Journal of Basic & Applied Mycology (Egypt) 4 (2013): 47-58

Terrestrial fungi tolerating the hypersaline water of Wadi El-Natrun Lakes, Egypt

A. H. Moubasher, M. A. Ismail*, N. A. Hussein, H. A. A. Gouda

Department of Botany and Microbiology, Faculty of Science & Assiut University Mycological Centre (AUMC), Assiut University, Assiut, Egypt.

***Corresponding author: e-mail: ismailmady60@yahoo.com**
Received 1/5/2013, Accepted 22/6/2013

Abstract: Chemical analysis revealed that water samples collected from Wadi El-Natrun Lakes were highly alkaline, of pH ranging from 8.4 –9.5 and of high levels of total soluble salts, chlorides, sodium and potassium. Water collected from El-Zugm Lake showed the highest levels of organic matter, sodium, calcium, magnesium and chlorides among the 8 lakes investigated. On the other hand, some parameters showed their peak in other lakes e.g. pH (9.4) and total soluble salts (87%) in Fasida. A total number of genera (16) and species (33) were recorded from water samples collected from all lakes during the seasons of study, with the widest spectrum of species being isolated on the control medium (14) and the lowest on 10% NaCl medium (3). *Aspergillus, Acremonium* followed by *Penicillium* were the most dominant genera possessing the highest proportions of propagules on all isolation media except on 10 % NaCl. On the other hand, only species of the genera *Scopulariopsis* and *Acremonium* were isolated on 10% NaCl medium. *Aspergillus* showed its count peak in Al-Beida Lake during winter 2007 on both acidic and alkaline media while in spring 2007 on control medium (from Khadra Lake) and on 40% sucrose (from El-Zugm Lake). From *Aspergillus, A. terreus* followed by *A. flavus* and *A. niger* were the most common on all the isolation media, but *A. ochraceus* was dominant on acidic media only. Other most common species, namely *Penicillium chrysogenum* and *P. puberulum* were encountered on all media but not on 10 % NaCl medium. Some species were isolated on one medium but not on the others: *Scopulariopsis halophilica* (on 10% NaCl), *Emericella quadrilineata* (on 40% sucrose), *Staphylotrichum coccosporum* (on medium adjusted at pH 4) and *Acremonium hyalinulum* (on alkaline media).

Key words: Hypersaline waters, lakes, Wadi El-Natrun, extremophilic fungi, terrestrial.

Introduction

Extreme environments, such as acidic or hot springs, saline and/or alkaline lakes, deserts and the ocean beds are found in nature, which are too harsh for normal life to exist (Satyanarayana, *et al*. 2005). Hypersaline environments can be found in all continents and in most countries. They consist of two primary types: thalassohaline and athalassohaline systems. Thalassohaline systems arose from seawater evaporation and hence contain sodium chloride as the predominant salt. The Great Salt Lake, Utah, is an example of such, but other examples are salt mine drainage waters, playas, natural coastal splash zones and tide pools, brine springs from underground salt deposits, and solar salterns (Litchfield and Gillevet 2002). Athalassohaline systems arose from non-seawater sources and contain different ion ratios. These athalassohaline systems are dominated by potassium, magnesium, or sodium and are frequently the sources of potash, magnesium metal, soda, and even borax if the waters were high in boron. Some examples of these are the alkaline soda lakes of Egypt (e.g., Wadi El-Natrun), the Dead Sea, the soda lakes of Antarctica, and Big Soda Lake and Mono Lake in California (Gunde-Cimerman *et al.* 2000, Ulukanli and Digrak 2002, Litchfield and Gillevet 2002, Oren 2002 and Cantrell *et al*. 2006).

Alkaline environments e.g. East African Rift Valley, Wadi El-Natrun in Egypt, Indian Sambhar Lake (Satyanarayana *et al.* 2005) are considered type of athalassohaline systems. Soda lakes and soda deserts represent the major type of naturally occurring highly alkaline environments. The pH of these environments fluctuates due to their limited buffering capacity and therefore, alkalitolerant microbes are more abundant in these habitats than alkaliphiles. These lakes are often closed basins with no obvious outflow, forming semipermanent standing bodies of water. Surface evaporation rates exceed the rate of inflow of water allowing the dissolved minerals to concentrate with $CO3^{-2}$ and Cl^{-1} as major anions creating a pH 8.5 to > 12 (Grant *et al.* 1990, Jones *et al.* 1994, 1998, Jones and Grant 1999 and Grant 2006).

Wadi El-Natrun Depression is situated at the western side of the Nile Delta of Egypt and includes some water bodies characterized by high salinity. It is a narrow depression located approximately 90 km south of Alexandria and 110 km North West of Cairo. It is about 50 km long, narrow at both ends and wider in the middle (Zahran and Willis 1992). It lies 23 m below sea level and 38 m below the water-level of Rossetta branch of the Nile (Abdel-Malek and Rizk 1963). It is characterized by a series of twenty small disconnected lakes in the bottom of the Wadi. Ten of these lakes are relatively larger in size and have permanent water in all or some of their parts. Inland saline lakes and salt crusts occupy the area surrounded by contour zero (Abu Zeid 1984). The principal lakes of Wadi El-Natrun are Fasida, Umm-Risha, Al-Razoniya (Rosetta), Abu-Gubara, Hamra, El-Zugm (Zaagig), Al-Beida, Khadra and Al-Gaar (Taher 1999 and Zahran and Willis 1992). The Wadi El-Natrun depression gets its water from two sources: the springs in the bottom (e.g. in Lake Hamra), and seepage into the lakes. Pavlov (1962) attributed the source of the water to the radial inflow of underground water towards the lakes. Shata and El Fayoumi (1967) noted that the main source of water to the depression comes from underground water flowing from the Rosetta branch and its branches. It is believed also that the water originates from the Nile, infiltrating through sands and gravels constituting the main strata separating the wadi from the river (Atia *et al*. 1970). Most lakes reach maximum levels between December and March, with the lowest levels in summer. Shallow saline pools shrink in volume by >60% following evaporation in summer. It is assumed that the underground water from the Nile Delta infiltrating into Wadi El-Natrun has roughly the same relative salt composition when it reaches the lakes. The differences found between the relative composition of different lakes are mainly the result of differing microbial activities in the sediments and brines (Taher 1999). The water of Wadi El-Natrun saline lakes is enriched in dissolved minerals that have accumulated in the brines following solar evaporation. Detailed chemical analysis of the lakes of Wadi El-Natrun depression in Egypt revealed high pH level (> 11.5) and high concentration of carbonate, chloride, phosphate, sodium, potassium and silicon oxide (Grant 2006).

