4 Results and Discussion

4.1 Cyanobacterial community

4.1.1 Freshwater lakes

In Lake Victoria in 2001 a bloom of *Anabaena flos-aquae*, *Anabaena discoidea* and *Microcystis aeruginosa* could be observed in the Nyanza gulf near Kisumu (I). 94.5% of the biomass belonged to *A. flos-aquae* and *A. discoidea*. *Anabaena discoidea* was only mentioned in early phytoplankton studies of L. Victoria (Schmidle 1902, Ostenfeld 1908, WoŁoszynska 1914). In later investigations this species was not reported again (Bachmann 1933, Talling 1966, Talling 1987, Gophen et al. 1995, Lung´ayia et al. 2000). *Anabaena flos-aquae* is described as an abundant species in Lake Victoria since early investigations by Schmidle (1902). With increasing eutrophication it has developped into one of the most common species together with *Microcystis aeruginosa* and *Aphanocapsa* sp. in the open lake and in the Nyanza Gulf (Talling 1987, Ochumba and Kibaara 1989, Gophen et al. 1995, Lung´ayia et al. 2000, Kling et al. 2001).

The cyanobacterial biomass measured in this study was 272 mg L^{-1} wet weight (I). This considerably exceeds cyanobacterial biomasses with a maximum of 6 mg L^{-1}, measured offshore during different periods beween 1960 and 1995 in the lake (Kling et al. 2001).

In Lake Baringo *Microcystis aeruginosa* was the dominant cyanobacterial species during the investigation period (II). The dominance of *Microcystis* in the lake was already described by Jenkin (1929), Beadle (1932), Patterson and Wilson (1995), and Oduor (2000). The cyano-bacterial biomasses reaching a maximum of 5.5 mg L^{-1} were relatively low which can be attributed to the high turbidity of the lake (II). The turbidity in L. Baringo is mainly caused by the high amount of inorganic suspended particles caused by erosion in the catchment area. The secchi depth never exceeded 0.1 m during the measurements (II). In L. Baringo salinity and conductivity have increased during the last decades. In 1962 in L. Baringo a conductivity of 416 µS cm^{-1} was measured (Talling and Talling 1965). In 1988 the conductivity had increased to 790 µS cm^{-1}, and in 2000 to 1290 µS cm^{-1} (Patterson and Wilson 1995, Oduor 2000). This study showed a further increased conductivity of 1670 µS cm^{-1} in May 2002 due to a long drought period during which the lake level declined considerably (II, Krienitz et al. 2003). The salinity of the lake water (0.5 - 0.7‰) has reached the level of subsalinity

according to Hammer (1986). The increase in salinity did so far not influence on the dominance of *M. aeruginosa* (II). Kebede and Willén (1998) investigated six freshwater and subsaline lakes in Ethiopa. Two of the subsaline lake were dominated by *Microcystis aeruginosa* like L. Baringo. In the other four freshwater and subsaline lakes *Cylindrospermopsis* sp. and *Planktolyngbya* spp. were dominant with only a low abundance of *Microcystis* spp. All the lakes are described as turbid due to high amounts of inorganic material or phytoplankton (Kebede and Willén 1998).

4.1.2 Alkaline lakes

During the investigation period the phytoplankton communities of all the alkaline lakes were characterised by mass developments of filamentous cyanobacteria. In the volcanic crater lake L. Sonachi and in L. Bogoria at all sampling dates *Arthrospira fusiformis* was the dominating species contributing to more than 94% of the total cyanobacterial biomass. High cyanobacterial biomasses up to 3159 mg L^{-1} in L. Sonachi and up to 769 mg L^{-1} in L. Bogoria lakes could be measured (IV, V).

Lake Nakuru, L. Elmenteita and L. Simbi had more variable phytoplankton communities, in which beside *A. fusiformis* at times *Anabaenopsis arnoldii* and *Anabaenopsis abijatae* dominated. In L. Nakuru an unknown *Anabaena* sp. was observed at times with elevated biomasses (IV). This species was also observed in L. Magadi (personal observation). The cyanobacterial biomasses measured were lower than in L. Bogoria and L. Sonachi and reached a maximum concentration of 96 mg L^{-1} in L. Nakuru, of 197 mg L^{-1} in L. Elmenteita and of 347 mg L^{-1} in L. Simbi (IV, V). *Anabaenopsis arnoldii* is described as a common species in alkaline lakes and is already reported from L. Nakuru and L. Elmenteita in studies conducted in the seventies of the last century (Iltis 1969, Melack 1988, Vareschi 1982). It was also observed in small amounts in L. Sonachi during this investigation where it had not been reported in earlier studies (V). *Anabaenopsis abijatae* was first described from the Ethiopian alkaline Lake Abijata by Kebede and Willén (1996). It was observed at times in high amounts in L. Nakuru, L. Elmenteita and L. Simbi (IV, V). *Anabaenopsis abijatae* and *Anabaena* sp. were in this study found for the first time in Kenyan lakes.

