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Evaluation of water quality in an urban park for environmental sensitization: A large scale simulation model

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ABSTRACT

Urban parks are important components of the urban environment since they are critical to improving livelihoods and the environment in densely populated cities, offering also shelter to several wildlife species and opportunities for outdoor educational activities. The park of Environmental Information and Sensitization ''Antonis Tritsis'' is the largest park of the Athens metropolitan area ($\sim$1.15 km^2) including an artificial system of six large reservoirs referred as lakes of total surface of approximately 6 hectares (5–6% of its total surface) constituting the largest surface of fresh water within the city structure.

The aforementioned system is a ''controlled'' one since it is fed by two distinctly different, monitored water sources, namely the pumped local water and the occasional runoff from rains. The bottom of the ''lakes'' is covered by geomembrane allowing the system to be considered as a very large scale simulation experiment. The results obtained provide insight into the biochemical functioning of the water system which constitutes a useful tool as a model. Two seasonal samplings were carried out, the first during the dry summer period when water supply for the lakes is provided exclusively from a local drilling and the second in autumn of 2007 directly after an intense rainfall. The physicochemical parameters measured were temperature, conductivity, suspended particulate matter, dissolved oxygen and pH and those directly related to eutrophication were ammonium, nitrites, nitrates, phosphates, chlorophyll *a* and dissolved organic carbon. The microbial charge was also assessed through analyses of *Enterococci, Coliforms* and *Escherichia coli*.

From the results obtained it became clear that water deriving from the drilling has high concentrations of nitrates and the microbiological parameters studied. Runoff, which washes out the nearby urban area, introduces significant quantities of nutrients, mostly phosphates, to the lake system. In the wetland in the northern part of the park, where lakeside vegetation is abundant, concentrations of both nitrates and phosphates are significantly reduced. Measurements of dissolved organic carbon and chlorophyll *a* indicate increased algal presence in the central lakes, linked to a certain extent to aesthetic deterioration.

Keywords: Water quality; Lakes; Urban; Park; Athens

1. Introduction

Given the accelerating rate of urbanization worldwide, urban green spaces are becoming increasingly

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important to society as nodes of interactions between humans and nature [1], but also as shelters of wildlife in urban areas. Urban parks, formed by a combination of historical, ecological and socioeconomic drivers [2], are characterized, in many cases, by an important biodiversity of the local fauna and flora [1,3–5]. All kinds of parks, biosphere reserves and areas designated under various types of ''protection'' are very important also for educational purposes [6]. The notion of ''sustainable urban park'' has emerged recently, focusing on how policy makers and the public can integrate parks in sustainable development planning as valuable contributors to approach self-sufficiency, in regard to material resources and maintenance, to the creation of new standards for aesthetics and landscape management, as well as to facing larger urban and ecological problems [7].

Such a ''sustainable park'' was recently established (in the early 90s) in a space which was originally a prototype farming area created by queen Amalia almost immediately after the independence of Greece as a new state around 1840. The place was known as ''Pyrgos Vassilissis'' (Queen's Tower) in Attica, in the ''greater Athens Metropolitan area'', where almost half of the Greek population resides. One of the main features of the region is the poor planning which has decreased substantially the ''free space'' and green areas. The ''Antonis Tritsis'' park of Environmental Information and Sensitization of western Attica, was established in view of ameliorating the environment of the relatively degraded municipalities of western Attica.

It is the largest (approximately 1.15 km^2) in the urban environment of Athens. Its landscape is featured by the abundance of water, an element rare throughout Attica. The lake system of the park comprises 5–6% of its total surface [8,9].

Abundance of fresh water, rich vegetation and biodiversity (both flora and fauna) contribute to its significance. The park actually represents one of the last remaining shelters of wildlife within the urban web of Athens. During the last few years more than 150 different species of wild birds have been observed there. This is quite an impressive number compared to the no more than 200 bird species found in the Attica region. Furthermore, at least three species of fish, two of amphibious animals and four of reptiles have been recorded in the park [8].

