WATER POLLUTION LEVEL OF THE GROUNDWATER AND SURFACE WATER IN THE LAKE KOURNAS, CRETE-GREECE.

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ABSTRACT

Seasonal variation of water pollution was studied in Kournas Lake, the only freshwater natural lake in Crete, for the period from December 2007 through to December 2008. The two sampling sites for the surface water were located 2m from the bank on the east and south side of the lake. The groudwater sample, from a depth of 16m, was collected from the central municipal pump located in the south side of the lake. The measured values of the physical, chemical and bacteriological water quality parameters showed an oligotrofic lake with heavy metals concentration far below the limits of potable water. The higher values of the microbiological qualitative parameters were measured in the east side of the lake exceeding the limits for bathing water.

1. INTRODUCTION

Lakes have distinct structures determined by basin morphometry and physical, chemical and biological interactions. These elements provide a simple way to describe many important lake features. Morphometry refers to the shape of the underwater basin. The physical structure is determined by the distribution of light, heat, waves and currents and varies by day and season. The chemical structure results from the uneven distribution of chemicals such as nutrients and dissolved oxygen. Superimposed of these abiotic components is the distribution of living organisms [1].

Most of the Greek lakes are located in the western and northern parts of the country, where precipitation exceeds 1000 mm per annum. Concerning their altitude, the lakes can be classified in two groups, lakes which lie between 0 and 145 m above the sea level and lakes situated higher than 470 m above the mean sea level. Sixteen of a total of 40 lakes are smaller than 2 km^2, while only seven are larger than 40 km^2. Only three lakes reach depths exceeding 50 m, while many shallow ones are characterized as temporary. Five lakes occupy cryptogenous depressions and lie in graben basins, while a few are coastal lakes in recent formations, excluding the numerous lagoons in the western and northern parts of the country. Mean annual pH values vary between 7.8 and 8.6, with a maximum peak of 10.6 indicating increased biological activity that takes place during the productive period in the epilimnion. Conductivity mean values range from 247 to 1,200 μS/cm, with a maximum value that reaches 11,000 μS/cm for lake Vistonis, because of surface seawater intrusions [2].

Signs of lake-water quality degradation have been apparent for decades [3]. Since many Greek lakes are the final receivers of agricultural runoff and of municipal and industrial-waste-water discharges, they become enriched with nutrients, sediments and heavy metals [4]. Saltwater intrusion is another serious problem which affects the coastal lakes. Nutrient levels are of great interest because of their relation to eutrophication. In the majority of Greek lakes, total phosphorus concentration exceeds 20 μg/1, indicating that there is anthropogenic influence on the lake catchment. In contrast, average total inorganic nitrogen levels exceed 0.5 mg N/1 - which is accepted as the cutoff value for unpolluted lake water [2] - in only two lakes. Agricultural runoff and untreated sewage discharges are the most significant causes of nutrient enrichment in Greek lakes. More specifically, lake Vegoritis has a high content of inorganic nitrogen compounds as a result of wastewater discharges from the local fertiliser factory. For the majority of Greek lakes, the N/P ratio which governs the primary productivity is above 12 during the spring overturn. This value indicates, according to OECD (1983) [2], that the limiting nutrient for algal growth is phosphorous.

The lake of Kournas, the only natural freshwater lake on Crete, is one of the most important natural habitats of West Crete and is included in the network Natura 2000. However, the recent tourist development of the area resulted in human interventions, often not mild. The aim of the present research was to record the water quality in almost monthly intervals and evaluate the seasonal variation of the qualitative parameters with the human activities.

2. MATERIALS AND METHODS

The lake of Kournas is located 2.5 km south of the northern coast of Crete at the Municipality of Georgioupolis in the north-eastern part of Chania Prefecture (Figure 1). It has an almost circular shape and covers a surface of 60ha with maximum length 1080m S-N and 880m E-W and a maximum depth of 22.5 which fluctuates by 3-4 m over the year. The water of the lake lies on a relatively impermeable marl sediment substratum and the deepest point is 3.5m below the sea level. There is constant turn over of the water in the lake being fed mainly by a karstic spring in the bottom of the S-E side of the lake. The sinkhole is below the sea level [5].

