Leaflet No.8/2019

The Republic of the Union of Myanmar

Ministry of Natural Resources and Environmental Conservation

Forest Department

Water quality assessment of Yezin Dam based on Phytoplankton and Physio-chemical properties

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December, 2019

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စာတမ်းအကျဉ်း

မြန်မာနိုင်ငံရှိ ရေကန်များနှင့် မြစ်ချောင်းများအတွက် ကနဦး အကြံပြု သတ်မှတ်ထားသော နော်ဝေနိုင်ငံသုံး ရေအရည်အသွေးဆိုင်ရာ သတ်မှတ်ချက် စံချိန်စံညွှန်းများကို အသုံးပြု၍ ရေဆင်းဆည်၏ ဂေဟစနစ် အခြေအနေအား လေ့လာသုံးသပ်သည့် သုတေသနလုပ်ငန်းအား ၂၀၁၇ ခုနစ် မတ်လမှ ၂၀၁၈ ခုနစ် ဖွန်လအတွင်း ဆောင်ရွက်ခဲ့ပါသည်။ ရေ၏ ရူပအခြေအနေ တိုင်းတာမှုနှင့်၊ ရေညှိနှင့် ရူပဓါတုဂုဏ်သတ္တိများအတွက် ရေနမူနာကောက်ယူခြင်း၊ ဓါတ်ခွဲ စမ်းသပ်ခြင်း လုပ်ငန်းများအား ဆောင်ရွက်ခဲ့ပါသည်။ ကနဦး ကန်အဆင့်အတန်း သတ်မှတ်ချက် စံညွှန်းနှင့် ကန်၏ ရူပဓါတုနှင့် မြေမျက်နှာသွင်ပြင် အခြေအနေအရ ရေဆင်းဆည်သည် မြေနိမ့်ဒေသရှိ အတော်အသင့် ကျယ်ဝန်းသော ဆီလီကာကြွယ်ဝပြီး၊ နက်သော၊ ကြည်လင်သည့် ကန် အမျိုး အစားဖြစ်ပါသည်။ နော်ဝေနိုင်ငံသုံး ရေအရည်အသွေးအဆင့်အတန်း နယ်နမိတ် သတ်မှတ်ချက်အရ ဆည်အတွင်းရှိ စုစုပေါင်း နိုက်ထရိုဂျင် ပါဝင်မှုမှာ ကောင်းမွန်သည့် အခြေအနေတွင် ရှိသော်လည်း စုစုပေါင်း ဖော့စဖောရပ်စ်ဓါတ် ပါဝင်မှုမြင့်မားပြီး Secchi depth ကိန်းဂဏန်း အရ ဆိုးရွားသည့် အခြေအနေ ဖြစ်ကြောင်း တွေ့ရှိရပါသည်။ ရေဆင်းဆည်တွင် ရေညှိမျိုးစိတ် ၅၀ နှင့် မျိုးစု ၉၉ မျိုးရှိကြောင်း တွေ့ရှိရပါသည်။ စိမ်းပြာရေညှိ (Cyanobacteria) မျိုးရင်းမှာ ၂၀၁၇ ခုနစ်တွင် Dinophyceae (သို့မဟုတ်) Bacillariophyceae မျိုးရင်း ပြီးလျှင် ဒုတိယ အများဆုံး ပေါက်ဖွားကြောင်း တွေ့ရှိရသော်လည်း ၂၀၁၈ ခုနစ်တွင် ပေါက်ဖွားမှု အများဆုံးဖြစ်ကြောင်း တွေ့ရှိရပါသည်။ ရေညှိများ၏ ဇီဝဒြပ်ထုမှာ ရေ ၁ လီတာတွင် ၄.၆ မှ ၃၂.၆၈ မီလီဂရမ်နှုန်း ပါဝင်နေသောကြောင့် ရေညှိပါဝင်မှုကို အခြေခံသည့် စံချိန်စံညွှန်းအရ ဆိုးရွားသည့် အခြေအနေတွင် ရှိကြောင်း သတ်မှတ်နိုင်ပါသည်။ ထို့အပြင် ဇီဝအခြေအနေကို အခြေခံသည့် ရေအဆင့် အတန်းစံချိန် စံညွှန်းများအရ ဆည်အတွင်းရှိ ရေနမူနာ ကောက်ယူသည့် နေရာအားလုံးသည် ဆိုးရွားသော မှ အလွန်ဆိုးဝါးသော အခြေအနေ ဖြစ်ကြောင်း သတ်မှတ်ရပါသည်။ ရေဆင်းဆည်အတွင်း အဆိပ်အတောက်ထုတ်နိုင်သည့် စိမ်းပြာရေညှိ (Cyanobacteria) ပေါက်ဖွား နေခြင်းသည် ရေဆင်းဆည် ရေဧရိယာအတွင်း နေထိုင်သည့်၊ ရေဆင်းဆည်ရေအား တိုက်ရိုက်သောက်သုံးနေသည့် ဒေသခံ လူများ၏ ကျန်းမာရေးအခြေအနေကို ဆိုးကျိုးသက်ရောက်

စေနိုင်ကြောင်း ညွှန်ပြနေခြင်း ဖြစ်ပါသည်။ ရေဆင်းဆည်သည် စိုက်ပျိုးရေနှင့် သောက်သုံးရေ အတွက် အဓိကအရင်းအမြစ်ဖြစ်သောကြောင့် ရေအရည်အသွေးနှင့် အဆိပ်အတောက် ထုတ်လွှတ်မှု အခြေအနေကို စောင့်ကြည့် လေ့လာခြင်းအား နိုင်ငံ၏ ရေသယံဇာတ စီမံအုပ်ချုပ်ခြင်း အစီအစဉ်တွင် အဓိကလုပ်ငန်းစဉ်အဖြစ် ထည့်သွင်း စဉ်းစားသင့်ကြောင်း အကြံပြု တင်ပြ အပ်ပါသည်။

Water quality assessment of Yezin Dam based on Phytoplankton and Physio-chemical properties

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Abstract

Assessing the ecological status of Yezin Dam using the Norwegian boundaries, which are preliminary suggestions for typology criteria and indices for lakes and rivers in Myanmar, was carried out between March 2017 to June 2018. Physical measurements, water samples for phytoplankton and physico-chemical parameters were collected and analyzed. Based on the preliminary type factors of lakes, and the morphological and water chemistry data, Yezin Dam can be characterized as a lowland, medium, deep, siliceous, clear reservoir. Total Nitrogen concentrations were found in the good status according to the boundaries. However, the Secchi depth and Total phosphorous were being in the bad/poor status.Ninety-nine (99) phytoplankton species belonging to (50) genera were documented from the Yezin Dam. Cyanobacteria (Blue-green algae) formed the second most dominant species in year 2017 after Dinophyceae or Bacillariophyceae, and then become the most dominant species in year 2018. The phytoplankton biomass ranged from 4.6 to 32.675 mg/l, which indicate bad status of the Yezin Dam phytoplankton. Based on the phytoplankton biomass and composition, and the trophic index PTI (without chlorophyll), and with Norwegian boundaries, the phytoplankton at all three sampling stations Y1, Y2 and Y3 in Yezin Dam could be classified as poor to bad.The enzyme-linked immunosorbent assay (ELISA) confirmed that all of five *Raphidiopsis* strains isolated from Yezin Dam were cylindrospermopsin producers. It is also confirmed that one of two *Microcystis* strains produced Microcystins (MCs). The present of these potent toxin producing cyanobacteria in Yezin Dam highlighted the potential risk for human health in the area. As the dam is an important source for drinking and irrigation water, water quality and toxins monitoring should be considered as a main activity in the integrated water resources management plan of the country.