Fungi can also grow in hypersaline waters. Some “terrestrial” fungi had been isolated from sea water or sea water flora and fauna. *Aspergillus* and *Cladosporium* were the most frequent isolates found in samples of sand, wood and mangrove in Puerto Rico (Acevedo-Ríos 1987). Others, namely *Cephalosporium*, *Diplodia*, *Fusarium*, *Helminthosporium*, *Penicillium*, *Trichoderma*, *Scopulariopsis* and *Pleospora* were found particularly in sand (Acevedo-Ríos 1987). Xerophilic and halophilic fungi are able to grow in media with low water activities (a_w) and they can be expected to survive in this type of environment. In 1977, Cronin and Post reported the isolation of halophilic fungi belonging to the genus *Cladosporium* were growing in a submerged piece of pine wood in the Great Salt Lake in Utah. Later, Butinar *et al.* (2005b) reported the occurrence of the yeasts *Debaryomyces hansenii* and *Metschnikowia bicuspidate* in this lake. *Aspergillus versicolor*, *Chaetomium globosum*, *Eurotium herbariorum*, *E. amstelodami* and *E. rubrum* were also isolated from Dead Sea waters (Kis-Papo *et al*. 2001, 2003a). On the other hand, *Gymnascella marismortui* (an obligate halophile), *Ulocladium chlamydosporum* and *Penicilium westlingii* (halotolarant) were recorded in Dead Sea waters by Buchalo *et al*. (1998a). Several culturable fungi such as *Cladosporium* spp., *Alternaria* spp., *Aspergillus sydowii*, *Nigrospora* spp., and *Penicilliun solitum* from deep-sea water samples (below 500 m depth) have been reported from different geographical locations (Roth *et al.* 1964 and Raghukumar *et al*. 1992).

To our knowledge, no report was published up till now about mycobiota inhabiting the hypersaline habitat environment of Wadi El-Natrun lakes. So, this work has been designed to highlight on the extremophilic groups of fungi (including osmophilic/ osmotolerant, halophilic/ halotolerant, acidiphilic/ aciditolerant, and alkaliphilic and alkalitolerant fungi) that may be found in the hypersaline waters of Wadi El-Natrun lakes.

Materials and Methods

Collection of water samples

Water samples were collected during three seasons naming autumn of year 2006, winter and spring of year 2007, from the big eight lakes (Fasida, Umm-Risha, Rosetta, Hamra, El-Zugm, Al-Beida, Khadra, Al-Gaar) of Wadi El-Natrun depression. The 24 water samples were collected in sterile bottles at a depth of about 10-20 cm near the lake shore from different sites. Samples were brought into the laboratory and kept in a cold place (5°C) till chemical and fungal analysis.

Chemical analysis of water samples

PH value: The pH meter (Orior Research Model GOHL Digital Ionalyzer) electrode was immersed directly in water sample for the determination of water pH (Jackson 1958).

Total soluble salts (TSS): The specific electrical conductance (EC expressed in mmhos /cm) was measured in the samples using the conductance meter (YSI, model 35). The percentage total soluble salts in a sample were estimated using the following equation:

% TSS in the dry sample = 0.064 × EC × extract ratio. The conversion factor to percentage salts (0.064) is fairly applied for solutions extracted from alkaline and saline soils (Richards 1954 and Jackson 1958).

Carbonate and bicarbonate: Total carbonate was determined directly in water according to the method described by Jackson (1958).

Chloride (Cl^-): Soluble chloride was estimated by applying the silver nitrate titration method using potassium chromate as an indicator (Jackson 1958).

Calcium and magnesium (Ca^{+2} & Mg^{+2}): The versene (disodium dihydrogen ethylene diamine tetraacetic acid) titration method as recommended by Schwarzenbach and Biedermann (1948) was employed for Ca^{+2} and Ca^{+2} + Mg^{+2} determination.

Sodium and potassium (Na^+ & K^+): Flame photometer method (Williams and Twine 1960) using Carl Zeiss flame photometer was used for the determination of Na^+ and K^+ cations.

Isolation of terrestrial fungi from water samples

Seven agar media types (5 plates each) were used for enumeration and isolation of terrestrial fungi from lakes water. One ml of lake water was transferred into each of Petri-dish and mixed by rotation with agar medium. After solidification of the agar, the plates were incubated at 28ºC for 7-15 days. The developing fungal colonies were counted and calculated per ml water and preserved in agar slants for identification.

The seven media types used for isolation of fungi are: 1. Modified Czapek Dox agar in which glucose (10 g/l) replaced sucrose, of the following composition (g/l) sodium nitrate 3.0, potassium dihydrogen phosphate 1.0, magnesium sulphate 0.5, potassium chloride 0.5, ferrous sulphate 0.01, glucose 10.0, agar 15.0), to which rose bengal (1/15000) and chloramphenicol (25 μg/ml) were used as bacteriostatic agents (Smith and Dawson 1944, Al- Doory 1980). This medium was adjusted to pH7.3 and was used as a control medium; 2. Czapek Dox agar supplemented with 40% sucrose for isolation of osmophilic and osmotolerant fungi; 3. Modified Czapek Dox agar medium (in which glucose, 10g/l, replaced sucrose) supplemented with 10% sodium chloride was used for isolation of halophilic and halotolerant fungi; 4 and 5. Modified Czapek Dox agar media in which pH was adjusted at 4 or 5 using diluted HCl were used for isolation of acidiphilic and aciditolerant fungi; 6 and 7. Modified Czapek Dox agar in which pH was adjusted at 10, 13 using NaOH were used for isolation of alkaliphilic and alkalitolerant fungi.

Identification of fungi

The identification of fungal genera and species (purely morphologically) was based on macroscopic and microscopic features following the keys and descriptions of Ellis (1971, 1976), for Dematiaceous Hyphomycetes, Pitt (1979), for *Penicillium* and its teleomorphic states *Eupenicillium* and *Talaromyces*, Raper and Fennell (1965), for *Aspergillus* species, Moubasher (1993), Domsch *et al.* (2007) for fungi in general and Booth (1971), Leslie and Summerell (2006) for *Fusarium* specie.

Results and Discussion

Chemical analysis of water samples

Chemical analysis of water samples collected during spring 2007 from Wadi El-Natrun lakes revealed that pH was highly alkaline in different lakes ranging from 8.4 in El-Zugm to 9.5 in Fasida (Table 1). This is in agreement with previous results obtained by Taher (1999) and Moussa *et al.* (2009) in Wadi El-Natrun Lakes (pH 8.51-9.45) and by Steiman *et al.* (2004) of Mono Lake of California (pH 9.4-9.8); however it is remarkably different from that of the Dead Sea water which is acidic (pH 6.6) (Steiman *et al.* 1995). Total soluble salts (TSS%) was much higher in water than those recorded in both soil and mud samples (Gouda 2009), ranging from 50% in Al-Gaar to 87% in Fasida; however higher amounts were recorded in salt samples (Gouda 2009). In the study of Taher (1999) the concentration of the total soluble salts (TSS) ranged from 283 g/l in Khadra to 557 g/l in Al-Beida Lake. However she reported the lowest salt contents of water in spring (97 g/l), a very low value compared to our results in spring. The higher values of total soluble salts in water of all lakes are due to the high concentrations of both sodium and chloride ions, which is similary reported by Taher (1999). Although the Dead Sea (Steiman *et al.* 1995) and the Great Salt lake (Utah Geological survey, 2001) have similar salinities to those of Wadi El-Natrun lakes water, but their chemical composition is different. Sodium cations (mg/ml) ranged from 13.0 in Fasida to 44.0 in El-Zugm Lake; results agreed with those reported by Moussa *et al.* (2009) who found nearly similar composition of sodium (954.0 mmol/l = 41.5 mg/ml), however, lower than those (30.2 – 295.2 g/l) reported by Taher (1999).

