Chiang Mai J. Sci. 2004; 31(1) : 85 - 94
www.science.cmu.ac.th/journal-science/josci.html
Contributed Paper

Monitoring of Water Quality in Ang Kaew Reservoir of Chiang Mai University Using Phytoplankton as Bioindicator from 1995-2002

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Received: 10 March 2003
Accepted: 26 November 2003

Abstract

The monitoring of water quality in Ang Kaew Reservoir which is the water used for water supply in Chiang Mai University, was carried out by using phytoplankton as bioindicator including physico-chemical properties from 1995-2002. It was found that the average water quality in the reservoir could be classified as mesotrophic to eutrophic status. In the summer and rainy seasons, the water quality was indicated as mesotrophic to eutrophic whilst in the winter, it was indicated as mesotrophic except from the end of 2001 to the beginning of 2002, the water quality showed hypereutrophic in consequence to the drawing of polluted water from irrigation canal which was added to the reservoir. The large scale blooming of toxic cyanophytes, *Anabaena catenula* (Kützing) Bornet & Flahault occurred during this period, the algal toxin, microcystin-LR was found in small amounts.

The water quality of the reservoir is classified by the standard surface water quality of Thailand, it was in the second to third category which is suitable for household consumption after being properly treated.

One hundred and eighty-six species of phytoplankton in Division Cyanophyta, Chlorophyta, Euglenophyta, Chrysophyta, Pyrrhophyta, and Cryptophyta were found. The species which indicated eutrophication to hypereutrophication was *Anabaena catenula* (Kützing) Bornet & Flahault; the mesotrophication to eutrophication indicator species were *Euglena acus* Ehrenberg, *Phacus meson* Pochmann, *Phacus pleuronectus* Müller and *Trachelomonas volvocina* Ehrenberg, the mesotrophication indicator species were *Planktolyngbya limnetica* Lemmermann, *Cylindrospermopsis raciborskii* (Woloszynska) Seenayya and Subba et Raju, *Aulacoseira granulata* (Ehrenberg) Simonsen and *Peridinium inconspicuum* Lemmermann.

Keywords: monitoring of water quality, Ang Kaew Reservoir of Chiang Mai University, phytoplankton, bioindicator

1. Introduction

Ang Kaew Reservoir is situated in Chiang Mai University. It was constructed in 1962 to reserve the raw water to be the water supply for 18,000 citizens in this university. The water supply plant of this reservoir could produce the amout of 6,000 m^3 of water per day. There are two inflows, Huay Kaew and Huay Koo

Khao which receive the water from the catchment area around Doi Suthep-Pui National Park, Chiang Mai Province. These two inflows pass through Chiang Mai Zoo, so the waste from the animals had contaminated the two inflows and in the reservoir, especially during the rainy season. In the dry season, the water from the irrigation canal may be pumped and added to this reservoir. In this case, the water in this reservoir would be sensitive to contamination of polluted water. Therefore, continuous monitoring of physical, chemical and biological factors of the reservoir to meet required standards, and the maintenance of clean water qualities are extremely important.

Phytoplankton in the reservoir is an important biological indicator of water quality. These organisms are important primary producers. They are the basis of the whole food chain in open waters. Moreover, some species can be harmful to man and other vertebrates by releasing toxic substances into the water. Therefore, proliferation of these organisms should be continuously monitored. Species composition of the phytoplankton community is an efficient bioindicator of water quality. In addition to phytoplankton, coliform bacteria was investigated in this study to monitor the hygienic water quality. Results from both analyses are used for management of this reservoir.

Study Site: Ang Kaew Reservoir is located at 18° 48′ 15″- 18° 48′ 45″ N and at 98° 56′ 15″-98° 57′ 17″ E and at an altitude of 330 m above sea level. The maximum volume of the reservoir is 400,000 m^3. It was constructed across the Huay Kaew and Huay Koo Khao inflows. The surface area of the reservoir is 64,000 m^2 , and the catchment area is 13 km^2. The maximum water depth varies between 5 m and 9 m. The reservoir is surrounded mainly by deciduous dipterocarp forest and the residences of Chiang Mai University staff. The reservoir has two major inflows (Huay Kaew and Huay Koo Khao) which recieve the water from the catchment area of Doi Suthep-Pui National Park, Chiang Mai. Only one outflow is near the water supply plant of the university, which pumps the raw water from the reservoir as the university water supply (Figure 1).