Keywords: Norwegian boundaries, Phytoplankton, physico-chemical parameters, ecological status, cyanobacteria, Yezin dam

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1. Introduction

Nowadays, eutrophication in freshwater system becomes a challenging environmental problem around the world. The excessive nutrient loading into surface water system is considered as one of major eutrophication mechanisms. The polluted water due to eutrophication is a good habitat for the blooming of harmful algae like cyanobacteria. The presence of cyanobacteria can lead to increased cyanotoxin concentrations if they are toxin-producing strains, which have been recognized as a big issue for human and animal health problems.

Yezin dam, which is located near Yezin village in Zayyarthiri Township, Nay Pyi Taw, is an earth embankment man-made reservoir. It is completed in 1974 with a total capacity of 0.074 km^3 (FAO, 2011) and mainly used for irrigation purposes (Than et al., 2019). The water consumption from Yezin Dam has been increasing due to the development activities or the expansion of urban development around the watershed area. Forest degradation by the increased population and annual forest fires in the Yezin watershed area, have gradually increased the rate of sedimentation in the dam since 1975 (Win and Keh, 2003). It has been shown that the water surface area of Yezin dam was decreased by 74% between 2011 and 2016 (Than et al., 2019).

The anthropogenic activities like fishing, bathing, laundry detergent disposal due to washing clothes in the dam, poor sanitation and wastewater treatment systems in the watershed area caused decreasing water quality of the dam. The study was initiated since we noticed the algae blooming in the dam during the survey time with the experts from NIVA in 2017. We assumed these algae blooms can counteract the societal need for a good water quality and will pose the serious health problems to the people who directly used the water from the dam.

2. Objectives

The aims of this study are to reveal the algal species in the phytoplankton communities; to characterize and assess the water quality and ecological status of Yezin Dam based on Phytoplankton community by using the Norwegian boundaries.

3. Materials and Methods

3.1 Study area

Yezin dam is situated between latitudes 19° 50' 22" N and 19° 57' 54" N and longitude 96° 16' 04" E and 96° 22' 40" E at 133 m above sea level. According to the estimated data in 2016, the surface water area is about 2.36 km^2 (Than et al, 2019). Water from the dam directly and indirectly supplies domestic activities including drinking water to millions of people living in Yezin Watershed areas.

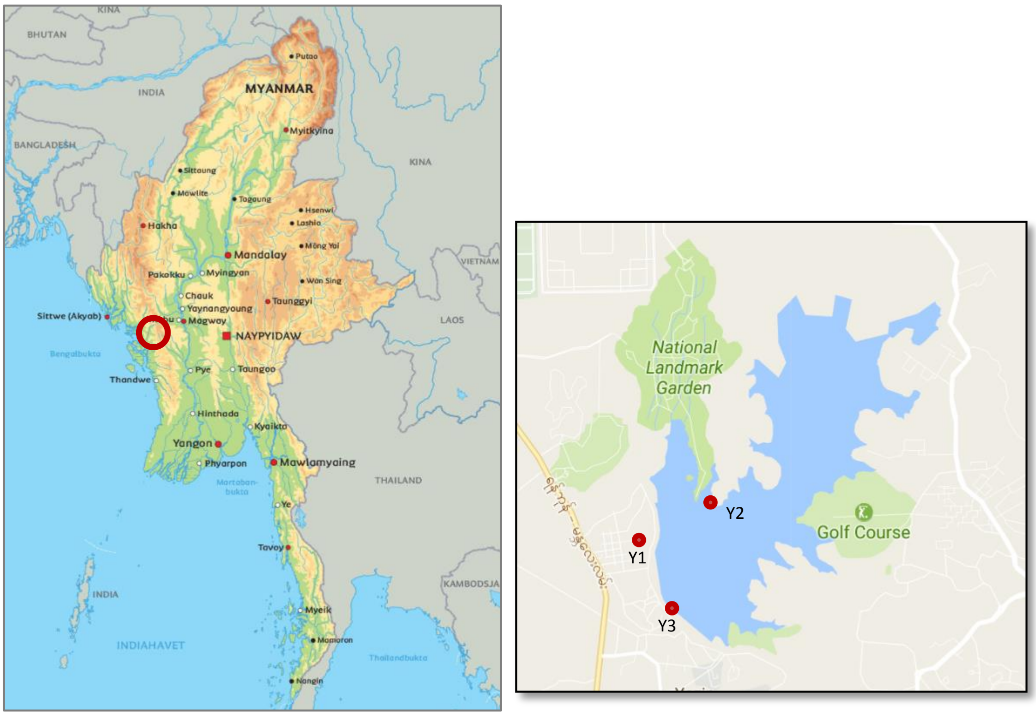


Figure 1. Map of Yezin Dam and Sampling points

3.2 Methods

3.2.1 Water sampling

Water samples were collected at three stations; near the shore, in the middle and at the nearest site to the military zone from March 2017 to June 2018 (Figure 1). Water transparency was measured with Secchi disks. The pH, Conductivity, Oxygen and water temperature were measured in situ with the aid of multi-parameter instrument (Hach, HQd Portable Meter). For water chemistry analysis, the integrated water samples were collected from the trophogenic zone (two times the secchi depth) with Limnos water sampler. Water samples were preserved with 4M H_2SO_4 for nutrient analysis and not preserved for analysis of Turbidity, Total Alkalinity, Color, Calcium and other cations. These samples were analysed at the Water Quality Laboratory in FRI, Yezin.

The physico-chemical elements are supporting quality elements to detect the main pressures for rivers and lakes (Mjelde et al., 2017). The Norwegian boundaries for physico-chemical parameters for tracing eutrophication pollution such as Secchi-depth, total-phosphorous and total-nitrogen were used in this study (Table 1, 2, and 3).

Table 1. Boundaries for secchi depth in different lake types in Norway (from Direktoratsgruppa 2015).