In all three lakes the phytoplankton community changed considerably during the study period. In L. Nakuru an *Anabaenopsis abijatae* dominated community changed to one dominated by

Arthrospira fusiformis. In L. Elmenteita *A. abijatae* also was dominant at the beginning of the study in June 2001. The percentage of *A. fusiformis* and *A. arnoldii* increased during the investigation, at the end of the study in September 2002 only *A. arnoldii* dominated (IV). In L. Simbi in the first investigation *A. fusiformis* and *A. abijatae* were dominant while in the second investigation *A. abijatae* had almost completely disappeared (V).

Several authors have described changes in the composition of the phytoplankton communities of Kenyan alkaline lakes. Palaeolimnological and limnological investigations in L. Sonachi showed that blooms of filamentous cyanobacteria alternated with dominant growth of nonfilamentous cyanobacteria depending on meromictic conditions or the disruption of the meromixis (Beadle 1932, Melack 1982, Njuguna 1988, Verschuren 1999). Tuite (1981), Vareschi (1982) and Melack (1988) observed in the 1970s changes in the cyanobacterial communities of L. Nakuru and L. Elmenteita. In L. Nakuru an almost monocyanobacterial *Arthrospira* bloom changed to one dominated by *Anabaenopsis* sp. and picoplanctic cyanobacteria, in L. Elmenteita a dominant bloom of *Arthrospira fusiformis* and *A. arnoldii* disappeared completely (Vareschi 1982, Melack 1988).

Melack (1988) suggests shifts in salinity exceeding the physiological tolerance as one possible explanation for the variation in species composition. Of all five investigated alkaline lakes L. Sonachi and L. Simbi had the lowest salinity around 10‰, L. Bogoria the highest up to 47‰ (IV, V). This confirms that *Arthrospira* sp. can tolerate a wide range of salinity, which was also shown by Vareschi (1982) and Kebede (1997). *Anabaenopsis abijatae* and *A. arnoldii* possibly have a lower salinity tolerance than *Arthrospira fusiformis*. These species were never found in the highly saline L. Bogoria during this study (IV). The salinity of L. Simbi, where *A. abijatae* was codominant beside *A. fusiformis*, is similar to that of L. Sonachi. There *A. abijatae* was not observed in any sample. In the Ethiopian Lake Abijata, where *A. abijatae* first was found together with *A. fusiformis* in the 1990s, the salinity had increased considerably in the last decades from 16.2 to 26.4‰ (Wood and Talling 1988, Kebede et al. 1994). In samples taken in the 1960s and 1990 *Arthrospira fusiformis* had been the only dominant species (Kebede and Willén 1998).

The dominance of *Arthrospira* and *Anabaenopsis* spp. in the alkaline lakes and *Microcystis* sp. and *Anabaena* spp. in the freshwater lakes during the study period is influenced by the high turbidity of all lakes. The secchi depth in all alkaline lakes never exceeded 0.5 m, in L.

Baringo 0.1 m and in L. Victoria 0.6 m (I, II, IV, V). All dominant cyanobacterial genera possess gas vacuoles. The production of gas vacuoles enables the formation of free floating colonies. The control of the vertical location is an important factor in turbid waterbodies like the investigated lakes (Walsby 1994).

Other environmental factors that have been considered to influence the dominance of cyanobacteria are temperature and nutrient loading (Paerl 1996). Many bloom forming cyanobacteria show optimal growth rates at temperatures of 25 °C or higher (Robarts and Zohary 1987). The water temperature of all investigated lakes ranged between 17 and 34 °C (I, II, IV, V). Since water blooms of cyanobacteria also can be observed during periods of colder water temperature in the temperate regions, temperature alone can not explain the dominance of cyanobacteria. It is more likely the influence of stratification caused by high water temperatures. Such conditions favour the growth of gas-vacuolate cyanobacteria (Walsby 1994, Oliver and Ganf 2000).