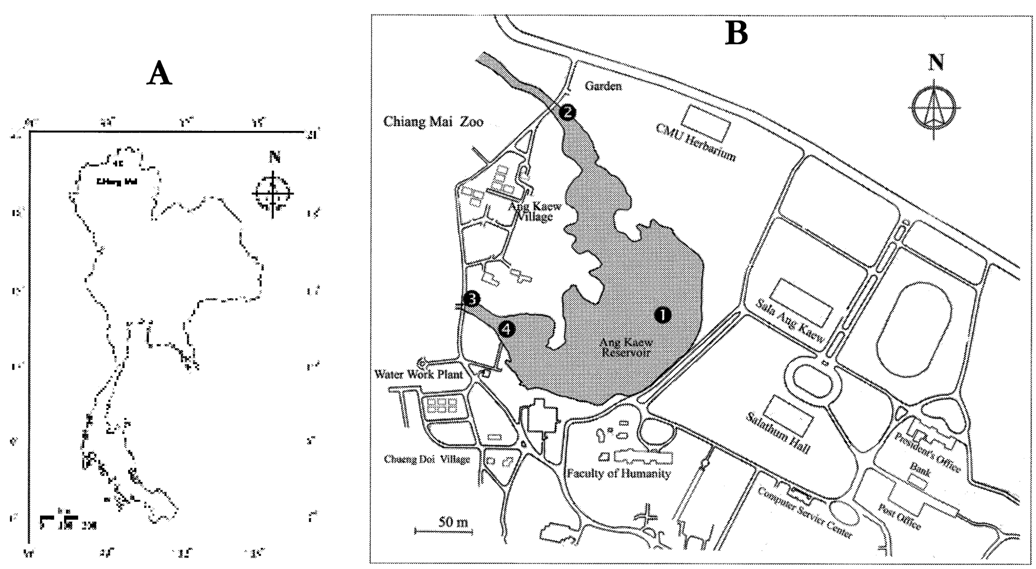


Figure 1. A. Map of Thailand showing the location of Chiang Mai and the study area (AK).
B. Map of Ang Kaew Reservoir, Chiang Mai University, Chiang Mai, Thailand showing the drainage system, inflows, outflow and sampling points.
1. Maximum depth of the reservoir (site 1) 2. Inflow 1 (Huay Kaew) (site 2).
3. Inflow 2 (Huay Koo Khao) (site 3) 4. Outflow (Water Supply Plant) (site 4).

Climate of the study area: The northern part of Thailand is situated on the Indochina Peninsula within the monsoonal belt. There are 3 seasons: the rainy season (June - September), the cool dry season or winter (October-February) and the hot dry season or summer (March-May) [1].

2. Material and Methods

2.1 Scope of Study

The study area covered Ang Kaew Reservoir of Chiang Mai University. Samples were collected at 1 meter intervals of the maximum depth of the reservoir (site 1) including the two main water inflows (Huay Kaew; site 2 and Huay Koo Khao; site 3), and the water outflow (Water Supply Plant; site 4) (Figure 1). The duration of this study ran from July 1995 to July 2002. The timing of sample collection in each year depended on the independent study or the thesis of each student (undergraduate and master degree students).

2.2 Physical and Chemical Qualities of Water at the Sampling Sites

Measurement of some physico-chemical properties of water in the reservoir were done at the sampling sites. The depth of the water which the sunlight could get through was measured with a Secchi disc. The temperature was measured with a thermometer and pH levels were taken with a pH meter. Conductivity was measured with a conductivity meter and dissolved oxygen (DO) was measured by Azide modification method [2].

