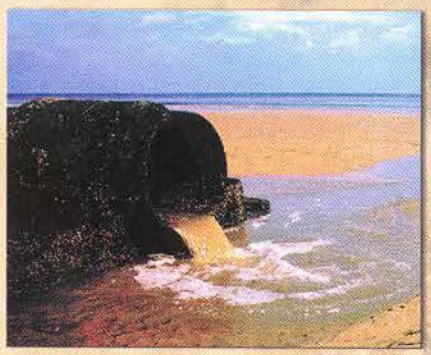
ECOLOGY OF WASTEWATER PONDS IN QATAR



Abulfatih H.A., Al-Thani R.F, Al-Naimi I.S., Sweileh J.A., Elhag E.A. and Kardousha M.M.

Scientific and Applied Research Center (SARC), University of Qatar

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Hussain A. Abulfatih
Department of Biological Sciences

Roda F. Al-Thani
Department of Biological Sciences

Ibrahim S. Al-Naimi
Department of Chemistry

Jamal A. Sweileh
Department of Chemistry

Elhag A. Elhag
Department Of Marine Sciences

Mahmoud M. Kardousha
Department of Biological Sciences

Faculty of Science, University of Qatar, P.O. Box 2713, Doha, Qatar

**Scientific and Applied Research Center (SARC), University of Qatar,
P.O. Box 2713, Doha, Qatar**

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PREFACE

Qatar with its severe arid conditions and the lacks of natural rivers, ponds and lakes, depend for its water need on ground water and water desalinization. The only inland water bodies found in Qatar are those ponds that produced by the accumulation of the treated and untreated wastewater near towns and cities. The scarcity of the information on the chemical and biological nature of such ponds, added to the constant complaint of the public about the state of these ponds, encouraged us to conduct this study.

We have chosen two of the largest wastewater ponds in Qatar, which were established around 1982, at the outskirts of Doha City. Abu-Nakhla pond receives treated wastewater from Doha-South and Doha-West wastewater treatment stations. Water pumped into Abu-Nakhla pond received primary, secondary and tertiary treatments, by removing debris, grit, organic suspended solids, oxidation of soluble organic matter, filtration of fine organic suspended solids and chlorination. Abu-Hamour pond on the other hand receives untreated wastewater.

At the present time large percentage of the wastewater produced at the treatment stations is used in creating green areas in Doha City and irrigating alfalfa field.

The project is divided into various units and highly qualified research specialists dealt with each unit comprehensively. In each pond, the following environmental parameters were evaluated: ecology of flowering plants and algae, the diversity of invertebrates and vertebrates, pathogenic microorganisms such as bacteria and parasites, and inorganic and organic materials of the water and soil deposits. The project also aimed toward the evaluation of the potentials of these ponds for establishing a sustainable aquatic wildlife, and the reuse of treated wastewater in irrigation. Such study is extremely valuable to biologists, naturalists, agriculturists, environmentalists, and planners.

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PART- 1

PLANT ECOLOGY OF WASTEWATER PONDS IN QATAR

Hussain A. Abulfatih
Department of Biological Sciences, Faculty of Science,
University of Qatar, P.O. Box 2713, Doha, Qatar
e-mail: abulfatih44@hotmail.com

SUMMARY

The ecological study of the two largest wastewater ponds in Qatar revealed that Abu-Nakhla pond which receives treated wastewater and Abu-Hamour pond, which receives highly polluted untreated wastewater, contain different sets of flowering species.

Plant survey of wastewater ponds and the surrounding areas revealed the presence of different vegetation zones, littoral, wetland and terrestrial. Limnetic zone was ignored because of the absence of plants and having very little algae. Algae and a number of emerging flowering plants are commonly present in the littoral zone. Herbaceous, succulents and few woody shrubs are present in the wetland zone. The terrestrial zone maintain sparse vegetation of mostly dwarf perennial succulent plants and few thorny shrubs.

The littoral zones of both ponds maintain collectively the following flowering species: ***Phragmites australis***, ***Rumex dentatus, Sporobolus spicata, Typha domingensis, Juncus rigidus*** and a submerged species; and the following common algae: ***Anabaena, Anacystis***, ***Chlorella, Diatoms, Euglena, Oscillatoria, Spirogyra*** and ***Spirulina;*** and following less common algae: ***Chlorogonium, Lyngbya, Oedogonium, Scenedesmus*** and ***Zygnema.***

The wetland zones of both ponds maintain collectively the following flowering species: ***Aeluropus lagopoides, Alzoon canarlense, Amaranthus viridus, Anabasis setifera, Arnebia hispidissima, Chloris virgata, Cressa critica, Cymbopogon purkeri, Cynodon dactylon, Euphorbia granulata, Fagonia sp., Herniaria hemistemon, Juncus rigidus, Lasiurus hirsutus, Launa nudicaulis, Malva parviflora, Polypogon monospliensis, Portulaca oleracae, Pulicaria crispa, Rumex dentatus, Salsola baryosma, Solanum elaengifolium, Spergularia falax, Sporobolus arabicus, Stipagrostis plumosa, Suada aeyptiaca, Suada vermiculata, Tamarix ramossissima, Tribulus terrestris, Urospermum plcroides, Zygophyllum qatarense*** and ***Zygophyllum simplex.***

The presence of blue-green algae (***Anabaena***, ***Anacystis***, ***Lyngbya, Oscillatoria*** and ***Spirulina***) in the shallow waters of these ponds is an indication of eutrophication. Such waters also contained good amounts

of diatoms, *Euglena*, ciliates, and nematodes. Moreover, the emission of extremely offensive odor from the untreated wastewater is a sign of high activity of anaerobic microorganisms.

Masses of algal scum produced near shores particularly during the warm parts of the year. The following species have the tendency of producing such scum: *Anabaena, Anacystis, Clorella Spirogyra* and *Spirulina.*

High water salinity in the western parts of Abu-Hamour pond seems to be the primary cause for the presence of *Spirulina* algae in the water, and the dense halophytic succulent vegetation on the nearby shores.

Differences between Abu-Hamour and the Abu-Nakhla ponds are significant with respect to the types of algae species and the flowering aquatic species. Seasonal changes in species composition, growth and survival were conspicuous among flowering plants and algae. Water salinity and total dissolved solids were generally higher in Abu-Hamour pond. Birds were more common in Abu-Nakhla pond. Fishes and frogs were present only in Abu-Nakhla pond.

ARABIC SUMMARY

البيئة النباتية لبرك مياه الصرف الصحي في قطر

حســـــــين علي ابوالفتح

قسم العلوم البيولوجية، كلية العلوم، جامعة قطر، ص ب 2713، الدوحة، قطر
e-mail: abulfatih44@hotmail.com

الدراسة البيئية لأكبر اثنين من برك مياه الصرف الصحي في قطر أظهرت بأن بركة أبو نخلة تحتوي على تركيبة معينة من النباتات والطحالب وذلك لاحتوائها علـــى مياه الصرف الصحي المعالجة، ومن جانب آخر أظهرت بركة أبو هامور شديدة التلـوث والتي تحتوي على مياه الصرف الصحي غير المعالجة على تركيبة مختلفة نسبيا مـــن النباتات والطحالب.

تبين من دراسة الغطاء النباتي لهذه البرك وجود نطاقات محددة تتمثـــل فيمـــا يلي: نطاق المياه العميقة، ونطاق المياه الضحلة، ونطاق الأرض الرطبة، ونطاق الأرض الجافة المحيطة بهذه البرك. يحتوي نطاق المياه العميقة فقط على القليل من الدياتومات، ويحتوي نطاق المياه الضحلة بشكل واضح على الطحالب ونباتات القصب والحشـــائش المائية، والنطاق الرطب يحتوي على الأعشاب والنباتـــات العصاريـــة، والقليـــل مـــن الشجيرات. أما الأراضي الجافة المحيطة بهذه البرك فتحتوي على القليل من النباتـــات العصارية الصغيرة المعمرة والشجيرات الشوكية.

و من بين أهم النباتات الزهرية التي تعيش في المياه الضحلة و بغزارة ما يلي:
Phragmites australis, Typha domingensis, Sporobolus spicatus, Tamarix ramossissima, Rumex dentatus, Juncus rigidus and a submerged species.

و أهم الطحالب التي تعيش في المياه الضحلة ما يلي:
Anabaena, Anacystis, Chlorella, Diatoms, Euglena, Oscillatoria, ***Spirogyra*** and ***Spirulina.*** يضاف إليها الطحالب التي تنمو بأعداد قليلة وفـــي فترات متقطعة من السنة، أمثال:
Chlorogonium, Lyngbya, Oedogonium, Scenedesmus and ***Zygnema.***

وعلى الشواطئ الرطبة لهذه البرك يوجـــد العديـــد مـــن النباتـــات الحوليـــة، والنجيلية، والنباتات المعمرة العصارية الصغيرة، ونوع واحد من الشجيرات، كما فـــي القائمة التالية:
Aeluropus lagopoides, Aizoon canariense, Amaranthus viridus, Anabasis setifera, Arnebia hispidissima, Chloris virgata, Cressa critica, Cymbopogon purkeri, Cynodon dactylon, Euphorbia granulata, Fagonia sp., Herniaria hemistemon, Lasiurus hirsutus, Launa nudicaulis, Malva parviflora, Polypogon monospliensis, Portulaca oleracae, Pulicaria crispa, Salsola baryosma, Solanum elaengifolium, Spergularia falax, Stipagrostis plumosa, Suada aegyptiaca, Suada vermiculata, Tamarix ramossissima, Tribulus terrestris, Urospermum picroides, Zygophyllum qatarense and ***Zygophyllum simplex.***

وتحتوي المياه الضحلة على الكثير من الطحالب الخضراء المزرقة أمثال:
Anabaena*, *Anacystis*, *Lyngbya*, *Oscillatoria* and *Spirulina
والتي تعتبر دليلا قاطعا على ارتفاع نسبة الملوثات في هذه المياه من العناصر المعدنية والمواد العضوية. احتوت هذه المياه كذلك على الكثير من الطحالب الخضراء ضافة إلى الديوتومات واليوغلينا والهدبيات والديدان. انبعاث الروائح الكريهة من بركة أبو هامور لدليل على كثرة الكائنات الدقيقة ذات التنفس اللاهوائي.

بعض الطحالب اختارت مواقع محددة في هذه البرك دون سواها. فمثلا الطحلب *Spirulina* يوجد بوفرة في الجزء الغربي من بركة ابو هامور في مياه الموقعين H3 و H4 البعيدين عن المصب، حيث الارتفاع الشديد في نسبة الملوحة. كذلك تكثر النباتات الملحية العصارية على الشواطئ الملحية المجاورة.

ومن الملاحظات الجديرة بالذكر زيادة الرغوة الخضراء على سطوح المياه في فصل الصيف، حين تكون درجات الحرارة مرتفعة. و من الأنواع الرئيسية التي لها القدرة على تكوين هذه الرغوة الخضراء ما يلي:
***Anabaena, Anacystis, Clorella Spirogyra* and *Spirulina*.**

وعند إجراء مقارنة عامة بين هاتين البركتين نلاحظ ما يلي: أنواع النباتات المائية كثيرة في أبو نخلة، و أنواع الطحالب متباينة بين هاتين البركتين. و التغير الموسمي واضحا في تعاقب النباتات الزهرية والطحالب في المياه الضحلة، و الشواطئ الرطبة. كذلك ارتفاع ملوحة الماء ومجموع المواد الصلبة الذائبة في مياه أبو هامور، و كثرة الطيور في أبو نخلة، أما الأسماك والضفادع فموجودة في أبو نخلة وغير موجودة في أبو هامور. بكتيريا القولون والفطريات كثيرة في مياه أبو هامور مقارنة بمياه أبو نخلة.

INTRODUCTION

This study is part of a larger project carried out by a number of specialists to study the chemistry, microbiology, parasitology, invertebrates and vertebrates. Each specialist has found a number of hazardous materials and organisms in these ponds, and their findings written separately.

This publication is dealing with the ecology of producers in two of the largest wastewater ponds in Qatar. The study deals with a wide spectrum of topics, including the environmental conditions, landscape, pond ecology, water treatment and the impact of wastewater ponds on the environment.

Moreover, the current work provides important information on algae and flowering plants, and their distribution in two ponds containing treated and untreated wastewater. Moreover, salinity, total dissolved solids and pH of the water also studied.

Earlier work in Qatar with regard to plant ecology, vegetation and flora include a number of publications (e.g., Abulfatih *et al.* 1999; Abulfatih 2000; Abulfatih 2001; Abulfatih *et al.* 2001a, 2001b, 2001c, 2001d; Abulfatih *et al.* 2002; Abulfatih and Abdel Bari 1999a, 1999b; Boulos 1978; Abdel-Raziq and Ismail 1990; Batanouny 1981; Moubahser 1993; Moubasher and Al-Subai 1987; Rizk and El-Ghazaly 1995; Sayed 1994).

Various aspects of water studies in Qatar were found in a number of publications, dealing with water resources (Abulfatih *et al.* 2002, Williamson and Pomeyrol 1938), water resources and their development (FAO 1981), water research statistics (DAWR 1998) and sewage treatment (WHO/EMRO/CEHA 1992), water resources of Qatar for municipal and agricultural uses (Burdon 1967, Al-Sharafi *et al.* 2001). Different wastewater treatment systems were used in Qatar in the following places: Doha-South, Doha-East, Al-Khor, Al-Thakheera, Slaughter-House, Jumeliya, Al-Khraib, Abu-Fontas, Duhail, Sailiyya, Barzan, Noth-Camp, Al-Gazal, and Hoan (Al-Sharafi *et al.* 2001).

On the regional basis, water resources and uses, wastewater ecology, treatment and management were dealt with in a number of publications, such as the biological survey of Abha lake (Abulfatih and Al-Khalili I979), Reuse of

1. Littoral Zone:

At the littoral zone, water salinity and total dissolved solids recorded higher values in the untreated wastewater of Abu-Hamour than in the treated wastewater of Abu-Nakhla. Insignificant differences of pH recorded in these waters. Waters were slightly alkaline in both ponds (Table 2).

The littoral zone constantly maintained shallow water where light easily reaches the bottom floor in both ponds. The littoral zone occurs at the edge of ponds with variable width. There is a series of concentric rings of rooted plants in Abu-Nakhla pond including the emergent *Phragmites australis, Typha domingensis, Sporobolus spicatus, Rumex dentatus, Juncus rigidus* and a submerged species (Table 3, Figure 5 & Appendix B). On the other hand, Abu-Hamour pond had only *Phragmites australis*.