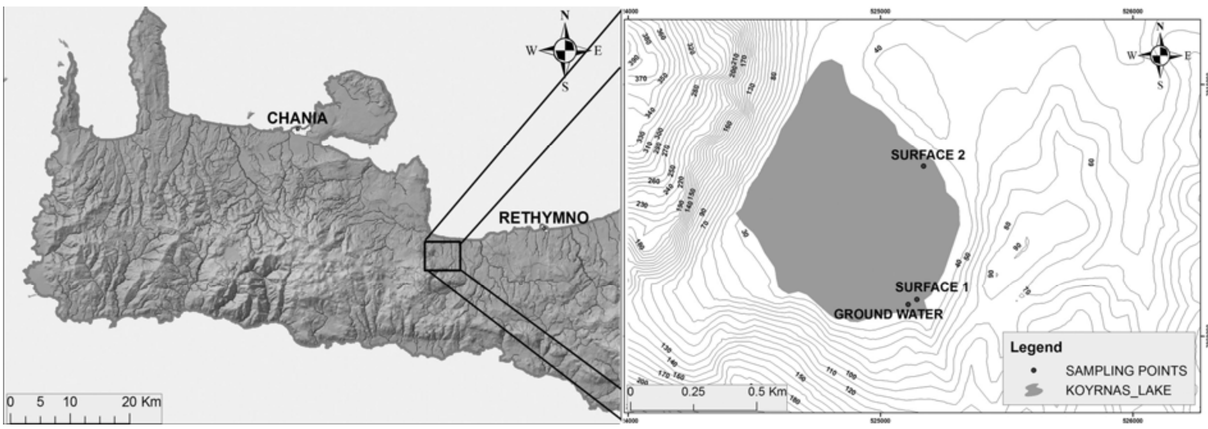


Figure 1. Geographical location of Kournas Lake and the three sampling points.

The two sampling sites for the surface water were located 2m from the bank on the south (named SURFACE 1) and east side (named SURFACE 2) of the lake. The groundwater sample (named GROUNDWATER), in a depth of 16m, was collected from the central municipal pump located in the south side of the lake on the spring called Amati. Water samples were collected every 15days or at monthly intervals, depending on the intensive human activities around the lake for the period from December 2007 through to December 2008. Each of the samples was collected in double, placed in 1lt plastic polyethylene and glass bottles, and transferred in a portable cooler to the laboratory, where samples were analysed within 6 hours of collection.

For the analysis of the qualitative parameters pH, EC, DO, BOD, COD, Cl^-, Na^+, NO_3^-, NH_4^+, PO_4^{3-} as well as for the bacterial detection, official methods [6] and test kits were employed [7]. The physicochemical parameters of pH, DO and EC were measured by a HACH (sension 156) instrument equipped with the respective electrodes. The concentration of the biochemical oxygen demand (BOD_5) was measured manometrically with special BOD device (Lovibond), which was provided with bottles equipped with digital sensors. The determination of chemical oxygen demand (COD), nitrate (NO_3^-), ammonia (NH_4^+), phosphate (PO_4^{3-}) was carried our using test kits (MERCK, 14560, 9713, 14752, 14848) and photometetric detection (MERCK Spectroquant NOVA 60) [7]. The chloride (Cl^-) concentration was determined according to the Mohr method [6]. The Na^+ concentration was determined with a flamephotometer (Sherwood 410). For the determination of total coliforms, *E.coli*, and *S. faecalis*, water samples of 100ml were filtered through sterile 0.45pore size cellulose filters and placed in petri dishes with the respective substrate, Membrane Lauryl Sulphate Broth ((LAB M 82) or Slanetz & Bartley Medium (LAB M 166), for incubation. Results were expressed as colony forming units cfu/100ml.