All studied lakes were characterised by high mean total phosphorus (TP), between 1.0 and 15.1 mg L^{-1} and mean total nitrogen (TN) values between 2.8 and 5.5 mg L^{-1} (I, II, IV, V). In L. Victoria at the time of the *Anabana flos-aquae* and *A. discoidea* bloom high TP and TN values of 1.9 mg L^{-1} and 21.5 mg L^{-1} were measured (I). The TP and TN values of all lakes have reached a level typical for hypertrophic conditions (OECD 1982). One reason for the high nutrient loading of the Rift Valley lakes is the accumulation of nutrients due to the absence of an outflow. Deforestation, overgrazing, erosion, intensified agriculture and the growth of human settlements in the drainage basins of the lakes are further elevating nutrient concentrations and siltation of the lakes (Mwaura and Moore 1991, Hecky and Bugenyi 1992, Lung´ayia et al. 2001).

Cyanobacterial water blooms are worldwide associated with high nutrient concentrations and eutrophication (Paerl 1996, Oliver and Ganf 2000). Especially a low ratio of total nitrogen to total phosphorous has been suggested as a major factor favouring cyanobacterial dominance (Smith 1982, 1983). In contrast, other studies have found little evidence that low TN:TP ratios are important for cyanobacterial dominance (Jensen et al. 1994, Scheffer et al. 1997). According to Reynolds (1992) and Oliver and Ganf (2000) the TN:TP ratio is insignificant if the nutrient concentrations exceed concentrations limiting cyanobacterial growth. According to Hecky (1993) increasing anoxic areas in the deep water of L. Victoria are responsible for

an increasing denitrification. Hence, during mixing times the N:P ratio in surface water also decreases, than favouring heterocystous cyanobacteria.

4.1.3 Hot springs

The investigations of the hot springs near L. Bogoria in this study revealed a cyanobacterial community similar to one described by Hindák (2001). The sample he described was from 1981. The dominant species found during this study were *Synechococcus bigranulatus* Skuja, *Spirulina subsalsa* Oersted, *Oscillatoria willei* Gardner and *Phormidium* cf. *terebriformis* (Aghardh ex Gomont) (III). *Synechococcus* spp. are described from hot springs worldwide (Komárek and Anagnostidis 1999, Ward and Castenholz 2000). *Phormidium terebriformis* is a cosmopolitan member of thermal and sulfur springs (Geitler 1932, Ward and Castenholz 2000). Members of the genus *Spirulina* are known to have a wide ecological distribution and are found in freshwater, brackish and marine habitats. They are also common in inland saline lakes and in thermal springs (Anagnostidis and Golubić 1966, Castenholz et al. 2001). *Oscillatoria willei* is regarded as pantropical and occurs also in Lake Chad (Compère 1974).
The cooler and less saline hot spring effluents at L. Bogoria are used by the flamingo population for drinking and bathing. According to Brown (1973) and Mari and Collar (2000) the flamingos need low saline water for drinking and bathing daily. During this procedure they also ingest cells and filaments of the hot spring cyanobacteria. These cells and fragments were found beside filaments of *Arthrospira fusiformis* in gut contents and fecal pellets of Lesser Flamingos (III).

4.2 Cyanobacterial toxins

The investigations on cyanotoxins in the Kenyan East African Rift Valley in 7 lakes and in hot springs near Lake Bogoria have shown that in almost all waterbodies with mass developments of cyanobacteria cyanobacterial toxins were found (I, II, III, IV, V). The toxins belonged to the hepatotoxic microcystins and the neurotoxic anatoxin-a. These are the first findings of cyanobacterial toxins in Kenyan waterbodies. The detection of cyanotoxins in cyanobacterial mats in hot springs near L. Bogoria is the first evidence in thermal habitats worldwide. Table 3 shows the cyanotoxin variants found in the different investigated Kenyan waterbodies.

