EVALUATION OF DIFFERENT WATER QUALITY PARAMETERS FOR THE NILE RIVER AND THE DIFFERENT DRAINS

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ABSTRACT

A water quality index is a mean to summarize large amounts of water quality data into simple terms (e.g., good) for reporting to management. It is useful as information about the overall quality for the different water resources for the different water uses. In this paper, different water quality parameters are selected namely, Dissolved oxygen (DO), Nitrate (NO_3), Biochemical oxygen demand (BOD) and Chemical oxygen demand (COD). The index is calculated for the Nile River and the drains. The results conclude that DO, NO_3 and BOD conditions vary from good to excellent for the Nile and from fair to good for the drains. The worst conditions are registered for the COD, where the quality status is poor for both the Nile and the drains

Key Words: Drains water quality, Nile River, Water quality index

INTRODUCTION

The data used in this paper are collected through work plan of the National Water Quality and Availability Management project (NAWQAM) which recommend two yearly field trips during February and August. Five field trips were carried out during the period from February 2000 to August 2002. The first three field trips were carried out in February 2000, August 2000 and in February 2001 during the baseline phase, while the last two field trips were carried out in March and August 2002 during the national monitoring phase. The fourth and the fifth trips were carried out according to the new modified monitoring program. This program includes collecting water samples from 4 sites in Lake Nasser, 25 sites from the Nile River and its two branches in addition to 9 irrigation canals and 2 Rayahs. Moreover, 29 point sources of agricultural drains at the spillage points into the Nile River are monitored. The current study concentrates on the analysis of four selected water quality parameters along the Nile River and the monitored drains.

WATER QUALITY INDEX

An integral part of any environmental monitoring program is the reporting of results to both managers and the general public. This poses a particular problem in the case of water quality monitoring because of the complexity associated with analyzing a large number of measured variables. The traditional practice has been to produce reports describing trends and compliance with official guidelines or other objectives on a variable by variable basis. The advantage of this approach is that it provides a wealth of data and information. Rather, they require statements concerning the general health or status of the system of concern. One possible solution to this problem is to reduce the multivariate nature of water quality data by employing an index that will mathematically combine all water quality measures and provide a general and readily understood description of water. In this way, the index can be used to assess water quality relative to its desirable state (as defined by water quality objectives) and to provide insight into the degree to which water quality is affected by human activity.

The applied water quality index (Canadian Water Quality Index) has been developed by the Water resources Management Division for application in Newfoundland and Labrador. Water quality variables (e.g., DO, BOD, NO_3) are compared to water quality guidelines or site-specific objectives. The results of those comparisons are combined to provide a water quality ranking (good, average, poor) for individual water bodies (CCME, 2001 [12]).

The advantage of an index include the ability to represent measurements of a variety of variables in a single number, the ability to combine various measurements in a variety of different measurement units in a single metric, and the facilitation of communication of the results.

The index is based on three attributes of water quality that relate to water quality objectives:

Scope- How many? The number of water quality variables that do not meet objectives in at least one sample during the time period under consideration, relative to the total number of variables measured.

Frequency- How often? The number of individual measurements that do not meet objectives, relative to the total number of measurements made in all samples for the time period of interest.

Amplitude- How much? The amount by which measurements which do not meet the objectives depart from those objectives.

CALCULATION OF THE INDEX

The body of water, the period of time and the variables and objectives should be defined first. Then the three factors that make up the index must be calculated. The calculation of F_1 and F_2 is relatively straightforward and F_3 requires some additional steps (CCME, 2001 [12]).

F_1 (Scope) represents the percentage of variables that do not meet their objectives at least once during the time period under consideration ("failed variables"), relative to the total number of variables measured.

$$F_1 = \left[\frac{\text{Number of failed variables}}{\text{Total number of variables}}\right] * 100 \qquad (1)$$

F_2 (Frequency) represents the percentage of individual tests that do not meet objectives ("failed test"):

$$F_2 = \left[\frac{\text{Number of failed tests}}{\text{Total number of tests}}\right] * 100 \qquad (2)$$

F_3 (Amplitude) represents the amount by which failed test values do not meet their objectives. F_3 is calculated in three steps.

