Journal of Environmental Sciences, 2016; Vol. 45, No. 1 : 63-73

Journal of Environmental Sciences

JOESE 5

ISSN 2090-9233

Journal homepage http://eulc.edu.eg/jes

Original Article

Ecological Studies on Water-borne Parasites at Dakahlia Governorate, Egypt.

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Article Info

Article history :
Received 3/1/2016
Received in revised form 6/2/2016
Accepted 22/2/2016

Keywords:
Water Variables
Entamoeba
Giardia
Cryptosporidium
Damietta Branch
El-Dakahlia

Abstract

The biological contamination of drinking water with protozoan pathogens possess a serious threat to millions of people in the developing countries. The present investigation aims to study the surveillance of *Cryptosporidium* sp. oocysts, *Giardia* sp. and *Entamoeba* sp. cysts for one year and to evaluate the correlation between the abundance of these pathogens and the environmental factors in the inlet of some water treatment facilities in Dakahlia Governorate. Raw water samples were collected monthly from January 2014 to December 2014 from the inlet of each facility. Water samples were then filtrated; materials retained by filters were stained with iodine and examined microscopically. Physical and chemical parameters of water were assessed according to the standard methods for the examination of water and waste water. The prevalence rates of different parasites were as follows; *Cryptosporidium* spp. (43.12%), *Giardia* spp. (33.94%) and *Entamoeba* spp. (22.93%). Contamination rates were shown to be at Meet-khamis station (mean= 6.25) and El-Manzala station (mean= 5.17) followed by, Belqas station (mean= 4.25) and Sherbin station (mean= 2.5). As regard to seasonal fluctuation of detected parasites, winter (mean= 2.5 ± 0.63), spring (mean= 5.17 ± 0.81), summer (mean= 6.25 ± 0.91) and autumn (mean= 4.25 ± 0.79). Turbidity, electrical conductivity (EC) and total dissolved solids (TDS) had the highest correlation with the prevalence of detected parasites. Turbidity, electrical conductivity and total dissolved solids can be used as markers to indicate the prevalence of cysts/oocysts. In addition, close management of water supplies during summer months is recommended. Furthermore, stricter regulations must be activated to protect water resources from sewage discharges and therefore minimize the risk of waterborne diseases.

1. Introduction

Surveillance of drinking water is an imperative matter to ensure continuous supplies of healthy water. Outbreaks of waterborne disease still occur and continue to

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threat drinking water quality and safety in developed and developing countries. In 1996, the World Health Organization (WHO) reported that at least 25% of the developing world's population does not have access to safe drinking water and over 66% lack adequate sanitation systems contributing to the continuous occurrences of waterborne infectious diseases related illnesses worldwide (WHO, 1996).

Transmission of protozoal pathogens is typically associated with poor faecal-oral hygiene. Water and food are the most common transmission agencies, although person-to-person or animal-to-person direct contacts are also important routes of infection. Immune compromised individuals (i.e. AIDS and cancer patients, the very young or the elderly) are most at risk from the clinical consequences of these diseases (Keserue *et al.,* 2011). Water is the major transmission route of *Giardia*, where it can resist and remain infective due to its robust form, the cyst (Thompson, 2000). The infected hosts shed in the environment a large number of this transmissive and infective stage, contributing to increase of environmental contamination, in particular water sources. Cysts not only remain infective for long periods in environment but are also resistant to the conventional treatment processes of water, representing a serious problem of public health (Lobo *et al.,* 2009).

Several epidemiological and ecological studies have been conducted to detect the presence and the abundance of *Giardia* and *Cryptosporidium* in surface waters (Barwick *et al.,* 2000; Sroka *et al.,* 2013). As drinking water supplies are most frequently obtained by the collection and treatment of surface water, it is important to constantly monitor the presence and seasonal fluctuation of these parasites in a given catchment area (Sroka *et al.,* 2013).

In present study, we had conducted a one year study during 2014 at the inlet of four water treatment plants in Dakahlia Governorate (Sherbin, Belqas, Meet-Khamies and El-Manzala Districts) to outline the prevalence of *Entamoeba* spp. *Giardia* spp. and *Cryptosporidium* spp. and to assess the relationship between the prevalence of these parasites and the water factors.

2. Materials and methods

2.1. Sampling

Water samples (each sample 10 L) were collected monthly from the inlet of each facility. Some analyses were carried out at the time of sampling and some others were analyzed in the laboratory.

2.2. Sample Processing

One liter of water sample was filtrated through a cellulose nitrate membrane (GEMA, Spain) 47 mm diameter, 0.45 µm pore size.

2.3. Microscopy

Materials retained by filters were stained with Lugol iodine and examined microscopically. Identification was carried out with an Olympus CX41 light microscope.