The littoral zone contains invertebrates, fishes, frogs and birds, particularly in the less polluted, Abu-Nakhla pond.

2. Wetland Zone:

Certain parts of pond shores because of their gentle slopes and flatness are more frequently inundated as a result of the fluctuation in the water discharge rate and winter rainfall. Such areas are common around Abu-Nakhla pond. The rate of species turn over is relatively high in such areas. Numerous terrestrial plants germinate and grow in such habitat (Table 3). Similar situations do exist on the edges of brackish and saline marshes in various parts of the arid and semi-arid areas of the Middle East (Abulfatih 1975 and 1997, Chapman 1974).

Plants present in the wetland zones in of both ponds include the following categories:

A. Perennial Dicots:

***Pulicaria crispa, Salsola baryosma, Tamarix ramossissima* and *Zygophyllum qatarense*.**

B. Annual Dicots:

Aizoon canariense, Amaranthus viridus, Arnebia hispidissima, Cressa critica, Euphorbia granulata, Fagonia sp., Herniaria hemistemon, Launa nudicaulis, Malva parviflora, Portulaca oleracae, Solanum elaengifolium,

Spergularia falax, Tribulus terrestris, Urospermum picroides and ***Zygophyllum simlex.***

C. Perennial Monocots:

Aeluropus lagopoides, Cymbopogon purkeri, Cynodon dactylon, Chloris virgata, Lasiurus hirsutus, Sporobolus arabicus, Sporobolus spicatus and ***Typha domingensis.***

D. Annual Monocots:

Stipagrostis plumosa.

Succession of Littoral and Wetland Flowering Plants

Seasonal turnover of populations is common in pond's ecosystem, where one population replaces another. Such species replacement is natural and related mainly to the life span of each species and the monthly changes in the environmental conditions. Such turnover is more evident in the wetland zone (Table 4 and Appendix B).

Plant succession revealed that two groups prevailed, rooted perennial plants with rhizomes in the littoral zone and annuals and perennials in the wetland zone. Perennials growing in the littoral zone show much change in their vegetative growth throughout the year. On the other hand, annuals grow in abundance and thrive for short periods.

Table 4. Succession of flowering plants found in the littoral and the wetland zones of Abu-Hamour and/or Abu-Nakhla wastewater ponds, with respect to the time of the year.

Habitats and Species	Months and Species Presence											
	J	F	M	A	M	J	J	A	S	O	N	D
LITTORAL ZONE												
Juncus rigidus	*	*	*	*	*	*	*	*	*	*	*	*
Phragmites australis	*	*	*	*	*	*	*	*	*	*	*	*
Rumex dentatus	*	*	*	*	*	*	*	*	*	*	*	*
Sporobolus arabicus	*	*	*	*	*	*	*	*	*	*	*	*
Submerged species					*	*						
Typha domingensis	*	*	*	*	*	*	*	*	*	*	*	*
WETLAND ZONE												
Aeluropus lagopoides	*	*	*	*	*	*	*	*	*	*	*	*
Aizoon canariense	*	*	*	*	*	*	*					
Amaranthus viridus					*	*	*	*	*	*		
Anabasis setifera		*	*	*	*	*	*	*	*			
Arnebia hispidissima		*	*									
Chloris virgata	*	*	*	*	*	*	*	*	*	*	*	*
Cressa critica			*	*	*							
Cymbopogon purkeri		*	*	*								
Cynodon dactylon					*	*	*	*				
Euphorbia granulata	*	*										
Fagonia sp.		*	*	*	*	*						
Herniaria hemistemon		*	*	*	*	*						
Lasiurus hirsutus		*	*	*								
Launa nudicaulis	*	*	*	*								
Malva parviflora		*	*									
Polypogon monospliensis		*	*	*	*	*						
Pulicaria crispa	*	*	*	*	*	*	*	*	*	*	*	*
Salsola baryosma	*	*	*	*	*	*	*	*	*	*	*	*
Solanum elaengifolium		*	*	*	*	*						
Spergularia falax	*	*	*									
Stipagrostis plumosa		*										
Suada aeyptiaca	*	*	*	*	*	*	*	*	*	*	*	*
Suada vermiculata	*	*	*	*	*	*	*	*	*	*	*	*
Tamarix ramossissima	*	*	*	*	*	*	*	*	*	*	*	*
Tribulus terrestris		*	*	*								
Urospermum picroides		*	*	*	*	*						
Zygophyllum qatarense	*	*	*	*	*	*	*	*	*	*	*	*
Zygophyllum simlex		*	*	*	*	*						

The word presence is used to indicate the appearance of the plant living aerial parts above the ground surface or water surface.

Morphology of Littoral Flowering Plants

Flowering plants are vascular plants and having the conductive tissues xylem and phloem. Neither free-floating nor suspended flowering plants were encountered in these ponds. All flowering plants growing in these ponds are attached to the bottom.

Flowering plants come in different forms and sizes, divided into dicots and monocots and reproduce typically by seeds. However, vegetative reproduction is very common among aquatics, where many of which multiply by the formation of new shoots from underground rootstocks and rhizomes or by fragmentation.

The most common aquatic plants, which live in the shallow wastewater of Abu-Nakhla (littoral zone), include *Phragmites australis, Typha domingensis, Juncus rigidus, Rumex dentatus, Sporobolus spicatus* and a submerged species. Plants commonly living in habitats inundated periodically (wetland) include mainly *Aeluropus lagopoides, Cressa critica, Tamarix ramossissima,* in addition to many opportunistic annual species (Table 3 & Appendix B). Littoral plants in Abu-Hamour pond included only *Phragmites australis*.

It is worthwhile describing briefly the morphological features of the common species living in the littoral zone of these wastewater ponds:

Juncus rigidus: a perennial grass, about 1-m high, having high amount of fibers, flower in April-May, live in periodically inundate areas, in shallow waters and in wetlands of Abu-Nakhla pond (Figures D11 & D-12).

Phragmites australis: a perennial monocot reed grass, has long flat leaves, plume-like flower clusters and stiff stems, grow to 3-m high, common in shallow wastewater ponds, flowers in January-February. Found in both Abu-Hamour and Abu-Nakhla ponds (Appendix D, Figures D-11 to D-15).

Rumex dentatus: a dicot annual plant, 50-cm high, common in flooded to wet habitats, flower in November. Found in Abu-Nakhla pond (Appendix D, Figures D-10 & D-11).

Sporobolus arabicus: a perennial monocot grass, 60-cm high. Live around the wastewater ponds in flooded to wet

soils. Flowering from March to early autumn. Found in Abu-Nakhla ponds (Appendix D, Figure D-9).

Submerged species: Unidentified rooted submerged species were found in the littoral zone of Abu-Nakhla pond. Masses of this species were sent to shore by the wave force, during June and July).

Typha domingensis: a perennial monocot reed, having upper clusters of male flowers (staminate) and lower clusters of female flowers (pistillate). Flowers are minute and closely jointed on the stem. Leaves are linear. Growing in clump-form in shallow waters and along muddy shores. Grow up to 2-m, flowering from February to May and found in Abu-Nakhla pond (Appendix D, Figures D-12 & D-13).

Community of Algae of the Littoral Zone

Algae occupy mostly the littoral zone, and their distribution is highly controlled by the quality of water, which differ from site to site (Table 2). Thirteen algae species encountered in these ponds, including the followings:

Anabaena, Anacystis, Chlorella, Chlorogonium, Diatoms, Euglena, Lyngbya, Oedogonium, Oscillatoria, Scenedesmus, Spirogyra, Spirulina and Zygnema. (Table 5 & Appendix C). Algae contain chlorophyll and other types of pigments, and their biological contribution to upper trophis levels of the ecosystem is highly important.

Microscopic living organisms like ciliates, flagellates amoeba-like protozoa, rotifers and crustaceans are frequently encountered in the littoral zones.

The study revealed the presence of *Anabaena* only in the treated wastewater of Abu-Nakhla pond in the southrn (KS) and western (KW) locations, in areas with minimum vegetation cover. *Spirulina* was found in Abu-Hamour wastewater pond in the southwestern (H3) and northwestern (H4) locations, where water salinity was very high.

Algae commonly encountered in both ponds, in numerous locations, including the followings: *Anacystis, Chlorella, Diatoms, Euglena, Oscillatoria* and *Spirogyra*. Algae rarely encountered in these ponds include the

followings: *Chrologonium, Lyngbya, Oedogonium, Scenedesmus* and *Zygnema.* The water discharge site location (KNP) of Abu-Nakhla pond had no algae.

Table 5. Algae encountered in Abu-Hamour (H) and Abu-Nakhla (K) wastewater ponds, at various locations of the shallow littoral waters.

ALGAE	Abu-Hamour Pond (H) Sampling Location & Freq. of Presence				Abu-Nakhla Pond (K) Sampling Location & Freq. of Presence				
	H1	H2	H3	H4	KNP	KN	KE	KS	KW
Anabaena								*	*
Anacystis	*	*		*		*		**	**
Chlorella	**	**		*		**	**	**	**
Chlorogonium			*	*					
Diatoms	*	*	*	*		*	*	*	*
Euglena	*	*	*	*		*	*		*
Lyngbya			*	*					
Oedogonium								*	
Oscillatoria	**	**	**	**		*	*	*	*
Scenedesmus			*					*	
Spirogyra				*			*	*	**
Spirulina			**	**					
Zygnema			*	*		*			

Water samples of Abu-Hamour pond (H1, H2, H3, H4) were collected consequently from the north eastern side at the wastewater discharge site, south east, south west, and north west shores. Water samples of Abu-Nakhla pond (KNP, KN, KE, KS and KW) were collected consequently from northern discharge pipeline, northeastern, eastern, southern and western shores. Species less frequently (*) and more frequently (**) encountered during the 12 months of the year. H2 location is polluted with petroleum oil.

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Table B-1. The association between the presence of flowering plants and moisture levels at Abu-Hamour (H) and Abu-Nakhla (K) wastewater ponds. Records of October 2000.

Flowering Plants	Abu-Hamour pond Moisture Level & Plant Presence		Abu-Nakhla pond Moisture Level & Plant Presence	
	littoral	wetland	littoral	wetland
Aeluropus lagopoides		**f		**f
Aizoon canariense				
Amaranthus viridus				
Anabasis setifera				
Arnebia hispidissima				
Chloris virgata				
Cressa critica		**f		**f
Cymbopogon purkeri				
Cynodon dactylon				
Euphorbia granulata				
Fagonia sp.				
Herniaria hemistemon				
Juncus rigidus			*	
Lasiurus hirsutus				
Launa nudicaulis				
Malva parviflora				
Phragmites australis	**f		**f	
Polypogon monospliensis				
Portulaca oleracae				
Pulicaria crispa		*		
Rumex dentatus			*	*
Salsola baryosma		**		**
Solanum elaengifolium				
Spergularia falax				
Sporobolus arabicus			*f	**f
Stipagrostis plumosa				
Suada aegyptiaca				
Suada vermiculata				
Submerged species				
Tamarix ramossissima	*f	**f	*f	**f
Tribulus terrestris				
Typha domingensis			**	**
Urospermum picroides				
Zygophyllum qatarense				
Zygophyllum simplex				

(*) Present, (**) prominently present, (f) flowering. The word presence is used to indicate the appearance of the plant living aerial parts above the ground surface or water surface.

Table B-2. The association between the presence of flowering plants and moisture levels at Abu-Hamour (H) and Abu-Nakhla (K) wastewater ponds. Records of November 2000.

Flowering Plants	Abu-Hamour pond		Abu-Nakhla pond	
	Moisture Level & Plant Presence		Moisture Level & Plant Presence	
	littoral	wetland	littoral	wetland
Aeluropus lagopoides		**f		**f
Aizoon canariense				
Amaranthus viridus				
Anabasis setifera				
Arnebia hispidissima				
Chloris virgata				
Cressa critica		**f		**f
Cymbopogon parkeri				
Cynodon dactylon				
Euphorbia granulata				
Fagonia sp.				
Herniaria hemistemon				
Juncus rigidus			*	
Lasiurus hirsutus				
Launa nudicaulis				
Malva parviflora				
Phragmites australis	**f		**f	
Polypogon monospliensis				
Portulaca oleracae				
Pulicaria crispa		*		
Rumex dentatus			*	*
Salsola baryosma		**f		**f
Solanum elaengifolium				
Spergularia falax				
Sporobolus arabicus			*f	**f
Stipagrostis plumosa				
Suada aegyptiaca				
Suada vermiculata				
Submerged species				
Tamarix ramossissima	*f	**f	*f	**f
Tribulus terrestris				
Typha domingensis			**	**
Urospermum picroides				
Zygophyllum qatarense				
Zygophyllum simplex				

(*) Present, (**) prominently present, (f) flowering. The word presence is used to indicate the appearance of the plant living aerial parts above the ground surface or water surface.

Table B-3. The association between the presence of flowering plants and moisture levels at Abu-Hamour (H) and Abu-Nakhla (K) wastewater ponds. Records of December 2000.

Flowering Plants	Abu-Hamour pond Moisture Level & Plant Presence		Abu-Nakhla pond Moisture Level & Plant Presence	
	Littoral	wetland	littoral	wetland
Aeluropus lagopoides		**f		**f
Aizoon canariense				
Amaranthus viridus				
Anabasis setifera				
Arnebia hispidissima				
Chloris virgata				
Cressa critica		**		**
Cymbopogon purkeri				
Cynodon dactylon				
Euphorbia granulata				
Fagonia sp.				
Herniaria hemistemon				
Juncus rigidus			*	
Lasiurus hirsutus				
Launa nudicaulis				
Malva parviflora				
Phragmites australis	**f		**f	
Polypogon monospliensis				
Portulaca oleracae				
Pulicaria crispa		*		
Rumex dentatus			**	**
Salsola baryosma		**f		**f
Solanum elaengifolium				
Spergularia falax				
Sporobolus arabicus			*	**
Stipagrostis plumosa				
Suada aegyptiaca				
Suada vermiculata				
Submerged species				
Tamarix ramossissima	**f	**f	*f	**f
Tribulus terrestris				
Typha domingensis			**	**
Urospermum picroides				
Zygophyllum qatarense				
Zygophyllum simlex				

(*) Present, (**) prominently present, (f) flowering. The word presence is used to indicate the appearance of the plant living aerial parts above the ground surface or water surface.

