DISTRIBUTION OF SEA WATER POLLUTION IN THE VENETIAN HARBOUR CHANIA, GREECE.

STAVROULAKIS G., KALDERIS D., PAPAFILIPPAKI A. and MINOU A.

Technological Educational Institute of Crete – School of Applied Sciences.
Department of Environmental & Natural Resources Engineering,
PO Box 89, 73103 Chania.
E-mail: gstav@chania.teicrete.gr

ABSTRACT

The level of water pollution in the coastal area of the Venetian Harbour of Chania was studied in the period of February - October 2014. Surface water samples were collected from 7 sampling positions and the values of DO, BOD, COD, NO_3^-, NH_4^+, PO_4^+, fecal coliforms, *E. coli* and enterococci were determined. Dissolved oxygen concentration was decreased to 4mg/l during the summer touristic season, whereas the BOD and COD levels were measured at 7 mg/l each. NO_3^- concentration was in the range of 2,5-6,6 mg/l, whereas the concentrations of NH_4^+ and PO_4^+ were 0,27 and 0.5 ppm, respectively. The levels of bacteriological loads were significant throughout the study period, whereas a sharp increase in *E.coli* and enterococci colonies (150-500 cfu/100ml) was observed in the summer months. The sea water pollution levels indicate the need for implementation of a strategic plan for the protection of the sea water quality of the study area as the numbers of incoming visitors and the ingoing and outgoing flow of touristic and private vessels are expected to increase steadily in the future.

Keywords: seawater pollution, anthropogenic impact.

1. Introduction

The sustainable environmental management of the coastal zone is a multi-component issue, common in many coastal cities worldwide. Sea water quality can be affected by inland practices as well as intensive sea water use. The urban runoff infrastructure in the city of Chania has several outlets in the Venetian harbor, therefore stormwater flow can carry dust, road depositions and other pollutants and affect the sea water quality. Leaks from the wastewater infrastructure or illegal connections to the sewer further increase the polluting load reaching the sea (Ruggieri *et al*., 2011, Tselentis, 2008). Additionally, the heavy use of the harbor's marina for recreational purposes (especially the summer months) often leads to pollution incidents.
The increasing presence of nutrients in coastal waters is responsible for the development of algae and is an indication of contamination from city point sources. The overall quality of the coastal waters is determined by the examination of physical, chemical and biological parameters. Coastal water is a dynamic system, in which the flow and currents have a significant effect on these parameters (Ruggieri *et al*., 2011).

This work focuses on the coastal waters of the Venetian harbor of Chania, an area with very high touristic profile throughout the year. The physical, chemical and biological parameters of the water are measured at different times and sampling locations. Finally, the study suggests potential steps towards protection of the coastal waters from stormwater runoff.

2. Materials and methods

The area of study can be seen in Figure 1. Seven water sampling locations (St1-St7) were selected within the Venetial harbor. The city sewer network has outlets near these locations. The main marina (where the majority of yachts, touristic and fishing boats are stationed) is located at the eastern part of the harbor (locations St6 and St7). Samples were collected

throughout the period of February to October 2014, in order to obtain a more uniform (both in high- and low-touristic season) view of the water quality.

Figure 1: Map of the Venetian harbor, showing the 7 sampling locations.

The sea water samples were collected in sterilized vials and the following parameters were measured within 2 hrs of sampling: dissolved oxygen (DO), BOD_5, COD, NO_3^-, NH_4^-, PO_4^{3-} fecal coliforms, *E. coli* and enterococci. Details on the analytical protocols used for the determination of these parameters can be found in our previous publication (Stavroulakis et al. 2014).