2.4. Water factors

Physicochemical parameters of water were assessed according to methods used by APHA (2005). These include:

a. Physical parameters of water: Turbidity, Temperature, pH, Electrical conductivity (EC), Total dissolved solids (TDS).

b. Chemical parameters: Total alkalinity, Chlorides, Sulphates, Total hardness.

c. Pollution parameters: Ammonia, Nitrates (NO_3), Nitrites (NO_2), Dissolved oxygen (DO_2), Total organic carbon (TOC).

d. Minerals of water: Sodium (Na^+), Potassium (K^+), Calcium (Ca^{++}) and Magnesium (Mg^{++}).

e. Heavy metals: including Iron (Fe), Manganese (Mn) and Aluminum (Al) were analyzed using Buck Scientific Accusys 211 Atomic Absorption Spectrophotometer according to Allen *et al.* (1974).

2.5. Statistical analysis and treatment of data

Statistical analysis of the obtained data was performed in order to reveal the relationships between water factors and abundance of parasites through the different months of the year, using MVSP (multivariate statistical package) version 2 program.

3. Results

3.1. Microscopic examination

In the present study a total of forty eight raw water samples were collected at the inlet of four water treatment stations (Sherbin, Belqas, Meet-Khamies and El-Manzala) and investigated for the prevalence of Cryptosporidium sp. oocysts, *Giardia* sp. cyst and *Entamoeba* sp. cysts. A total of 218 cysts/oocysts were detected and the most common protozoan detected was Cryptosporidium sp. (94/218; 43.12%), followed by *Giardia* sp., (74/218; 33.94%), and *Entamoeba* sp., (50/218; 22.93%). The prevalence of detected protozoan parasites is shown in (Table 1).

It was found that; Meet-Khamies showed the highest rate of contamination (mean= 6.25) followed by El-Manzala (mean= 5.17), Belqas (mean= 4.25) and Sherbin (mean= 2.5).

Seasonal variation in the prevalence of parasites during the year was shown to be as follows; the highest prevalence was recorded during the summer months (mean= 6.25) followed by spring months (mean= 5.17), autumn months (mean= 4.25) and winter months (mean= 2.5) as shown in Table (2).

3.2. Water factors

Most of the water factors (physico-chemical parameters) were shown to reach its peak in winter, then decrease gradually during spring and fall to the lowest values during summer (Table 3). Then, the values start to increase again during winter and so on. On the other hand, temperature and turbidity break this cycle and moves in the reverse direction (i.e. peak during summer and decrease during winter).

As regard to the values of the physico-chemical variables of water, they were in the normal range and no odd results were detected. Unlike results of the microscopic examination, values of water factors in the different studied sites were shown to be close and overlapped to somewhat. This may reflect the narrow distribution of sampling study sites (i.e in the same Governorate).

Table 1. Prevalence of Water-borne parasites at different study sites.

Month	Sherbin				Belqas				Meet-Khamis				El-Manzala			
	C	G	E	T	C	G	E	T	C	G	E	T	C	G	E	T
January	2	2	0	4	0	0	0	0	1	2	1	4	0	0	0	0
February	2	1	0	3	2	3	2	7	4	3	2	9	2	1	2	5
Mars	0	1	1	2	1	1	1	3	0	0	0	0	2	1	0	3
April	2	2	1	5	3	1	1	5	2	0	0	2	2	1	1	4
May	1	0	0	1	2	2	1	5	3	2	2	7	3	1	3	7
June	0	0	0	0	2	1	1	4	3	3	1	7	2	2	1	5
July	1	1	0	2	2	2	1	5	4	3	3	10	2	2	0	4
August	3	2	2	7	4	3	2	9	3	4	3	10	4	4	2	10
September	2	1	1	4	1	0	1	2	3	4	2	9	4	3	3	10
October	0	0	0	0	3	2	2	7	2	2	1	5	3	1	1	5
November	1	1	0	2	2	2	0	4	2	2	1	5	2	1	1	4
December	0	0	0	0	0	0	0	0	3	2	2	7	2	2	1	5
Total	14	11	5	30	22	17	12	51	30	27	18	75	28	19	15	62
Mean	1.17	0.92	0.42	2.5	1.83	1.42	1	4.25	2.5	2.25	1.5	6.25	2.33	1.58	1.25	5.17
±SE	0.30	0.23	0.19	0.63	0.34	0.31	0.21	0.79	0.34	0.37	0.29	0.91	0.31	0.31	0.30	0.81

Abbreviations: C: *Cryptosporidium* sp. oocysts; G: *Giardia* sp. cysts; E: *Entamoeba* sp. cysts; T: Total.

Table 2. Seasonal Variations of different parasites at different study sites.

Season	Sherbin				Belqas				Meet-Khamis				El-Manzala			
	C	G	E	T	C	G	E	T	C	G	E	T	C	G	E	T
Winter	1.33	1.33	0.33	3	1.00	1.33	1.00	3.33	1.67	1.67	1.00	4.33	1.33	0.67	0.67	2.67
Spring	1.00	0.67	0.33	2	2.33	1.33	1.00	4.67	2.67	1.67	1.00	5.33	2.33	1.33	1.67	5.33
Summer	2.00	1.33	1.00	4.33	2.33	1.67	1.33	5.33	3.33	3.67	2.67	9.67	3.33	3.00	1.67	8
Autumn	0.33	0.33	0.00	0.67	1.67	1.33	0.67	3.67	2.33	2.00	1.33	5.67	2.33	1.33	1.00	4.67

Abbreviations: C: *Cryptosporidium* sp. oocysts; G: *Giardia* sp. cysts; E: *Entamoeba* sp. cysts; T: Total.

