9 species for 2 properties.

Table 2 Cyanoprokaryotes occurred in water bodies of Maldah scrutinized for their beneficial and nuisance properties

S. No.	Name of Cyanoprokaryotes	Properties										
		Beneficial									Nuisance	
		Protein	Carbohydrates	Lipids	Antibiotic, Medicines, Vitamins, etc.	Bio-fertilizer & Land Reclamation	Metal Removal	As Indicator			Filter Bed Clogging	Toxic
								Clean Water	Taste and Odor	Pollution		
1.	<i>Anabaena affinis</i> Lemmerm.											+
2.	<i>Anabaena constricta</i> (Szafer) Geitler									+		
3.	<i>Anabaena fertilissima</i> C.B.Rao				+					+		
4.	<i>Anabaena flos-aquae</i> Bréb. ex Bornet & Flahault									+	+	+
5.	<i>Anabaena planctonica</i> Brunth.				+				+	+		+
6.	<i>Lyngbya aerugineo-coerulea</i> (Kütz.) Gomont				+							+
7.	<i>Lyngbya contorta</i> Lemmerm.											+
8.	<i>Lyngbya mesotricha</i> Skuja									+		
9.	<i>Microcystis aeruginosa</i> (Kütz.) Kütz.			+	+				+	+		+
10.	<i>Microcystis flos-aquae</i> (Wittr.) Kirchn.									+		
11.	<i>Microcystis robusta</i> (H.W.Clark) Nygaard									+		
12.	<i>Microcystis viridis</i> (A.Braun) Lemmerm.											+
13.	<i>Microcystis wesenbergii</i> (Komárek) Komárek									+		+
14.	<i>Nostoc calcicola</i> Bréb. ex Bornet & Flahault	+	+	+		+				+		
15.	<i>Nostoc ellipsosporum</i> Rabenh. ex Bornet & Flahault	+		+	+							+
16.	<i>Nostoc ellipsosporum</i> var. <i>violaceum</i> C.B.Rao	+										
17.	<i>Nostoc linckia</i> Bornet ex Bornet & Flahault	+	+	+	+	+						
18.	<i>Oscillatoria amoena</i> (Kütz.) Gomont		+	+	+	+						
19.	<i>Oscillatoria amphibia</i> C.Agardh ex Gomont										+	
20.	<i>Oscillatoria chalybea</i> G.Mertens ex Gomont									+	+	

21.	<i>Oscillatoria formosa</i> Bory ex Gomont									+		+
22.	<i>Oscillatoria geminata</i> Menegh. ex Gomont									+		+
23.	<i>Oscillatoria limnetica</i> Lemmerm.									+		
24.	<i>Oscillatoria limosa</i> C.Agardh ex Gomont									+		+
25.	<i>Oscillatoria princeps</i> Vaucher ex Gomont				+					+	+	
26.	<i>Oscillatoria raoi</i> DeToni				+							
27.	<i>Oscillatoria redekei</i> Goor				+							
28.	<i>Oscillatoria rubescens</i> DC. ex Gomont				+			+		+	+	
29.	<i>Oscillatoria splendida</i> Grev. ex Gomont							+		+	+	
30.	<i>Oscillatoria subbrevis</i> Schmidle									+		
31.	<i>Oscillatoria tenuis</i> C.Agardh ex Gomont			+	+					+		+
32.	<i>Oscillatoria willei</i> N.L.Gardner									+		
33.	<i>Phormidium ambiguum</i> Gomont			+						+		
34.	<i>Phormidium molle</i> (Kütz.) Gomont			+				+				
35.	<i>Phormidium tenue</i> (Menegh.) Gomont			+	+					+		
36.	<i>Pseudanabaena catenata</i> Lauterborn				+							
37.	<i>Synechocystis pevalekii</i> Erceg.			+				+		+		
		4	3	10	14	3	2	2	2	24	6	13
Total		64									19	
		(77.10%)									(22.89%)	

Ref.: Palmer (1980), Becker (1994), Brettum and Andersen (2005), Ray (2006), Subramaniyan et. al (2007) and Kumar (2011) referred for beneficial and nuisance properties of above listed species.

