Environmental quality of an urban stream. The case of Pikrodafni stream in Athens

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Abstract

The stream of Pikrodafni, at the SW part of Attica, is a perennial stream with length of 9300m that springs from Hymettus mountain, and its estuary is at the Saronikos Gulf. Pikrodafni flows through urban areas and is affected by various anthropogenic activities.For the evaluation of the environmental quality of the stream water and its influence on the marine environment, water samples were collected from nine sampling sites, every two months, during the period 2012-13. The main physico-chemical parameters of the water were measured in situ whereas the concentrations of major ions, nutrients, heavy metals and organic carbon were determined in the laboratory. Microbiological analyses were also performed.The concentrations of nutrients were high at all sampling sites and sampling periods and their values increased downstream causing nutrient enrichment in the coastal environment. The stream water quality was found to be moderate to bad regarding the studied nutrients.Heavy metals values didn't exceed the permitted legal limits, but the percentage of Cr(VI) was high. With few exceptions, metals in the streamwater were found mainly in dissolved forms.The results from the microbiological analyses indicated that there were high concentrations of pathogenic microorganisms in the water of the stream and decreasing outside the mouth of the stream. At all sampling sites the water had bad quality with regards to the microbiological parameters.

Keywords: nutrients, heavy metals, microbial contamination

1. Introduction

The term ''urban stream syndrome'' describes the consistent ecological deterioration of streams draining urban areas. The most common and general effect is the replacement of natural surfaces and vegetation by impenetrable surfaces (asphalt, concrete and rooftops) within the urban catchments. This in turn alters the hydrology and geomorphology of the stream channel. Specifically, the amount of run-off entering streams is increased and flashier. Furthermore, the runoff from urbanized surfaces as well illicit municipal and industrial discharges result in increased loading with nutrients, metals, and microbiological contaminants in the streams. All these effects alter the stream habitats transforming them, to varying degrees, from functioning ecosystems to engineered flood control channels or just problematic gutters. There are some concerns for the risks to public health by urban streams with poor water quality. The presence of pathogens is attributed to discharge of inadequately treated or untreated sewage water runoff, combined sewer overflows and sanitary sewer overflows. It has been reported that the increase in the percentage of impervious surfaces in watersheds has led to linear increase in the abundance of faecal coliforms down-stream because sites such as driveways, sidewalks, and parking lots concentrate and convey the highly polluted waters. Apart from the direct anthropogenic activities the excrements of wild animals (birds and rodents) but especially pets (cats and dogs) have been implicated as non-point sources of faecal coliforms to urban streams. Furthermore, some concerns arise from the fact that polluted streams affected by sewer overflow are significant habitats of mosquitoes, which have been associated with the spreading of various diseases. Therefore urban streams represent opportunities for environmental scientists, ecologists, urban managers and planners to study the existing disturbance and adverse phenomena and to contribute to more effective urban stream and adjacent landscape management. (Paul and Meyer 2001, Morley and Karr 2002, Walsh *et al* 2005, Bernhard and Palmer 2007). In this context, the present paper presents a study of chemical and microbiological quality of the lower part of the urban stream Pikrodafni located in the SW suburbs of Attica. The measured parameters were compared to existing legislation standards. Furthermore some suggestions for further study and management advice are included in order to assist local stakeholders (municipalities and citizen associations).

2. Study area, materials and methods

Pikrodafini stream is located in the SW of Athens. The springs of Pikrodafni are at the west of Hymmetus mountain (Kareas area). The total drainage basin is 22.4Km^2 and the stream runs for approximately 9.3 km through the urban municipalities of Vyronas, Ilioupoli, Agios Dimitrios, Palaio Faliro until it discharges into Saronikos gulf (Alimos area). A few smaller streams also discharge into Pikrodafni and sections of two NATURA protected areas of Attica are located within its drainage basin (Hymmetus mountain and Kaisariani aesthetic forest). Pikrodafni urban stream has a yearlong flow and has not a balanced geo-morphological state as it is in a continuous state of erosion. It is considered as an area of significant environmental interest in Athens since most of its length (6.6km) is not channelled; it has been degraded by uncontrolled expansion of urban residencies, illegal waste disposal, overflows of sewage pipelines and urban surfaces runoff, but is still characterized by ecological integrity in some sections that are active habitats for various local species of fauna and flora, with 32 bird species reported in the mouth in 2011. The main land use in Pikrodafni drainage basin is urban fabric (66%) and the rest is comprised of transitional woodland shrubs(26%), coniferous forest (5%) and to lesser extents sclerophyllous vegetation, green urban areas and industrial or commercial units. (Argyraki *et al* 2013, Dimitriou *et al* 2015). For the purposes of this research six water samplings were performed (April 2012, June 2012, July 2012, October 2012, January 2013 and February 2013) at 9 stations , 6 along the stream, one at the mouth and two on the coast on either side of the mouth. Temperature, conductivity, salinity and pH were measured in situ with a portable polymeter (YSI 63). The samples were collected in pre-cleaned HDPE bottles and filtered through Millipore membrane filters (mixed cellulose esters types with 8μm and 0.45 μm pore diameter) within 24 hours of collection in order to quantify the suspended particulate matter (SPM) and to separate water and particles and proceed to further chemical analyses. Sub-samples of the filtred waters were divided for analysis of major anions (Cl^-, SO_4^{2-}), nitrogen and phosphorus forms, dissolved organic carbon (DOC) and dissolved metals (Cd, Cr, Cu, Ni, Pb, Zn). The anions were measured using ion chromatography (Metrohm 820 IC Separator Center, 819 IC Detector). Nitrogen and phosphorus forms were measured using spectrophotometric methods (Grasshoff *et al* 1999 using Varian Cary 1E). DOC was was measured with an automatic analyzer (Shimadzu TOC/5000). Microbiological parameters (E.coli and Enterococci) were also measured (ISO 9308-1:2014, ISO 7899-2:2000). The dissolved metals were pre-concentrated using Chelex 100 resin(Riley and Taylor 1968, Dassenakis *et al* 1997). The particulate metals were quantified after dissolution of the filters with concentrated nitric acid (Dassenakis *et al* 1997). The dissolved and particulate metals were measured with atomic absorption spectrometry (FAAS Varian SpectrAA 200, Graphite Furnace AAS Varian GTA 100-Zeeman 640Z with autosampler).

