ARTICLE IN PRESS

Egyptian Journal of Aquatic Research (2017) xxx, xxx–xxx

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National Institute of Oceanography and Fisheries

Egyptian Journal of Aquatic Research

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FULL LENGTH ARTICLE

Indices of water quality and metal pollution of Nile River, Egypt

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Received 25 June 2016; revised 24 December 2016; accepted 25 December 2016

KEYWORDS

Nile River;
Water quality;
Water quality index;
Heavy metal pollution index;
Contamination index

Abstract Nile River is the valued natural and exclusive source of fresh water in Egypt, where the drinking water supply is limited to the river. The water quality of 24 sites between Aswan and Cairo along the Nile was investigated. To evaluate the suitability of water for aquatic life and drinking purposes, the indices of water quality (WQI), heavy metal pollution (HPI) and contamination (C_d) were computed. The water quality variations were mainly related to inorganic nutrients and heavy metals, where, the sites affected by intensive load of urban, agricultural and industrial wastewater showed serious deterioration of water quality compared with other sites. The anthropogenic impact sites showed high HPI and C_d values and associated with high risks, where, most of the studied metals often exceeded the drinking water and aquatic life limits. The aquatic WQI indicated that the Nile water quality deteriorated and extended from poor to marginal, while drinking WQI varied from marginal to good. Accordingly, the river becoming unfit for aquatic life and the situation is getting worse by decreases in the water budget from the Nile in Egypt by building of the Grand Ethiopian Renaissance Dam, where the dilution strength of the Nile system will reduce.

Introduction

Freshwater is essential for human life and its quality is a matter of global concern. The Nile River is the life artery of Egypt and represents the main freshwater resource needed for nearly all drinking and irrigation water demands (Ali et al., 2014). Nile River water quality has been steadily deteriorating over several decades due to the dumping of untreated effluents and anthropogenic inputs. However, the Aswan High Dam (AHD) construction resulted in significant changes in physical, chemical and biological properties of the downstream Nile water (Abdel-Satar, 2005; Abd El-Hady, 2014).

The quality of Nile water is a matter of serious concern due to the expansion of industrial, agricultural and recreational activities in addition to the poor structured drainage and sewerage system (Goher et al., 2015). The changes in water quality of Nile River are influenced not only by water management interventions like the hydrodynamic regimes regulated by the Nile barrages, but also, by the land and water use, including

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Peer review under responsibility of National Institute of Oceanography and Fisheries.

http://dx.doi.org/10.1016/j.ejar.2016.12.006
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agricultural return, industrial, municipal and river ships wastewaters (Abdel-Satar, 2005; Shamrukh and Abdel-Wahab, 2011).

Degradation of Nile River water quality is a major issue in Egypt. The water quality released from AHD remains relatively clean from contamination and shows little degradation until it reaches the Delta (Masoud et al., 2002). The quality of Nile water showed some improvement in the average during the high flood period, where excess water behind the AHD is discharged into Nile River, which renews the water in the river (Abdel-Shafy and Aly, 2002). The water quality of mid-stream Nile water is still, at a clean level on an average, due to the dilution effect and the degradation of the discharged pollutants (Abdel-Satar, 2005). Major point sources of pollution in Nile River are the discharge of untreated sewage from open drains carrying agricultural return flows; sewage and industrial wastewater (Abd El-Hady, 2014). The Nile River from Aswan to Delta Barrage receives drainage water from 67 agricultural drains of which 43 are considered major drains. However, 10 drains only are compliant to the Egyptian standards that regulate the admissible quality of the drainage water discharged into the Nile (Agricultural Policy Reform Program, 2002; Shamrukh and Abdel-Wahab, 2011). The rise in the level of pollution caused by the Nile's low water level becomes the major problem facing Egypt; especially after completing the Ethiopia Dam building. Heavy metals are considered the main pollutant in Nile River, where the contamination of Nile water by it is mainly derived from multiple anthropogenic sources including industrial, agricultural and domestic effluents. Heavy metal contamination of surface water is a serious ecological problem due to their potential toxicity for human beings and the environment. They are non-degradable and can bioaccumulate through the food chain (Shamrukh and Abdel-Wahab, 2011; Ezzat et al., 2012; Goher et al., 2014).

