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Ecotoxicological Studies. 6. The first comparative study between Lake Qarun and Wadi El-Rayan wetland (Egypt), with respect to contamination of their major components

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Abstract

Water, sediment and fish samples collected from Lake Qarun and Wadi El-Rayan lakes (Egypt) were subjected to different analyses in order to compare contamination levels in these ecosystems. The waters showed similar ionic characteristics, but those from Lake Qarun contained total dissolved salts (TDS) ranging from ca. 4.0 to 35.0 g/l with an average of 19.0 g/l which was much higher than those recorded for the first and the second lakes of Wadi El-Rayan (e.g. 1.6 and 4.7 g/l, respectively). The bacterial count was also greater in the water and sediment from Lake Qarun. Heavy metals (e.g. iron, manganese, zinc, nickel, copper, cobalt, chromium, lead, cadmium, tin) and pesticide residues (e.g. HCB, lindane, aldrin, some DDT analogues, malathion, pirimiphos-methyl) were detected in the major components of Lake Qarun. Some of these contaminants were also detected in different samples from Wadi El-Rayan, but at lower concentrations. The toxicity bioassay of Wadi El-Rayan water against *Daphnia magna* neonates and *Culex pipiens* larvae resulted in negligible mortality values. Lake Qarun water induced 8.0–100.0 and 3.0–100.0% mortality, respectively against the tested organisms. The overall results of this study revealed that Lake Qarun components were more polluted than those of Wadi El-Rayan lakes, and the second lake of this wetland was more contaminated than the first. Therefore, solutions have to be found; otherwise this virgin wetland will face pollution problems similar to those of Lake Qarun.

1. Introduction

Lake Qarun, which is one of the large lakes of Egypt, is a remnant of a much bigger one, "the historic Lake Moreis", and was originally a fresh water lake. It is a closed basin used as a general reservoir for agricultural wastewater drainage of Fayoum Province. Most of this discharge is brought to the lake via the so called Bats and Wadi Drains.

As a result of increasing land reclamation in Fayoum Province over the past decade, it was necessary to find another reservoir to receive quantities of agricultural wastewater drainage exceeding the capacity of the lake. This was achieved by transferring the surplus drainage to Wadi El -Rayan Depression, where two man-made lakes were created at two different levels. The first lake has nearly half the area of the second lake, and they are joined by a connecting channel (Zahran, 1973). The first lake of Wadi El-Rayan receives frequent effluent of wastewater from the Wadi Drain. The surplus water from this lake floods to the second one via the shallow connecting channel (El-Shabrawy, 1999).

As a result of extensive evaporation of water from such closed ecosystems, the gradual increase of salts, heavy metals, pesticides and other pollutants is expected to change their quality and affect their aquatic life. For this reason, a number of investigations have dealt with the water chemistry of lake Qarun (Abdel-Moniem, 1991; Bishai & Kirollus, 1980; FWMP, 1999; Mansour, Messeha, & Sidky, 2000; Naguib, 1958). Studies of similar nature on the lakes of Wadi El-Rayan are yet rare and limited (El-Shabrawy, 1999). Moreover, there is no information to enable us to make valid comparisons between an old ecosystem, such as Lake Qarun, and a virgin one, such as Wadi El-Rayan Lakes; with respect to contamination of their major components.

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The present study, never previously attempted, was undertaken to provide comparable data about the contamination potential in these particular wetlands.

2. Material and methods

2.1. The studied ecosystems: description (Fig. 1)

The studied ecosystems are represented by Lake Qarun and the two Lakes of Wadi El-Rayan (1st and 2nd Lakes). They are located in the western desert of Egypt (approx. 85 and 125 km to the southwest of Cairo, respectively).

Lake Qarun is a remnant of a much bigger one, which was originally a freshwater lake. It occupies the lowest pit of the Fayoum depression and lies between 30° 34′ and 30° 49′ E longitude and 29° 25′ and 29° 34′ N latitude at 44 m below the sea level. The lake covers, as a whole, an area of about 226 km^2, with an average depth of 4 m. It is a closed basin used as a general reservoir for the agricultural drainage water of Fayoum Province (Naguib, 1958). According to recent studies (Mansour et al., 2000), the lake receives annually about 470 million cubic metres of drainage water through 12 drains of which "Bats" and "Wadi" drains carry most of the water brought to the lake. The minor drains were recently connected with a larger channel, namely Dayer El-Birka drain, which transfers a lot of wastewater to the lake by pumping.

