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Water quality of Rosetta branch in Nile delta, Egypt

Jokiveden laatu Rosettan haarassa Niilin suistossa Egyptissä

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Rosetta branch is one of the two main branches in Nile delta and El-Rahawy drain is one of this main sources, which outlet on the branch. It is subjected to many sources of pollutions from municipalities, agriculture and industry, but only little information is available on the quality of river water. The aim of this study was to analyze the river water quality in Rosetta branch at the outlet of El-Rahawy drain, Nile delta. Water samples were collected seasonally from El-Rahawy and Rosetta branch and the following physicochemical parameters were analyzed: hydrogen ion concentration (pH), total dissolved solids (TDS), electrical conductivity (EC), dissolved oxygen (DO), ammonia (NH_3), total alkalinity (CO_3+HCO_3); biochemical oxygen demand (BOD) and chemical oxygen demand (COD). The results were compared with the water quality standards of Egypt (Law 48/1982), FAO and Canadian Water Quality standards (CWQGs). Statistical studies were carried out by calculating correlation coefficients between different parameters. The large transports of NH_3, and TDS with low COD, BOD and DO values along El-Rahawy drain were seriously deteriorating the water quality in the downstream of Rosetta branch, especially during the low flow condition in winter.

Key words: river water, stream flow, water pollution, El-Rahawy drain.

1. Introduction

In Egypt, the Nile river is the lifeline supplying water to tens of millions people. It flows into Mediterranean Sea by its two main branches, Damietta and Rosetta, which are flowing through the Nile delta wetland (Badr et al. 2006). It receives wastes discharged by agricultural, industrial and domestic activities. Along the river, there are totally 56 larger drains discharging water and transporting pollutants from industrial and settlement areas, and 72 drains discharging water mainly from agricultural areas (El-Sherbini & El-Moatassem 1990). The exports from agricultural areas and domestic wastes have been the main sources of water pollutants in the Nile river.

El-Rahawy drain is one of the main drains, which outlet on Rosetta branch, and receives considerable waste waters from Greater Cairo area (ElBourie 2008). There are two main sources of pollutions, which potentially affect and deteriorate the water quality of El Rahawy drain: first, the agriculture and the domestic wastes from villages distributed along the drain discharging their wastes without purification directly into water courses, and secondly, the wastewater treatment plants particularly Abu Rawash and Zenein significantly affect the water quality in the river (Agricultural Policy Reform Program 2002). El Bouraie et al. (2010) observed high concentrations of organic and inorganic pollutants at the outlet of El Rahawy drain, which may produce harmful effect on the aquatic ecosystem. However, only little measured information is available on the water quality at Nile delta.

The aim of this study was to analyze the river water quality of in Rosetta branch at the outlet of El-Rahawy drain, Nile delta, Egypt. As the characteristics of water quality, a set of important element concentrations and physical parameter were measured. The values of the measured water quality parameters were then compared to the domestic and international recommendations.

Material and methods

Water samples were collected once seasonally (spring, summer, autumn and winter) from June 2008 to May 2009 from surface water (Table 1). The sampling points were located at Delta Barrage (used as the reference point), Rosetta branch (upstream and downstream El-Rahawy), El-Rahawy drain (outlet, middle and inlet) and El-Moheet drain (after and before mixing with both gennabiea) (Figure 1). Water samples were taken by using Van Dorn plastic bottles (1.5 liter capacity). The samples after collection were stored in the refrigerator at about 4 ˚C.

The weather conditions in the Nile basin in Egypt during the sampling year were close to the long-term average with hot and dry summer and mild winter.

Sampling, preservation and experimental procedure of the water samples were carried out according to the standard methods for examination of water (APHA 1992, 1998). Hydrogen-ion concentration (pH) and electrical conductivity (EC) were measured from water sample using the Orion digital pH- and EC-meters. The total dissolved solids (TDS) concentration was determined gravimetrically and the dissolved oxygen (DO) concentration was measured using profiline dissolved oxygen meter WTW. The ammonia (NH_3) concentration was analysed by Kjeldahl,s method and the alkalinity (CO_3^{2-} and HCO_3^-) were analysed by titration method. The biological oxygen demand (BOD) was analysed using Orion BOD fast respirometry system and the chemical oxygen demand (COD) was analysed using a HACH 2000 spectrophotometer at 600 nm wavelength. The data were statistically analyzed for intercorrelations matrix using Minitab 12 for Window.