Table 3: Microcystin (MC) variants and anatoxin-a in Kenyan Rift Valley lakes and hot springs. + = detected, - = not detected

Body of water	Microcystin variants					
	MC-LR	MC-RR	MC-LA	MC-LF	MC-YR	Anatoxin-a
freshwater						
Lake Baringo	+	+	-	-	+	+
Lake Victoria	+	+	+	+	-	-
alkaline-saline						
Lake Bogoria	+	+	-	-	-	+
Lake Elmenteita	-	-	-	-	-	-
Lake Nakuru	+	+	+	+	+	+
Lake Simbi	+	+	+	-	+	+
Lake Sonachi	-	+	-	-	-	+
Hot springs (Lake Bogoria)	+	+	-	+	+	+

4. 2. 1 Freshwater lakes

In Lake Victoria four different microcystins (microcystin-RR, -LR, -LA, -LF) were detected (Table 3) (I). The highest total microcystin concentration measured was 41.4 µg g^{-1} cyanobacterial dry weight (DW). The detected toxins can be related to a bloom of *Anabaena flos-aquae*, *Anabaena discoidea*, and *Microcystis aeruginosa* (I). *Anabaena flos-aquae* and *M. aeruginosa* are worldwide known for the production of microcystins (Sivonen 1996, Carmichael 1997, Codd et al. 1999, Chorus 2001). It is so far not clear if all or only one of the found species produces the toxins.

In phytoplankton samples of L. Baringo three variants of microcystins (microcystin-LR, -RR and -YR) and anatoxin-a were detected (Table 3). The total microcystin concentrations ranged from 310 to 19,800 µg g^{-1} DW, the anatoxin concentration from 273 to 1,256 µg g^{-1} DW (II). The only possible source of the microcystins is *Microcystis aeruginosa*, due to the rare findings of other potential producers of the cyanotoxins e.g. *Anabaena* sp., *Phormidium* sp., and *Pseudanabaena* sp. (II). In the samples also anatoxin-a was detected which *M. aeruginosa* is possibly able to produce. This ability is described by Park et al. (1993) from

Japanese *Microcystis* strains. Thus it is most likely that *M. aeruginosa* is responsible for the production of microcystins and anatoxin-a in L. Baringo (II).

As the water of Lake Victoria and Lake Baringo is used by the local human population for washing and as drinking water for the livestock and sometimes for their own consumption, there is a risk of poisoning by the cyanobacterial toxins. The values measured in Lake Baringo exceed in two of four samples with 3.3 and 3.0 µg L^{-1} the consumption safe level of 1 µg microcystin L^{-1} (II, WHO 1998). The microcystin values measured in L. Victoria during the bloom of *A. flos-aquae, A. discoidea* and *M. aeruginosa* were between 1.0 and 1.1 µg L^{-1} after conversion from µg microcystin g^{-1} cyanobacterial DW to µg microcystin L^{-1} lakewater.

4.2.2 Alkaline lakes

With the exception of Lake Elmenteita, microcystins and anatoxin-a were detected in phytoplankton samples of all investigated alkaline lakes (Table 3, IV, V). With five variants, the highest number of microcystins occurred in samples of Lake Nakuru, whereas in L. Sonachi only one microcystin variant was found (Table 3). The highest microcystin concentration of 4594 µg g^{-1} DW and anatoxin-a concentration of 223 µg g^{-1} DW were measured in Lake Nakuru (IV). One possible source for the production of the toxins is *Arthrospira fusiformis*. In this study strains of *Arthrospira fusiformis* from 6 alkaline lakes were isolated and cultivated. Using HPLC and MALDI-TOF microcystins (MC-YR) and anatoxin-a were detected in the *Arthrospira* strains AB2002/10 from Lake Bogoria and AB2002/02 from Lake Sonachi, in the strain AB2002/04 from Lake Nakuru only anatoxin-a (Table 4, IV, V). In *Arthrospira* strains from Lake Elmenteita (AB2002/01), L. Magadi (AB2002/03) and L. Simbi (AB2002/11) toxins were not found (Table 4, IV, V). From each lake only one strain of *Arthrospira* was investigated for cyanobacterial toxins. It remains unclear if in blooms of *Arthrospira fusiformis* toxic and nontoxic strains exist, like in blooms of other cyanobacteria, e.g. *Microcystis* (Carmichael 1992a, Chorus 2001).