3. Results and discussion

The statistics (ranges and averages) of the physicochemical parameters measured in Pikrodafini stream are presented in Table 1. The average winter temperature in all stations was 13 °C, while the average summer temperature 23°C, both normal corresponding to the respective season. The average conductivity in the stream (0.915 ms/cm) was normal for fresh water. In all samplings conductivity was below the legislation threshold of 2.5ms/cm, but most samples (27 of 30) presented values above 0.7ms/cm. The station at the mouth was affected by seawater on most occasions and especially in the dry season when the fresh water flow was minimal. The pH values were also normal for fresh and seawater (average 8.2). The SPM (suspended particulate material) of the river presented extremely high variability, between sampling stations and between seasons. The maximum value was measured at the stream in February, but the stations on the adjacent coast in general had overall higher levels of SPM (highest minimum value 13.5 mg/L and increased median 15.3mg/L) compared to the stream and mouth due to increased turbidity from the influence of waves. Despite one extreme value at a stream station in February after heavy rainfall the expected seasonal pattern, showing higher SPM levels in the wet season was not clearly manifested. The wet season average SPM was 59.5mg/L, highly affected by the extreme value of 995mg/L, while the dry average was 11.6mg/L, however the statistical comparison of the two groups of values did not lead to a clear difference because the median SPM values were 6.6 and 9.0 mg/L, approximately equal, for the wet and dry season respectively. The expected higher SPM levels in the wet season naturally attributed to rainfall, run-off and increased flow, were not always thus because some stations had very low levels in the wet season and some other stations had increased levels during the dry season. These unexpected findings were due to stream bed morphology. Dissolved organic carbon (DOC) presented much higher levels in the main stream and the mouth of the river (average value 4.8 mg/L) in comparison to the costal seawater (1.0mg/L) which is expected due to dilution. There was a seasonal pattern in the variation of DOC with higher values measured during the wet season samplings, with the wet season average increased (5.1mg/L) compared to the dry average (3.0mg/L). The major anions (Cl^- and SO_4^{2-}) presented a very strong spatial variability. The station at the mouth was highly affected by the sea, with very high levels of anions during the dry season where the decreased stream flow and the wind and wave action brought sea water inside. Concerning the seasonal variability Cl^- showed increased levels in the dry season (69.0 mg/Lvs 36.6mg/L) while the SO_4^{2-} presented the reverse trend (34.6 mg/L in the dry vs 54.7 mg/L in the wet season). The spatial distribution of total nitrogen and total phosphorus is similar to that of DOC, i.e. the levels at the sea are significantly lower, as seen by the average and range values in Table 1. In the case of phosphorus the main form is inorganic phosphates, but in the case of nitrogen there is difference in the dominant species, dependent on the water type. Specifically, in the stream samples the inorganic forms (ammonium, nitrites and nitrates) prevail while in the coastal seawater the dominant species are the organic nitrogen compounds. The seasonal variation of nutrients also verifies that increased run off during the wet season leads to increased concentrations. Specifically, the average total nitrogen and phosphorus levels in the wet season are 939 μmolN/L and 23.2 μmolP/L compared to 396 μmolN/L and 8.6 μmolP/L during the dry months. Based on the river water quality classification for nutrients by Skoulikidis *et al* 2006 each station was given a characterization (high, good, average, poor and bad) based on the concentrations of each nutrient form and each sampling. The overall percent scoring for the stream is presented in Figure 1. In most cases of samples the quality was adequate and poor. The results of the microbiological analyses were evaluated according to the directive for bathing waters (2006/7/EC). The counts for EC (*E. coli*) and ENT (*Enterococci*) at the stream stations indicate constant poor quality while at the sea the quality was invariably poor for both parameters in the wet season and poor for ENT - excellent for EC in the dry season. So the stream is mainly characterized as having average and poor water quality in respect to microbiological parameters and nutrients which are both indicators of urban run-off and wastewater pollution. Concerning the dissolved trace metals they did not exhibit any seasonal pattern and their levels did not exceed the yearly average concentrations dictated by the Hellenic Legislation (M.D. 51354/2641/ E103/ 2010) on inland and coastal water quality except for Cr(VI). The ranges of particulate metals were: Cr (0.05 – 7.9 μg/L), Cu (0.16 – 3.8 μg/L), Ni (0.07 – 4.6 μg/L), Pb (0.02 – 3.1 μg/L) and Zn (0.39 – 7.6μg/L). The average particulate Cu value at the coastal stations was slightly higher than the stream (0.96 and 1.4 μg/L).But for all other metals that difference was more significant. The stream average concentrations were 0.64, 0.46, 0.30 and 1.85 μg/L for particulate Cr, Ni, Pb and Zn, while at the sea the