Members of the NGO ''Hellenic Ornithological Society'' being active at the ''Antonis Tritsis'' park noted a great biomass of vegetation combined with eutrophication phenomena appearing in several parts of the reservoirs within the park. Furthermore, in order to designate a management framework for the park, it is essential to examine key components that need to be taken into account. Under this perspective, the main goal of the present work constitutes the study of water quality at the lake system of the park oriented towards the correlation with eutrophication phenomena, since similar studies have not been carried out so far. The study of water quality is correlated not only with public health, but also with the condition of the specific ecosystem. Moreover, the system of lakes, the bottom of which is covered with geomembrane and which is exclusively supplied with water of specific quality originating from a drilling, constitutes an appropriate large scale simulation experiment, in order to obtain information relative to the biochemical processes taking place in larger aquatic systems. For these reasons, the physicochemical parameters of temperature, conductivity, dissolved oxygen and pH, parameters related to eutrophication such as concentrations of ammonium, nitrite, nitrate, phosphate and dissolved organic carbon as well as microbiological parameters (Total *Coliforms, Feacal Coliforms, Escherichia coli, Enterococci*) were studied.

2. Study area

The ''Antonis Tritsis'' park also known as ''Pyrgos Vassilissis'' (Queen's Tower), is located at the western part of Attica (Fig. 1), at the northern edge of the Kifissos river basin, at a small distance from the Liossia stream, which meets the river Kifissos at the southern point of ''Tris Gefyres'' (Three Bridges), forming a geographical triangle, in the centre of which the park is located. At the north part of the area, the park is boarded by the slopes and foothills of Pikilo oros (mountain) and the Parnis mountain (Hellenic Ministry for Environment).

The so-called ''lake'' system of the park, a system of reservoirs, is artificial (Fig. 1). In its present form it is new. It was created in the 1993–1996 period and is located at the bed of a stream previously existing at the same area. Its total surface is approximately 6 ha, constituting the largest surface of fresh water within the Athens metropolitan area structure. At the southern edge of each ''lake'' there is a dam made of concrete in order to retain the water. For the waterproofing of the lakes geomembrane lining was used. Only in the lower lake (which was recently repaired) inert materials were added on the surface of its bottom on top of the membrane. The six reservoirs, which are going to be referred in this paper as ''lakes'', since they are known with this name in the area, are fed by a local drilling functioning permanently and they also receive rainwater and runoff from the small catchment area, through a stream at the north edge of Melia lake. They are arranged in a north-south axis (Melia, Korykia, Kifissis, Naias, Assopias, Achelois) and are all connected in such a way that the water overflows in a natural way from each lake to the next (Fig. 1). Adequate