Table 3. Variation of physical and chemical parameters of water during the year from the studied sites.

Month	Site	Water Parameters																				
		Turbidity	Temp. (^oC)	pH	EC (µmhos/cm)	T.D.S	$D.O_2$	ALK.	T.H	Cl	SO_4	Ca	Mg	Na	K	NH_3	NO_3	NO_2	O.C	Fe	Mn	Al
						(mg/l)																
January	Sh	4.62	16	7.69	612	367	6	200	200	62	50	62	16.8	33.21	8.16	0.33	3.71	0.1	5.06	0.31	0.011	0.01
	B	495	18	7.4	531	319	5.8	176	150	47	42	40	11	41.74	7.84	0.25	3.2	0.032	4.38	0.32	0.011	0.035
	MK	4.5.	17	8.01	482	289	6.2	176	150	30	41	33	21.1	33.44	8.69	0.28	2.74	0.041	3.8	0.25	0.011	0.047
	Mn	5.11	17	7.81	506	304	5.9	160	192	45	47	42	16	40.72	7.43	0.28	2.54	0.045	3.88	0.31	0.011	0.032
February	Sh	5.63	18	7.48	573	344	5.9	174	180	50	38	43	17.2	29.42	7.44	0.03	4.3	0.29	4.9	0.28	0.011	0.035
	B	6.63	17	7.56	459	275	5.8	170	160	40	45	38	16	36.61	8.2	0.02	2.14	0.032	4.01	0.31	0.011	0.024
	MK	5.31	17	7.75	495	297	5.9	170	156	40	44	34	21	30.26	7.63	0.02	3.2	0.045	3.92	0.28	0.011	0.034
	Mn	5.11	17	7.81	506	304	5.7	160	192	45	47	42	16.8	35.2	6.87	0.26	2.54	0.045	4.3	0.31	0.011	0.032
March	Sh	5.8	19	7.57	442	254	6	156	140	32	33	34	13.4	24.32	7.72	0.23	4.3	0.29	4.7	0.28	0.011	0.035
	B	13.6	20	7.81	433	260	5.5	166	146	33	35	40	11	29.14	8.23	0.21	2.14	0.032	3.94	0.31	0.011	0.042
	MK	4.64	20	7.68	460	267	5.8	170	160	42	34	36	17.2	28.14	6.98	0.2	3.2	0.045	4.5	0.24	0.011	0.034
	Mn	14.1	21	7.61	483	290	5.5	162	160	45	37	35	16.8	30.66	7.3	0.22	2.48	0.069	4.24	0.31	0.011	0.032
April	Sh	6.98	20	7.66	461	267	5.6	166	144	36	41	36	12.9	20.58	7.12	0.27	2.83	0.14	4.52	0.28	0.011	0.031
	B	17.2	22	7.61	414	248	5.7	154	130	27	32	34	11	23.15	9.67	0.24	2.2	0.025	4.52	0.31	0.011	0.029
	MK	4.17	25	7.52	439	263	5.5	150	138	28	33	35	12	23.68	7.14	0.18	2.02	0.22	4.56	0.24	0.011	0.034
	Mn	19.9	22	7.93	438	262	5.3	162	140	37	39	36	12	12.03	7.36	0.2	1.47	0.136	4.21	0.31	0.003	0.032
May	Sh	5.84	23	7.57	400	240	5.3	140	134	27	33	36	10.5	22.58	8.67	0.25	2.83	0.08	4.5	0.35	0.011	0.023
	B	19.5	22	7.71	384	230	5.3	140	140	24	35	32	14	19.45	5.28	0.22	4.2	0.024	4.15	0.29	0.01	0.04
	MK	5.23	24	7.58	400	240	5.5	144	142	28	33	39	12	21.58	8.36	0.15	1.99	.06	5.68	0.23	0.011	0.028
	Mn	15.84	23	7.98	420	252	5.6	160	130	35	38	32	10.5	19.85	8.12	0.25	1.32	0.123	4.79	0.31	0.001	0.032
June	Sh	5.11	25	7.3	405	243	5.3	150	124	22	34	36	8.16	23.1	7.77	0.2	2.65	0.07	4.3	0.35	0.011	0.014
	B	7.6	24	7.83	346	218	5.4	140	134	22	37	32	13	15.58	6.17	0.18	1.56	0.24	3.71	0.21	0.01	0.039
