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WATER QUALITY AND CONDITION OF RIVERBANKS OF KIFISOS RIVER, ATTICA, GREECE

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Abstract

The aim of this study is to assess the condition of Kifisos river in Attica, Greece, with respect to water quality and riparian ecosystems status. Four representative sampling sites were examined. Water samples were collected in winter and spring 2013 and the following parameters were examined: water and air temperature, pH, conductivity, nitrate, nitrite and phosphate ion concentration, BOD_5 and COD. The sites were sampled twice for macroinvertebrate fauna; specimens were identified to the appropriate level. The riparian ecosystems status was established based on the HMS index and HQA score of the RHS protocol. The results led to proposals for the holistic management of the Kifisos river ecosystem, as part of the urban landscape.

Key words: *river, ecology, macroinvertebrate, quality, RHS, riparian ecosystem, Kifisos*

1. INTRODUCTION

During the last decades and especially after the implementation of the Water Framework Directive (WFD) 2000/60 that introduced a holistic way to manage a river ecosystem depending on physicochemical, geological and biological characteristics, studies for the river management are becoming more and more common, as a response to continuous degradation of aquatic ecosystems and loss of habitats and organisms (in Marsh & Grossa, 2005).

In order to study water quality, there is an abundance of biomarkers available; the most common are the benthic macroinvertebrates, the diatoms, the fish, the water and riparian vegetation along with physicochemical factors (in Iliopoulou-Georgudaki et al., 2003).

Intertwined with water quality, sources of pollution are being studied and evaluated. Point and non-point sources play an important role and are related closely to land uses (in Marsh and Grossa, 2005). Municipal waste, litter, inadequate wastewater treatment, illegal sewage pipes, contribute a lot to river pollution, especially to urban rivers (in Da Silva & Sacomani, 2001). The physicochemical parameters that are most meaningful and examined in most studies are: the temperature of the air and the water, the pH, the conductivity, nitrate and nitrite concentrations, phosphate concentrations, BOD_5 and COD (in Faulker et al., 2000).

One of the most widely used biomarkers is benthic macroinvertebrates, that can show the degree of human intervention in surface waters' quality (in Skoulikidis et al., 2009) and in habitats' degradation (in Pace et al., 2012).

The interactions of fauna with riparian vegetation have also been a field of interest, under the provisions of WFD as the composition of riparian flora play an important role at maintaining the biogeochemical cycles of nutrients and high quality habitats (Tullos & Neumann, 2006), and can also be a great indicator for pollution (Harguinteguy et al., 2013 & in Feio et al., 2012).

1.1 Study area

Kifisos is one of the two major rivers of Attica, collecting 67% of rainwater of the area (in Papapetrou –Zamani, 1989). Its length is 22 km, 14 km of which run through an urban urea. The drainage basin's area is 381.10 km^2; Kifisos stems from mountain Parnitha and flows in 9.5m depth at the haven of 'Faliro'. 150 km is the length of the streams that end up in Kifisos, while only the upper part of the river is natural. Regarding geological substrate, the mountainous and hilly parts of the basin consist mainly of limestone, marble, schist and alluvial deposits, while the plain is occupied by concrete blocks and concrete (in Mountrakis, 1985). The use of land that

dominates both upstream and downstream is the unregulated urban construction (in Exarxou et al., 2004), while the dominant riparian species observed is *Platanus* spp. Kifisos has been serving Attica with water for irrigation purposes during centuries, nowadays, due to interventions, is a degraded ecosystem, or even a mass of cement (in Exarxou et al., 2004), in spite of the attempts of regulators to protect it. Pollution from solid waste, hazardous liquid industrial waste, but also from urban wastewater degrade Kifisos ecosystem, not allowing it provide services like drinkable water, fresh air and recreational time.

2. MATERIALS AND METHODS

In order to study the quality condition of Kifisos, four representative sampling sites were selected: the first near the springs, the second downstream and in the most natural environment, the third in the center of the city and the last one at the estuary (figure 1) whilst all the parameters were examined in winter and spring 2013.