3. Results and discussion

Figure 2 shows the results obtained from the dissolved oxygen, BOD and COD measurements. Dissolved oxygen concentrations ranged between 4 and 8 mg/l. It is known that DO largely depends on water temperature, since more oxygen can be dissolved in water during the winter. Bottom feeders, crabs, oysters and worms need minimal amounts of oxygen (1-6 mg/L), while shallow water fish need higher levels (4-15 mg/L) (Kemker, 2013). Therefore, the DO levels recorded are considered normal throughout the study period. However, the BOD and COD levels were considerably higher compared to the ones obtained from Faragallah et al. (2009) who measured BOD, COD and other parameters in the open Mediterranean Sea (near Crete). The higher BOD values of 9-10 mg/L were obtained at the August 2014 sampling, at all sampling locations. Faragallah et al. reported values in the range of 2-3 mg/L, therefore our measurements are an indication that the Venetian harbor may have been contaminated to some extent by either inland, shore (commercial) or sea activities.

The COD values obtained were in the region of 8-18 mg/L (seasonal fluctuations) and showed a similar pattern as the BOD values. These values were 3 to 4 times higher compared to the values obtained by Faragallah et al. (3-5 mg/L). Again, this is an additional indication that – depending on the season – the Venetian harbor receives some anthropogenic organic loads.

Nitrate concentrations throughout the study period ranged between 2.6 and 6.6 mg/L (Figure 3), showing no major fluctuations between the sampling locations. Faragallah et al. reported values in the range of 0.21 – 0.33 mg/l. The high levels of nitrates may be attributed to the decomposition of organic matter in the area. Ammonium ion values showed a good match between sampling locations and dates (~0.1 mg/l), with the exception of 4 measurements (stations 2, 3, 5 and 7) that recorded much higher values, in the range of 0.4 mg/l. This was probably due to isolated pollution incidents from point sources.

The microbiological parameters exhibited the same increasing trend during the high touristic season (May – October 2014). Generally, the first three sampling stations had the highest counts of bacteria, followed by St6 and St7. Although the values are within the limits set by EU legislation for bathing water, the increasing trend observed during the summer months possibly means that there may be illegal connections from adjacent businesses or isolated incidents related to touristic activity that pollute the sea water. Sampling locations 2 - 5 reflect the busiest

part of the Venetian harbor with the highest recreational activity. Sampling locations 6-7 are based on the marina, where most fishing and recreational boats are stationed.