2.3 Laboratory Investigation of Water Samples

Coliform bacteria was analyzed by the method of Harrigan and Cance [3]. Alkalinity was measured by methyl orange indicator method. BOD was measured using Azide modification method. Amounts of nutrients, i.e. soluble reactive phosphorus, nitrate nitrogen, and ammonium nitrogen were measured according to the method described by APHA, AWWA and WPCF [2]. Chlorophyll a was measured by the method of ISO 10260 [4]. Turbidity was measured with a turbidity meter. Water quality was evaluated from the main parameters (DO, BOD, conductivity, chlorophyll a nitrate nitrogen, ammonium nitrogen, soluble reactive phosphorus and chlorophyll a) according to Lorraine and Vollenweider [5], and Wetzel [6]. Microcystins were analyzed with HPLC [7, 8].

2.4 Sampling and Phytoplankton Study

2.4.1 Sampling of Phytoplankton Samples

Sampling of phytoplankton to identify the species and to determine the density was done at the maximum depth of the reservoir using a plankton net (pore size = 10 μm). The samples were filtered from 10 litre water samples to give about 100 ml and preserved in 6-7 drops of Lugol's solution.

2.4.2 Identification and Counting

The identification of phytoplankton species was carried out with related text [9-13]. For detailed identification of the genera and species, several special publications from tropical environments were used. The number of cells were counted with a counting chamber or haemacytometer, and calculated as number of cell.ml^{-1}.

3. Results and Discussions

3.1 Water Quality of Ang Kaew Reservoir

The study of water quality in Ang Kaew Reservoir, Chiang Mai University from 1995-2002 by investigation of phytoplankton as bioindicator including physico-chemical properties. It was found that the water quality was rather fluctuated throughout the investigation. The water quality was classified by the trophic level [5, 6]. The methods have been modified to use in the reservoir of northern Thailand by Applied Algal Research Laboratory, Chiang Mai University by altering the amounts of DO, BOD, conductivity, chlorophyll a, nitrate nitrogen, ammonium nitrogen and soluble reactive phosphorus [14]. The reservoir was in mesotrophic-eutrophic status and was in hypereutrophic status in January to February 2002 (Figure 2).

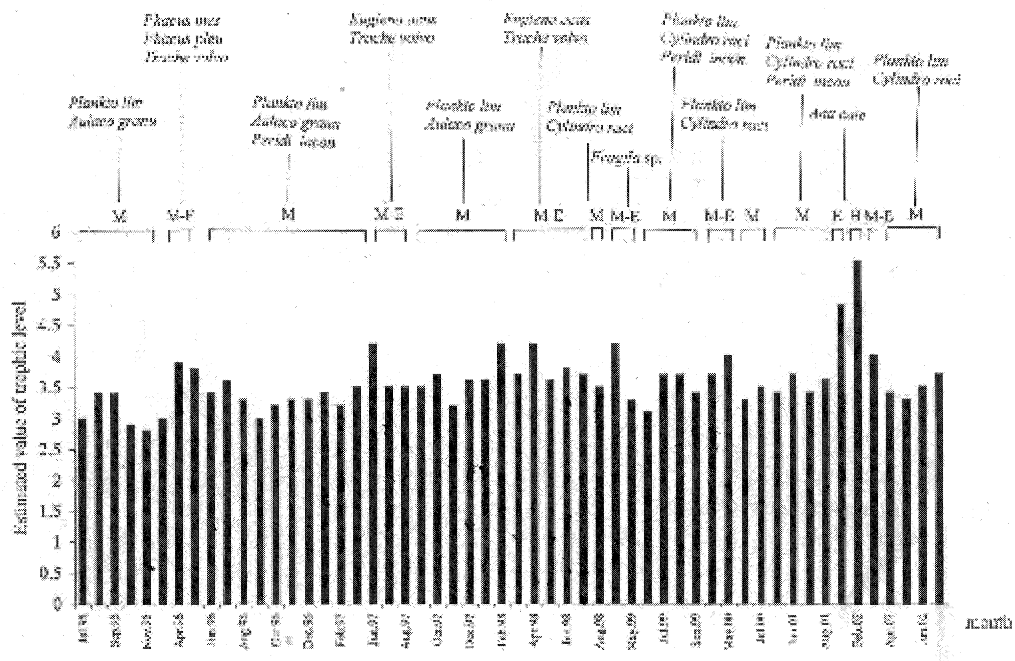
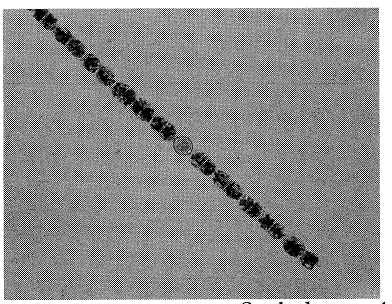