Water quality index is a mathematical mechanism for summarizing the water quality data into simple terms (e.g., Excellent, good, bad, etc.); it reflects the level of water quality in rivers, streams, and lakes (Al-Shujairi, 2013). The water quality class is defined depending on the measured physical, biological and chemical parameters besides the purposes for water used such as; drinking water, water used in agriculture, or water used in industry (Sargaonkar and Deshpande, 2003). Also, the metal quality indices have been applied for assessing the drinking water resources with respect to metals (Mohan et al., 1996; Backman et al., 1997).

Water quality evaluation of Nile River water is very important to see the feasibility of using the Nile water as a source for various activities like suitability for aquatic life and drinking. The present study was aimed to evaluate the current water quality of Nile River from Aswan to Cairo through several physical and chemical analyses using indices of water quality (WQI), heavy metal pollution (HPI) and contamination (C_d).

Materials and methods

Study area

The Nile is the main source of fresh water in Egypt; its flow rate relies on the available water stored in Nasser Lake to achieve needs within Egypt's annual water budget (Agricultural Policy Reform Program, 2002). The Nile River enters Egypt at its southern boundary with Sudan and runs through a narrow valley (1000 km long) which varies from 2 to 20 km in width. Subsequently, it is bifurcate at a distance of 25 km (north of Cairo) into the Rosetta and Damietta branches forming a delta with its base on the Mediterranean Sea shore (NBI, 2005). The water allowed to pass through AHD is 55.5 km^3/year as set out in an agreement with Sudan in 1959 (Wahaab and Badawy, 2004). The uncontrolled dumping of anthropogenic waste from different drains located along the Nile banks has significantly increased the Nile water contamination to the critical level (Shamrukh and Abdel-Wahab, 2011). Most of the industries in Egypt have made little effort to meet Egyptian environmental laws cited for Nile protection, where, the Nile supplies about 65% of the industrial water needs and receives more than 57% of its effluents. Excessive application of fertilizers and pesticides in agriculture also causes water pollution problems for Nile River (Wahaab and Badawy, 2004). Loads of organic and inorganic pollutants discharged from drains into the Nile in the studied area were presented in Table 1.

Samples collection and analysis

24 water quality monitoring sites were set up on the main stem of the river, covering 925 km along the Nile, Fig. 1. The area under investigation extended from Aswan (24° 2′13.26″ Lat. and 32°51′57.02″ Long.) to Cairo (30° 8′52.23″ Lat. and 31° 9′43.81″ Long.). Environmental monitoring system contains 5 sites from 24 selected to monitor potential anthropogenic impacts from agricultural activities, municipal and industrial wastewater on Nile quality. The water quality sampling sites are presented in Table 2. Duplicate co-located samples were collected at a monitoring site, where, the percent difference between the laboratory results recorded for the various samples were less than 10%. Water samples were collected just under the water surface for analysis of selected parameters. The analysis was done upon 29 physical and chemical parameters. Transparency, electrical conductivity (EC), temperature and pH were recorded in situ using Secchi-disc, USA conductivity meter (S.C.T.33 YSI) and pH500/mv/Temp meter, respectively. Chemical variables were estimated according to the procedures laid down in APHA (1998). The analysis of total Cd, Pb, Cu, Ni, Zn, Mn and Fe were determined after water sample digestion by conc. HNO_3 using the Australian

Table 1 Loads of organic and inorganic pollutants* discharged from drains into the Nile in the studied area.

Drain name	Discharge Mm^3/day	COD kg day^{-1}	BOD kg day^{-1}	Heavy metals kg day^{-1}
Kom Ombo	0.1439	218,099	59,704	309.1
Etsa	0.5680	56,798	21,583	105.4

* Cited from NBI (2005).