1) The number of times by which an individual concentration is greater than (or less than, when the objective is a minimum) the objective is termed an "excursion" and is expressed as follows:

When the test value must not exceed the objective:

$$excursion_i = \left[\frac{\text{Failed Test Value}}{\text{Objective}_j}\right] - 1 \qquad (3)$$

For the cases in which the test value must not fall below the objective:

$$excursion_i = \left[\frac{\text{Objective}_j}{\text{Failed Test Value}_i}\right] - 1 \qquad (4)$$

2) The collective amount by which individual tests are out of compliance is calculated by summing the excursions of individual tests from their objectives and dividing by the total number of tests (both those meeting objectives and those not meeting objectives). This variable, referred to as normalized sum of excursions, or nse, is calculated as:

F_3 is then calculated by an asymptotic function that scales the normalized sum of the excursions from objectives (nse) to yield a range between 0 and 100.

$$nse = \frac{\sum_{i=1}^{n} \text{excursion}_i}{\text{number of tests}} \tag{5}$$

$$F_3 = \left[\frac{nse}{0.01nse + 0.01} \right] \tag{6}$$

Once the factors have been obtained, the index itself can be calculated by summing the three factors as if they were vectors. The sum of the squares of each factor is therefore equal to the square of the index. This approach treats the index as a three-dimensional space defined by each factor along one axis. With this model, the index changes in direct proportion to changes in all three factors.

$$CWQI = 100 - \left[\frac{\sqrt{F_1^2 + F_2^2 + F_3^2}}{1.732} \right] \tag{7}$$

The CWQI value ranges between 1 and 100, the result is further simplified by assigning it to a descriptive category.

Excellent: (CWQI value 95-100), water quality is protected with a virtual absence of threat or impairment; conditions very close to natural or pristine levels. These index values can only be obtained if all measurements are within objectives virtually all of the time.

Good: (CWQI value 80-94), water quality is protected with only a minor degree of threat or impairment; conditions rarely depart from natural or desirable levels.

Fair: (CWQI value 65-79), water quality is usually protected but occasionally threatened or impaired; conditions sometimes depart from natural or desirable levels.

Marginal: (CWQI value 45-64), water quality is frequently threatened or impaired; conditions often depart from natural or desirable levels.

Poor: (CWQI value 0-44), water quality is almost always threatened or impaired; conditions usually depart from natural or desirable levels.

WATER QUALITY PARAMETERS

For the selected water quality parameters, general information, environmental effects and the different point and non-point sources are presented in the next section (Radwan, 2002 [9], El-Sadek, 2001 [4]).

DISSOLVED OXYGEN

General Information

Oxygen enters the water by photosynthesis of aquatic biota and by the transfer of oxygen across the air-water interface. The amount of oxygen that can be held by the water depends on the water temperature, salinity, and pressure. Gas solubility increases with decreasing temperature (colder water holds more oxygen). Gas solubility increases with decreasing salinity (freshwater holds more oxygen than does saltwater). Both the partial pressure and the degree of saturation of oxygen will change with altitude. Finally, gas solubility decreases as pressure decreases. Thus, the amount of oxygen absorbed in water decreases as altitude increases because of the decrease in relative pressure (Smith, 1990 [10]).

Environmental Effects

The introduction of excess organic matter may result in a depletion of oxygen from an aquatic system. Prolonged exposure to low dissolved oxygen levels (<5 - 6 mg/l) may not directly kill an organism, but will increase its susceptibility to other environmental stresses. Exposure to < 30% saturation for one to four days may kill most of the biota in a system. If all oxygen is depleted, aerobic (oxygen-consuming) decomposition ceases and further organic breakdown is accomplished anaerobically.

Sources

Low dissolved oxygen levels may occur during warm, stagnant conditions that prevent mixing. Even when the amount of organic pollution in the water is limited, high natural organic levels can cause a depletion of dissolved oxygen.

