Effects of industrial pollutants on physicochemical characteristics of the River Nile water and fish productivity

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Abstract: River Nile is one of the longest rivers in the world, (6850 km). Its basin has an area of 2.9 million km^2. This area includes parts from eleven African countries through which the Nile passes, namely, Ethiopia, Eritrea, Uganda, Burundi, Tanzania, Rwanda, Sudan, South Sudan, Democratic Republic of Congo, Kenya and Egypt. The Nile River of Egypt is an unusual river system because of its arid climate setting and the impact of the Aswan High Dam. River Nile is the principal freshwater resource for Egypt that has a wide usage in different fields include drinking, domestic water supply, agricultural, industrial, navigation, fishery and others. It flows 1,350 km from the Aswan High Dam, to its discharge into the Mediterranean Sea. At the city of Cairo, the River Nile bifurcates into two branches enclosing the delta region between them. These are the Rosetta (the western) branch and the Damietta (the eastern) branch that discharge Nile water into the Mediterranean through the Nile estuary. River Nile flow rate relies on the available water stored in Lake Nasser to meet needs within Egypt's annual share of water, which is fixes at 55.5 Billion Cubic Meters (BCM) annually according to an agreement signed with Sudan in 1959.
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Introduction:

Effects of industrial pollutants on physicochemical characteristics

Industrial effluents are characterized by their abnormal turbidity, conductivity, pH, temperature, chemical oxygen demand (COD), biological oxygen demand (BOD), total suspended solids (TSS), total hardness, nitrogen and phosphorus **(Ezenobi and Okpokwasili, 2004; Kanu and Achi, 2011)**. The Ministry of Irrigation and Water Resources declared the **Egyptian governmental law No. 48 (1982)** which deals with protection the River Nile and its waterways from pollution. The water quality standards provided by this law are presented in table (1).

Table (1): Water quality standards for protecting River Nile and freshwater resources from pollution according to Egyptian governmental law No. 48 (1982).

Item	Permissible limit	Item	Permissible limit
Temperature	5°C above normal	Arsenic (As)	< 0.05 mg/l
pH	7 - 8.5	Cadmium (Cd)	< 0.01 mg/l
Turbidity	< 30 mg/l	Chromium (Cr)	< 0.05 mg/l
Total solids (TS)	< 500 mg/l	Copper (Cu)	< 1 mg/l
Total dissolved solids (TDS)	< 1200 mg/l	Iron (Fe)	< 1 mg/l
Dissolved oxygen (DO)	≥ 5 mg/ l	Lead (Pb)	< 0.05 mg/l
Biological oxygen demand (BOD)	≤ 6 mg/l	Mercury (Hg)	< 0.001 mg/l
Chemical oxygen demand (COD)	≤ 10 mg/l	Nickel (Ni)	< 0.1 mg/l
Ammonia (NH_3)	< 0.5 mg/l	Zinc (Zn)	< 1 mg/l
Nitrate (NO_3)	45 mg/l	Phenols	< 0.02 mg/l
Total nitrogen	1 mg/l	Detergents	0.5 mg/l
Nitrite (NO_2)	-	Cyanides	< 0.1 mg/l
Phosphate (PO_4)	< 1 mg/l	Color	Free
Sulphate (SO_4)	< 200 mg/l	Oil and grease	< 0.1 mg/l
Chlorine (Cl)	1 mg/l	All Pesticides	0.00

The quality and the nature of water can be determined by physical and chemical analysis. Effluents resulting from daily industrial activities may induce considerable changes in the physicochemical properties of water bodies **(Abdel-Satar and Elewa, 2001)**. Any disturbance in the following parameters can cause harmful effects on fish.

Water temperature

Fish are poikilothermic animals, which their body temperature are characterized by similarity with surrounded water temperature (± 0.5–1.0 °C). In natural environment, fish can easily tolerate the seasonal changes in temperature. However, these changes should not be abrupt, because temperature shock occurs if the fish suddenly exposed to colder or warmer temperatures through showing symptoms of paralysis of the respiratory and cardiac muscles **(Svobodová, 1993)**. Water temperature has a great influence on the initiation of most fish diseases **(Deane and Woo, 2009)**. Moreover, water temperature controls the rate of response to toxic concentrations, where causing increase toxicity, as well as affects the ionization of ammonia and dissolved oxygen (DO) **(Zaki *et al.*, 2012b)**.