Figure 2. The water quality and phytoplankton distribution as bioindicator in the Ang Kaew Reservoir, Chiang Mai University (1995-2002).

0-0.9 = ultraoligotrophic status	1.0-1.8 = oligotrophic status
1.9-2.7 = oligotrophic-mesotrophic status	2.8-3.6 = mesotrophic status
3.7-4.5 = mesotrophic-eutrophic status	4.6-5.4 = eutrophic status
> 5.4 = hypereutrophic status	
M = mesotrophic status	M-E = mesotrophic-eutrophic status
E = eutrophic status	H = hypereutrophic status

It was clear that, the water quality in Ang Kaew Reservoir was more polluted in the rainy season and summer than in winter by significant amounts, especially it showed hypereutrophication from January to February 2002 (Figure 2). The water quality in this reservoir was classified by the standard surface water quality of Thailand [15], it was in 4 category which means, the water in this reservoir could not be used for consumption at all. Whilst all the investigations, the water quality in the reservoir were classified in 2-3 category, which could be used for consumption after being properly treated.

When we considered the physical properties of the water in the reservoir, it was found that the turbidity of water in the reservoir was low, the colour of water was brownish green in winter and summer but in the rainy season, the turbidity from the particles of soil passed through the reservoir, it would be present in brownish colour, whilst in the period of hypereutrophic, the water in the reservoir showed high turbidity and greenish colour, like vegetable soup from the presence of *Anabaena catenula* blooming (Figure 3).



Scale bar = 10 µ

Figure 3. *Anabaena catenula* (Kützing) Bornet & Flahault, the blooming species in the Ang Kaew Reservoir, Chiang Mai University (January-February 2002).

The water level in this reservoir (8-9 m) was more shallow than during the first period of construction (12 m). In the rainy season, the precipitation would pass through 2 inflows (Huay Kaew and Huay Koo Khao) to the reservoir. But in the dry season (winter and summer) the quantity of water in this reservoir was not enough to use for the consumption in university, so the university would pump the water from the irrigation canal to the reservoir. The study of the water quality in the 2 inflows during the rainy season was found that the water quality was more polluted than the water quality in the maximum depth of the reservoir, which was the representative point of the water in the reservoir (Figure 4). The parameters which showed clearly in this case were ammonium nitrogen (Figure 5) and coliform bacteria (Figure 6). It was a consequence of the precipitation which passed through Chiang Mai Zoo and became to the inflows 1 and 2, so the waste from the animals had contaminated the 2 inflows and ultimately the reservoir.