	MK	4.98	22	7.6	383	229	5.3	138	130	24	33	31	10	15.45	6.49	0.19	1.69	0.54	4.42	0.15	0.033	0.028
	Mn	12.8	23	7.97	390	234	5.2	150	122	26	32	32	12	18.3	6.45	0.17	1.46	0.133	4.34	0.31	0.003	0.034
July	Sh	4.24	25	7.64	375	225	5.2	130	124	23	33	31	11	20.17	8.47	0.21	1.59	0.042	4.09	0.18	0	0.043
	B	5.19	25	7.68	357	214	5.3	154	132	18	30	32	12	27.85	3.44	0.17	1.53	0.055	4.24	0.28	0.04	0.038
	MK	6.38	24	7.65	368	220	5.2	142	140	20	31	34	11	16.95	4.28	0.14	1.58	0.056	4	0.21	0.033	0.038
	Mn	24.1	25	7.57	384	230	5.6	142	116	26	28	28	12.9	20.98	5.36	0.15	1.59	0.019	3.7	0.31	0.003	0.037
July	Sh	4.24	25	7.64	375	225	5.2	130	124	23	33	31	11	20.17	8.47	0.21	1.59	0.042	4.09	0.18	0	0.043
	B	5.19	25	7.68	357	214	5.3	154	132	18	30	32	12	27.85	3.44	0.17	1.53	0.055	4.24	0.28	0.04	0.038
	MK	6.38	24	7.65	368	220	5.2	142	140	20	31	34	11	16.95	4.28	0.14	1.58	0.056	4	0.21	0.033	0.038
	Mn	24.1	25	7.57	384	230	5.6	142	116	26	28	28	12.9	20.98	5.36	0.15	1.59	0.019	3.7	0.31	0.003	0.037
August	Sh	7.53	26	7.87	377	226	5.2	160	126	24	25	32	11	18.52	5.36	0.19	1.71	0.017	3.63	0.18	0	0.003
	B	7.4	25	7.86	365	219	5.2	154	128	27	31	32	12	22.46	4.36	0.21	1.54	0.042	3.85	0.27	0.01	0.01
	MK	6.07	24	7.9	365	219	5	154	124	25	30	32	13	15.47	4.35	0.2	1.57	0.036	3.79	0.25	0.01	0.021
	Mn	17.6	23	7.8	481	288	5.4	160	140	45	37	34	10.5	30.8	6.09	0.2	1.89	0.019	3.85	0.32	0.003	0.028
September	Sh	6.5	25	7.88	406	243	5.1	154	134	27	31	35	11	15.4	6.83	0.22	1.71	0.039	3.32	0.18	0	0.029
	B	10.2	27	7.84	449	269	5.5	160	144	36	33	36	13	18.65	7.54	0.2	2.65	0.089	5.5	0.28	e0.01	0.055
	MK	4.1	24	7.9	410	246	5.7	150	130	25	30	34	14	16.58	4.52	0.2	1.57	0.036	3.79	0.25	0.01	0.021
	Mn	14.2	25	7.89	440	264	5.4	152	150	36	34	35	11	18.82	7.8	0.19	3.1	0.096	3.85	0.28	0.003	0.028
October	Sh	10.8	24	7.8	441	246	5.3	156	160	30	37	40	14	17.58	5.98	0.22	2.64	0.049	3.87	0.17	0	0.028
	B	6.48	24	7.85	430	258	5.7	160	150	30	38	39	12	17.34	6.09	0.23	3.21	0.13	3.2	0.14	0	0.035
	MK	9.1	20	7.8	485	291	5.6	154	142	34	43	36	10	28.13	7.68	0.2	3.59	0.035	5.65	0.17	0.036	0.022
	Mn	23.8	23	7.81	442	265	5.5	150	132	35	32	36	12	41.34	6.2	0.24	2.61	0.039	4.42	0.35	0.003	0.043
November	Sh	9.42	23	7.88	424	254	5.6	154	134	34	30	39	8.6	32.56	6.48	0.26	3.3	0.05	4.1	0.25	0	0.04
	B	10.4	22	7.85	441	264	5.7	164	150	31	36	36	14	23.78	6.17	0.23	3.47	0.134	3.8	0.23	0	0.038
	MK	5.8	21	7.61	450	270	6	166	150	30	36	40	23.5	40.91	6	0.21	3.11	0.55	4.2	0.34	0	0.031
	Mn	14.2	20	7.84	488	292	5.7	150	188	36	29	36	12	38.59	6.35	0.25	3.87	0.094	4.8	0.35	0.003	0.042