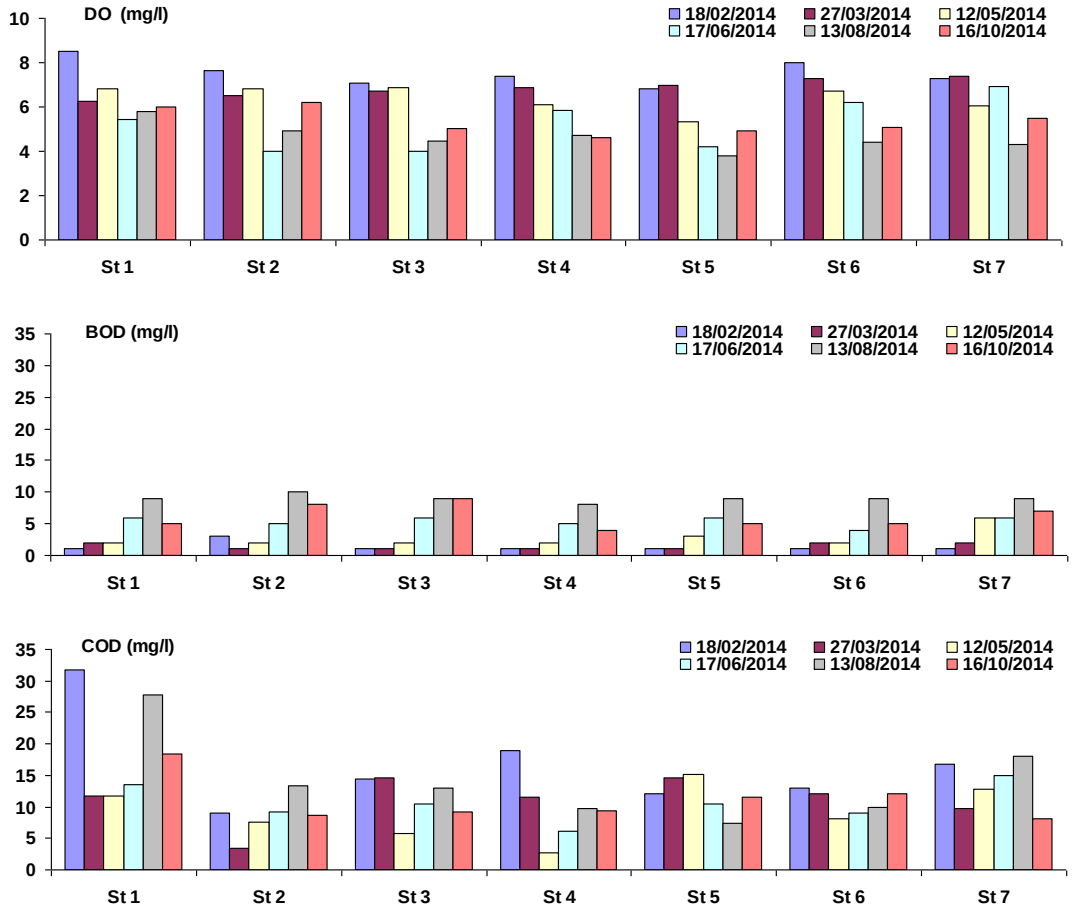

Figure 2: Measurements of DO, BOD, COD, throughout the study period.

The results indicate that the Venetian harbor of Chania is under considerable environmental pressure from human activities that are related to city businesses (within or outside the harbor's boundaries) and other touristic activities. Therefore, there is the need for developing a Strategic Plan for sustainable environmental management of the city's storm water runoff in parallel with a modern environmental management system (such as ISO 14001) for the environmentally-friendly operation of the harbor itself. This Strategic Plan may consist of the following components: 1) Full digital mapping of the sewer network, 2) Development of an illicit discharge and illicit connection program, 3) Establishment of total maximum daily loads (TMDLs) for the Venetian harbor – TMDLs is a calculation of the maximum amount of a pollutant that a waterbody can receive and still safely meet water quality standards, 4) Development of guidelines for new construction works within the city boundaries – these guidelines will ensure that the potential runoff quality and quantity after the construction is finished, is at least the same as before the construction, 5) Registration of the Venetian harbor to the European Sea Ports Organization (ESPO)/EcoPorts – registration to this organization is the first step towards implementation of ISO 14001 or Port Environmental Review System (PERS) 6) Development of an information and dissemination action that will involve Chania's citizens and professionals and provide knowledge on the hazards of storm water runoff, analyze the best management practices for homes and businesses and initiate partnerships for better protection of the Venetian harbor's waters and other receiving bodies.