Table 4: Toxin producing and non-toxic strains of *Arthrospira fusiformis*, *Anabaenopsis abijatae*, *Phormidium* cf. *terebriformis* and *Spirulina subsalsa* from different Kenyan lakes. + = detected, - = not detected

Species	Strain	Lake	Microcystins	Anatoxin-a
Arthrospira fusiformis	AB2002/01	Elmenteita	-	-
Arthrospira fusiformis	AB2002/02	Sonachi	+ (MC-YR)	+
Arthrospira fusiformis	AB2002/03	Magadi	-	-
Arthrospira fusiformis	AB2002/04	Nakuru	-	+
Arthrospira fusiformis	AB2002/10	Bogoria	+ (MC-YR)	+
Arthrospira fusiformis	AB2002/11	Simbi	-	-
Spirulina subsalsa	AB2002/06	Nakuru	-	-
Phormidium cf. *terebriformis*	AB2002/07	Nakuru	-	-
Anabaenopsis abijatae	AB2002/09	Simbi	-	-
Anabaenopsis abijatae	AB2002/14	Nakuru	-	-
Anabaenopsis abijatae	AB2002/18	Elmenteita	-	-

Arthrospira is regarded as nontoxic (Ciferri 1983, Jassby 1988). In some parts of the African continent and in Central America, *Arthrospira* is used or known as a traditional foodsource by indigenous people (Iltis 1969, Abdulqader et al. 2000). Because of the high nutritional value several strains of this genus are widely used in mass culture for the production of food, animal feed and chemicals in subtropical and tropical countries (Richmond and Vonshak 1978, Vonshak 1987, Vonshak 1997). However, several studies have demonstrated that strains of *Arthrospira* possibly are producers of cyanobacterial toxins. *Spirulina/Arthrospira* based tablets and capsules for a human dietary supplement also gave positive results when analyzed for microcystins using HPLC and Elisa methods (Gilroy et al. 2000). Iwasa et al. (2002) correlated human liver injury of a 52-year-old Japanese to the intake of *Spirulina*/*Arthrospira*. Salazar et al. (1998) found no toxic effect during toxicity studies with *Spirulina maxima* on mice.

Members of the genus *Anabaenopsis* may also be responsible for the toxins detected in the alkaline lakes. Lanaras and Cook (1994) have found microcystins in a water bloom dominated by *Anabaenopsis milleri* in Lake Porto Lagos, Greece. In cultivated *Anabaenopsis abijatae* isolates from Lakes Nakuru, Elmenteita, and Simbi no microcystins or anatoxin-a were detected (Table 4, IV, V).

Other possible toxin producers e.g. *Phormidium* sp., *Oscillatoria* sp., *Spirulina subsalsa* *Synechocystis* sp., and *Synchococcus* sp. were observed in small amounts in the investigated alkaline lakes (IV, V). In isolated strains of *Phormidium* cf. *terebriformis* and *Spirulina subsalsa* from Lake Nakuru no cyanobacterial toxins were produced (Table 4, IV). In cyanobacterial mats consisting of *Phormidium* sp. and *Oscillatoria* sp. from Scottish freshwater lakes and Swiss alpine lakes microcystins and anatoxin-a could be found (Skulberg et al. 1992, Mez et al. 1997). *Synechocystis* is known as a source for microcystins from investigations in Morocco and Brazil (Oudra et al. 2001, 2002, Domingos et al. 1999).

4.2.3 Hot springs

In the hot springs at L. Bogoria the investigation for cyanotoxins revealed the occurrence of four variants of microcystins (microcystin-RR, -LR, -LF, -YR) and anatoxin-a (Table 3, III). The origin of the toxins remains unclear because of the occurrence of different cyanobacterial species (*Phormidium* cf. *terebriformis*, *Spirulina subsalsa*, *Oscillatoria willei*, and *Synechococus bigranulatus*) in the hot springs. From L. Nakuru a strain of *Spirulina subsalsa* (AB2002/06) and *Phormidium* cf. *terebriformis* (AB2002/07) were isolated. In the cultures of both strains no toxins were detected (Table 4). Morphologically they resemble *S. subsalsa* and *P.* cf. *terebriformis* found in the hot springs but it is incertain if they belong to the same species.

The findings of cyanobacterial toxins in the alkaline lakes and in cyanobacterial mats in the hots springs at L. Bogoria make it likely that they are a contributory cause to the mass deaths of flamingos, beside infectious diseases and poisoning by heavy metals and pesticides. These mass deaths were observed in recent years in the Kenyan Rift Valley especially at L. Nakuru and L. Bogoria. The daily feeding rate of an adult flamingo is about 72 g dry weight of cyanobacteria (Vareschi 1978). For L. Bogoria this corresponds to a daily intake of up to 11,160 µg microcystins and 670 µg anatoxin-a and for L. Nakuru of up to 330,700 µg microcystins and 16,000 µg anatoxin-a (IV). As microcystins and anatoxin-a were detected in the stomach contents, intestines, and liver samples taken from flamingo carcasses from L. Nakuru and L. Bogoria it is obvious that flamingos ingest cyanotoxins with their food (III, Ballot et al. 2002). In stomach contents and fecal pellets taken from dead flamingos cyanobacterial cells and filaments of hot spring cyanobacteria as well as *Arthrospira*

filaments were found (III). This confirms that flamingos also ingest toxic cyanobacteria during the drinking and bathing procedure, which they conduct at the less saline hot springs (III).