Chloride anions exhibited the highest value in Umm Risha (23.0 mg/ml) and the lowest in Al-Beida (10.5). In agreement with our results Moussa *et al.* (2009) recorded almost similar concentrations of chlorides in Wadi El-Natrun water (920.0 mmol/l = 25.6 mg/ml). However higher concentrations (12.7- 125.7 g/l) were reported by Taher (1999). Also Steiman *et al.* (2004) and Mason (1967) recorded 1.4-11.4 and 17.5 g/l in Mono Lake water respectively. However, far highest amounts of chlorides were obtained from the Dead Sea water (223.3 g/l) (Steiman *et al*. 1997) and in the Great Salt Lake (54.51) (Utah Geological survey, 2001). Potassium cations (K^+, 0.1-0.3 mg/ml), carbonates ($CO3^{-2}$, 0.2- 2.0), bicarbonates ($HCO3^-$, 0.1-1.0), calcium cations (Ca^{+2}, 0.01-0.5) and magnesium cations (Mg^{+2}, 0.02-0.4) showed lower values

Table 1: Chemical analysis of water samples collected from Wadi El-Natrun lakes.

Lake	Al-Gaar	Khadra	Al-Beida	El-Zugm	Hamra	Rosetta	Umm-Risha	Fasida
pH	8.8	9	9.0	8.4	9	9.1	9	9.5
OM	0.05	0.1	1.0	0.1	0.07	0.08	0.05	0.1
TSS	50	80	65	80.2	80	67	70.2	87
Na^{+}	17	22	22	44	40	20	40	13
K^{+}	0.2	0.3	0.2	0.2	0.3	0.3	0.1	0.2
CO_3^{-2}	0.2	1.1	1.3	0.2	0.5	0.3	1.0	0.2
HCO_3^{-}	0.22	2	0.23	0.2	1.0	0.11	1.2	0.19
Ca^{+2}	0.02	0.04	0.1	0.5	0.01	0.1	0.01	0.1
Mg^{+2}	0.03	0.05	0.02	0.4	0.03	0.3	0.03	0.09
Cl^{-}	12	14	10.5	22	20.1	12.5	23	15.2

Figures were obtained during spring 2007 of study; OM and TSS are calculated as % of the water samples analyzed; Na^{+}, K^{+}, CO_3^{-2}, HCO_3^{-}, Ca^{+2}, Mg^{+2} and Cl^{-} are calculated as mg/ml water.

than their respectives in different lakes ranging from 0.01 in calcium to 2.0 in carbonates. In agreement with our results, Moussa *et al.* (2009) found almost similar concentrations of calcium (6.32 mmol/l = 0.15 mg/ml), magnesium (8.76 mmol/l = 0.3 mg/ml), potassium (21.48 mmol/l = 0.6 mg/ml) and bicarbonates (98.5 mmol/l = 1.6 mg/ml).

Wadi El-Natrun Lake water contained extremely lower concentrations of magnesium (0.4 mg/ml) and calcium (0.1 mg/ml) than those reported in the Dead Sea (22.0 and 42.4 for calcium and magnesium respectively) (Steiman *et al*. 1995) and the Great Salt Lake (0.2 for calcium, 3.3 for magnesium g/l) (Utah Geological Survey, 2001). However lower concentrations of calcium and magnesium were reported in Mono Lake water (Mason, 1967; Steiman *et al*. 2004). Comparison of Wadi El Natrun lake water analysis in the current study and the studies of Taher (1999) and Moussa *et al.* (2009) with that of Sothern African lakes studied by Steiman *et al*. (1991) revealed that the latters were much less saline (mostly <50 g/l) and with pH varies between 9.2 and 10.4.

Terrestrial Fungi recovered from water samples

Fifteen species related to 7 genera were recovered on Czapek Dox agar (as control medium) from water collected from the 8 lakes during the 3 seasons of study. *Aspergillus* (5 species), *Acremonium* (3), *Penicillium* (3) were the most common genera. They accounted for 49.0%, 30.2% and 9.9% of total fungi respectively (Table 6).

Aspergillus (with *A. terreus* being the most dominant species, 24.1% of total fungi) was reported from all lakes during winter and spring seasons only. The peak of *Aspergillus* count was recorded from Khadra during spring 2007. The remaining *Aspergillus* species were recorded from 3 lakes: *A. niger* and *A. flavus* (El-Zugm, Umm-Risha and Al-Gaar), or one lake: *A. fumigatus* (Al-Beida, winter 2007) and *A. parasiticus* (Al-Gaar). The current results agree with those reported by Faryal and Hameed (2005) who isolated *A. niger, A. fumigatus* and *A. flavus* from water samples with pH values between 8.06 to 12.44 in Peshawar Road, Rawalpindi. Also, *Aspergillus candidus, A. melleus, A. niger, A. ochraceus, Chaetomium globosum, Cladosporum cladosporioides, C. sphaerospermum, Hortaea werneckii, Myrothecium roridum, Penicillium citrinum* and *P. chrysogenum,* have been reported in hypersaline waters from temperate or tropical regions (Butinar *et al.* 2005a, b, Gunde-Cimerman *et al*. 2004 and Kis-Papo *et al.* 2001, 2003). *Acremonium* and its dominant species *Acremonium furcatum* were isolated from Rosetta and Khadra lakes or from Rosetta only (*A. kiliense, A. strictum*) during winter 2007. *Acremonium persicinum* and *A. terricola* were isolated from Dead Sea water (Buchalo *et al.* 1999, 2000 a,b and Kis-Papo *et al.* 2001).

Penicillium was recorded from 3 lakes (Al-Beida, El-Zugm and Al-Gaar). *P. chrysogenum* and *P. puberulum* were recovered each from 2 lakes during winter or spring season while *P. oxalicum* was recovered from one lake (Al-Gaar, winter 2007). Also, Cantrell *et al.* (2006) isolated *Penicillium citrinum, P. chrysogenum, P. oxalicum* and *P. variabile* from water of salt ponds in hypersaline environments of solar salterns in Puerto Rico.