Table 1. Statistics of chemical parameters in Pikrodafni stream

Parameter	Range	Average
Temperature °C	13.2 – 26.7 °C	19.3°C
Conductivity (main stream)	0.915 – 1.290 mS/cm	1.290 mS/cm
Conductivity (river mouth)	1.273 – 50 mS/cm	37.19 mS/cm
Conductivity (sea)	55.7 – 62.6 mS/cm	59.9 mS/cm
pH	7.7 – 9.0	8.2
SPM (stream and mouth)	0.4 – 995 mg/L	43.2 mg/L (median = 5.1)
SPM (sea)	13.5 – 59.0 mg/L	24.9 mg/L (median = 15.3)
DOC (stream and mouth)	1.5 – 15.0 mg/L	4.8 mg/L
DOC (sea)	0.9 – 1.3 mg/L	1.0 mg/L
TN (stream and mouth)	145-2546 μmolN/L	776 μmolN/L
TN (sea)	120-182 μmolN/L	150 μmolN/L
TP (stream and mouth)	2.4 – 77.4μmolP/L	17.3 μmolP/L
TP (sea)	0.66 – 1.5 μmolP/L	1.0 μmolP/L
Cl (stream)	1.5 – 200 mg/L	44.1 mg/L
SO_4^{2-}(stream)	2.7 – 121 mg/L	47.3 mg/L
Dissolved Cd	0.02 – 0.40μg/L	0.08 μg/L
Total Dissolved Cr	0.72 – 10.4μg/L	3.1μg/L
Dissolved Cr VI	0.2 – 12.0 μg/L	3.9 μg/L
Dissolved Cu	0.47 – 8.7 μg/L	3.8 μg/L
Dissolved Ni	0.95 – 19.5 μg/L	5.0 μg/L
Dissolved Pb	0.05 – 2.7 μg/L	0.33 μg/L
Dissolved Zn	1.8 – 29.5 μg/L	12.4 μg/L

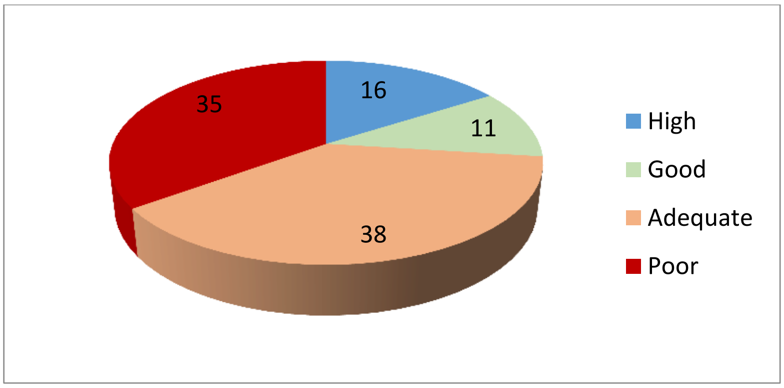

Figure 1. Per cent of sample cases to each nutrient water quality class

average concentrations were higher (2.2, 1.5, 1.0 and 4.1 μg/L)This could be attributed to the presence of garbage and metallic scrap objects on the beach and in the sea. For all metals the dissolved form prevails in the stream stations and the particulate form in the sea An explanation for both these findings is also the flocculation and precipitation of particulates during the mixing of fresh and seawater. There was no seasonal variation of particulates metals.

4. Conclusions

From the results of this study it has become apparent that the quality of the stream is poor due to uncontrolled intentional or accidental discharges of pollution loads. And that the stream affects the coastal area where it discharges especially with pathogens. The pollution status is not extremely high beyond repair but measures need to be implemented to achieve improvement and prevent further deterioration of this important urban stream ecosystem. The local authorities and concerned stakeholders should organize awareness campaigns to residents and garbage clean up actions of the stream bed organized. Also local authorities should implement some type of monitoring of garbage and waste disposal and be able to impose strict fines to polluters. A more permanent monitoring network of the stream from both a chemical and ecological point should be established with regular samplings, at least on seasonal basis if not quarterly basis. Finally, there should be plans and measures to handle storm water overflow during rainfall to avoid discharge of heavily polluted run-off water into the stream.

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