2. RESULTS AND DISCUSSION

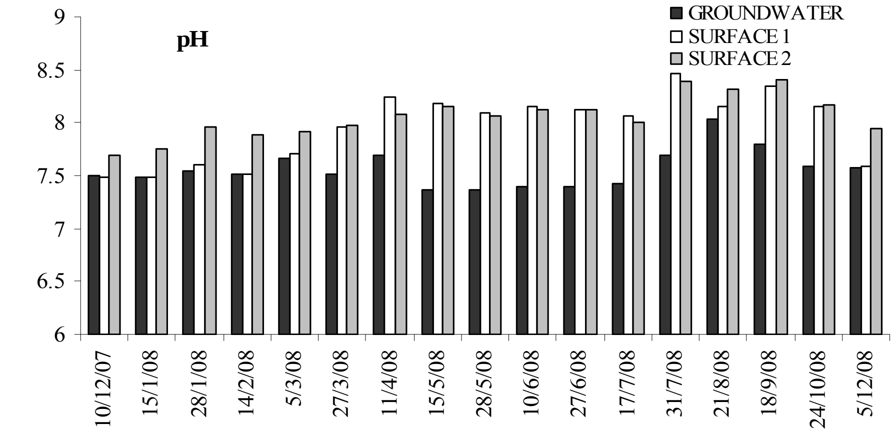
The annual monitoring of pH in ground water which feeds the lake showed an almost constant value (7.4 to 7.6) increasing to 8.0 in the measurement of August. Higher values were measured in both samples of surface water reaching 8.5 in the summer months. Similar behavior was observed in previous studies [8,9] and maybe due to human activities on the lake during the summer period.

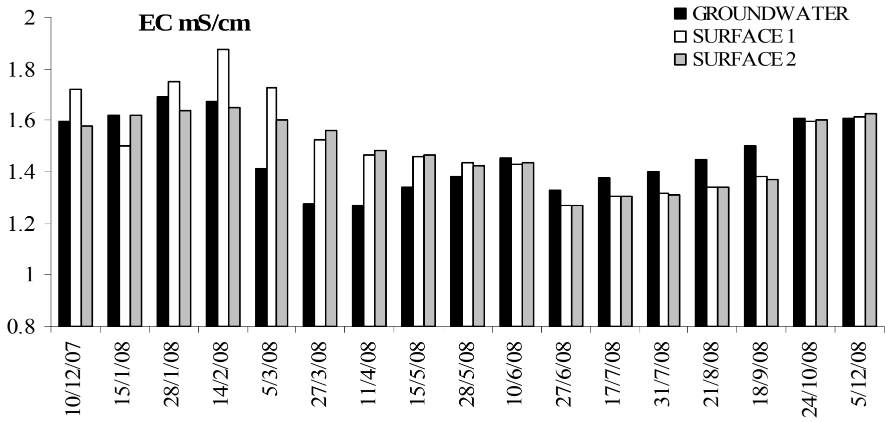
The electrical conductivity of groundwater was decreased about 300mS/cm during the period March to April and 150 mS/cm during the period May to September from the high values of 1600 to 1700 mS/cm in the period from October to December. The variation of the concentration of Na^+ and Cl^- during the study period of the water of the lake as showed in Figure 2 is parallel and follows the change of the electrical conductivity. At high values of electrical conductivity the concentration of Na^+ reaches at 170-180 mg / l and the concentration of Cl^- reaches at 330-370 mg / l. The seasonal coincidence of maximum and minimum values of conductivity with the concentration of chloride and sodium ions indicates a direct relationship between the three parameters of water quality of Kournas' Lake. This combined with the period of heavy rain and snow melting (March-June 2007) during the study, leads to the conclusion that the lake is directly influenced by seawater intrusion during periods of reduced feeding supply and indicates relationship of reason / effect. Similar behavior was found in previous study [8,9] in Kournas lake.