Altitude	Type	high	good	moderate	poor	bad
Lowland	siliceous, clear, shallow	>6	4-6	2-4	1-2	<1
Lowland	siliceous, clear, deep	>8	5-8	3-5	1,5-3	<1,5
Lowland	siliceous, humus-rich	>4	3-4	1,5-3	0,7-1,5	<0,7
Lowland	calcareous, clear	>4	3-4	1,5-3	0,7-1,5	<0,7
Lowland	calcareous, humus-rich	>3	2-3	1-2	0,5-1	<0,5
Forest	siliceous, clear	>8	6-8	3-6	1,5-3	<1,5
Forest	siliceous, humus-rich	>5	3,5-5	1,7-3,5	0,8-1,7	<0,8
Mountains	siliceous, humus-rich	>9	7-9	3,5-7	1,7-3,5	<1,7

Table 2. Boundaries for Total Nitrogen (T-N) in different lake and river types in Norway (from Direktoratsgruppa 2015).

Altitude	Type	high	good	moderate	poor	bad
Lowland	siliceous, clear, shallow	1-325	325-475	475-775	775-1350	>1350
Lowland	siliceous, clear, deep	1-200	200-400	400-650	650-1300	>1300
Lowland	siliceous, humus-rich	1-475	475-650	650-1075	1075-1755	>1755
Lowland	calcareous, clear	1-425	425-675	675-950	950-1425	>1425
Lowland	calcareous, humus-rich	1-550	550-775	775-1325	1325-2025	>2025
Forest	siliceous, clear	1-250	250-425	425-675	675-1250	>1250
Forest	siliceous humus-rich	1-400	400-550	550-900	900-1500	>1500
Forest	calcareous humus -rich	1-475	475-650	650-1075	1075-1755	>1755
Mountains	siliceous, clear	1-175	175-250	250-475	475-775	>775
Mountains	siliceous humus-rich	1-250	250-425	425-675	675-1250	>1250

Table 3. Boundaries for Total phosphorous (T-P) in different lake types in Norway (from Direktoratsgruppa 2015).

Altitude	Type	high	good	moderate	poor	bad
Lowland	siliceous, clear, shallow	1-11	11-17	17-30	30-60	>60
Lowland	siliceous, humus-rich	1-17	17-24	24-45	45-83	>83
Lowland	calcareous, clear	1-15	15-25	25-38	38-65	>65
Lowland	calcareous, humus-rich	1-20	20-29	29-58	58-98	>98
Forest	siliceous, clear	1-8	8-15	15-25	25-55	>55
Forest	siliceous, humus-rich	1-14	14-20	20-36	36-68	>68
Forest	calcareous humus -rich	1-17	17-24	24-45	45-83	>83
Mountains	siliceous, clear	1-5	5-8	8-17	17-30	>30
Mountains	siliceous humus-rich	1-8	8-15	15-25	25-55	>55

3.2.2 Phytoplankton sampling and morphological identification

Field method

Water samples collected from the surface at three sampling points (Fig 1) with phyto-net (20 µm mesh) were fixed with formaldehyde for qualitative analysis. Integrated water samples for quantitative analysis were fixed with Lugo solutions. All samples were stored in the dark until analysed at the University of South-eastern Norway, Bø, using inverted and compound microscopes.

Analysis methods

The species were identified to species or genus level using selected identification keys (Büdel et al. 1978-2015, Croasdal et.al 1983, Huber-Pestalozzi 1969, Prescott et al 1977, 1981, 1982, Skuja 1949). Enumeration was performed with Utermöhl sedimentation chambers (Utermöhl, 1958) and inverse microscope Olympus (Optical Co-ltd Japan, Model CK2). Measurements of length and width of 100 vegetative cells, heterocytes and akinetes z

Several parameters with phytoplankton such as Cholorophyll-a, total biovolume of phytoplankton, Phytoplankton Trophic Index (PTI) and biomass of cyanobacteria were used to characterized the ecological status of lakes (freshwater systems) and these indices are well correlated to phosphorous levels in the systems (Lyche-Solheim et al., 2013).

Chlorophyll-a was used as a proxy for phytoplankton biomass as it is the most significant pigment from the photosynthesis of phytoplankton (Ballot et al., 2017). Chlorophyll-a analysis could not performed in this study due to methodological challenges so far in Water Quality Laboratory of Forest Research Institute, Yezin, Myanmar.

The Phytoplankton Trophic Index (PTI) modified by Ptacnik et al., (2009) sums up the indicator value for each taxon in a sample related to the proportion of each taxon per sample. The indicator value for each taxon can vary from 1 to 5.

$$\text{PTI} = \frac{\sum_{j=1}^{n} a_j s_j}{\sum_{j=1}^{n} a_j}$$

The maximum volume for cyanobacteria (Cyanomax) means the presence of unwanted cyanobacteria (Ballot et al., 2017).

The boundaries for phytoplankton indices in Norwegian lake types were used to access the biological status of the dam (Table 4). The Norwegian boundaries, however, is an example and suitable boundaries for Myanmar will be suggested based on feedback from Myanmar experts.

Table 4. Class boundaries for phytoplankton indices in Norwegian lakes

(H = High, G= Good, M= moderate, P= poor, B=bad)

Lake-Type	Class	chlorophyll µg/l	Biovolume mg/l	PTI	Cyanomax mg/l
Lowland, calcareous, clear, shallow	H	<6	<0,64	<2,26	<0,16
	G	6-9	0,64-1,04	2,26-2,43	1,00
	M	9-18	1,04-2,35	2,43-2,60	1,00-2,00
	P	18-36	2,35-5,33	2,60-2,86	2,00-5,00
	B	>36	>5,33	2,86-4,0	>5,00
Lowland, siliceous, clear, shallow or Forest, calcareous, clear, shallow	H	<4	<0,40	<2.17	<0,16
	G	4-6	0,40-0,64	2,17-2,34	0,16-1,00
	M	6-13	0,64-1,60	2,34-2,51	1,00-2,00
	P	13-27	1,60-3,79	2,51-2,69	2,00-5,00
	B	>27	>3,79	2,69-4,0	>5,00
Lowland, siliceous, clear, deep	H	<2	<0,18	<2,09	<0,16
	G	2-4	0,18-0,40	2,09-2,26	0,16-1,00
	M	4-7	0,40-0,77	2,26-2,43	1,00-2,00
	P	7-15	0,77-1,90	2,43-2,60	2,00-5,00
	B	>15	>1,90	2,60-4,0	>5,00
Lowland, siliceous, humus-rich, shallow or Forest, calcareous, humus-rich, shallow	H	<5,4	<0,60	<2,26	<0,16
	G	5,4-9	0,60-1,00	2,26-2,43	0,16-1,00
	M	9-16	1,00-2,00	2,43-2,60	1,00-2,00
	P	16-32	2,00-4,60	2,60-2,86	2,00-5,00
	B	>32	>4,60	2,86-4,0	>5,00
Lowland, siliceous, clear, shallow or deep Forest, siliceous, clear, shallow or deep	H	<2	<0,18	<2,00	<0-0,16
	G	2-4	0,18-0,40	2,00-2,17	0,16-1,00
	M	4-7	0,40-0,77	2,17-2,34	1,00-2,00
	P	7-15	0,77-1,90	2,34-2,51	2,00-5,00
	B	>15	>1,90	2,51-4,0	>5,00
Lowland or forest, siliceous, humus-rich, shallow	H	<4	<0,40	<2,17	<0,16
	G	4-6	0,40-0,64	2,17-2,34	0,16-1,00
	M	6-12	0,64-1,46	2,34-2,51	1,00-2,00
	P	12-25	1,46-3,46	2,51-2,69	2,00-5,00
	B	>25	>3,46	2,69-4,0	>5,00
Lowland, calcareous, humus-rich, shallow	H	<7	<0,77	<2,39	<0,16
	G	7-10,5	0,77-1,24	2,39-2,56	0,16-1,00
	M	10,5-20	1,24-2,66	2,56-2,73	1,00-2,00
	P	20-40	2,66-6,03	2,73-3,07	2,00-5,00
	B	>40	>6,03	3,07-4,0	>5,00