Fusarium (represented only by *F. solani)* was recorded from 5 lakes (Hamra, Al-Beida, El-Zugm, Rosetta and Umm-Risha) during winter and spring 2007. The remaining 3 species were isolated from 3 lakes: *Trichoderma* sp. (El-Zugm, Umm-Risha and Fasida during winter), or 2 lakes: *Cladosporium cladosporioides* (Hamra and Fasida during autumn and winter seasons) and *Cochliobolus tuberculatus* (El-Zugm, Al-Gaar, winter 2007 during winter). In this respect, *Cladosporium cladosporioides* was reported from Dead Sea water (Buchalo *et al.* 1999, 2000 a, b and Kis-Papo *et al.* 2001). *C. cladosporioides, C. oxysporum, C. sphaerospermum* and *Emericella nidulans* were isolated from the water of the salt ponds in hypersaline environments in Puerto Rico (Cantrell *et al.* 2006).

Osmophilic and osmotolerant terrestrial fungi from water samples

Six genera represented by 12 species of osmophilic and osmotolerant fungi were recovered from water samples collected from Wadi El-Natrun lakes during 3 seasons on Czapek Dox agar supplemented with 40% sucrose compared to 7 genera and 15 species on the control medium (Table 3).

Aspergillus (5 species), *Penicillium* (2) and *Acremonium* (1) were the most common genera on 40% sucrose medium accounting for 65.8%, 15.0% and 2.8% of total fungi respectively (Table 6).

Aspergillus and its dominant species *A. terreus* (37.1%) were recovered from all lakes during the 3 seasons of study. Their count peaks were recorded from El-Zugm during spring 2007. The remaining *Aspergillus* species were isolated from 3 lakes: *A. niger* (El-Zugm, Khadra and Fasida during the 3 seasons), 2 lakes: *A. flavus* (Al-Gaar and Fasida during winter and spring 2007), or one lake: *A. ochraceus* (Fasida during autumn 2006 and spring 2007) and *Aspergillus* sp. (Umm-Risha during spring 2007). In this respect, *A. flavus* and *Aspergillus* sp. were reported from the water of the salt ponds collected from hypersaline environments in Puerto Rico (Cantrell *et al.*, 2006) and *A. niger* from swash zone interstitial water during June and August 2005 on a Mediterranean beach, Genoa, Italy (Vezzulli *et al.* 2009). Also, Faryal and Hameed (2005) isolated *A. niger, A. fumigatus* and *A. flavus* from water samples at pH values between 8.06 to 12.44 in Peshawar Road, Rawalpindi.

Penicillium was recovered from 5 lakes during 2 seasons of study. It had the highest CFUs in water of Al-Beida Lake**.** *P. chrysogenum* was recovered from 4 lakes during winter and spring 2007 while *P. puberulum* was recorded from 3 lakes during winter 2007 (Hamra, Al-Beida and Umm-Risha). *P. chrysogenum* was also recovered from water of salt ponds in hypersaline environments of Puerto Rico (Cantrell *et al.* 2006) and from Dead Sea water (Buchalo *et al.* 1999, 2000 a, b and Kis-Papo *et al.* 2001).

Acremonium furcatum was recovered from water of Rosetta and Khadra lakes during winter 2007. Other species of *Acremonium* (*A. persicinum* and *A. terricola*) were isolated from Dead Sea water by Buchalo *et al.* (1999, 2000 a,b) and Kis-Papo *et al.* (2001).

Fusarium (represented by 2 species) was recorded from water of 4 lakes during winter and spring 2007. The peak of *Fusarium* count was recorded from Rosetta during spring 2007. *F. solani* was encountered during 2 seasons from 3 lakes (Hamra, El-Zugum and Rosetta) while *F. subglutinans* was isolated only during winter 2007 from Umm-Risha Lake water. Other remaining 2 species were recorded either from 2 lakes: *Cladosporium cladosporioides* (Umm-Risha and Al-Gaar during spring 2007), or one lake: *Emericella quadrilineata* (Al-Beida during winter 2007). Also, *C. cladosporioides*, *C. oxysporum*, *C. sphaerospermum* and *Emericella nidulans* were isolated from the water of the salt ponds in hypersaline environments in Puerto Rico (Cantrell *et al.* 2006). *C. cladosporioides* was also reported from Dead sea water by Buchalo *et al.* (1999, 2000 a, b) and Kis-Papo *et al.* (2001), and *Cladosporium* spp. on medium containing 50% and 70% sugar from hypersaline waters throughout the whole season in Sečovlje salterns in the south east part of the Piran bay, at the delta of the Drag-onja river, at the border between Slovenia and Croatia (Gunde-Cimerman *et al.* 2000).

Halophilic and halotolerant terrestrial fungi recovered from water samples

Using Czapek Dox agar supplemented with 10% NaCl, only 3 species related to *Scopulariopsis* (*S. halophilica* and *S. brumptii*) and *Acremonium* (*A. hyalinulum*) were isolated from water samples during one season only. In this respect, *Acremonium persicinum* and *A. terricola* were isolated from Dead sea water (Buchalo *et al.* 1999, 2000 a, b and Kis-Papo *et al.* 2001)**.**

Table 2: Seasons of isolation of terrestrial fungi on control medium from water of different lakes of Wadi El–Natrun.

Fungal taxa	Hamra	Al-Beida	El-Zugum	Rosetta	Umm-Reisha	Al-Gaar	Khadra	Fasida
Acremonium W. Gams				2			1, 2, 3	
A. furcatum Moreau & Moreau ex Gams				2			1, 2, 3	
A. kiliense Gütz				2				
A. strictum W. Gams				2				
Aspergillus P. Micheli ex Link	2, 3	2, 3	2, 3	2, 3	2, 3	2, 3	2, 3	2, 3
A. flavus Link			3		2	2, 3		
A. fumigatus Fresenius		2						
A. niger van Tieghem			2, 3		2	2		
A. parasiticus Speare						2		
A. terreus Thom	3	3	2, 3	2, 3	3		3	2, 3
Cladosporium cladosprioides (Fresenius) de Vries	2							1
Cochliobolus tuberculatus Sivanesan			2			2		
Fusarium solani (Martius) Saccardo	2	2	2	3	2			
Penicillium Link		2, 3	2			2		
P. chrysogenum Thom		2				2		
P. oxalicum Currie & Thom						2		
P. puberulum Bainier		2, 3	2					
Trichoderma sp.			2		2			2
No. of genera (7)	3	3	5	3	3	3	2	1
No. of species (15)	3	5	7	5	5	6	4	4

1 = autumn 2006, 2 = winter 2007 and 3 = spring 2007

Table 3: Seasons of isolation of osmophilic and osmotolerant fungi from water of different lakes of Wadi El–Natrun.