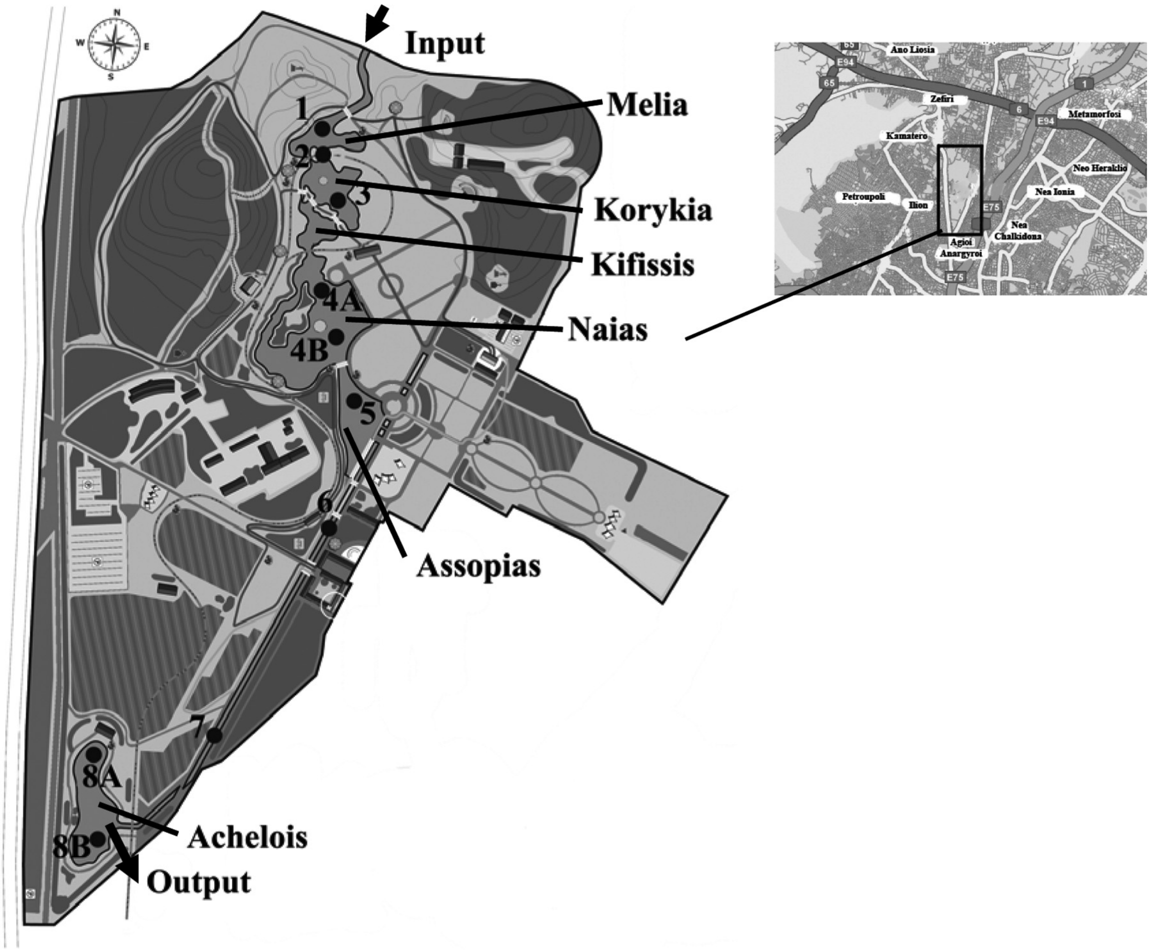

Fig. 1. The lake system of ''Antonis Tritsis'' park.

quantities of water are retained in the lakes throughout the year even during the dry summer periods. Drilling water flows in to the second lake (Korykia), whereas the upper lake (Melia) is mainly fed by rainwater. The upper lakes of the system (Korykia, Kifissis) carry the features of a wetland, characterized by abundant vegetation. The last two lakes of the system (Assopias, Achelois) are in contact with each other through a channel of a total length of approximately 600 m. Water overflowing from the last lake (Achelois) ends up to a drainage. The total amount of water in the lake system is estimated at approximately 100,000 m^3. This corresponds approximately to 100 days pumping of the water of the drilling.

3. Sampling and analysis

3.1. Sampling

Two samplings were carried out during summer and autumn of 2007. The first sampling took place during the dry period, whereas the second one following an intense rainfall (>3 cm). It is well known that storm water runoff in urban areas can influence significantly the quality of the receiving surface waters [10,11].

For the determination of nutrients samples were collected in polypropylene bottles thoroughly cleaned by soaking for a week in 10–15% hydrochloric acid and then carefully and repeatedly rinsed with water (18.2 MΩ cm, Milli-Q, Millipore). For organic carbon and chlorophyll *a* determinations samples were kept in glass vials thoroughly rinsed with Milli-Q water followed by heating at 500 °C for 3 h.

3.2. Materials and methods

Handling of samples in the laboratory and preparation of equipment and reagents used were carried out inside a laminar flow cabinet.

Conductivity and pH measurements were carried out using a Radiometer CDM 230 conductivity meter and by a Jenway 3310 pH-meter, respectively. Dissolved oxygen was determined employing the Winkler method [12].

The measurement of nitrites was performed with the use of a continuous flow analyzer BRAN+LUEBBE [13]. The nitrate in the sample is reduced quantitatively to nitrite by passage of the sample through a copperized cadmium column in the continuous flow analyzer. The resulting nitrite plus any nitrite originally in the sample is determined as a sum. For ammonium the automated phenate method was used, whereas for phosphate the ascorbic acid method [12]. Photometric measurements were performed by employing a Varian Cary-1E UV spectrophotometer.

Determination of chlorophyll *a* was carried out spectrophotometrically [13].

Dissolved organic carbon (DOC) was measured by using the catalytic oxidation method [14], with the use of an organic carbon analyzer Shimadzu TOC-5000A.