Results and discussion

The results of the physico-chemical analysis of the river water samples are shown in tables 2 and 3.

The highest pH value (8.25) at Rosetta branch upstream El-Rahawy drain during summer

Table 1. Location of the study sites of the water quality at Nile delta, Egypt.

Taulukko 1. Tutkimuksessa käytetyt vedenlaadun mittauspisteet Niilin suistossa.

Site	Latitude	Longitude
RF Delta Barrage on Rosetta Branch	30°11’21.03”N	31°6’34.08”E
E1 Upstream El-Rahawy drain	30°12’48.79”N	31°2’39.26”E
E2 El-Rahawy drain outfall	30°12’26.53”N	31°1’57.84”E
E3 Downstream El-Rahawy drain	30°11’58.42”N	31°1’15.02”E
E4 El-Rahawy drain the middle	30°12’7.6”N	31°2’ 8.16”E
E5 El-Rahawy drain inlet	30°11’46.89”N	31°2’19.37”E
E6 El-Moheet drain	30°10’4.09”N	31°3’17.50”E
E7 El-Moheet drain	30°09’39.15”	31°3’31.16”E

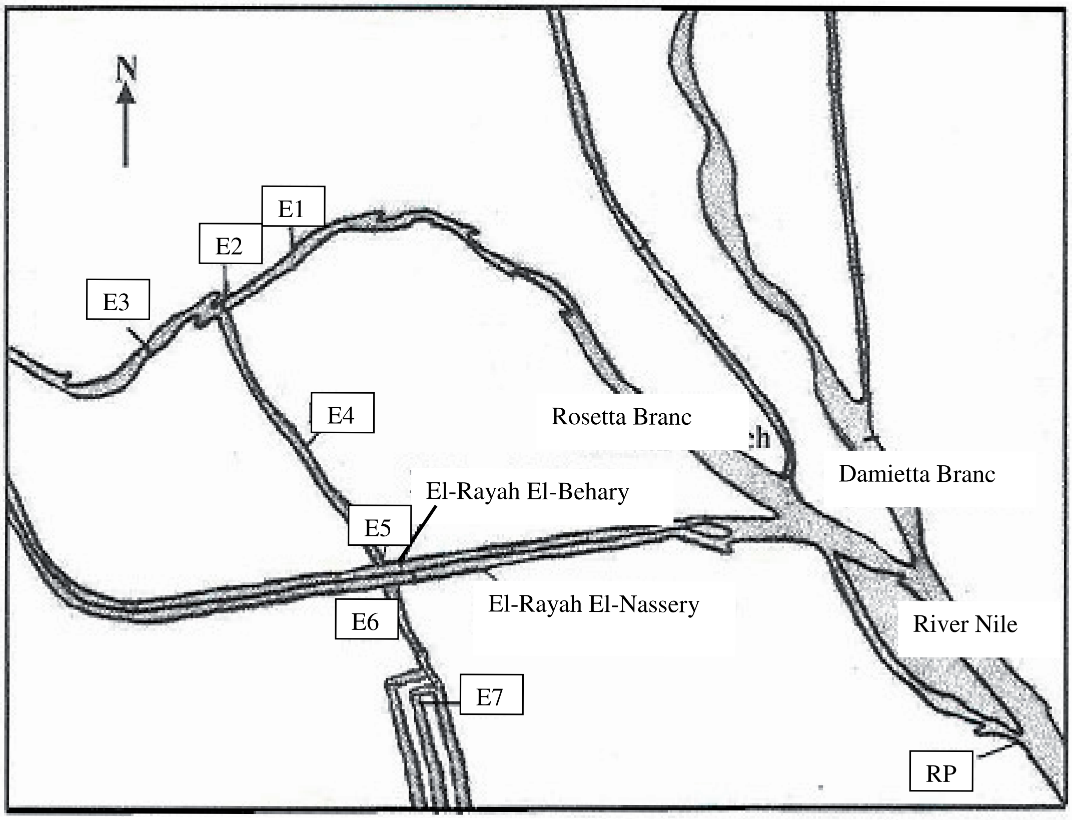

Figure 1. The locations of the study points (RP and E1–E7) of the river water quality at Nile delta, Egypt. For more detailed locations, see Table 1.