Table B-4. The association between the presence of flowering plants and moisture levels at Abu-Hamour (H) and Abu-Nakhla (K) wastewater ponds. Records of January 2001.

Flowering Plants	Abu-Hamour pond		Abu-Nakhla pond	
	Moisture Level & Plant Presence		Moisture Level & Plant Presence	
	littoral	wetland	littoral	wetland
Aeluropus lagopoides		**f		**f
Aizoon canariense				**
Amaranthus viridus				
Anabasis setifera				
Arnebia hispidissima				
Chloris virgata				
Cressa critica				
Cymbopogon parkeri				
Cynodon dactylon				
Euphorbia granulata				**
Fagonia sp.				
Herniaria hemistemon				
Juncus rigidus			*	
Lasiurus hirsutus				
Launa nudicaulis				**
Malva parviflora				
Phragmites australis	**f		**f	
Polypogon monospliensis				
Portulaca oleracae				
Pulicaria crispa		*		
Rumex dentatus			**	**
Salsola baryosma		**		**
Solanum elaengifolium				
Spergularia falax				**f
Sporobolus arabicus			**	**
Stipagrostis plumosa				
Suada aegyptiaca				
Suada vermiculata				
Submerged species				
Tamarix ramossissima	**f	**f	*f	**f
Tribulus terrestris				
Typha domingensis			**f	**f
Urospermum picroides				
Zygophyllum qatarense				
Zygophyllum simplex				

(*) Present, (**) prominently present, (f) flowering. The word presence is used to indicate the appearance of the plant living aerial parts above the ground surface or water surface.

Table B-5. The association between the presence of flowering plants and moisture levels at Abu-Hamour (H) and Abu-Nakhla (K) wastewater ponds. Records of February 2001.

Flowering Plants	Abu-Hamour pond		Abu-Nakhla pond	
	Moisture Level & Plant Presence		Moisture Level & Plant Presence	
	littoral	wetland	littoral	wetland
Aeluropus lagopoides		**f		**f
Aizoon canariense				**f
Amaranthus viridus				
Anabasis setifera				
Arnebia hispidissima		*f		*f
Chloris virgata		*f		
Cressa critica				
Cymbopogon purkeri		*f		
Cynodon dactylon				
Euphorbia granulata				**
Fagonia sp.		*f		*f
Herniaria hemistemon		*f		*f
Juncus rigidus			*	
Lasiurus hirsutus		*f		
Launa nudicaulis				**
Malva parviflora		*f		
Phragmites australis	**f		**f	
Polypogon monospliensis				*
Portulaca oleracae				
Pulicaria crispa		*f		
Rumex dentatus			**	**
Salsola baryosma		**		**
Solanum elaengifolium		*f		
Spergularia falax				**f
Sporobolus arabicus			*	**
Stipagrostis plumosa				*f
Suada aegyptiaca				
Suada vermiculata				
Submerged species				
Tamarix ramossissima	**f	**f	*f	**f
Tribulus terrestris		*f		*f
Typha domingensis			**f	**f
Urospermum picroides		*f		
Zygophyllum qatarense				
Zygophyllum simplex		*f		*f

(*) Present, (**) prominently present, (f) flowering. The word presence is used to indicate the appearance of the plant living aerial parts above the ground surface or water surface.

Table B-6. The association between the presence of flowering plants and moisture levels at Abu-Hamour (H) and Abu-Nakhla (K) wastewater ponds. Records of March 2001.

Flowering Plants	Abu-Hamour pond		Abu-Nakhla pond	
	Moisture Level & Plant Presence		Moisture Level & Plant Presence	
	littoral	Wetland	littoral	wetland
Aeluropus lagopoides		**f		**f
Aizoon canariense		**f		**f
Amaranthus viridus				
Anabasis setifera		**		
Arnebia hispidissima		*f		*f
Chloris virgata		*f		
Cressa critica		*f		*f
Cynodon dactylon				
Cymbopogon purkeri		*f		
Euphorbia granulata				
Fagonia sp.		*f		*f
Herniaria hemistemon		**f		*f
Juncus rigidus			*	
Lasiurus hirsutus		*f		
Launa nudicaulis		**		**
Malva parviflora		*f		
Phragmites australis	**f		**f	
Polypogon monospliensis				*f
Portulaca oleracae				
Pulicaria crispa		*f		
Rumex dentatus			**f	**f
Salsola baryosma		**		**
Solanum elaengifolium		*f		
Spergularia falax				**f
Sporobolus arabicus			*	**
Stipagrostis plumosa				
Suada aegyptiaca		**		**
Suada vermiculata		**		**
Submerged species				
Tamarix ramossissima	**f	**f	*f	**f
Tribulus terrestris		*f		*f
Typha domingensis			**f	**f
Urospermum picroides		*f		
Zygophyllum qatarense		**f		
Zygophyllum simplex		**f		**f

(*) Present, (**) prominently present, (f) flowering. The word presence is used to indicate the appearance of the plant living aerial parts above the ground surface or water surface. Large number of birds present in "K" pond.

Table B-7. The association between the presence of flowering plants and moisture levels at Abu-Hamour (H) and Abu-Nakhla (K) wastewater ponds. Records of April 2001.

Flowering Plants	Abu-Hamour pond		Abu-Nakhla pond	
	Moisture Level & Plant Presence		Moisture Level & Plant Presence	
	littoral	wetland	littoral	wetland
Aeluropus lagopoides		**f		**f
Aizoon canariense		**f		**f
Amaranthus viridus				
Anabasis setifera		**		
Arnebia hispidissima				
Chloris virgata		*f		
Cressa critica		*f		*f
Cymbopogon purkeri		*f		
Cynodon dactylon				
Euphorbia granulata				
Fagonia sp.		*f		*f
Herniaria hemistemon		**f		*f
Juncus rigidus			*f	
Lasiurus hirsutus		*f		
Launa nudicaulis		**		**
Malva parviflora				
Phragmites australis	**f		**f	
Polypogon monospliensis				*f
Portulaca oleracae				
Pulicaria crispa		*f		
Rumex dentatus			**f	**f
Salsola baryosma		**		**
Solanum elaengifolium		*f		
Spergularia falax				
Sporobolus arabicus			*	**
Stipagrostis plumosa				
Suada aegyptiaca		**		**
Suada vermiculata		**		**
Submerged species				
Tamarix ramossissima	**f	**f	*f	**f
Tribulus terrestris		*f		*f
Typha domingensis			**f	**f
Urospermum picroides		*f		
Zygophyllum qatarense		**f		**f
Zygophyllum simplex		**f		**f

(*) Present, (**) prominently present, (f) flowering. The word presence is used to indicate the appearance of the plant living aerial parts above the ground surface or water surface. Large number of birds present in "K" pond.

Table C-1. Algae found in Abu-Hamour (H) and Abu-Nakhla (K) wastewater ponds. Water samples collected from shallow littoral waters in October 2000.

Algae	Abu-Hamour Pond Sampling Locations & Presence of Algae				Abu-Nakhla Pond Sampling Locations & Presence of Algae				
	H1	H2	H3	H4	KNP	KN	KE	KS	KW
Anabaena								**	**
Anacystis								**	**
Chlorella	*	*				*	*	**	**
Chlorogonium			*	**					
Diatom	*	*	*	**		**	*	*	*
Euglena	**	*	**	**		*	**	*	*
Lyngbya			*	*					
Oedogonium									
Oscillatoria	**	**	**	**		**	*	*	*
Scenedesmus				*					
Spirogyra							*	*	**
Spirulina			*	*					
Zygnema			*	*		*			

KNP, KN, KE, KS and KW consequently represent the northeastern wastewater discharge pipeline, northeastern, eastern, southern and western shores. H1, H2, H3 and H4 consequently represent the northeastern wastewater discharge shore, southeast, southwest, and northwest shores. Present (*), prominently present (**). H2 location is polluted with petroleum oil.

Table C-2. Algae found in Abu-Hamour (H) and Abu-Nakhla (K) wastewater ponds. Water samples collected from shallow littoral waters in November 2000.

Algae	Abu-Hamour Pond Sampling Locations & Presence of Algae				Abu-Nakhla Pond Sampling Locations & Presence of Algae				
	H1	H2	H3	H4	KNP	KN	KE	KS	KW
Anabaena								**	**
Anacystis								**	**
Chlorella	*	*				*	*	**	**
Chlorogonium			*	**					
Diatoms	*	*	**	**		**	*	*	*
Euglena	**	*	**	**		*	**	*	*
Lyngbya									
Oedogonium									
Oscillatoria	**	**	**	**		**	*	*	*
Scenedesmus				*					
Spirogyra							*	*	*
Spirulina			*	*					
Zygnema									

KNP, KN, KE, KS and KW consequently represent the northeastern wastewater discharge pipeline, northeastern, eastern, southern and western shores. H1, H2, H3 and H4 consequently represent the northeastern wastewater discharge shore, southeast, southwest, and northwest shores. Present (*), prominently present (**). H2 location is polluted with petroleum oil.

Table C-3. Algae found in Abu-Hamour (H) and Abu-Nakhla (K) wastewater ponds. Water samples collected from shallow littoral waters in December 2000.

Algae	Abu-Hamour Pond Sampling Locations & Presence of Algae				Abu-Nakhla Pond Sampling Locations & Presence of Algae				
	H1	H2	H3	H4	KNP	KN	KE	KS	KW
Anabaena								*	*
Anacystis									
Chlorella	*	*				*	*	*	*
Chlorogonium			*	**					
Diatoms	**	*	*	**		**	*	*	**
Euglena	**	*	*	**		*	**	*	*
Lyngbya									
Oedogonium									
Oscillatoria	**	*	**	**		**	*	*	**
Scenedesmus									
Spirogyra									**
Spirulina			**	**					
Zygnema									

KNP, KN, KE, KS and KW consequently represent the northeastern wastewater discharge pipeline, northeastern, eastern, southern and western shores. H1, H2, H3 and H4 consequently represent the northeastern wastewater discharge shore, southeast, southwest, and northwest shores. Present (*), prominently present (**). H2 location is polluted with petroleum oil.

Table C-4. Algae found in Abu-Hamour (H) and Abu-Nakhla (K) wastewater ponds. Water samples collected from shallow littoral waters in January 2001.

Algae	Abu-Hamour Pond Sampling Locations & Presence of Algae				Abu-Nakhla Pond Sampling Locations & Presence of Algae				
	H1	H2	H3	H4	KNP	KN	KE	KS	KW
Anabaena								*	*
Anacystis									
Chlorella	*	*				*	*	*	*
Chlorogonium									
Diatoms	*	*	*	*		*	**	*	*
Euglena	**	**	*	*		*	**	*	*
Lyngbya									
Oedogonium									
Oscillatoria	**	**	*	*		*	*	*	*
Scenedesmus									
Spirogyra							*	*	*
Spirulina			**	**					
Zygnema									

KNP, KN, KE, KS and KW consequently represent the northeastern wastewater discharge pipeline, northeastern, eastern, southern and western shores. H1, H2, H3 and H4 consequently represent the northeastern wastewater discharge shore, southeast, southwest, and northwest shores. Present (*), prominently present (**). H2 location is polluted with petroleum oil. Algae reduced immensely in KS and KW areas because of the rise of water level and the disturbance of algal microhabitats.

Table C-5. Algae found in Abu-Hamour (H) and Abu-Nakhla (K) wastewater ponds. Water samples collected from shallow littoral waters in February 2001.

Algae	Abu-Hamour Pond Sampling Locations & Presence of Algae				Abu-Nakhla Pond Sampling Locations & Presence of Algae				
	H1	H2	H3	H4	KNP	KN	KE	KS	KW
Anabaena								*	*
Anacystis									
Chlorella	*	*				*	*	*	*
Chlorogonium									
Diatoms	*	**	**	**		*	*	**	**
Euglena	*	*	*	*		*	*	*	*
Lyngbya									
Oedogonium								*	
Oscillatoria	**	**	*	*		*	*	**	**
Scenedesmus									
Spirogyra							*	*	*
Spirulina			**	**					
Zygnema									

KNP, KN, KE, KS and KW consequently represent the northeastern wastewater discharge pipeline, northeastern, eastern, southern and western shores. H1, H2, H3 and H4 consequently represent the northeastern wastewater discharge shore, southeast, southwest, and northwest shores. Present (*), prominently present (**). H2 location is polluted with petroleum oil. Algae reduced in "K" pond because of the rise of water level and the disturbance of algal microhabitats. Water in H3 location is exceptionally dark green in color, because of the presence of high density of *Spirulina* algae.

Figure D-4. Upper and lower plates showing oil spills and the dying aquatic plants at the southeastern side of Abu-Hamour pond.

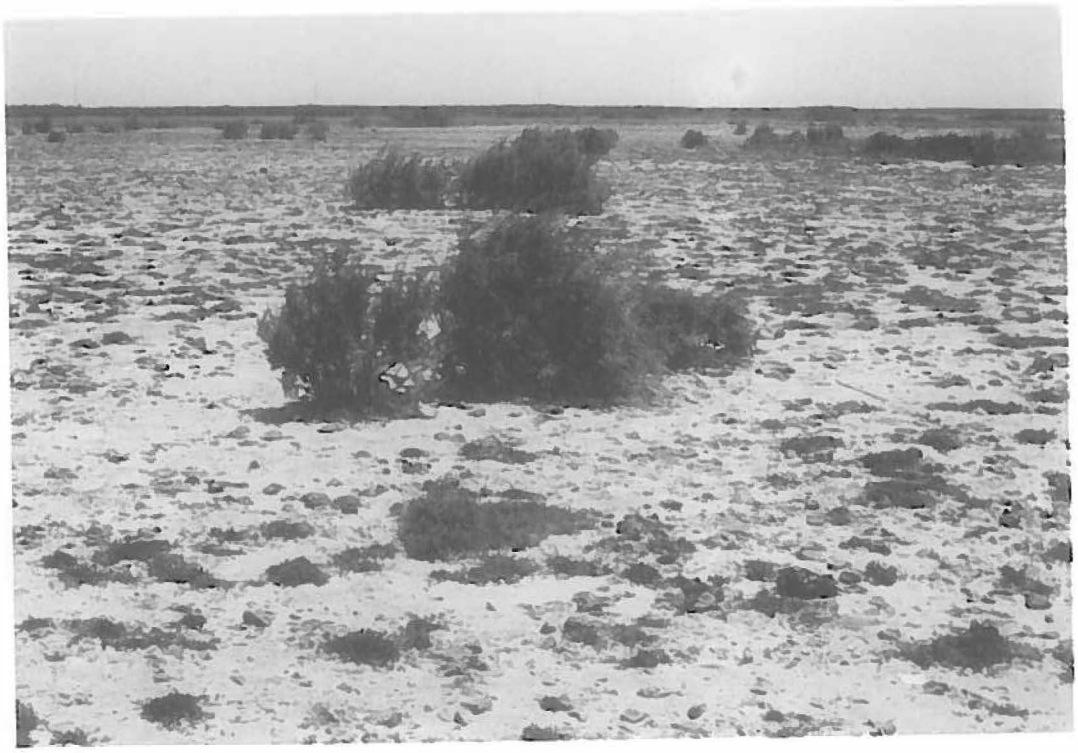


Figure D-5. Upper and lower plates showing *Tamarix ramossissima* shrubs growing on flattened moist edges of Abu-Nakhla pond. The associated small plants are mostly *Aeluropus lagopoides* grasses.

