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REGIONAL MARINE POLLUTION EMERGENCY RESPONSE CENTRE FOR THE MEDITERRANEAN SEA (REMPEC)

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STUDY OF THE SHORT AND MEDIUM TERM ENVIRONMENTAL CONSEQUENSES OF THE SINKING OF THE AGIA ZONI II TANKER ON THE MARINE ECOSYSTEM OF THE SARONIKOS GULF

Submitted by Greece

SUMMARY

Executive Summary: On 10 September 2017, the chemical/product tanker Agia Zoni II sank in the Piraeus anchorage area. Oil was observed on the sea surface the same day which in the following days stranded along approximately 4 km of shoreline on Salamis Island, as well as approximately 25 km of the Piraeus/ Athens Riviera shoreline on the mainland. Following the incident, the Institute of Oceanography of the Hellenic Centre for Marine Research (H.C.M.R.) has carried out a series of systematic surveys to monitor the possible impacts of the incident on the marine ecosystem of the Saronikos Gulf. The general outcomes from the environmental impact assessment are presented in detail in this document and its Annexes.

Action to be taken: Paragraph 2

Related documents: REMPEC/WG.45/8

Introduction

1 On 10 September 2017, the chemical/product tanker Agia Zoni II sank in the Piraeus anchorage area. Oil was observed on the sea surface the same day which in the following days stranded along approximately 4 km of shoreline on Salamis Island, as well as approximately 25 km of the Piraeus/ Athens Riviera shoreline on the mainland.

2 Following the incident, the Institute of Oceanography of the Hellenic Centre for Marine Research (H.C.M.R.), under the direction of the Ministry of Shipping and Island Policy and taking into account the provisions of paragraphs 3.5.13 and 3.15.1 of the National Emergency Plan on oil pollution incidents (Presidential Decree 11/2002, Government Gazette Issue 6 A'/2002), has carried out a series of systematic surveys to monitor the possible short-term and medium-term impacts of the incident on the marine ecosystem of the Saronikos Gulf.

3 The general outcomes from the environmental impact assessment were:

(i) the major consequences of the oil spill were constrained along the shoreline and specifically in the areas of Salamis, Ellhniko and Glyfada for a period of three months following the incident,

(ii) not major findings regarding the presence of petroleum hydrocarbons were identified along the shoreline after December 2017, (iii) marine organisms seem unaffected by the incident, while also there are no evidence of bioaccumulation in respect to the incident, and

(iv) regarding seabed mapping there were no petroleum residues detected in the zone of 3 to 20 m depth of the studied areas following the conclusion of clean-up operations.

Actions requested by the Meeting

4 **The Meeting is invited to**:

.1 **take note** of the information provided in the present document; and

.2 **comment**, as appropriate.

Appendix

STUDY OF THE SHORT AND MEDIUM TERM ENVIRONMENTAL CONSEQUENSES OF THE SINKING OF THE AGIA ZONI II TANKER ON THE MARINE ECOSYSTEM OF THE SARONIKOS GULF

1. BACKGROUND

The existence of H.C.M.R. long time series of background data on the ecological/pollution status of the area, the ecosystemic approach as provided by the relevant European directives (WFD, MSFD) and the state-of-the-art chemical analysis techniques of petroleum hydrocarbons, assured the reliable investigation of the environmental consequences of the incident on the marine ecosystem health of the affected area

The study of the Institute of Oceanography, from September 18th 2017 till March 30th 2018, has been pursued on the following axes:

(a) Recording of chemical pollution in seawater and sediments. Between September 18th 2017 and March 21st 2018 a series of seawater samplings were conducted in order to record the levels of environmental burden caused by the oil spill and its development in the coastal zone as well as open sea areas of the Saronikos Gulf. The seawater sampling network included 70 stations, 56 coastal and 14 open sea, and a total of 247 seawater samples were collected. The collected seawater samples were analyzed for total petroleum hydrocarbons and polycyclic aromatic hydrocarbons. Regarding sediments, three samplings have been conducted with *R/V* Aegaeo on September 2017, November 2017 and January 2018, in the open Saronikos Gulf. The monitoring network included 22 stations, with a total of 59 sediment samples being collected. Aliphatic and polycyclic aromatic hydrocarbons, as well as the metals vanadium and nickel, were determined in the sediment samples.

(b) Assessment of the ecological status of the Saronikos area following the incident based on the indicators related to the bio-communities of the zoo- and phytobenthos, as provided by the relevant European directives (WFD, MSFD). To this, two samplings of benthos were conducted in the open Saronikos Gulf (September 2017 and January 2018) in order to investigate the possible impacts of the incident on the zoobenthic communities of the sublittoral zone. Furthermore, in order to assess the status of macroalgae of the upper sublittoral zone a macrobenthos sampling has been conducted in March 19-22nd 2018 at the coasts of Salamina and Attica.

(c) In order to investigate the potential bioaccumulation of contaminants related to the incident and the possible biological effects on marine organisms the following sub-actions have been taken: On January 23-24th 2018 mussels *Mytilus galloprovincialis* were immersed in cages at four sites, Salamina, Agios Kosmas, Glyfada and Asteras Vouliagmenis. The mussel cages were immersed at two depths in each site (5 and 20 m below the sea surface) and were collected after approximately six weeks on March 7th 2018. In the collected mussels: (i) the concentrations of hydrocarbons and heavy metals were determined in their tissue, (ii) a set of biomarkers indicative of oxidative stress (catalase), phase II biotransformation (glutathione S-transferase) and neurotoxicity (acetylcholinesterase) were measured, (iii) condition index (CI) was determined as a measure of the health status of the animals that summarizes their physiological activity (e.g., growth, reproduction, secretion) under given environmental conditions and (iv) metallothioneins (MTs) were determined. Furthermore, determination of aliphatic hydrocarbons was carried out in the tissue of selected fish (*Mullus barbatus, Merluccius merluccius, Parapenaeus longirostris, Illex coidentii*, depending on availability) which were sampled by demersal towed gears (trawlers) in October and November 2017 by the Institute of Marine Biological Resources and Inland Waters of H.C.M.R. in the wider area of the Saronikos Gulf.

Finally, **(d) in order to inspect the present condition and investigate the potential presence of macroscopic oil residues on coastal benthic habitats** of the Saronikos gulf, after the completion of the cleaning operations and the removal of the Agia Zoni II wreck, underwater visual surveys were conducted using drop camera. The survey focused on parts of the coasts of Salamis Island and Attica mainland where the impact of the accident was mainly manifested. The visual survey was carried out along underwater transects running parallel and perpendicular to the shoreline at depths between 3-20 meters. Particular emphasis was placed on the critical examination of the Posidonia meadows and the vegetation of shallow reefs, in order to identify indirect signs of disturbance. This allowed for a systematic seabed inspection of a total length of ~ 25 km.

In Figure 1.1 that follows the complete survey network and conducted monitoring in the wider Saronikos Gulf is presented. The final scientific report of the Institute of Oceanography H.C.M.R. on the short- and medium term environmental consequences of the sinking of the Agia Zoni II tanker on the marine ecosystem of the Saronikos Gulf was released on April 5th 2018 (182 pages – see Annex I).

Figure 1.1: The survey network and conducted monitoring in the wider area of the Saronikos Gulf.

2. TOTAL PETROLEUM HYDROCARBONS AND POLYCYCLIC AROMATIC HYDROCARBONS IN SEAWATER SAMPLES (COASTAL ZONE AND OPEN SEA AREAS)

2.1. Seawater samplings

Seawater samplings (sea surface) from the coastal zone of the Saronikos Gulf have been conducted on September 18th, 22nd, 29th, October 3rd, 10th, 23rd, November 2nd and December 4th 2017, January 19th and March 21st 2018. Regarding open sea areas of the Saronikos Gulf, seawater samplings have been conducted on September 21-22nd 2017 and November 13-14th 2017 with *R/V* Aegaeo (HCMR) from the sea surface and various water depths along the water column in the sampling stations. In the vicinity of the Agia Zoni II shipwreck (approx. 60 m from the antipollution barrier) water samples were collected from six depths of the water column. In total, the survey effort includes 70 sampling sites, of which 56 coastal and 14 open sea areas. The collected seawater samples, 239 in total, were analyzed for total petroleum hydrocarbons and polycyclic aromatic hydrocarbons after proper pre-treatment. The sampling sites at the coastal and open sea areas of the Saronikos Gulf are presented in Figure 2.1 that follows.

2.2. Methodology

All seawater samples collected from coastal and open sea areas of the Saronikos Gulf have been analyzed for total petroleum hydrocarbons by gas chromatography - flame ionization detector (GC - FID) after proper pre-treatment (in-house variant of the ISO 9377-2 standard) and polycyclic aromatic hydrocarbons by gas chromatography - mass spectrometry (Agilent 5973C GC-MSD) according to the in-house methodology of the accredited by ISO/IEC 17025 for the analysis of polycyclic aromatic hydrocarbons in seawater samples organic chemistry laboratory of HCMR.

2.3. Results and Discussion

For the interpretation of the results the following remarks are taken into account:

(a) Although the background values for total petroleum hydrocarbons in marine waters range from 0.5 to 2 μg/L, in the inner Saronikos Gulf, according to the H.C.M.R. database over the last decade (98 observations), values up to 20 μg/L have often been reported which are therefore considered as being normal. Also, under the Greek and European legislation there are no limit values regarding total petroleum hydrocarbons concentrations in seawater.

(b) Regarding polycyclic aromatic hydrocarbons, for determining the chemical status of the considered seawater samples the annual mean concentration (AA) and the maximum allowable concentration (MAC) for naphthalene, anthracene, fluoranthene, benzo(b)fluoranthene, benzo(k) fluoranthene, benzo(a)pyrene and benzo(ghi)perylene have been considered, according to the environmental quality standards for priority substances for the determination of chemical and ecological status of waters (Directive 2013/39/EC).

Figure 2.1. Seawater sampling sites at the coastal zone and open sea areas of the Saronikos Gulf.

2.3.1. Total petroleum hydrocarbons and polycyclic aromatic hydrocarbons in the coastal zone of the Saronikos Gulf

Regarding total petroleum hydrocarbons, at 37 out of the 56 considered coastal sampling stations their concentrations were recorded within normal levels in all cases. On the contrary, extended petroleum pollution was initially recorded (September 2017) in the regions of Elliniko, Glyfada, Selinia and Kinousoura. A smaller burden of petroleum hydrocarbons was also recorded at the areas of Phloisvos (till October 10th 2017), Asklipieio Voulas (on September 18th 2017), Megalo Kavouri (on September 18th 2017), Vouliagmeni beach club (on September 18th 2017), Mavro Lithari at Anavyssos (on September 18th 2017), locally within the Tomb of Themistocles in Piraeus (on October 10th and October 23rd 2017) and Batis (on January 19th 2018 after a severe weather event followed by rough sea) (Figure 2.2). Specifically, at the sampling sites of Elliniko and Glyfada, extended petroleum pollution was observed during the sampling of September 18th 2017 with the exception of the 4th Marina of Glyfada. On September 22nd 2017 high concentrations of total petroleum hydrocarbons were observed at Agios Kosmas and at the 1st and 2nd Marina of Glyfada. In the following samplings (October 3rd and October 23rd 2017) total petroleum hydrocarbons levels were declining but still remaining high in some cases, presenting various fluctuations as a result of extensive rocky and beach clean up operations that prevented a representative sample being obtained in some cases. On November 2nd 2017, December 4th 2017 and January 19th 2018 total petroleum hydrocarbons levels were recorded at normal levels with the exception of Aigyptiotes Naval Club were a slightly elevated value was recorded on January 19th 2018 (after a severe weather event followed by rough sea). Regarding polycyclic aromatic hydrocarbons at the sampling sites of Elliniko and Glyfada, following the evolution of total petroleum hydrocarbons values above the maximum allowable concentration for benzo(a)pyrene (Agios Kosmas on September 22nd 2017) and benzo(ghi)perylene (on September 18th 2017 at Glyfada 1, September 18th and 22nd 2017 at

Glyfada 3, October 3rd 2017 at H.C.M.R facilities and Glyfada 5, October 23rd 2017 at the Aigyptiotes naval club, until October 23rd 2017 at Agios Kosmas and Glyfada 4) were recorded. On November 2nd 2017, December 4th 2017 and January 19th 2018 their concentrations were recorded within limits at all sampling sites.

Regarding the sampling sites of Selinia and Kinosoura, on September 29th 2017 extended petroleum pollution was evident at both stations. On October 23rd 2017 both sampling sites were not considered since extended beach cleanup was being performed, resulting in the presence of petroleum residues at the adjacent coastal area. Thus, the collection of a representative seawater sample was not possible in any case. On December 4th 2017, following the conclusion of cleanup activities in the areas total petroleum hydrocarbons were recorded at normal levels at both sites. On March 21st 2018 total petroleum hydrocarbons were also recorded at normal levels at both sites.

Figure 2.2. The sampling sites along the coastal zone of the Saronikos Gulf, in total, where marked green are the ones where total petroleum hydrocarbons concentrations were recorded at normal levels in all cases, while marked red and yellow respectively are the areas where an extended or smaller burden of petroleum hydrocarbons was initially recorded.

As earlier mentioned a smaller burden of petroleum hydrocarbons was also initially recorded in other sampling sites. Specifically:

At Phloisvos sampling site total petroleum hydrocarbons concentration was slightly elevated on September 22nd 2017, while at the same day a value above the maximum allowable concentration for benzo(ghi)perylene was also recorded. The sample collected on October 3rd 2017 at the same sampling site was not considered since sand clean up (flushing method) was performed, resulting in the presence of petroleum residues at the adjacent coastal area. Thus, the collected seawater sample was not considered as not being representative. The elevated total petroleum hydrocarbons levels as well as the value above the maximum allowable concentration for benzo(ghi)perylene on October 10th 2017 could be likely attributed to the shore clean up operations conducted during the previous days. On October 23rd and November 2nd 2017, following the conclusion of cleanup activities in the area, total petroleum hydrocarbons were recorded at normal levels. On January 19th 2018 (after a severe weather event followed by rough sea) total petroleum hydrocarbons were also recorded at normal levels.

Traces of petroleum hydrocarbons were also recorded on September 18th 2017 at **Asklipieio Voulas, Megalo Kavouri and Vouliagmeni Beach Club**, the levels of which rapidly declined (up to and/or higher than 90% of the initial values) on September 22nd 2017 and furthermore on October 3rd 2017 at normal levels. At **Asklipieio Voulas and Megalo Kavouri** sites values above the maximum allowable concentration for benzo(ghi)perylene were also recorded on September 18th 2017 which declined within limits on September 22nd 2017. A similar trend was also recorded at the

Mavro Lithari of the Municipality of Saronikos, where the slightly elevated value of total petroleum hydrocarbons concentrations and the value above the maximum allowable concentration recorded for benzo(ghi)perylene on September 18th 2017 decreased to normal levels/within limits respectively at the sampling round of October 3rd 2017.

During the samplings of October 10th and October 23rd 2017 a burden of petroleum hydrocarbons was recorded locally within the **Tomb of Themistokles**, with their levels clearly declining on November 2nd 2017. It should be noticed that in the adjacent coastal sampling site "Aegean Sea Naval Command - Rocky Shore" on the corresponding sampling dates the total petroleum hydrocarbons concentration was below the limit of detection in all cases.

Finally, a slightly elevated value of total petroleum hydrocarbons was recorded on January 19th 2018 **at Batis** (after a severe weather event followed by rough sea). On March 21st 2018 total petroleum hydrocarbons were recorded at normal levels.

2.3.2. Total petroleum hydrocarbons and polycyclic aromatic hydrocarbons in open sea areas of the Saronikos Gulf

In both seawater samplings conducted in open sea areas of the Saronikos Gulf, total petroleum hydrocarbons levels were normal. Furthermore, in no case values higher than the annual average concentration and maximum allowable concentration for PAHs were recorded, in accordance with the environmental quality standards for priority substances for the determination of chemical and ecological status of waters (Directive 2013/39/EC). Total PAHs concentrations fluctuated at low levels, in accordance to those previously reported in various Greek seas (Hatzianestis and Sklivagou, 2002, Parinos and Gogou, 2016, and references therein). During the sampling of September 21-22nd 2017, total petroleum hydrocarbons concentrations ranged from not detected to 6.8 μg/L, with an average of 2.1 μg/L, while during the sampling of November 13-14th 2017 total petroleum hydrocarbons concentrations ranged from not detected to 3.9 μg/L, with an average of 1.3 μg/L. These minor variations can be interpreted in the context of the physical variability of the total petroleum hydrocarbons content of the water column of the study area. In all cases, however, they clearly indicate the absence of a petroleum residues burden at the sampling sites and the corresponding sampling depths in open sea areas of the Saronikos Gulf during the sampling dates.

3. HYDROCARBONS IN OPEN SEA SURFACE SEDIMENTS

3.1. Sediment samplings

Sediment samplings in open sea areas of the Saronikos Gulf have been conducted on September 21-22nd 2017, November 13-14th 2017 and January 23-24th 2018 with *R/V* Aegaeo (HCMR), in order to investigate any possible burden regarding petroleum hydrocarbons released from the Agia Zoni II shipwreck on sediments of the study area. The sediment sampling sites at the open sea areas of the Saronikos Gulf are presented in Figure 3.1 that follows. Sampling stations S7, S8, S11, S13, S16 and S43 belong to the Saronikos Gulf systematic monitoring network, for which a time series of data is available covering the past years. They are therefore a reliable basis for comparing data gathered before and after the sinking of the Agia Zoni II in order to examine any possible impact of the incident on the marine ecosystem of the area. OS1-OS15 sampling stations are new stations added to the existing monitoring network, taking into account the direction of the oil spill caused by the incident, in order to examine its possible impact on affected areas.

3.2. Methodology

All sediment samples were collected by using a stainless steel Box Corer with dimensions of 40x40 cm. Using this particular sampler it is possible to sample undisturbed sediment from the upper 0-1 cm which is considered herein. All collected samples were wrapped in pre-combusted aluminum foil and kept frozen at -20 ^{o}C till further laboratory analysis. Moreover, the collected sediment samples were macroscopically examined for large sized tar aggregates or traces of extensive petroleum pollution in both surface and sub-surface layers at the time of their sampling. In the laboratory, the samples were initially freeze-dried and subsequently homogenized. The analytical determination of hydrocarbons was based on the methodology proposed by IOC (IOC, 1993). Briefly, 5 g of sediment is extracted into a Soxhlet apparatus for 24 hours with a methanol-dichloromethane mixture (2:1, *v/v*), and subsequently the extract is saponified with a methanolic potassium hydroxide solution and the non-saponified components are extracted with *n*-hexane. The extract is then fractionated on an activated silica gel column and two fractions are collected, the first one with 10 mL of *n*-hexane containing the aliphatic hydrocarbons and the second one with 10 mL of hexane-ethyl acetate (9:1, *v/v*) containing the polycyclic aromatic hydrocarbons. Quantitation of the compounds was performed by gas chromatography - mass spectrometry (Agilent 5973C GC-MSD) on a full scan mode. The organic chemistry laboratory of H.C.M.R. is accredited by ISO/IEC 17025 for the analysis of polycyclic aromatic hydrocarbons in marine sediments.