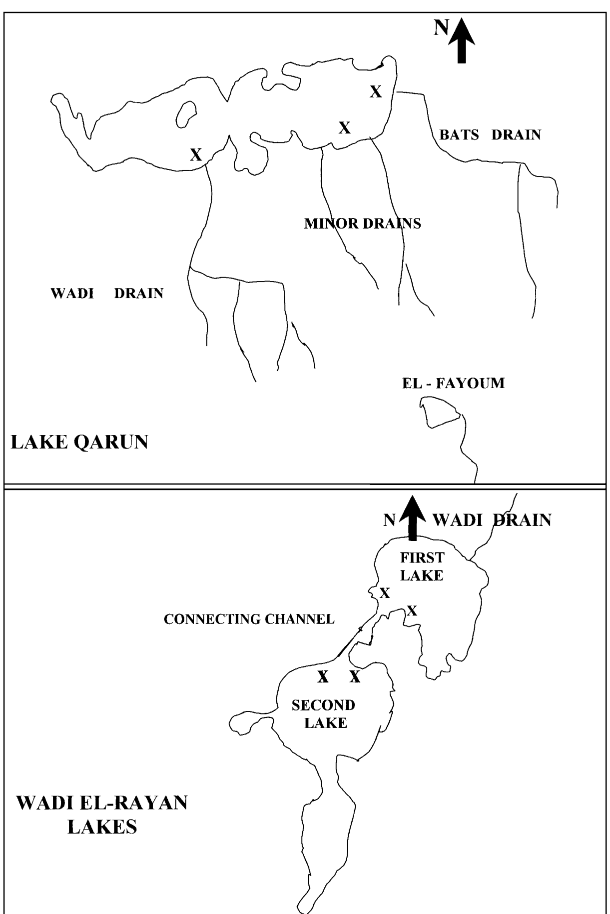

Fig. 1. Key map of the studied ecosystems. X: The major sampling locations.

Wadi El-Rayan is a great depression (703 km^2) situated in the Western Desert, 40 km southwest of Fayoum Province. Since 1973, the depression has been used as a water reservoir for agricultural drainage water exceeding the capacity of Lake Qarun. Two man-made lakes (i.e. First and Second Lakes), joined by a connecting channel, were created at two different levels (Fig. 1). The first Lake covers an area of about 53 km^2 at 10 m below the sea level, while the second Lake is larger than the first one (110 km^2 at 18 m below the sea level). The surplus water from the first lake floods to the second lake via the shallow connecting channel (Zahran, 1973). About 200 million cubic metres of agricultural drainage water are transported annually, via Wadi Drain, to Wadi El-Rayan lakes (El-Shabrawy, 1999).

2.2. Sampling locations

Three locations in Lake Qarun, and two in each of the first and the second lakes of Wadi El-Rayan were selected as major stations for sampling purposes. The stations in Lake Qarun were chosen to represent the mouth outlets of Wadi, Bats and minor drains. Those of Wadi El-Rayan Lakes were near the opening of the connecting channel into the first and the second lakes (Fig. 1).

2.3. Sampling procedures

During the period October 1998–April 1999, samples of water, sediment and fish were taken from the studied ecosystems. A total number of 12 water and 12 sediment samples were collected from each specified station. Fish samples (e.g. *Tilapia* sp. and *Mugil* sp.) were obtained twice from Lake Qarun and the first lake of Wadi El-Rayan.

A water sampler of 2-l capacity was used to collect surface water (e.g. 0–15 cm depth) from the different locations, while sediment samples were taken by hand (0–20 cm depth). Also, glass bottles (250 ml) were completely filled and covered under the water surface for determination of dissolved oxygen (DO) concentration. Fresh fish samples were purchased from the authorized catching centres located at lake Qarun and Wadi El-Rayan first lake. The different kinds of samples were transferred quickly, in ice boxes, to the laboratory.

2.4. Physicochemical analysis of water

The water samples collected from different locations in the studied ecosystems were subjected to a number of physicochemical analyses as mentioned later.

For on-site sampling, the pH was measured by means of a pocket-pH meter (Micro Checkit® pH+ , Lovibond, England).

Dissolved oxygen (DO) concentration was determined titrimetrically according to the modified Winkler, full-bottle technique (Method 360.2; EPA, 1983).

Carbonate (CO_3^{--}) and bicarbonate (HCO_3^-) ions were determined titrimetrically against 0.1 N–HCl, using phenolphthalein and bromo-phenol indicators, respectively. Chlorides (Cl^-) were titrated against (0.1 N $AgNO_3$, using potassium chromate indicator (Vogel, 1961).

Sulphates (SO_4^{--}) were determined gravimetrically as barium sulphate in a hydrochloric acid medium by the addition of barium chloride (Method 375.3; EPA, 1983).

Calcium (Ca^{++}) ion concentration was determined by using the EPA method 215.2 (EPA, 1983), while magnesium (Mg^{++}) ion concentration was measured according to Vogel (1961).

For each analysed water sample, the reported amounts of different ions were used to estimate the expected salts hypothetically and the residual amount of sulfate ions. The latter were used to calculate the concentration of sodium ions (Mansour et al., 2000).