Figure D-6. Upper and lower plates showing the wet edges of Abu-Hamour pond, where *Tamarix ramossissima* shrubs and other salt and pollution enduring plants are found.

Figure D-7. Upper and lower plates showing *Aeluropus lagopoides* grasses growing on flattened moist banks of Abu-Nakhla pond.

Figure D-8. Upper and lower plates showing the area around Abu-Nakhla pond, which are being grazed by camels.

Figure D-9. Upper plate showing *Chloris virgata* grass growing along the banks of Abu-Hamour pond. Lower plate showing *Polypogon monospleinsis* grass growing along the banks of Abu-Nakhla pond.

Figure D-10. Upper plate showing *Sporobolus arabicus* in the foreground and *Phragmites australis* in the background. Lower plate showing branches of *Sporobolus arabicus*, The species is common in shallow waters at the eastern side of Abu-Nakhla pond.

Figure D-11. Upper and lower plates showing *Rumex dentatus* plants growing along the banks of Abu-Nakhla pond, on moist soil.

APPENDIX- E

PHOTOGRAPHS OF ALGAE OF ABU-HAMOUR AND ABU-NAKHLA WASTEWATER PONDS

Figure E-1. Upper plate showing algae attached to rocks in shallow water, in Abu-Hamour pond. Lower plate showing algal scum growing along the southern and western shorelines of Abu-Nakhla pond.

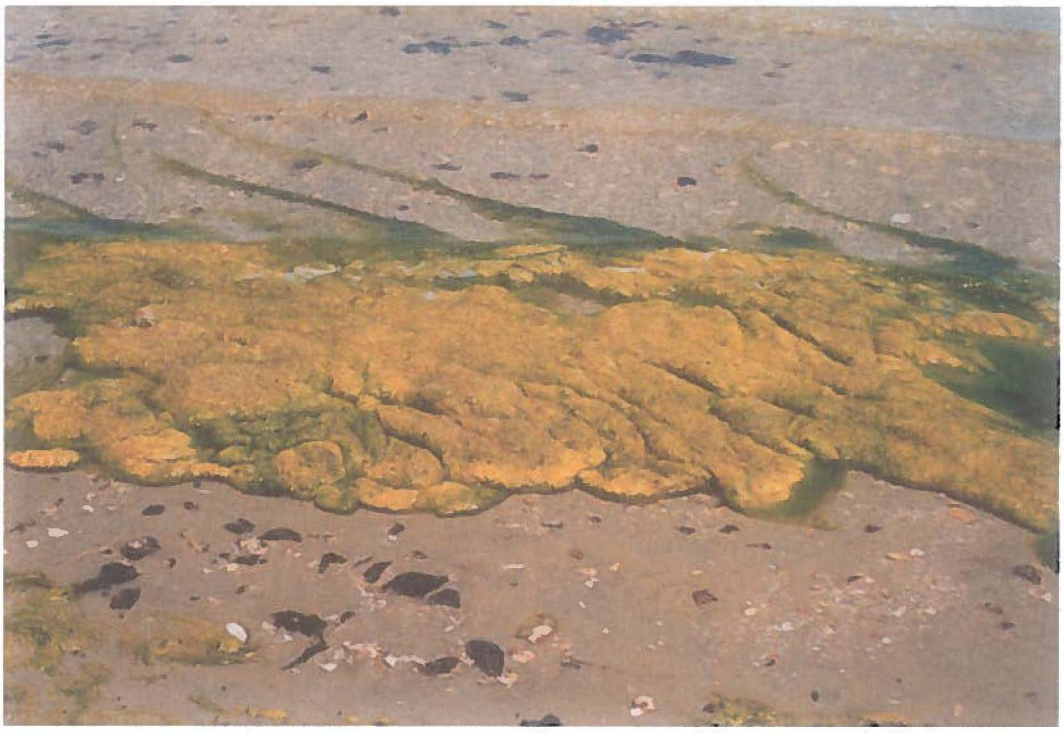
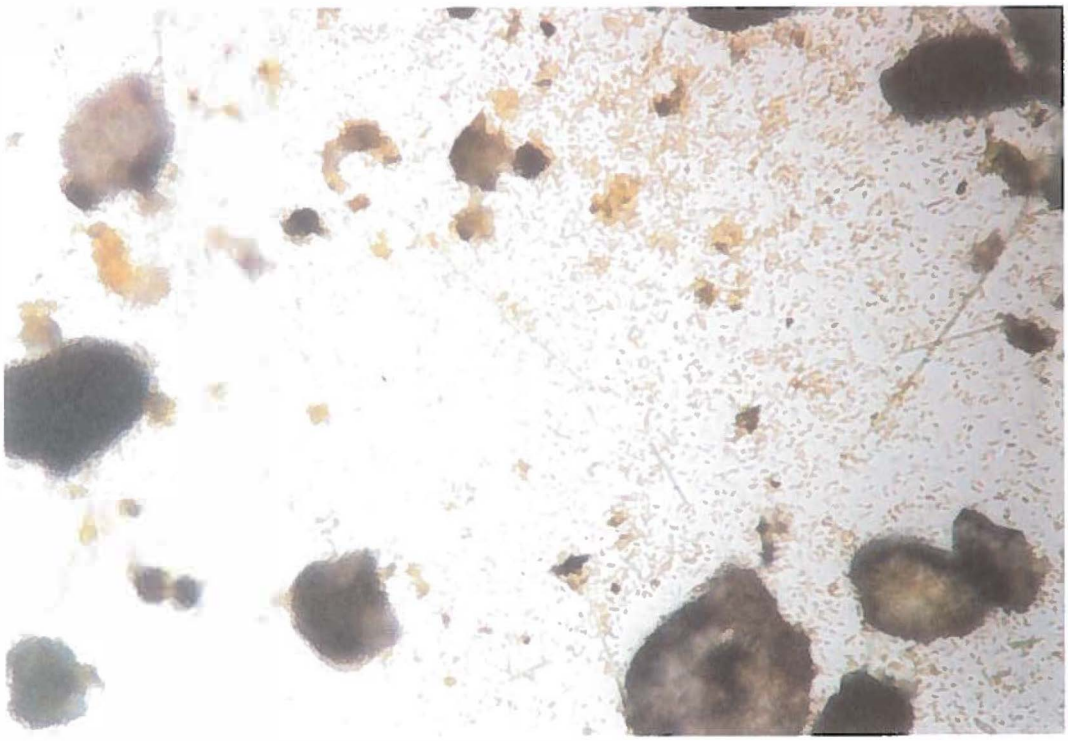


Figure E-12. Dense population of the tiny, highly active ciliates are shown in the upper and lower plates. They are more common in the untreated wastewater of offensive odor of Abu-Hamour pond. Dark bodies in the lower plate are soil particles.



PART - 2

COLIFORM BACTERIA OF WASTEWATER PONDS IN QATAR

Roda F. Al-Thani
Head of the Agriculture Sciences Unit,
Department of Biological Sciences,
Faculty of Science, University of Qatar,
P.O. Box 2713, Doha, Qatar
e-mail: drralthani@qu.edu.qa

SUMMARY

The microbiological study of the wastewater and the moist soils around Abu-Hamour pond (untreated wastewater pond) and Abu-Nakhla pond (treated wastewater pond), located on the outskirts of Doha City, revealed that coliform bacteria (*Escherichia coli*) is prominently present in the former one than in the latter one. *E. coli* was present in the coastal wastewater in all sites around both ponds. Yet, *E. coli* was present in wet soils around these ponds primarily near the discharge sites where new water is constantly poured in. Also the following bacteria were prominently present in the coastal waters of Abu-Hamour pond than in Abu-Nakhla pond: *Aeromonas hydrophilia, Pseudomonas aeruginosa, Klebsiella pneumoniae* and *Chromobacterium violaceum*. Moreover, *Streptomyces sp., Bacillus sp.* and *Macrococcus sp.* were more prominent in the wet soils around Abu-Hamour pond than Abu-Nakhla pond.

ARABIC SUMMARY

بكتيريا القولون في برك مياه الصرف الصحي في قطر

روضة فهد آل ثاني

رئيسة وحدة العلوم الزراعية، قسم العلوم البيولوجية
كلية العلوم، جامعة قطر، ص ب 2713، الدوحة، قطر
e-mail: drralthani@qu.edu.qa

في هذه الدراسة الميكروبيولوجية تم تحليل عينات عديدة وشهريا من المـــاء والتربة من محيط بركة أبو هامور (ذات مياه الصرف الصحي غير المعالجة) و بركة أبو نخلة (ذات مياه الصرف الصحي المعالجة)، والواقعتين في الجنوب الغربي مـــن مدينـــة الدوحة في قطر. و تبين من الدراسة أن المياه الساحلية لبركة أبو هامور تكون فيـــها بكتيريا القولون ***Escherichia coli*** والفطريات كثيرة نسبيا، في حين بركة أبو نخلـــة تكون فيها هذه البكتيريا قليلة.

وتوجد بكتريا القولون بكثرة في الماء قرب الشواطئ وطوال العام في جميـــع أطراف البركتين، في حين توجد نفس هذه البكتريا بكثرة في التربة الرطبة المحيطة قرب مصبات المياه وتقل او تنعدم في المواقع البعيدة عن مناطق المصبات.

وتبين كذلك من الدراسة وجود البكتيريا التالية و بكثرة في المياه الســـاحلية في أبو هامور و قليلة في أبو نخلة:

Aeromonas hydrophilia, Pseudomonas aeruginosa, Klebsiella pneumoniae and ***Chromobacterium violaceum.***

و بينت الدراسة أيضا أن تواجد الأنواع التالية من البكتيريا في التربة الرطبة المحيطة ببركة أبو هامور أعلى من تلك الموجودة حول بركة أبو نخلة:

Streptomyces sp., Bacillus sp. and ***Macrococcus sp.***

INTRODUCTION

A great deal of information is found in the literature concerned with the microbiology of wastewater. Among such publication, which deal with specific aspects of wastewater are the followings: waste water reuse (Al-Layla 2001), wastewater treatment and reuse (Al-Sharafi *et al.* 2001), wastewater pollution (Sadiq 1999), costs benefits of pathogen control of drinking water (Clark *et al.* 1993), *Escherichia, Salmonella, Shiegella,* and *Yersinia* (Gray 1995), human-associated bacterial pathogens (Hackney and Potter 1994), diarrhea associated with cyanobacterial-like bodies in an immuno-competent host (Hale *et al.* 1994), aquatic microbiology, general microbiology and microorganisms (Tortora *et al.* 2001).

Sewage discharge has a highly important effect on human health because it can spread pathogenic bacteria and viruses. Untreated wastewater contains many billions of bacteria per liter, most of these are not harmful to humans, and some are even helpful in wastewater treatment processes (Midigan *et al.* 2000). However, people may discharge some of these harmful organisms along with their body wastes. Many serious outbreaks of communicable diseases have been traced to direct contamination of drinking water or food supplies by the human's body waste (Tables 1 and 2). Among the known examples of disease, which may be spread through wastewater are typhoid, cholera, dysentery, polio and hepatitis.

Fortunately the bacteria that grow in the intestinal tract of diseased humans are not likely to find in the wastewater favorable environment for their growth and reproduction. Although many pathogenic organisms are removed by natural die-off during the wastewater treatment processes, sufficient numbers can remain to cause a threat to any downstream use involving human contact or consumption (Rheinheimer 1992).

The microorganisms of natural waters are extremely diverse. The numbers and types of bacteria presence will depend on the presence and the amounts of organic matter, toxic substances and salinity; in addition to the environment factors such as pH, temperature and aeration (Toranzons and McFeters 1997). The largest numbers of

PART- 3

PRELIMINARY ASSESSMENT OF PARASITES IN WASTEWATER PONDS IN QATAR

MAHMOUD M. KARDOUSHA
Department of Biological Sciences, Faculty of Science,
University of Qatar, P.O. Box 2713, Doha, Qatar
e-mail: mkardousha@hotmail.com

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PART- 4

INVERTEBRATES OF WASTEWATER PONDS IN QATAR

Elhag A. Elhag
Department of Marine Sciences, Faculty of Science,
University of Qatar, P.O. Box 2713, Doha, Qatar
e-mail: e.a.elhag@qu.edu.qa

SUMMARY

The invertebrate life of two wastewater ponds around Doha City was studied for the period October 2000 – October 2001. The substrate nature of the two ponds was found to be similar but the densities of occurrence of the different species were variable. Seven phyla were encountered, namely Platyhelminthes, Nematoda, Gastrotricha, Rotifera, Annelida, Mollusca and Arthropoda. Generally, the invertebrate life was richer in Abu-Nakhla pond (treated wastewater) than in Abu-Hamour pond (untreated wastewater). The ratio of occurrence of copepod / Nematode fluctuated in no particular manner depending on the state of water level in the two ponds.

ARABIC SUMMARY

اللافقاريات في برك مياه الصرف الصحي في قطر

الحاج أبو جبر الحاج

قسم علوم البحار، كلية العلوم، جامعة قطر، ص ب 2713، الدوحة، قطر
e-mail: e.a.elhag@qu.edu.qa

في الفترة من أكتوبر 2000 و إلى أكتوبر 2001 درست اللافقاريات القاطنة في بركتين ناتجتين عن مياه الصرف الصحي لمدينة الدوحة. و بالرغم من أن طبيعة قاع البركتين وجدت متشابهة، إلا أن كثافة تواجد اللافقاريات اختلفت. رصدت سبع شعب حيوانية و هي الديدان المفلطحة، الديدان الخيطية، شوكيات البطن، الدوامات، الديدان الحلقية، الرخويات، و مفصليات الأرجل. و عموما كانت بركة أبو نخلة (ذات المياه المعالجة) أغنى باللافقاريات من بركة أبو هامور (ذات المياه غير المعالجة). و كانت نسب تواجد الديدان الخيطية لمجدافية الأقدام مختلفة مع اختلاف منسوب المياه المتكور في البركتين.