ORGANIC MATTER

General Information

Natural organics consist of biodegradable organic matter such as wastes from biological material processing, human sewage, and animal feces. Microbes aerobically break down the complex organic molecules into simpler, more stable end-products. Microbial degradation yields end products such as carbon dioxide, water, phosphate and nitrate. Each step above results in consumption of dissolved oxygen (Dunne et al., 1978 [2]). Organic particles in the water may harbor harmful bacteria and pathogens. Infection by the microorganisms may occur if the water is used for primary contact or as a raw drinking water source.

Environmental Effects

If excess organics are introduced to the system, there is potential for complete depletion of dissolved oxygen. Without oxygen, the entire aquatic community is threatened. The only organisms present will be air- breathing insects and anaerobic bacteria (Gower, 1980 [5]). In areas of high organics there is frequently evidence of rapid sewage fungus colonization. Organic levels decrease with distance away from the source. No standard is currently established for natural organics. However, standards are set for dissolved oxygen, biological oxygen demand, and coliform bacteria, three parameters that may be directly influenced by the presence of natural organics. To measure the amount of organic matter, the following parameter are used: (APHA, 1992 [1])

1. Five-Day Biochemical Oxygen Demand (BOD_5): BOD_5 is defined as the amount of oxygen required by bacteria to decompose organic matter for a specified time (usually 5 days) under aerobic conditions. The amount of oxygen reported with this method represents only the carbonaceous oxygen demand (CBOD) or the easily decomposed organic matter. BOD_5 is commonly used to measure natural organic pollution.
2. Chemical Oxygen Demand (COD): COD is defined as the oxygen equivalent of the organic portion of the sample that is susceptible to oxidation by a strong chemical oxidant. COD does not distinguish between refractory or "inert" organic matter. COD tests require approximately three hours.

Sources

Natural organics can be directly discharged into surface water systems or may be carried from an inland source by overland flow. A distinction can be made between nonpoint and point sources.

Nonpoint Sources

- *Agriculture:* Primary agricultural sources of organics include livestock excrement from barnyards, pastures, rangelands, feedlots, and uncontrolled manure storage areas; corn silage wase and liquor; and areas of land application of sewage sludge.
- *Residential and Urban:* Failed on-site wastewater disposal systems can contribute organics to a water body. Domestic pet excreta may also contribute.
- *Other:* Other organic sources include excreta from wild animals in surrounding watersheds, excreta from waterfowl that congregate on the water body, and overboard discharges of raw sewage from boats.

Point Source

Sewage treatment plants are the primary contributors of organics in many areas. Periodically, treatment facilities may need to bypass treatment of their wastewater. Some areas encourage practices that may be harmful to estuarine systems, such as dumping untreated sewage sludge offshore or discharging treated water offshore (Kennish, 1992 [6]). Additional organics may be contributed by industries, such as the pulp and paper industry, which discharge organic-laden effluent.

NITROGEN-NITRATE

General Information

The nitrogen cycle is composed of three processes. Two of the processes (ammonification, and nitrification) convert gaseous nitrogen into usable chemical forms. The third process, denitrification, converts fixed nitrogen back to the unusable gaseous nitrogen state (Smith, 1990 [10]).

- Ammonification is a one-way reaction in which organisms break down amino acids and produce ammonia (NH_3).
- Nitrification is the process in which ammonia is oxidized to nitrite and nitrate, yielding energy for decomposer organisms. Two groups of microorganisms are involved in nitrification. *Nitrosomonas* oxidizes ammonia to nitrite and water. Subsequently, *Nitrobacter* oxidizes the nitrite ions to nitrate.
- Denitrification is the process in which nitrates are reduced to gaseous nitrogen. This process is used by facultative anaerobes. These organisms flourish in an aerobic environment but are also capable of breaking down oxygen-containing compounds (e.g. NO_3^-) to obtain oxygen in an anoxic environment. Examples include fungi and the bacteria *Pseudomonas* (Smith, 1990 [10]).