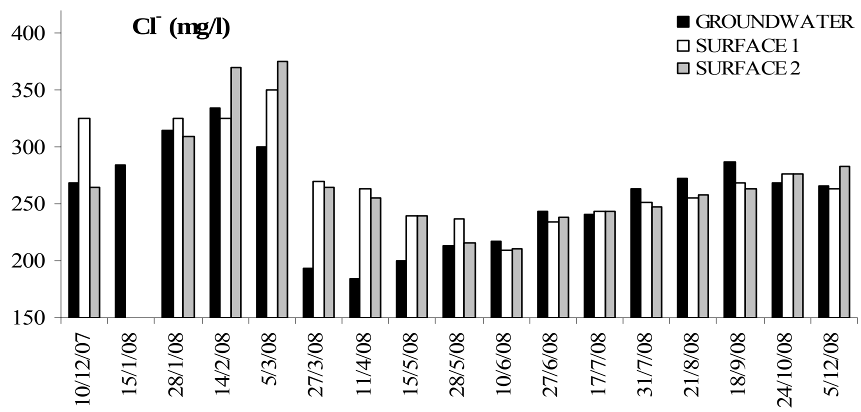
The unprecedented high values of BOD (30mg/l O_2) and COD (45 mg/l O_2) measured in the samples of the surface water from the sampling point Mati, were 4-5 times higher than the values recorded in the lake in previous research with 2 years duration [8,9]. These values were measured in the heart of the winter and maybe were due to the organic nature of runoff from the leaching of the mountains surrounding the lake with the rain waters or to the wastewater flows due to human activities in the lakeside area. The maintenance of DO values between 8,5-10,0 mg/l and BOD and COD in levels of 2-10 mg/l even in the summer period of the research, shows the need for continuous monitoring of the lake to avoid organic man-nature charge, which may degrade the surface water of the lake to the class of slightly polluted [10,11]. In opposition, the situation of the groundwater as it was evaluated in the sampling point seems to be normal.

The concentration of PO_4^{3-} in surface water samples was connected to that of the ground water and showed similar seasonal variations during the study, with maximal and minimal concentrations to coincide temporal for the three sampling points, which indicates a possible common seasonal source (Fig.4). The similar concentrations in surface and ground waters showed probable physical burden except the high value on 15/1/08 which followed the high COD value of the same date, maybe due to human activity.

The variation of the concentration of NH_4^+ in the surface water sample (SURFACE 1) is similar to that in groundwater (GROUNDWATER) only during the winter and spring measurement periods (Fig. 4), whereas summer and fall measurements varied significantly with higher values in surface water.