4. Results and Discussion

4.1 Identification of water bodies and typology

According to the preliminary type factors of lakes, and the morphological and water chemistry data suggested by Mjelde et al., (2017), the Yezin Dam is characterized as a low land, medium and deep, siliceous, clear reservoirs.

Table 5. Characteristic data for Yezin dam

Water body	State/ Division	Type	Altitude m. asl	Area (km2)	Depth (m)	Calcium µg/L	Alkalinity mmol/L	Color mg Pt/L
Yezin Dam	Zayar Thiri tsp, Nay Pyi Taw	Man-made	130	2.3*	21	6.61	1.28	14.73

* - 2016 data from Mu Mu Than et al., (2019)

4.2 Physico-chemical properties

The water from Yezin Dam is slightly alkaline with mean pH value of 8.21 ranging between 7.2 to 9.06. The water can be classified as clear according to mean turbidity value of 4.45 FNU. The water temperatures varied from 27.4 to 32.5 °C, and the conductivity ranged between 77 and 87 μScm^{-1}. The lowest secchi depth value of 1 m and the highest of 1.5 m were found during the sampling period, which indicate poor status of the dam according to the boundaries class for secchi depth. The Total Phosphorous (TP) concentrations ranged from 32 μgL^{-1} to 36 μgL^{-1} and Total Nitrogen concentrations varied between 213.9 μgL^{-1} to 302.7 μgL^{-1}. With average color values at 14.73 mg Pt/L, it can be characterized as a clear dam. Although nitrogen contents were low, high phosphorous contents were observed in the dam (Table 6).

Table 6. Physical chemical data from Yezin dam 2017-2018 (min, max and mean values).

Period 2017-18	**Water Temp**	**Oxygen**	**pH**	**Cond.**	**Turbidity**	**Color**	**Alkilinity**	**Cl**	**Sulphate**
	°C	**mg/L**		**µS/cm**	**FNU**	**mg Pt/L**	**mmol/L**	**µg/L**	
Min	27.4	5.9	7.20	81.7	3.10	6.14	0.63	0.72	0.01
Max	30.6	10.45	9.06	85.9	5.98	43.6	4.74	2.85	0.5
Mean	28.96	8.55	8.33	83.48	4.45	14.73	1.28	1.50	0.19

Table 6. (Cont.)

Period 2017-18	**K**	**Na**	**Mg**	**Ca**	**Si**	**O-P**	**T-P**	**Nitrite + Nitrate**	**Total N**
	µg/L								
Min	2.13	3.32	0.02	3.41	4125	4.44	20.03	3.09	32.31
Max	4.21	8.4	1.2	9.48	13493	37.8	56.87	222.59	253.7
Mean	2.70	6.55	0.82	6.61	9737	15.21	35.25	54.45	157.98

4.3 Classification of Physico-chemical parameters

The EU WFD focus mainly on the status of biological elements. However, the physico-chemical elements are supporting quality elements and assigned to detect the main pressures for rivers and lakes (Ballot et al., 2017). Therefore, the nutrient concentrations such as total nitrogen (TN) and total phosphorous (TP) were used in this study to exemplify the classification for the supporting physico-chemical elements.

The secchi depth value indicated poor status of the dam according to the boundaries class for Secchi depth as shown in Table 1. Yezin dam had low total nitrogen (TN) concentrations throughout the sampling period in 2017-19, which can be classified as good and very good status according to the Norwegian boundaries.

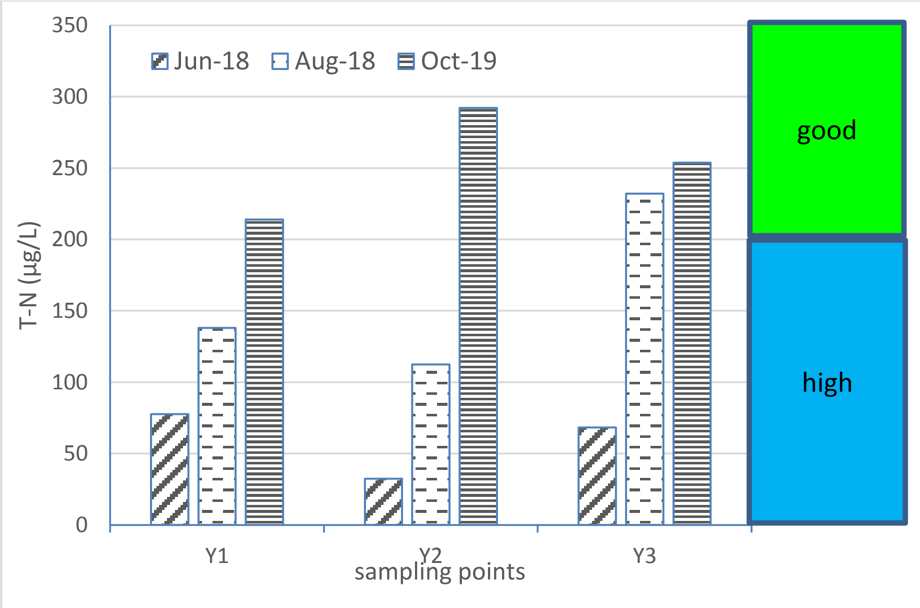


Figure 2. Classification of Yezin using average total nitrogen (TN)-concentrations (sampling points see Fig. 3.1). The status is based on boundaries in Table 2.