The total dissolved salts (TDS) were determined gravimetrically at 105–110 °C (Method 160.3; EPA, 1983).

2.5. Determination of heavy metals

Concentrations of some heavy metals were determined in water, sediment and fish samples. The samples analysed were prepared by the methods of the Association of Official Analytical Chemists (1995). Fish samples were prepared as edible (flesh or muscles) and non-edible (head + viscera) parts prior to analyses.

Stock standard solutions of zinc (Zn), iron (Fe), manganese (Mn), copper (Cu), cadmium (Cd), chromium (Cr), nickel (Ni), lead (Pb), Cobalt (Co), and tin (Sn), were obtained from Merck in concentrations of 1000 mg / l (Merck, Darmstadt, Germany).

A Perkin-Elmer (2380) atomic absorption spectrophotometer was employed for the analyses. The maximum absorbance was obtained by adjusting the cathode lamps at specific slits and wavelengths as shown in Table 1. Under practical analytical conditions, it is possible to detect concentrations as low as 0.1 ppb from Cd, Zn, Ni, Mn and Sn, and 0.5 ppb from the other measured metals.

2.6. Determination of pesticide residues

The different samples (e.g. water, sediment, fish) collected from the studied ecosystems were subjected to pesticide residue analyses to identify and determine concentration of the characterized pesticides. The samples analysed were extracted and prepared according to the methods of the Association of Official Analytical Chemists (1995). In fish analysis, edible and non-edible parts were separated and processed individually.

Table 1
Wavelengths and slit widths for determination of heavy metals

Metal	Wavelength (nm)	Slit width (nm)
Zinc (Zn)	319.9	0.7
Ferrous iron (Fe)	248.3	0.2
Manganese (Mn)	279.5	0.2
Copper (Cu)	324.8	0.7
Cadmium (Cd)	228.8	0.7
Chromium (Cr)	425.4	0.2
Nickel (Ni)	232.0	0.2
Lead (Pb)	217.0	0.7
Cobalt (Co)	240.7	0.2
Tin (Sn)	286.3	0.7

A mixture of pesticide standards containing hexachlorobenzene (HCB), lindane, aldrin, heptachlor, heptachlor epoxide, dieldrin, endrin, dichloro diphenyl trichloroethane (p, p'-DDT), p, p'-DDT analogues (e.g. *o*, p'-DDT, *o*, p'-DDE, *p*, p'-DDE, *o*, p'-DDD, *p*, p'-DDD), malathion , parathion, methyl parathion, dimethoate, pirimiphos-methyl, profenofos, and diazinon, were provided by the Environmental Protection Agency (EPA).

Aliquots of 1-2 µl of final extracts were injected into a Hewlett-Packard gas chromatograph model 5890 II, equipped with ^{63}Ni electron capture detector (ECD) and HP 5970 mass selective detector, fitted with HP-1 capillary column (cross-linked methyl silicon gum; 30 m×0.25 mm×0.25 µm film thickness).

The column oven temperature was programmed from 80 to 160 °C at a rate of 3 °C/min., held 2 min, increased to 220 °C at a rate of 5 °C/min, and then held for 20 min. Injection and detector temperatures were, respectively, adjusted at 220 and 300 °C.

Compounds were identified by comparing their retention times (RT) with those of authentic standards , and the residues were quantitated by means of a HP 3395 computing integrator coupled to the GC, based on the peak areas given.

Under the earlier mentioned conditions, the detection limit for quantitation of chlorinated hydrocarbon pesticides (e.g. BHC, lindane, aldrin, heptachlor, DDT isomers) is approximately 0.01 ppb, and 0.10 ppb for the organophosphorus pesticides (e.g. malathion, pirimiphos-methyl, profenofos).

2.7. Microbiological examination and counting

In the course of the present study, the Official Microbiological Method of the American Spice Trade Association (1976) was used to detect and enumerate some microbial organisms, either in water or sediment samples collected from the studied ecosystems.

The standard plate count (SPC) technique was used to determine total bacterial spores (aerobic and anaerobic mesophiles and thermophiles) and sporformer (thermophilic) bacteria (M—2.1 of ASTA Methods).

Determinations of *Coliform, Escherichia coli* (M—3.2 of ASTA Methods), *Staphylococci* (M—7.1 of ASTA Methods), and *Salmonella* (M—8.0 of ASTA Methods) were performed according to the most probable number (MPN) techniques (ASTA, 1976).

Aliquots of the tested water (10 ml each) were buffered to pH 7.0 (using phosphate buffer; APHA, 1992); then decimal dilutions were prepared (at least three dilutions, depending on the expected bacterial load of the sample examined). After inoculation with the proper media and incubation according to the specified period, the number of spores (colonies) per unit (1 ml or 1 g sample) was then determined by multiplying number of colonies in each plate by the corresponding dilution factor (when using the SPC technique). When using the MPN technique, the spore count values were obtained from the "MPN Tables" (ASTA, 1976).