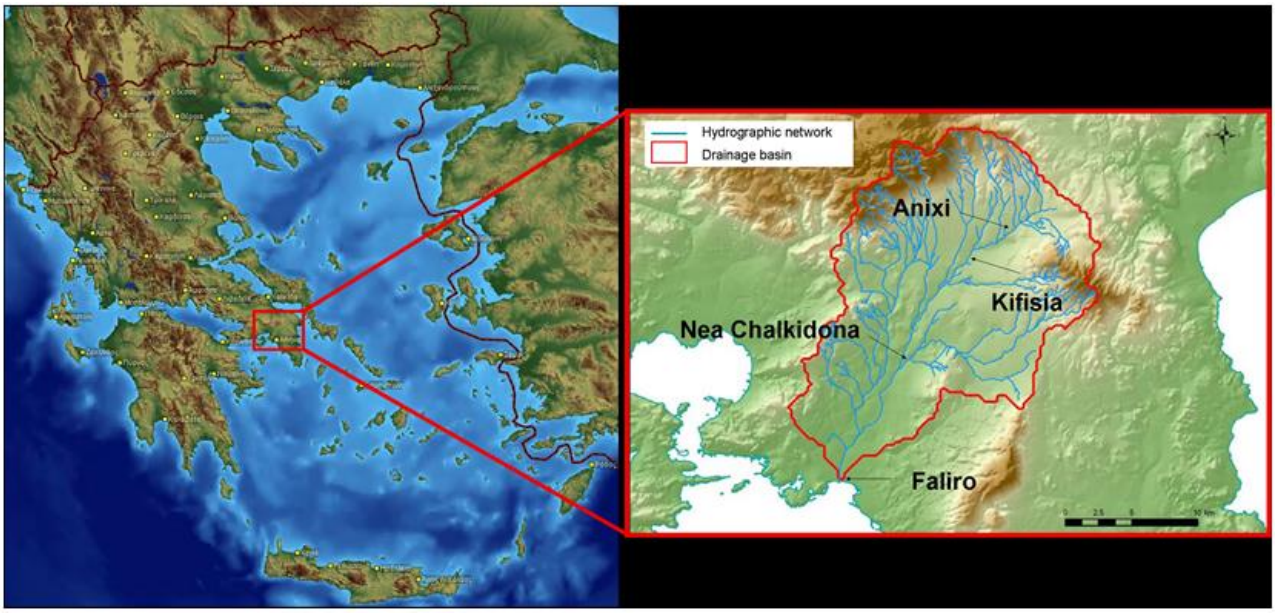


Figure 1: Geomorphological map of Greece and map of the study area in the former prefecture of Attica with the sampling sites pointed out.

The aim of this study was to examine three out of the four main parameters of the WFD in the ecosystem of Kifisos River in Attica, Greece.

The parameters measured in the field were air and water temperature, while water samples were collected (two bottles of 1,5 L each) so as to be examined in the lab, regarding pH, conductivity, nitrate, nitrite, phosphate ions concentration, BOD_5 and COD (in Iliopoulou-Georgudaki et al., 2003). The spectrophotometric method was used for determining the nutrients concentration, for the BOD_5 the dilution method with dilution water (in Attiogbe et al., 2007 and EPA, 2000), 'Pertaining to water sampling', Draft (1). EPA Guidelines) and the COD was estimated by oxidation with $K_2Cr_2O_7$. The mathematical formula for BOD_5 is

BOD= (D1-D2)/p,

Where:

D1 is the dissolved oxygen (DO) of the diluted solution after preparation (mg/l)

D2 is the DO of the diluted solution after 5 day incubation (mg/l)

p is the decimal dilution factor,

Whereas COD results from the type

COD (mg/l) = (B –T) x 1000mg O2/l / S

Conductivity is measured in millisiemens per centimeter (mS/cm) (in Greenberg et al., 1992).

The sampling of macroinvertebrates was held in apical parts of the bed constantly covered with water and ideally adjacent aquatic macrophytes. Specifically, samples were collected from five square surfaces areas 50cm x 50cm, in a bed length of 100m (Economou-Amilli, 2006). The sampling took place to three of the four sites, as the estuary is totally artificial.

The study of the riparian ecosystem was conducted according to the RHS (River Habitat Survey) protocol and especially by examining the Habitat Modification Score and (HMS) and by Habitat Quality Assessment (HQA) (Raven et al., 1998). The study was not conducted in "Faliro", which was completely embanked.

3. RESULTS AND DISCUSSION

3.1 Water quality of river and macroinvertebrate fauna

Results showed that Kifisos River is highly polluted and modified with a very poor in species biological community.

The observed values of both water (figure 2) and air temperature (figure 3) were anticipated taking into account the season and the general climate and microclimate of the sampling sites. The mean value of the first sampling's water temperature was 11°C while the second sampling's mean value was 16°C.

pH values were higher in sampling sites 'Anixi' and 'Kifisia' during both samplings, while at the second sampling the values were lower in all sites, except in 'Nea Chalkidona' (figure 4).

Conductivity values were low at both samplings in all sites (figure 5) with the exception of 'Faliro' site, in which conductivity is higher than in the others and increased at the second sampling by 20 units.

Phosphate concentrations were low at the first sampling in all sites. At the second sampling, they increased significantly and mostly in 'Kifisia' site (figure 6).

While during the first sampling the nitrate and nitrite concentrations were very low (in 'Kifisia' site nitrites' concentration almost zero), at the second sampling they increased, with a remarkable increase in 'Nea Chalkidona' site (figure 7 and 8). In figures 9 and 10, it is being shown that in both samplings, nitrate ions concentration is much higher than this of nitrite.

BOD_5 values in the first sampling indicated a very polluted area, as in 'Nea Chalkidona' and 'Faliro' site the values approached the limit of 25 mg/l, according to Directive 91/271/EEC *'On the treatment of urban waste water'*. In the second sampling, the values were lower, almost half (figure 11).

COD values in all sites exceeded both the limit of 30 mg / L, which the European Union has set as a maximum value of COD for water intended for drinking after treatment, but also the value of 20 mg / L, which the National Centre for Environment & Sustainable Development set in 2003 as a limit for the prevention of eutrophication, while values above this limit are considered unsatisfactory. In the second sampling a decline in concentrations of COD was observed, except in ' Faliro ', where the value has more than doubled (figure 12).