Microbial parameters (*Coliforms, E. coli* ISO 9308-1:2000; *Enterococci* ISO 7899-2:2000) were determined according to ISO EN 17025:2005, in samples obtained during the first sampling.

Detection limits are 0.04 μmol/L for nitrites, 0.1 μmol/L for nitrates, 0.03 μmol/L both for phosphates and ammonium, 0.5 mg/L for DOC. The overall analytical precision and accuracy were about 5%.

4. Results and discussion

Water temperature in the lakes is significantly affected by the prevailing atmospheric temperature, due to their small depth. The lowest temperatures for both samplings (19 °C and 13 °C, respectively) were recorded in the water from the drilling. Water temperature gradually increases with distance from the drilling towards the lower lake of the system (Achelois).

Conductivity varied between 613 and 793 μS/cm and 413 and 748 μS/cm during the first and the second sampling, respectively (Fig. 2a). Conductivity of rainwater was measured equivalent to 200 μS/cm, significantly lower than that of water from the drilling (764 μS/cm). Consequently, during the first sampling water in the lakes originated exclusively from the drilling, whereas lower conductivity values recorded in the upper lakes of the system (Melia, Korykia) during the second sampling (Fig. 2a) are due to the input of significant amounts of rainwater through runoff to these lakes after the rainfall.

The concentration of dissolved oxygen in the two samplings ranged respectively between 5.5 and 16.3 mg/L and 1.6 and 9.7 mg/L (Fig. 2b). Generally, the relatively high values of dissolved oxygen recorded

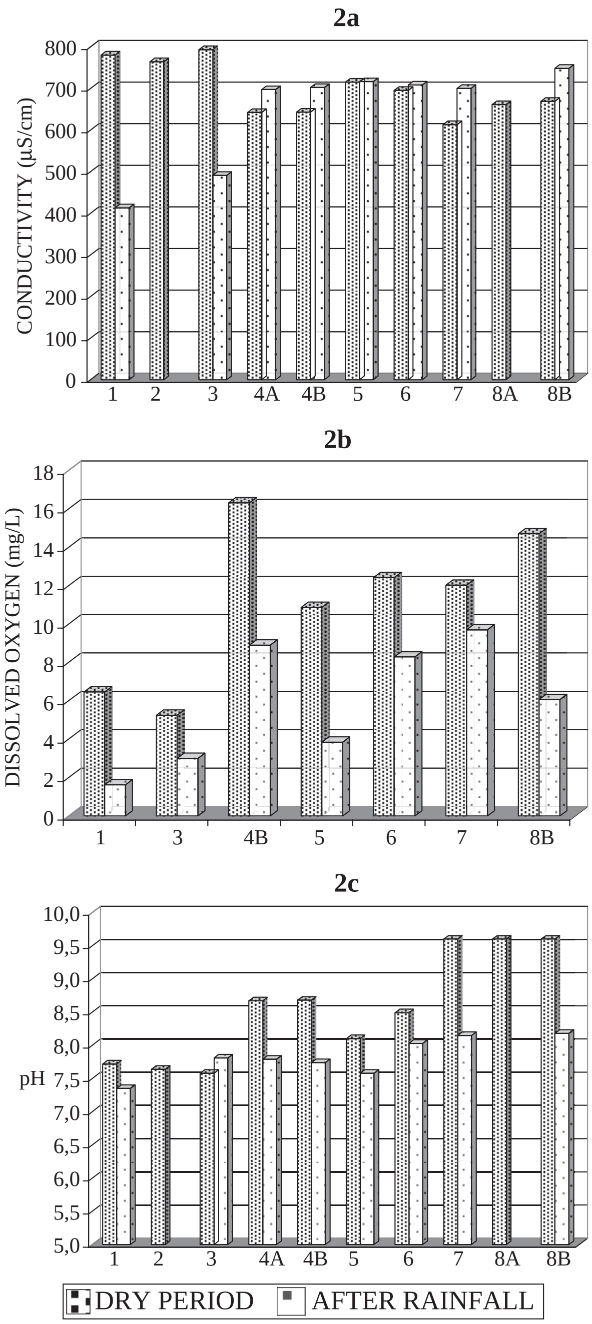

Fig. 2. Conductivity (μS/cm), dissolved oxygen (mg/L) and pH values.

indicate that the lake system is in general well oxygenated, at least near the surface. Flowing water is more likely to have high dissolved oxygen levels because of the water flow close to the air-water interface. The comparatively lower concentrations which were determined in the lakes Melia and Korykia demonstrate significant oxygen consumption in the specific lakes, due to the presence of significant biodegradable biomass (Fig. 2b).