Table 3. Continued.

December	Sh	6.65	20	7.81	535	321	5.9	162	158	42	41	43	12	30.25	6.35	0.31	3.5	0.22	4.39	0.25	0	0.05
	B	5.44	20	7.8	529	317	5.7	160	154	42	38	40	13	35.47	6.72	0.24	3.67	0.19	4.33	0.23	0	0.035
	MK	5.15	20	7.53	511	306	5.9	170	160	45	36	40	21.12	32.58	6.49	0.26	4.05	0.017	4.84	0.34	0	0.036
	Mn	9.45	20	7.84	480	288	5.8	160	188	36	29	40	14	38.59	6.35	0.28	3.87	0.094	5.09	0.35	0.003	0.042
Mean	Sh	6.59	22.0	7.68	452.75	269.9	5.53	158.5	146.5	34.08	35.5	38.92	12.21	23.97	7.20	0.25	2.92	0.12	4.28	0.26	0.006	0.028
	B	9.55	22.2	7.73	429.67	257.6	5.55	158.2	143.2	31.42	36.0	35.92	12.67	25.94	6.64	0.22	2.54	0.07	4.14	0.26	0.010	0.037
	MK	5.62	21.5	7.71	437.33	262.2	5.63	157.0	143.5	30.92	35.3	35.33	15.49	25.26	6.55	0.20	2.53	0.06	4.43	0.25	0.015	0.03
	Mn	14.68	21.6	7.82	454.83	272.8	5.55	155.7	154.2	37.25	34.9	35.67	13.04	28.82	6.81	0.22	2.40	0.08	4.29	0.32	0.005	0.03
±SE	Sh	0.55	0.94	0.052	22.61	13.74	0.10	5.01	6.89	3.47	1.87	2.37	0.82	1.74	0.30	0.01	0.27	0.03	0.15	0.02	0.002	0.004
	B	1.40	0.87	0.042	16.88	10.15	0.06	3.11	2.10	2.49	1.27	0.99	0.43	2.41	0.51	0.01	0.23	0.02	0.16	0.02	0.003	0.003
	MK	0.39	0.80	0.046	14.78	8.89	0.10	3.71	3.46	2.25	1.41	0.86	1.44	2.40	0.44	0.01	0.25	0.02	0.19	0.02	0.004	0.002
	Mn	1.79	0.77	0.036	12.17	7.33	0.06	1.89	8.34	1.96	1.95	1.20	0.67	2.98	0.23	0.01	0.26	0.01	0.16	0.01	0.001	0.002

Abbreviations : Sh; Sherbin, B; Belqas, MK; Meet-khamis, Mn; El-Manzala, EC; Electerical Conductivity, T.D.S; Total dissolved solids, $D.O_2$; Dissolved oxygen, ALK.; Alkalinity, T.H; Total hardness, Cl; Chlorides, SO_4; Sulphates, Ca; Calcium, Mg; Magnesium, Na; Sodium, K; Potassium, NH_3; Ammonia, NO_3: Nitrates, NO_2; Nitrites, O.C; Organic carbon, Fe; Iron, Mn; Manganese, Al; Aluminum.

3.3. Correlation between water factors and the prevalence values

In this context, Canonical Correspondence Analysis (CCA) software was used to analyze the input data of physico-chemical parameters of water with different the prevalence values for each study site and then detects the degree of correlation between each water parameter with prevalence values. In the CCA biplot, the length of the arrow for each parameter indicates the effective degree (significance) of this parameter with the prevalence value. The correlation between water variables and prevalence values is indicated on the ordination diagram produced by Canonical Correspondences Analysis (CCA) as shown in Figure (1).

It was found that, temperature, potassium (K^+), organic carbon (OC), turbidity, nitrites (NO^-_2), chlorides (Cl^-), ammonia (NH_4^+), calcium (Ca^{++}), electrical conductivity (EC), total dissolved solids (TDS), Nitrates (NO_3^-), sodium (Na^+) and pH showed high significance with the prevalence of *Cryptosporidium* sp. oocysts, *Giardia* sp. cyst and *Entamoeba* sp. cysts. In addition, a moderate significance was reported with dissolved oxygen (DO_2), sulphates (SO_4^{--}), magnesium (Mg^{++}) and manganese (Mn^{++}). Finally, iron (Fe^{++}), total hardness,

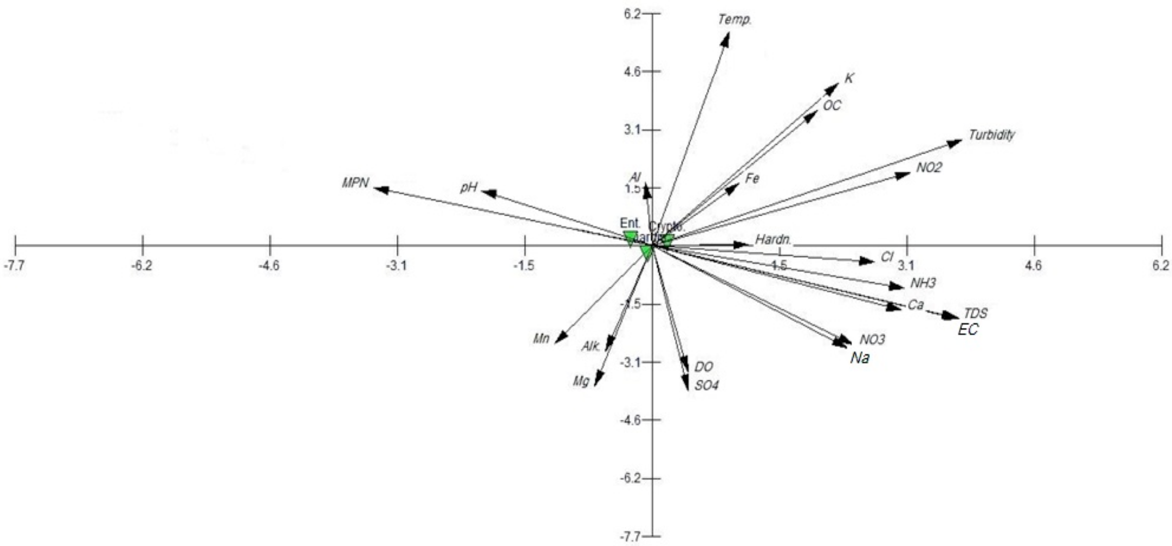

Fig. 1. Canonical Corresponding Analysis (CCA) ordination diagram of the prevalence values of *Cryptosporidium* sp., *Giardia* sp. and *Entamoeba* sp. according to the gradient of environmental variables (arrows) during the year in the study sites.