Table 6. Occurrence of Invertebrate species at Abu-Nakhla and Abu-Hamour ponds during March 2001.

	Abu-Nakhla Pond					Abu-Hamour Pond			
	KNP	KN	KE	KS	KW	H1	H2	H3	H4
PHYLUM Platyhelminthes:									
CLASS Turbellaria									
Rhabdocoela: Catenula sp.		*		*	*				
Tricladida: Planaria sp.									
PHYLUM Nematoda:									
Phasmidia: Phasmid sp.		*		*				*	*
PHYLUM Gastrotricha									
Chaetonotida: Chaetonotid sp.									
PHYLUM Rotifera									
Monogonta sp.			*	*					
PHYLUM Annelida:									
CLASS Oligochaeta: Haplotaxida:									
Enchytreus sp., Tubifex sp.		*	*	*	*				
PHYLUM Arthropoda:									
Crustacea:									
Ostracoda: Podocopa sp.			*	*	*				
Copepoda:									
Harpacticoid sp.				*	*			*	*
Cyclopoid sp.									
Cyclops sp.			*		*				
Branchiopoda									
Diplostraca: Daphnia sp.									
CLASS Insecta:									
Exopterygota:									
Orthoptera:									
Anacridium sp., Truxalis sp.									
Odonata: Coenagrionidae sp.									
Hemiptera: Nazara sp.									
Endopterygota:									
Lepidoptera: Anaphais sp.									
Diptera:									
Aèdes sp., Muscoid flies									
Coleoptera: Adasmia sp.									
Hymenoptera:									
Cataglyphis sp., Formicidae sp.	*	*	*	*					
Insect larvae		*	*						
CLASS Arachnida:									
Araneae: Lycosa sp., Pisauridae sp.			*	*					
PHYLUM Mollusca:									
Eulamellibranchiata: Sphaeriidae sp.									

KNP, KN, KE, KS and KW respectively represent the northeastern wastewater discharge pipeline, northeastern, eastern, southern and western shores. H1, H2, H3 and H4 respectively represent the northeastern wastewater discharge shore, southeast, southwest and northwest shores. *present, **prominently present.

Table 7. Occurrence of Invertebrate species at Abu-Nakhla and Abu-Hamour ponds during April 2001.

	Abu-Nakhla Pond					Abu-Hamour Pond			
	KNP	KN	KE	KS	KW	H1	H2	H3	H4
PHYLUM Platyhelminthes:									
CLASS Turbellaria									
Rhabdocoela: Catenula sp.									
Tricladida: Planaria sp.									
PHYLUM Nematoda:									
Phasmidia: Phasmid sp.			*	*	*			*	*
PHYLUM Gastrotricha									
Chaetonotida: Chaetonotid sp.				*					
PHYLUM Rotifera									
Monogonta sp.			*	*	*				
PHYLUM Annelida:									
CLASS Oligochaeta: Haplotaxida:									
Enchytreus sp., Tubifex sp.		*			*				
PHYLUM Arthropoda:									
Crustacea:									
Ostracoda: Podocopa sp.		*						*	
Copepoda:									
Harpacticoid sp.								**	**
Cyclopoid sp.									
Cyclops sp.				*	*				
Branchiopoda									
Diplostraca: Daphnia sp.									
CLASS Insecta:									
Exopterygota:									
Orthoptera:									
Anacridium sp., Truxalis sp.									
Odonata: Coenagrionidae sp.		*	*	*	*			*	
Hemiptera: Nazara sp.									
Endopterygota:									
Lepidoptera: Anaphais sp.									
Diptera:									
Aedes sp., Muscoid flies			*	*					
Coleoptera: Adasmia sp.									
Hymenoptera:									
Cataglyphis sp., Formicidae sp.	*	*	*	*	*				
Insect larvae		*	*	*					
CLASS Arachnida:									
Araneae: Lycosa sp., Pisauridae sp.		*	*						
PHYLUM Mollusca:									
Eulamellibranchiata: Sphaeriidae sp.		*							*

KNP, KN, KE, KS and KW respectively represent the northeastern wastewater discharge pipeline, northeastern, eastern, southern and western shores. H1, H2, H3 and H4 respectively represent the northeastern wastewater discharge shore, southeast, southwest and northwest shores. *present, **prominently present.

Table 8. Occurrence of Invertebrate species at Abu-Nakhla and Abu-Hamour ponds during May 2001.

	Abu-Nakhla Pond					Abu-Hamour Pond			
	KNP	KN	KE	KS	KW	H1	H2	H3	H4
PHYLUM Platyhelminthes:									
CLASS Turbellaria									
Rhabdocoela: Catenula sp.			*						
Tricladida: Planaria sp.			*						
PHYLUM Nematoda:									
Phasmidia: Phasmid sp.			**					*	*
PHYLUM Gastrotricha									
Chaetonotida: Chaetonotid sp.									
PHYLUM Rotifera									
Monogonta sp.				*					
PHYLUM Annelida:									
CLASS Oligochaeta: Haplotaxida:									
Enchytreus sp., Tubifex sp.			*	*	*			*	*
PHYLUM Arthropoda:									
Crustacea:									
Ostracoda: Podocopa sp.			*	*	*			*	
Copepoda:									
Harpacticoid sp.								*	*
Cyclopoid sp.									
Cyclops sp.				*	*				
Branchiopoda									
Diplostraca: Daphnia sp.									
CLASS Insecta:									
Exopterygota:									
Orthoptera:									
Anacridium sp., Truxalis sp.									
Odonata: Coenagrionidae sp.			*	*					
Hemiptera: Nazara sp.									
Endopterygota:									
Lepidoptera: Anaphais sp.									
Diptera:									
Aèdes sp., Muscoid flies		*	*	*	*				
Coleoptera: Adasmia sp.									
Hymenoptera:									
Cataglyphis sp., Formicidae sp.		*	*	*	*				
Insect larvae			*	*	*				
CLASS Arachnida:									
Araneae: Lycosa sp., Pisauridae sp.			*	*					
PHYLUM Mollusca:									
Eulamellibranchiata: Sphaeriidae sp.			*	*					

KNP, KN, KE, KS and KW respectively represent the northeastern wastewater discharge pipeline, northeastern, eastern, southern and western shores. H1, H2, H3 and H4 respectively represent the northeastern wastewater discharge shore, southeast, southwest and northwest shores. *present, **prominently present.

Table 9. Occurrence of Invertebrate species at Abu-Nakhla and Abu-Hamour ponds during June 2001.

	Abu-Nakhla Pond					Abu-Hamour Pond			
	KNP	KN	KE	KS	KW	H1	H2	H3	H4
PHYLUM Platyhelminthes:									
CLASS Turbellaria									
Rhabdocoela: Catenula sp.		*						*	*
Tricladida: Planaria sp.		*							
PHYLUM Nematoda:									
Phasmidia: Phasmid sp.				*	*			*	*
PHYLUM Gastrotricha									
Chaetonotida: Chaetonotid sp.									
PHYLUM Rotifera									
Monogonta sp.				*	*				
PHYLUM Annelida:									
CLASS Oligochaeta: Haplotaxida:									
Enchytreus sp., Tubifex sp.				*	*				
PHYLUM Arthropoda:									
Crustacea:									
Ostracoda: Podocopa sp.			*		*			*	
Copepoda:									
Harpacticoid sp.			*					*	*
Cyclopoid sp.			*	*					*
Cyclops sp.									
Branchiopoda									
Diplostraca: Daphnia sp.									
CLASS Insecta:									
Exopterygota:									
Orthoptera:									
Anacridium sp., Truxalis sp.									
Odonata: Coenagrionidae sp.									
Hemiptera: Nazara sp.									
Endopterygota:									
Lepidoptera: Anaphais sp.									
Diptera:									
Aèdes sp., Muscoid flies		*	*						
Coleoptera: Adasmia sp.									
Hymenoptera:									
Cataglyphis sp., Formicidae sp.	*	*	*	*	*			*	*
Insect larvae									
CLASS Arachnida:									
Araneae: Lycosa sp., Pisauridae sp.									
PHYLUM Mollusca:									
Eulamellibranchiata: Sphaeriidae sp.									

KNP, KN, KE, KS and KW respectively represent the northeastern wastewater discharge pipeline, northeastern, eastern, southern and western shores. H1, H2, H3 and H4 respectively represent the northeastern wastewater discharge shore, southeast, southwest and northwest shores. *present, **prominently present.

Table 10. Occurrence of Invertebrate species at Abu-Nakhla and Abu-Hamour ponds during July 2001.

	Abu-Nakhla Pond					Abu-Hamour Pond			
	KNP	KN	KE	KS	KW	H1	H2	H3	H4
PHYLUM Platyhelminthes:									
CLASS Turbellaria									
Rhabdocoela: Catenula sp.									
Tricladida: Planaria sp.				*	*				
PHYLUM Nematoda:									
Phasmidia: Phasmid sp.		*	*		*			*	*
PHYLUM Gastrotricha									
Chaetonotida: Chaetonotid sp.									
PHYLUM Rotifera									
Monogonta sp.									
PHYLUM Annelida:									
CLASS Oligochaeta: Haplotaxida:									
Enchytreus sp., Tubifex sp.									
PHYLUM Arthropoda:									
Crustacea:									
Ostracoda: Podocopa sp.									
Copepoda:									
Harpacticoid sp.			*					*	
Cyclopoid sp.			*	*					*
Cyclops sp.									
Branchiopoda									
Diplostraca: Daphnia sp.									
CLASS Insecta:									
Exopterygota:									
Orthoptera:									
Anacridium sp., Truxalis sp.									
Odonata: Coenagrionidae sp.									
Hemiptera: Nazara sp.									
Endopterygota:									
Lepidoptera: Anaphais sp.									
Diptera:									
Aèdes sp., Muscoid flies	*	*	*	*	*				
Coleoptera: Adasmia sp.									
Hymenoptera:									
Cataglyphis sp., Formicidae sp.	*	*	*	*	*				
Insect larvae									
CLASS Arachnida:									
Araneae: Lycosa sp., Pisauridae sp.									
PHYLUM Mollusca:									
Eulamellibranchiata: Sphaeriidae sp.									

KNP, KN, KE, KS and KW respectively represent the northeastern wastewater discharge pipeline, northeastern, eastern, southern and western shores. H1, H2, H3 and H4 respectively represent the northeastern wastewater discharge shore, southeast, southwest and northwest shores. *present, **prominently present.

Table 11. Occurrence of Invertebrate species at Abu-Nakhla and Abu-Hamour ponds during August 2001.

	Abu-Nakhla Pond					Abu-Hamour Pond			
	KNP	KN	KE	KS	KW	H1	H2	H3	H4
PHYLUM Platyhelminthes:									
CLASS Turbellaria									
Rhabdocoela: Catenula sp.									
Tricladida: Planaria sp.									
PHYLUM Nematoda:									
Phasmidia: Phasmid sp.				*	*			*	*
PHYLUM Gastrotricha									
Chaetonotida: Chaetonotid sp.									
PHYLUM Rotifera									
Monogonta sp.									
PHYLUM Annelida:									
CLASS Oligochaeta: Haplotaxida:									
Enchytreus sp., Tubifex sp.									
PHYLUM Arthropoda:									
Crustacea:									
Ostracoda: Podocopa sp.									
Copepoda:									
Harpacticoid sp.			*		*				*
Cyclopoid sp.									
Cyclops sp.									
Branchiopoda									
Diplostraca: Daphnia sp.									
CLASS Insecta:									
Exopterygota:									
Orthoptera:									
Anacridium sp., Truxalis sp.									
Odonata: Coenagrionidae sp.									
Hemiptera: Nazara sp.									
Endopterygota:									
Lepidoptera: Anaphais sp.									
Diptera:									
Aèdes sp., Muscoid flies	*	*	*					*	*
Coleoptera: Adasmia sp.									
Hymenoptera:									
Cataglyphis sp., Formicidae sp.	*	*	*	*	*		*	*	*
Insect larvae									
CLASS Arachnida:									
Araneae: Lycosa sp., Pisauridae sp.		*	*						
PHYLUM Mollusca:									
Eulamellibranchiata: Sphaeriidae sp.									

KNP, KN, KE, KS and KW respectively represent the northeastern wastewater discharge pipeline, northeastern, eastern, southern and western shores. H1, H2, H3 and H4 respectively represent the northeastern wastewater discharge shore, southeast, southwest and northwest shores. *present, **prominently present.

Table 12. Occurrence of Invertebrate species at Abu-Nakhla and Abu-Hamour ponds during September 2001.

	Abu-Nakhla Pond					Abu-Hamour Pond			
	KNP	KN	KE	KS	KW	H1	H2	H3	H4
PHYLUM Platyhelminthes:									
CLASS Turbellaria									
Rhabdocoela: Catenula sp.		*							
Tricladida: Planaria sp.									
PHYLUM Nematoda:									
Phasmidia: Phasmid sp.			*		*			*	*
PHYLUM Gastrotricha									
Chaetonotida: Chaetonotid sp.		*		*					
PHYLUM Rotifera									
Monogonta sp.									
PHYLUM Annelida:									
CLASS Oligochaeta: Haplotaxida:		*		*					
Enchytreus sp., Tubifex sp.		*			*				
PHYLUM Arthropoda:									
Crustacea:									
Ostracoda: Podocopa sp.									
Copepoda:									
Harpacticoid sp.				*	*			*	*
Cyclopoid sp.									
Cyclops sp.									
Branchiopoda									
Diplostraca: Daphnia sp.									
CLASS Insecta:									
Exopterygota:									
Orthoptera:									
Anacridium sp., Truxalis sp.									
Odonata: Coenagrionidae sp.									
Hemiptera: Nazara sp.									
Endopterygota:									
Lepidoptera: Anaphais sp.									
Diptera:									
Aèdes sp., Muscoid flies									
Coleoptera: Adasmia sp.									
Hymenoptera:									
Cataglyphis sp., Formicidae sp.		*		*	*				
Insect larvae		*		*	*				
CLASS Arachnida:									
Araneae: Lycosa sp., Pisauridae sp.									
PHYLUM Mollusca:									
Eulamellibranchiata: Sphaeriidae sp.		*		*	*				

KNP, KN, KE, KS and KW respectively represent the northeastern wastewater discharge pipeline, northeastern, eastern, southern and western shores. H1, H2, H3 and H4 respectively represent the northeastern wastewater discharge shore, southeast, southwest and northwest shores. *present, **prominently present.

