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Environmental assessment of drainage water impacts on water quality and eutrophication level of Lake Idku, Egypt☆

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ABSTRACT

Lake Idku, northern Egypt, receives large quantities of drainage water from four main discharging drains. Ecological and biological status of Lake Idku has been monitored during (autumn 2012 to summer 2013) to examine the lake water quality and eutrophication level in response to the quality as well as the source of the discharging water. Discrete water samples were collected from the lake body and the drains. Chemical analyses revealed an excessive nutrient load goes into the lake. A range of 1.4–10.6 mg nitrites/L was determined for drain waters, however a sudden increase was observed in lake and drain water samples of up to 84 and 74.5 mg/L, respectively. Reactive silicate ranged between 2.9 and 4.8 mg/L; while inorganic phosphate fluctuated between 0.2 and 0.43 mg/L. Transparency varied from 45 cm to 134 cm with better light conditions at drain sites. Biological results indicated a hyper-eutrophic status for the lake with a range of chlorophyll-a varied from a minimum of 39.9 μg/L (at Idku Drains) and a maximum of 104.2 μg/L (at El-Khairy drain). Phytoplankton community structure revealed higher abundance at lake sites compared with the drains. Maximum phytoplankton density was detected during summer with the dominance of Bacilariophyceae (e.g. Cyclotella meneghiniana, Cyclotella comate, Melosira varians) followed by Chlorophycean taxon (e.g. Scenedesmus dimorphus, S. bijuga and Crucigenia tetrapedia). Five indices were applied to evaluate the water quality of the lake. Diversity Index (DI) indicated slight to light pollution along all sites; while Sapropic Index (SI) indicated slight pollution with acceptable oxygen conditions and an availability of sensitive species. Palmer Index (PI) gave a strong evidence of high organic pollution at some sites in the lake, while Generic Diatom Index (GDI) revealed that levels of pollution varied from average to strong. Trophic Index (TI), suggest that there are an obvious signs of eutrophication in the lake.

1. Introduction

The Mediterranean Coastal Region of Egypt extends for about 970 km, from Sallum to Rafah, with five natural lakes along this coast occupy about 6% of the non-desert surface area of Egypt (Abu Al-Izz, 1971), of which Lake Idku occupies about 70×10^3 Km^2. Lake Idku is considered as an important local fishing ground with an average production of 500 kg fish/feddan (i.e. 8500 tones fish/year). The lake is currently contributing with 8.8% of the total national agricultural income in 2014. After the construction of the Aswan High Dam, considerable changes have been observed in the morphology, water characters and biotic composition of the northern lakes (Aleem, 1972; Nixon, 2004; Tortajada et al., 2012). In addition, they became subjected to gradual shrinkage due to land reclamation and transformation of significant areas into fish farms and aquatic vegetation overgrowth which reduce the entrance of open sea water into the lake and hence speed up the process of land transformation (Ali and Abou El Magd, 2016).

Naturally, oligotrophic water bodies require thousands of years, if brought under natural succession, to become eutrophic. However, increasing discharges of human wastes and excessive fertilizers from agricultural lands brings such water bodies down under an undesirably increased rate of eutrophication (Khan and Ansari, 2005). Lake Idku receives huge amounts of drainage water from four main drains, which open into the eastern and the southern basin of the lake (Okbah and El-Gohary, 2002). According to Abdel Moati and El-Sammak (1997), the amount of water discharged

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annually is about 2.06×10^9 m^3. The drainage water contains unspecified quantities of urban, industrial and agricultural chemicals from the Beheira Governorate and beyond. The development of an irrigation and drainage system in its catchment area together with other human-induced pressures and interferences have played an important role in lakes deterioration and water pollution (Ahmed et al., 2001).

The agricultural drainage water containing pesticides, fertilizers and effluents of industrial activities and runoffs in addition to sewage effluents supply the lake water body and sediment with huge quantities of inorganic anions, such as phosphates, nitrates, and ammonia, combined organic nitrogen and/or heavy metals (Shaltout and Khalil, 2005; Khan and Ansari, 2005). These conditions accelerate biological productivity along the lake although being classified among the oligotrophic lakes several years ago (Gharib, 1999), however, it is currently described as eutrophic lake with a tendency to hypertrophy (Zaghloul and Hussein, 2000; Ossman and Badr, 2010). Similarly, effluents from urbanized Bangalore city (India) have changed the oligotrophic nature of Lake Bellandur to become an artificial reservoir of domestic sewage and industrial effluents (Chandrashekar et al., 2003).