The organisms found during the first sampling in all sites were not aquatic, but liquophilic. In 'Nea Chalkidona' site the macroinvertebrates found were: one gastropod (Class: Pulmonata), one diplopod (Diplopoda, Order: Polydesmida) and one collembola (Order: Collembola). In 'Anixi' site three Clitellata (Order: Clitellata), three gastropods (Order: Pulmonata) and one Hymenoptera, while in 'Kifisia' site only an Araneida and a Clitellata were found in the water. During the second sampling, aquatic organisms were found in the water, mainly due to the fact that pupation has already taken place. In 'Nea Chalkidona' only a diptera larva was found in the water, in 'Anixi' the macroinvertebrates collected were: one Diptera larva, one Coleoptera (Family: Dytiscidae), fifteen Hemiptera (Order: Hemiptera, Suborder: Heteroptera, Family: Hydrometridae, Genus: *Hydrometra*, Species: *Hydrometra stagnorum*) and nine Coleoptera (Family: Hydrophilidae). In 'Kifisia', the biodiversity was increased, with 14 Hemiptera (Order: Hemiptera, Suborder: Heteroptera, Family: Hydrometridae, Genus: *Hydrometra*, Species: *Hydrometra stagnorum*), one Odonata larva (Order: Odonata, Suborder: Zygoptera), which acts as biomarker for non-polluted surface waters, one Plecoptera larva (Order: Plecoptera) and two Hemiptera (Order: Hemiptera), one of the family of Veliidae (Order: Hemiptera, Family: Veliidae) (figure 13).