Table 13. Occurrence of Invertebrate species at Abu-Nakhla and Abu-Hamour ponds during October 2001.

	Abu-Nakhla Pond					Abu-Hamour Pond			
	KNP	KN	KE	KS	KW	H1	H2	H3	H4
PHYLUM Platyhelminthes:									
CLASS Turbellaria									
Rhabdocoela: Catenula sp.		*							
Tricladida: Planaria sp.									
PHYLUM Nematoda:									
Phasmidia: Phasmid sp.		*		*	*			*	
PHYLUM Gastrotricha									
Chaetonotida: Chaetonotid sp.									
PHYLUM Rotifera									
Monogonta sp.									
PHYLUM Annelida:									
CLASS Oligochaeta: Haplotaxida:		*		*					
Enchytreus sp., Tubifex sp.		*			*				
PHYLUM Arthropoda:									
Crustacea:									
Ostracoda: Podocopa sp.									
Copepoda:									
Harpacticoid sp.			*		*			**	**
Cyclopoid sp.									
Cyclops sp.									
Branchiopoda									
Diplostraca: Daphnia sp.									
CLASS Insecta:									
Exopterygota:									
Orthoptera:									
Anacridium sp., Truxalis sp.									
Odonata: Coenagrionidae sp.									
Hemiptera: Nazara sp.									
Endopterygota:									
Lepidoptera: Anaphais sp.									
Diptera:									
Aèdes sp., Muscoid flies									
Coleoptera: Adasmia sp.									
Hymenoptera:									
Cataglyphis sp., Formicidae sp.		*		*	*				
Insect larvae		*		*	*				
CLASS Arachnida:									
Araneae: Lycosa sp., Pisauridae sp.									
PHYLUM Mollusca:									
Eulamellibranchiata: Sphaeriidae sp.		*		*	*				

KNP, KN, KE, KS and KW respectively represent the northeastern wastewater discharge pipeline, northeastern, eastern, southern and western shores. H1, H2, H3 and H4 respectively represent the northeastern wastewater discharge shore, southeast, southwest and northwest shores. *present, **prominently present.

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PART 5

PRELIMINARY ASSESSMENT OF VERTEBRATE COMMUNITY OF WASTEWATER PONDS IN QATAR

Mahmoud M. Kardousha
Department of Biological Sciences, Faculty of Science,
University of Qatar, P.O. Box 2713, Doha, Qatar
Email: mkardousha@hotmail.com

Bar-tailed godwit *Limosa lapponica* and Caspian tern *Sterna caspia* (Jennings 1981 and Oldfield and Oldfield, 1994). Another remarkable winter passage, which was seen in both ponds, is the black-winged stilt *Himantopus himantopus,* which is easily distinguished bird with its black wings, white body and long pink to orange legs. It was seen in both Abu-Nakhla and Abu-Hamour ponds in large numbers (Oldfield and Oldfield, 1994).

5- Mammals:

Camels (*Camelus dromedarius*) are the most abundant visitors among all mammals (Appendix-1, Fig. 9), especially in abu-Nakhla pond. The water found in this pond is usually drinkable to camels, goats and sheep, which were seen grazing in the area. Some rodents were seen in March near the water discharge point in Abu-Nakhla pond. From the color pattern and external features it seems that they belong to Gerbils *Gerbillus nanus* and *G. cheesmani* and Jerboa *Jaculus jacullus,* which are the most common rodents in the Qatari desert. Mammals like the hare *Lepus capensis* and the hedgehog *Paraechinus aethiopicus* are expected to be present in such habitats (Table 1).

Table 1. Vertebrate animals found in both Abu-Nakhla (K) and Abu-Hamour (H) wastewater ponds in Qatar, from October 2000 up to October 2001.

Vertebrate Species (Scientific Name)	English Name	Locality	Status	Season
FISHES:				
Oreochromis niloticus	Nile Tilapia	K	Endemic	All year
Amphibians:				
Bufo viridis	Green toad	K	Endemic	All year
REPTILES:				
Acanthodactylus boskianus	Fringed-toes sand lizard	K	Endemic	All year
Agama flavimaculata	Jayakari's agama	K, H	Endemic	All year
Banopus tuberculatus	Stone Gecko	K, H	Endemic	All year
Coluber ventromaculatus	Rat snake	K	Endemic	All year
Cyrtodactylus scaber	Keeled rock Gecko	H	Endemic	All year
Eremias brevirostris	Short-nosed desert lizard	K, H	Endemic	All year
Uromastyx microlepis	Dhab	K , H	Endemic	All year
BIRDS:				
Charadrius dubius	Ringed plover	K	Migrant	Winter
Egretta gularis	Reef Heron	K	Resident	All year
Galerida cristata	Crested larks	K , H	Visitor	All year
Himantopus Himantopus	Black-winged stilt	K , H	Migrant	Spring Winter
Lanius excubitor	Grey shrike	K , H	Migrant	Spring
Larus genei	Slender-billed gull	K , H	Visitor	Winter
Larus hemprichii	Sooty gull	K , H	Visitor	Winter
Limosa lapponica	Godwit	K , H	Migrant	Winter
Motacilla alba	White wagtail	K	Visitor	All year
Passer domesticus	House sparrows	K , H	Visitor	All year
Phoenicopterus ruber	Great flamingo	K , H	Resident	All year
Rallus aquaticus	Water rail	K , H	Resident	All year
Sterna caspia	Caspian tern	K	Migrant	Winter
Streptopelia Senegalensis	Palm doves	K , H	Visitor	All year
Tackybapterus Ruficollis	Little grebes	K , H	Resident	All year
Tringa stagnatillis	Sandpiper	K , H	Migrant	Winter
MAMMALS:				
Camelus dromedarius	Camels	K	Visitor	All year
Gerbillus nanus	Baluchistan gerbil	K	Endemic	All year
G. cheesmani	Cheesman' gerbil	K	Endemic	All year
Jaculus jaculus	Lesser Jerboa	K, H	Endemic	All year
Lepus capensis	Cape hare	K	Endemic	All year
Paraechinus aethiopicus	Ethiopian hedgehog	K	Endemic	All year
Sheep and Goats	Cattle	K	Visitor	All year

Figure 8. A dead body of the grey heron found around Abu-Nakhla pond.

Figure 9. Grazing camels around Abu-Nakhla pond.

PART – 6

TRACE METALS IN WASTEWATER PONDS IN QATAR

Jamal A. Sweileh
Department of Chemistry, Faculty of Science
University of Qatar, P.O. Box 2713
Doha, Qatar
e-mail: sweilehj@qu.edu.qa

EXPERIMENTAL METHOD

Study Site:

Abu-Hamour pond is located at the southern outskirt of Doha neighboring the industrial city. It receives both domestic and industrial waste. Abu-Nakhla pond is located about 7-km southwest of the industrial city on Salwa Road and receives treated water only from two water treatment plants in the area. Figure 1 shows the relative areas of the two ponds and the sampling points.

Sampling:

For each pond, samples of water and sediments were taken monthly between November 2000 and October 2001 at four locations indicated in Figure 1. Grab samples of water were taken in 1-L size acid-washed polypropylene bottles about 1.5 m from the shore at a depth of 10 to 25 cm. Using surgical gloves wet sediment samples were collected and transferred into seal-able polypropylene bags. All samples were shipped to the laboratory in ice-boxes and stored at 4 °C. Six control soil samples were collected some 1.5 to 3 km away from each wastewater pond. Each sample was processed similar to pond sediments and analyzed for the targeted elements in duplicate.

Sample treatment:

For the determination of acid soluble metals [7], 100 ml of each water sample (equilibrated at room temperature) was pipetted into a polypropylene beaker and acidified by dropwise addition of nitric acid (1:1, v/v) to pH 1.75 ± 0.1 and left standing for 16 hours. Next, pH was rechecked and adjusted if necessary by addition of the above nitric acid or ammonia solution (1:10, v/v) and a portion of this sample was filtered using 0.45-µm pore size cellulose filter (Millipore). The filtrate (about 35 ml) was then acidified with two drops of nitric acid and submitted for atomic absorption analysis in disposable plastic centrifuge tube. Turbid water samples were allowed to settle and the 100-ml aliquot was taken from the clear supernatant portion.

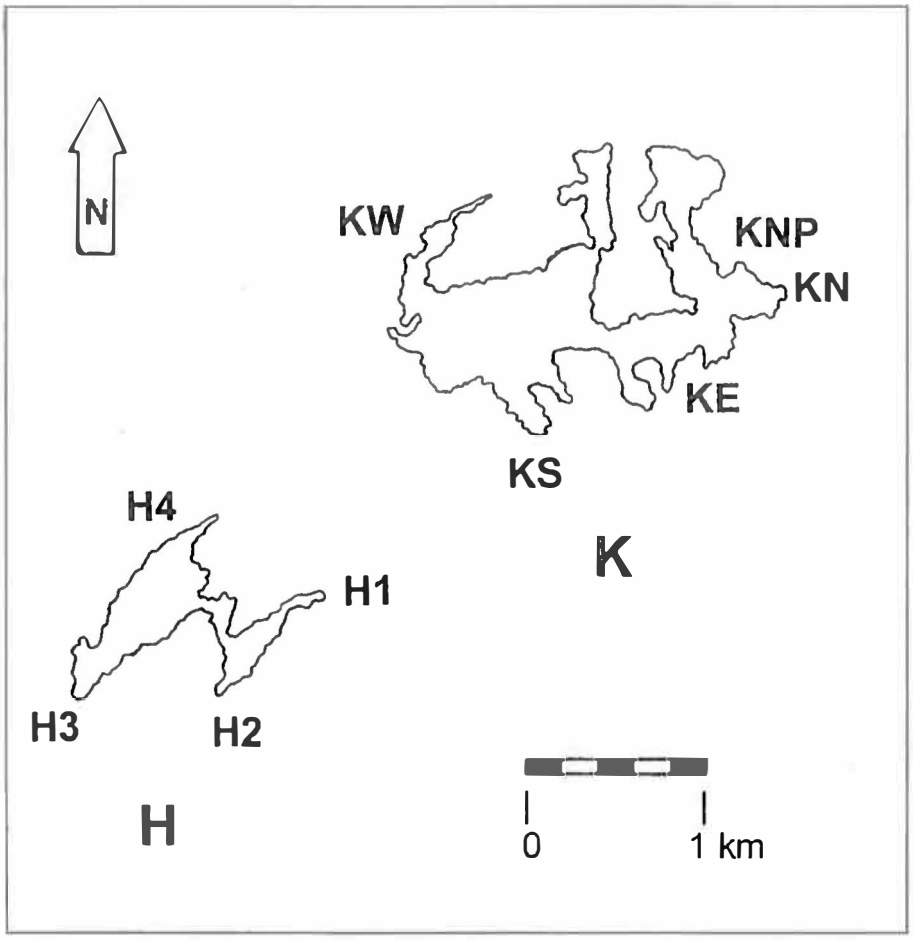

Figure 1. Maps of Abu-Hamour (H) and Abu-Nakhla (K) wastewater ponds showing relative size and sampling points.

For sediments, the sample was dried at 90 °C, pulverized and homogenized. Then, 4.000 g of the powder was mixed with 100 ml of distilled de-ionized water and acidified with drops of nitric acid to pH 1.75 ± 0.1 and agitated for 30 minutes. After standing at room temperature for 16 hours, the pH was re-adjusted, filtered using 0.45 µm filter and the filtrate was treated as described above for water samples.

For the determination of mercury [8] 100 ml of the water sample was transferred to a biological oxygen demand (BOD) bottle and digested for 2 minutes with 5 ml of freshly prepared Aqua-Regia; mixture of hydrochloric and nitric acid (3:1, v/v) at 95 °C on a water bath. After cooling, 15 ml of 5% (w/v) potassium permanganate was added and the content was mixed thoroughly and digested on the water bath for 30 min. The solution was cooled and 6 ml of an aqueous solution of sodium chloride-hydroxylamine sulfate (12% each component, w/v) was added to reduce the excess permanganate. This solution (115ml) was submitted for cold vapor atomic absorption determination using sodium borohydride reduction.

For sediments, 0.2000 g of the dried powdered sample was digested for 2 min. in a BOD bottle using 5 ml of Aqua-Regia and 5 ml of water at 95 °C. After cooling, 50 ml of water and 15 ml of potassium permanganate solution were added and the treatment was concluded as described above for water samples.

For accuracy and precision check laboratory blanks and spiked blanks as well as duplicates for water and sediment samples were carried out through the whole procedure for all parameters.

Instrumental analysis:

The determination of all metals was performed in the Central Laboratory facility at the Department of Chemistry of the University of Qatar. A Perkin-Elmer model AAnalyzer 700 atomic absorption spectrometer was used. The instrument is equipped with a deuterium lamp background corrector. Metals were determined using a Perkin-Elmer model HGA graphite furnace unit and an AS 800 auto-sampler. Mercury was determined by cold vapor technique using the flow injection accessory in a quartz tube atom

cell. Mercury reduction was achieved by a solution was 0.2% (w/v) sodium borohydride in 0.05% (w/v) sodium hydroxide. Instrumental parameters for the each element are listed in Table 1. The atomic absorption instrument is controlled by a micro-computer based data acquisition system comprised of a Perkin-Elmer AAnalyzer software, a Dell GXl micro computer and a Hewlett-Packard model 895CXl printer.

Table 1. Instrumental parameters for atomic absorption determination of trace metals in wastewaters and sediments.

Parameter	Element						
	Pb	Cd	Cu	Ni	Cr	Mn	Hg
Wavelength (nm)	283.3	228.8	324.8	232.0	357.9	279.5	253.7
Slit width (nm)	0.7	0.7	0.7	0.2	0.7	0.2	0.7
Lamp current (mA)	10	4	30	25	25	20	185
Background correction	ON	ON	ON	ON	ON	ON	ON
Furnace program (°C)							Cold vapor
Dry (1)	100	100	100	100	100	100	
Dry (2)	140	140	140	140	140	140	
Ash	700	850	1000	1400	1650	1400	
Atomize	2400	2400	2600	2600	2600	2550	100

RESULTS AND DISCUSSION

For each month, initial data indicated very little variability in available metal content between sampling point in both wastewater and sediment samples. An exception is the second sampling point of Abu-Hamour pond, which is characterized by high oil content in both water and sediment. Therefore, a composite sample was made from sampling points H1, H3 and H4 only, while the second sampling point, H2 was treated as a separate sample. Table 2 and Table 3 summarize the concentration of trace metals in wastewater and sediment samples in both ponds, respectively.