Property-wise maximum 24 species were recorded as indicators of pollution followed by 14 species for antibiotic, medicines, vitamins, etc., 10 species for lipid and 4 species as source of protein. Rest other beneficial properties like carbohydrates and bio-fertilizer & land reclamation were found in case of 3 species and metal removal and indicator of clean water and taste and odor in 2 species. The nuisance causing 13 species as scrutinised have been reported for toxin productions (Komárek and Anagnostidis, 1999, 2005; Kumar and Gopal, 2003; Gupta and Kumar, 2005 and Gupta and Husain, 2007) which have deleterious effects in living being of aquatic and terrestrial system. Such toxins and blooms if come in contact and or such waters if used directly and indirectly may be lethal and even they may also kill. These may be checked and or its impact may be reduced by treating sewage and wastewater before disposal in water bodies and by reducing and or use of fertilizers specifically nitrogen and phosphorus judiciously in agricultural fields for cultivation. Application of lethal concentration of copper sulphate (CuSO₄) may help in elimination of blooms and or retard its growth to the satisfactory level. Biologically, introduction of *Lemna* (Angiosperm) / *Ochromonas danica* (Chrysophytic algae) / *Daphnia magma* (Zooplankton) in stagnant water bodies may help in control of over growth of bloom forming species. Besides, following precautions may also be followed to have less risk of illness or discomfort caused due to diverse types of toxins (like microcystins, anatoxins, PS endotoxins, etc. produced by the bloom forming cyanobacteria) in the following manner :

- Avoid contact with bloom infested water.
- Do not swim and bath in water bodies if bloom is evident.
- Children are considered to be at higher risks.
- Do not drink and use such bloom infested water for meals or brushing teeth.
- If contact has been made with bloom infested water, simply wash off affected body part with fresh water. Skin irritations may occur, in some cases, after prolonged contact. If irritations persist, contact physicians or local health centres.

- Keep pets and livestock away from bloom infested water to save themselves from effect of toxins.
- Toxins produced by bloom forming cyanoprokaryotes cannot be removed by boiling.

Overall, as compared to beneficial properties, nuisance species were evaluated 22.89% only. Hence, keeping in view of 77.10% species of beneficial properties as recorded may help in betterment of mankind in future on large scale by undertaking further multidisciplinary R & D research along and at national level for inventorisation, screening and production of end products and use in collaboration with the biologists, bioengineers, nanotechnologists and others.