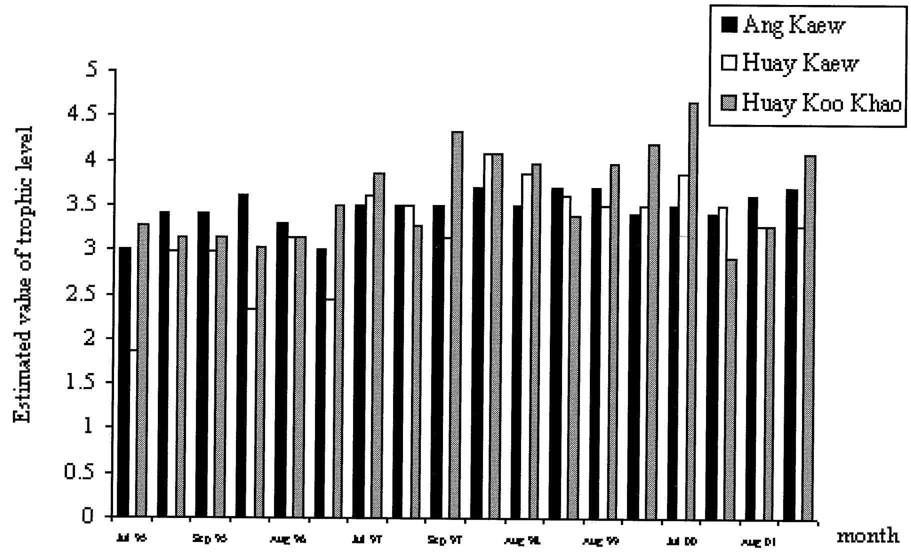


Figure 4. Comparison of water quality in the Ang Kaew Reservoir, Chiang Mai University (1995-2002) between the maximum depth and two inflows (Huay Kaew and Huay Koo Khao).

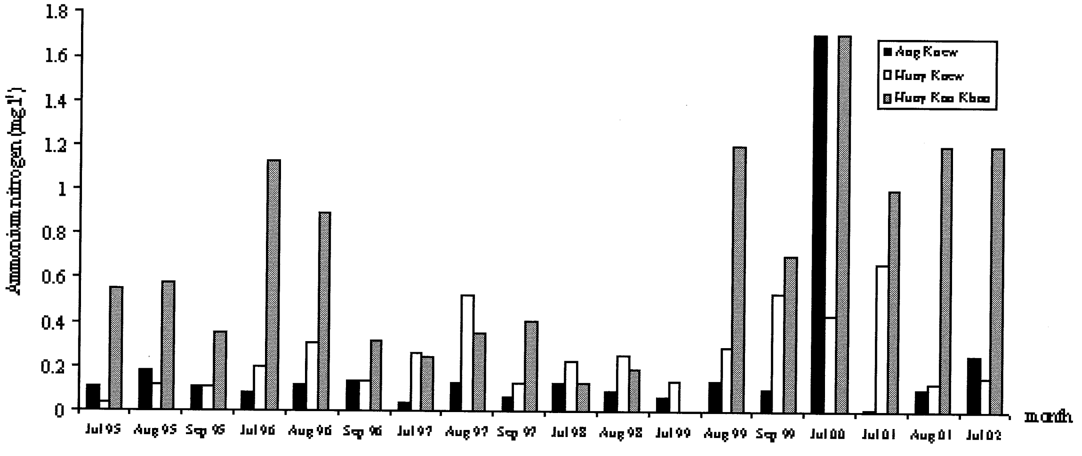


Figure 5. Comparison of the amount of ammonium nitrogen in the Ang Kaew Reservoir, Chiang Mai University (1995-2002) between the maximum depth and two inflows (Huay Kaew and Huay Koo Khao).

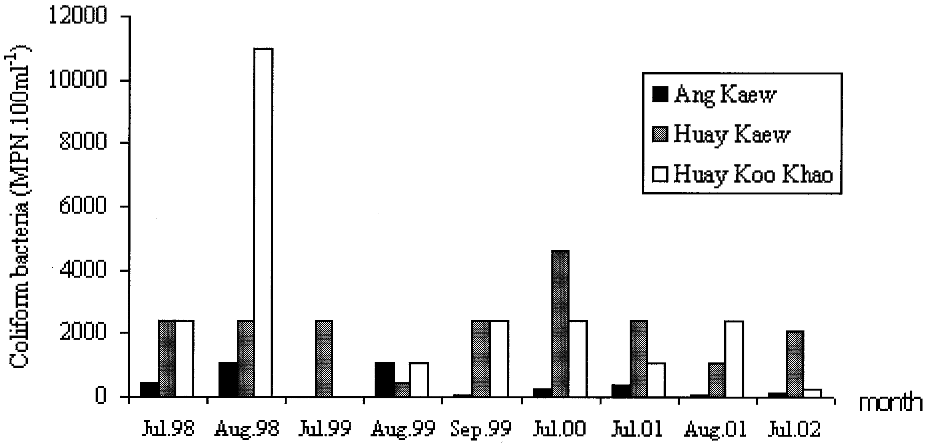


Figure 6. Comparison of the amount of coliform bacteria in the Ang Kaew Reservoir, Chiang Mai University (1998-2002) between the maximum depth and two inflows (Huay Kaew and Huay Koo Khao).