Kuva 1. Jokivedenlaadun mittauspisteet (RP, E1–E7) Niilin suistossa Egyptissä. Pisteiden tarkempi kuvaus taulukossa 1.

season, which is related to photosynthesis and growth of aquatic plants i.e. the photosynthesis consumes carbon dioxide leading to the increase in the pH value (Shakweer 2006). Respectively, the lowest pH value (7.11) was observed at the middle of El-Rahawy drain during winter season that was related to the high bicarbonate (HCO_3) concentration in water as a result of decreased uptake of CO_2 by phytoplankton (Abdel-Satar 2005). The measured pH values were within the range of the permissible limits (FAO 1985 and Egyptian Law 48/1982).

The measured electric conductivity (EC) in the river water of Nile was within the range of 0.31 to 0.46 mS cm^{-1}. However, in the drains of El-Moheet and El-Rahawy, the EC values were significantly larger (0.91 to 1.87 mS cm^{-1}) and the waters charging to the Rosetta branch from these drains affected the EC also in the Rosetta downstream, where those values varied from 0.41 to 1.32 mS cm^{-1}. These higher EC values are a result from the concentrations of soluble salts, cations and anions, which are higher in the drains than in the River Nile upstream water Ahmed 2007). The measured EC values were within the permissible limits of the water used for irrigation of agricultural crop lands (0.31–1.87 mS cm^{-1}) (see FAO 1985).

The concentration of the total dissolved solids (TDS) varied between 198–1200 mg l^{-1}. The highest concentration was found at the middle of El-Rahawy drain during winter that can be attributed to untreated agricultural and domestic wastes discharged into the drain (see El-Sherbini

& El-Moatassem 1990). All the measured TDS concentrations in El-Rahawy and El-Moheet drains were above the desirable limit of 500 mg l^{-1} throughout the year.

The concentration of dissolved oxygen (DO) in river water ranged from 0.38 to 5.57 mg l^{-1}. The water samples from El-Rahawy and El-Moheet drains had considerably low DO values and they were below the lowest permitted limit in Egypt (Egyptian Law (48/1982). The lowest concentrations, which were observed in winter (low flow conditions), can be related to the high transport of organic pollution and nutrients combined with low effluent rate and microbial decomposition of the organic matter.

The ammonia NH_3 concentration varied in the range from <0.20 to 23.90 mg l^{-1}. The highest concentrations were observed from El-Rahawy

Table 2. The measured characteristics of water quality in the study areas at Nile delta. For the sample sites, see Table 1 and Figure 1. For the abbreviations of the characteristics, see the text.

Taulukko 2. Mitatut jokivedenlaatua kuvaavat tunnukset ja ainepitoisuudet mittauspisteissä vuodenajoittain. Ks. mittauspisteet taulukossa 1.

Character	Season	RP	E1	E2	E3	E4	E5	E6	E7
pH	winter	7.85	7.85	7.3	7.36	7.15	7.2	7.28	7.25
	automn	7.95	7.96	7.31	7.36	7.28	7.28	7..32	7.28
	spring	8.01	7.93	7.6	7.8	7.25	7.29	7.43	7.34
	summer	8.11	8.21	7.7	7.84	7.31	7.32	7.37	7.34
EC, mS cm^{-1}	winter	0.46	0.48	1.53	1.32	1.87	1.75	1.57	1.59
	automn	0.44	0.45	1.25	1.23	1.37	1.37	1.26	1.37
	spring	0.38	0.4	1.44	1.22	1.69	1.6	1.44	1.56
	summer	0.31	0.33	0.91	0.41	1.1	1.09	0.98	1.09
TDS, mg l^{-1}	winter	300	309	980	850	1200	1120	1005	1020
	automn	292	286	801	786	884	882	807	879
	spring	262	242	925	784	1085	1028	925	1002
	summer	217	198	585	257	706	700	628	699
DO, mg l^{-1}	winter	5.16	5.17	1.23	2.4	0..38	0.4	0.52	0.5
	automn	5.12	5	1.52	3	0.52	0.59	0.74	0.58
	spring	5.31	5.28	1.44	3.24	0.57	0.5	0.78	0.65
	summer	5.57	5.5	1.75	4.32	0.63	0.76	0.95	0.86
NH_3, mg l^{-1}	winter	0.3	0.42	19.82	17.9	23.85	22.32	20	20.64
	automn	0.25	0.39	19.25	17.37	20.61	20.27	19.25	19.93
	spring	0.17	0.2	15.15	12.16	18.56	17.28	15.83	16.6
	summer	< 0.2	< 0.2	16.1	8.04	20.2	19.97	16.85	19.8
HCO_3^-, mg l^{-1}	winter	198	200	355	325	390	380	365	376
	automn	190	195	346	310	375	370	352	366
	spring	155.18	172	287.92	258	322.08	316.71	298.65	312
	summer	165	161	308	180	352	340	332	334
BOD, mg l^{-1}	winter	1	3	60	50	130	100	70	90
	automn	2	3	47	35	110	100	55	70
	spring	1	2	40	30	80	70	50	60
	summer.	1	1	20	18	75	65	47	55
COD, mg l^{-1}	winter	6	7	131	110	198	183	155	170
	automn	4	4	75	40	179	155	100	135
	spring	5	7	110	80	189	175	132	155
	summer	4	5	47	30	141	85	70	65