Fungal taxa	Hamra	Al-Beida	El-Zugum	Rosetta	Umm-Reisha	Al-Gaar	Khadra	Fasida
Acremonium furcatum				2			2	
Aspergillus	3	3	2, 3	2	2, 3	2	2, 3	1, 2, 3
A. flavus						2, 3		3
A. niger			1, 2				2	1, 3
A. ochraceus Wilhelm								1, 3
A. terreus	3	3	2, 3	2	2, 3	2	2, 3	1, 2, 3
Aspergillus sp.					3			
Cladosporium cladosporioides					3	3		
Emericella quadrilineata (Thom & Raper) Benjamin		2						
Fusarium	2		2	3	2			
F. solani	2		2	3				
F. subglutinans (Wollenweber & Reinking) Nelson, Toussoun & Marasas					2			
Penicillium	2	2			2, 3	2, 3	2	
P. chrysogenum		2			3	2, 3	2	
P. puberulum	2	2			2			
No. of genera (6)	3	3	2	3	4	3	3	1
No. of species (12)	3	4	3	3	6	4	4	4

The same legends as below Table 2

Acidiphilic and aciditolerant terrestial fungi recovered from water samples

A total of twenty-one species related to 10 genera of acidiphilic and aciditolerant fungi were collected at pH4, 12 species and 6 genera and at pH5, 13 spp. and 6 genera, compared to 15 spp. and 7 genera on Czapek Dox agar (as a control medium, pH 7) (Table 4).

Aspergillus (7 species), *Acremonium* (3) and *Penicillium* (5) comprised the major proportions of the total propagules at both pHs. They accounted for 87% and 65.4%, 8.4%, 28.8%, and 1.5% and 1.0% of total fungi on media adjusted at pH 4 and pH 5 respectively (Table 6). *Aspergillus* was the most common fungus in water from the 8 lakes investigated on both acidic media. The peak of *Aspergillus* was recorded from Al-Beida during winter 2007 at both pHs. *Aspergillus* and its dominant species *A. terreus* (57.4%, 42.2% of total fungi) were recorded from all lakes during winter and spring seasons only. *A. ochraceus* was recovered from 5 lakes while *A. flavus* from 4 lakes, each during 2 seasons. The remaining *Aspergillus* species were recovered from water of 3 lakes: *A. niger* (Al-Beida, Al-Gaar and Fasida during winter 2007), or one lake: *A. fumigatus, A. sydowii* (both from Al-Beida) and *A. ustus* (Khadra). In this respect, *Aspergillus candidus, A. melleus, A. niger, A. ochraceus, Chaetomium globosum, Cladosporum cladosporioides, C. sphaerospermum, Hortaea werneckii, Myrothecium roridum, Penicillium citrinum* and *P. chrysogenum,* have been reported in hypersaline waters from temperate to tropical regions (Butinar *et al.* 2005a, b, Gunde-Cimerman *et al*. 2004 and Kis-Papo *et al.* 2001, 2003a, b). Also, Khallil and Abdel-Sater (1992) found that the water and submerged mud directly exposed to industrial effluents of Mankabad superphosphate factory (highly acidic, low content of oxygen and relatively high contents of total soluble salts, phosphate, sulphate, calcium and magnesium) were poor in terrestrial fungi. They also found *Aspergillus fumigatus, A. niger* and *A. flavus, Alternaria alternata, Fusarium verticillioides* and *Stachybotrys chartarum* were the most prevalent terrestrial fungi.

Acremonium was recovered in 3 lakes during winter 2007 only. The peak of *Acremonium* was recorded from Umm-Risha Lake at both pHs. *Acremonium furcatum* was identified from 2 lakes (El-Zugm and Umm-Risha) while an unidentified *Acremonium* species was recovered from Hamra Lake. In this respect, *Acremonium persicinum* and *A. terricola* were isolated from Dead Sea water by Buchalo *et al.* (1999, 2000 a, b) and Kis-Papo *et al.* (2001)**.**

Pencillium and its dominant species *P. puberulum* were recorded from 5 lakes during winter and spring seasons. The peak was recorded from Al-Beida at pH4 and from El-Zugm at pH5. The remaining *Pencillium* species were recorded from water of either 3 lakes: *P. chrysogenum* (Al-Beida, El-Zugm and Al-Gaar), or 2 lakes during winter 2007 only: *P. aurantiogriseum* (Al-Beida and El-Zugm), or one lake: *P. expansum* (El-Zugum). In this respect, Cantrell *et al.* (2006) reported several species of *Penicillium: P. citrinum, P. chrysogenum, P. oxalicum* and *P. variabile* from the water of the salt ponds in hypersaline environments of solar salterns in Puerto Rico, most of them are halotolerant.

The remaining fungal species were isolated during winter 2007 from water of either 3 lakes: *Cochliobolus tuberculatus* (El-Zugm, Umm-Risha and Al-Gaar), 2 lakes: *Scopulariopsis brumptii* (Rosetta and Khadra), or one lake: *Alternaria tenuissima*, *Paecilomyces* sp., *Ulocladium botrytis* (from Al-Beida), *Staphylotrichum coccosporum* (from Umm-Risha), *Trichoderma* sp. (Fasida). A wide variety of fungi have been reported from water samples of Korangi Creek and Clifton areas of Karachi, Pakistan and these were *Aureobasidium pullulans, Bispora* sp., *Botrytis* sp., *Cladosporium* sp., *Fusarium solani, Humicola* sp., *Mucor* sp., *Penicillium* sp., *P. expansum, P. brefeldianum, Phoma* sp., *Pythium* sp., and *Rhizopus* sp. (Mehdi and Saifullah 1992) and from deep-sea water samples from different geographical locations (*Cladosporium* spp., *Alternaria* spp., *Aspergillus sydowii, Nigrospora* spp., and *Penicilliun solitum*) (Roth *et al.* 1964 and Raghukumar *et al.* 1992).

Alkaliphilic and alkalitolerant terrestial fungi recovered from water samples

Seventeen species related to 8 genera of alkaliphilic and alkalitolerant fungi were recovered from water samples collected from Wadi El-Natrun lakes on Czapek Dox agar adjusted at pH10 (13 species related to 5 genera) and pH13 (7 species related to 3 genera) (Table 5).

Aspergillus (6 species), *Acremonium* (2) and *Penicillium* (5) were the most common genera at both pHs accounting for 64.1%, 31.2% and 1.2%, and 65.6%, 32.4% and 1.4% of total fungi at pH 10 and pH 13 respectively. However, no fungi were isolated from water samples collected from the Mono Lake in California, an alkaline, hypersaline and closed

Table 4: Seasons of isolation of acidiphilic and aciditolerant terrestrial fungi from water in different lakes of Wadi El-Natrun.