In temperate zones, soil nitrate concentrations will vary seasonally with temperature and moisture levels. Fall and winter rains thoroughly remove all nitrates from the soil. No nitrate is naturally added to the soil during the late fall and winter because the cold weather prohibits mineralization and nitrification processes. During the spring and summer, the increased nitrogen-fixing activity of organisms and the addition of fertilizer causes the concentration of nitrates in the soil to steadily increase. Water carries nitrates to surface water systems in (1) overland flow (runoff), (2) unsaturated flow (interflow), and (3) groundwater flow (baseflow). Overland flow is the most direct route for water transportation. Underground flow is less direct because water flow is impeded by soil permeability and porosity constraints. Nitrate concentrations (as NO_3^-) larger than 45 mg/l (or larger than 10 mg/l NO_3-N) may cause Methemoglobinemia (Blue Baby Syndrome) in infants (Straub, 1989 [11]). Water contaminated with nitrate is very difficult and costly to treat.

Environmental Effects

Excessive nitrate-nitrogen production may negatively impact fresh water environments in the following ways:

- Alge mats, decaying algae clumps, odors, and discoloration of the water will interfere with recreational and aesthetic water uses.
- Extensive growth of rooted aquatic macrophytes will interfere with navigation, aeration, and channel capacity.

- Dead macrophytes and phytoplankton settle to the bottom of a water body, stimulating microbial breakdown processes that require oxygen. Eventually, dissolved oxygen will be depleted.
- Aquatic life uses may be hampered when the entire water body experiences daily fluctuations in dissolved oxygen levels as a result of nightly plant respiration. Extreme oxygen depletion can lead to death of desirable fish species.

Sources

Nonpoint Source

- Agriculture: Primary agricultural sources of nitrate include livestock excrement (from barnyards, pastures, rangeland, feedlots, and uncontrolled manure storage areas); nitrogenous fertilizers; irrigation return flows; and decomposing plant debris (Straub, 1989 [11]).
- Residential and urban: Primary residential sources of nitrate include nitrogenous fertilizer used on lawn and garden, leaky on-site wastewater disposal/septic systems, sewage treatment system outfalls, sewage treatment bypass outfalls, and domestic pet excreta.
- Other: The combustion of fossil fuels, industrial and agricultural discharges of nitrogen- containing gases, aerosols, and air-borne particles contribute to the atmospheric nitrogen load. Evidence suggests that the atmospheric deposition of nitrogen in water bodies (directly and via rainfall) constitutes a large portion of total nitrogenous inputs to estuarine and marine systems and a somewhat lesser portion of total nitrogen inputs to freshwater systems (Paerl, 1993 [8]). Additional nitrate sources include excreta both from wild animals in the surrounding watersheds, excreta from wildfowl congregating on the water body and boats that discharge raw sewage overboard.

Point Source

Industries that use nitrates in manufacturing may release nitrate in the effluent water. Nitrate is used in the following processes: meat curing, production of fertilizer, explosives, glass, heat-transfer fluid, and heat-storage medium for solar-heating applications (Kubek et al., 1990 [7]). Additional nitrates may be contributed by sewage treatment systems and sewage treatment bypass outfalls (during high flow periods).

DISCUSSION OF THE RESULTS

The water quality index (Canadian Water Quality Index) has been applied to the following water quality variables (Dissolved Oxygen, Biochemical Oxygen Demand, Chemical Oxygen Demand and nitrate). Observed concentrations for the selected parameters are compared to water quality guidelines (Law 48/1982). The results of those comparisons are combined to provide a water quality ranking (good, fair, poor) for individual water bodies (the Nile and different drains). The results are presented in Tables 1, 2, 3 and 4.

The results **of the Nile and the two branches** are presented in Table 1. The calculation results for the selected parameters (DO, NO_3, BOD and COD) along the Nile indicates that for the DO, 53 sites are monitored, 8 of them violate the standard. For all campaigns (5 campaigns) and all monitoring sites, there are 183 tests, 10 of them are failed ones (violate the standards (Law 48/1982)). By calculating F_1, F_2 and F_3 as explained under "calculation of the index section", CWQI was further calculated. The calculated CWQI for the DO is 90.56 which indicate **Good DO** condition along the Nile and the two branches. The results of NO_3, BOD and COD indicate **Excellent NO_3, Good BOD and Poor COD** conditions.