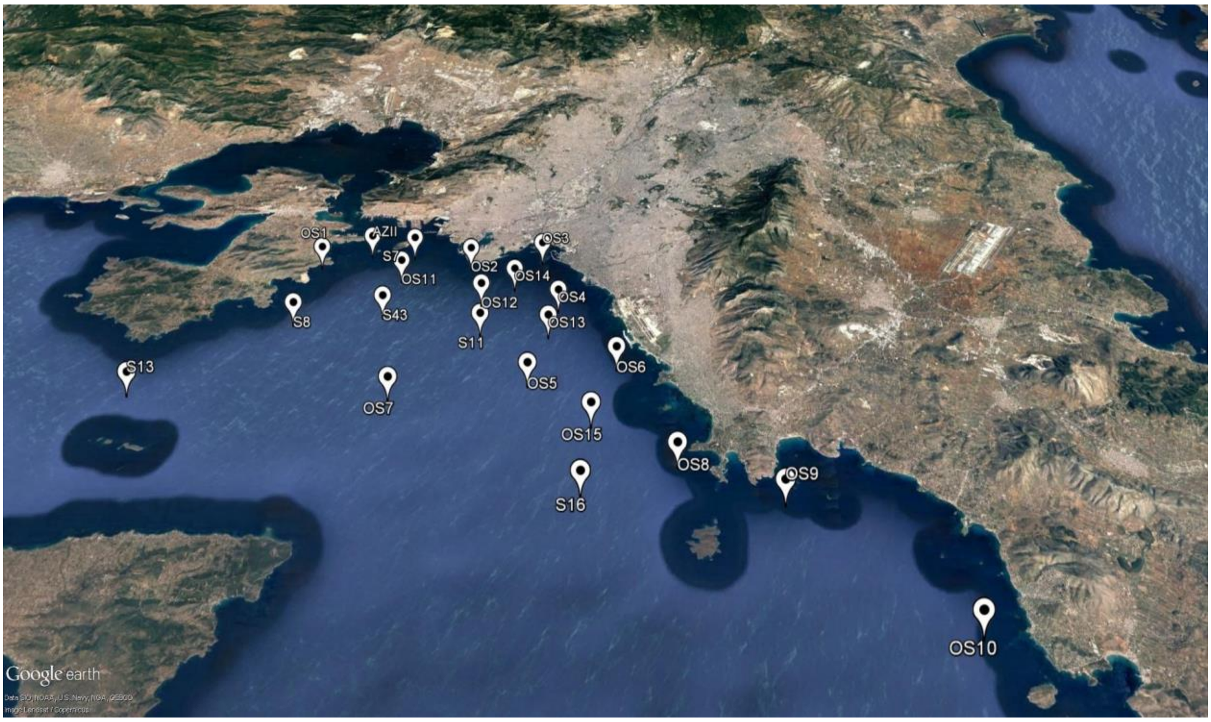


Figure 3.1. Sediment sampling sites in open sea areas of the Saronikos Gulf.

3.3. Results and Discussion

Macroscopically no large sized tar aggregates or traces of extensive petroleum pollution were observed either in the surface or in the sub-surface layers of the collected sediment samples in all cases. Very limited 1-2 mm sized tar balls were visually observed during the sampling of November 13-14th 2017 at the sampling site of the shipwreck of Agia Zoni II and the sampling site south of Psittaleia (Figure 3.2).

Figure 3.2. Limited 1-2 mm sized tar balls visually observed during the sampling of November 13-14th 2017 at the sampling site of the shipwreck of Agia Zoni II (left) and the sampling site south of Psittaleia (right).

Table 3.1 below summarizes the results of the determination of total aliphatic hydrocarbons and total polycyclic aromatic hydrocarbons in the collected sediment samples together with the corresponding time series data for sampling stations S7, S8, S11, S13, S16 and S43 belonging to the Saronikos Gulf systematic monitoring network.

Table 3.1. Total aliphatic hydrocarbons (in µg/g of dry sediment) and total polycyclic aromatic hydrocarbons (PAHs; in ng/g of dry sediment) concentrations for the collected sediment samples in the open Saronikos Gulf along with the corresponding time series data for sampling stations belonging to the Saronikos Gulf systematic monitoring network.

STATION	**∑aliphatic hydrocarbons (in µg/g)**				**∑PAHs (in ng/g)**			
	2000-2012	**09/2017**	**11/2017**	**01/2018**	**2000-2012**	**09/2017**	**11/2017**	**01/2018**
S7	1800 - 4700	1220	1140	1160	7900-9100	4430	4570	4330
S8	236-368	69.8	108	215	790-930	446	1530	1130
S11	145-177	64.2	63.5	70.0	390-410	422	705	1510
S13	46-57	116	59.8	91.7	190-220	491	245	337
S16	49-75	48.5	37.3	39.5	220-530	809	331	144
S43	156-247	98.9	120	169	890-1270	646	789	990
AZ II		282	354	248		1260	3490	2540
OS1		419	225	377		1010	627	1040
OS2		555	179	494		3750	1820	4420
OS3		129	117	94.0		1240	2140	1890
OS4		103	66.7	79.7		840	307	437
OS5		64.5	41.0			592	184	
OS6		85.3	75.8	63.0		466	388	209
OS7		121	80.2			654	453	
OS8		44.2	25.3	51.5		153	141	261
OS9		28.8				98.6		
OS10		23.4				53.1		
OS11			196	288			1430	1950
OS12			58.8	69.0			328	347
OS13			96.9	84.3			423	284
OS14			158	271			2210	3600
OS15			22.9	53.9			112	165
Saronikos Gulf (Outer)	40-52				110-190			
Background values	< 30				< 50			

Total aliphatic hydrocarbons concentrations in the considered sediment samples ranged from 22.9 to 1220 µg/g, with an average of 193 µg/g. Their concentrations in all three sampling rounds showed an increasing trend from southeast to northwest with the highest concentrations being recorded at station S7 in Psittaleia (Figure 3.3). Compared to the stations S7, S8, S11, S13, S16 and S43 belonging to the Saronikos Gulf systematic monitoring network, total aliphatic hydrocarbon concentrations after the incident varied at lower levels in almost all cases (Table 3.1).

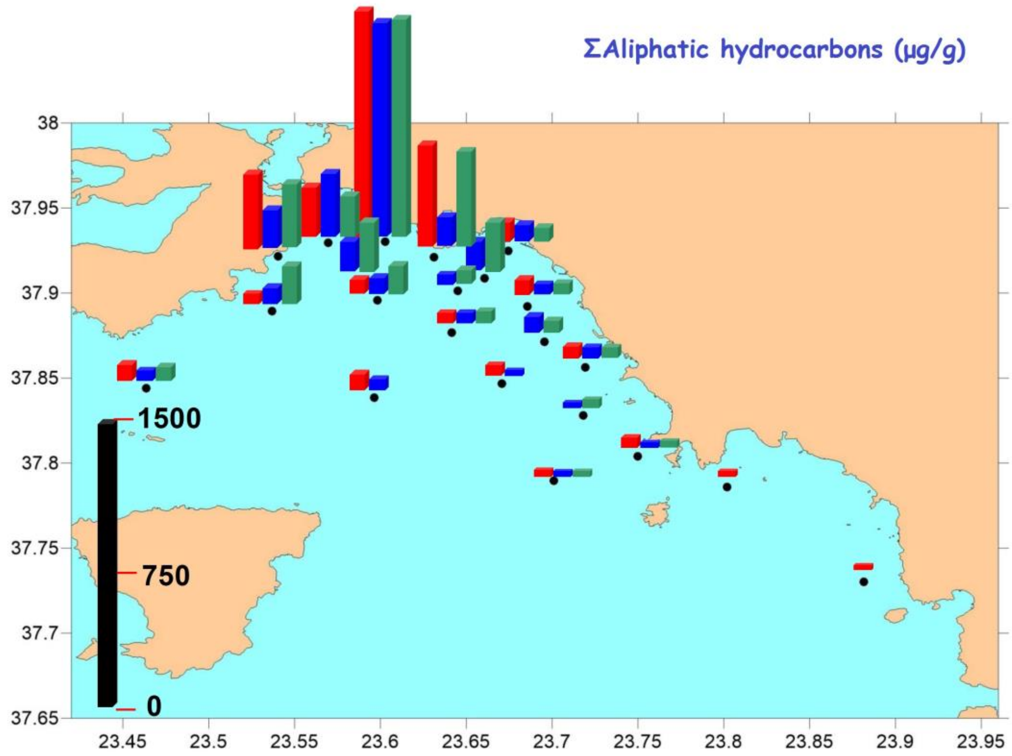


Figure 3.3. Concentrations of total aliphatic hydrocarbons (in μg/g of dry sediment) for the collected sediment samples on September 21-22nd 2017 (red color), November 13-14th 2017 (blue color) and January 23-24th 2018 (green color) in the open Saronikos Gulf.

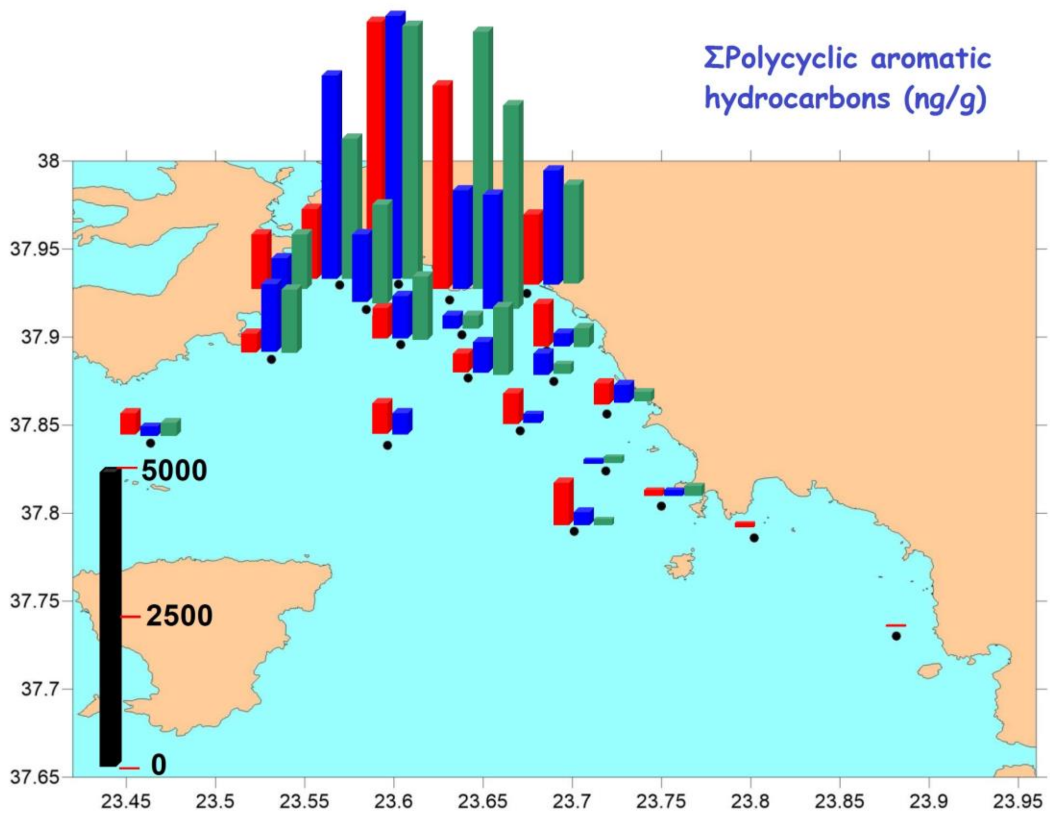


Figure 3.4. Concentrations of total polycyclic aromatic hydrocarbons (in ng/g of dry sediment) for the collected sediment samples on September 21-22nd 2017 (red color) November 13-14th 2017 (blue color) and January 23-24th 2018 (green color) in the open Saronikos Gulf.

The presence of aliphatic hydrocarbons in marine sediments does not necessarily imply pollution since a significant proportion of them may be of biogenic origin, either marine or terrestrial (Bouloubassi and Saliot, 1993). Typically in the gas chromatography analysis the chromatographs of the aliphatic fractions have two characteristics: compounds which are sufficiently resolved and are predominantly *n*-alkanes; and a mixture of unresolved compounds, the so-called "unresolved complex mixture" (UCM: unresolved complex mixture). This mixture consists of branched, alicyclic and partially degraded hydrocarbons which cannot be separated by existing gas chromatography techniques. The existence of this mixture is to a large extent considered as an indication of the presence of residues of degraded petroleum products. The ratio of non-resolved to resolved aliphatic compounds (U/R) is often being used as a criterion for the origin of hydrocarbons and values for this ratio greater than 4 indicate chronic pollution from petroleum products (Mazurek and Simoneit, 1984).

The U/R ratio values for the considered surface sediment samples were greater than 5.2 in all cases, and greater than 7.7 in 96% of the cases, which clearly indicates chronic pollution from petroleum residues in the sediments, which can be rather attributed to the anthropogenic background associated with the petroleum burden of the Saronikos Gulf and not to the recent incident of the sinking of the Agia Zoni II. However, as discussed below, in some stations a mild petroleum burden associated to the Agia Zoni II incident is recorded, which however is very small in relation to the chronic petroleum-associated anthropogenic background of the area.

A typical gas chromatograph of the aliphatic fraction (full scan mode) of the considered sediment samples is presented below in Figure 3.5.

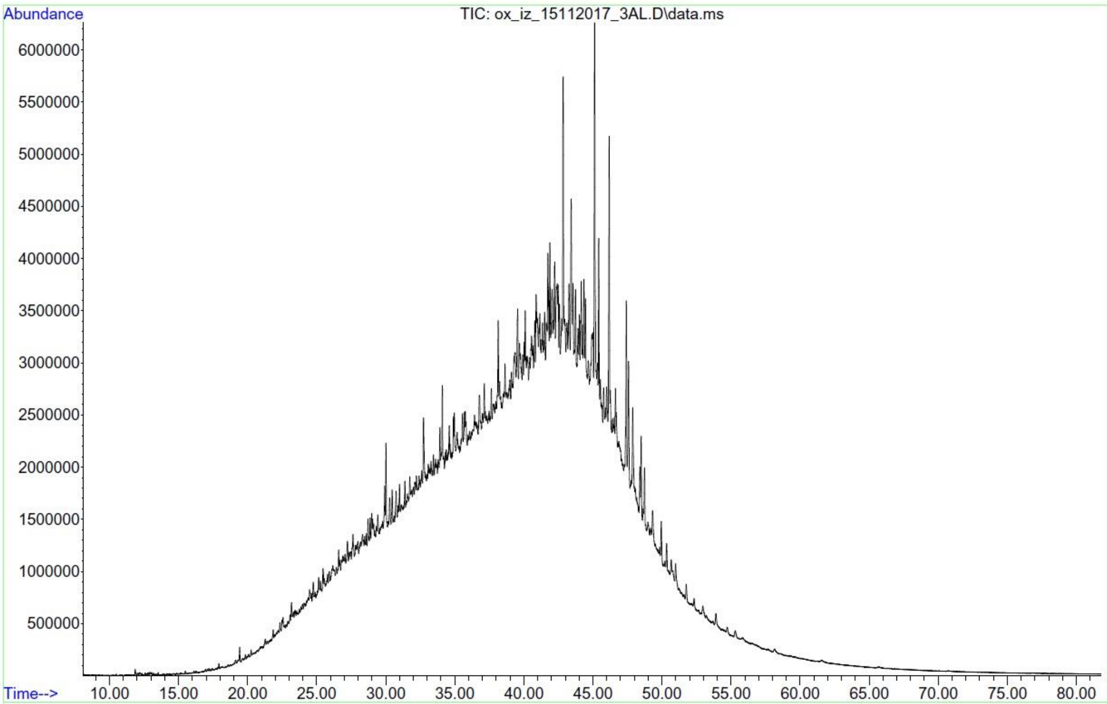


Figure 3.5. A typical gas chromatograph of the aliphatic fraction (full scan mode) of the considered sediment samples. The high ratio of non-resolved to resolved aliphatic compounds indicates chronic pollution from petroleum residues in the sediments, which can be rather attributed to the chronic petroleum-associated anthropogenic background of the Saronikos Gulf.

A similar distribution was observed for the concentrations of total polycyclic aromatic hydrocarbons in the considered sediments, which ranged from 53.1 to 4570 ng/g, with an average of 1180 ng/g, with the highest concentrations being recorded at S7 station in Psittaleia (Figure 3.4). Compared to the S7, S8, S11, S13, S16, and S43 stations belonging to the Saronikos Gulf systematic monitoring network, concentrations of total polycyclic aromatic hydrocarbons showed mixed trends. They were lower, after the incident, at S7 station in Psittaleia, higher at station S11 and S13, while in all other cases mixed trends were recorded (Table 3.1).

Polycyclic aromatic hydrocarbons (PAHs), with the exception of perylene that can be of biogenic origin and retene produced by coniferous trees on land, are purely anthropogenic compounds with primary sources being all kinds of combustion of organic materials (pyrolytic PAHs) but also petroleum products. As for the distribution of the individual compounds, Table 3.2 shows the percentage distributions of the concentrations of hydrocarbons of pyrolytic origin (sum of compounds with a molecular weight of 202, 228, 252, 276 and 278) and of petrogenic-petroleum origin (phenanthrene and its methylated derivatives) to the total sum of determined PAHs for the considered sediment samples. In marine sediments, the predominance of pyrolytic PAHs is common due to their greater stability and only in the case of recent petroleum pollution higher rates of petrogenic-petroleum PAHs are recorded.

Table 3.2. The percentage distributions of the concentrations of polycyclic aromatic hydrocarbons of pyrolytic origin and of petrogenic-petroleum origin to the total sum of determined PAHs for the considered sediment samples.

STATION	POLYCYCLIC AROMATIC HYDROCARBONS					
	21-22/09/2017		13-14/11/2017		23-24/01/2018	
	PETROGENIC (%)	PYROLYTIC (%)	PETROGENIC (%)	PYROLYTIC (%)	PETROGENIC (%)	PYROLYTIC (%)
S7	12.6	56.1	10.8	61.5	10.1	61.6
S8	14.1	58.9	12.9	63.8	11.3	63.0
S11	19.4	56.5	12.7	65.8	17.6	56.9
S13	11.1	65.5	15.9	55.1	14.3	57.3
S16	12.4	67.5	13.3	59.5	14.3	62.5
S43	12.8	62.9	12.7	64.0	12.1	63.9
AZ II	**25.6**	41.3	**19.0**	51.0	13.2	61.8
OS1	15.2	55.9	12.5	59.5	11.8	60.7
OS2	12.1	61.6	12.2	62.7	11.9	62.3
OS3	**50.2**	17.4	10.1	67.6	8.9	69.6
OS4	**46.6**	22.9	17.7	53.2	14.7	56.8
OS5	20.3	45.8	18.4	47.2	-	-
OS6	**48.7**	19.6	**21.2**	42.1	17.9	59.6
OS7	14.7	55.9	11.9	61.4	-	-
OS8	16.2	60.7	19.2	46.6	17.6	59.2
OS9	18.4	52.7	-	-	-	-
OS10	20.3	56.5	-	-	-	-
OS11	-	-	14.0	60.1	13.1	62.1
OS12	-	-	11.8	65.7	14.7	55.8
OS13	-	-	14.0	58.3	15.9	53.2
OS14	-	-	10.5	62.9	9.5	62.8
OS15	-	-	15.7	59.2	16.2	54.8

As shown in Table 3.2 on September 21-22nd 2017, high percentages of petrogenic PAHs are recorded at stations OS3 (off Palaio Faliro), OS4 (off Agios Kosmas), OS6 (off Glyfada) and AZII (near the shipwreck). This suggests that a recent oil pollution imprint was recorded at these stations. This observation is confirmed by GC.MS ion analysis (*m/z* 71) of the aliphatic fraction for the corresponding sediment samples (Figure 3.6) where an increase in the presence of normal alkanes in the *n*-C17 to *n*-C26 range is observed. The same molecular profile is found in samples of tar balls (24 in total) collected from the coastal zone of the Saronikos Gulf during the early days of coastal samplings, as well as, and most importantly, in the molecular profile of a petroleum sample drawn from the shipwreck of Agia Zoni II on September 16th 2017 and was distributed for analysis to H.C.M.R. (Figure 3.7). This fact clearly demonstrates that the recent petroleum pollution imprint encountered in these sediments is due to the Agia Zoni II incident. In all cases this recent burden is very mild in respect to the chronic petroleum-associated anthropogenic background of the Saronikos Gulf, to the extent that it is not clearly reflected in the full scan chromatographic analysis of the aliphatic fractions.