The available concentrations of Cd and Hg in the study sites are below or close to the limits of detection (LOD). These limits of detection were calculated as the

average laboratory blanks plus three times it, standard deviation. The limit of quantification (LOQ) is taken as the average blank value plus 10 times. It's standard deviation [9]. The analytical precision for each element was calculated from the analysis of the field duplicate samples (n = 8 to 12) collected on monthly bases using the formula below to calculate the standard deviation (s)

$$s = \sqrt{\Sigma d_i^2 / 2n}$$

Where d_i is the difference between individual duplicate values and n is the number of duplicate samples analyzed [10]. Table 4 summarizes the data obtained for LOD, LOQ and analytical precision (expressed as the relative standard deviation, RSD) for available metal determination in wastewater and sediment samples.

The average available Pb concentration in wastewater of Abu-Hamour pond (1.92 µg/L) and Abu-Nakhla pond (1.65 µg/L) are statistically insignificantly different. However, month-to-month variability in Abu-Hamour pond is higher as indicated by the larger confidence interval of the mean value at 95% probability. For sediment samples, lead levels seem to have increased steadily during the study period (Figure 2).

Table 5 summarizes the data obtained for replicate soil "control" samples which are supposedly unaffected by wastewater discharge in the two ponds. For both ponds the average available Mn, Cu and Ni in ponds sediments are statistically similar (at 95 % confidence level) to the corresponding average available trace metals of the control soil samples. However, average available lead concentration in pond sediments is statically higher than that of the control soil samples. The average available chromium concentration in both ponds is higher than that of the control samples indicating a certain level of environmental impact. A summary of t-testing data is given in Table 6. Figure 3 through Figure 6 are bar graphs for available copper, nickel, chromium and manganese in wastewater and sediments of both ponds, respectively.

The "total" metal concentration in water is usually performed after strong acid addition and digestion. The "available " metal concentration in wastewater performed in this work is similar to the total metal obtained by strong acid digestion because a sediment-free water samples were used, and because GFAAS gives the total metal content of such samples. Therefore it is legitimate to compare the wastewater data with the international guideline limits of metals for water reuse. The concentration of available target metals in Abu-Hamour and Abu-Nakhla ponds are less than the upper limits of the Saudi Arabian guidelines for wastewater re-use [11] and even less than those of the World Health Organization guidelines for drinking-water quality [12].

CONCLUSIONS AND RECOMMENDATIONS

This work is the first systematic attempt to study the metal contamination of Abu-Hamour and Abu-Nakhla wastewater ponds and underlying sediments. The selection of metals and analytical tests is not as comprehensive as we aspired. The limited budget, manpower and equipment dictated curtailing the analytical parameters and the sampling locations. The choice of "available" metal (leaching at pH = 1.75) rather than the total metal should yield the same values for water samples, but may give lower values for sediment samples. Available metal concentration is a better indicator of environmental vulnerability of the ecosystem to man-made pollution such as acid rain. Also, it could serve as an indicator for potential transfer of such pollutants to vegetation and aquatic life.

Overall, available metal contamination is low and if other aspects of water quality are favorable, the wastewater can be used for agricultural irrigation. A future study might correlate metal concentration in sediments and water to those in plants, birds and fish species inhabiting the area. Core sediment samples from several locations in the water body may shed some light on the history of waste discharge.

During the twelve sampling trips conducted in the two areas, we witnessed a thriving community of plants, fish species and different birds such as ducks, flamingos,

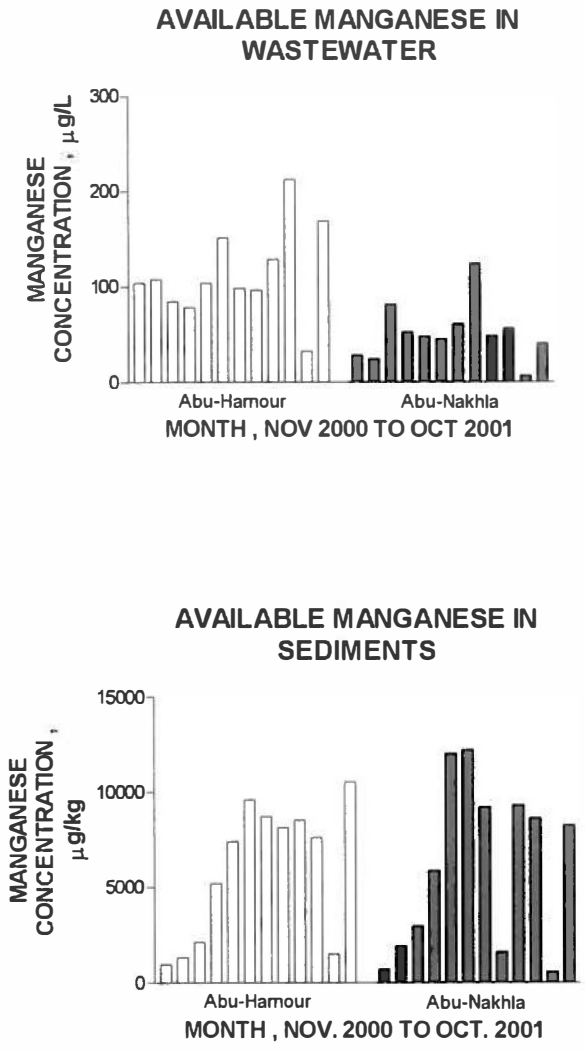

Figure 6. Available manganese in wastewaters and sediments

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PART – 7

POLYCHLORINATED – BIPHENYLS (PCB'S) AND ORGANIC MATTER IN QATARI WASTEWATER PONDS

Ibrahim S. Al-Naimi
Department of Chemistry, Faculty of Science
University of Qatar, P.O. Box 2713, Doha, Qatar
e-mail: i.s.alnaimi@qu.edu.qa

SUMMARY

Polychlorinated biphenyls (PCB's) are classified as persistent chemicals, largely due to their chemical structure, which makes them difficult to be degraded in the natural environment, thus becoming the priority pollutants to be monitored in various aquatic environments. Similarly the role of Organic Matter in transfer and binding of these pollutants cannot be overemphasized. Thus the two ponds located on the outskirts of Doha City were screened for the levels of these compounds over a period of one year, with an aim to establish the levels and evolve a strategy to monitor these compounds in such ponds and in other similar ponds. Results have indicated a slight contamination of Abu-Hamour pond both as regards the levels of PCB's as well as TOM in pond water and in sediments indicating the possible buildup. In comparison the pond Abu-Nakhla was not found to be contaminated possibly because it largely receives treated wastewater as compared to the other pond. Strategies for future work and investigations are recommended and the limitations of the data are discussed.

Table 3. PCB Concentrations in Sediment Samples, from Abu-Nakhla Pond (K), Doha – Qatar.

Sr. No.	Sample Code and Location	Period of Sampling	PCB Concentrations, ppm (dry weight)
1	K-Mixed	Nov. 2000	1.43
2	K-Mixed	Dec. 2000	N.D
3	K-Mixed	Jan. 2001	N.D
4	K-Mixed	Feb. 2001	N.D
5	K-Mixed	March 2001	N.D
6	K-Mixed	April 2001	0.33
7	K-Mixed	May 2001	N.D
8	K-Mixed	June 2001	N.D
9	K-Mixed	July 2001	N.D
10	K-Mixed	Aug. 2001	N.D
11	K-Mixed	Sept. 2001	2.02
12	K-Mixed	Oct. 2001	N.D
13	Control K-1		N.D
14	Control K-2		1.28
15	Control K-3		N.D

N.D. = Not detectable

Table 4. PCB Concentrations in Sediment Samples, from Abu-Hamour Pond (H), Doha – Qatar.

Sr. No.	Sample Code and Location	Period of Sampling	PCB Concentrations, ppm (dry weight)
1	H-Mixed	Nov. 2000	N.D
2	H-Mixed	Dec. 2000	0.31
3	H-Mixed	Jan. 2001	N.D
4	H2	Jan. 2001	N.D
5	H-Mixed	Feb. 2001	32.7
6	H2	Feb. 2001	1.78
7	H-Mixed	April 2001	2.87
8	H2	April 2001	N.D
9	H-Mixed	May 2001	N.D
10	H2	May 2001	N.D
11	H-Mixed	June 2001	96.92
12	H2	June 2001	0.88
13	H-Mixed	July 2001	15.05
14	H2	July 2001	5.13
15	H-Mixed	Aug. 2001	44.5
16	H2	Aug. 2001	N.D
17	H-Mixed	Sept. 2001	4.92
18	H2	Sept. 2001	N.D
19	H-Mixed	Oct. 2001	135.65
20	H2	Oct. 2001	N.D
21	Control H-1		1.39
22	Control H-2		2.80
23	Control H-3		N.D

N.D. = Not detectable

Table 5. Total Organic Carbon in Wastewater Samples (µg/L).

Sample ID	Abu-Nakhla (K)	Abu-Hamour (H)	H-2
NOV. 2000	1.10	2.50	5.6
DEC. 2000	0.90	0.90	8.9
JAN. 2001	1.30	3.78	4.7
FEB. 2001	2.90	5.60	11.3
MAR. 2001	3.20	6.30	15.3
APR. 2001	3.90	7.50	26.0
MAY 2001	5.00	22.4	24.8
JUN. 2001	2.70	70.80	10.0
JUL.2001	4.0	30.40	11.6
AUG.2001	3.50	20.90	131.3
SEP. 2001	2.80	19.30	95.9
OCT. 2001	0.40	4.90	44.0
Average ± Standard Dev.	2.64±1.42	16.27±19.63	32.45±40.17

Table 6. Total Organic Matter in Sediment Samples (%).

Sample ID	Abu-Nakhla (K)	Abu-Hamour (H)	H-2
NOV. 2000	0.02	0.45	18.7
DEC. 2000	0.03	0.78	21.9
JAN. 2001	0.05	0.55	26.7
FEB. 2001	0.08	0.69	24.1
MAR. 2001	0.03	1.65	22.3
APR. 2001	0.08	3.00	20.9
MAY 2001	0.03	3.00	24.1
JUN. 2001	0.03	2.08	19.6
JUL.2001	0.03	2.91	21.9
AUG.2001	0.03	1.97	29.0
SEP. 2001	0.03	0.99	12.1
OCT. 2001	0.02	0.33	31.1
Average ± Standard Dev.	0.038± 0.020	1.533±1.038	22.7±4.98

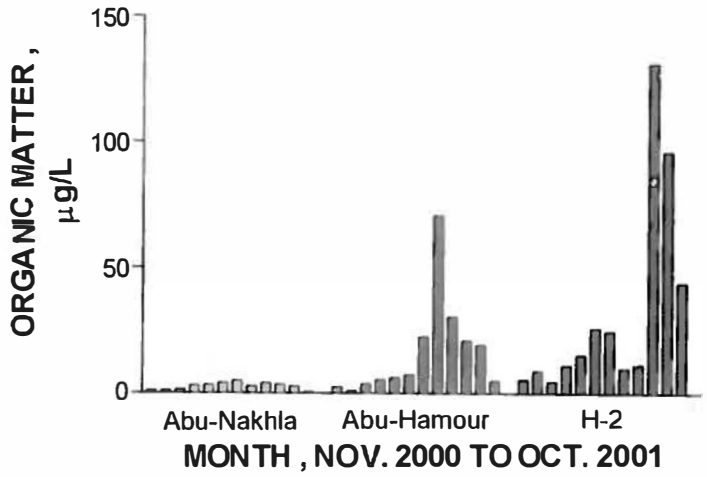

Figure 2. Total organic matter in wastewater samples (µg/L).

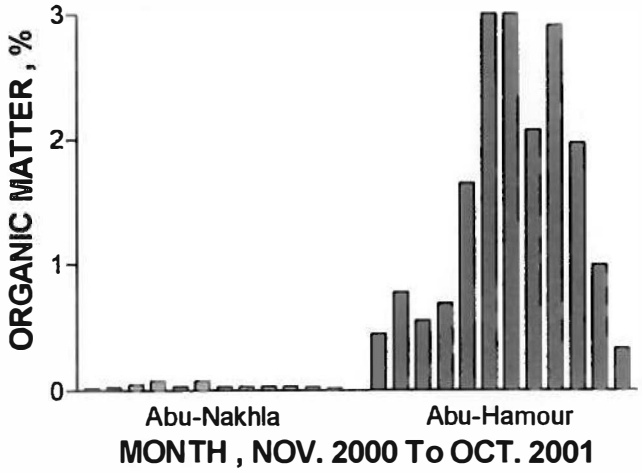

Figure 3. Total organic matter in sediment samples (%).

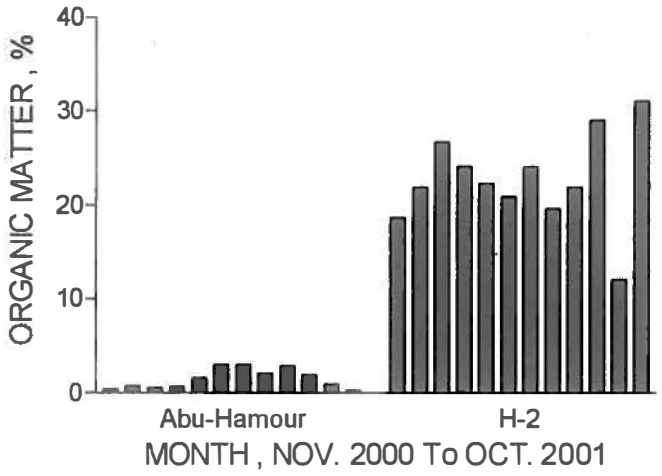

Figure 4. Total organic carbon in sediment samples (%).

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مركبات ثنائية حلقة البنزين عديدة الكلور، والمواد العضوية:

تصنف مركبات ثنائية حلقة البنزين عديدة ذرات الكلور(PCB) على أنها مركبات كيميائية شديدة الثبات بسبب تركيبها الكيميائي الذي يجعل تحللها في الظروف البيئية الطبيعية من الصعوبة بمكان مما دفع الباحثين على اعتبارها من الملوثات الرئيسة التي يجب مراقبتها و تتبعها في البيئات المائية. كذلك وبالمثل يكون للمواد العضوية (TOM) التي ترتبط بهذه المركبات و تنقلها أهمية خاصة عند إجراء أية دراسات مسحية للملوثات في البيئة المائية.