Water pH

The optimal pH for fish is ranged from 6.5 – 8.5. Above or below the optimal range can cause harmful effect and eventually kill fish **(Boyd, 1990)**. This harmful effect can be direct on the ability of fish to maintain their natural salt balance or indirect such as reducing food supply **(Zaki *et al.*, 2012b)**. Acidic water doesn't support the growth of phytoplankton, zooplankton and detritus-digesting bacteria. All these organisms are important as they collectively provide an environment conducive for fish growth **(Birungi *et al.*, 2007)**. External symptoms like hemorrhages in gills and lower part of body have been noticed with extremely high or low pH values **(Carvalho and Fernandes, 2006)**. Water pH also has a significant influence on the toxic action of a number of other substances on fish (e.g. ammonia, hydrogen sulphide, cyanides, and heavy metals) **(Köhler *et al.*, 2002)**.

Dissolved oxygen

The factor most frequently responsible for a significant reduction in the oxygen concentration of the water (oxygen deficiency) is pollution by biodegradable organic substances (including wastewaters from the food industry). These substances are decomposed by bacteria which use oxygen from the water **(Palanivelu *et al.*, 2005)**. The concentration of organic substances in water can be measured by means of the chemical oxygen demand (COD) and the biological oxygen demand (BOD). Oxygen deficiency causes asphyxiation and fish will die, depending on the oxygen requirements of the species and to a lesser extent on their rate of adaptation **(Boyd, 1990)**. Fish exposed to oxygen deficient water showed stress way like, do not take food, collect near the water surface, gasp for air, become torpid, fail to react to irritation, lose their ability to escape capture and ultimately die **(Fang *et al.*, 2004)**. In addition, reduced DO causes increased toxicity of pollutants and pathological changes in gills **(Zaki *et al.*, 2012b)**.

Ammonia

Ammonia pollution of water may be caused by industrial effluents from gas works, coking plants and power generator stations. Ammonia is highly toxic to fish. The first signs of ammonia toxicity include a slight restlessness and increased respiration. In later stages, fish gasp for air, their restlessness increases with rapid movements and respiration becomes irregular; then follows a stage of intense activity. Finally, the fish react violently to outside stimuli; they lose their balance, leap out of the water, and their muscles twitch in spasms **(Randall and Ip, 2006)**. Affected fish lay on their side and spasmodically open wide their mouths and gill opercula; the body surface becomes pale and the fish die **(Eddy, 2005)**.

Nitrites, nitrates and total nitrogen

The main sources of nitrate, nitrite and total nitrogen pollution of surface water are the discharge of industrial effluents **(Grosell and Jensen, 2000)**. The toxic action of nitrite on fish is incompletely known. However, it depends on a number of internal and external factors (such as fish species and age, and general water quality) **(Doblander and Lackner, 1996)**. Nitrite ions are taken up into the fish by the chloride cells of the gills. In the blood, nitrites become bound to hemoglobin, giving rise to methemoglobin, and then reduce the oxygen transporting capacity of the blood **(Kroupova *et al.*, 2008)**. The toxicity of nitrates to fish is very low, and mortalities have only been recorded when concentrations have exceeded the permissible limits **(Amisah and Cowx, 2000)**.

Other physicochemical parameters affecting fish are turbidity (transparency or suspended solids), total solids (TS), total dissolved solids (TDS), electrical conductivity (EC) and phosphate. In particular, turbidity induces physiological stress in many aquatic organisms; reduce water clarity/visibility, reducing the amount of sunlight and primary production, the basis of the food web. Many studies have reported altered spawning behavior, reduced larval survival, decreased growth, and reduced diversity of fishes in response to turbidity **(Blann *et al.*, 2009)**. Higher values of electrical conductivity in aquatic system indicate the presence of high content of dissolved solids and high amount of organic and inorganic constituents **(Saad *et al.*, 2011)**. Phosphorus (phosphate) is a plant nutrient that can cause the excessive growth of algae and eutrophication which cause depletion of dissolved oxygen **(Anders and Ashley, 2007)**.