Fungal taxa	Hamra	Al-Beida	El-Zugum	Rosetta	Umm-Reisha	Al-Gaar	Khadra	Fasida
Acremonium	2		2		2			
A. blochii (Matruchot) W. Gams								
A. furcatum			2		2			
Acremonium sp.	2							
Alternaria tenuissima (Kunze: Fries) Wiltshire		2						
Aspergillus	2, 3	2, 3	2, 3	2, 3	2, 3	2, 3	2, 3	2, 3
A. flavus		2, 3	2, 3			2, 3		2
A. fumigatus		2						
A. niger		2				2		2
A. ochraceus		2	2, 3	2		2		2
A. sydowii (Bainier & Sartory) Thom & Church		2, 3						
A. terreus	2, 3	3	2, 3	3	2, 3	2	2, 3	2, 3
A. ustus (Bainier) Thom & Church							2	
Cochliobolus tuberculatus			2		2	2		
Paecilomyces sp.		2						
Penicillium		2, 3	2, 3	2	2	2		
P. aurantiogriseum		2	2					
P. chrysogenum		2	2			2		
P. expansum Link			2					
P. puberulum		2, 3	2, 3	2	2	2		
Scopulariopsis brumptii Salvanet-Duval				2			2	
Staphylotrichum coccosporum Meyer & Nicot					2			
Trichoderma sp.								2
Ulocladium botrytis Preuss		2						
No. of genera (10)	2	5	4	3	5	3	2	2
No. of species (21)	2	12	9	4	5	7	3	5

The same legends as below Table 2

basin (Steimen *et al*. 2004) as well as from the Dead Sea water (Guiraud *et al.* 1995 and Steimen *et al.* 1995). These authors stated that this may be attributed to the high salt levels (mostly sodium and potassium) in both waters combined with alkaline pH (9.4-9.8) in the Mono Lake or acidic pH (6.6) in the Dead Sea, which usually not favorable to fungal life. On the other hand, halophilic and halotolerant fungal species can live in some hypersaline waters (Zalar *et al.* 1999, Buchalo *et al.* 1998a, b and Grunde-Cimerman *et al*. 2000). *Aspergillus* was the most common fungus in water of the 8 lakes investigated on both alkaline media and from 6 out of 8 lakes on the control medium. The peak of *Aspergillus* count was recorded from Al Beida during winter 2007 at both pHs. The total CFUs of *Aspergillus* collected from the 8 lakes during the 3 seasons of study was higher at pH10 than at pH13. *Aspergillus* and its dominant species *A. terreus* (47.2% and 43.4% of total fungi on both pHs) were recovered from all lakes during winter and spring seasons. *A. flavus* was found in 4 lakes (Al-Beida, El-Zugm, Umm-Risha and Al-Gaar). The remaining *Aspergillus* species were recorded either from 3 lakes: *A. niger* (Al-Beida, Al-Gaar and Fasida), 2 lakes: *A. ochraceus* (El-Zugm and Rosetta), *A. ustus* (Al-Gaar and Khadra), or from Al-Beida Lake only (*A. fumigatus*). In this respect, several species of *Aspergillus* such as *A. candidus, A. caespitosus, A. flavus, A. flavipes, A. melleus, A. nidulans, A. ochraceus, A. penicillioides* and *A. unguis* most of them are halotolerant were recovered from the water of the salt ponds in hypersaline environments of solar salterns in Puerto Rico (Cantrell *et al.* 2006). Also, Faryal and Hameed (2005) found that the fungi from water samples of textile industry effluent (pH 8.06 to 12.44) included species of *Rhizopus*, *Aspergillus*, *Penicillium*, *Candida*, *Drechslera*, and *Rhodotorula* with species of *Aspergillus* (*A. niger*, *A. fumigatus* and *A. flavus*) and *Rhizopus* spp. being the most predominant, and *Drechslera* spp. showing the lowest incidence. *Acremonium* was isolated from water collected from 4 lakes during winter 2007 only. It had the highest CFUs in water samples collected from Umm Risha Lake at both pHs**.** *A. hyalinulum* was isolated in Al-Beida, El-Zugm and Umm-Risha lakes and the unidentified *Acremonium* species was isolated from Khadra Lake. Other species of *Acremonium* were reported from Dead Sea water (Buchalo *et al.* 1999, 2000 a, b and Kis-Papo *et al.* 2001).

Penicillium (with *P. puberulum* being the most common) was recorded from 6 lakes. The remaining *Penicillium* species were recorded either from 2 lakes: *P. aurantiogriseum* (Al-Beida and Rosetta), or one lake during winter 2007: *P. chrysogenum* and *P. expansum* (Al-Beida) and *P. verrucosum* (Hamra). In this respect, Cantrell *et al.* (2006) reported *Penicillium citrinum, P. chrysogenum, P. oxalicum* and *P. variabile* from the water of the salt ponds in hypersaline environments of solar salterns in Puerto Rico.

The remaining fungi were recorded from either 2 lakes: *Trichoderma* sp. (Rosetta and Fasida), or from one lake during winter 2007 only: *Humicola grisea*, *Paecilomyces* sp., yeasts (from Khadra) and *Eurotium chevalieri* (Al-Beida). In this respect, Mehdi and Saifullah (1992) isolated *Humicola* sp. from water samples of Clifton, Pakistan. Butinar *et al.* (2005c) isolated six species of *Eurotium* from hypersaline waters of salterns and determined *in vitro* the adaptive ability of propagules to survive prolonged exposure to hypersaline conditions indicating that *E. amstelodami*, *E. herbariorum* and *E. repens* contribute to the indigenous fungal community in hypersaline water environments, while *E. rubrum*, *E. chevalieri* and *E. halotolerans* are only temporal inhabitants of brine at lower salinities. Moreover, some species were also isolated from surface and deep waters of the Dead Sea: *Aspergillus phoenicis, Chaetomium nigricolor, Emericella nidulans, Gymnascella marismortui*, *Paecilomyces farinosus, Penicillium variabile, P. westlingii* and *Acremonium* sp., *Stachybotrys chartarum* and *Ulocladium chlamydosporum* (Buchalo *et al*., 1998a, b, 1999, 2000a).

In conclusion: chemical analysis revealed that waters of Wadi El-Natrun lakes were highly alkaline and were high in total soluble salts, chloride, sodium and potassium ions. Water collected from El-Zugm Lake showed the highest levels of organic matter, sodium, calcium, magnesium and chloride among all lakes. On the other hand, the other parameters showed their peak in other lakes e.g. pH and total soluble salts in Fasida. A total number of genera (16) and species (33) were recorded from water samples collected from all lakes and the widest spectrum of species was recorded on the control (14) and the lowest on 10% NaCl media (3). *Aspergillus, Acremonium* followed by *Penicillium* were the most dominant genera possessing the highest proportions of propagules on all isolation media except on 10 % NaCl. Only species of the genera *Scopulariopsis* and *Acremonium* were isolated on 10% NaCl medium. From *Aspergillus, A. terreus* followed by *A. flavus* and *A. niger* were the most common on all isolation media. On the other hand, *A. ochraceus* was dominant on acidic media only. Other most commonly encountered species, *Penicillium chrysogenum* and *P. puberulum* were encountered on all media but not on 10 % NaCl medium. Some species were isolated on one medium but not on the others.

Table 5: Seasons of isolation of alkaliphilic and alkalitolerant terrestrial fungi from water in different lakes of Wadi El–Natrun.