For sediment, the sample (25 g) was blended with 225 ml phosphate buffer solution (APHA, 1992) at 15,000–20,000 rpm for 2.30 min. Decimal dilutions of the slurry were prepared and subjected to evaluation, as previously mentioned for water samples.

In this respect, the microbial contamination was considered not detectable if any examined sample appeared to be free of one bacterial colony.

2.8. Water toxicity bioassay

The water samples collected from the different locations were subjected to toxicity bioassay, using two different invertebrate organisms (e.g. the water flea, *Daphnia magna* Straus and the mosquito, *Culex pipiens* L.) as test organisms.

Laboratory cultures of both organisms were used to provide neonates (0–24 h old) of *D. magna,* and 1st-instar larvae of *C. pipiens* (1–2 days old) required for this study. These organisms were, respectively, reared and maintained according to Mansour, Hassan, and Sidky (1992) and Gayar and Shazli (1968). The bioassay was carried out as described later.

In 250-ml glass beakers, each containing 100 ml of the water to be tested, 10 neonates of *D. magna* or 10 larvae of *C. pipiens* were placed. Each test was run in three beakers (replicates) along with three others containing deionized water (control). The beakers were maintained at room conditions (20±2 °C; 70±5% R.H.), and examined after a 24-h exposure period. The number of killed animals (i.e. immobilized) was recorded and mortality percentages were computed according to Abbott's formula (Abbott, 1925).

3. Results and discussion

3.1. Water ionic characteristics

The water from the different studied lakes proved to be slightly alkaline with an average pH of ca. 8.0 (Table 2). Dissolved oxygen concentration showed an average of 11.1 mg/l in the water sampled from the 1st lake of Wadi El-Rayan, which was slightly higher than those found in the water from Lake Qarun and 2nd lake of Wadi El-Rayan (ca. 10.0 mg/l). Carbonate anions (CO_3^{--}) were detected at concentrations lower than bicarbonates (HCO_3^-). Sulphate, chloride, calcium, magnesium and sodium ions were found in Lake Qarun water at very high concentrations compared with those found in the lakes of Wadi El-Rayan. The 2nd lake contained such ions at concentrations higher than those recorded for the 1st lake. The TDS ranged from 3.60 to 35.40 g/l with an average of 18.80 g/l in Lake Qarun water. Corresponding values for the first and second lakes of Wadi El-Rayan were found to be 1.52–1.70 g/l (Av.=1.61 g/l) and 4.60–4.70 g/l (Av.=4.65 g/l), respectively (Table 2).

3.2. Heavy metals in different components

The water from Lake Qarun appeared to have detectable concentrations of iron, manganese, copper, and chromium. On average, the concentrations of these metals were 0.46, 0.29, 0.24, and 0.36 ppm, respectively (Table 3). The other analysed metals (e.g. zinc, cadmium, nickel, lead, cobalt) were detected at very low concentrations. The water from the two lakes of Wadi El-Rayan had undetectable concentrations of Ni, Pb, Co, and Sn, and low concentrations of the other measured metals. Total heavy metal concentrations in the water of Lake Qarun was 1.42 ppm, corresponding to 0.38 and 0.29 ppm, respectively, for the first and the second lakes of Wadi El-Rayan (Table 3).

Table 4 shows that the sediment from the studied lakes had considerable concentrations of certain metals (e.g. Fe, Mn, Ni, Zn, Cu, Cr, Co). For example, iron concentration in Lake Qarun sediment ranged from ca. 336–1241 ppm, with an average of ca. 815 ppm. These values were ca. 22–61 ppm (Av.=ca. 43 ppm) for the first lake of Wadi El-Rayan, and ca. 395–699 ppm (Av.=ca. 507 ppm) for the second lake of Wadi El-Rayan. Total heavy metal concentration in sediment of Lake Qarun was the highest (ca. 1142 ppm), followed by the 2nd lake of Wadi El-Rayan (ca. 561 ppm), and finally the 1st lake (ca. 68 ppm).