alkalinity and aluminum (Al^{+3}) exhibited low significant correlations.

3.4. Pearson-moment correlation between different water variables

It has been found that, exhibited high negative significant correlations with electrical conductivity (EC), total dissolved solids (TDS), dissolved oxygen (DO_2), alkalinity, hardness, chlorides (Cl^-), sulphates (SO^-_4), magnesium (Mg^{+2}), Sodium (Na^+) and Nitrates (NO^-_3), but moderate significant negative correlations with calcium (Ca^{+2}) and ammonia (NO^-_3). Electrical conductivity showed high positive significant correlations with TDS, DO_2, alkalinity, hardness, Cl^-, SO^{--}_4, Ca^{+2}, Na^+, NH^+_3 and NO_3, whereas low positive correlation with Mg^{+2}. The water variable total dissolved solids proved high positive correlations with DO_2, alkalinity, hardness, Cl^-, SO^{--}_4, Ca^{+2}, Na^+, NH^+_3, and NO^-_3, while a low correlation with Mg^{+2} cation. Dissolved oxygen showed high positive significant correlations with Na^+ and NO^-_3, and moderate significant correlations with alkalinity, Cl^-, Mg^{+2} and NH^+_3, while low positive correlations with SO^{--}_4 and Ca^{+2}. The water alkalinity exhibited high positive significant correlations with Cl^-, SO^{--}_4 and Ca^-, but moderate positive significant correlations with hardness, Mg^{+2} and NH^+_3 and low significant correlations with Na and NO^-_3. However water harness proved high positive significant correlations with Cl^-, Ca^{+2} and NH^+_3, while moderate significant correlations with SO^{--}_4, Na^+ and NO^-_3, but a low positive correlation with Mg^{+2}. The water soluble chlorides exhibited high positive correlations with SO^{--}_4 and Ca^{+2}, while moderate positive correlations with Na^+, NH^+_3 and NO^-_3. Whereas the water soluble sulphates showed a moderate positive correlation with Ca^{+2}, and low correlations with Mg^{+2} and NH^+_3. Calcium cation proved a moderate positive correlation with NH^+_3 and low positive correlations with Na^+ and NO^-_3. Sodium cation exhibited low positive significant correlations with NH^+_3, NO^-_3 and Fe^{+2}. Finally ammonia exhibited a moderate positive significant correlation with NO^-_3 (Table 4).

Table 4. Pearson-moment correlation (r) between the environmental factors in the study sites during the year.

	Turb	Temp	pH	Cond	TDS	DO_2	Alk	Hard	Cl^-	SO^{--}_4	Ca^{+2}	Mg^{+2}	Na^+	K^+	NH_3	NO^-_3	NO^-_2	OC	Fe^{+2}	Mn^{+2}	Al^{+3}
Turb	1																				
Temp	0.222	1																			
pH	0.238	0.118	1																		
Cond	-0.159	*** -0.758	-0.109	1																	
TDS	-0.163	*** -0.764	-0.113	*** 0.997	1																
DO	-0.209	*** -0.754	-0.127	*** 0.720	*** 0.729	1															
Alk	-0.202	*** -0.656	-0.015	*** 0.762	*** 0.761	** 0.641	1														
Hard	-0.221	*** -0.717	-0.005	*** 0.790	*** 0.783	** 0.600	** 0.584	1													
Cl^-	-0.032	*** -0.705	-0.068	*** 0.923	*** 0.925	** 0.602	*** 0.763	*** 0.748	1												
SO^{--}_4	-0.277	*** -0.743	-0.114	*** 0.692	*** 0.688	* 0.510	*** 0.574	** 0.60	*** 0.657	1											
Ca^{+2}	-0.283	** -0.550	-0.123	*** 0.765	*** 0.755	* 0.495	*** 0.679	*** 0.739	*** 0.731	** 0.612	1										
Mg^{+2}	-0.244	*** -0.565	-0.046	* 0.451	* 0.448	** 0.632	** 0.537	* 0.499	0.399	* 0.437	0.284	1									
Na^+	-0.077	*** -0.667	-0.182	*** 0.656	*** 0.666	*** 0.653	* 0.480	** 0.603	** 0.594	0.406	* 0.468	0.420	1								
K^+	-0.035	-0.394	-0.227	0.383	0.390	0.368	* 0.250	0.205	0.370	0.387	0.274	0.045	0.190	1							
NH^+_3	-0.158	** -0.623	-0.065	*** 0.724	*** 0.723	** 0.587	** 0.575	** 0.630	** 0.651	* 0.449	** 0.651	0.274	* 0.511	0.328	1						
NO_3	-0.170	*** -0.558	-0.215	*** 0.688	*** 0.684	*** 0.659	* 0.452	** 0.613	** 0.555	0.350	* 0.533	0.349	* 0.532	0.244	** 0.616	1					
NO^-_2	-0.158	-0.161	-0.098	0.329	0.332	0.276	0.168	0.194	0.235	0.072	0.226	0.023	-0.030	0.151	0.315	0.419	1				
OC	-0.055	-0.210	-0.276	0.351	0.358	0.258	0.126	0.269	0.313	0.079	0.318	0.004	0.236	0.372	0.195	0.381	0.270	1			
Fe^{+2}	0.338	-0.312	-0.219	0.284	0.303	0.279	0.255	0.253	0.355	0.069	0.188	0.225	* 0.519	0.187	0.277	0.185	0.014	0.257	1		
Mn^{+2}	-0.248	-0.070	-0.260	-0.169	-0.158	-0.125	-0.134	-0.079	-0.219	0.099	-0.129	0.128	-0.083	-0.134	-0.294	-0.162	-0.126	0.265	-0.171	1	
Al^{+3}	-0.183	-0.156	0.084	0.123	0.126	0.296	-0.068	0.142	0.056	0.053	-0.100	0.155	0.250	0.117	0.098	0.200	0.170	0.097	0.106	0.085	1