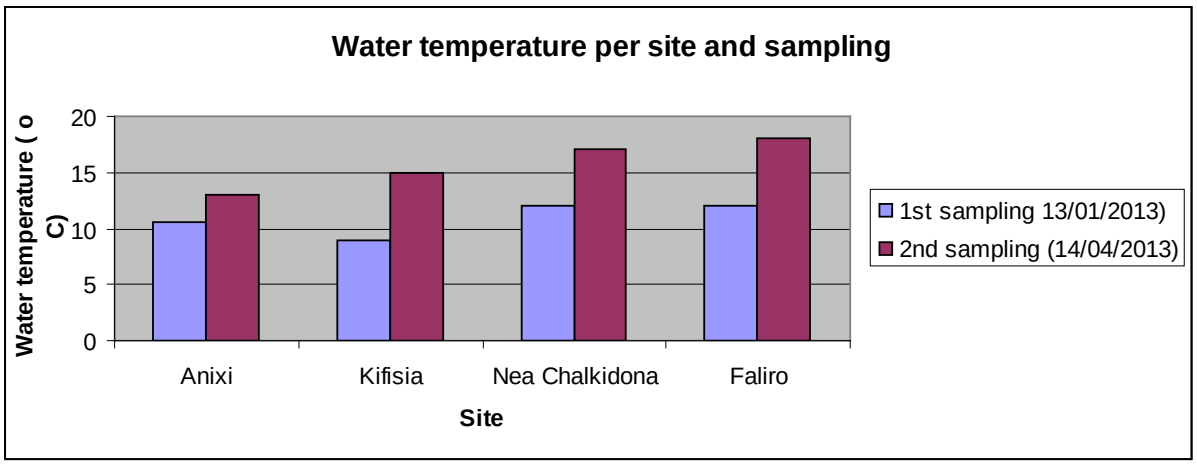


Figure 2: Water temperature results

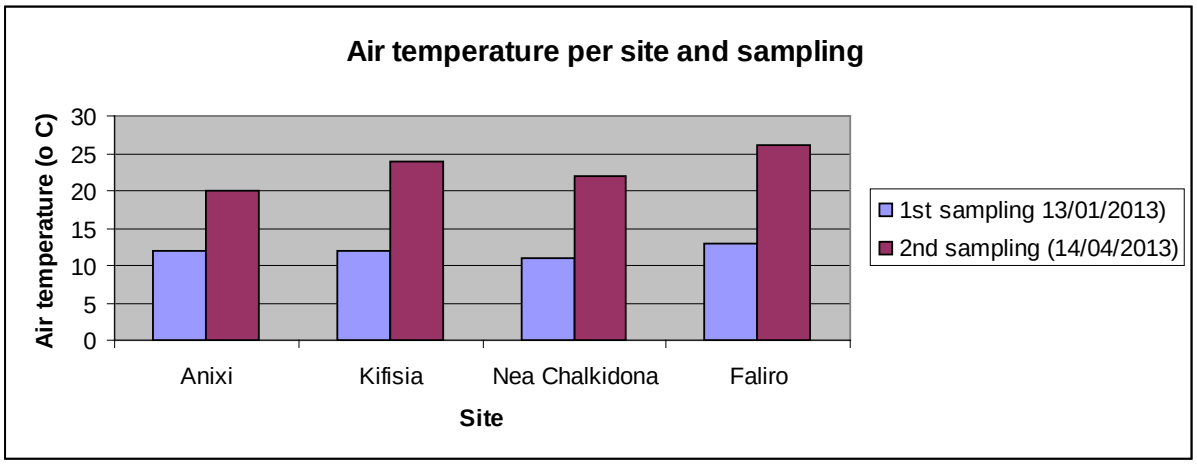


Figure 3: Water temperature results

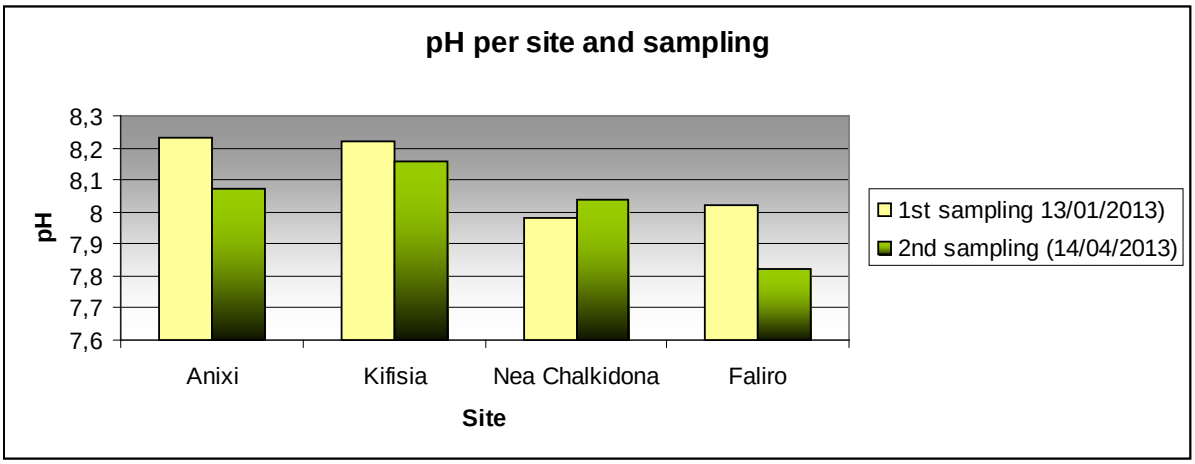


Figure 4: pH results

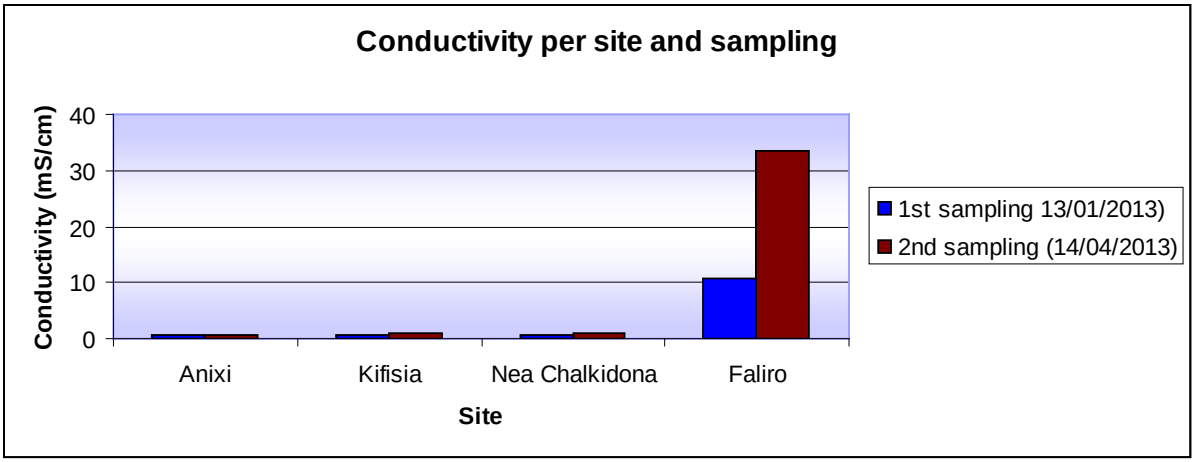


Figure 5: Water temperature results

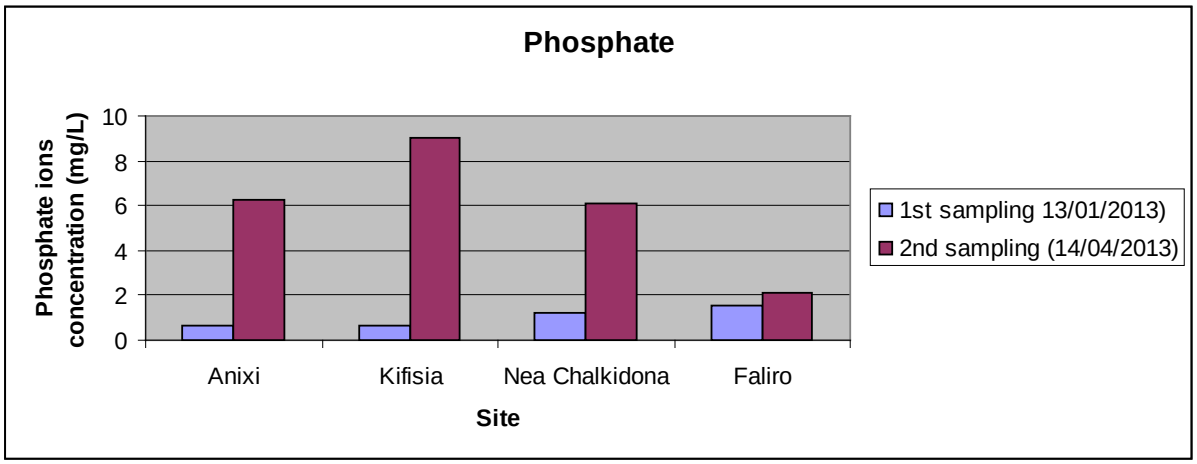


Figure 6: Phosphate ions concentration results