3.2 Biodiversity of Phytoplankton in Ang Kaew Reservoir

Biodiversity of phytoplankton in this reservoir was of interest. One hundred and eighty-six species of phytoplankton were found. They belonged to 6 divisions. The highest number of species was Division Chlorophyta 48.39%, followed by Cyanophyta 18.28%, Euglenophyta 17.20%, Chrysophyta 10.22%, Pyrrhophyta 1.61% and Cryptophyta 4.30% respectively (Table 1). The dominant species of phytoplankton in this investigation were *Planktolyngbya limnetica* followed by *Aulacoseira granulata* and *Cylindrospermopsis raciborskii.*

Table 1. List of phytoplankton species in the Ang Kaew Reservoir , Chiang Mai University, Chiang Mai, Thailand. (July 1995 – July 2002).

Division Cyanophyta	
Anabaena aphanizomenoides Forti	*Merismopedia punctata* Meyen
A. catenula (Kützing) Bornet & Flahault	*M. tenuissima* Lemmermann
A. spiroides var. *crassa* Lemmermann	*Microcystis aeruginosa* Kützing
A. verrucosa BoyePeterson	*M. incerta* (Lemmermann) Crow
Anabaena sp.	*Oscillatoria* sp.
Aphanizomenon gracile Lemmermann	*O. subbrevis* Schmidle
Aphanizomenon sp	*Pseudanabaena* sp.
Chroococcus minutus (Kützing) Nägeli	*Planktolyngbya contorta* Lemmermann
C. minimus (Keissler) Lemmermann	*P. limnetica* Lemmermann
C. turgidus (Kützing) Nägeli	*Spirulina major* Kützing
C. limneticus Lemmermann	*Stichosiphon* sp.
C. dispersus (Keissler) Lemmermann	*Phormidium* sp.
Coelomoron pusillum (Van Goor) Komarek	*Raphidiopsis curvata* Fritsch and Rich
Cyanosarcina sp.	*Synechococcus* sp.
Cylindrospermopsis raciborskii (Woloszynska) Seenayya & Subba et Raju	*Synechocystis* sp.
C. philippinensis (Taylor) Ka	**Division Chlorophyta**
Gloeocapsa sp.	*Actinastrum hantzchii* Lagerheim
Gloeothece rupestris (Lyngbye) Born	*Actinastrum* sp.
Lyngbya sp.	*Ankistrodesmus convolutus* Corda

Table 1. (continued)