On the other hand, water turbidity, pH value, Mg^{+2} cation, K^{+} cation, NO^{-}_{3}, NO^{-}_{2}, organic carbon (OC), Fe^{+2}, Mn^{+2} and Al did not show any correlations with any water parameters in the present investigation (Table 4).

4. Discussion

Contamination of drinking water by protozoan parasites represents a major risk that threats millions of people especially in the developing world (WHO, 2011). Ximénez *et al.* (2011) stated that; carrier individuals excrete cysts in their feces, which can contaminate food and water sources.

In the present study, *Cryptosporidium* sp. oocysts, *Giardia* sp. cysts and *Entamoeba* sp. cysts were detected in the inlet of four drinking water facilities in Dakahlia Governorate (Sherbin, Belqas, Met-Khamis and El-Manzala). These results were in agreement with other studies conducted in some other governorates where, the prevalence of these protozoan parasites were reported in water samples in Assiut Governorate (Dyab *et al.,* 2015), El-Minia Governorate (Khalifa *et al.,* 2014), Alexandria Governorate (Khalifa *et al,* 2011), Ismailia Governorate (Rayan *et al.,* 2009), El-Dakahlia Governorate (El Shazly *et al,* 2007), Al-giza governorate (Ali *et al,* 2004) and Al-Gharbia governorate (Antonios *et al,* 2001). In addition, these water-borne pathogens were documented by other studies worldwide even in the developed countries including; France (Céline *et al.,* 2009), Russia and Bulgaria (Karanis *et al.,* 2006), Italy (Briancesco and Bonadonna, 2005), Japan (Hashimoto *et al.,* 2002; Tsushima *et al.,* 2001) and Czech (Dolejs *et al.,* 2000).

As regard to the prevalence order of protozoan pathogens detected in the present study, *Cryptosporidium* sp. oocysts were detected nearly in the majority of water samples (43.12%), followed by *Giardia* sp., (33.94%), and *Entamoeba* sp., (22.93%) as illustrated in Table (1). These results agreed with El-Szhazly *et al.* (2007) and disagreed with the results obtained by Briancesco and Bonadonna (2005) and Horman *et al.* (2004).

In the present study, seasonal distribution of the prevalence of parasites under study proved to be the highest during the summer months (mean= 6.25); these results were in harmony with Keeley and Faulkner (2008) and El-Szhazly *et al.* (2007). These results could explain the higher rate of human infection with protozoan pathogens during summer than in winter seasons (Furness *et al.,* 2000). However, these results disagreed with another study in Assuit Governorate where higher detection rate was observed in winter than in summer seasons (Dyab *et al.,* 2015). In addition, Keeley and Faulkner (2008) reported peaks of water contamination with protozoa during spring and winter seasons in UK and Ireland.

On the other hand, there was a significant correlation between the turbidity and the prevalence of parasites. These results were in accordance with that of Lechevallier *et al.* (1991). In addition, Hsu *et al.* (2002) found that turbidity was the most important factor in relationship to parasite concentrations among other water quality parameters. Hence, it could coccluded that, turbidity must be used as an indicator to predict the occurrence of parasites.

Both electrical conductivity (EC)/ total dissolved solids (TDS) are known to be two sides of the same coin. In the present work, a significant correlation was observed between the prevalence of parasites under study and both EC and TDS. In accordance with the present study, a positive correlation was observed between electrical conductivity and the prevalence of both *Cryptosporidium* and *Giardia* in water samples from recreational rivers in Malaysia (Azman *et al.,* 2009), in source and tap water in China (Feng *et al.,* 2011) and in a drinking water reservoir in Luxembourg (Helmi *et al.,* 2011).