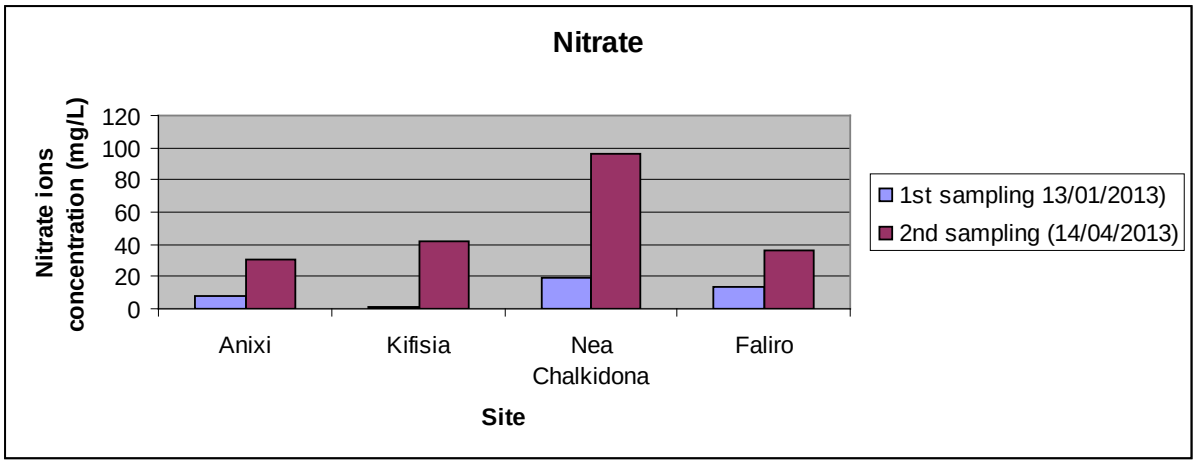


Figure 7: Nitrate ions concentration results

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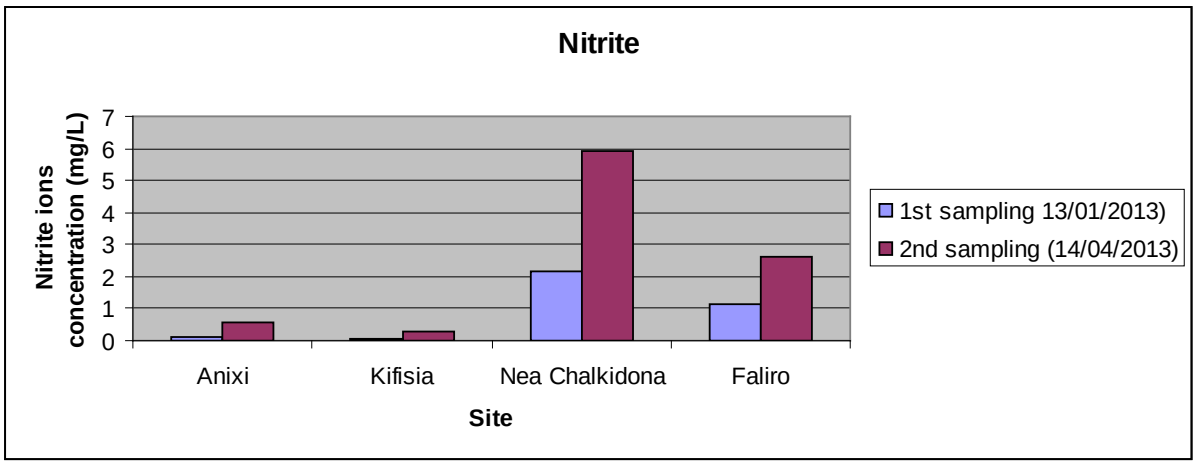


Figure 8: Nitrite ions concentration results

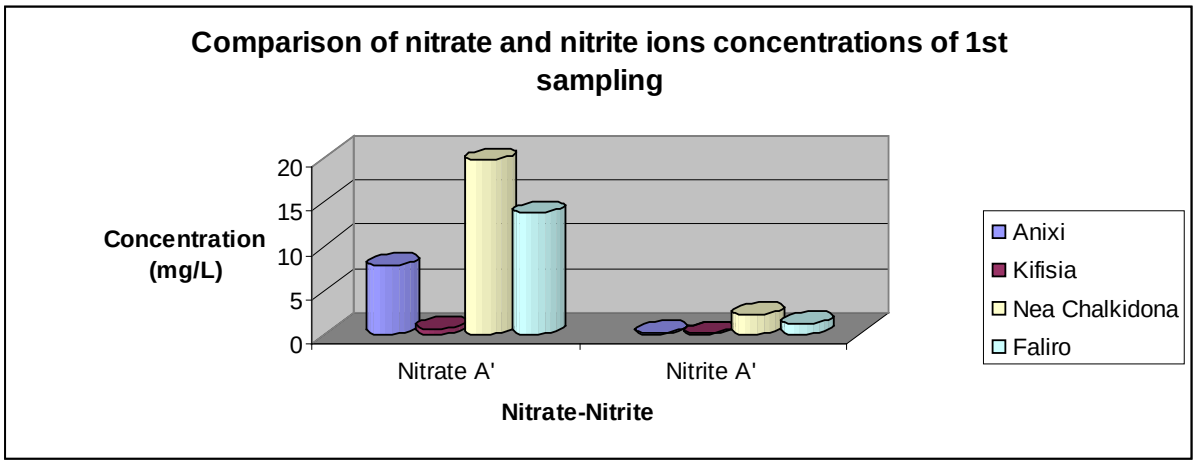


Figure 9: Comparative results of nitrate and nitrite ions concentrations of the first sampling