The concentrations of heavy metals in fish samples taken from Lake Qarun and the first lake of Wadi El-Rayan are shown in Table 5. The results indicate that all fish species have undetectable concentrations of cobalt and tin. Moreover, the fish from Wadi El-Rayan

Table 2
Some physicochemical characteristics of water from the studied ecosystems

Parameter	Unit	Lake Qarun		Rayan 1st lake		Rayan 2nd lake	
		Range	Mean±S.E.	Range	Mean±S.E.	Range	Mean±S.E.
pH	–	7.3–8.3	7.9±0.18	7.6–8.1	7.9±0.12	7.7–8.1	7.9±0.10
DO	mg/l	8.0–13.6	10.0±0.80	9.1–13.5	11.1±1.03	8.3–10.8	9.9±0.56
CO_3^{--}	g/l	0.0–0.03	0.02±0.005	0.006–0.012	0.01±0.001	0.006–0.024	0.01±0.003
$H\ CO_3^-$	g/l	0.26–0.35	0.29±0.01	0.22–0.24	0.23±0.01	0.23–0.26	0.25±0.01
SO_4^{--}	g/l	0.88–9.22	5.02±1.63	0.35–0.38	0.37±0.01	1.02–1.20	1.08±0.03
Cl^-	g/l	1.19–13.18	6.78±2.27	0.40–0.46	0.43±0.02	1.56–1.70	1.62±0.03
Ca^{++}	g/l	0.12–0.50	0.32±0.07	0.052–0.058	0.055±0.001	0.096–0.124	0.108±0.007
Mg^{++}	g/l	0.13–1.25	0.68±0.22	0.060–0.068	0.064±0.001	0.153–0.175	0.165±0.004
Na^+	g/l	0.89–10.14	5.27±1.75	0.34–0.39	0.36±0.01	1.20–1.26	1.24±0.01
TDS	g/l	3.6–35.4	18.8±6.1	1.52–1.70	1.61±0.05	4.60–4.75	4.65±0.03

Table 3
Concentrations of heavy metals (ppm) in water from the studied ecosystems

Metal	Lake Qarun		Rayan 1st lake		Rayan 2nd lake	
	Range	Mean±S.E.	Range	Mean±S.E.	Range	Mean±S.E.
Zn	0.016–0.028	0.02±0.002	0.011–0.022	0.02±0.002	0.006–0.016	0.01±0.002
Fe	0.318–0.661	0.46±0.05	0.102–0.201	0.15±0.02	0.008–0.172	0.08±0.04
Mn	0.07–0.52	0.29±0.09	0.0–0.01	0.004±0.001	0.015–0.023	0.02±0.001
Cu	0.18–0.28	0.24±0.01	0.11–0.13	0.12±0.004	0.05–0.10	0.07±0.008
Cd	0.002–0.05	0.02±0.008	0.001–0.006	0.003±0.001	0.002–0.007	0.004±0.001
Cr	0.211–0.564	0.36±0.06	0.051–0.098	0.08±0.01	0.086–0.133	0.11±0.01
Ni	0.0–0.022	0.01±0.004	ND[a]	–	ND	–
Pb	0.016–0.045	0.02±0.006	ND	–	ND	–
Co	0.0–0.008	0.004±0.001	ND	–	ND	–
Sn	ND	–	ND	–	ND	–
Total of means	1.42		0.38		0.29	

[a] ND, not detectable.

Table 4
Concentrations of heavy metals (ppm) in sediment from the studied ecosystems

Metal	Lake Qarun		Rayan 1st lake		Rayan 2nd lake	
	Range	Mean±S.E.	Range	Mean±S.E.	Range	Mean±S.E.
Zn	6.90–12.4	8.63±0.79	1.88–3.26	2.73±0.31	3.65–7.20	5.35±0.93
Fe	336–1241	814.5±152.5	21.52–61.3	42.9±8.8	394.6–699.0	507±67.3
Mn	117–491	288.0±71.7	5.63–14.11	10.12±2.18	26.60–52.80	394±6.16
Cu	2.75–5.14	4.06±0.37	0.59–1.65	1.11±0.23	1.88–2.08	1.97±0.04
Cd	0.27–0.64	0.45±0.07	0.06–0.12	0.10±0.01	0.02–0.09	0.06±0.02
Cr	1.88–2.86	2.31±0.16	0.91–3.68	2.90±0.35	0.96–2.46	1.78±0.39
Ni	14.7–21.0	17.1±1.41	2.96–3.90	3.30±0.21	1.69–5.19	3.23±0.87
Pb	0.66–0.76	0.70±0.02	0.40–0.51	0.48±0.03	0.11–0.21	0.15±0.02
Co	0.80–5.16	2.88±0.80	2.16–5.24	3.82±0.72	2.13–2.97	2.71±0.20
Sn	1.36–4.62	2.82±0.52	0.0–0.10	0.02±0.01	0.0–0.08	0.02±0.01
Total of means	1142		67.5		561	

appeared to be free of nickel and lead, which were detectable in the fish from Lake Qarun. Generally, the *Mugil* sp. seemed to be more contaminated than the *Tilapia* sp., and both of species from Lake Qarun had metal contaminants at concentration levels higher than those found in the same species from Wadi El-Rayan. Of especial concern, *Mugil* sp. from Lake Qarun contained 0.65 ppm of cadmium, of which 0.41 ppm were found in the muscles (flesh), while *Tilapia* sp. from the same source contained 0.17 ppm of cadmium of which only 0.06 ppm were found in the muscles. The concentration of total heavy metals (calculated on whole body weight basis) reached 42.8 and 63.7 ppm, respectively, for *Tilapia* and *Mugil* species from Lake Qarun. Such