A. bibraianus (Reinsch) Koršinov	*P. duplex* var. *gracillium* West & West
A. falcatus (Corda) Ralfs	*P. longicornutum* (Gutwinki) Comas
A. fusiformis Corda	*P. tetras* (Ehrenberg) Ralfs
Botryococcus braunii Kützing	*P. biradiatum* Meyen
Centritractus belanophorus Lemmermann	*Radiococcus* sp.
Chlamydomonas sp.	*Scenedesmus acuminatus* (Lagerheim) Chodat
Chlorella sp.	*S. calyptratus* Comas
Chlorococcum sp.	*S. intermedius* Chodat
Chlorosarcina sp.	*S. opoliensis* Hortobágyi
Closterium lanceolatum Kützing	*S. communis* Hegewald
C. parvulum Nägeli	*S. perforatus* Lemmermann
Coelastrum cubicum Nägeli	*Scenedesmus* sp.1
C. polychordum (Koršinov) Hindak	*Scenedesmus* sp.2
C. microporum Nägeli	*Scenedesmus* sp.3
C. reticulatum (Dangeard) Senn	*Sphaerocystis* sp.
C. sphaericum Nägeli	*Staurastrum paradoxum* West & West
Coelastrum sp.	*S. muticum* Brébisson
Coenocystis sp.	*S. octoverrucosum* Scott & Grönblad
Cosmarium contractum Kirchenbauer	*S. bieneanum* Rabenhorst
C. mikron Skuja	*S. limneticum* var. *rectum* Lemmermann
C. nudum (Turner) Gutawinski	*Staurastrum* sp.
C. punctulatum Brébisson	*Staurodesmus colniculatus* (Lund) Teiling
Cosmarium sp.1	*S. manillatus* (Nordstedt) Teiling
Cosmarium sp.2	*S. glaber* (Ehrenberg) Teiling
Cosmarium sp.3	*Staurodesmus* sp.
Crucigenia tetrapedia (Kirchenbauer) West & West	*Tetraedron trigonum* (Nägeli) Hansgrig
Crucigeniella crucifera (Woll) Komarek	*T. triangulare* Kützing
C. pulchra (West & West) Komarek	*T. minimum* Hansgrig
Dictyosphaerium tetrachotonum var.*fallax* Komarek	*T. caudatum* (Corda) Hansgrig
D. pulchellum Wood	*Tetrastrum heteracanthum* (Nordstedt) Chodat
D. granulatum Hindak	*T. komarekii* Hindak
Dictyosphaerium sp.1	*Treubaria* sp.
Dictyosphaerium sp.2	*Xanthidium* sp.
Didymocystis sp.	
Elakatothrix viridis (Snow) Printz	**Division Euglenophyta**
Euastrum denticulatum (Kirchenbauer) Gay	*Distigma* sp.
Euastrum sp.	*Euglena pisciformis* Klebs
Eudorina sp.	*E. proxima* (Dangeard) Lemmermann
Eutetramorous polycoccus (Koršinov) Komarek	*E. tuberculata* Swirenko
Golenkinia radiata Chodat	*E. caudata* Hübner
Isthmochloron gracile (Reinsch) Hansgirg	*E. oxyuris* Schmarda
Kirchneriella pseudoaperta Komarek	*E. gasterosteus* Skuja
Koliella longiseta (Vischer) Comb	*Euglena* sp.1
Monoraphidium arcuatum (Koršinov) Hindak	*Euglena* sp.2
M. caribeum Hindak	*Phacus longicauda* Swirenko
M. griffithii (Berk) Komarková-Legnerova	*P. pleuronectus* Müller
M. circinale (Nygaard) Nygaard	*P. birgei* Prescott
M. contortum (Thuret) Komarková-Legnerova	*P. acuminatus* Stockes
M. komarkovac Nygaard	*P. caudatus* Hübner
M. tortile (West & West) Komarková-Legnerova	*P. meson* Pochmann
Nephrocytium sp.	*Phacus* sp.
Oocystis marsonii Lemmermann	*Strombomonas* sp.
Pandorina sp.	*Trachelomonas abrupta* Swirenko
Pediastrum simplex var. *simplex* Meyen	*Tr. hispida* (Perty) Stein

Table 1. (continued)

Tr. mirabilis Swirenko	*Gyrosigma* sp.
Tr. volvocina Conrad	*Navicula* sp.
Tr. volvocinopsis Swirenko	*Nitzschia* sp.1
Tr. dubia Swirenko	*Nitzschia* sp.2
Tr. armata (Ehrenberg) Stein	*Nitzschia* sp.3
Tr. caudata (Ehrenberg) Stein	*Nitzschia* sp.4
Tr. lemmermannii Swirenko	*Pinnularia* sp.
Tr. splendidissima Middelhoek	*Rhizosolenia longiseta* Zacharis
Tr. horrida Palmer	*Synedra* sp.
Tr. oblonga Lemmermann	
Tr. mucosa Swirenko	**Division Cryptophyta**
Trachelomonas sp.1	*Chroomonas* sp.
Trachelomonas sp.2	*Cryptomonas narssonii* Skuja
	Rhodomonas sp.
Division Chrysophyta	
Acanthocera zachariasii Ehrenberg Simosen	**Division Pyrhoophyta**
Aulacoseira alpigena (Grunow) Komark	*Ceratium* sp.
A. granulata Ehrenberg	*Gymnodinium* sp.
Achnanthes sp.	*Peridiniopsis* sp.
Cyclotella sp.	*Peridinium inconspicuum* Lemmermann
Cymbella sp.	*Peridinium* sp.1
Dinobryon sp.	*Peridinium* sp.2
Fragilaria sp.	*Peridinium* sp.3
F. crotonensis Kitton	*Peridinium* sp.4
Gomphonema sp.	