All investigated samplings in the dam are characterised by high TP concentrations characterising them in a poor to bad status. The high TP values originate from erosion and use of fertilisers in the catchment area and wastewater from settlements. The reasons for high TP concentrations could be the influence of domestic wastewater from the surrounding areas. The highest TP concentrations in the rainy season could also be nutrients carried from the upstream areas to the dam. This could also be reason for having high TP concentrations in the sampling point Y3 which is nearest point from other parts of upstream area.

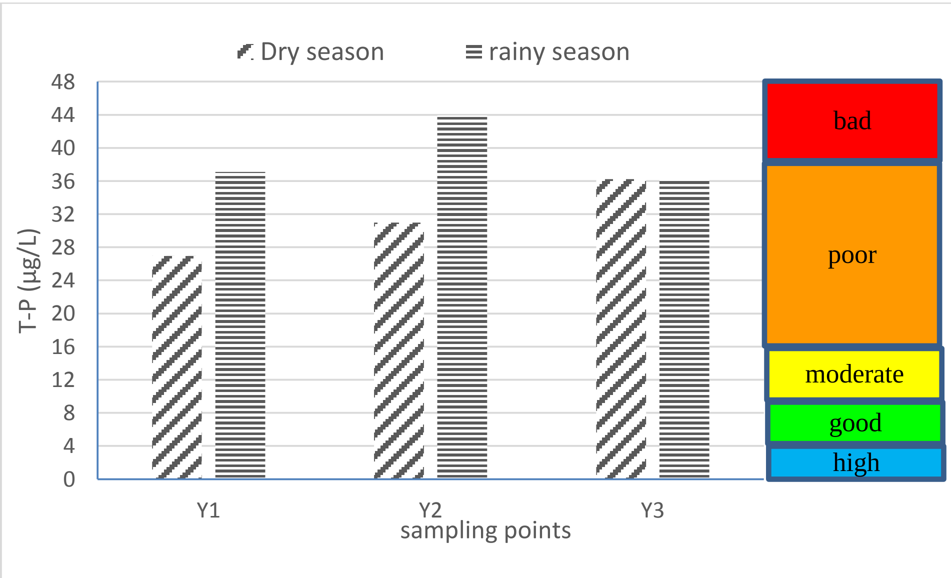


Figure 3. Classification of Yezin Dam using average total phosphorus (TP)-concentrations (sampling points see Fig. 3.1). The status is based on boundaries in Table 3

4.4 Phytoplankton communities

A total of ninety-nine (99) phytoplankton species belonging to (50) genera were documented from the Yezin Dam and of which 12 belonging to Chlorophyceae, 11 to Cyanobacteria (blue-green algae), 8 to Trebouxiophyceae, 6 to Conjugatophyceae and 4 to Bacillariophyceae, 3 each to Dinophyceae and Euglenophyceae, and 1 genera each to Synurophyceae, Cryptophyceae and Chrysophyceae.

The Dinophyceae were the most common species throughout the sampling period except in June 2017 where the diatoms (Bacillariophyceae) were the dominating groups followed by cyanobacteria. Cyanobacteria formed the second most dominant species in year 2017 and then become the most dominant species in year 2018. The highest densities of cyanobacteria were recorded in summer time of 56% in March, 79% in April and 72% in June of the total phytoplankton biomass of 20.69 mgL^{-1}, 14,41 mgL^{-1} and 4,57 mgL^{-1} respectively (Table 7 & Figure 4). The phytoplankton biomass ranged from 4.6 to 32.675 mg/l, which indicate bad status of the Yezin Dam phytoplankton, see Figure 4.

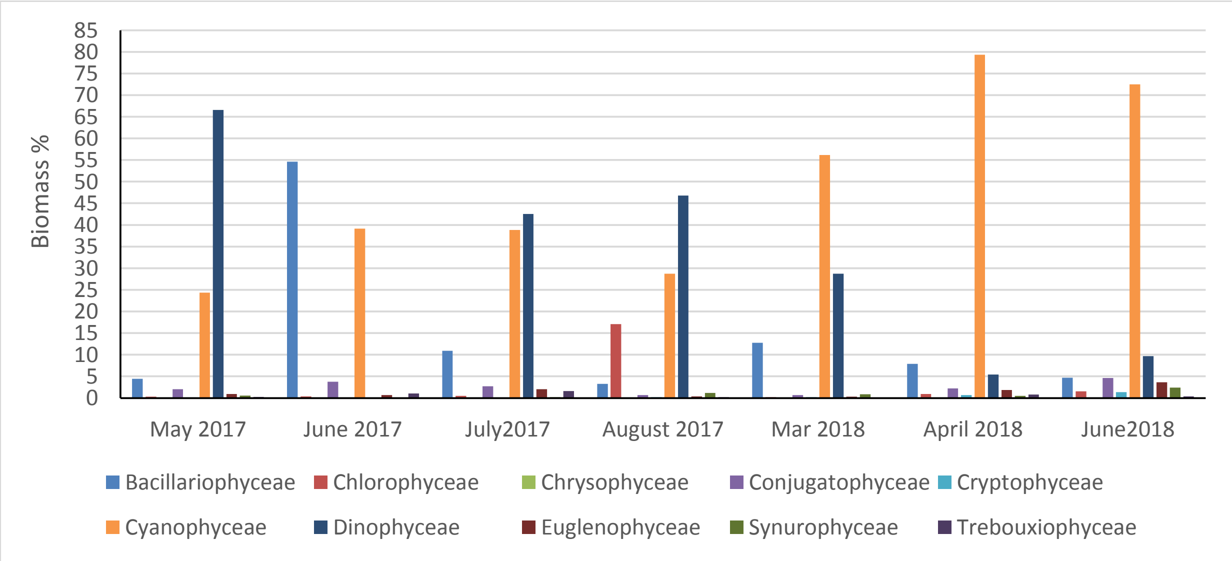
Table 7 Biomass of phytoplankton groups in Yezin Dam (from May 2017 to June 2018)

Taxa Group	May 2017		June 2017		July2017		August 2017	
	Freshw. [mg/l]	Biomass %	Freshw. [mg/l]	Biomass %	Freshw. [mg/l]	Biomass %	Freshw. [mg/l]	Biomass %
Bacillariophyceae	0,81	4,42	17,89	54,62	1,57	10,94	0,68	3,29
Chlorophyceae	0,06	0,31	0,13	0,38	0,07	0,51	3,54	17,08
Conjugatophyceae	0,38	2,06	1,23	3,74	0,39	2,70	0,14	0,68
Cryptophyceae	0,03	0,15	0,03	0,09	0,00	0,00	0,04	0,19
Cyanobacteria	4,45	24,37	12,82	39,12	5,57	38,81	5,95	28,74
Dinophyceae	12,15	66,54	0,03	0,08	6,11	42,54	9,68	46,76
Euglenophyceae	0,17	0,95	0,22	0,66	0,29	2,01	0,08	0,39
Synurophyceae	0,11	0,58	0,00	0,00	0,03	0,21	0,25	1,18
Trebouxiophyceae	0,04	0,22	0,35	1,05	0,23	1,60	0,04	0,19

Table 4.3. (Contd.)