Effects of industrial pollution on physicochemical characteristics of the River Nile water

Several studies were carried out on the effect of industrial pollution on physicochemical characteristics of the River Nile water. The study which carried on the water quality of the River Nile in front of industrial area of Shoubra El-Kheima revealed deterioration in the physicochemical characteristics of the water due to the thermal pollution of electric power station **(Elewa *et al.,* 2001)**. Also, **Abdo (2002)** recorded abnormal values of different physical and chemical parameters of water in the Rosetta branch of the River Nile at areas affected by different industrial wastes discharged. Similarly, **Sayed (2003)** pointed out that, the water quality of Rosetta branch of the River Nile was potentially affected and threatened by Kafr El-Zayat industrial area which discharge wastes into the branch. Moreover, **Abdel-Satar (2005)** investigated the water quality of the River Nile from Idfo to Cairo, and recorded a steady increase in EC, TS, TDS, COD and ammonia from south to north. **Ahmed (2007)** studied the surface and bottom water quality of the River Nile at Helwan and showed increasing in BOD, COD, ammonia, nitrite, nitrate and decreasing in DO and transparency and attributed these changes to industrial wastes at this region. **Moustafa *et al.* (2010)** assessed the water quality of Rosetta and Damietta branches of the River Nile by studying the seasonal variation of DO, BOD, HCO^-_3 and TDS and mentioned that the water of Damietta branch was better than Rosetta branch, this was attributed to the presence of many sources of pollution along the extent of Rosetta branch, especially factories in Kafr El-Zayat City. **Abdo (2010)** recorded the highest EC values at sites received industrial effluents at Rosetta Nile Branch from Kafr El-Zyat Company area. **Osman *et al.* (2012)** evaluate the impact of industrial contaminants along the whole course of the River Nile, on water quality and recorded higher values of EC, COD, NH_3, NO_3, TS, SO_4, Cl and orthophosphate in the water of Damietta and Rosetta branches due to the greater level of contamination, where more industrial effluents have been released without adequate treatment.

Effects of water quality deterioration on fish productivity

Several studies were carried out on different fish species to evaluate the negative impacts of water quality changes with different types of pollutants in River Nile. **Tayel (2003)** observed clear increasing in the concentration of BOD, COD, EC, NH_3, NO_2 and NO_3, and decreasing in transparency of the river Nile water at El-Kanater El-Khyria, and these changes affect some hematological parameters (increase in WBCs count, protein, lipid and glucose and depletion in RBCs count) of *Clarias gariepinus* fish. Also, the study observed pathological alterations (fibrosis, necrosis, degeneration, fatty degeneration, hemorrhage, hemolysis, accumulation of hemosiderin; hemorrhage in primary and secondary lamellae, dilation, congestion in blood vessels, hyperplasia, degeneration, necrosis, and separation of epithelial cells of secondary lamellae; degeneration in muscle bundles and focal areas of necrosis) in liver, gills and muscles of some collected fish. **Bayomy and Mahmoud (2007)** noticed that *Clarias gariepinus* caught from El-Qanater El-Khyria and Helwan sites of the River Nile were suffering from increase in glucose, hemoglobin, AST and ALT in their blood due to the depletion in DO content and increase in temperature, BOD and COD of water which attributed to heavy load of industrial wastes discharged into the River Nile from several plants occurring there. **Tayel (2007)** showed changes in water quality (increase in temperature, pH and ammonia and depletion in DO levels) at Damietta branch of the River Nile, accompanied with alterations in skin and muscles of *Oreochromis niloticus* fish including, degeneration, necrosis, edema, hemorrhage, hemolysis and accumulation of hemosidrin pigments. The author attributed these results to the effect of industrial zone at Talkha on water quality and fish health. Also, **Tayel *et al.* (2008)** observed higher levels of total serum proteins, total serum lipids, and glucose, and several histopathological alterations in liver and spleen of *Clarias gariepinus*, obtained from the River Nile at El-Rayah El-Menoufy, due to water quality changes. **Saad *et al.* (2011)** reported that, the changes in water quality in River Nile at El-Kanater El-Khyria have negative impacts on blood biochemical parameters (increase in glucose, protein, albumin, globulin, ALT, AST, uric acid and urea levels) and histology of liver and spleen of *Clarias gariepinus* fish which consequently affect fish production.

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