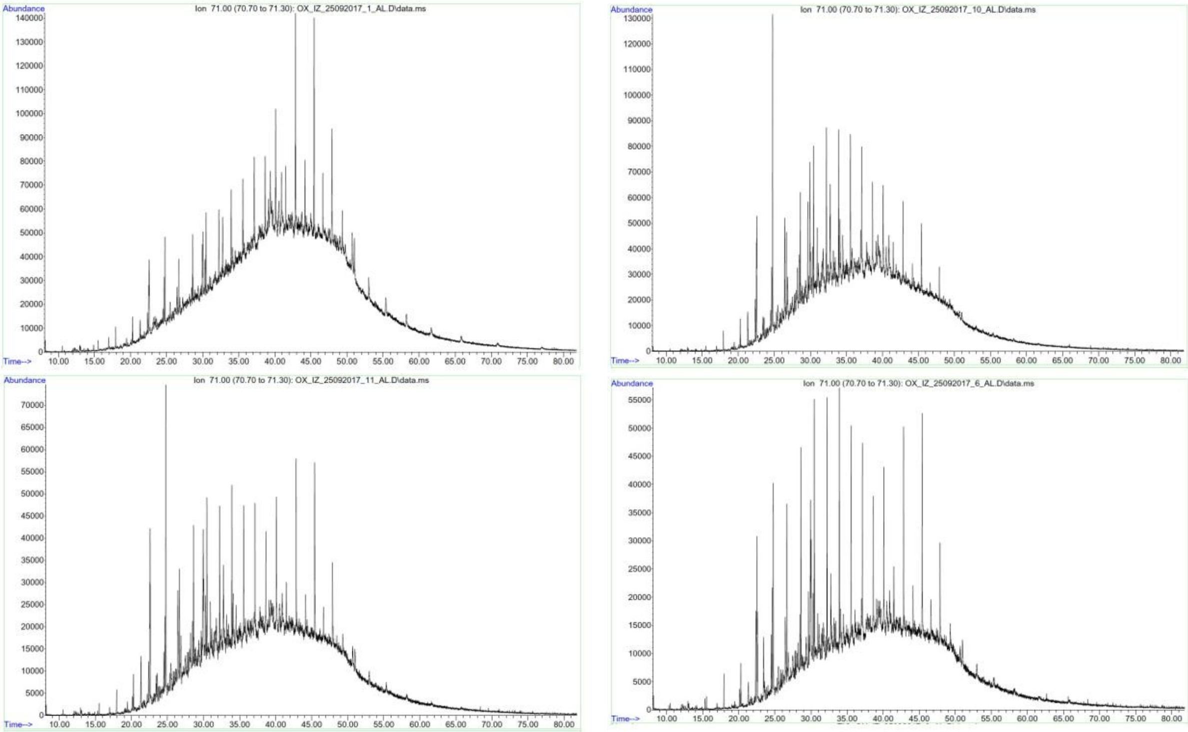


Figure 3.6. GC.MS trace (m/z 71) of the aliphatic fraction of the collected sediments at stations AZII (upper left), OS3 (upper right), OS4 (down left) and OS6 (down right) during the September 21-22nd 2017 sampling in the open Saronikos Gulf.

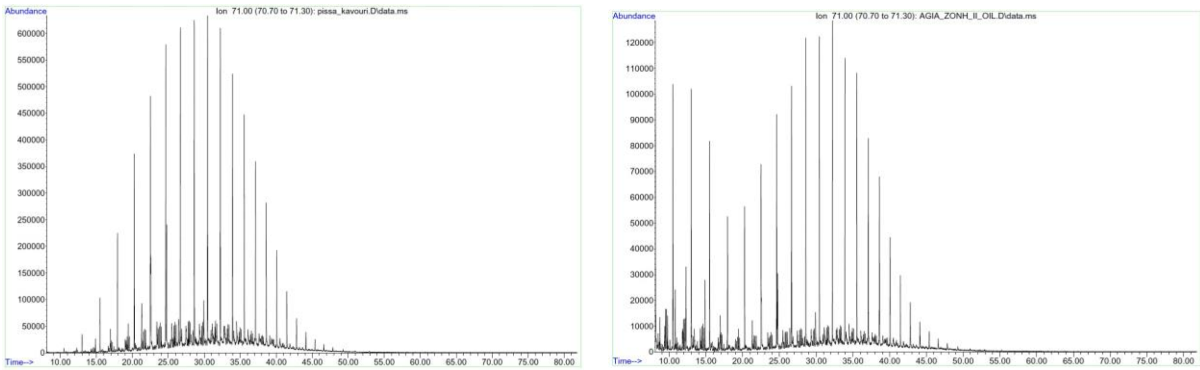


Figure 3.7. GC.MS trace (m/z 71) of the aliphatic fraction of a representative tar ball collected along the coastal zone of the Saronikos Gulf (left) and of a petroleum sample drawn from the shipwreck of Agia Zoni II and was distributed for analysis to H.C.M.R (right).

On November 13-14th 2017 and furthermore on January 23-24th 2018 in the corresponding sediments the recent imprint associated to the Agia Zoni II incident appears to be reduced (Table 3.2). This could be likely attributed to the degradation of the petroleum-associated compounds (aliphatic and polycyclic aromatic hydrocarbons) during their residence in the sediment.

4. GEOCHEMICAL STUDY OF SURFACE SEDIMENTS OF THE SARONIKOS GULF IN RESPECT TO POTENTIAL OIL CONTAMINATION

The presence of several metals in crude oil is known since decades. Crude oil may be enriched in cadmium, chromium, cobalt, copper, iron, manganese, molybdenum, zinc, and mainly vanadium and nickel, which can be found to be > 400 and > 1500 mg kg^{-1}, respectively. Since the study area is regularly monitored in respect to the sediment content in heavy metals, is way possible to compare data collected prior and after the Agia Zoni II incident. The assessment of potential contamination was made on one hand by comparing absolute metal contents and secondly by the estimation of Enrichment Factors (EFs; Karageorgis et al., 2009), as described here after.

4.1. Methodology

Herein we present results of sampling and analyses conducted in February 2016, March 2017, September 2017, November 2017 and January 2018 (Fig. 4.1). During the two sampling campaigns carried out prior to the incident, samples were collected from the regular monitoring network of stations of the Saronikos Gulf, whereas during the following three campaigns additional stations were occupied to describe in finer detail potential problems associated with the oil spill and its impact on the seabed. All samples were collected with a stainless steel Box Corer with dimensions 40x40 cm. Using his particular sampler it is possible to sample undisturbed sediment from the upper 0-1 cm. Bulk (not sieved and unwashed) samples were oven dried, ground to a fine powder in a twin swinging motorized mill with agate mortar and balls and were analyzed for their chemical composition in a Philips PW-2400 wavelength X-Ray fluorescence analyzer, equipped with Rh-tube. Major elements were determined in fused beads (SiO_2, Al_2O_3, TiO_2, Fe_2O_3, K_2O, Na_2O, CaO, MgO, P_2O_5). Fused bead preparation involved a complete fusion of 0.6 g of sample, with 5.4 g of flux (50:50 lithium meta-borate, lithium tetra-borate) and 0.5 g of lithium nitrate, the latter being used as an oxidizer. Loss on ignition (LOI) was determined after burning 1 g of sample for 1 h at 1000 °C. Minor elements were determined according to the following procedure: 5 g of powdered sample were mixed with 1.5 g of wax and subsequently pressed in a 31 mm aluminium cup. The powder pellets were analyzed in the XRF to determine minor element contents; herein we report results for V and Ni only. Analytical accuracy was checked by parallel analysis of certified sediment standards (MESS-2, PACS-2, MAG-1) and was found to be satisfactory for all elements analyzed (for details see Karageorgis et al. 2005).

4.2. Results and Discussion

The contents and spatial distribution of Saronikos Gulf sediments in V and Ni (mg kg^{-1}) are presented in Figure 4.1. Initially we observe that mean values of metal contents prior to the incident and approximately at the same network of stations are very similar, i.e. 46 and 45 mg kg^{-1} for vanadium and 69 and 66 mg kg^{-1} for nickel. In the following months mean values decrease to 32, 29 and 34 mg kg^{-1} for vanadium and 52, 50 and 59 mg kg^{-1} for nickel. This decrease is due to the fact that the additional stations occupied for the detailed coverage of the area (named OS) are generally sandier and therefore have naturally lower metal contents. Estimating mean metal values for September 2017, November 2017 and January 2018 only for the regular monitoring network stations, values similar to the previous months, February 2016 and March 2017, derive (in chronological order; V: 46, 45, 46, 39, 51 and 39 mg kg^{-1}, Ni: 69, 66, 70, 69 and 88 mg kg^{-1}). Nevertheless, the values of the examined metals don't show any enrichment after the incident, indicating that there is no impact associated with oil contamination. Looking into the spatial distributions of the metals in the five sampling periods, we observe no significant variations in the study area. Elefsis Gulf and the area south-southwest of the Psyttaleia Island in the outer Saronikos gulf exhibit locally increased values of the specific elements, which are due to the fine texture of the sediments, rather than anthropogenic influence, as we will explain below. By contrast, the east and southeast sector of the Saronikos Gulf exhibits low metal contents, which are associated with the sandier texture of the sediments and shows overall good conditions. From this examination, absence of impact in respect to the Agia Zoni II incident and the subsequent oil spill is derived.

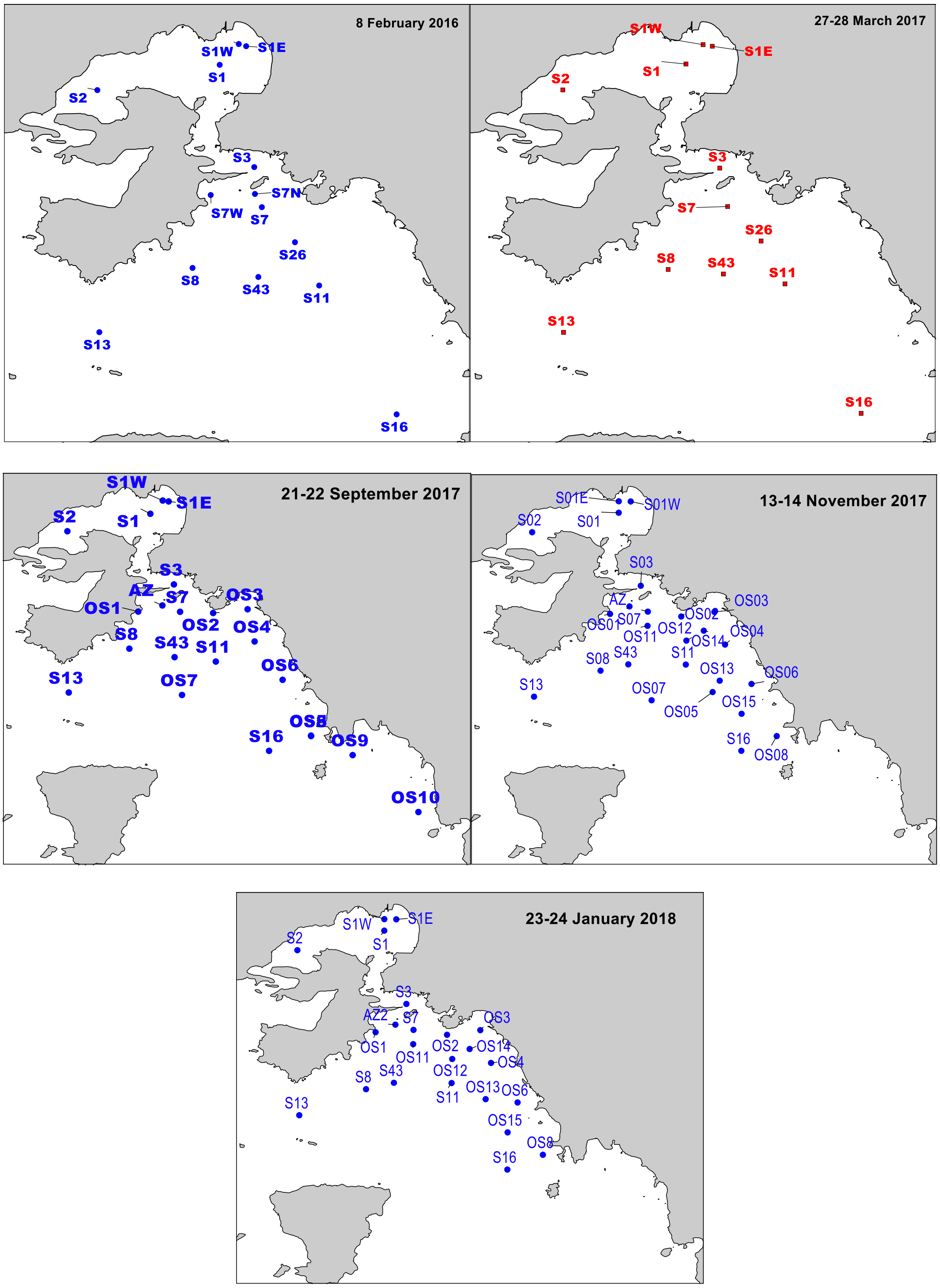


Figure 4.1. Saronikos sampling sites in February 2016, March 2017, September 2017, November 2017 and January 2018.

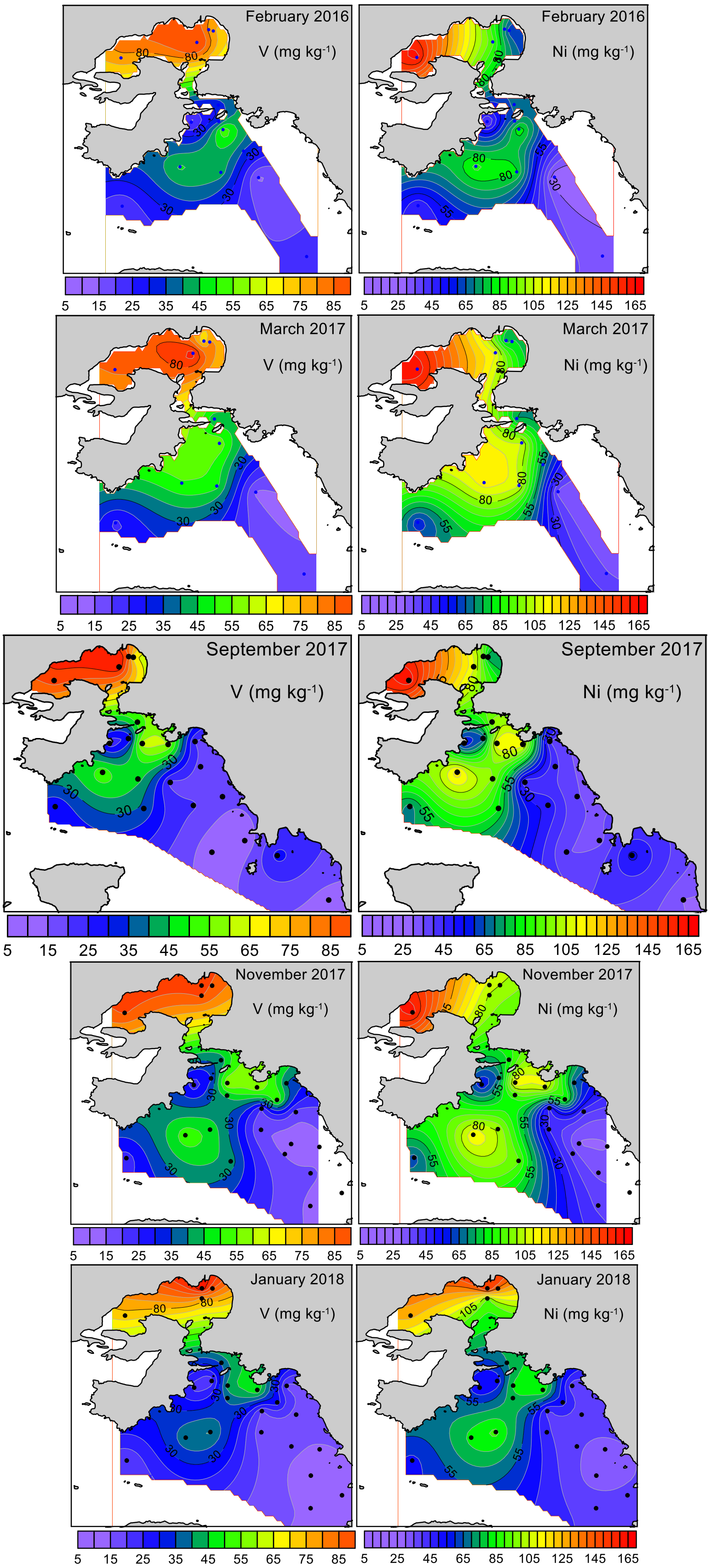


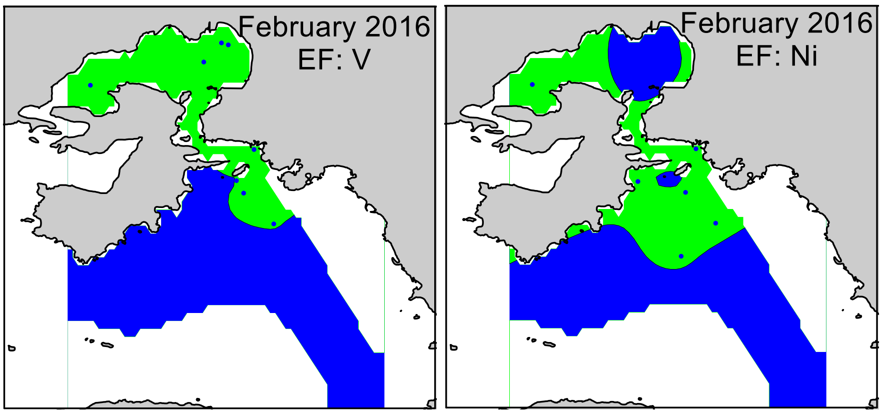
Figure 4.2. Spatial distribution of vanadium and nickel contents in February 2016, March 2017, September 2017, November 2017 and January 2018.

A reliable method to estimate the degree of contamination of a sediment in respect to the considered pristine sample of the same study area are the Enrichment Factors (EF; Ackermann, 1980; Luoma, 1990; Grousset et al., 1995). Enrichments Factors are calculated as follows:

$$EF = \frac{\left(\frac{El}{Al}\right) sed}{\left(\frac{El}{Al}\right) rs}$$

where $[El]_{sed}$ is the content of a minor element in the sediment, $[Al]_{sed}$ is the Al content in the sediment, and $[El]_{rs}$ and $[Al]_{rs}$ the contents of the element and Al in the reference sediment. The use of element rations to a lithogenic element as Al, aims at compensating for variations due to salts, organic carbon, and carbonates, and mostly to smooth grain-size variations between samples. It is a common normalization technique applied according to the literature (Förstner and Wittmann, 1983, Van Der Weijden, 2002). Al is used very often as a normalizer as it belongs to the lithogenic fraction of the sediment. Other elements often used as normalizers are Ti, Rb, Sc, Zr and other. The selection of Al a normalizer was based on the coefficient of variation *V* (standard deviation divided by the mean), after Van Der Weijden (2002). As a reference sediment we used the mean value of 7 samples (30-47 cm) obtained from a core sediment (S07, depth 70 m, south of Psyttaleia Island) collected in 2009 and analyzed with the same methods. Moreover, the samples have sandy mud texture, and are rich in carbonates, therefore have similar composition to the other samples from the study area. After radiocarbon AMS dating of shells from a depth 45-46 cm, we estimated the sedimentation rate in the vicinity of station S07 to 0.45 cm 100 y^{-1}, therefore the reference sediment is definitely dated at a pre-industrial period. EF values from 0 to 1 indicate background values, values 1-2 are also considered as similar to the reference sediment and are therefore lying within natural (non-anthropogenic) variability (GROUSSET *et al.*, 1995, SHUMILIN *et al.*, 2002). EF values 5>EF>2 indicate moderate enrichment and >5 high enrichment.