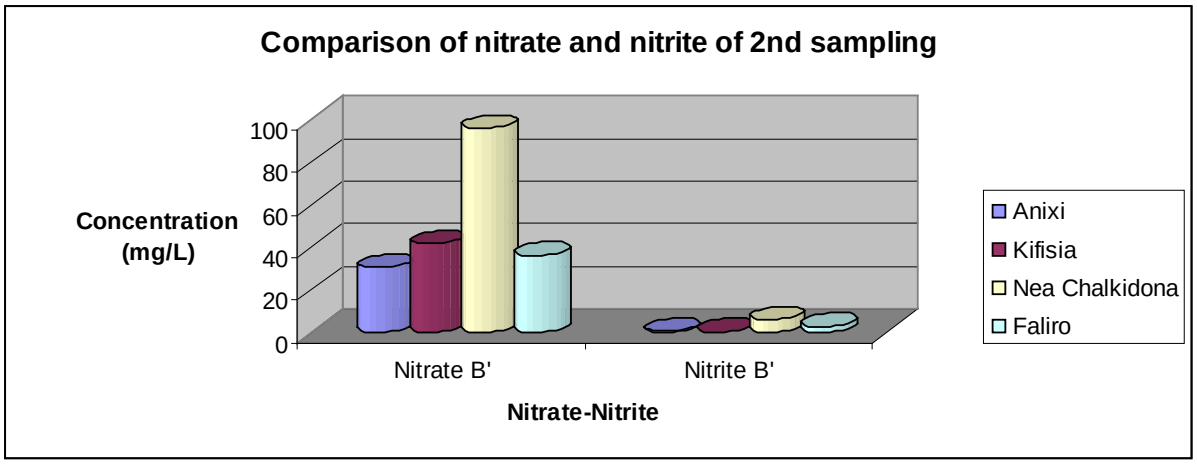


Figure 10: Comparative results of nitrate and nitrite ions concentrations of the second sampling