Table 5
Concentrations of heavy metals (ppm) in fish from Lake Qarun and first lake of Wadi El-Rayan[a]

Metal	Lake Qarun						Rayan 1st lake					
	Tilapia sp.			*Mugil* sp.			*Tilapia* sp.			*Mugil* sp.		
	Edible	Non-edible	Total	Edible	Non-edible	Total	Edible	Non-edible	Total	Edible	Non-edible	Total
Zn	2.80	6.00	8.80	4.11	7.32	11.43	3.14	3.73	6.87	3.10	4.66	7.76
Fe	9.18	18.3	27.4	12.1	26.1	38.2	1.50	7.76	9.26	1.99	11.22	13.21
Mn	0.69	2.60	3.29	1.16	3.32	4.48	0.13	1.48	1.61	0.31	4.10	4.41
Cu	0.66	1.25	1.91	2.18	4.00	6.18	0.36	0.97	1.33	0.78	2.07	2.85
Cd	0.06	0.11	0.17	0.41	0.24	0.65	ND[b]	ND	ND	0.02	0.05	0.07
Cr	0.28	0.41	0.69	0.52	0.87	1.39	0.07	0.17	0.24	0.07	0.15	0.22
Ni	0.03	0.12	0.15	0.01	0.02	0.03	ND	ND	ND	ND	ND	ND
Pb	0.09	0.23	0.32	0.55	0.70	1.25	ND	ND	ND	ND	ND	ND
Co	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Sn	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total (ppm)	13.8	29.0	42.8	21.1	42.6	63.7	5.2	14.1	19.3	6.3	22.2	28.5

[a] Each value is an average of four analyses. Edible part means flesh (muscles), and non-edible means head + viscera.
[b] ND, not detectable.

values reached 19.3 and 28.5 ppm, respectively, in the fishes from Wadi El-Rayan (Table 5).

3.3. Pesticide residues in different components

Out of 20 pesticides subjected to identification and determination in water and sediment samples collected from the studied ecosystems, only a few were found in Lake Qarun water (e.g. lindane, aldrin, malathion) at very low concentrations (0.003, 0.008, 0.042 ppm, respectively). Water samples from the two lakes of Wadi El-Rayan showed undetectable concentrations of the analysed pesticides (Table 6).

Sediment samples from Lake Qarun appeared to be more contaminated with pesticide residues than the samples from the lakes of Wadi El-Rayan (Table 6). Pesticidal contamination was mainly attributed to some organochlorine compounds, such as DDT analogues, lindane and aldrin, as well as organophosphorus compounds such as malathion and profenofos.

Fish from Lake Qarun, compared with those from Wadi El-Rayan, contained more and higher concentrations of certain pesticides as shown in Table 7. In both cases, the *Mugil* sp. was more contaminated than the *Tilapia* sp. The pesticidal contamination was mainly attributed to some organochlorine compounds and few organophosphorus ones (e.g. malathion & pirimiphos-methyl). The latter compound, for example, was found at a concentration of 0.806 ppm in *Mugil* sp. from Lake Qarun, corresponding to 0.132 ppm in the same species from Wadi El-Rayan.

Table 6
Detected pesticides and their concentrations (ppm) in water and sediment samples collected from the studied ecosystems

Sample	Lake Qarun	Rayan 1st lake	Rayan 2nd lake
Water	Lindane (0.003); Aldrin (0.008); Malathion (0.042)	None	None
Sediment	Aldrin (0.969); *o*, p′- DDE (0.264); *p,p*′- DDE (0.118); *p,p*′- DDD (0.646); Profenofos (0.013)	Lindane (0.001); Malathion (0.003)	Lindane (0.001); Malathion (0.002)

3.4. Microbial examination and counting

The total bacterial count, conducted on water and sediment samples from Lake Qarun, showed higher numbers of colonies in sediment (46×10^6) than in water (58×10^5). Similar samples from Wadi El-Rayan Lakes

Table 7
Detected pesticides and their concentrations (ppm) in fish from Lake Qarun and first lake of Wadi El-Rayan[a]

Fish species	Lake Qarun	Rayan 1st lake
Tilapia sp.	HCB (0.006); Lindane (0.008); Aldrin (0.004); *o,p*′-DDE (0.03); Malathion (0.006)	*o,p*′-DDD (0.02); *o,p*′- DDE (0.008); Pirimiphos-methyl (0.082)
Mugil sp.	HCB (0.021); Lindane (0.112); *p, p*′ -DDD (0.213); *o,p*′- DDE (0.25); Heptachlor epoxide (0.005); Pirimiphos-methyl (0.806)	*o,p*′- DDD (0.021); *p,p*′- DDD (0.102); *o,p*′- DDE (0.177); Pirimiphos-methyl (0.132)

[a] Out of 20 analysed pesticides, only the detected ones are listed in the table. The values between brackets express the maximum concentrations of the corresponding pesticides, calculated on whole body weight basis.

contained lower numbers, but in this case the water showed higher bacterial counts than the sediment (Table 8).