Taxa Group	Mar 2018		April 2018		June2018	
	Freshw. [mg/l]	Biomass %	Freshw. [mg/l]	Biomass %	Freshw. [mg/l]	Biomass %
Bacillariophyceae	2,65	12,79	1,14	7,91	0,21	4,67
Chlorophyceae	0,03	0,16	0,14	0,94	0,07	1,53
Conjugatophyceae	0,14	0,69	0,32	2,22	0,21	4,62
Cryptophyceae	0,04	0,19	0,10	0,66	0,06	1,37
Cyanobacteria	11,62	56,15	11,43	79,35	3,31	72,46
Dinophyceae	5,95	28,74	0,78	5,41	0,44	9,66
Euglenophyceae	0,06	0,29	0,27	1,84	0,17	3,61
Synurophyceae	0,17	0,84	0,08	0,52	0,11	2,41
Trebouxiophyceae	0,01	0,03	0,12	0,80	0,02	0,35

Among the water bloom-forming Cyanobacteria, the genera *Dolichospermum* presented the highest number of species with a biomass of 6.7 mgL^{-1} and followed by *Oscillatoria sp.*, of 2.5 mgL^{-1}, *Limnothrix sp.* of 2,4 mgL^{-1} and *Microcystis sp.*, of 0.9 mgL^{-1} and all these species were appeared in all sampling sites, except Chrysophyceae, Conjugatophyceae and Synurophyceae. The phytoplankton taxa and their abundance based on a semi-quantitative scale are depicted in Appendix B. Dominant presence of colonial cyanobacteria could be due to high nutrient concentrations (especially TP).



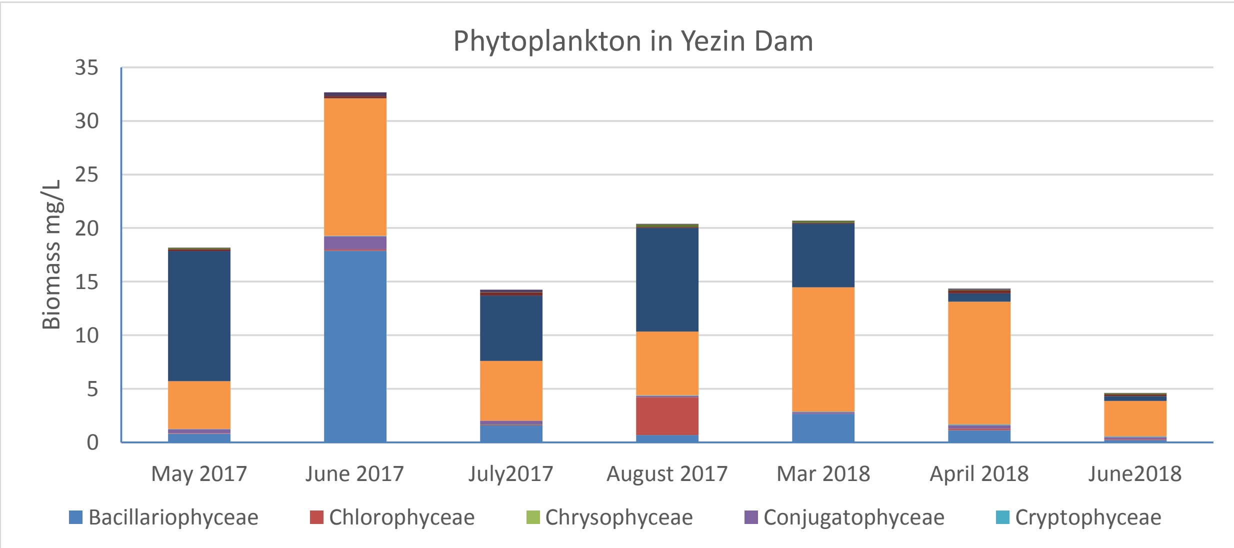


Figure 4. Phytoplankton composition and biomass of Yezin Dam

In Figure 5, the ecological status of Yezin Dam based on trophic indices for the years 2017 and 2018 is depicted. The analysis of phytoplankton composition and biomass and the calculation of the phytoplankton trophic index PTI shows that Yezin Dam was classified as being in a poor to bad status throughout the sampling period except in August in 2017 when was evaluated as being in a moderate status. This clearly shows a deterioration of the water quality of Yezin Dam.

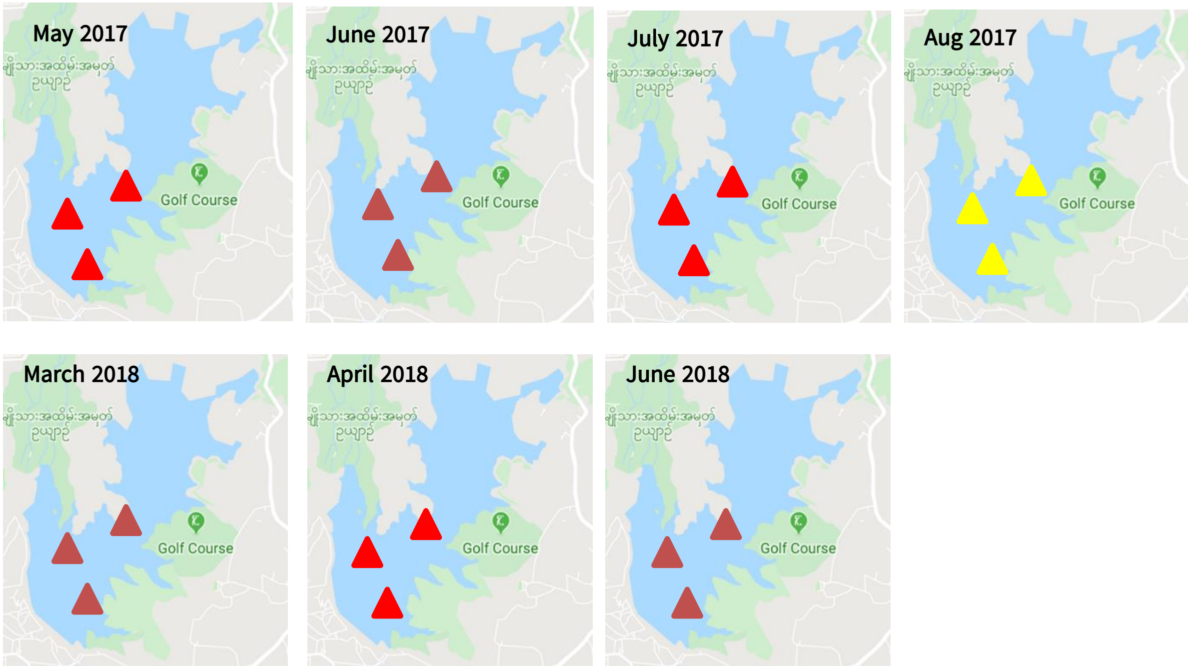


Figure 5. Ecological status of Yezin Dam in 2017-2018 determined using phytoplankton biomass, PTI and cyanbacteria biomass (cyanomax). The evaluation is based on Table 4.1 using the type: lowland, siliceous, clear, deep. Yellow = moderate status; Orange = poor status; Red= bad status.