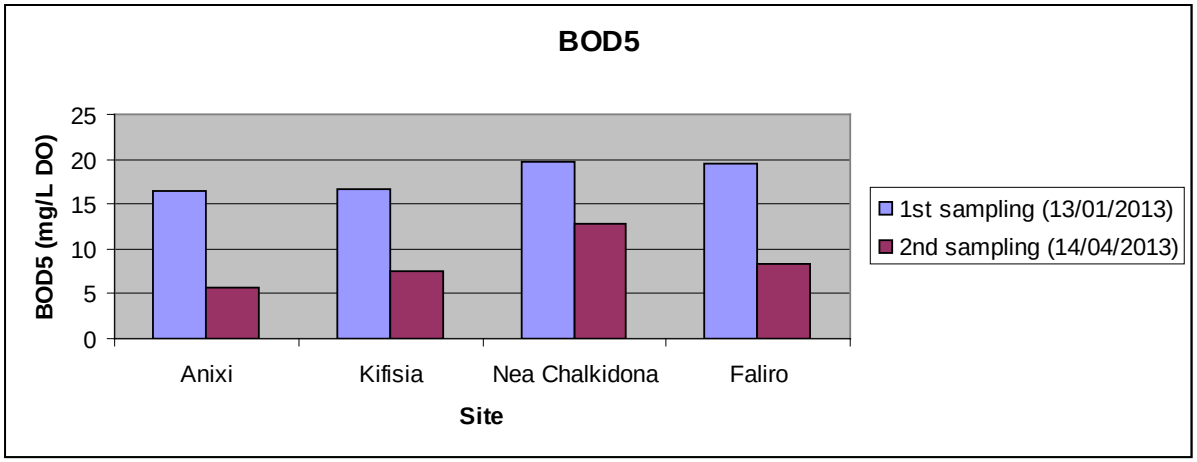


Figure 11: BOD_5 results

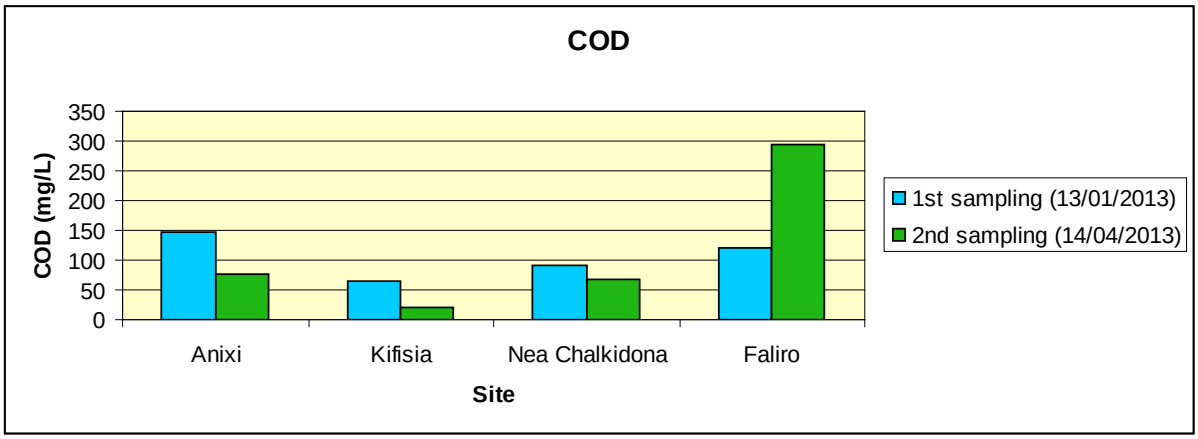


Figure 12: COD results

3.2 Riparian ecosystem

Habitat Modification Score- Habitat Quality Assessment

Riparian ecosystem's condition was revealed with the Habitat Modification Score. The Results showed that as we move downstream the river the riparian ecosystem becomes more and more modified, especially where the rivers runs in urban areas. 'Nea Chalkidona' site is the most modified followed by 'Anixi'. The least modified with also the best physicochemical conditions and the greatest biodiversity in macroinvertebrates is 'Kifisia' site. The features of the channel and banks along with the vegetation type are factors that play a significant role in the degree of modification and degradation. In all three sites, the main problems that Kifisos faces are the illegal waste discharge, the untreated water that flows in it through sewage pipes, the great quantity of solid waste and all the illegal land uses (polders, drillings, industrial activities, alterations of the channel). This is the reason why in all sites, aquatic and riparian plants are not common, but the most common species is *Platanus orientalis.*

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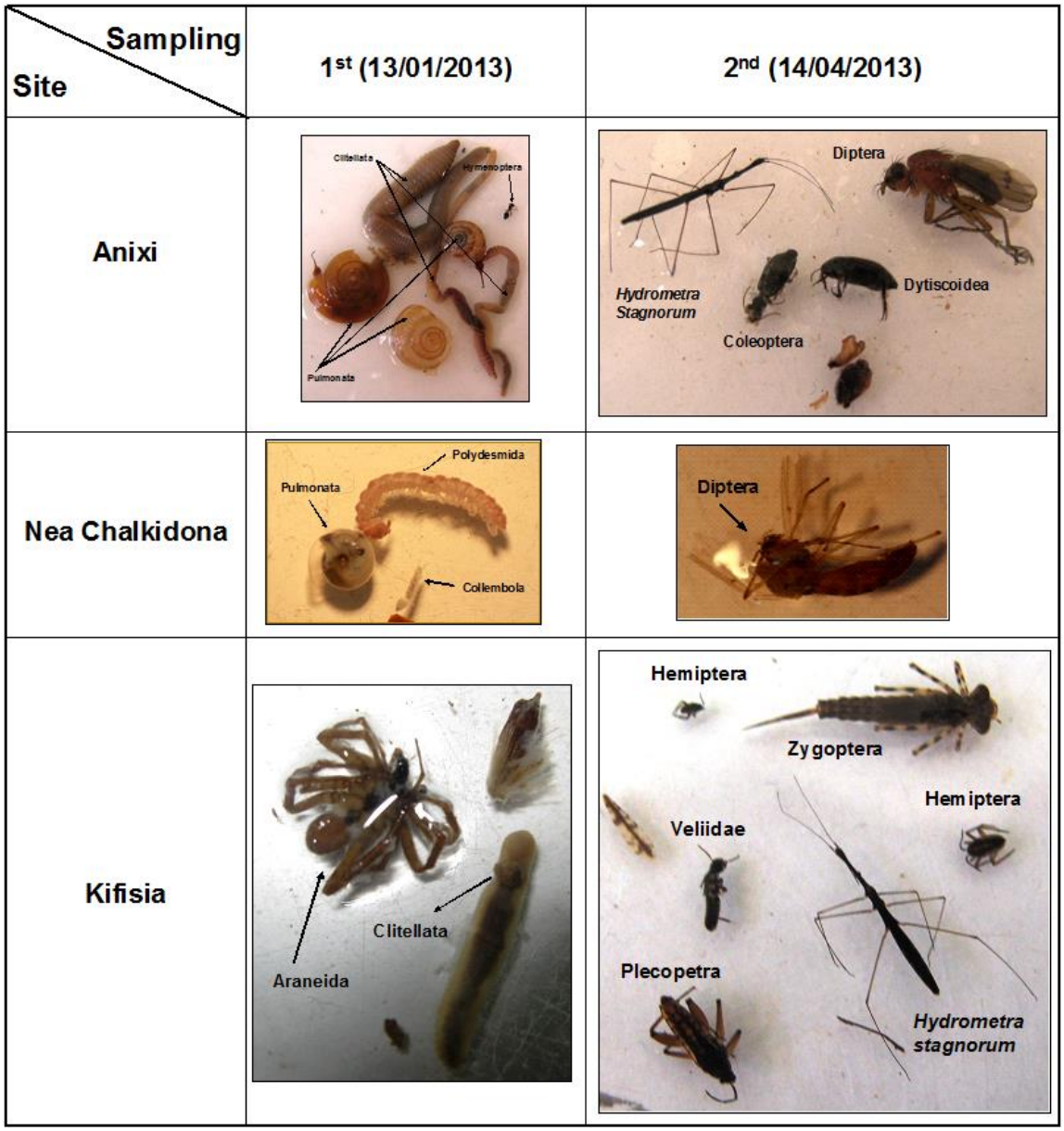


Figure 13: Macroinvertebrates found in the three sampling sites 'Anixi', 'Kifisia' and 'Nea Chalkidona' in both samplings.