All the samples examined contained sporformer bacteria but the waters from Wadi El-Rayan lakes seemed to be more contaminated than the water from Lake Qarun. *Coliform* bacteria and *Escherichia coli (E. coli)* counting, respectively, showed 13 and 10 cfu/ml in water, as well as 19 and 13 cfu/g in sediment from Lake Qarun. Only water samples from the 1st lake of Wadi El-Rayan contained small numbers of colonies of these bacteria (e.g. 10 and 5 cfu/ml, respectively). Neither *Salmonella* nor *Staphylococci* bacteria were detected in any of the samples examined (Table 8).

3.5. Water toxicity bioassay

Table 9
Percentage mortality in *Daphnia magna* neonates and *Culex pipiens* larvae after 24 h exposure time to water samples collected from the studied ecosystems

Test organism	% Mortality		
	Lake Qarun[a]	Rayan 1st lake[b]	Rayan 2nd lake[b]
D. magna	8.0–100.0	0.0–3.3	10.8–12.3
C. pipiens	2.6–100.0	0.0–0.0	3.3–6.6

[a] Percentage mortality expresses the range of values obtained from bioassaying water samples collected from three different locations in Lake Qarun (refer to Fig. 1). Specifically, the samples related to the "minor drains" caused the maximum mortality percentages (e.g. 100%).

[b] Percentage mortality expresses the range of values obtained from bioassaying water samples collected from two different locations in each of the two lakes of Wadi El-Rayan (refer to Fig. 1).

The water samples collected from Wadi El-Rayan lakes appeared to be of little or no toxicity to *Daphnia magna* neonates or *Culex pipiens* larvae (Table 9). The Lake Qarun water caused mortality to both organisms, ranging from <10 to 100%. Within this range, the minimum mortality values were usually attributed to water samples collected from the mouth outlets of Wadi and Bats drains, while the maximum mortality values (e.g. 100%) were mostly obtained on bioassaying water samples related to the outlet of minor drains (refer to Fig. 1; Lake Qarun).

To discuss the results of the present study, it may be useful to mention that when a subsurface irrigation drainage water is discharged into a wetland, a variety of serious impacts can occur (Lemly, 1996; Lemly, Finger, & Nelson, 1993; Micklin, 1988; van Schilfgaarde, 1986; Zahm, 1986). Such water is usually characterized by alkaline pH, elevated concentrations of salts, trace elements, and nitrogenous compounds, but low concentrations of pesticides (Fujii, 1988; Neil, 1987). This led Mansour et al. (2000) to conclude that the physicochemical characteristics of the Lake Qarun water are mainly due to the discharges of different drains into the lake. The water from Wadi El-Rayan lakes showed similar properties since these lakes receive the discharges of one of the major drains into Lake Qarun (i.e. Wadi Drain). The mechanism of the drainage water pathway from Wadi Drain to the lakes of Wadi El-Rayan may explain the lower concentrations of ionic salts in the first lake than in the second one (Table 2), while less soluble metals (Table 3) appeared at higher concentrations in the water of the first lake. The second lake is considered as an end point and retained higher concentrations of heavy metals in the sediment, than the first lake (Table 4). In all cases, the water and sediment samples from Lake Qarun showed higher contamination levels.

The occurrence of heavy metals in an ecosystem, such as a lake, is attributed to materials derived from geological sources, although airborne contribution of certain metals cannot be ruled out (Abernathy, Larson, & Mathews, 1984; Borg, 1987). Furthermore, the presence of metals in the environment, generally, may be due to other natural processes such as volcanic activity and erosion, but is mostly the result of industrial and domestic wastes (PNUE, 1984). When heavy metals enter an aquatic ecosystem, such as lakes or rivers, they change the water quality, bind to sediment, especially in hydric soils with a high clay content, and accumulate in the different components, causing adverse effects to the ecosystem and human health depending on their concentrations

Table 8
Microbiological examination of water and sediment samples collected from the studied ecosystems

Location	Counts of bacteria (cfu)[a]						
	Sample	Total bacterial count	*Coliform* bacteria	*E. coli*	*Salmonella*	*Staphylococcus aureus*	Sporformer bacteria
Lake Qarun	Water	58×10^5	13	10	ND[b]	ND	53×10^2
	Sediment	46×10^6	19	13	ND	ND	48×10^3
Rayan 1st lake	Water	80×10^4	10	5	ND	ND	42×10^3
	Sediment	44×10^3	ND	ND	ND	ND	26×10^1
Rayan 2nd lake	Water	81×10^4	ND	ND	ND	ND	46×10^3
	Sediment	10×10^3	ND	ND	ND	ND	30×10^1

[a] Colony forming unit/1 ml of water or unit/1 g of sediment samples.