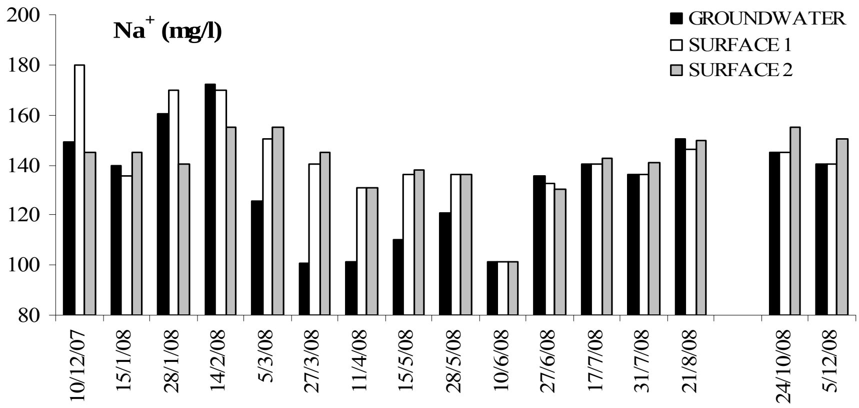
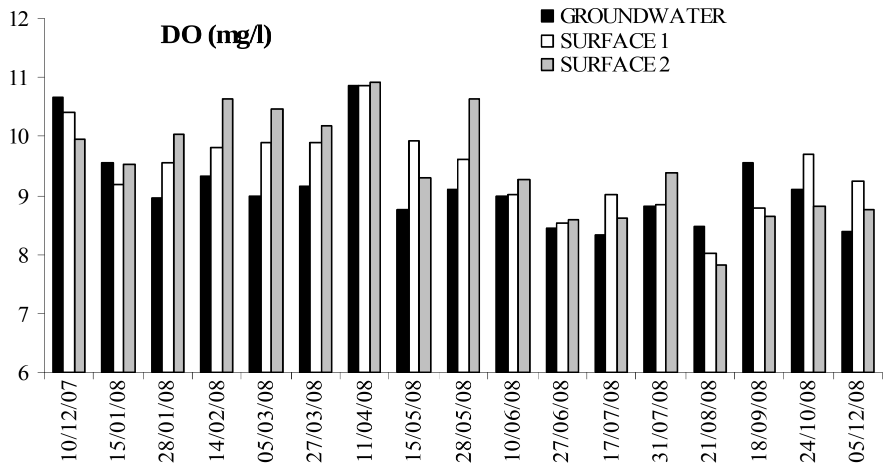
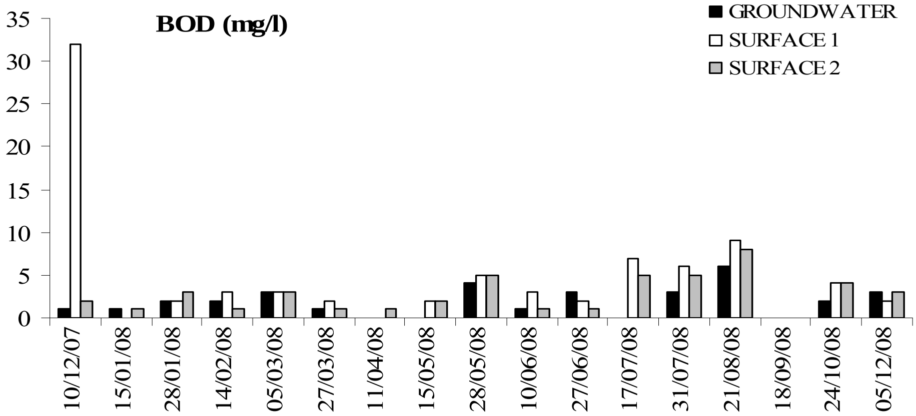


Figure 2. Monthly pH and EC values, Cl^- and Na^+ concentration in the Kournas' lake.