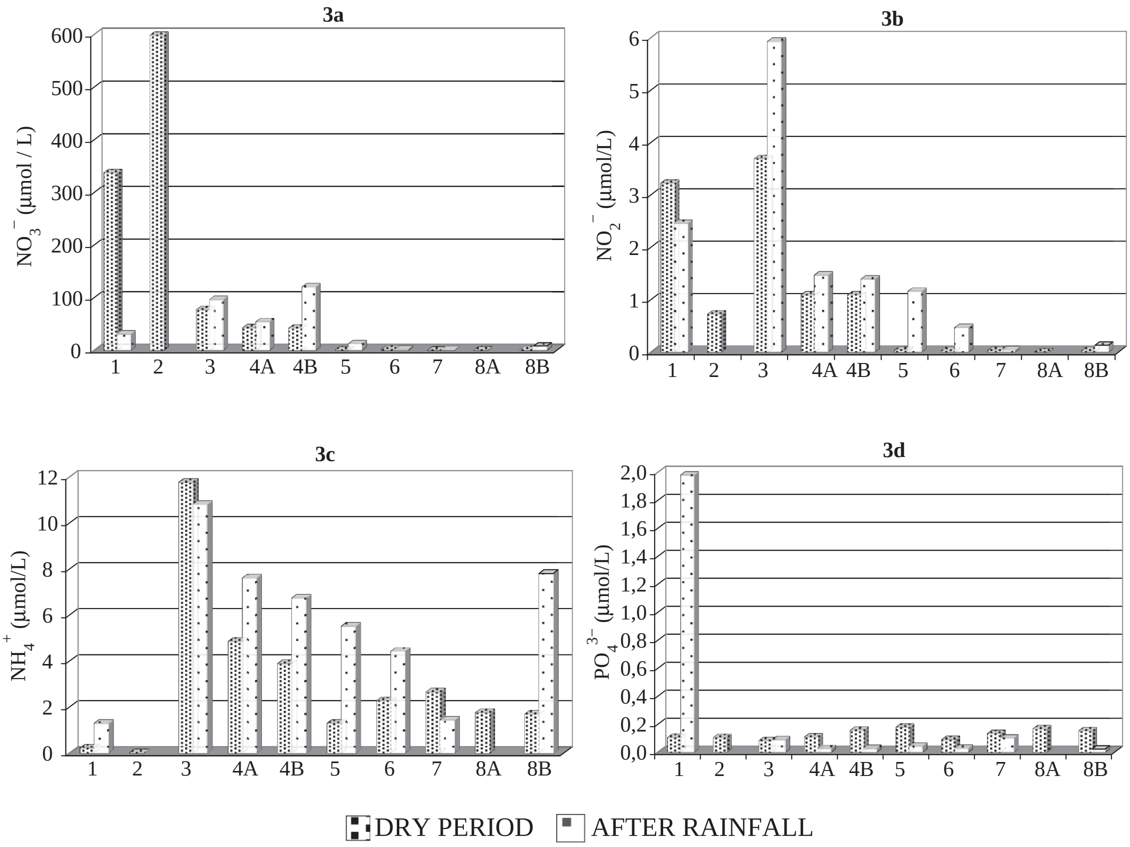

Fig. 3. Concentrations of nitrates, nitrites, ammonium and phosphates (all in μmol/L).

pH values varied between 7.57 and 9.60 during the first sampling and between 7.35 and 8.18 during the second one (Fig. 2c). pH of drilling and rain water entering the system is respectively 7.64 and 7.40. The gradual increase in pH from the upper lake towards the lower lake as well as the higher values determined during the summer sampling (Fig. 2c) are attributed to the photosynthetic activity.