[b] ND, not detectable.

(Brenner, Yoder, & Blair, 1995; Luckey & Venugopal, 1977). The accumulation of heavy metals in sediment usually occurs at concentrations very much higher than in the water of the same ecosystem (Alikhan, Giuseppe, & Shaheen, 1990; Salanki, Licsko, Laszlo, Balogh, Varanka, & Mastala, 1992).

The fish analyses showed varying contamination levels by heavy metals (Table 5) and pesticide residues (Table 7), and the species sampled from Lake Qarun had higher concentrations than those from Wadi El-Rayan. Specifically, the *Mugil* sp. from Lake Qarun contained 0.65 ppm of cadmium, exceeding the permissible limit proposed by FAO (1983), which is 0.20 ppm. The other measured metals were found below their permissible limits.

The presence of heavy metals in foods constitutes serious health hazards, depending on their concentrations. For example, cadmium injures the kidney and causes symptoms of chronic toxicity, including impaired kidney function, poor reproductive capacity, hypertension, tumours and hepatic dysfunction (Luckey & Venugopal, 1977).

Waters and sediment samples from Wadi El-Rayan lakes were less contaminated with pesticides than those sampled from Lake Qarun (Table 6). The occurrence of long persisting insecticides (e.g. HCB, lindane, aldrin, heptachlor, DDT analogues) in fish, sediment and water from different ecosystems in Egypt was previously reported by Abou-Arab, Gomaa, Badaway, and Naguib (1995) and Ibrahim (1996), although such compounds have been officially banned in the country for more than 25 years.

According to Faust and Aly (1964), surface water may be polluted by organic pesticides either directly by the application into the water or, indirectly, by the discharge of wastewater and/or agriculture runoff. Further contamination may arise from drift, washing of spraying equipment, or even rainfall.

The waters and sediment samples from the three studied lakes showed similar microbial contamination, but at different levels (counts; Table 8). The total bacterial count is an important indicator of water quality and the occurrence of a high population of aerobic bacteria in water is directly related to the incidence of opportunistic pathogens (Lechevallier, Seidler, & Evans, 1980). The presence of *coliform* bacteria in an aquatic ecosystem is associated with fecal pollution (WHO/UNEP, 1995). Sabae and Rabeh (2000) recorded high bacterial counts in water near the outlet of Wadi and Bats Drains into Lake Qarun, and referred the presence of *coliforms* to probable direct disposal of sewage into these drains.

In a recent study, Mansour, Messeha, and Ibrahim (2001) found that the toxicity of Lake Qarun water to *Daphnia magna* neonates and *Culex pipiens* larvae wass mainly due to the concentration of TDS (or salinity) in that water. They reported that the lake water causes no mortality to these organisms at TDS concentrations not exceeding 4.0 g/l. This again coincides with the bioassay results (Table 9) obtained in the present study.

From the viewpoint of contamination potential, the data obtained reveal that Lake Qarun components (e.g. water, sediment and fish) are generally more polluted than those of Wadi El-Rayan lakes. The second lake of this latter wetland is more contaminated than the first lake, with respect to the measured parameters. Many investigators (e.g. Bishai & Kirollus, 1980; FWMP, 1999; Mansour et al., 2000; Naguib, 1958; Soliman, 1989) have reported that Lake Qarun showed a gradual increase in salinity during the last century, due to its closed nature and extensive evaporation. Therefore, salts, heavy metals and pesticides, carried by agricultural drainage water, accumulate in the lake components. According to the FWMP report, the salinity of Lake Qarun has increased three times compared to its salinity at the beginning of the 20th century and, at present, the rate of salinization is 0.36 g/l/year with a reference lake level of −43.50 MSL (FWMP, 1999). Mansour et al. (2000) found that the average salinity amounted to 27 g/l and reached 37 g/l in some regions of the lake.

Due to the increase of human activities and the expansion in agriculture at Fayoum Province, one cannot yet claim that Wadi El-Rayan Wetland will take a similar period of time to reach the same salinity level as that of Lake Qarun. Our expectation is that this virgin wetland will be salinized in a much shorter period, and the second lake may take a shorter period than the first. Therefore, solutions have to be found to minimize the increase of salinity and pollutants in this important natural protectorate.

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