The results and spatial distribution of EFs for the 5 sampling periods are presented in Figure 4.3. We observe that in February 2016 all EF values are within natural limits for vanadium and nickel, whereas in March 2017 a minor enrichment in the vicinity of stations S11, S13 and S16 is observed, which are however sandy, with high biogenic carbonates abundance, and in parallel low values of the normalizing element Al; therefore, those results are not alarming. The situation after the incident, in September 2017, November 2017 and January 2018 is similar. i.e. absence of high EFs for vanadium and nickel, except for stations AZII, OS5, OS8 and OS13, which are also sandy, with high percentages of biogenic carbonates and low Al. The spatial distribution of EFs in February 2016 and March 2017 shows that the entire area exhibits values within normal limits. Relatively high values observed in the southwestern and southeastern sector of the outer Saronikos gulf are attributed to the sandy, biogenic texture of the sediments. Similar patterns occur for the EF values in September 2017, November 2017 and January 2018, which vary almost entirely between 1 and 2, i.e. within natural limits. Small exceptions in two coastal stations are associated with the coarse texture of the sediments. In any case, Enrichment Factors show there is no metal enrichment of the sediments in vanadium and nickel either before or after the incident.



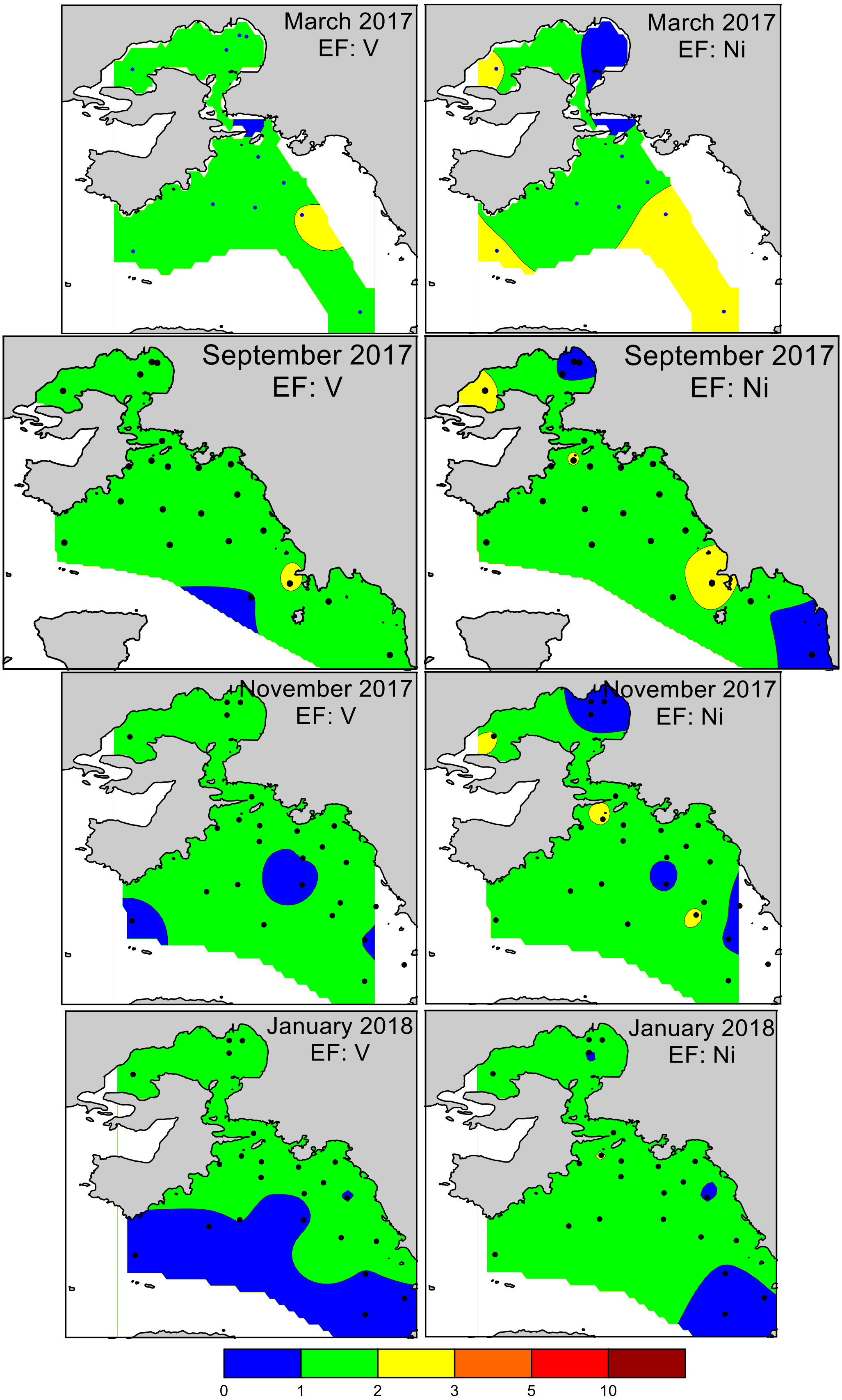


Figure 4.3. Spatial distributions of Enrichment Factors (EF) for vanadium and nickel in February 2016, March 2017, September 2017, November 2017 and January 2018.

5. CONTAMINANT BIOACCUMULATION AND EFFECTS IN MARINE ORGANISMS

5.1. Assessment of bioaccumulation and biological effects of contaminants in mussels (*Mytilus galloprovincialis)*

In order to investigate potential bioaccumulation of petroleum hydrocarbons and of other organic and inorganic contaminants from the incident, and to assess related biological effects of pollution in the study area, bivalves and specifically mussels of the genus *Mytilus* (Cardellicchio et al., 2008; Pellerin and Amiard, 2009) were used as bioindicator organisms. The benthic species *Mytilus galloprovincialis* is a bivalve mollusc, which flourishes in coastal waters, attached to the hard bottom where its natural populations are covering large surfaces. Under natural conditions, it is the dominant species in its ecological niche. It is a cosmopolitan sedentary species, it has a long life, it is easy to collect and identify, tolerant of exposure to environmental variations in physicochemical parameters and resistant to handling stress caused by laboratory experiments or field transplantation. Due to their feeding behavior (they are filter feeders) mussels take up large amounts of the available contaminants in their ambient waters even if polluting substances are at low concentrations. They are used as indicator species in pollution monitoring studies worldwide (M*ussel Watch*) and are also widely used in the Mediterranean Sea (http://mytimed.tvt.fr/).

Biological effects of pollution are among the tools proposed for the evaluation of pollution effects, one of the criteria used for the assessment of Good Environmental Status of Marine Waters according to the Marine Strategy Framework Directive (2008/56/EC) (JRC, 2010). Biomarkers are methods developed in the few last decades for assessing biological effects of pollution used in environmental monitoring programmes for risk assessment and monitoring of pollution impacts (Walker et al, 2016). Biomarkers detect early responses of indicator organisms to environmental stress before disturbances such as disease, mortality and population changes occur, thus provide early warning signals of environmental disturbance. Biomarkers have been applied in several studies assessing the impact of oil spills and have been clearly proven useful particularly for the assessment of sublethal effects (Martinez-Gomez et al., 2010).

5.1.1. Sampling and methodology

In order to investigate the potential bioaccumulation of petroleum hydrocarbons and of other organic and inorganic contaminants and to assess the possible biological effects of the Agia Zoni II incident in the study area, mussels *Mytilus galloprovincialis* were immersed in cages on January 23-24th 2018 at four sites, Salamina (MUS1), Agios Kosmas (MUS2), Glyfada (MUS3) and Asteras Vouliagmenis (MUS4) (Figure 5.1). Asteras Vouliagmenis (MUS4) was used as a reference site. The mussel cages were immersed at two depths in each site (5 and 20 m below the sea surface) and were collected after approximately six weeks on March 7th 2018.

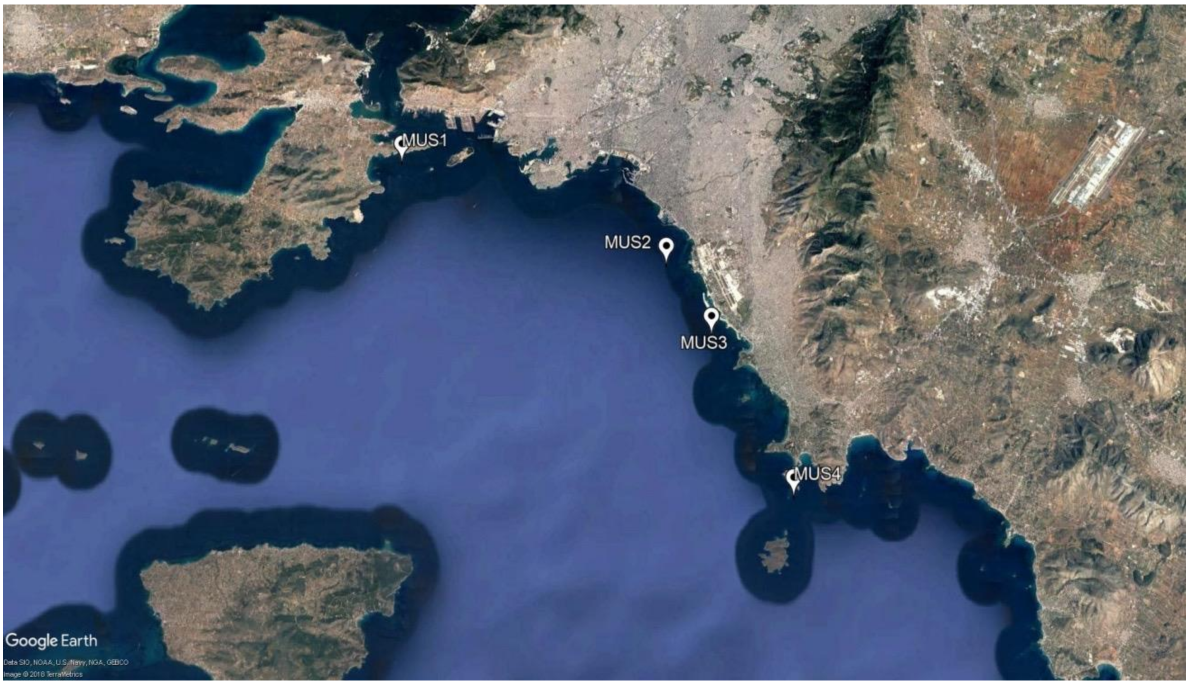


Figure 5.1. Sites of mussel cages immersion in January 2018.

In the collected mussels: (a) the concentrations of hydrocarbons and heavy metals were determined in their tissue, (b) a set of biomarkers indicative of oxidative stress (catalase), phase II biotransformation (glutathione S-transferase) and neurotoxicity (acetylcholinesterase) were measured, (c) condition index (CI) was determined as a measure of the health status of the animals that summarizes their physiological activity (e.g., growth, reproduction, secretion) under given environmental conditions (Pampanin et al., 2005) and (d) metallothioneins (MTs) were determined.

After their collection, the mussels were transported to the laboratory where, after their body characteristics were recorded, their tissue was isolated, freeze-dried under low pressure and temperature and then homogenized, before the determination of hydrocarbons and heavy metals. The mean wet to dry weight ratio of the mussels whole body soft tissue was 10.1 and this ratio can be used to convert the concentration units from the dry to the wet weight basis. Mean mussels hell length was 6-7 cm.

For the determination of hydrocarbons, after the addition of internal standards, the fresh tissue is saponified with a methanolic potassium hydroxide solution and the non-saponified components are extracted with *n*-hexane, followed by purification and fractionation by column chromatography on silica. The determination of aliphatic and polycyclic aromatic hydrocarbons in the two fractions collected was carried out by gas chromatography - mass spectrometry (see Chapter 3).

For the study of mussel metal concentrations, 30 pooled samples were prepared from the whole body soft tissue of the organisms of 20 individuals each, per station and depth for MUS1, MUS3 and MUS4 stations. Due to the limited remaining available mussels at station MUS2, only 3 pooled samples were prepared for this station (of 6 individuals each) from mussels placed near the bottom at 20 m depth. Nitric acid digestion of the homogenized dry tissue was performed into Teflon vessels in an ETHOSEZ/Milestone microwave digestion system. Cu, Zn, Fe and Mn concentrations were determined by flame Atomic Absorption Spectroscopy using the AA7000 Shimadzu spectrophotometer. Concentrations are expressed as μg of the metal per g of dry weight of the tissue. The accuracy and precision of metal chemical analysis in organisms were verified with certified reference materials of known metal concentrations and the measurement of control samples in random order amongst the mussel samples.

For the study of metallothionein (MT) concentrations, 40 pooled samples were prepared from the mussel digestive gland (5 pooled samples per station and depth of 6 individuals each). MTs content was evaluated according to the spectrophotometric method (Viarengo et al., 1997) in these mussel digestive gland samples. The MTs containing fraction was gradually isolated. Measurements were performed in a PerkinElmer (UV/VIS, Lamda 20) spectrophotometer at 412 nm. Concentrations are expressed as μg MT/g ww of the tissue.

For mussel metal and MTs concentrations, the Kolmogorov-Smirnov test was applied to determine whether data can be adequately modelled by the normal distribution. One-way analysis of variance (One-Way ANOVA) was performed to determine which means are significantly different from which others at the 95.0% confidence level. Post hoc comparisons assessed by the LSD test. Tests were performed using the statistical package Statgraphics Plus.

For CAT, GST and AChE biomarker analyses, gills and digestive glands of 30 individuals per site were dissected just after collection. Tissue samples were pooled (samples of six individuals) and five pooled samples per site were frozen in liquid nitrogen and stored at -70 ºC. CAT and GST activities were measured in digestive glands while AChE activities were measured in the gills.

For CAT and GST activity measurements, digestive glands were weighed, cut in small pieces and then homogenized using a Potter-Elvehjem homogenizer (Heidolph Electro GmbH, Kelheim, Germany) in 1:4 (w/v) 100 mM KH_2PO_4/K_2HPO_4, pH 7.4, 1 mM EDTA. Homogenates were centrifuged at 10,000×g for 30 min. All preparation procedures were carried out at 4 °C. CAT activity was measured through the loss of H_2O_2 that was measured colorimetrically with ferrous ions and thiocyanate on a microplate reader (BIOTEK Synergy HTX Multi-Mode Microplate Reader) (Cohen et al. 1996). CAT activity was determined by the difference in the absorbance at 490 nm per unit of time. CAT activity results are expressed in terms of the first-order reaction rate constant (k) and protein content as follows: U/mg proteins=k/mg proteins=[ln (A1/A2)/(t_2 −t_1)]/mg proteins where U represents units, ln is the natural log, and A1 and A2 are the observed mean absorbance at 490 nm at two time points, t_1 = 1 min and t_2 = 4 min. GST was measured by the method of Habig and Jacoby (1981) with 1-chloro-2,4-dinitrobenzene (CDNB) as a conjugation substrate, adapted to microplate reading by McFarland et al. (1999). Activity was expressed as nanomoles of conjugate per minute per milli- gram of proteins.

For AChE measurements, gill tissues were homogenized using a Potter-Elvehjem homogenizer in 1:2 (w/v) 0.1 M Tris–HCl buffer containing 0.1 % TRITON X 100, pH 7. Homogenates were centrifuged at 10,000×g for 20 min. All preparation procedures were carried out at 4°C. AChE activity was assayed by the method of Ellman et al. (1961) adapted to microplate reading by Bocquené et al. (1993). Enzyme activity was expressed as nanomoles of acetylthiocholine hydrolyzed per minute per milligram of proteins. Total protein content in the tissue extracts was measured using bovine serum albumin (BSA) as a standard (Bradford 1976).

For CI measurements, whole soft tissues of 30 to 50 individuals per sitewere stored at -20 °C. The whole soft tissues were dissected and lyophilized; shells were dried at 60 °C for 48 h and then weighed. The ratio of dry flesh weight to dry shell weight (FW/SW × 100) was used to determine CI for each sample.

CAT, GST, AChE and CI data are presented as mean ± SD. To assess for significant differences of CAT, GST, AChE and CI among sites, two-way analysis of variance (Two-Way ANOVA) (factors: site and depth) followed by the Tukey HSD multiple comparison test was applied.

Finally, during the initial immersion of the mussel cages a sediment sample was taken at the studied sites and seawater at the immersion depths in order to estimate the sediment and seawater quality of the study areas. When the cages were retrieved seawater sampling was repeated at the immersion depths. In the collected seawater samples total petroleum hydrocarbons and polycyclic aromatic hydrocarbons were determined, while aliphatic and polycyclic aromatic hydrocarbons were determined in the collected sediment samples. The methodology followed for the analysis of seawater and sediment samples is described in detail in Chapters 2 and 3 above respectively.

5.1.2. Results and discussion

In both seawater samplings conducted at the studied areas during the initial immersion and recovery of the mussel cages, total petroleum hydrocarbons levels were normal. Furthermore, in no case a value higher than the maximum allowable concentration (MAC) for PAHs was recorded while in only one case (station MUS1, 2m depth on March 7th 2018) a value higher than the annual average concentration (AA) was recorded for benzo(a)pyrene, following with the environmental quality standards for priority substances for the determination of chemical and ecological status of waters (Directive 2013/39/EC). Total aliphatic and total polycyclic aromatic hydrocarbons concentrations in the considered sediment samples were low, while in all cases the ratio of unresolved to resolved aliphatic compounds concentrations (U/R) was higher than 8.9, which clearly indicates chronic pollution from petroleum residues in the sediments which can be rather attributed to the anthropogenic background associated with the petroleum burden of the Saronikos Gulf and not to the recent incident of the sinking of the Agia Zoni II. Macroscopically no large sized tar aggregates or traces of extensive petroleum pollution were observed either in the surface or in the sub-surface layers of the collected sediment samples at the time of their sampling.

The results from the determination of aliphatic and polycyclic aromatic hydrocarbons in mussel samples are given in Table 5.1. The concentrations of aliphatic hydrocarbons were relatively small in all cases, did not exceed 30 μg/g of wet tissue, and indicate that there was no significant burden with petroleum products. Concentrations for mussels caged at 5m depth at stations MUS1 and MUS2 were slightly elevated compared to mussels caged at 20m depth, as well as to the mussels of the reference site in the area of Vouliagmeni but also to the initial values before the immersion of the mussel cages. This trend could be likely attributed to the increased hydrocarbons background in these areas of the Saronikos Gulf. Concentrations of polycyclic aromatic hydrocarbons were in all cases less than the initial values of mussels prior to their immersion indicating that there was no PAH burden either. As in the case of aliphatic hydrocarbons the highest concentrations were determined in mussels caged at stations MUS1 and MUS2. According to the legislation (EC Regulation 1881/2006) for hydrocarbons, the maximum allowable concentration for benzo(a)pyrene is 10 ng/g of wet tissue. In the caged mussels, concentrations of benzo(a)pyrene were in all cases well below this limit, with the highest value of 0.4 ng/g being recorded at station MUS1.

From the above results it appears that bioaccumulation of aliphatic and polycyclic aromatic hydrocarbons in the caged mussels has not been observed due to the incident.

Table 5.1. Concentrations of hydrocarbons (expressed as wet tissue weight) in the *Mytilus galloprovincialis* mussels caged at the Saronikos Gulf. **N.D.**: Not detected, detection limit 0.1 ng/g.