3.3 Phytoplankton as Bioindicator for Water Quality in Ang Kaew Reservoir

The species of phytoplankton which indicated mesotrophic to eutrophic status were *Phacus meson*, *P. pleuronectus* and *Trachelomonas volvocina*, which were found in high numbers from April to May 1996 but only *Tr. volvocina* was found in June 1997 and April 1998 again; *Euglena acus* in June 1997 and April 1998; *Fragilaria* sp. in April 1999. Eutrophic and hypereutrophic species was *Anabaena catenula* which was found in high quantity from January to February 2002 when the water in the reservoir showed eutrophication to hypereutrophication clearly. Mesotrophic species were *Planktolyngbya limnetica* followed by *Aulacoseira granulata* and *Cylindrospermopsis raciborskii*. These three species were found most from this investigation including *Peridinium inconspicuum* which was found from June 1996-March 1997 and May-August 2001. The study on bioindicator species was assessed with physico-chemical properties of water quality.

3.4 Algal Toxin in Ang Kaew Reservoir

The toxin analysis from *Anabaena catenula* was done by dry materials in Toxicological Laboratory of Prof. Dr. G.A. Codd, Dundee University, Scotland, United Kingdom. It was found that the microcystin LR was 0.3445 $\mu g.l^{-1}$ dry weight and the total microcystins were 5.736 $\mu g.l^{-1}$ MCE which was a small amount and did not cause toxicity in this reservoir.

3.5 Discussion

The study on water quality in Ang Kaew Reservoir, Chiang Mai University was done with in 7 years, from 1995-2002. The results showed that the water quality in the reservoir was clean enough to be the raw water in the water supply for the citizens of Chiang Mai University. Although in some seasons such as the rainy season and summer, the water quality decreased from the increasing amount of nutrients from the waste of the animals in Chiang Mai Zoo and the polluted water from irrigation canal. But owing to the large amount of water volume, nutrients would be diluted until the water quality was acceptable. The thing to be careful of was the significant amount of coliform bacteria, which contaminated the reservoir from the waste of the animals in the zoo. In the process of water supply we have to be careful in the number of these bacteria, which may be dangerous to the consumers in the university.

The large algal blooming phenomenon, which occurred at the end of 2001 to the beginning of 2002, in the reservoir caused the worry to some persons who supervised the water quality in this reservoir. Normally, there was no occurrence of this phenomenon in the reservoir except at the end of the year 2001, when the water from an irrigation canal was pumped into the reservoir during the dry season. Unfortunately, the water in the irrigation canal was polluted from the waste which was drained into the canal by the community near this canal and another reason, the water in the canal became stagnant during the construction of small dams in some parts of the irrigation canal. So in this cases, the eutrophication occurred easily in the canal. When the water was pumped into the reservoir, it appeared that waste water had been added to the reservoir. When the situation in the reservoir, such as the physicochemical properties, were suitable for the growth of *Anabaena catenula*, large algal bloom occurred. Although algal toxin (microcystin LR) from the production of this species was detected in small amount, but the water from the irrigation canal should be investigated before being pumped into the reservoir and the water quality in this reservoir should be monitor through the year and all along.

ACKNOWLEDGEMENTS

The authors would like to thank Chiang Mai University for providing a research grant for some of this research. The Office of Welfare Division, Chiang Mai University for support with Ang Kaew Reservoir and information of the reservoir, Professor Dr. G.A. Codd, Department of Biological Sciences, Dundee University, Scotland, United Kingdom for microcystin analysis and Mr. Kirk Hollis for proofing English in this publication.

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