اشتملت الدراسة على جمع و تحليل العينات من الماء و التربة، وتحليل وتفسير البيانات الخاصة بنسب الملوثات من PCB والمواد العضوية. وأشارت نتائج الدراسة إلى وجود تلوث بسيط متراكم في مياه وتربة بركة أبو هامور من مركبات عديدة الكلور (PCB) والمواد العضوية (TOM). وبالمقارنة فان بركة أبو نخلة قد وجدت خالية من أي تلوث بالمواد العضوية. والسبب قد يعود إلى أن بركة أبو نخلة تستقبل مياه مجاري معالجة على عكس بركة أبو هامور التي تستقبل مياه مجاري غير معالجة.

وكخلاصة عامة للدراسات المتنوعة التي تضمها مشروع البحث فيمكن القول بأن بركة أبو نخلة، والتي تتلقى مياه عادمة معالجة، هي بيئة ذات ملوثات كيميائية وميكروبية منخفضة إلى مستوى كبير، وهذا ما ساعد في نمو أنواع مختلفة من النباتات والحيوانات البرية فيها. وعلى العكس من ذلك فان ارتفاع نسبة الملوثات الكيميائية والميكروبية في بركة أبو هامور، والتي تستقبل مياه عادمة غير معالجة، أدى إلى انخفاض كبير في تنوع وكثافة النباتات والحيوانات البرية. وعليه يمكن اعتبار مياه أبو هامور ذات خطر شديد على الصحة العامة، ونقترح على الجهات المعنية بهذا الأمر منع صب المياه الملوثة في هذا الموقع، ومحاولة البحث عن طريقة مناسبة لمعالجة هذه المياه.

ومن جانب آخر فإننا ندعو إلى إنشاء قاعدة بيانات لمستويات هذه المكونات الكيميائية والبيولوجية في هذه البرك، ومحاولة رصدها من وقت لآخر، ضمن استراتيجية مسحية عامة لدراسة الملوثات وعلاقتها بالكائنات الحية، وذلك في سبيل المحافظة على البيئة وعلى المصادر الطبيعية في دولة قطر.

الحيوانات اللافقاريات:

تبين من الدراسة أن طبيعة القاع في البركتين متشابهة من حيث مكونات التربة، إلا أن كثافة تواجد اللافقاريات كانت مختلفة. رصدت في تربة القاع في المياه الضحلة الساحلية سبع شعب حيوانية و هي الديدان المفلطحة، الديدان الخيطية، شوكيات البطن، الدوامات، الديدان الحلقية، الرخويات، ومفصليات الأرجل. وعموما كانت بركة أبو نخلة ذات المياه المعالجة أغنى باللافقاريات من بركة أبو هامور ذات المياه غير المعالجة. وكانت نسب تواجد الديدان الخيطية لمجدافية الأقدام غير ثابتة خلال اشهر السنة وذلك بسبب اختلاف منسوب المياه المتكرر في البركتين.

تقييم أولي لمجتمع الفقاريات:

لقد لوحظ أثناء إجراء دراسة بينية مستفيضة لبرك مياه الصرف الصحي المعالجة وغير المعالجة وجود تنوع ملحوظ من أنواع متعددة من الحيوانات الفقارية. حيث تكثر اسماك البلطي في بركة أبو نخلة. وسجل أيضا من البرمائيات الضفدعة الخضراء في بركة أبو نخلة، في حين لم تلاحظ أبدا في بركة أبو هامور. ومن الزواحف كان الضب هو الأكثر تواجدا حول البركتين على مدى فترة الدراسة. كذلك برص الصخور والبرص الدرعي. ومن الزواحف أيضا النفيخى، السحلية مهدبة الأصابع والسحلية قصيرة الخطم. ومن الثعابين هناك ثعبان الفئران الشهير. أما الفقاريات الأكثر تواجدا فقد كانت الطيور بمختلف أنواعها، فمنها المقيم في البرك ويتكاثر فيها مثل طائر البلشون الرمادي، وطائر النحام الكبير، والجريب الصغير، و دجاج الماء. ومنها ما هو زائر مثل النورس الصلال، والنورس مستدق المنقار، ويمام النخيل، والقنبرة المتوجة، والعصفور الدوري، وطائر المستنقعات الطيطوي الصغير. ومن الطيور المارة في طريق هجرتها ببرك المستنقعات وخاصة في فصل الشتاء والتي رصدت في بركتي أبو هامور وأبو نخلة الصرد الرمادي الكبير، والقطقاط الصغير، وغريزة المستنقعات، واللموزية مخططة الذيل، والخرشنة القزويني، وطائر أبو ساق-أسود الجناحين. أما الحيوانات الثديية التي شوهدت فهي ما يرد بركة أبو نخلة للشرب والمرعى مثل الجمال، والأغنام، والماعز، وبعض القوارض خاصة جرذ جربل وجرذ شيزمان، بالإضافة إلى ما هو متوقع من الأرانب الصحراوية وفأر الجربوع.

العناصر المعدنية الشحيحة:

تم تقدير كميات العناصر الشحيحة في بركتي المياه العادمة في منطقتي أبو هامور وأبو نخلة وذلك بتحليل عينات مائية و عينات رواسب. وبينت دراسة الرواسب أن ترتيب معدل التركيز المتاح للعناصر الشحيحة هو على النحو التالي Ni<Pb<Cr<Cu<Mn . وكما بينت الدراسة أن محتوى الكادميوم والزنبق في العينات المائية والرواسب أقل من حد الكشف. وأظهرت دراسة الرواسب أن تركيز عناصر النحاس والنيكل والمنغنيز لا تختلف عن نظيراتها في عينات التربة التي أخذت من مواقع تبعد حوالي 1.5 إلى 3 كيلومتر عن حدود البركتين. أما بالنسبة لعنصري الكروم والرصاص فان تركيزهما في رواسب كلا الموقعين يفوق تركيزهما في عينات التربة التي جمعت من مواقع بعيدة عن هاتين البركتين. أما بالنسبة للمياه العادمة فان تركيز العناصر أعلاه تقل كثيرا عن الحدود العليا المسموح بها لإعادة استخدامها للري الزراعي، كما أنها تقل عن الحدود العليا لمنظمة الصحة العالمية للمياه الصالحة للشرب.

بعض الطحالب اختارت مواقع محددة في هذه البرك دون سواها، فمثلا الطحلب *Spirulina* يوجد بوفرة في الجزء الغربي من بركة ابو هامور في مياه بعيدة عن المصب، حيث الارتفاع الشديد في نسبة الملوحة. كذلك تكثر النباتات الملحية العصارية على الشواطئ الملحية المجاورة لهذا الموقع.

ومن الملاحظات الجديرة بالذكر زيادة الرغوة الخضراء على سطوح المياه في فصل الصيف، حين تكون درجات الحرارة مرتفعة. و من الأنواع الرئيسية التي لها القدرة على تكوين هذه الرغوة الخضراء ما يلي:

Anabaena, Anacystis, Clorella Spirogyra and *Spirulina.*

وعند إجراء مقارنة عامة بين هاتين البركتين نلاحظ ما يلي: أنواع النباتات المائية كثيرة في أبو نخلة، و أنواع الطحالب متباينة بين هاتين البركتين. و التغير الموسمي واضحا في تعاقب النباتات الزهرية والطحالب في المياه الضحلة، و الشواطئ الرطبة. كذلك ارتفاع ملوحة الماء ومجموع المواد الصلبة الذائبة في مياه أبو هامور.

<u>بكتيريا القولون:</u>

تبين من هذه الدراسة أن المياه الساحلية لبركة أبو هامور تكثر فيها بكتيريا القولون *Escherichia coli* والفطريات، في حين تكون قليلة نسبيا في بركة أبو نخلة. وتوجد بكتريا القولون بكثرة في الماء قرب الشواطئ طوال العام وفي جميع أطراف البركتين، وتوجد نفس هذه البكتريا بكثرة في التربة الرطبة قرب مصبات المياه وتقل أو تنعدم في التربة الرطبة البعيدة عن مناطق المصبات. وتبين كذلك من الدراسة وجود البكتيريا التالية و بكثرة في المياه الساحلية في أبو هامور و قليلة في أبو نخلة:

Aeromonas hydrophilia, Pseudomonas aeruginosa, Klebsiella pneumoniae and *Chromobacterium violaceum.*

وبينت الدراسة أيضا أن تواجد الأنواع التالية من البكتيريا في التربة الرطبة المحيطة ببركة أبو هامور أعلى من تلك الموجودة حول بركة أبو نخلة:

Streptomyces sp., Bacillus sp. and *Macrococcus sp.*

<u>تقييم أولي للطفيليات:</u>

بينت الدراسة أن بركة أبو هامور تحتوى على معدلات عالية من التلوث الطفيلي. ففي العينات التي جمعت مباشرة من بعض الشاحنات التي تحتوى على مياه مجارى عثر على بويضات الأسكارس، أما العينات التي جمعت من مكان صب المياه والتي تختلط فيها مياه الشاحنات بمياه البركة فلم نعثر على أية مراحل طفيلية. كذلك، فبركة أبو نخله التي تحتوي على مياه الصرف الصحي المعالجة لم يظهر في مياه المصب أية مراحل طفيلية.

تم أيضا فحص بعض أثار البراز الخاصة ببعض الحيوانات الزائرة مثل الجمال والأغنام والماعز والمقيمة مثل طيور البلشون الرمادية, وأسفر التحليل عن وجود بويضات خيطيات من نوع *Trichostrongylus* من براز الجمال ونوع تابع لخيطيات المرى في الطيور هو *Capillaria* . أما براز الأغنام والماعز وخاصة الطرية منها فقد أعطت بويضات *Fasciola hepatica* . وقد خضعت أيضا بعض الحيوانات الزائرة والمقيمة مثل الضب والضفادع للفحص الطفيلي، وأسفر الفحص عن وجود نوعين من الطفيليات الخيطية تشمل خيطيات المستقيم *Thelandros sp.* وخيطيات الرئة *Rhabdias bufonis* .

ملخص الدراسة

أجريت دراسة بيئية شاملة على مدى اثنا عشر شهرا، من أكتوبر2001 إلى أكتوبر 2002، لإثنين من أكبر برك مياه الصرف الصحي في قطر، والواقعتين في الجنوب الغربي من مدينة الدوحة، وهما بركة أبو نخلة (ذات مياه صرف صحي معالجة) وبركة أبو هامور (ذات مياه صرف صحي غير معالجة). وتم في هاتين البركتين تقييم النباتات الزهرية، الطحالب، بكتيريا القولون، الطفيليات، الحيوانات اللافقارية، الحيوانات الفقارية، العناصر المعدنية الشحيحة، مركبات ثنائية حلقة البنزين عديدة الكلور، والمواد العضوية. وملخص الدراسة على النحو التالي:

السنة النباتية:

أظهرت دراسة البيئة النباتية اختلافات في أنواع النباتات الزهرية والطحالب بين بركة أبو نخلة وبركة أبو هامور. وتبين من دراسة الغطاء النباتي لهذه البرك وجود نطاقات محددة تتمثل فيما يلي: نطاق المياه العميقة، ونطاق المياه الضحلة، ونطاق الأرض الرطبة، ونطاق الأرض الجافة المحيطة بهذه البرك. يحتوي نطاق المياه العميقة فقط على القليل من الدياتومات، ويحتوي نطاق المياه الضحلة على الطحالب ونباتات القصب والحشائش المائية، والنطاق الرطب يحتوي على الأعشاب والنباتات العصارية والقليل من الشجيرات. أما الأراضي الجافة المحيطة بهذه البرك فتحتوي على القليل من النباتات العصارية الصغيرة المعمرة والشجيرات الشوكية.

ومن بين أهم النباتات الزهرية التي تعيش في المياه الضحلة و بغزارة ما يلي:
Phragmites australis, Typha domingensis, Sporobolus spicatus, Tamarix ramossissima, Rumex dentatus, Juncus rigidus and a submerged species.

وأهم الطحالب التي تعيش في المياه الضحلة ما يلي:
Anabaena, Anacystis, Chlorella, Diatoms, Euglena, Oscillatoria, Spirogyra and *Spirulina.*

يضاف إليها الطحالب التي تنمو بأعداد قليلة وفي فترات متقطعة من السنة، أمثال:
Chlorogonium, Lyngbya, Oedogonium, Scenedesmus and *Zygnema.*

وعلى الشواطئ الرطبة لهذه البرك يوجد العديد من النباتات الحولية، والنجيلية، والنباتات المعمرة العصارية الصغيرة، ونوع واحد من الشجيرات، كما في القائمة التالية:
Aeluropus lagopoides, Aizoon canariense, Amaranthus viridus, Anabasis setifera, Arnebia hispidissima, Chloris virgata, Cressa critica, Cymbopogon purkeri, Cynodon dactylon, Euphorbia granulata, Fagonia sp., Herniaria hemistemon, Lasiurus hirsutus, Launa nudicaulis, Malva parviflora, Polypogon monospliensis, Portulaca oleracea, Pulicaria crispa, Salsola baryosma, Solanum elaengifolium, Spergula fallax, Stipagrostis plumosa, Suada aegyptiaca, Suada vermiculata, Tamarix ramossissima, Tribulus terrestris, Urospermum picroides, Zygophyllum qatarense and *Zygophyllum simplex.*

وتحتوي المياه الضحلة على الكثير من الطحالب الخضراء المزرقة أمثال:
Anabaena, Anacystis, Lyngbya, Oscillatoria and *Spirulina*

والتي تعتبر دليلا قاطعا على ارتفاع نسبة تلوث هذه المياه بالعناصر المعدنية والمواد العضوية. احتوت هذه المياه كذلك على الكثير من الطحالب الخضراء إضافة إلى الديوتومات واليوغلينا والهدبيات والديدان. انبعاث الروائح الكريهة من بركة أبو هامور لدليل على كثرة الكائنات الدقيقة ذات التنفس اللاهوائي.

بسم الله الرحمن الرحيم

بيئة بركة مياه الصرف الصحي في قطر

أ. د. حسين علي أبوالفتح
د. روضة فهد آل ثاني
أ. د. إبراهيم صالح النعيمي
د. جمال أمين صويلح
د. الحاج أبو جبر الحاج
د. محمود محمد كردوشة

كلية العلوم، جامعة قطر، ص ب 2713، الدوحة، قطر