Station	**MUS1**		**MUS2**		**MUS3**		**MUS4**		**Initial value**
Depth (m)	**5m**	**20m**	**5m**	**20m**	**5m**	**20m**	**5m**	**20m**	
Total hydrocarbons (μg/g)	25.2	20.8	26.7	18.2	12.1	15.6	4.0	3.0	9.0
Aliphatic hydrocarbons (μg/g)	25.1	20.7	26.6	18.2	12.1	15.5	4.0	3.4	9.1
U/R	10.2	11.6	10.0	8.0	5.8	7.2	3.9	4.0	2.6
PAHs (ng/g)									
Naphthalene	0.8	0.7	1.4	0.6	0.6	0.5	0.6	0.7	0.9
Methylnapthalenes	1.3	1.0	2.3	0.7	0.7	0.5	0.7	0.5	1.5
Acenaphthylene	0.2	0.2	0.1	0.2	0.1	0.1	0.1	0.1	0.1
Acenaphthene	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Dimethylnapthalenes	1.9	1.6	2.9	1.1	1.0	0.4	0.6	0.6	5.8
Trimethylnapthalenes	5.1	3.0	4.1	1.6	1.2	1.0	0.6	0.6	4.4
Fluorene	0.2	0.2	0.2	0.1	0.2	0.1	0.1	0.2	0.3
Dibenzothiophene	0.1	0.1	0.1	0.1	N.D	N.D	N.D	N.D	0.2
Methyldibenzothiophenes	0.6	0.6	0.4	0.2	0.1	0.3	0.1	N.D	1.4
Dimethyldibenzothiophenes	3.6	2.7	2.0	1.2	0.5	0.9	0.4	0.3	7.5
Phenanthrene	1.6	1.4	1.8	1.4	1.5	1.5	1.1	1.1	2.3
Anthracene	0.4	0.3	0.2	0.1	0.1	0.1	0.1	0.1	0.2
Methylphenanthrenes	4.6	3.7	3.3	2.4	2.0	2.2	1.3	1.1	3.7
Dimethylphenanthrenes	14.3	10.2	8.1	5.1	3.9	6.0	2.2	1.6	16.4
Trimethylphenanthrenes	16.7	13.9	9.1	6.8	4.4	6.4	3.1	2.4	17.2
Fluoranthene	1.1	0.9	1.0	0.8	0.6	0.6	0.4	0.3	1.2
Pyrene	0.6	0.6	0.4	0.3	0.2	0.2	0.1	0.1	1.0
Methylpyrenes	2.2	1.8	1.4	1.1	0.8	0.7	0.4	0.5	2.1
Dimethylpyrenes	3.0	2.8	1.7	1.2	0.5	0.9	0.3	0.3	1.8
Retene	0.7	0.6	0.6	0.5	0.4	0.4	0.3	0.3	0.9
Benz[a]anthracene	0.4	0.4	0.3	0.2	0.2	0.2	0.1	0.1	0.5
Chrysene	1.7	1.5	1.5	1.2	1.0	1.1	0.7	0.7	2.8
Methylchrysenes	1.8	1.6	1.2	0.8	0.6	0.8	0.3	0.3	1.6
Dimethylchrysenes	2.3	2.7	1.3	1.1	0.6	1.1	0.4	0.4	0.3
Benzo[b]fluoranthene	2.3	2.2	0.9	1.1	0.7	1.0	0.6	0.5	2.0
Benzo[k]fluoranthene	0.8	0.7	0.4	0.3	0.3	0.4	0.2	0.2	0.6
Benzo[e]pyrene	1.9	1.8	0.7	0.9	0.7	0.8	0.3	0.3	1.4
Benzo[a]pyrene	0.4	0.4	0.1	0.1	0.1	0.1	N.D	N.D	0.2
Perylene	0.2	0.2	0.1	0.1	0.1	0.1	0.1	N.D	0.1
Indeno[1,2,3-cd]pyrene	0.5	0.6	0.2	0.3	0.1	0.2	0.1	0.1	0.4
Benzo[ghi]perylene	0.8	0.8	0.3	0.5	0.1	0.3	0.1	N.D	0.5
Dibenz[a,h]anthracene	0.1	0.1	N.D	N.D	N.D	N.D	N.D	N.D	0.1
ΣPAHs (ng/g)	**72.3**	**59.4**	**48.2**	**32.2**	**23.4**	**29.0**	**15.5**	**13.5**	**79.5**

CAT, GST και AChE activities in the caged mussels are shown in Figures 5.2, 5.3, and 5.4. CAT, GST και AChE activities were similar in caged mussels at sites MUS1, MUS2, MUS3 and at the reference site MUS4 (Two-WayANOVA, $p>0.05$). CAT and AChE activities did not vary with respect to caging depth (Two-WayANOVA, $p>0.05$), while GST activities were higher in the mussels caged at 5 m depth (Two-WayANOVA, $p<0.05$).

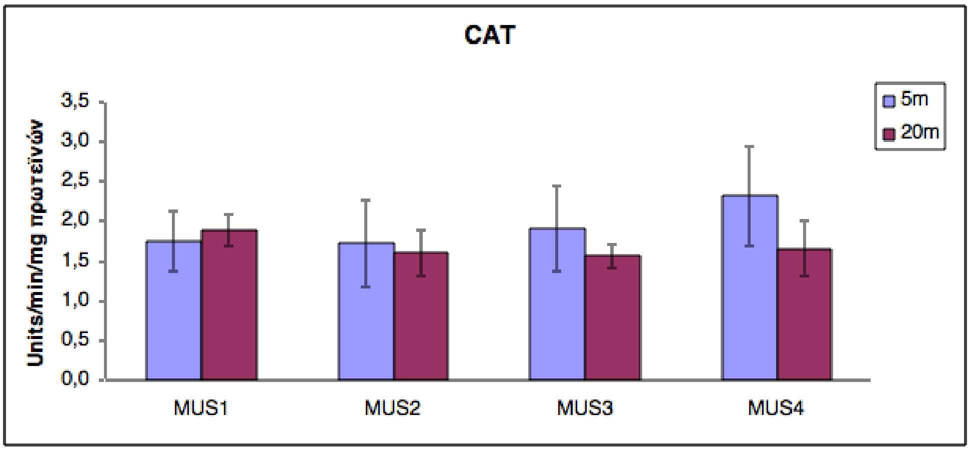


Figure 5.2. Catalase (CAT) activity in caged mussels at MUS1, MUS2, MUS3 and MUS4 sites. Mean ± SD, n=5.

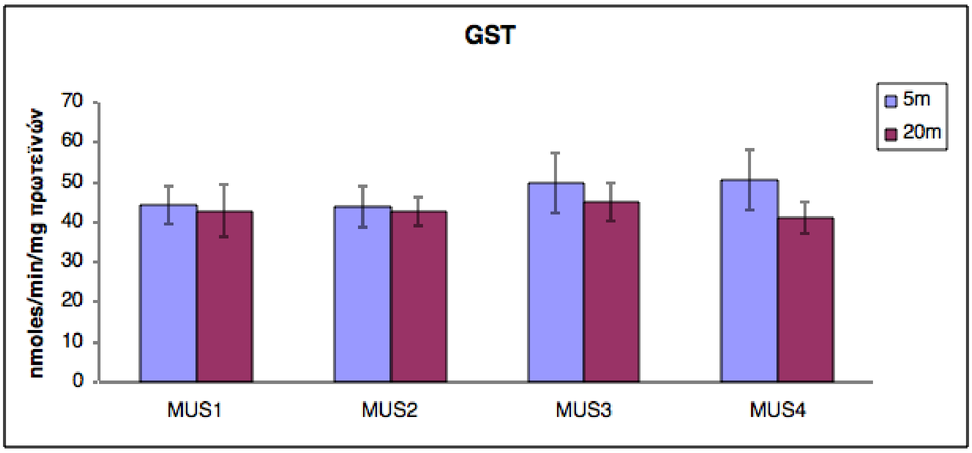


Figure 5.3. Glutathione S-trensferase (GST) activity in caged mussels at MUS1, MUS2, MUS3 and MUS4 sites. Mean ± SD, n=5.

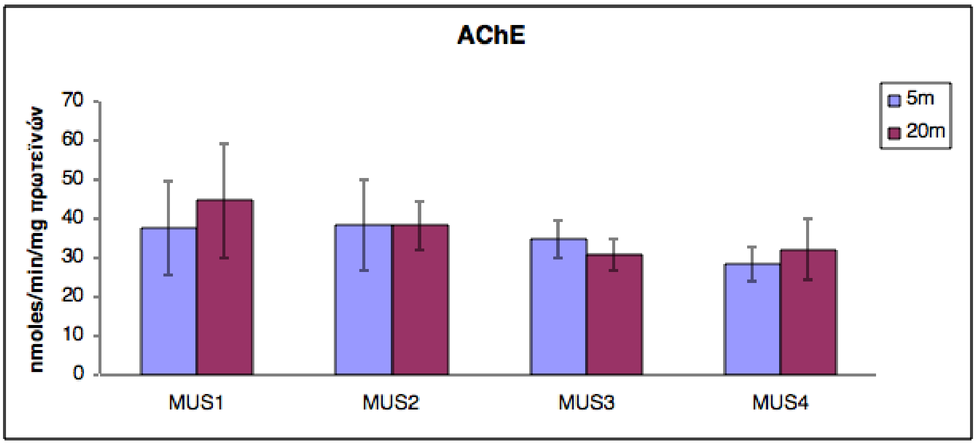


Figure 5.4. Acetylcholinesterase (AChE) activity in caged mussels at MUS1, MUS2, MUS3 and MUS4 sites. Mean ± SD, n=5.

Condition index results are shown in Figure 5.5. At MUS2 site, part of the mussels were lost during the caging period, thus the mussel samples were not enough to measure CI at 5 m depth. In contrast to CAT, GST and ACHE activities, CI values varied among sites (Two-WayANOVA, $p<0.05$). CI was significantly lower in caged mussels at the reference site MUS4 with respect to those caged at MUS1 in Salamina and MUS2 in Agios Kosmas (TukeyHSDtest, p<0,05). Condition index is influenced by environmental conditions, primarily food availability and/or reproductive condition (gamete release) (Bayne et al. 1985). In the present study, the caged mussels were taken from the same population and were in the same stage of the reproductive cycle, thus the lower CI value at MUS4 is possibly related to lower food availability with respect to sites MUS1 and MUS2.

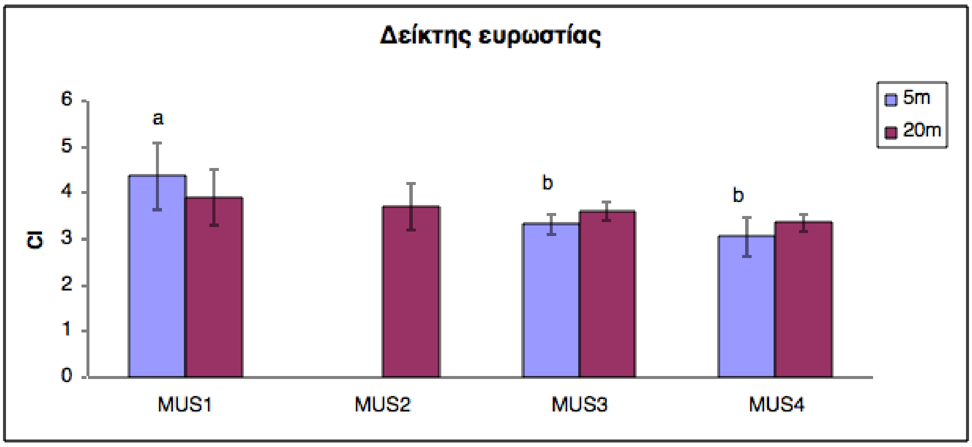


Figure 5.5. Condition index (CI) in caged mussels at MUS1, MUS2, MUS3 and MUS4 sites. Mean ± SD, n=5. Significant differences between sites are shown by different letters (TukeyHSDtest, $p<0.05$).

In conclusion, the set of biomarkers applied to assess effects of the oil spill in caged mussels showed no variations among the four studied sites in the Saronikos Gulf. Thus, our results on biomarkers indicative of oxidative stress, biotransformation and neurotoxicity do not show oil spill effects in these bio-indicator organisms. Levels of CAT, GST and AChE activities in the caged mussels at the four studied sites fall within the range of values reported by previous studies in caged or native mussels in the Saronikos Gulf (Tsangaris et al., 2004, 2010, 2014, 2016).

Mussel metal concentrations (whole body soft tissue) and MTs (digestive gland) are summarized in Table 5.2.

Table 5.2. Concentrations of metals (μg/g dw) and MTs (μg/g ww) in the whole body soft tissue and digestive gland respectively of transplanted mussels in the Saronikos gulf per station and depth (sur: surface & bot: bottom).

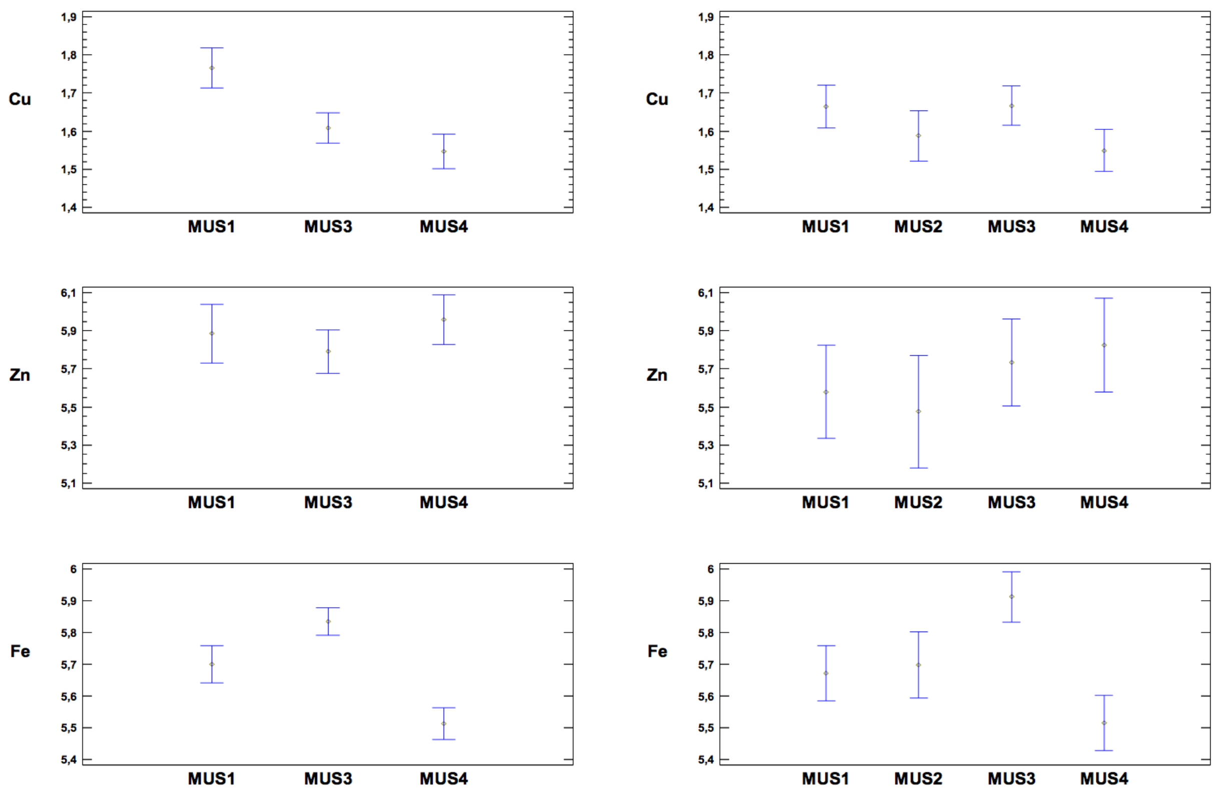
Station/ depth		**Cu**	**Zn**	**Fe**	**Mn**	**MTs**
MUS 1 sur	*avg±std*	5.89±0.35	314±70	282±27	4.38±0.27	194±26
n=5	*min-max*	5.42-6.41	236-403	256-319	4.05-4.65	155-224
MUS 1 bot	*avg±std*	5.30±0.39	268±119	294±39	4.66±0.79	322±118
n=5	*min-max*	4.71-5.58	115-445	249-339	3.75-5.53	189-484
MUS 2 sur	*avg±std*					225±66
	min-max					142-315
MUS 2 bot	*avg±std*	4.90±0.37	244±87	299±7	3.88±0.52	384±160
n=3	*min-max*	4.48-5.15	158-332	291-304	3.28-4.21	209-554
MUS 3 sur	*avg±std*	4.99±0.23	350±65	349±10	4.68±0.18	302±98
n=5	*min-max*	4.75-5.36	266-436	337-364	4.44-4.93	215-441

MUS 3 bot	*avg±std*	5.31±0.42	322±82	373±58	5.03±0.71	262±90
n=5	*min-max*	4.84-5.93	195-405	324-472	4.60-6.29	165-368
MUS 4 sur	*avg±std*	4.68±0.23	432±43	259±18	3.76±0.16	275±16
n=5	*min-max*	4.41-4.95	382-501	236-285	3.66-4.03	248-294
MUS 4 bot	*avg±std*	4.71±0.30	369±37	248±20	3.71±0.34	321±130
n=5	*min-max*	4.40-5.15	308-400	224-275	3.31-4.05	247-553

(***n*** number of samples, ***avg±std*** average ± standard deviation, ***min-max*** minimum–maximum values)

According to the statistical analysis, no differences were observed between surface and bottom in mussel metal concentrations for all examined metals while MTs values were higher in mussels transplanted near the bottom in relation to mussels placed near the surface (ANOVA, LSD test for $p<0.05$). A spatial decreasing gradient of Cu, Fe and Mn mussel concentrations was observed along the north-west (station MUS1) to the south-east geographical axis (stationMUS4) for mussels placed near the surface. Spatial variation was not significant for Cu and Zn for mussels placed near the bottom and was limited for Fe and Mn (higher values of Fe at station MUS3, Figure 5.6). Differences of MTs among stations at both depths were not significant (Figure 5.7).

SURFACE (5m) **BOTTOM (20m)**



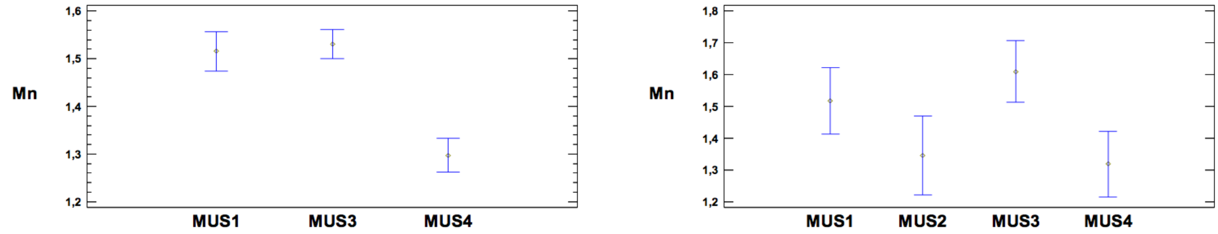


Figure 5.6. Spatial variation of Cu, Zn, Fe, Mn concentrations (μg/g dw) in the whole body soft tissue of the transplanted mussels in the studied areas of the Saronikos Gulf (ANOVA, LSD test for $p<0.05$). Values are log transformed and the flesh condition index was used as covariate.

SURFACE (5m) **BOTTOM (20m)**

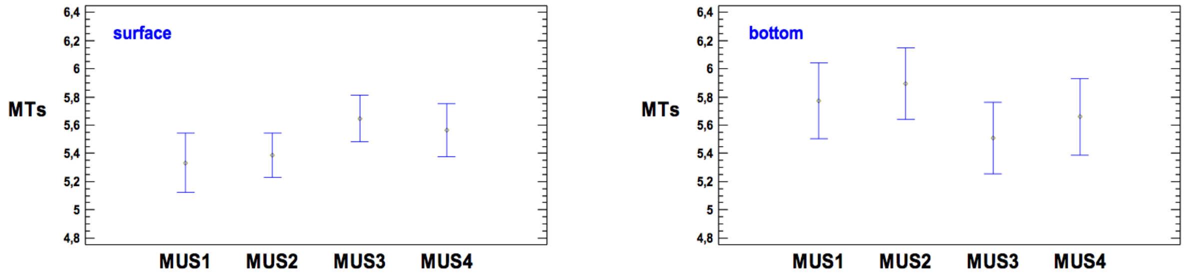


Figure 5.7. Spatial variation of MTs concentrations (μg/g ww) in the digestive gland of the transplanted mussels in the studied areas of the Saronikos Gulf (ANOVA, LSD test for $p<0.05$). Values are log transformed and the flesh condition index was used as covariate.