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REFERENCES

1. APHA. *Standard Method for the Analysis of Water and Wastewater*. 20th Ed., American Public Health Association, Washington, D. C., 1998
2. BAES. *District Statistical Handbook, Maldah. Bureau of Applied Economics and Statistic*, Government of West Bengal, Kolkata, 2005, 174 pp
3. Becker EW. *Microalgae: biotechnology and microbiology*. Baddiley, J. (ed.). Cambridge Univ. Press, Cambridge, New York, 1994, 178
4. Brettum P, Andersen, T. *The use of phytoplankton as indicators of water quality*. Norwegian Institute for Water Research. The Research Council of Norway, 2005, Report No. O-20032, 33
5. Cassidy E. *What's It All About ...Algae?*, ALN World, Vicon Publishing Inc., Canada, 2009
6. Desikachary TV. *Cyanophyta*. Indian Council of Agricultural Research, New Delhi, 1959, 686 pp
7. Desikachary TV. *Taxonomy and biology of blue-green algae*. Univ. of Madras, 1972, 591 pp
8. Fritsch FE. *Structure and reproduction of algae*. Cambridge, 1935, 1, 791 pp
9. Geitler, L. 1932. Cyanophyceae. In: Rabenhorst, L. (ed.), *Kryptogammenflora von Deutschland, Osterreich, under de Sweitz*. Akad. Verlagsges, Leipzig 14: 1196 p
10. Gupta P. Biodiversity of Larsemann Hills, Antarctica. *Climate Change*, 2015, 1(3), 174-183
11. Gupta P, Husain MM. Cyanobacterial toxins monitoring and management. In: *Pollution Managements*. Trivedi, P. C. and Nehra, S. (eds.), Pointer Publisher, 2007, 249 - 290 p
12. Gupta P, Kumar S. Microcystis aeruginosa Kützing bloom in ponds of Maldah District, West Bengal. *Bull. Bot. Surv. India*, 2005, 47(1-4), 115 - 120
13. Gupta P, Shukla AC Cyanophyceae and pollution inter-web in Ganga water at Bithoor. *Res. J. Pl. Environ.*, 2002, 18, 117 - 119
14. Hallegraeff GM. A review of harmful algal blooms and their apparent global increase. *Phycologia*, 1993, 32, 79 - 99
15. Kant S. Algae as indicators of organic pollution. *All India Appli. Phycol. Congr.*, 1983, 77 - 86
16. Kant S, Gupta P. *Algal flora of Ladakh*. Bharat Press (Printers), Jodhpur, 1998, 341 pp
17. Kohli D, Pandey PS, Gupta HP, Khandelwal A. Algal flora and water pollution of Samaspur lake, Rai Bareli, U. P. *Geophytology*, 1994, 24(1), 123 - 128
18. Komárek J. Studies on the Cyanophytes (Cyanobacteria, Cyanoprokaryota) of Cuba 11. Freshwater Anabaena species. *Preslia*, 2005, 77, 211 - 234
19. Komárek J, Anagnostidis K. Cyanoprokaryota. 1. Chroococcales. In: *Süßwasserflora von Mitteleuropa*. (Ettl, H., Gärtner, G., Heynig, H. & Mollenhauer, D. Eds), 1999, 19, pp. 548. Heidelberg; Berlin: Spektrum, Akad. Verl.
20. Komárek J, Anagnostidis K. *Cyanoprokaryota*. 2nd Part : Oscillatoriales. In: Büdel, B., Krienitz, L., Gärtner, G. and Schagerl, M. (eds.), *Süßwasserflora von Mitteleuropa*, Elsevier / Spektrum, Heidelberg, 2005, 19(2), 759 p
21. Kumar S. and Krishna G. Cyanobacterial toxins: Occurrence, properties and biological significance. In: *Natural Resource Management and Conservation*. Singh, J. and Pandey, G.