In water from the drilling nitrate and nitrite concentrations were determined equivalent to 598 and 0.7 μmol/L, respectively, whereas ammonium was not detected. Water from the drilling enriches the lake system in nitrates but neither in nitrites nor ammonium. Given the lack of any important agricultural activity at the specific area, the relatively elevated nitrate concentration in drilling water is attributed to the extended use of pits (until the early 90s) at the relatively densely populated urban areas surrounding the park, due to the absence of local urban drainage system. Rainwater does not seem to enrich the system significantly in nitrates since their concentrations at the upper lake (Melia) after the second sampling following intense rainfall were comparatively low (Fig. 3a). The relatively high nitrite but not ammonium concentration in Melia lake during the second sampling are primarily attributed to rain water [11] and secondarily to the reduction part of nitrates (Fig. 3b and c).

As water flows through the system of the successive lakes, a gradual decrease in the concentration of nitrates is observed (Fig. 3a), mainly due to their consumption by biota. Therefore, the lowest nitrate concentrations were measured in the lower lakes. The highest concentrations of nitrite and ammonium were detected in lake Korykia during both samplings, due to the high biological productivity of these areas, as well as to the reduction part of the increased nitrate concentration [15]. A gradual decrease in nitrite and ammonium concentrations is observed towards the lower lakes (Fig. 3b and c). The relatively high concentrations of nitrogenous nutrients seem to be related to the high lakeside vegetation at the upper lakes. The significant decrease of nitrate concentration in Korykia lake demonstrates the features of phytoremediation of water by the higher plants found at this area and has been a critical component in ecologically engineered systems [16 and references therein].

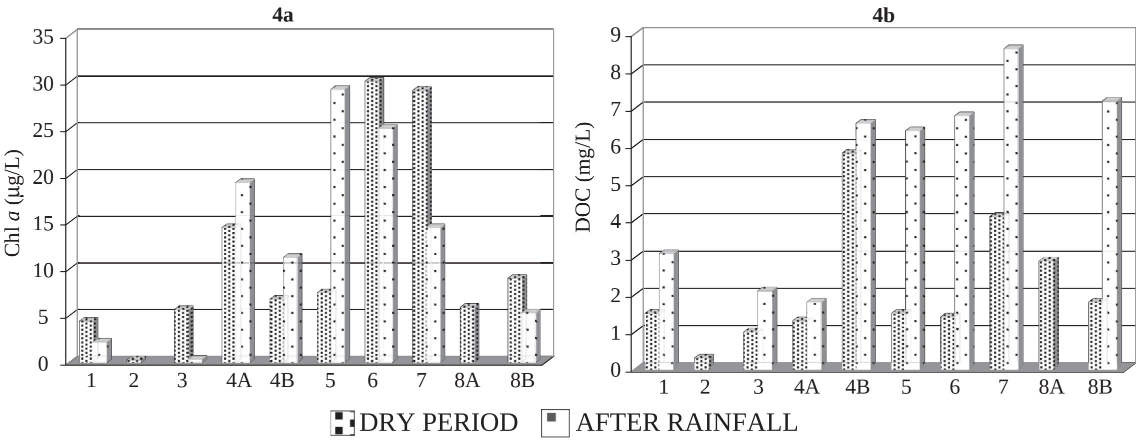

Fig. 4. Concentrations of chlorophyll *a* (µg/L) and dissolved organic carbon (mg/L).

The particularly elevated phosphate concentration (2.0 µmol/L) determined during the second sampling at the specific point where rainwater enters the system (lake Melia) indicates influx of significant quantities of phosphates in the lake system (Fig. 3d). This rather increased phosphate concentration is attributed to the pathway of rainwater, which constitutes runoff water from urban areas neighboring the park. Similarly to nitrates, a significant decrease in the elevated phosphate concentration is observed during the second sampling at Korykia lake. Wetlands can play an important role in attenuating nutrient loads to subsequent river and lake systems and indirectly influencing dissolved oxygen levels because of the linkage among nutrient supplies, biological activity and photosynthesis/respiration. Such attenuation may be of particular relevance in terms of the environmental management of many lowland river and lake systems where pollutant nutrient loading can lead to issues of eutrophication and deteriorating water and biological quality [17–20].