5.2. Determination of aliphatic hydrocarbons in the tissue of selected fish

5.2.1. Sampling and methodology

In order to study the possible bioaccumulation of petroleum hydrocarbons from the incident, further determination of aliphatic hydrocarbons was carried out in the tissue of selected fish (*Mullus barbatus, Merluccius merluccius, Parapenaeus longirostris, Illex coidentii*, depending on availability) allocated to the Institute of Oceanography of H.C.M.R. for analysis. The sampling was carried out by demersal towed gears (trawlers) in October and November 2017 by the Institute of Marine Biological Resources and Inland Waters of H.C.M.R. in the wider area of the Saronikos Gulf. The routes taken are presented in Figure 5.8.

Figure 5.8. Sampling routes carried out by demersal towed gears (trawlers) in October and November 2017 in the wider area of the Saronikos Gulf.

The determination of total aliphatic hydrocarbons was carried out on a mixed sample of wet fish tissue following the methodology described in Section 3.

5.2.2. Results and discussion

Table 5.3 below summarizes the results of the determination of total aliphatic hydrocarbons (THC) (expressed in wet weight of the tissue) for the case-by-case samples analyzed from the corresponding bottom trawl routes (Figure 5.8).

Table 5.3. Total aliphatic hydrocarbons (THC) (expressed as wet weight of the tissue) for the case-by-case samples analyzed from the corresponding bottom trawl routes in the wider Saronikos Gulf.

Route	Date	Fish species	THC (μg/g)
1	**10/2017**	*Mullus barbatus*	8.9
	10/2017	*Merluccius merluccius*	1.1
2	**11/2017**	*Mullus barbatus*	7.3
3	**11/2017**	*Mullus barbatus*	7.7
4	**11/2017**	*Mullus barbatus*	5.4
5	**10/2017**	*Mullus barbatus*	6.7
	10/2017	*Merluccius merluccius*	1.2
6	**10/2017**	*Merluccius merluccius*	2.0
	10/2017	*Mullus barbatus*	8.7
7	**10/2017**	*Mullus barbatus*	3.0

8	**10/2017**	*Illex coidentii*	2.0
9	**10/2017**	*Merluccius merluccius*	1.6
		Parapenaeus longirostris	3.5
10	**10/2017**	*Parapenaeus longirostris*	3.1
		Parapenaeus longirostris	6.2
11	**10/2017**	*Illex coidentii*	2.5

It should be noted that at routes no. 1, 2 and 4 (located within the direction of the oil spill caused by the incident) traces of oil, of small diameter, were observed on the nets. These traces were extracted with a suitable organic solvent and the ion analysis (*m/z* 71) of the chromatographs showed an increased presence of *n*-alkanes in the range n-C_{17} to n-C_{26}. This molecular profile is in line with the molecular profile of a sample of oil pumped out from the Agia Zoni II wreck and was allocated for analysis at H.C.M.R. However, higher concentrations of total aliphatic hydrocarbons were determined in samples of *Mullus barbatus*, a benthic fish species, on routes no. 1 (south of Piraiki) and no. 6 (northeast of Aegina), while the lowest concentrations of total aliphatic hydrocarbons for the same species on routes no. 4 (off Glyfada) and no. 7 (northwest of Aegina).

Taking into account the above observations, a cause-effect relationship cannot be securely established between the presence of an oil trace from the Agia Zoni II wreck in the sampling net and the bioaccumulation of petroleum products in the tissue of *Mullus barbatus*, which being a benthic fish potentially constitutes an indicator of oil burden in the sediments in which it inhabits. It should be noted however that petroleum compounds are being metabolized by the fish organism and therefore are detected in their flesh only in cases of extended petroleum pollution.

6. IMPACTS ON THE ZOOBENTHIC COMMUNITIES OF THE SUBLITTORAL ZONE

Herein we examine the possible impacts of the Agia Zoni II incident on the zoobenthic communities of the sublittoral zone of the Saronikos Gulf. Studies on the effects of oil spill events show significant impacts on benthic organisms (HCMR, 2016a and references within). The substances of oil and especially its water soluble clusters are toxic to marine organisms and can cause detrimental effects, increased mortality, reduce of species number, destabilization of communities and even disappearance of communities locally in the more affected areas. However, through adaptive mechanisms, communities may recover after a period (Teal and Howarth, 1984).

6.1. Sampling and methodology

The first phase sampling for the monitoring of the impacts of the Agia Zoni II incident on the benthic communities of the Saronikos Gulf was conducted on September 21-22nd 2017 using the *R/V* Aegaeo (HCMR). A Van Veen benthic sampler was used (0.16 m^2 sampling surface). Sampling was repeated 4 months after the incident on January 23-24th 2018 in a subset of stations at which a recent imprint of oil pollution attributed to the Agia Zoni II was recorded in September 2017 (see Section 3 above) and specifically at stations AZII, OS2 (Peiraiki), OS3 (Faliro), OS4 (Agios Kosmas) and OS6 (Glyfada), in order to detect possible short- and medium term impacts of the oil spill on the zoobenthic communities of the sublittoral zone.

The aim of the sampling was to examine the sublittoral zone within 20-60m depth in the area of the incident in Salamina coasts (ship wreck and Selinia) and in the coastal areas where the oil spill was beached: Peiraiki, Faliro, Glyfada, Agios Kosmas and Vouliagmeni. Psittalia station (S7) was also sampled, belonging to the regular monitoring network of the Saronikos Gulf for which a long time series of data is available (HCMR, 2016b). It is noted that in all the new areas sampled (named OS) there exist time series of data from stations with similar or slightly lower depths. Recent data from these areas-stations will be used for comparisons of benthic indices before and after the Agia Zoni II incident.

Two replicate samples were collected at each station for the analysis of zoobenthos. Samples for fauna analysis were sieved on board through a 1 mm sieve and stored in 4 % formalin solution, stained with Rose Bengal. A third replicate sample was retained for sedimentological analysis. Samples were sorted in the lab and were grouped into the main benthic groups. Subsequently most of the specimens were identified to the species level and only when this was not possible to a higher taxonomic level (genus or family). Based on the qualitative and quantitative composition of the macrofauna, the following ecological-biological parameters were calculated: a) number of species over the sampling surface of 0.1 m^2 (S), b) abundance (N) or population density expressed as number of individuals found, c) community diversity (H') using the Shannon-Wiener Index (Shannon and Weaver, 1963) and d) evenness of distribution (J) of individuals among species (Pielou, 1969). For the calculation of each index the average value of the two replicate samples was taken into account. Finally for the evaluation of the ecological quality status of the benthic communities the biotic index BENTIX (Simboura and Zenetos, 2002) was used. This index was developed for the purposes of the European Water Framework Directive for water policy (EEC, 2000) that consists the new European framework for water management policy. A classification analysis was carried out (clustering analysis and multidimentional scaling MDS) on log(x+1) transformed data using the "group average" technique. Sedimentological analysis was performed with a Sedigraph 5100E device after the separation of the sand fraction (> 63 μm) with liquid sieving and subsequently the percentages of sand, silt and clay were calculated. Sediment granulometric classification followed Folk (1954). Total carbon, nitrogen and organic carbon were measured in an elemental EA 1108 CHN analyzer after the methodology of Cutter and Radford-Knoery (1991) and Verardo et al. (1990).

6.2. Results and Discussion

6.2.1. Benthic indices

Recent data from adjacent stations (at slightly lower depths) from the same areas (Psittaleia, Faliron, Agions Kosmas, Vouliagmeni-Kavouri) available from the Saronikos gulf monitoring network, were used for the comparative analysis of the benthic indices' levels at the oil spill sampling stations (OS) (HCMR, 2016b; HCMR, 2017). According to HCMR experience from similar accidental occassions ex. the Sea Diamond oil spill at Santorini (Simboura et al., 2008) and the international literature (see introduction), the most direct and short term indicators of the response of the benthic communities to oil spill incidences are the number of species and the number of specimens, while the indices of Shannon diversity, eveness of distribution and the ecological quality index BENTIX are among the the medium and long term indicators of such a response. These indices levels were evaluated and also in comparison with reference levels before the accident in the same areas. Alos the sediment content in organic carbon and nitrogen were evaluated as indicators of organic pollution in sediment. Figures 6.1 and 6.2 show the variance of the indices using comparative data from the 2016-2017 regular monitoring network.

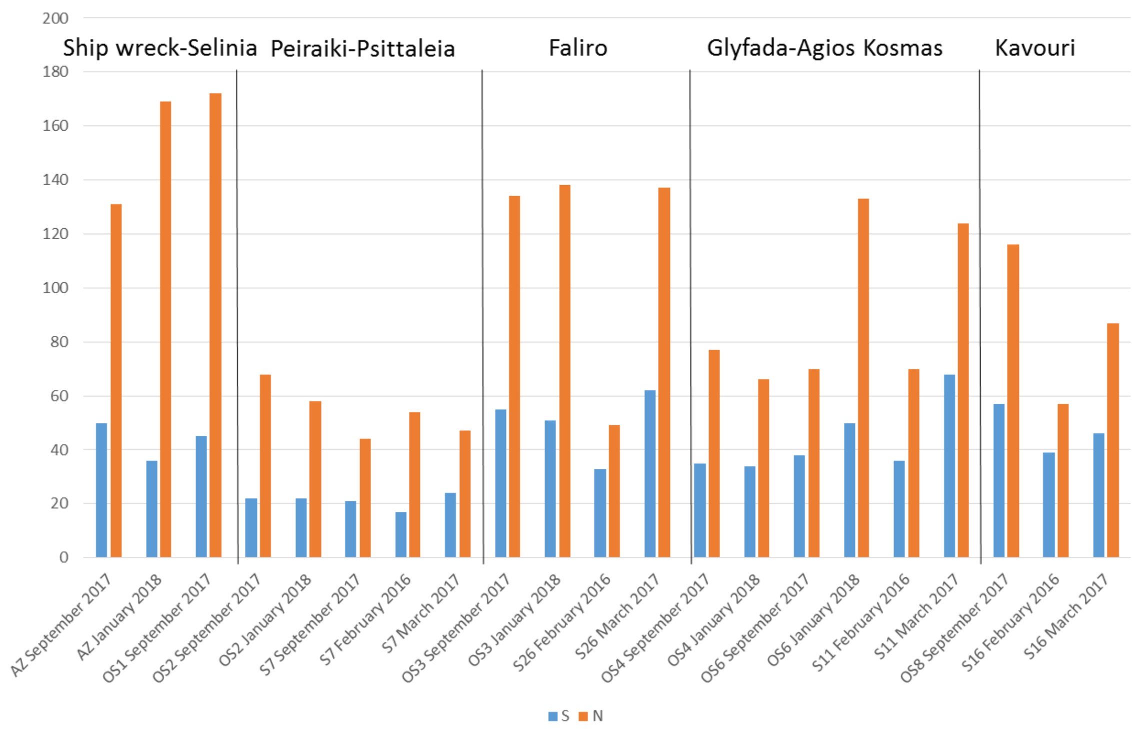


Figure 6.1. Number of Species (S) and number of individuals (N) in the sampling stations and comparative data before the Agia Zoni II incident (HCMR, 2016β; HCMR, 2017).

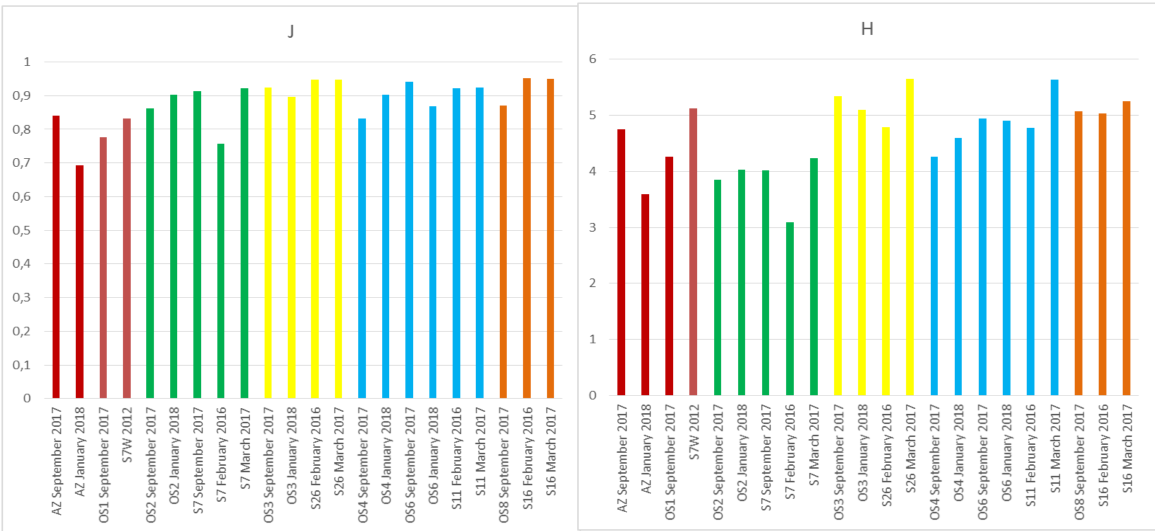


Figure 6.2. Shannon Diversity index (H') and eveness index (J) in the sampling stations and comparative data before the Agia Zoni II incident (HCMR, 2016b; HCMR, 2017).

The values of the Species richness (number of species), the number of individuals, diversity and evenness after the incident were similar of even higher than those of the respective areas based on recent data (2016-2017) available before the incident. The values of indices in the sampling of January 2018 do not present significant variation in relation to the values of the September 2017 sampling period. An exception is stations AZII and OS3 at which communities structural indices S, N, J, H´ present a slight decrease in 2018 which however is not accompanied by any decrease of the ecological status index BENTIX; on the contrary the value of BENTIX is increased in January at these two stations without however a change in quality class. These changes are attributed to the significant increase in density of two sensitive species of polychaetes: *Aponuphis brementi* and *Marphysa bellii* at these two stations in the second sampling together with the absence of some mainly sensitive species. On the contrary the BENTIX index is positively influenced by the increase of these two sensitive species. The higher values of the structural indices (species richness) in some shallower stations (OS8) in relation to deeper stations of the respective region (S16), are attributed to the variability of these indices depending on the type of sediment and the depth that aldo define in a great extent the benthic ecotypes (Simboura et al., 2012b).

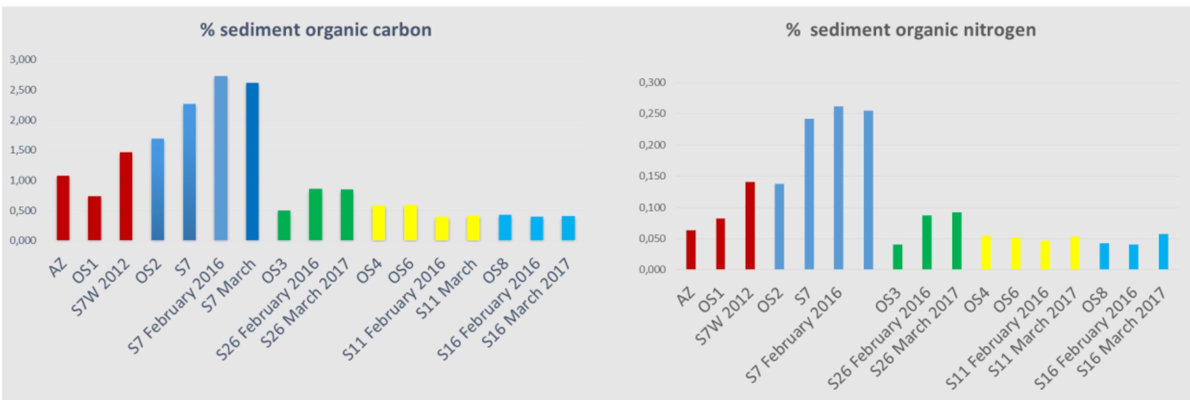


Figure 6.3. Sediment content in organic carbon and nitrogen in the sampling stations and comparative data before the Agia Zoni II incident (HCMR, 2016b; HCMR, 2017).

Figure 6.4 shows the ecological quality at the OS stations also in comparison with the stations of the wider monitoring network of Saronikos Gulf. The ecological quality in the stations after the incident are of the same class or even with higher BENTIX values compared to the respective areas based on recent data before the incident. The lower ecological quality class among OS stations corresponds to that of station OS2. The values of indices in 2018 are comparable with those of 2017 at the stations where the sampling was repeated and fall within the range of variance of the indices. Analysis of variance (ANOVA) run for testing differences of indices values before and after the incident and between periods of sampling did not show any statistical significance for all indices tested (p>0,05).

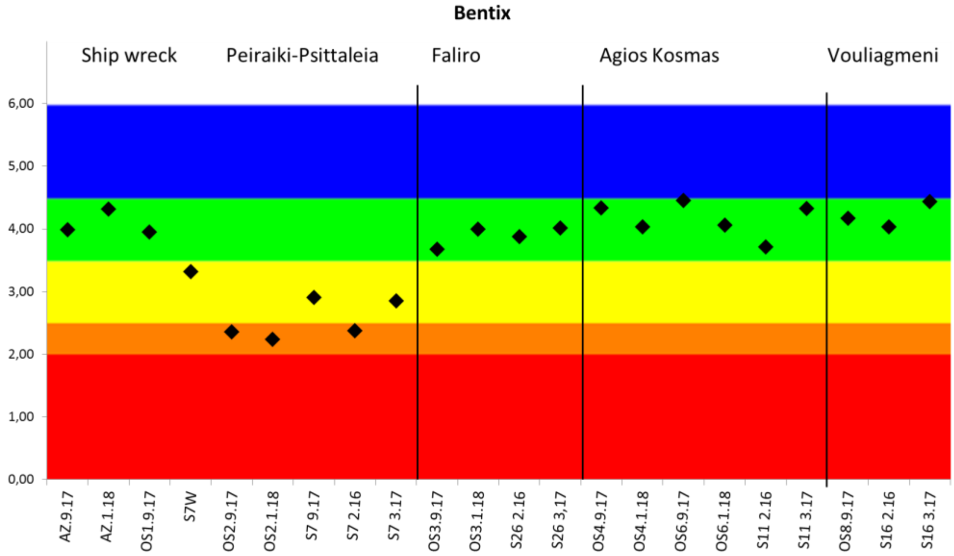


Figure 6.4. BENTIX index values and resulted quality classes in the sampling stations and in comparison to those of the respective regular monitoring network stations before the incident (HCMR, 2016b-2017). Blue=high quality class, green=good, yellow= moderate, orange=poor and red=bad.

6.2.2. Benthic communities' composition

Table 6.1 shows the most abundant benthic indices and their respective abundance values over the two sub-samples taken at each stations, the sediment content in fine material (mud), the depth, and the ecological group of each species according to the BENTIX index methodology, where GT are the generally tolerant species and GS the generally sensitive ones. Table 6.1 also gives the type of biocoenosis according to Peres and Picard (1964) that the species characterize or are typical of (Simboura and Nicolaidou, 2001). Based on Table 6.1, the benthic communities correspond to the community type of the biogenic detritus with mud (DE) with the exception of station at Peiraiki (OS2) and Psittaleia S7 where the dominant community type is that of the coastal terrigenous muds (VTC). Both types of communities belong to the circalittoral benthic zone (lower than 30-35m depth).

Table 6.1. Dominant species (10) at each station. The abundance values refer to the total number of individuals found at each station and over the two sub-samples. GS: Sensitive, GT: Tolerant. SVMC=biocoenosis of the calm water muddy sand. DE=the muddy detritus bottoms, DC=the coastal detritic, SFBC=of the well sorted fine sands, VTC=the coastal terrigenous mud community.