Fungal taxa	Hamra	Al-Beida	El-Zugum	Rosetta	Umm-Reisha	Al-Gaar	Khadra	Fasida
Acremonium		2	2		2		2	
A. hyalinulum (Saccardo) W. Gams		2	5		2			
Acremonium sp.							2	
Aspergillus	3	2, 3	2, 3	2, 3	2, 3	2, 3	2, 3	2, 3
A. flavus		2, 3	3		3	2, 3		
A. fumigatus		2						
A. niger		2				2		2

A. ochraceus			2, 3	2				
A. terreus	3	3	2, 3	2, 3	2, 3	3	2, 3	2, 3
A. ustus						2	2	
Eurotium chevalieri Mangin		2						
Humicola grisea Traaen							2	
Paecilomyces sp.							2	
Penicillium	2	2	2, 3	2	2	2		
P. aurantiogriseum		2		2				
P. chrysogenum		2						
P. expansum		2						
P. puberulum	2	2	2, 3		2	2		
P. verrucosum Peyronel	2							
Trichoderma sp.				2				2
Yeasts							2	
No. of genera (8)	2	4	3	3	3	2	5	2
No. of species (17)	3	10	5	4	4	5	6	3

The same legends as below Table 2

Table 6: Percentage counts of the most common fungi (of the total) recovered from water samples collected from Wadi El-Natrun lakes on different isolation media.

Fungal taxa	Cz %	pH4 %	pH5	pH10	pH13	40% S	10% Nacl
Aspergillus	49.0	87	65.4	64.1	65.6	65.8	0.0
Acremonium	30.2	8.4	28.8	31.2	32.4	2.8	40
Penicillium	9.9	1.5	1	1.2	1.4	15.0	0.0

References

Abdel-Malek Y and Rizk SG (1963): Bacterial sulphate reduction and the development of alkalinity. III. Experiments under natural conditions. Journal of Applied Bacteriology 26:20–26.

Abu Zeid KA (1984): Contribution to the geology of Wadi El-Natrun area and its surroundings. M. Sc. Thesis, Faculty of Science, Cairo University.

Acevedo-Ríos C (1987): Hongos marinos de arena, madera y mangle de la Parguera, Puerto Rico. Master Thesis. University of Puerto Rico, Mayagüez Campus, 38 pp.

Al-Doory Y (1980): Laboratory Medical Mycology, pp. 240, 357-367. Lea Febiger Philadelphia Kimpton Publishers, London.

Atia AKM, Hilmy ME and Bolous SN (1970): Mineralogy of the encrustation deposits of Wadi El-Natrun. Desert Institute Bulletin, Egypt 2: 301-325.

Booth C (1971): The Genus *Fusarium*. Kew, UK, Commonwealth Mycological Institute, England.

Buchalo AS, Nevo, E, Wasser SP, Oren A and Molitoris HP (1998a): Fungal life in the extremely hypersaline water of the Dead Sea: First records. Proceedings of the Royal Society of London B 265: 1461-1465.

Buchalo AS, Nevo E, Wasser SP, Oren A, Molitoris HP and Volz PA (1998b): Diversity of fungal life in the extremely hypersaline water of the Dead Sea. In: Abstracts of the VIth International Mycological Congress, Jerusalem, Israel: 180.

Buchalo AS, Wasser SP, Molitoris HP, Volz PA, Kurchenko I, Lauer I and Rawal B (1999): Species diversity and biology of fungal life in the extremely hypersaline water of the Dead Sea. In: SP Wasser (ed.): Evolutionary Theory and Processes: Modern Perspectives. Papers in Honour of Eviatar Nevo, Kluwer Academic Publishers, Dordrecht, pp 293–300.

Buchalo AS, Nevo E, Wasser SP, Oren A, Molitoris HP and Volz PA (2000a): Fungi discovered in the Dead Sea. Mycological Research 104:132–135.

Buchalo AS, Nevo E, Wasser SP and Volz PA (2000b): Newly discovered halophilic fungi in the Dead Sea. In: J Seckbach (ed.) Journey to Diverse Microbial Worlds.

Kluwer Academic Publishers, Dordrecht, pp. 239–252.

Butinar L, Santos S, Spencer-Martins I, Oren A and Gunde-Cimerman N (2005a): Yeast diversity in hypersaline habitats. FEMS Microbiology Letters 244: 229–234.

Butinar L, Sonjak S, Zalar P, Plemenitas A and Gunde-Cimerman N (2005b): Melanized halophilic fungi are eukaryotic members of microbial communities in hypersaline waters of solar salterns. Botanica Marina 48: 73-79.

Butinar L, Zalar P, Frisvad JC and Gunde-Cimerman N (2005c): The genus *Eurotium*- members of indigenous fungal community in hypersaline waters of salterns. FEMS Microbiology Ecology 51(2): 155-66.

Cantrell AS, Casillas-Martinez L and Molina M (2006): Characterization of fungi from hypersaline environments of solar salterns using morphological and molecular techniques. Mycological Research 110: 962-970.

Cronin AE and Post FJ (1977): Reports of a dematiaceous hyphomycete from Great Salt Lake, Utah. Mycologia 69: 846-847.

Domsch KH, Gams W and Anderson TH (2007): Compendium of Soil Fungi. 2nd edition, IHC-Verlag, Eching, 672 pp.

Ellis MB (1971): Dematiaceous Hyphomycetes. Commonwealth Mycological Institute, Kew, Surrey, England, 608 pp.

Ellis MB (1976): More Dematiaceous Hyphomycetes. Commonwealth Mycological Institute, England, 481pp.

Faryal R and Hameed A (2005): Isolation and characterization of various fungal strains from textile effluent for their use in bioremediation. Pakistan Journal Botany 37(4): 1003-1008.

Gouda HAA (2009): Studies on xerophilic, acidiphilic and alkaliphilic fungi in Wadi El-Natrun. M SC Thesis, Department of Botany, Faculty of Science, Assiut University.

Grant WD (2006): Alkaline environments and biodiversity, in: Extremophilies, Gerday C, and Glansdorff N (eds.), in Encyclopedia of Life Support Systems (EOLSS), Developed under the Auspices of the UNESCO, EOLSS Publishers, Oxford, UK, [http://www.eolss.net].

Grant WD, Jones BE and Mwatha WE (1990): Alkaliphiles: ecology, diversity and applications. FEMS Microbiology Reviews 75:255-270.

Guiraud P, Steiman R, Seigle-Murandi F and Sage L (1995): Mycoflora of soil around the Dead Sea. II- Deuteromycetes (except *Aspergillus* and *Penicillium*). Systematic and Applied Microbiology 18: 318–322.

Gunde-Cimerman N, Zalar P, de Hoog GS and Plemenitas A (2000): Hypersaline water in salterns-natural ecological niches for halophilic black yeasts. FEMS Microbiology Ecology 32: 235-240.

Gunde-Cimerman N, Zalar P, Petrovic U, Turk M, Kogej T, de Hoog GS and Plemenitas A (2004): Fungi in the Salterns. In: Ventosa A (ed.), Halophilic Microorganisms. Springer-Verlag, Heidelberg, pp. 103–113.

Jackson ML (1958): Soil Chemical Analysis. Constable and Co., London.