4.3 Phylogenetic relationship of *Arthrospira, Phormidium* and *Spirulina* strains

In this study the phylogenetic relationship of *Arthrospira fusiformis* strains from six Kenyan lakes and of *Arthrospira indica* Desik. et Jeeji-Bai strains from three Indian waterbodies was investigated using the 16S rRNA gene, the intertranscribed spacer region (ITS) and the cpcB-cpcA region of the phycocyanin locus (PC-IGS) (VI). Morphologically the strains could be distinguished e.g. in coiling and number of coils. Only the filaments of the strains of *A. indica* had calyptrated end cells (VI). The similarity of DNA sequences was 100% between the strains in the case of 16S and PC-IGS. The comparison of the ITS-region revealed that all *A. fusiformis* and one *A. indica* strain corresponded to 100%. The two other *A. indica* strains had similar sequences but corresponded only to 99.6% to the other *Arthrospira* strains. In the phylogenetic trees of 16S and PC-IGS all investigated *Arthrospira* strains were found in the same clusters (VI). In the ITS-tree the Kenyan *A. fusiformis* strains and one Indian *A. indica* strain formed one cluster, the two other Indian *A. indica* strains were found in a closely related cluster. Scheldemann et al. (1999) and Baurain et al. (2002) have investigated the ITS region of *Arthrospira* strains from four continents. They found that the *Arthrospira* strains could be distinguished in two main clusters with two subclusters each. *Arthrospira* strains from L. Sonachi in their investigation belonged to cluster I, two *Arthrospira* strains from L. Nakuru belonged to subcluster II. They have found no relationship between the cluster and the geographic origin of the strains. Similar results were described by Manen and Falquet (2002), who studied the phycocyanin locus of different *Arthrospira* strains for phylogenetic relationship. In contrast to their results, in this study all Kenyan strains were identical and grouped in one cluster, subcluster IA according to Baurain et al. (2002) (VI).

A *Phormidium* cf. *terebriformis* strain from L. Nakuru shows a close phylogenetic relationship to *Arthrospira*. In the 16S, the PC-IGS and the ITS trees the *P.* cf. *terebriformis* strain AB2002/07 was always found close to or in the *Arthrospira* cluster. That makes it evident that it is closely related to *Arthrospira.* In the 16S tree the *Phormidium* strain AB2002/07 is clearly separated from the strain *Phormidium* KR2003/25 isolated from hot

springs near L. Bogoria. This is supported by a 16S similarity of 92.0% only. Both strains are living in habitats with differences in temperature and salinity conditions and most likely they are not members of the same species. *Phormidium terebriformis* is actually described as a common species in thermal and sulfur springs (Geitler 1932). In North American hot springs a thermal red form of *Oscillatoria terebriformis* is often found in a temperature range of 40 to 54 °C (Castenholz 1978). These temperatures are much higher as those of 17 to 32 °C measured in L. Nakuru. In the hot springs at L. Bogoria, *P.* cf. *terebriformis* grows in running water at a temperature range of 40 to 50 °C. A transport by flamingos from the hot springs to other lakes is possible. The flamingos use the hot spring water for washing and drinking and move frequently between the lakes.

The *Spirulina subsalsa* strain from L. Nakuru is clearly separated from the *Arthrospira* cluster in the 16S tree and is found in the same cluster as other *Spirulina* and *Halospirulina* strains. Inside the *Spirulina* cluster a separation between a freshwater strain from India, the alkali tolerant strain from Kenya and a halotolerant *Halospirulina* strain can be seen (VI). This result is similar to findings of Margheri et al. (2003) who found different clusters when investigating *Spirulina* strains of different salt and alkalitolerance with amplified ribosomal DNA restriction analysis (ARDRA) and unweighted pair group method with arithmetic mean (UPGMA).