Ecolog. group	Community type	Species	S7 9.17	AZ 9.17	AZ 1.18	OS1 9.17	OS2 9.17	OS2 1.18	OS3 9.17	OS3 1.18	OS4 9.17	OS4 1.18	OS6 9.17	OS6 1.18	OS8 9.17
		% of fines in sediment	85	15		36	91		11		29		19		13
		DEPTH (m)	91	50	50	51	56	56	22	22	45	45	35	35	53
GT	DC	*Ditrupa arietina*												23	
GS	DC	*Drilloneris filum*										2			
GT	DC	*Pista cristata*									6				
GS	DE	*Aponuphis bilineata*				3			4						
GS	DE	*Aponuphis brementi*		30	70	54			7	12	17	13	4		4
GT	DE	*Atlantella distorta*		3											
GT	DE	*Eunice vittata*								6		2	5	4	
GT	DE	*Glycera alba*				3		2							
GT	DE	*Hilbigneris gracilis*													
GT	DE	*Kirkegaardia heterochaeta*	5	5	5	11	10	9		6					
GT	DE	*Loimia medusae*			6										
GT	DE	*Lumbrineris pinaster*				4		3							
GT	DE	*Lysidice unicornis*		10	11	5			5			4		4	
GT	DE	*Melinna palmata*										2			
GT	DE	*Myrtea spinifera*						3							
GT	DE	*Nepthys hombergii*	2											4	
GT	DE	*Notomastus sp.*		3	7				11	4					
GT	DE	*Paralacydonia paradoxa*				13		3			3	4	7	5	24
GT	DE	*Pseudoleiocapitella fauveli*	4	4					11	6					
GT	DE	*Spiophanes sp.*								13					
GT	DL	*Lanice conchylega*		10	15				4		6	4			3
GT	DL	*Poecilochaetus serpens*	2	3	6	6	4								
GS	SFBC	*Paradoneis harpagonea*													4
GT	SFBC	*Protodorvillea kefersteini*												6	
GT	SVMC	*Loripes lacteus*				3			4						
GT	VTC	*Aphaelochaeta marioni*	3				3	3							
GT	VTC	*Chaetozone sp.*					2	6							
GT	VTC	*Cossura coasta*					7								
GT	VTC	*Glycera unicornis*			6				4	8		2			
GT	VTC	*Labioleanira yhleni*	2												
GT	VTC	*Levinsenia demiri*				9		7				2			
GS	VTC	*Marphysa bellii*		3					4	12	2	3			
GS	VTC	*Nepthys hystricis*				3									
GT	VTC	*Spiochaetopterus costarum*													
GT	VTC	*Sternaspis scutata*					4	5							
GT	VTC	*Thyasira flexuosa*					2								
GS	SAND	*Lygdamis muratus*			6					6					
GT		*Nemertea*			5			4							
GS		*Syllis gerlachi*												17	

6.2.3. Multivariate analysis

Figure 6.5 shows the hierarchical clustering and two-dimensional scaling of the stations superimposed with the mud content in sediment, depth and the hydrocarbon concentrations at the OS stations sampled on September 2017 and January 2018. The similarity is calculated on the basis of their qualitative and quantitative faunal composition. Data were transformed using the (Log 1+x) transformation. The dendrogramm of Figure 6.5 shows a high similarity level without significant differences between the two sampling periods of September 2017 and January 2018 for those statiosn sampled twice. The multidimensional scaling (nMDS) ordination plot based on the faunal similarities (Figure 6.6) and the superimposition of the ordination plot with environmental factors including hydrocarbon concentrations provides a visual representation of possible correlations. The comparative similarity among stations (Figure 6.6) seems to be governed by the type of sediment (mud sediment content) and depth that define the ecotype. Most of the OS stations are characterized by more coarse sediment compared with the regular monitoring stations with the exception of stations OS2 και S7. Regarding hydrocarbons (pertrogenic related to oil pollution and pyrolytic) it seems that there is no association to the patterns of benthic communities based on their structure and composition.

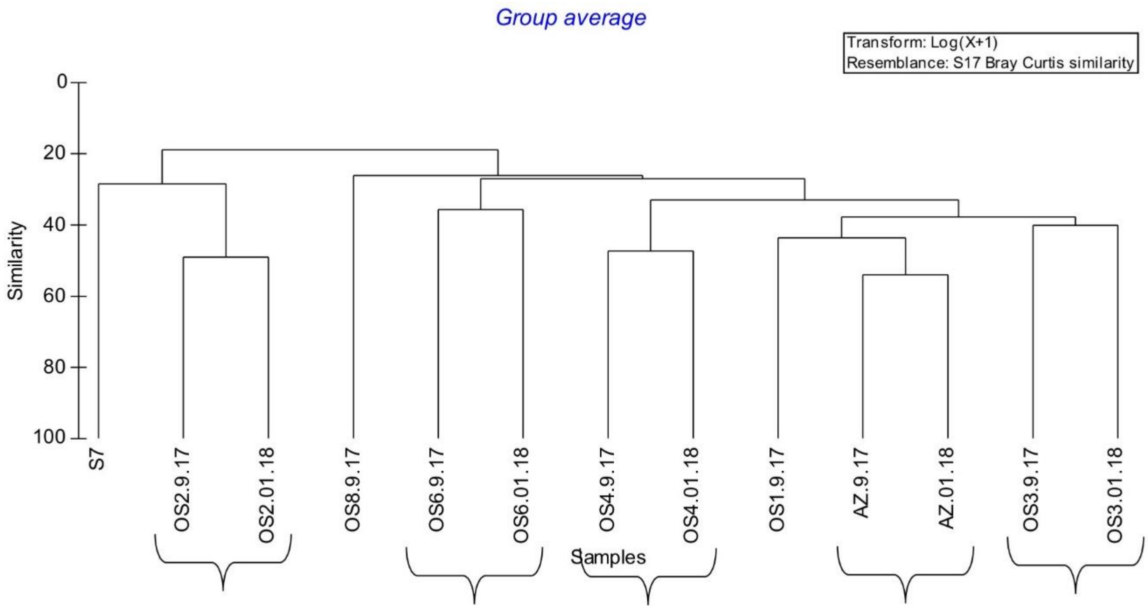


Figure 6.5. Hierarchical clustering of stations sampled in September 2017 and January 2018 after the incident.

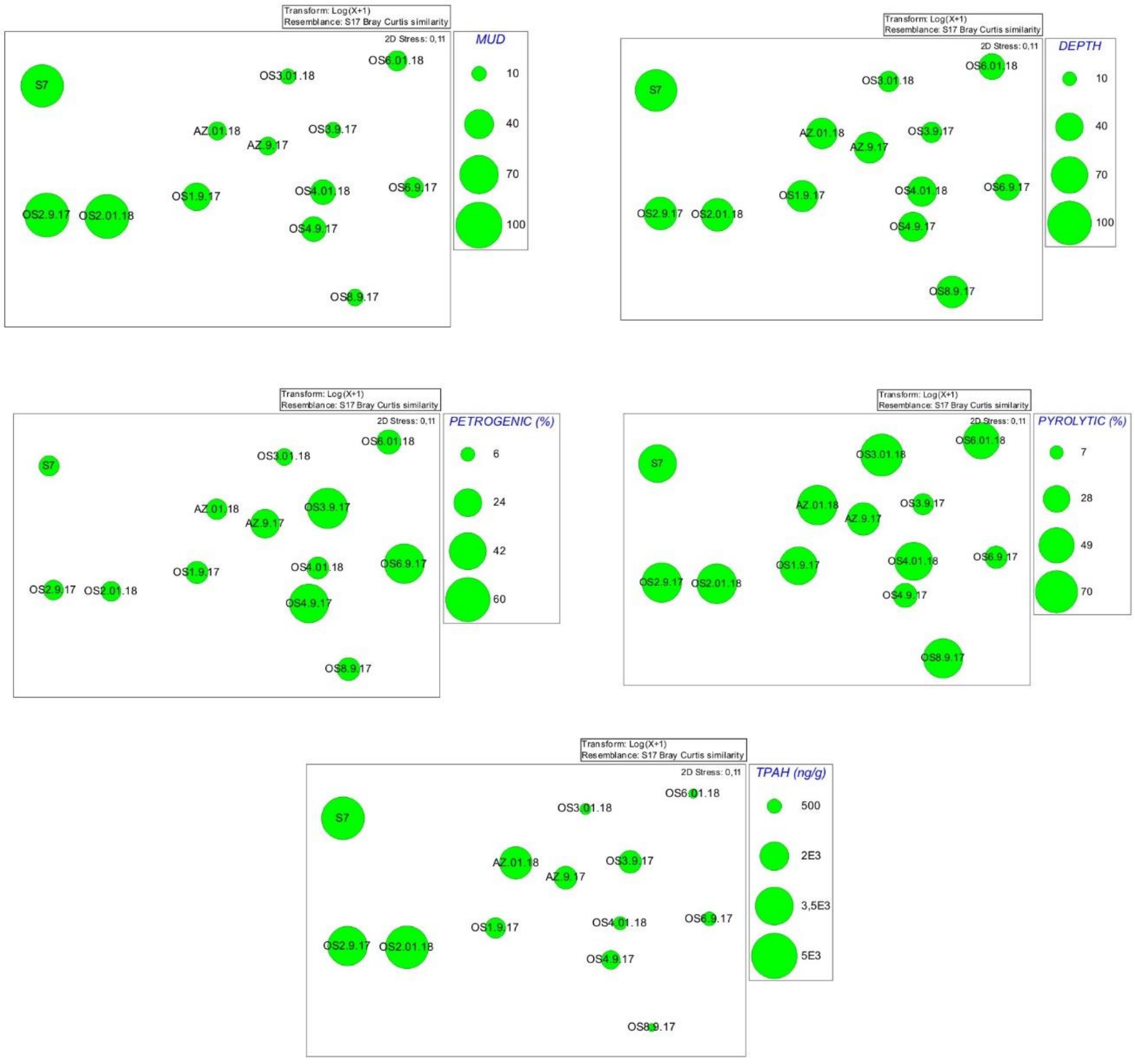


Figure 6.6. Two-dimensional scaling of stations sampled in September 2017 and January 2018 after the incident. Superimposition with mud sediment content and depth and total polyaromatic hydrocarbons (TPAH - ng/g), and their pyrolytic and petrogenic fractions.

7. STUDY OF MACROALGAE IN THE UPPER SUBLITTORAL ZONE

Macroalgae are marine plants that form well organized communities on hard substrata. They can be found in shallow waters and up to 100-120 meters depth, depending on water transparency, as they are photosynthetic organisms and need light to survive. Macroalgal communities present typical composition, structure and function, depending on the environmental conditions of a given area. Therefore, they are a reliable indicator of the ecological status of the coastal ecosystems. Particularly, macroalgae that dominate hard substrata in shallow waters (<1 m = upper sublittoral zone) are considered among the best indicators worldwide (LITTLER & MURRAY, 1975; TEWARI & JOSHI, 1988). The macroalgal flora of the Mediterranean Sea is characterized by high biodiversity (COLL *et al.,* 2010). In the Mediterranean coasts, the pristine sublittoral zone is dominated by species of the genus *Cystoseira* (PERGENT, 1991). These brown algae are canopy-forming perennial erect species. They form extensive communities of high biodiversity, which have long been considered according to PÉRÈS & PICARD (1964), as the climax stage of the shallow-water Mediterranean rocky shores. Most *Cystoseira* species show high sensitivity to natural (intense grazing, high hydrodynamic conditions) and human disturbances (THIBAUT *et al*., 2005; BALLESTEROS *et al.,* 2007; SALES & BALLESTEROS, 2009). On the contrary, in disturbed environments opportunistic green algae prevail, such as species of the genera *Ulva* and *Cladophora*, which commonly thrive in organically enriched ecosystems (DIEZ *et al.,* 1999). Therefore, replacing Cystoseira species with opportunistic green algae is a sign of degradation, a phenomenon that has frequently been observed on the Mediterranean coasts (SOLTAN *et al*., 2001; PANAYOTIDIS *et al*., 2004). On these grounds, macroalgae of the upper sublittoral zone, have been commonly used as indicators of marine ecosystem quality (CHRYSSOVERGIS & PANAYOTIDIS, 1995; ORLANDO-BONACA ET *al*., 2008), while their use is widespread in the implementation of the European Water Framework Directive (WFD, 2000/60/EC).

The complexity of ecosystems and the interactions between organisms, may cause direct or indirect effects and thus prolong the recovery process of a community (PETERSON 2001). Typically, macroalgae are less sensitive to elevated concentrations of hydrocarbons than other groups of organisms such as macroinvertebrates and juvenile fish (IPIECA-IOGP 2015, 2016). Limpets and other molluscs, which feed on macroalgae on rocky substrates, exhibit high levels of sensitivity to oil (SOUTHWARD & SOUTHWARD 1978; SUCHANEK 1993). In some cases of oil spills, habitat changes have been recorded due to high mortality rates of macroalgae (perennial species of the genera *Fucus* and *Laminaria*) combined with the loss of important grazing gastropods (limpets). In these cases, the free space on the rocks is usually covered by ephemeral green algae (*Ulva* spp. and *Enteromorpha* spp.). These r-selected species, have high growth rates and reproduction potential by producing large quantities of spores that enables them to exploit every opportunity of vegetation (ephemeral – opportunistic species). Therefore, in several impact studies of oil spills in the coastal ecosystems, the blooms of ephemeral green algae are associated with the limited number of grazers due to mortality (HAWKINS and SOUTHWARD 1992; EDWARDS and WHITE 1999; PETERSON 2003; IPIECA-IOGP 2016).

7.1. Sampling and methodology

The present study concerns the evaluation of macroalgal assemblages in the upper sublittoral zone of the coasts of Salamina and Attica, which were affected by the “Agia Zoni II” oil spill in September 2017. This is a comparative study between results obtained six months after the oil spill and a time series of 3 years prior to the oil spill. At the framework of the program “Monitoring of Saronikos & Elefsina gulfs under the influence of Psyttalia wastewater treatment plant” samplings are performed by the Institute of Oceanography-HCMR on a network of selected points (sampling stations) (Figure 7.1). The current sampling took place in 19-22 March 2018 on the eastern coast of Salamina and the southern shores of Attica. Four sites were selected from the given network of sampling stations and in particular those that received the largest oil quantities (Ampelakia-Limnionas (A) on the eastern coasts of Salamina, as well as Peiriaki (P-Π), Agios Kosmas (AK), Kavouri (KA) on the southern coasts of Attica). All sampling stations are characterized by rocky substrate and the macroalgae assemblages were examined in shallow waters (<1 m = upper sublittoral zone), where the coast was covered by oil.

The sampling stations were examined by free diving and the sampling method was photographic (non-destructive sampling). In some cases, representative macroalgae were collected in order to confirm the photographic speciments. The samples collected in the field were placed in labeled plastic bags and transferred to the laboratory for further processing. The study and taxonomy of macroalgae was carried out in the Phytobenthos Lab of HCMR, by using an OLYMPUS SZX10 stereoscope and an OLYMPUS BX43 microscope. Nomenclature and systemic classification of macroalgae were based on the following catalogs: GALLARDO *et al.* (1993) for green algae, RIBERA *et al.* (1992) for brown algae, ATHANASIADIS (1987) and GOMEZ-GARRETA *et al.* (2001) for red algae. In cases where species level recognition was not possible, macroalgae were identified at genus level. For estimating macroalgae abundances, the Braun-Blanquet scale was applied (WIKUM D.A. and SHANHOLTZER G.F. 1978). This methodology is used for rapid assessment and description of the vegetation on a given area. Two scales are used, one concerns the coverage percentage of recorded species and the "values" given range from + (insignificant presence) to 5 (covering more than 75% of the area). The second scale, which was not used in the current study, concerns to how macroalgae species develop on rocky substrate (individual species, clusters or solid populations).

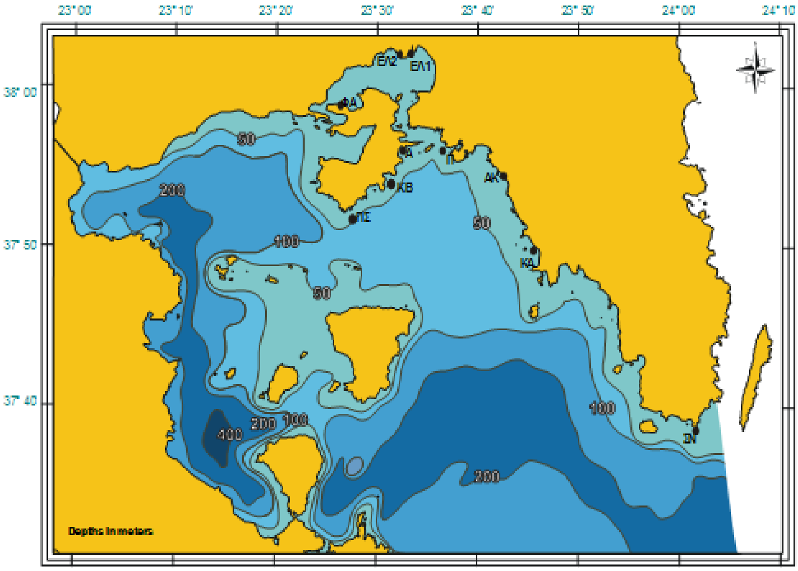


Figure 7.1. Network of sampling stations. Peristeria (PS-ΠΣ), Kaki Vigla (KV-KB), Ampelakia-Limnionas (A), Peiriaki (P-Π), Agios Kosmas (AK), Kavouri (KA), Sounio (SN-ΣΝ).

7.2. Results and Discussion

7.2.1. Marine Macroalgae

In total, 29 taxa of macroalgae were identified: 5 green algae, 10 brown algae και 14 red algae. The presence of macroalgae in the four sampling stations during March 2018 is noted with a + sign (Table 7.1). Species number for each station ranged from 14 to 18, corresponding to previous studies in the Saronikos Gulf (SIOKOU-FRANGOU *et al*., 2002), as well as other areas of the Aegean Sea (CHRYSSOVERGIS & PANAYOTIDIS, 1995 and PANAYOTIDIS *et al.,* 1999). In all the studied stations a common core of predominant species was observed. Among them, the brown algae *Dictyota dichotoma* var. *intricata, Colpomenia sinuosa* and *Sphacelaria cirrosa*, with the red algae *Jania* spp. and the green alga *Cladophora* spp. Regarding the seasonality of macroalgae, species of the cold period were recorded, such as the brown algae *Colpomenia sinuosa* and *Scytosiphon lomentaria.* The expected fluctuations in the abundance of certain species due to their natural seasonal cycle was observed, such as the increase in the abundance of the green algae *Ulva* spp. and the brown algae *Dictyota dichotoma* var. *intricata* during the cold period. The nitrophilous *Ulva* spp. species are typically known to thrive in early spring, sometimes forming extensive blooms, and usually decline again during the warm season. The perennial brown alga *Cystoseira compressa*, which has re-occurred in the Saronikos Gulf after the operation of the Psyttalia wastewater treatment plant, was found in most sampling stations apart from Ampelakia-Limniona. The absence of the species is not related to the oil spill. The presence of alien species, such as *Asparagopsis taxiformis, Caulerpa cylindracea* and *Stypopodium shimperi,* was noteworthy but not related to the oil spill.