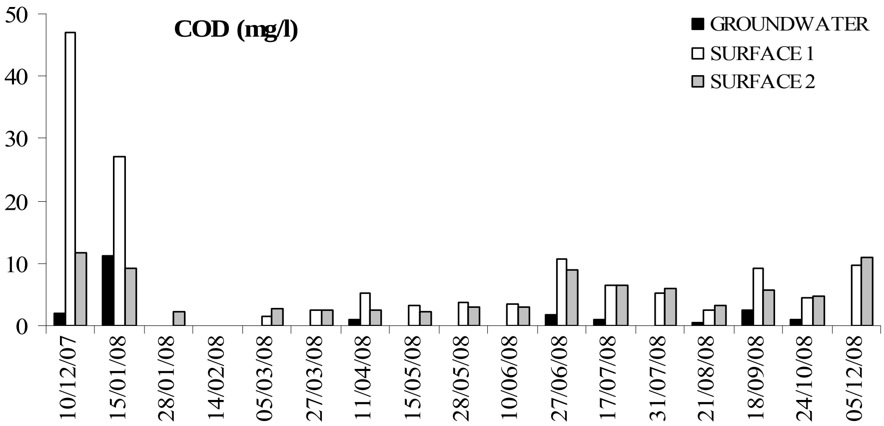
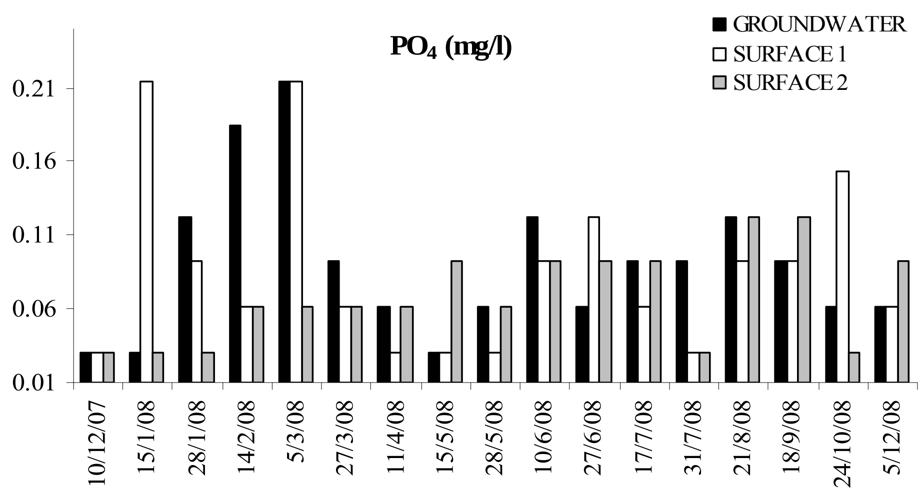
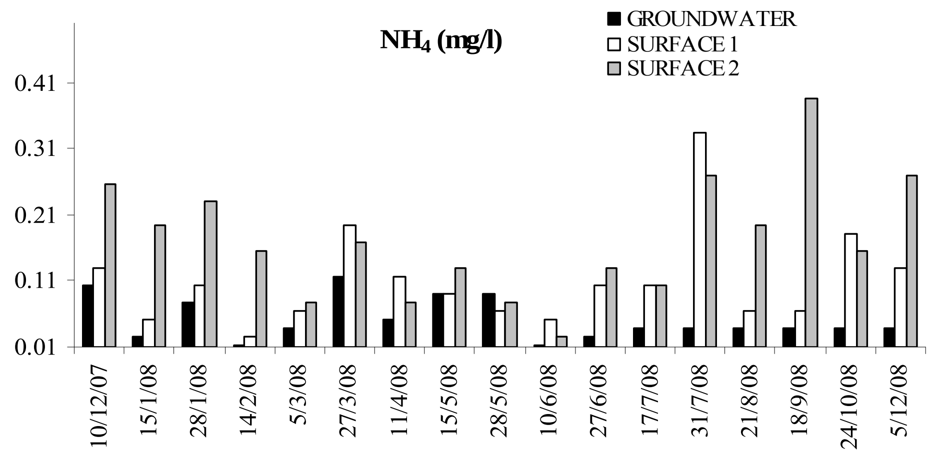


Figure 3. Monthly DO, BOD, COD concentration in the Kournas lake.

The concentration of NH_4^+ in water samples in the sampling point SURFACE 2 was found 0,25 mg/l in the winter period while in the period from July to September measured up to 0,38 mg/l NH_4, 2-10 times higher from the concentration in groundwater. This seasonal increase of NH_4^+ in surface water samples indicates strong relationship with the summer tourist activities which are developed deep in the lakeside area.

High concentrations of NO_3^- (about 5 mg/l) were observed initially at all sampling points, probably because of groundwater loading of the lake. Maybe the first rains of the autumn caused the leaching of fertilizers on agricultural areas in the southern region of the aquifer loading of the lake. The next samples of groundwater showed a reduction of NO_3^- concentration, which ranged between 1.7 and 3mg/l throughout the duration of the measurements. The concentration of NO_3^- in the surface water sampling points was ranged significantly lower (0-2mg/l) compared with the values of groundwater NO_3^- except values 4,8 mg/l and 4 mg /l which were measured on 28/1/08 and 5/12/08 in sampling points SURFACE 2 and SURFACE 1 respectively. The higher values of nitrate which were observed during the winter are considered to be due to runoff from agricultural soils and animal wastes entering the lake which is favored by the large slopes of the mountain area surrounding the lake [8, 9].