Cylindrospermopsins (CYN), Microcystins (MCs), Saxitoxins (SXT) were also analysed from fresh culture materials of two *Microcystis*, four *Raphidiopsis* and eight *Dolichospermum* isolated strains from Yezin dam using ELISA according to the manufacturer's instruction. All investigated *Microcystis*, *Dolichospermum* and *Raphidiopsis* strains from Yezin Dam tested negative for saxitoxins, and anatoxin-a using ELISA. All five *Raphidiopsis* strains from Yezin Dam were confirmed as cylindrospermopsin producers using ELISAs (data not shown). One out of two *Microcystis* strains produced Microcystins (MCs).

5. Conclusions

In this study, Norwegian indices and boundaries were used to exemplify the physico-chemical status and ecological status for phytoplankton in Yezin Dam. Based on the available data and the suggested characterisation parameters, Yezin Dam is characterised as a lowland, medium and deep, siliceous, clear reservoir. The dam was characterised in good status according to the TN concentrations, but a poor to bad status were shown based on TP concentrations. Domestic wastewater, fishing, bathing and using laundry detergent could be the sources for increased TP concentrations in the dam.

Water quality of Yezin Dam is deteriorating according to the trophic indices based on the analysis of phytoplankton composition and biomass and the calculation of the phytoplankton trophic index PTI. During the survey period, a few species of aquatic macrophytes (*Hydrilla* and *Chara* spp.) were found. Increased growth of phytoplankton could be due to the little growth of aquatic macrophytes in Yezin Dam, which have very negative effects for the water quality of the dam.

Cyanobacteria are associated with eutrophication in lakes. They can produce high biomasses and are potential toxin producers. Their presence can limit the use of lakes as drinking water source for recreation and other purposes. The higher input of nutrients (expeically TP) in Yezin Dam might induce the increasing concentrations of toxins in dam water, which will affect the animal and human health in the area. If pollution sources cannot be eliminated in time, the concentration of cyanotoxins could be increased and the amount might be beyond the proposed warning for drinking water of 1 μg-^{1} (Humpage and Falconer, 2003, Burch, 2008). As the dam is an important source for drinking and irrigation waters, toxin monitoring should be considered as a main activity in the integrated water resources management plan of the country.

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Appendix A. Phytoplankton composition in Yezin Dam from March 2017 to June 2018. Legend: + = sporadic, ++ = frequent, +++ = dominant.

Taxon	Mar 2017	May 2017	June 2017	July 2017	Aug 2017	Mar 2018	April 2018	June 2018
Domain Eubacteria **Division Cyanobacteria (Cyanoprokaryota)**								
Rhodomonas lacustris Pascher & Ruttner in Pascher 1913	–	++	–	–	–	–	–	–
Aphanocapsa delicatissima West & G.S.West 1912	+++	+++	+++	+++	+++	+++	+++	+++
Aphanocapsa planctonica (G.M.Smith) Komárek & Anagnostidis 1995	++	++	++	++	+++	++	++	+++
Aphanothece smithii Komárková-Legnerová & G.Cronberg 1994	–	+++	+++	–	+++		+++	+++
Chroococcus minutus (Kützing) Nägeli 1849	+++	+++	+++	–	+++	+++	+++	+++
Chroococcus sp. Nägeli	+++	++	+++	++	+++	+++	++	+++
Chroococcus turgidus (Kützing) Nägeli 1849	+++	+++	+++	+++	+++	+++	+++	+++
Cylindrospermopsis raciborskii (Woloszynska) Seenayya & Subba Raju 1972	++						+	
Dolichospermum solitarium (Kleb.) Wacklin, L.Hoffm. & Komárek	+++	+++	+++	+++	+++	+++	+++	+++
Limnothrix planctonica (Woloszynska) Meffert 1988	+++	–	–	+++	+	+++	+++	–
Merismopedia tenuissima Lemmermann 1898	–	+++	+++	–	+++	–	+++	+++
Microcystis aeruginosa (Kützing) Kützing 1846	+++	+++	+++	+++	+++	+++	+++	+++
Microcystis botrys Teiling 1942	–	–	+++	–	–	–	–	–
Microcystis smithii Komárek & Anagnostidis 1995	+	–	+++	–	+++	–	–	–
Microcystis wesenbergii (Komárek) Komárek ex Komárek in Joosen 2006	+	+	+	+	+	+	+++	+++
Pseudanabaena limnetica (Lemmermann) Komárek 1974	–				+++		+	
Oscillatoria princeps Vaucher ex Gomont	+					+		
Domain Eukarya **Class Bacillariophyceae**								
Fragilaria fasciculata (C.Agardh) Lange-Bertalot 1980	–	–	–	–	–	–	+	+++
Aulacoseira granulata (Ehrenberg) Simonsen 1979	–	–	++	+++	+++	–	++	+++
Aulacoseira granulata var. angustissima (Otto Müller) Simonsen 1979	–	–	+	–	+	–	–	+++
Aulacoseria sp.	–	+++	+++	+	–	–	–	–
Rhizosolenia setigera Brightwell 1858	–	–	–	–	–	–	–	+
Cyclotella (Kützing) Brébisson	++	+	–	–	+++	+++	+++	+
Cyclotella meneghiniana Kützing 1844	–	–	++	–	+++	–	–	+
Class Chlorophyceae								
Ankistrodesmus fusiformis Corda 1838	–	++	–	–	–	–	–	–
Coelastrum pseudomicroporum Korshikov 1953	–	–	+++	–	+++	–	–	+++
Desmodesmus serratus (Corda) S.S.An, Friedl & E.Hegewald 1999	–	–	–	–	–	–	+++	+++
Eudorina elegans Ehrenberg 1832	–	–	–	–	–	–	–	+++
Gloeococcus sp. A. Braun 1850	–	–	–	–	+++	–	–	–

Golenkinia radiata Chodat 1894	–	–	–	–	–	–	–	+
Kirchneriella lunaris (Kirchner) Möbius 1894	+++	–	–	–	+++	+++	+++	–
Kirchneriella subcapitata Korshikov 1953	–	–	+	++	+++	–	–	+

Appendix A (Contd.)