4. CONCLUSION

The drainage basin – the shape of which reflects geologic conditions- plays a significant role in understanding that there is a continuity in river ecosystems (River Continuum Concept, RCC) (Economou-Amilli, 2006). In fact, a river is a chain of physical templates, changing during time and in close relationship with biological modifications (Lekkas, 1999). Geological and hydrological characteristics shape the basic template on which the biocommunities adapt. Moreover, the vegetation type of the channel affects the shape of it (in Bridge, 2003), while the main stress factors arise from the presence of a modified type of habitat.

Even though the majority of rivers in Greece is not highly polluted and few of them indicate human intervention as well as increase of pollution factors in relation with time (Skoulikidis et al., 2004), Kifisos seems to be a rather polluted and modified urban river with a low percentage of (semi-) natural biological communities.

Significant fluctuations in temperature are neither anticipated, nor observed (in Argyropoulos & Dasenakis, 1997), while pH values are closely related to geological substrate and are mainly alkaline, except from the value of the second sampling in the site 'Faliro' which can be attributed to acidic waste.

Water conductivity is determined by the number of ions diffused in it and this is the reason why in areas near the sea conductivity is high due to sea or brackish water, a fact that can be seen at the site 'Faliro', which is the estuary of the river.

Phosphate ions concentrations are generally below 2mg/L, values much lower than the limit of 6,7mg/L, set by the European Commission for drinking water (in Koutsomitrou, 2004). Regarding eutrophication, the values measured in all sites during both samplings can create algae blooming (Kiely, 2007).

Taking into account the nitrate ions concentrations, all sites are eutrophic at the second sampling, at spring. Activity of riparian zones affects N and NH_3 concentrations in rivers and of course emergent discharge of sewage can also be an explanation for increased values. Nitrite ions concentration result to the same as above.

In general BOD_5 is in low levels, whereas COD is high, making us conclude that there is chemical pollution with inorganic matter, which organisms cannot degrade. COD's high levels can be attributed to nearby manufacturing activity in the site 'Anixi' –point pollution- , in 'Nea Chalkidona' to illegal municipal sewage pipes and in 'Faliro' to high levels of conductivity (in Katsampanis, 2005).

The macroinvertebrate taxa that were found in all three sampling sites can be found in a wide variety of habitats and water quality conditions (in Camp & Daugherty, 1998), whereas differences between the two samplings are due to seasonality (in Lazaridou-Dimitriadou, 2002). The hydro biotic organisms were found only at spring and among them the Odonata larva is a biomarker of intermediate pollution and the Plecoptera larva is a biomarker of non-polluted environment (site 'Kifisia'). We cannot, of course, conclude that this site is not polluted, as only one organism was found, but we can conclude that there is a positive relationship between COD values and abundance of fauna species. Furthermore, according to Prat et al. (2013), the discharge of treated water into a river does not affect the composition and abundance of dominant taxa- resistant to pollution and present in water of 'poor' ecological status - but the few sensitive species that were found upstream the river before the point of the discharge, disappeared after it downstream the river.

Aquatic insects are ubiquitous in shallow stagnant and flowing waters, which is demonstrated by our results (in Economou-Amilli, 2006). Taking into account the results of RHS protocol, the site' Kifisia ' would still be the one where higher macroinvertebrate presence was most expected, 'Anixi', the second and the last one would be 'Nea Chalkidona'.

The HMS index indicates the degree to which the ecosystem has been altered. The HMS results for Kifisos were rather expected, taking also into account results of the physicochemical parameters and the macroinvertebrate fauna. The site 'Kifisia' appears as the least disturbed, 'Anixi' as obviously modified, while the riparian environment with the greatest modification and disruption seems to be 'Nea Chalkidona'. On the other side, the HQA indicates the quality of the habitat. The most important elements for the habitats are the flow rate of the river, the oxygenation of the water, the presence of food and temperature fluctuations. Again, the conditions are better in 'Kifisia', in a way that the shape of the banks and channel favor the presence of life. Industrial activities and many pollutants in the other two sampling sites have altered the natural riparian environment, resulting in the inability of the river ecosystem to support sensitive life forms.

Even if nowadays the Kifisos river is totally connected to the big highway that is named after it, many measures can be taken to improve its condition. End-pipe solutions in Mediterranean rivers are not efficient (in Prat & Munne, 2000) and what is really needed is quality management subject to the River Continuum Concept (RCC) (in Economou-Amilli, 2006) and based on the four basic management principles of the WFD : a) Sustainable development, b) 'The polluter pays', c) Stand-still principle and d) Precautionary and preventive action. Having been established by the European legislation as the primary element of management needs for surface waters, ecological status is used to monitor and manage ecosystems sustainably with the aquatic biological evaluation to be a transaction between legislative requirements, better scientific knowledge and socio-economic implications (in Birk et al., 2012). Information and awareness of the citizens and the state can result to Kifisos functioning again as an ecological corridor, preventing floods, helping to the renewal of the atmospheric air of the city (with a positive effect on the climate), forming a valuable habitat with aesthetic and ecological value, an area of environmental education that is a substantial part, not only of the urban landscape but also of residents' lives.

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