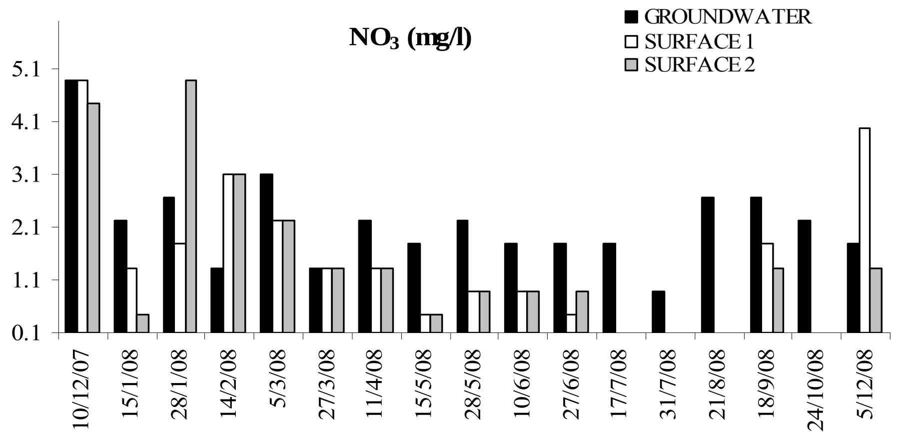
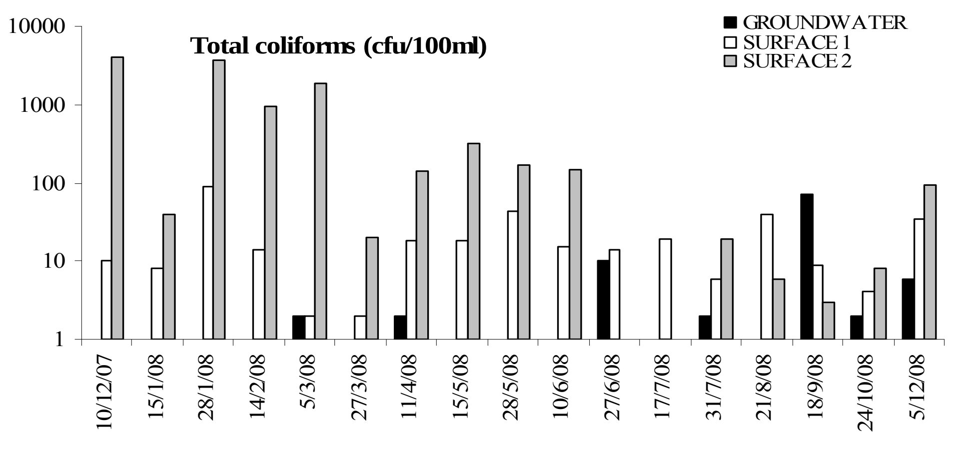


Figure 4. Monthly PO_4^{3-}, NO_3^-, NH_4^+ concentration in the sampling stations in Kournas lake.