Monoraphidium arcuatum (Korshikov) Hindák 1970	–	–	–	–	–	–	++	–
Monoraphidium contortum (Thuret in Brébisson) Komárková-Legnerová 1969	–	+++	+	+++	–	–	++	+++
Monoraphidium komarkovae Nygaard 1979	–	–	–	–	–	–	++	+++
Monoraphidium griffithii (Berkeley) Komárková-Legnerová 1969	–	–	–	–	–	–	++	–
Pandorina Bory de Saint-Vincent sp.	+	+	+	+	+	+	+	+
Pediastrum duplex Meyen 1829		+	+	+	+		+	+
Pediastrum simplex Meyen 1829	–	–	–	–	–	–	–	+++
Scenedesmus ecornis (Ehrenberg) Chodat 1926	–	–	–	–	–	–	+++	+++
Scenedesmus incrassatulus Bohlin 1897	–	++	–	–	–	–	–	+++
Tetraëdron caudatum (Corda) Hansgirg 1888	+++	++	+++	–	++	+++	+++	–
Tetraëdron minimum (A.Braun) Hansgirg 1888	+++	+++	+	+++	+++	+++	–	+++
Class Chrysophyceae								
Dinobryon divergens O.E.Imhof 1887	–	–	–	+	–	–	–	–
Class Conjugatophyceae	–	–	–	–	–	–	–	–
Closterium dianae Ehrenberg ex Ralfs 1848	–	+	–	–	+++	–	+++	–
Closterium dianae var. arcuatum	–	–	++	+++	–	–	++	+++
Closterium jenneri Ralfs 1848	–	+	+++	–	–	–	–	–
Closterium sp. kuetzingi Brébisson 1856	–	+	–	+	++	–	–	+
Closterium parvulum Nägeli 1849	–	–	–	–	–	–	–	+
Closterium pronum Brébisson 1856	–	–	–	–	–	–	–	+++
Coelastrum pseudomicroporum Korshikov 1953	+	+	+	+	+	+	+	+
Cosmarium contractum O. Kirchner 1878	+++	+++	+++	+++	+++	+++	+++	+++
Cosmarium sp. Corda ex Ralfs	+++	+++	+++	+	–	+++	+	+++
Cosmarium depressum Bailey 1851	–	+	+++	+++	++	–	+	++
Cosmarium moniformer var. panduriforme	–	–	+++	+++	+++	–	–	–
Cosmarium pachydermum P.Lundell 1871	–	+	+++	+++	+++	–	+++	+++
Cosmocladium perissum J.Roy & Bisset 1894	–	+++	–	+++	++	–	–	++
Staurastrum sp. Meyen ex Ralfs	+++	++	++	+++	++	+++	+++	+++
Euastrum binale f. hians West 1892	++	++	++	++	++	++	++	+++
Staurastrum arctiscon (Ehrenb.) P. Lundell	++	++	++	++	++	++	++	–
Staurastrum johnsonii West & G.S.West 1896	++	++	++	++	++	++	++	+++
Staurodesmus convergens (Ehrenberg ex Ralfs) S.Lillieroth 1950	–	–	+	+	–	–	–	–
Teilingia excavata (Ralfs ex Ralfs) Bourrelly 1964	+++	–	–	+++	++	+++	+++	+++
Teilingia granulata (J.Roy & Bisset) Bourrelly 1964	–	–	–	+++	++	–	–	–
Class Cryptophyceae								
Cryptomonas Ehrenb. Spp.	+++	–	++	–	+++	+++	+++	+++

Class Dinophyceae								
Ceratium hirundinella (O.F. Müller) Schrank 1793	++	+++			+++	++	+	+++
Peridiniopsis elpatiewskyi (Ostenfeld) Bourrelly 1968	++	+++			+++	++		

Appendix A (Contd.)

Peridinium aciculiferum Lemmermann 1900	++			+	+	++		
Peridinium gatunense Nygaard in Ostenfeld & Nygaard 1925	++		+	+++		++	++	
Peridinium sp.2	++	++		+	+++	++	++	++
Peridinium sp.3	++			+	+++	++	++	+
Peridinium sp.7	++			+	+++	++	++	+
Peridinum sp.1	++			++	+++	++	++	+
Peridinum sp.5	++			+	+	++	++	+
Class Euglenophyceae								
Euglena gracilis G.A.Klebs 1883	–						+++	+++
Phacus longicauda (Ehrenberg) Dujardin 1841	–					+	++	+
Trachelomonas hystrix Teiling 1916	–							
Trachelomonas intermedia P.A.Dangeard 1902	+					+		
Trachelomonas scabra Playfair 1915	–		+					
Trachelomonas volvocina (Ehrenberg) Ehrenberg 1834	–	++	+++	+++	+++		+++	+++
Trachelomonas volvocinopsis (Svirenko 1914)	++	++	+++	+++	+++	+++	+++	+++
Class Synurophyceae								
Mallomonas crassisquama (Asmund) Fott 1962	–	+	–	–	+	–	++	+++
Mallomonas lychenensis W.Conrad 1938	+++	+	–	–	–	+++	–	–
Mallomonas sp 1	+++	–	–	+	++	+++	+++	–
Mallomonas sp. 2	+	–	–	–	–	+	–	–
Class Trebouxiophyceae								
Chlorella Beij.	–	–	+++	–	+++	–	–	+++
Crucigenia crucifera (Wolle) O.Kuntze 1898	–	–	–	+++	–	–	+++	+++
Dictyosphaerium pulchellum H.C.Wood 1873	–	–	–	–	+++	–	+++	+++
Franceia ovalis (Francé) Lemmermann 1898	–	–	–	–	–	–	++	++
Koliella longiseta (Vischer) Hindák 1963	–	–	–	+	–	–	+++	–
Nephrocytium agardhianum Nägeli 1849	–	–	+++	–	+++	–	+++	–
Oocystis borgei J.W.Snow 1903	–	–	–	+++	–	–	–	–
Oocystis solitaria Wittrock in Wittrock & Nordstedt 1879	+++	–	–	–	–	+++	+++	–
Tetrachlorella alternans (G.M.Smith) Korshikov 1939	–	–	–	–	+++	–	–	–
Unknown species 1 (cycle)	+++	+++	+++	+++	+++	+++	+++	++
Unknown species 2 (ellipsoid)	+	+++	++	+++	+++	+	+++	++
unknown sp 3 (sphere, colony)	+++	++	+++	+++	+++	+++	+++	++
unknown sp. 4 (ellipsoid, colony)	+++	++	++	++	++	+++	+++	+