and El-Moheet drains, especially during winter, when the concentrations exceed the desirable limits (Egyptian Law (48/1982). These high values may be attributed to the increased denitrification ($NO_2^- \rightarrow NO_3^- \rightarrow NH_3$) in water, when the oxygen concentration is low. Respectively, it has been suggested that the lower ammonia concentrations during high flow conditions can be attributed to the oxidation of ammonia rather than the uptake of ammonia by the phytoplankton cells (Shabana 1999).

The total alkalinity (CO_3^{2-} and HCO_3^- concentrations) in water ranged from 155.8 to 390.0 mg l^{-1}. The concentrations of CO_3^{2-} were observed to be lower than HCO_3^- concentrations that can be attributed to the decomposition in the dead phytoplankton leading to the release of CO_2 dissolving to water in the form of HCO_3^-. The concentration of HCO_3^- measured at El-Rahawy and El-Moheet drain exceeds the permissible limits especially during low flow condition. This can be attributed to the lower air and water temperature during cool season that affect the carbonate reactions (Abdo 2005).

The BOD concentration varied between 1.0–134.0 mg l^{-1} and the COD concentration between 4.0–198.0 mg l^{-1}, respectively. The concentrations were also larger during low flow condition in El-Rahawy and El-Moheet drains, and they exceeded the desirable limits. Both the concentrations were related to the oxygen content in water. The low oxygen demand values during high flow condition (summer) indicates the low exports of organic pollution due to the dilution effect, whereas high BOD values indicate excessive export of biodegradable organic matter increasing the de-oxygenation of water to the level where fish and other aquatic life can not survive (El Bourie 2008).

When testing the mutual relationships between the measured element concentrations, most of the elements correlated significantly with each other (Table 4). The largest correlation ($r = 0.98$) was found between the dissolved oxygen (DO) concentration and water pH. With other elements, the DO concentration was in negative correlation. Both these parameters are significant indicators of the water quality being in correlation with numerous elements and ecological processes such as with primary production. They are also rather cheap and easy to measure. Thus, they can be use as good indicator values assessing the quality of river water at Nile delta.

Conclusions

El-Rahawy drain is the significant source of the water pollution of NH_3, COD, BOD, TDS to Rosetta branch of Nile river, especially during the low flow conditions. Particularly, the concentrations of oxygen in water of Rosetta branch showed to be at a significantly low level beyond the desirable limits of Egyptian and international rules and recommendations. This was due to the

Table 3. Mean concentrations of the analyzed water quality characteristics in river water of Rosetta and the limit values for good water quality according to the Egyptian law and international guidelines. LAW 48/1982: Egyptian Law for protection of the River Nile and water ways from pollution, FAO (1985): Food and Agriculture Organi¬zation Guidelines, 1985; CWQGs: Canadian water quality guidelines for the protection of aquatic life, 2002, —: No guideline available.

Taulukko 3. Jokivedenlaatutunnusten keskiarvot ja vaihteluvälit Niilin Rosettan haarassa sekä vertailuna Egyptin vesiensuojelulain sekä FAO:n ja Kanadalaisen CWQGs:n ohjeiston mukaiset hyvän vedenlaadun vähimmäisvaatimukset.