The highest concentrations of chlorophyll *a* were determined in the middle area of the lake system, characterized by the presence of the largest amounts of algal biomass (Naias, Assopias, Channel; Fig. 4a). According to recent attempts towards the qualitative assessment and trophic state classification of lakes, a 10 µg/L average concentration and a 20 µg/L maximum concentration of chlorophyll *a* can be considered as threshold values, signifying eutrophication phenomena in lakes [21–23]. On the basis of the results of this study, it appears that for the middle area of the lake system chlorophyll *a* concentrations are higher than these threshold values, therefore an unacceptable trophic state is anticipated for this area. In the context of a more refined five grade water quality classification system in accordance with the provisions of the Water Framework Directive 60/2000 [21] the middle area of the lake system is classified as ''fair'' to ''bad'' quality (categories III, IV), whereas the other areas as ''good'' quality (quality II).

The highest concentrations of DOC, were determined in the middle area of the lake system as in the case of chlorophyll *a*. It is noteworthy that in lake Naias, where dissolved organic carbon concentration was elevated, a significant permanent population of ducks and geese is found. Dissolved organic carbon in drilling water was non detected. During the second sampling, the concentrations of dissolved organic carbon (mean value 5.3 mg/L) were higher in comparison to the corresponding of the first one (mean value 2.4 mg/L; Fig. 4b). The specific difference could be justified by sediment turbation at the area near the lake bottom, caused by the wind which had been blowing with high intensity right before the second sampling and to the rainstorm that took place. In lake Naias, which is the largest one, lakeside vegetation is comparatively limited, whereas its bottom is covered by geomembrane, having as result the easy resuspension of the fine-grained bottom sediment. Besides, rainwater was characterized by a relatively elevated concentration of dissolved organic carbon (2.7 mg/L).

Drilling provides water of relatively elevated numbers of *Total Coliforms, Enterococci and E. coli* (Table 1) and therefore inappropriate for human consumption [24]. The increase in the values of microbial parameters examined in lake Naias in comparison to the corresponding characterizing the drilling may be partly attributed to the presence of a significant number of birds and fish at that specific area. On the contrary, the highest values which were detected in lake Melia

Table 1
Concentrations of microbiological parameters (cfu/100 mL)

Parameter	Melia	Drilling	Naias	Achelois
Enterococci	430	13	50	1
Coliforms	1200	83	120	72
E. coli	1100	75	100	58

(Table 1) are attributed to water remaining stagnant in this lake, since no rainfall had occurred for a significant period of time before the first sampling.

5. Conclusions

In the lake system of the park, many different microenvironments appear, characterized by the flow, the origin, the qualitative features of water with which they are supplied, the constructive features of the lakes and the pressure imposed to the system by its visitors. In parallel such a ''controlled'' system may be considered as a large scale simulation experiment.

Drilling water constantly supplying the lakes is rich in nitrates, paralleled with relatively high concentrations of *Coliforms*, *Enterococci* and *E. coli*, indicating pollution of the ground water entering the system. Rainwater, which reaches the system following intense rainfall, is enriched in phosphates, dissolved organic carbon and to a lesser extent in nitrite and ammonium.

The great biomass of higher plants in the upper part of the lake system, which possesses the features of a wetland (Korykia, Kifissis lakes) seems to contribute significantly to the attenuation of nutrients mainly regarding the elevated nitrate and phosphate concentrations. Nitrates originating from the drilling are decreased by approximately 93% and phosphates originating from rainwater by approximately 99%.

In the middle part of the lake system (lake Naias, Assopias, Channel) indications of quality degradation of water are observed even visually, related to high values of dissolved organic carbon and chlorophyll *a*. These areas satisfy the recreational purposes of the park, receiving therefore the most important pressure by visitors, reflected, among others, to the deposition of significant quantities of food. In lake Naias, the largest one of the system, where lakeside vegetation is limited and the bottom of which is covered by geomembrane, resuspension of the fine-grained sediment is observed, accompanied by transition of organic matter from the particulate to the dissolved phase.

The specific lake system seems to constitute a large scale simulation experiment, demonstrating the significance of wetlands in attenuating nutrient loads, a procedure which may be of particular relevance in terms of environmental management of many lowland river and lake systems, where pollutant nutrient loading can lead to issues of eutrophication and water and biological quality deterioration.

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