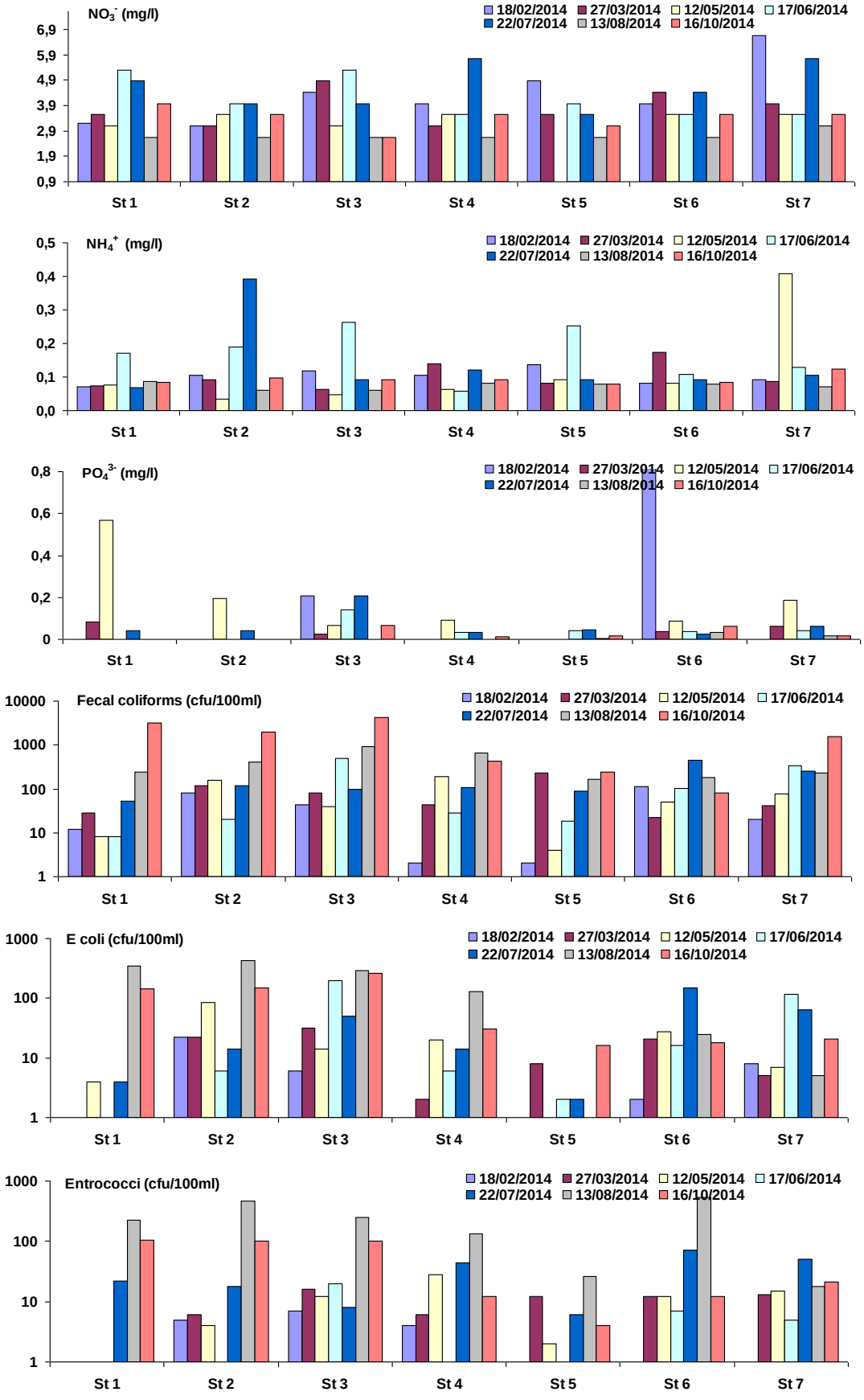

Figure 3: Measurements of NO_3^-, NH_4^+, PO_4^+ fecal coliforms, *E. coli* and enterococci, throughout the study period.

ACKNOWLEDGEMENTS

This project is implemented through the Operational Program "Education and Lifelong Learning" action Archimedes III and is co-financed by the European Union (European Social Fund) and Greek national funds (National Strategic Reference Framework 2007 - 2013). Project title: Decision support tool for the management of urban run-off in coastal cities –COASTSURF.

REFERENCES

1. Ruggieri N., M. Castellano, M. Capello, S. Maggi, P. Povero (2011), Seasonal and spatial variability of water quality parameters in the Port of Genoa, Italy, from 2000 to 2007, Marine Pollution Bulletin, 62: 340–349
2. Stavroulakis G., A Kirkou, A. Bampala. (2014), Sea water quality in the Venetian Port of Chania. In Proceedings of the 5th Environmental Conference of Macedonia. 14-16/3/2014 Thessaloniki. Greece.
3. Tselentis B.S. (2008), Marina Environmental Review System: A methodology to assess environmental management in recreational ports. European Research Studies Jounrnal, Volume XI, Issue (1-2) pp 47-56
4. Kemker Ch. “Dissolved Oxygen.” Fundamentals of Environmental Measurements. Fondriest Environmental, Inc. 2013
5. Faragallah, H. M. Askar, A. I. Okbah, M. A.and H. M. Moustafa (2009), Physico-chemical characteristics of the open Mediterranean sea water far about 60 Km from Damietta harbor, Egypt. Journal of Ecology and The Natural Environment 1(5):106-119.