Table 1 Calculation results for the Nile River

Parameter	DO	NO_3	BOD	COD
Total number of locations	53	53	53	53
Number of failed locations	8	0	10	47
Total number of tests	183	183	183	183
Number of failed tests	10	0	14	98
F_1	15.38	0	18.86	88.67
F_2	5.46	0	7.65	53.55
Excursion	1.57	0	3.80	85
Nse	0.0086	0	0.02	0.467
F_3	0.85	0	2.03	31.71
CWQI	90.56	100	88.18	37.44

Results of the different **drains** are presented in Table 2. For DO, the monitored drains are 43, 17 of them violate the standards. In total 176 tests are examined for all monitored drains during the five considered campaigns, 33 are failed ones (violate the standards). By calculating F_1, F_2 and F_3 as explained above, CWQI was further calculated. The calculated CWQI for the DO is 73.12 which indicate **Fair DO** condition for the different drains. The results of NO_3, BOD and COD indicate **Good NO_3, Fair BOD and Poor COD** conditions.

Table 2 Results of the drains

Parameter	DO	NO_3	BOD	COD
Total number of drains	43	43	43	43
Number of failed drains	17	6	9	40
Total number of tests	176	176	176	176
Number of failed tests	33	10	20	94
F_1	39.53	13.95	20.93	93.02
F_2	18.75	5.68	11.36	53.40
Excursion	33.27	22.48	206.25	529.4
Nse	0.189	0.127	1.17	3.00
F_3	15.89	11.32	53.95	75.04
CWQI	73.12	89.11	65.94	24.41

As the previous results of the drains are presenting a macroscopic overview, a microscopic view is presenting below. The excursion term which presents the violation of the standards results is used to rank the different drains. The drains are ranked in a descending order for the worst 15 drains as presented in Table 3. For example, the worst drain based on the DO and NO_3 concentrations is Khour El sail Aswan drain. It is obvious that Khour El sail Aswan, El Berba and Kom Ombo drains have the worst conditions for the considered water quality parameters. It is hereby recommended to have more intensive measurement campaigns along the drains to propose different scenarios for improving the current conditions.

Table 3 Drains violate the standards (ranked in a descending order for the worst 15 drains)

	DO	NO_3	BOD	COD
1	Khour El sail Aswan	Khour El sail Aswan	El Berba	Kom Ombo
2	Etsa	Radisia	Kom Ombo	El Berba
3	El Rayamoun	El Ghaba	Khour El sail Aswan	Khour El sail Aswan
4	El Tibeen	El Massanda	Etsa	Etsa
5	Houd El Sebaia	Fatera	El Rayamoun	El Ballas
6	Kom Ombo	Abu Wanass	Souhag	El Rayamoun
7	El Berba		El Tibeen	Radisia
8	El Ballas		El Massanda	El Tawansa
9	Hegr El Sebaia		El Ballas	Hamed
10	El Massanda			El Ghaba
11	El Saff			El Massanda
12	Mazata			El Tibeen
13	El Badary			Souhag
14	Habil El Sharky			Mazata
15	Bany Shaker			Fatera

A summary of the index results are presented in Table 4. According to the CWQI classification, for the Nile and the drains, NO_3 status is excellent for the Nile and Good for the drains. DO and BOD are Good for the Nile and Fair for the drains. The worst condition for the selected parameters is registered for the COD (poor for the Nile and the different drains).

Table 4 Water quality ranking for the Nile and Drains

Water body	DO	NO_3	BOD	COD
Nile	Good	Excellent	Good	Poor
Drains	Fair	Good	Fair	Poor

CONCLUSIONS AND RECOMMENDATIONS

The water quality index (Canadian Water Quality Index) has been developed by the Water Resources Management Division for application in Newfoundland and

Labrador. The method is applied to evaluate the status of different water quality variables. Dissolved Oxygen, Biochemical Oxygen Demand, Chemical Oxygen Demand and Nitrate are evaluated in the study. The results are combined to provide a water quality ranking (good, fair, poor) for the Nile and different drains. Results conclude that DO, NO_3 and BOD conditions vary from good to excellent for the Nile and from fair to good for the drains. The worst conditions are registered for the COD, where the quality status is poor for both the Nile and the drains. It is recommended to have more intensive measurement campaigns along Nile "where the concentrations violate the standard" and the worst drains "according to their rank (see Table 3)" to propose different scenarios to improve the current conditions.

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