- (eds.), Kalyani Publishers, New Delhi, 2003, 52 - 74 p.
22. Lois H. Nutrient limitation of algal standing crops in shallow Prairie lakes. *Ecology*, 1976, 57(4), 664 - 678
 23. Oliver RL. Floating and sinking in gas-vacuolate Cyanobacteria. *J. Phycol.*, 1994, 30, 161 - 173.
 24. Palmer CM. *Algae and water pollution: The Identification, significance and control of algae in water supplies and in polluted water*. Castle House Publications Ltd., USA, 1980, 123 pp
 25. Prasad BN, Mehrotra RK, Singh Y. On pH tolerance of some soil blue-green algae. *Acta Bot. Indica*, 1978, 6(2), 130 - 138
 26. Prescott GW. *Algae of the Western Great Lakes Area*. Otto Koeltz Science Publishers, W. Germany, 1982, 977 pp
 27. Puttaiah E, Hosmani S P, Govindappa D A. Observations on the bloom of *Euglena limnophylla* Lemm. Journal of Mysore University, Section B, 1985, 30, 26 - 28
 28. Ray S. *Cyanobacteria*. New Age International Publishers, New Delhi, 2006, 178 pp
 29. Schopf JW. Precambrian paleobiology: problems and prospectives. *Ann. Rev. Earth Planet. Sci.*, 1975, 3, 213 - 249
 30. Schopf JW. Disparate rates, differing fates: tempo and mode of evolution changed from the Precambrian to the Phanerozoic. *Proc. Natl. Acad. Sci., USA*, 1994, 91(15), 6735 - 6742
 31. Schopf JW. Cyanobacteria : Pioneers of the early Earth. *Nova Hedwigia*, 1996, 112, 13 - 32
 32. Sengar RMS, Sharma KD. Role of algae in the assessment of pollution in river Yamuna. *J. Indian Bot. Soc.*, 1987, 66, 325 - 334
 33. Shaji C, Patel RJ. Chemical and biological evaluation of pollution in the river Sabarmati at Ahmedabad, Gujarat. *Phykos*, 1991, 30(1 & 2), 91 - 100
 34. Shaji C, Patel RJ. Pollution status of a pond at Anand, Gujarat. *Geobios New Rep.*, 1992, 12(1), 52 - 55
 35. Shukla M, Shukla AC. Aquatic algal profile of Panki, Kanpur and its implications in allergenic diseases. *Res. J. Pl. Environ.*, 2002, 18, 73 - 76
 36. Singh V, Singh G, Singh RP, Singh DV. Occurrence of Cyanobacteria (Blue-green algae) on Alkaline/Saline 'User' Soil of Varanasi. *Advances Pl. Sci.*, 2009, 22(1), 27 - 30
 37. Sinha A. Study of water pollution of Najafgarh drain, Delhi on the basis of algal pollution indices. *J. Econ. Taxon. Bot.*, 2001, 25(2), 339 - 345
 38. Subramaniyan V, Nooruddin T, Chokkaiya M. Biodiversity of cyanobacteria in industrial effluents. *Acta Botanica Malacitana*, 2007, 32, 27 - 34
 39. Suthar SL, Prasad, K. Algae as indicator of water pollution in Lakotia reservoir of Pali city (Rajasthan). *J. Phytol. Res.*, 1992, 5(1 & 2), 59 - 62
 40. Thomas J, Gonzalves EA. Thermal algae of Western India I. Algae of the hot springs at Akloli and Ganeshpuri. *Hydrobiologia*, 1965a, 25, 230 - 240
 41. Thomas J, Gonzalves EA. Thermal algae of Western India II. Algae of the hot springs at Palli. *Hydrobiologia*, 1965b, 25, 340 - 351
 42. Thomas J, Gonzalves EA. Thermal algae of Western India III. Algae of the hot springs at Sav. *Hydrobiologia*, 1965c, 26, 21 - 28
 43. Thomas J, Gonzalves EA. Thermal algae of Western India IV. Algae of the hot springs at Aravali, Tooral and Rajewadi. *Hydrobiologia*, 1965d, 26, 29 - 40
 44. Thomas J, Gonzalves EA. Thermal algae of Western India V. Algae of the hot springs at Tuwa. *Hydrobiologia*, 1965e, 26, 41 - 54
 45. Thomas J, Gonzalves EA. Thermal algae of Western India VI. Algae of the hot springs at Unai, Lasundra and Unapdeo. *Hydrobiologia*, 1965f, 26, 55 - 65
 46. Thomas J, Gonzalves EA. Thermal algae of Western India VII. Algae of the hot springs at Rajapur. *Hydrobiologia*, 1965g, 26, 66 - 71
 47. Tiffany LH, Britton, ME. *The Algae of Illinois*. The University of Chicago Press, Chicago, Cambridge University Press, London, 1952, 397 pp
 48. Tripathi CKM. Phytoplanktons as indicators of water pollution in river Ganga at Varanasi. *Biol. Mem.*, 1989, 15(2), 65 - 72
 49. Vasishta PC. Thermal Cyanophyceae of India - I. *Phykos*, 1968, 7(1 - 2), 198 - 241

50. Walsby AE. Gas vesicles. *Microbiol. Rev.*, 1994, 58, 94 – 144
51. Walsby AE, Reynolds CS, Oliver RL, Kromkamp J, Gibbs MM.
The role of buoyancy in the distribution of *Anabaena* sp. in
Lake Rotongaio. *New Zealand. J. Mar. Freshwater Res.*, 1987,
21, 525 - 526