However, physical parameters of water did not show significant correlation with *Cryptosporidium* and Giardia and the authors concluded that, these parameters could not be used as a suitable indicator for the presence of *Giardia* and *Cryptosporidium* (Azman *et al.,* 2009).

Pollution parameters including ammonia (NH4), nix-ancesco and Bonadonna. 2005, Briancesco *et al.,* 1999). These findings suggest sewage discharge to be the main source of biological contamination of surface water.

However, Feng *et al.* (2011) reported that unexpected negative correlation between coliforms and Cryptosporidium, they also did not found any significant correlation between Giardia and water quality parameters.

5. Conclusion

Surveillance of *Cryptosporidium* sp. oocysts, *Giardia* sp. and *Entamoeba* sp. cysts in water resources is important task for controlling the transmission of these pathogens. The River Nile is the main source of fresh water in Egypt. However, the Nile is exposed to many polluting activities including sewage, agricultural and industrial discharges. The present work studied the prevalence of the dominant (domestic) and most common pathogenic protozoa in the inlet of some water treatment stations in El-Dakahlia Governorate. The occurrence of cysts/oocysts in raw water samples is hazardous due to its being resistant to the regular water disinfection practice which represents a potential risk to the public health. It is interest to denote that, water temperature, K,organic carbon, water turbidity, NO_2, Cl, NH_3, Ca, electrical conductivity, total dissolved solids, NO_3, Na and pH value were the most important water variables controlling the prevalence of the studied parasites. Hence, close and controlled management of water supplies during summer months is recommended in order to reduce waterborne diseases. In addition, protection of water resources enforced by laws regulation should be activated to limit sewage industrial and agricultural drainage in order to minimize the risk of water pollution.

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Journal of Environmental Sciences, 2016; Vol. 45, No. 1 : 63-73

الملخص العربى

دراسات بيئية على الطفيليات المنقولة بالماء فى محافظة الدقهلية - مصر

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إن تلوث مياه الشرب بالأوليات المُمرضة يشكل خطراً يهدد حياة الملايين من البشر فى الدول النامية. حيث أن الدراسة الحالية تهدف إلى مراقبة حويصلات كل من الكريبتوسبوريديوم والجيارديا والإنتاميبا وذلك لمدة عام كامل؛ ومن ثم تقييم العلاقة بين وفرة هذه الاوليات الطفيلية والعوامل البيئية؛ وذلك فى مدخل بعض محطات مياه الشرب فى محافظة الدقهلية. ولهذا الغرض تم تجميع عينات المياه الخام شهرياً - ابتداءاً من يناير 2014 وحتى ديسمبر - 2014 عند مدخل كل محطة. وقد خضعت عينات المياه بعد ذلك الى الترشيح؛ حيث ان المواد المتبقية على الغشاء تم صباغتها باستخدام اليود ليتم فحصها باستخدام الميكروسكوب الضوئى. اما عن الخواص الفيزيائية والكيميائية لعينات المياه؛ فقد تم قياسها وفقاً للطرق القياسية لفحص مياه الشرب. وقد وجد ان معدلات انتشار الطفيليات كانت كالآتى: الكريبتوسبوريديوم (% 43.12) والجيارديا ,(% 33.94) الإنتاميبا .(% 22.93) اما معدلات التلوث فكانت كالتالى؛ محطة ميت خميس بمتوسط ,(6.25)، يليها محطة المنزلة بمتوسط (5.17) ، ثم محطة بلقاس بمتوسط (4.25) ثم محطة شربين بمتوسط (2.5) وقد وجد ان التوزيع الموسمى للطفيليات محل الدراسة يزيد خلال فصل الصيف بمتوسط ,(6.25) ، يليه فصل الربيع بمتوسط (5.17) ثم فصل الخريف بمتوسط (4.25) ثم فصل الشتاء بمتوسط (2.5).

بالإضافة الى ذلك فقد وُجد ان عكارة المياه والتوصيل الكهربى والاملاح الذائبة الكلية لها أعلى ارتباط معنوي مع انتشار الطفيلي محل الدراسة. والخلاصة أن بعض خواص المياه مثل العكاره والتوصيل الكهربى والاملاح الذائبة الكلية قد تُمثل مؤشرات لإنتشار الحويصلات ,بالإضافة لذلك فإنه يُوصى بالمراقبة الدقيقة لمحطات المياه خاصة اثناء فصل الصيف. كما ان تفعيل القوانين الخاصة بحماية الموارد المائية من ملوثات الصرف الصحى قد يساهم بشكل كبير فى الحد من انتشار الأمراض المعدية والمنقولة بالماء.

Journal of Environmental Sciences

JOESE 5

Ecological Studies on Water-borne Parasites at Dakahlia Governorate, Egypt

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Reprint

Volume 45, Number 1 : 63-73

(2016)

http://eulc.edu.eg/jes

P-ISSN 1110-192X
e-ISSN 2090-9233