Character	Range	Mean	Law 48/1982	FAO	CWQGs
pH	8.11–7.15	7.5	7.8.2005	6.5–8.4	6.5–8.5
EC	1.87–0.31	1.1	-	<3	-
TDS	1200–198	707.6	500	<200	500
DO	5.57–0.38	2.21	>5	-	-
NH_3	23.85–<0.2	13.7	<0.5	-	-
HCO_3^-	155.8–390	293.3	<200	-	-
BOD	1–130	48.15	<6–10	-	-
COD	4–198	92.25	<10–15	-	-

Table 4. Relationships (correlation coefficients) between the water quality characteristics in river water at Nile delta.
Taulukko 4. Jokiveden laatutunnusten keskinäiset korrelaatiot tutkituilla alueilla Niilin suistossa.

Character	pH	EC	TDS	HCO_3^-	NH_3	DO	BOD	COD
pH	1							
EC	–0.994	1						
TDS	–0.994	0.999	1					
HCO_3^-	–0.994	0.995	0.995	1				
NH_3	–0.987	0.997	0.997	0.989	1			
DO	0.989	–0.984	–0.984	–0.995	–0.974	1		
BOD	–0.952	0.934	0.934	0.933	0.91	–0.926	1	
COD	–0.975	0.961	0.961	0.963	0.941	–0.957	0.994	1

exports from El-Rahawy drain, which is significantly polluted by domestic and agricultural waste waters.

In order to improve the water quality in river water of Nile delta, it would be essential to decrease the exports leaching to the drains discharging to the river. This would be possible, if the purification efficiency of the present waste water plants (such as Zeinen and Abo Rawash) is improved and larger amounts of the contaminated waters that now flows to the river are directed to the desert area, where it could be recycled in the agricultural use. Regular monitoring of water quality is also important to detect the pollution fluxes and restrict their environmental effects.

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Rosettan haara on toinen Niilin kahdesta päähaarasta Niilin suistoalueella ja niihin tulee runsaasti vesiä myös ympäröiviltä maa-alueilta. Yksi merkittävimmistä reiteistä, joilta tulee vettä Rosettan haaraan on El-Rahawy- uoma, joka kulkee myös merkittävien asutus-, teollisuus- ja maatalousalueiden kautta. Jätevesien puhdistus on näillä alueilla vajavaista ja siten runsaasti epäpuhtauksia kulkeutuu myös Niiliin uomia pitkin. Tietämys näiden päästöjen vaikutuksista Niilin vedenlaatuun on kuitenkin puutteellista, koska vedenlaadun seurantamittauksia on tehty vain vähän.

Tämän tutkimuksen tarkoituksena oli selvittää El-Rahawy uoman kautta tulevien epäpuhtauksien vaikutusta Niilin Rosettan haaran vedenlaatuun. Selvityksessä tehtiin vedenlaatumittauksia kahdeksasta paikasta Rosettan haarassa ja El-Rahawy-uomassa eri vuodenaikoina yhden vuoden ajanjakson aikana. Tutkittavina tunnuksina olivat jokiveden happamuus (pH), kiintoainepitoisuus, veden sähkönjohtavuus, happipitoisuus, ammoniakkipitoisuus, alkaliteetti sekä biologinen ja kemiallinen hapenkulutus. Mitattuja lukuarvoja verrattiin vastaaviin kotimaisiin ja kansainvälisiin hyvälaatuisessa jokivedessä sallittuihin aineiden pitoisuuksien raja-arvoihin. Selvitys osoitti, että El-Rahawy-uoman kiintoaine- ja ammoniakkipitoisuus sekä biologinen ja kemiallinen hapenkulutus olivat selkeästi suosituksia suuremmat ja happipitoisuus hyvin pieni. Uomaa pitkin tulevat aineet vaikuttivat merkittävästi myös Rosettan haaran vedenlaatua heikentävästi erityisesti pienten virtaamien aikaan talvella. Lopuksi esitetään toimenpide-ehdotuksia jokivedenlaadun parantamiseksi.

Avainsanat: jokivesi, virtaama, kuormitus, El-Rahawy.

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