Nutrient enrichment to such aquatic ecosystem is mostly followed by alterations in phytoplankton community structure (Ali, 2009). Since phytoplankton has a critical role in primary production, nutrient cycling, food webs and make up a significant proportion of the primary production in aquatic systems of the lakes (Dawes, 1998), any change in their composition, density and spatial distribution will affect the secondary producers, consumer and decomposers characteristics (Mohamed, 2005). Such nutrient richness creates good habitats for submerged plants which have an essential structuring affect on the whole ecosystem (Meerhoff and Jeppesen, 2009). It is well documented that most shallow lakes are highly productive per unit area of water compared to that of deep ones due to the greater recycling of nutrients that are directly availability to primary producers, especially phytoplankton and periphyton (Jeppesen et al., 1997; Moss, 1998). Un-planned human activities will not only cause the loss of important unique wetland habitats, but also will create new artificial un-balanced ecosystems (El-Banna and Frihy, 2009). Human activities seriously impacted the ecosystem biodiversity through several ways. For example, it accelerates conductivity changes which led to reductions in biodiversity (Davies et al., 2002; John et al., 2007).

Pollution of Lake Ldku and other shallow water ecosystems is a worldwide problem that imposes hazardous effects on health of the local community beside its vigorous impacts on the national economy as a major threat to the aquatic organisms including fish. The national production of fisheries resources in Egypt has been greatly changed (see Diagram I) during the last decades (i.e. from 80's till 2007) with dramatic diminishes in lakes production (Mehanna, 2008). According GAFRD (2014) the annual fish production of Lake Idku diminished from 10,910 tonnes in 2001–5855 tonnes in 2014 which evaluated at > 40% loss of the lake production.

Lake Idku was contributing with about 5.3% to the national income in 2014 (GAFRD, 2014) compared about 9% in 2013 (GAFRD, 2009). This is attributed to several factors including the overfishing activities, clarification practices as well as the continuous deterioration of the lake.

The operational management of water quality of aquatic ecosystems requires a methodology that can provide precise information on cycles and trends in water quality in an objective and reproducible manner. Such information can be provided by monitoring water quality variables and adoption of a water quality indexing system. To improve the ecosystem of Lake Idku, it is recommended to simulate the standard conditions for the lake and propose applicable mitigation measures with good alternatives for the lake restoration. The "optimal" strategy, according to Ansari and Khan (2014), should adopt an effective (decreasing the loading with a sufficient number of tons) and cost-effective (at the lowest possible cost) manners.

Environmental indicators and integration of environmental and human systems into a common conceptual framework is becoming an applicable approach based on the causality chain framework are became an important tool in decision-making for aquatic environment restoration. A national water framework directive should be proposed to protect, prevent further deterioration and enhance the status of aquatic ecosystem in Egypt. This, according to the European Water Framework Directive (WFD), needs to characterize the surface waters and identify the ecotypes (e.g. rivers, lakes, Transitional waters, Coastal waters and all heavily modified or artificial surface water bodies). Source: Scottisch Enviromental Protection Agency (SEPA) http://www.scotland.gov.uk/Publications/2011/03/16182005/31. In addition, the DPSIR framework (Drivers-Pressure-State- Impact-Response) is formally an adaptive environmental management approach developed by the European Environmental Agency (EEA, 1999). This approach is dealing with the drivers that generate the pressures to the environment that modify its state, causing the impacts, and then helps to identify responses.

2. Description of the study area

2.1. Geographical location

Lake Idku (Fig. 1) is a shallow brackish coastal basin situated on the western margin of the Nile Delta, 30 km to the east of Alexandria with an area of about 126 km^2 (El-Shenawy, 1994). It lies west of the Rosetta branch of the River Nile, and extends from east to west for a distance of about 19 km, with a surface area of about 85 km^2 and an average depth of about 1 m. It is adjoining the Mediterranean coast at latitude 31° 15′ N and longitude 30° 15′ E. It has an average width of 6 km with an average depth of about one meter.

Lake Idku is directly connected with the Mediterranean Sea at its western extremity through a narrow channel (Boughaz EL-Maadiya). The lake receives large quantities of drainage water ($83–280 \times 10^3$ m^3 day^{-1}) released from agricultural land of Beheira Province via three discharging points from four main drains [El-Khairy (D1), Idku (D2), El-Bouseily (D3) and Barzik (D4)]. Drainage water is discharged into the lake through a group of pumping stations (see the schematic diagram in Fig. 2a). Idku (D2) and Barsik (D4) drains are the most important drains, with regards to the water volume discharging into the lake with a monthly discharge of about 222.6 and 98.8 million m^3/month, respectively (DRI, pers. *comm.*) (Table 1). The lake communicates with the Mediterranean Sea (at the village of Maadiya) through a narrow 2-m depth short channel (Boughaz El-Maadia). The width of the lake (N-S direction) is about 11 km at its widest part, where the narrowest part is only about 5 km.

2.2. Idku hydrological data

The lake receives large quantities of drainage water ($83–280 \times 10^3$ m^3 day^{-1}) released from agricultural land of Beheira Province via three discharging points from four main drains (ElKairy, Idku, El-Bouseily and Barzik). Barsik (D4) and Idku (D2) drains are considered the most important drains among others with regards to the water volume discharging into the lake with a monthly discharge of about 222.6 and 98.8 million m3/month, respectively (DRI, pers. *comm.*) (Table 1).