Jones BE and Grant WD (1999): Microbial diversity and ecology of the soda lakes of East Africa. In: Microbial Biosystems: New Frontiers. Proceedings of the 8th International Symposium Microbial Ecology. In: Bell CR, Brylinsky M and Johnson-Green P (eds.), Atlantic Canada Society for Microbial Ecology, Halifax, Canada.

Jones BE, Grant WD, Collins NC and Mwatha WE (1994): Alkaliphiles: diversity and identification. In: Priest FG, Ramos-Cormenzana A, Tindall BJ (eds.), Bacterial Diversity and Systematics, Plenum Press, New York, pp. 195-229.

Jones BE, Grant WD, Duckworth AW and Owenson GG (1998): Microbial diversity of soda lakes. Extremophiles 2: 191-200.

Khallil AM and Abdel-Sater MA (1992): Fungi from water, soil and air polluted by the industrial effluents of Manquabad superphosphate Factory (Assiut, Egypt). Journal of Basic Microbiology 33(2): 83-100.

Kis-Papo T, Grishkan I, Oren A, Wasser SP and Nevo E (2001): Spatiotemporal diversity of filamentous fungi in the hypersaline Dead Sea. Mycological Research 105: 749-756.

Kis-Papo T, Oren A, Wasser SP and Nevo E (2003): Survival of filamentous fungi in hypersaline Dead Sea water. Microbial Ecology 45(2): 183-90.

Kis-Papo T, Oren A, Wasser SP and Nevo E (2003b): Survival of filamentous fungi in hypersaline Dead Sea water. FEMS Microbiology Ecology 45: 183-190.

Leslie JF and Summerell BA (2006): *Fusarium* laboratory workshops- A recent history. Mycotoxin Research 22(2): 73-74.

Litchfield CD and Gillevet PM (2002): Microbial diversity and complexity in hypersaline environments: A preliminary assessment. Journal of Industrial Microbiology and Biotechnology 28: 48-55.

Mason DT (1967): Limnology of Mono Lake, California. University of California, Publications in Zoology, 83 pp.

Mehdi FS and Saifullah SM (1992): Mangrove fungi of Karachi Coast. Journal of the Islamic Academy of Sciences 5: 24-27.

Moubasher AH (1993): Soil fungi of Qatar and other Arab Countries. The Scientific and Applied Research Centre, University of Qatar, Doha, Qatar, 566 pp.

Moussa AB, Kantiranis N, Kontantinos SV, John AS, Mona FA, Vasilios C (2009): Diagnosis of weathered-Coptic wall paintings in the Wadi El-Natrun region, Egypt. Journal of Cultural Heritage 10: 152-157.

Oren A (2002): Diversity of halophilic microorganisms: environments, phylogeny, physiology, and applications. Journal of Industrial Microbiology and Biotechnology 28: 56-63.

Pavlov M (1962): Preliminary report on the ground water beneath the Wadi El-Natrun and adjacent areas. Report to the General Desert Development Organization of the U. A. R. Desert Institute, Cairo (Cited in: Taher, G.A. (1999): Inland saline lakes of Wadi El-Natrun depression, Egypt. International Journal of Salt Lake Research 8: 149-169.

Pitt JI (1979): The Genus *Penicillium*. Academic Press, London, 635 pp.

Raghukumar C, Raghukumar S, Sharma S and Chandramohan D (1992): Endolithic fungi from deep-sea calcareous substrata: isolation and laboratory studies. In: Deasai BN (ed.), Oceanography of the Indian Ocean. Oxford IBH Publ, New Delhi, pp. 3-9.

Raper KB and Fennell DI (1965): The genus *Aspergillus*. Williams and Wilkins, Baltimore.

Richards LA (1954): Diagnosis and improvement of saline and alkali soils. US Salinity Laboratory, US Department of Agriculture, Handbook 60, 160 pp.

Roth FJ, Orpurt PA and Ahearn DJ (1964): Occurrence and distribution of fungi in a subtropical marine environment. Canadian Journal of Botany 42: 375-383.

Satyanarayana T, Raghukumar C and Shivaji S (2005): Extremophilic microbes: Diversity and perspectives. Current Science 89: 1-10.

Schwarzenbach G and Biedermann W (1948): Complexons. X-Alkaline earth complexes of O, O-dihydroxy azo dyes. Helvetica Chimica Acta 31: 678-687.

Shatta A and El Fayoumi IF (1967): Geomorphological and morphopedological aspects of the region west of the Nile Delta with special reference to Wadi El-Natrun area. Desert Institute Bulletin, Egypt 17(1).

Smith NR and Dawson VT (1944): The bacteriostatic action of rose bengal in media used for the plate count of soil fungi. Soil Science 58: 467-471.

Steinman AD, Mulholland PJ and Kirschtel DB (1991): Interactive effects of nutrient reduction and herbivory on biomass, taxonomic structure, and P uptake in lotic periphyton communities. Canadian Journal of Fisheries and Aquatic Sciences 48: 1951-1959.

Steiman R, Guiraud P, Seigle-Murandi F and Lafond JL (1995): Mycoflora of soil around the Dead Sea. I- Ascomycetes (including *Aspergillus* and *Penicillium*), Basidiomycetes, Zygomycetes. Systematic and Applied Microbiology 18: 310-317.

Steiman R, Guiraud P, Seigle-Murandi F and Lafond JL (1997): Soil mycoflora from the Dead Sea oases of Ein Gedi and Einot Zugim. Antonie van Leeuwenhoek 72: 261-270.

Steiman R, Ford L, Ducros V, Lafond J and Guiraud P (2004): First survey of fungi in hypersaline soil and water of Mono Lake area (California). Antonie Van Leeuwenhoek 85(1): 69-83.

Taher GA (1999): Inland saline lakes of Wadi El-Natrun depression, Egypt. International Journal of Salt Lake Research 8: 149-169.

Ulukanli Z and Diğrak M (2002): Alkaliphilic micro-organisms and habitats. Turkish Journal of Biology 26: 181-191.

Utah Geological Survey (2001): Great Salt Lake. http://geology.utah.gov/online/PI-39.

Vezzulli L, Zotti M, Marin V, Moreno M, Pezzati E and Fabiano M (2009): Swash zone interstitial water is a reservoir of fungal micro-organisms on a Mediterranean beach (Genoa City, Italy). Marine Biodiversity Records 2, e19 doi:10.1017/S1755267208000225.

Williams V and Twine S. (1960): Flame photometric method for sodium, potassium and calcium. In: Paech K, Tracev M: V. (ed.): Modern Methods of Plant Analysis. Vol. V, pp 3-5, Springer-Verlag, Berlin.

Zahran MA and Willis AJ (1992): The Vegetation of Egypt. Chapman and Hall, London, 424 pp.

Zalar P, de Hoog GS and Gunde-Cimerman N (1999): Ecology of halotolerant dothideaceous black yeast. Studies in Mycology 43: 41-52.