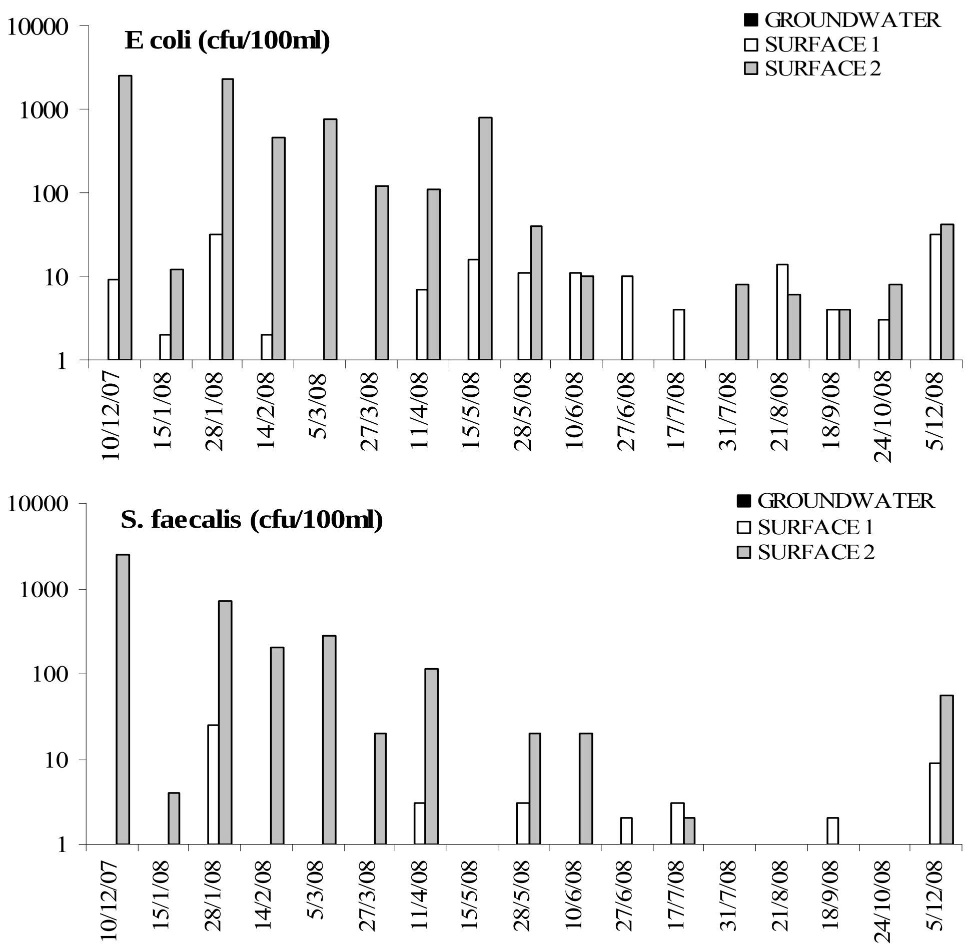


Figure 5. Monthly density of Total coliforms, *E coli*, *S. faecalis* in the Kournas lake.

The groundwater that enters the lake can not be held responsible for the microbiological load of the lake, since analysis showed no *E. coli* and *S. faecalis* concentrations. In contrast, areas around the lake should be examined as the values for all indexes in sampling points of surface water and particularly in SURFACE 2 exceed even the high levels of swimming waters. Although the concentration ratio of FC / FS ranges from 2 to 3.5 indicating anthropogenic origin of high infection, [12] the fact that these values correspond to winter months suggests that the participation of animal contamination reaches to the lake via soil leaching. The level of infection, at least during the summer period did not exceed the limits of the swimming water even though there are extended touristic activities during that period.

4. CONCLUSIONS

According to Skoulikidis *et al.* [2] the shallow Greek lakes are eutrophic (lakes with high nutrients and high plant growth), while the majority of Greek lakes are also moderately polluted and are characterized by phosphorus-limited photosynthesis. Fortunately, Lake of Kournas does not follow the aforementioned behavior and could be characterized marginally as oligotrophic. In fact, seasonal variation of the qualitative parameters showed water enrichment with nutrients mainly due to agricultural runoff and local point pollution sources related to human activities [8, 9].

Lake management requires a consensus of public opinion concerning the current versus desired status of the Kournas lake. Without popular and political support for the water quality protection project, data based conclusions may be ignored [1]. Although this seems obvious at first glance, the parties involved have many different views on the ultimate goals. Establishing consensus on preventing water clarity may require time for meetings and negotiations. Unfortunately, decision makers almost always require quick solutions at the least possible financial cost. Fortunately, monitoring of water quality [8, 9] provides sound data for realistic planning in order to maintain lake-water uses and prevent Kournas Lake ecosystem from degradation. The challenge is ahead.

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