7.2. Community structure

According to data collected over the past 20 years at the Phytobenthos Lab of the Institute of Oceanography-HCMR, the vegetation of the sublittoral zone in the Saronikos Gulf can be subdivided into the following main floors:

a) The **canopy**-forming floor, which is characterized by perennial photophilic algae that act as ecosystem-engineers forming “forests” in the sublittoral zone, represented mostly by large brown algae of the genera *Cystoseira* and *Sargassum*. The canopy-forming floor takes its typical form during the warm period (August-September). During the cold period, lower biomass levels are observed. At the samplings of March 2018, the canopy-forming species where present in most stations, except for Ampelakia-Limnionas in Salamina. However, this fact should not be attributed to the effects of the oil spill because it has been observed in the past.

b) The **bushy** floor, which is characterized by species who occupy the free space between the canopy-forming floor, such as the brown algae *Dictyota* spp., *Halopteris scoparia*, *Padina pavonica*, the red algae *Jania* spp. και *Corallina* spp. and the green alga *Ulva* spp. During the cold period (February-March) some typical species may occur, which may be dominant in some cases, such as the brown algae *Scytosyphon lomentaria* and *Colpomenia sinuosa*. At the same time, a seasonal bloom of nitrophilous green algae (“green tide” *Ulva spp*.) may be observed. Finally, it’s worth noting that in the past 5-10 years various alien species, such as *Caulerpa cylindracea*, *Asparagopsis armata* and *Stypopodium shimperi*, have a permanent presence in the bushy floor. During the samplings of March 2018 all the aforementioned species were observed, with minor variations between the stations. The presence of alien species is not related to the oil spill.

c) The **crustose** floor, which is characterized by sciophilic crustose coralline algae that grow below the canopy-forming and bushy floors. These rock-hard calcareous red algae were present with some variations between the stations which were not related to the oil spill.

d) The **epiphytic** floor, which includes relatively small sized species that grow upon other larger algae. Typical species of the epiphytic floor are the brown algae of the *Sphacelaria* genus, the red algae of the genera *Polysiphonia* and *Ceramium* and the green algae of the genera *Chaetomorpha* and *Cladophora*. During the samplings of March, some of the above mentioned species were observed, but no visible differences possibly related to the oil spill were recorded.

Table 7.1. Qualitative analysis of macroalgae during March in the sampling station Ampelakia-Limnionas (A), Peiraiki (P), Agios Kosmas (AK) and Kavouri (KA). Species presence is noted with (+).

	A	P	AK	KA
CHLOROPHYTA				
Acetabularia acetabulum			+	
Caulerpa cylindracea		+	+	+
Cladophora spp.	+	+	+	+
Halimeda tuna			+	
Ulva spp.	+	+		
FUCOPHYCEAE				
Colpomenia sinuosa	+	+	+	+
Cystoseira compressa		+	+	+
Cystoseira crinitophylla			+	+
Dictyopteris polypodioides		+	+	
Dictyota dichotoma var. *intricata*	+	+	+	+
Halopteris scoparia	+		+	+
Padina pavonica		+	+	+
Sargassum vulgare		+	+	+
Sphacelaria cirrosa	+	+	+	+
Stypopodium schimperi	+			
RHODOPHYCEAE				
Asparagopsis taxiformis	+	+		+
Ceramium virgatum		+		
Chondracanthus acicularis	+	+		
Corallina spp.	+	+		
Hypnea musciformis	+	+	+	
Jania spp.	+	+	+	+
Laurencia spp.	+			
Lithophyllum spp.				+
Osmundea truncata	+	+		
Palisada spp.		+	+	
Plocamium cartilagineum	+			

Pterocladiella capillacea	+	+		
	A	**P**	**AK**	**KA**
Rytiphlaea tinctroria				+
Schizymenia dubyi		+		
Total species number	**16**	**18**	**16**	**14**

In most of the sampling stations, no traces of oil tars were observed on the soft or rocky substrate. However, in Ampelakia-Limniona station traces of oil tars were noticed on marine litter (plastic bottles) that is being washed out on the coast due to waves. The presence and abundance of macroalgae in the sampling stations (Ampelakia-Limnionas, Peiraiki, Agios Kosmas, Kavouri), before (March 2017, 2016 and 2014) and after (March 2018) the oil spill, are listed in Table 7.2. Because marine algae exhibit seasonal variations, just like terrestrial vegetation, they are usually examined during the warm (September) and cold (March) period. Thus, it is important that the comparison of the data is made between the same sampling periods. In the network of stations examined in March 2018, no major differences were observed in the community structure and composition, when compared to the results of previous years (March 2017, March 2016 and March 2014). No significant changes in the distribution patterns, species abundances and number of species per sampling station were noticed. No intense cover of opportunistic algae (*Ulva* spp.) was observed, other than the "normal" presence and coverage documented in previous samplings. As mentioned, the expected fluctuations in the abundance of certain species (*Ulva* spp. and *Dictyota dichotoma* var. *intricata*) were recorded but were attributed to natural variability.

Table 7.2. Braun-Blanquet cover-abundance scale of macroalgae during the cold period (March 2018, March 2017, March 2016 and March 2014) at the sampling stations of Ampelakia-Limnionas, Peiraiki, Agios Kosmas and Kavouri.

	Ampelakia-Limnionas				Peiraiki				Agios Kosmas		Kavouri			
	2018	**2017**	**2016**	**2014**	**2018**	**2017**	**2016**	**2014**	**2018**	**2017**	**2018**	**2017**	**2016**	**2014**
CHLOROPHYTA														
Acetabularia acetabulum									+					
Caulerpa cylindracea				1	+	1		+	+		1	1	1	1
Chaetomorpha aerea			+	+						+				
Cladophora spp.	2	2	+		+		+		1	1	2	2	2	2
Halimeda tuna									+	+				
Ulva spp.	2	2	2	2	1		+						+	
Valonia utricularis										+				+
FUCOPHYCEAE														
Colpomenia sinuosa	1	1	+	2	1	+	1	1	+	+	1	1	+	
Cystoseira compressa		+			3	3	3	3	3	3	2	1	2	2
Cystoseira crinitophylla									2	2	3	3	2	3
Dictyopteris polypodioides					+	+	+		+	+				
Dictyota dichotoma var. *intricata*	4	4	4	2	2	2	2	1	2	2	2	2	2	2
Halopteris scoparia	2	2	1	2		+	1	+	1	2	2	2	1	2
Hydroclathrus clathratus													+	
Padina pavonica					+	1	+		1	1	2	2	2	2
Sargassum vulgare					2	2	2	2	1	1	2	2	2	2
Sphacelaria cirrosa	+		+	+	+	+		+	+	+	1	1	1	1
Stypopodium schimperi	+													
Taonia atomaria				2						+				
RHODOPHYCEAE														
Amphiroa beauvoisii		+	+	1										
Asparagopsis taxiformis	+	1	1	+	+	+	+				+		+	
Ceramium virgatum					2	2	2	2						
Champia parvula				1										
Chondracanthus acicularis	+	+	1	2	1	2	1	2						
Corallina spp.	2	2	2	3	2	2	3	3				1	1	2
Hypnea musciformis	+	1	1	2	1	1	1	2	1					1
Jania spp.	+	+	1	2	1	1	1	1	2	2	2	2	2	2
Laurencia spp.	+													
Lithophyllum spp.											+	+		
Osmundea truncata	+		1	1	+									
Palisada spp.					+	+	1	2	1				+	+
Plocamium cartilagineum	+	+		1										
Pterocladiella capillacea	1	+	2	2	2	2	2	2						
Rytiphlaea tinctroria											+		+	
Schizymenia dubyi					2	2	2	2						
Total Species Number	**16**	**14**	**15**	**18**	**18**	**18**	**18**	**15**	**16**	**15**	**14**	**13**	**17**	**14**

8. UNDERWATER VISUAL SURVEYS TO INVESTIGATE MACROSCOPIC SEABED CONDITIONS

The aim of the underwater visual survey was to inspect the present condition and investigate the potential presence of macroscopic oil residues on coastal benthic habitats of the Saronikos gulf, after the completion of the cleaning operations and the removal of the Agia Zoni II wreck. The survey focused on parts of the coasts of Salamis Island and Attica mainland, where the impact of the accident was mainly manifested (Figure 8.1). The visual survey was carried out along underwater transects running parallel and perpendicular to the shoreline, at depths between 3-20 meters of: (a) the Selinia bay and around the Agia Zoni II wreck site (29/03/2018) (Figures 8.1.A and 8.2), (b) Phloisbos to Agios Kosmas coasts (30/03/2018) (Figures 8.1.B and 8.3) and (c) Agios Kosmas to Voula coasts (08/12/2017) (Figures 8.1.C and 8.4).

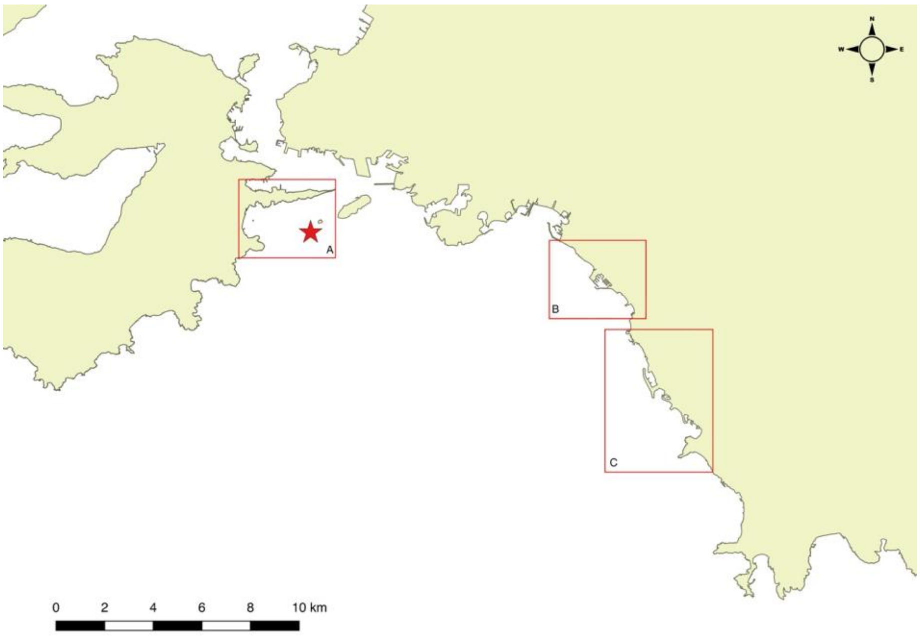


Figure 8.1. Map of the wider study area, indicating focus sub-areas A, B and C.

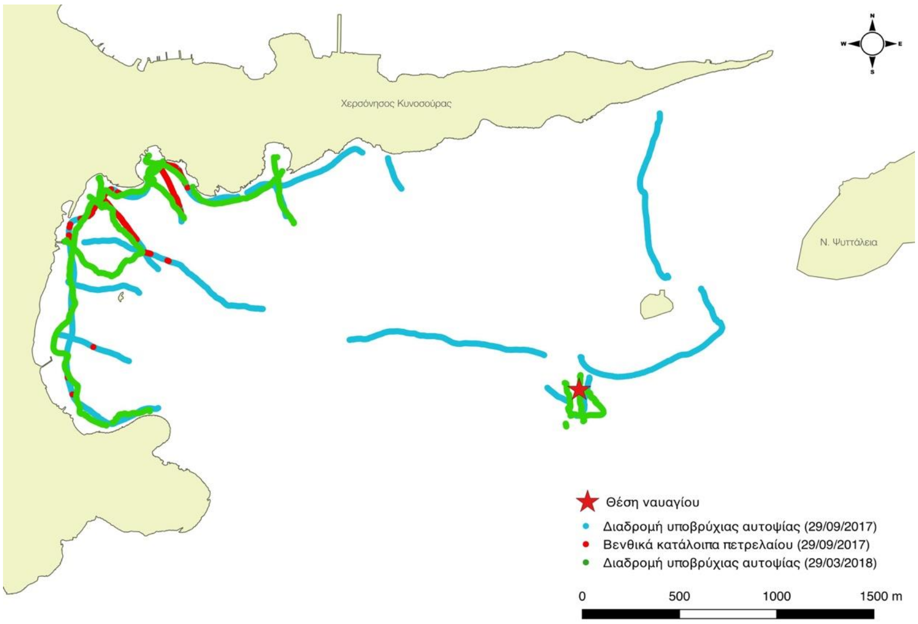


Figure 8.2. Map of study sub-area A, Selinia bay, Salamina island. The transects performed during the recent survey (29/03/2018) are highlighted in green, while the transects highlighted in blue refer to those performed during the initial survey and before the removal of the wreck (29/09/2017), when oil residues were detected on the seabed (red highlights).

Figure 8.3. Map of study sub-area B, Phloisbos to Agios Kosmas coasts, depicting locations of the underwater visual transects performed.

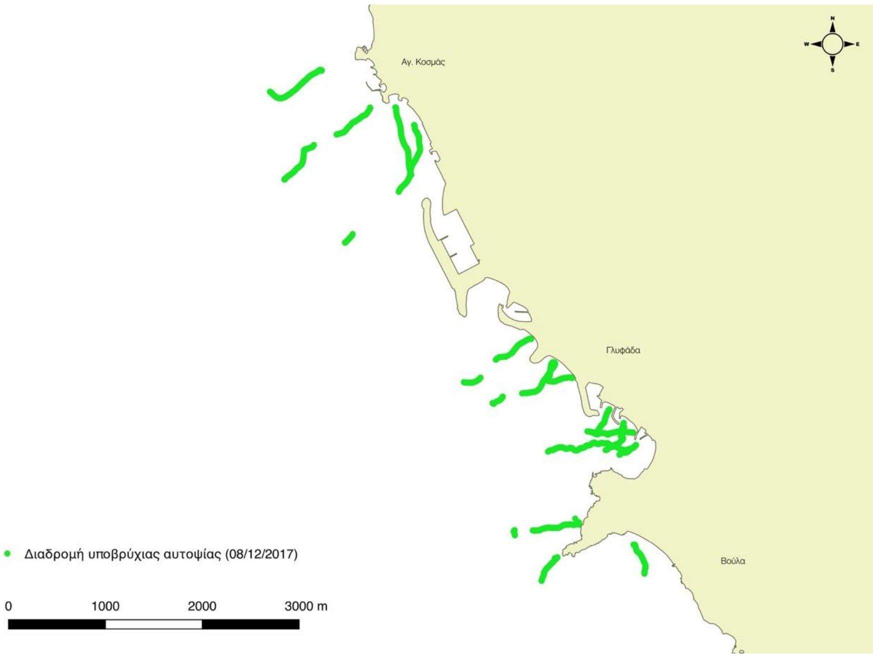


Figure 8.4. Map of study sub-area C, Agios Kosmas to Voula coasts, depicting locations of underwater visual transects performed.

The survey was carried out by an HCMR team using RIB boats suitable for the safe handling and successful navigation of the underwater tow camera system. This allowed for a systematic seabed inspection of a total length of ~ 25 km as well as the simultaneous HD video recording of a total duration of 9.21 hours (Table 8.1).

According to the results of the on-site seabed inspection, as well as the further examination of the recorded digital material (photos and video), no macroscopic oil residues or other evidence of oil pollution were detected along the transects performed, regardless of the benthic habitat types examined (sandy and muddy bottoms, rocky reefs, Posidonia seagrass meadows, as well mixed phases thereof) in the wider study area, despite the fact that special attention was given at sites with high potential of trapping of suspended and drifting material (e.g. innermost parts of sheltered bays, seagrass meadows interstices and their lower and upper boundary zones, rocky reef recesses, etc.). The presence of plastic and other litter was however recorded in the majority of the inspected area.

Table 8.1. Length of underwater visual transects, underwater video recording duration and number of underwater photographs captured per sub-area.

STUDY SUB-AREA (SURVEY DATE)	VISUAL TRANSECT LENGTH (m)	DURATION OF VIDEO RECORDING (min)	NUMBER OF PHOTOGRAPHS CAPTURED
Selinia bay (29/03/2018)	5,871	138	1,667
Phloisbos – Agios Kosmas (30/03/2018)	10,266	232	2,786
Agios Kosmas – Voula Coast A (08/12/2017)	8,609	183	2,196
TOTAL	**24,746**	**553**	**6,649**

Particular emphasis was placed on the critical examination of the Posidonia meadows and the vegetation of shallow reefs, in order to identify indirect signs of disturbance. However, the ecosystem was found to reflect the natural ecological conditions, as anticipated on the basis of our background knowledge of the study area and the season of the survey (H.C.M.R. 2015; 2016; 2017). Particularly for the Selinia bay sub-area, where macroscopic petroleum residues were found during the initial phase of our survey (29/09/2018), this latter inspection (29/03/2018) rather implies their successful removal or degradation. However, since the area is characterized by significant accumulations of macroalgal drifts (predominantly *Dictyota* spp., *Stypopodium* sp., and Cladophorales) - typical of this region and season - the presence of smaller residues or tarballs between or below this drifting biomass is difficult to exclude with certainty. Similar caution should be expressed for the seabed around the Agia Zoni II (ex) wreck site, where particularly dimmed light conditions, due to increased depth (30-50 m) and high turbidity, did not allow the recording of high quality underwater images so as to safely detect or exclude the presence of oil residues on the seabed. The area should therefore be revisited by means of more suitable underwater visual systems equipped with external artificial lighting (e.g. ROV).

9. CONCLUSIONS

From the results presented in this report the following concluding remarks can be drawn:

Regarding seawater samples collected from the coastal zone of the Saronikos Gulf

Regarding total petroleum hydrocarbons, at 37 out of 56 considered coastal sampling stations their concentrations were recorded within normal levels in all cases. On the contrary, extended petroleum pollution was initially recorded (September 2017) in the regions of Elliniko, Glyfada, Selinia and Kinousoura. A smaller burden of petroleum hydrocarbons was also recorded at the areas of Phloisvos (till October 10th 2017), Asklipieio Voulas (on September 18th 2017), Megalo Kavouri (on September 18th 2017), Vouliagmeni beach club (on September 18th 2017), Mavro Lithari at Anavyssos (on September 18th 2017) and locally within the Tomb of Themistocles in Piraeus (on October 10th and October 23rd 2017). On November 2nd 2017, December 4th 2017 and January 19th 2018 total petroleum hydrocarbons concentrations were recorded within normal levels at all sampling locations. A slightly elevated value of total petroleum hydrocarbons concentrations was recorded at Aigyptiotes Naval Club and Batis on January 19th 2018 (after a severe weather event followed by rough sea) with their levels recorded at normal values on March 21st 2018.

Regarding seawater samples collected from open sea areas of the Saronikos Gulf

In both seawater samplings conducted in open sea areas of the Saronikos Gulf, total petroleum hydrocarbons levels were normal. Furthermore, in no case values higher than the annual average concentration and maximum allowable concentration for PAHs were recorded, in accordance with the environmental quality standards for priority substances for the determination of chemical and ecological status of waters (Directive 2013/39/EC). Minor variations in total petroleum hydrocarbons levels can be interpreted in the context of the physical variability of the total petroleum hydrocarbons content of the water column of the study area. In all cases they clearly indicate the absence of a petroleum residues burden at the sampling sites and the corresponding sampling depths in open sea areas of the Saronikos Gulf during the sampling dates.

Regarding sediment samples collected in the open Saronikos Gulf

Macroscopically no large sized tar aggregates or traces of extensive petroleum pollution were observed on the collected sediments at the time of their sampling (September 2017, November 2017 and January 2018) either in the surface or in the sub-surface layers. Very limited 1-2 mm sized tar balls were visually observed during the sampling of November 13-14th 2017 at the sampling site of the shipwreck of Agia Zoni II and the sampling site south of Psittaleia. Compared to the stations belonging to the Saronikos Gulf systematic monitoring network, for which a time series of data is available covering the past years, total aliphatic and polycyclic aromatic hydrocarbons concentrations after the incident were on general terms recorded in the same or in many cases at lower levels compared to data before the incident. However, the molecular analysis and the use of diagnostic indices showed that at stations OS3 (off Palaio Faliro), OS4 (off Agios Kosmas), OS6 (off Glyfada) and AZII (near the shipwreck) a recent oil pollution imprint associated to the Agia Zoni II incident was recorded on September 21-22nd 2017. This recent burden is very mild in respect to the chronic petroleum-associated anthropogenic background of the Saronikos Gulf. On November 13-14th 2017 and furthermore on January 23-24th 2018 in the corresponding sediments the recent imprint associated to the Agia Zoni II incident appears to be reduced. This could be likely attributed to the degradation of the petroleum-associated compounds (aliphatic and polycyclic aromatic hydrocarbons) during their residence in the sediment. However, the limitations in the sampling procedure associated with the use of a Box Corer sampler with a surface area of 40x40 cm should be considered.

Geochemical composition of open sea surface sediments

The study on the geochemical composition of surface sediments of the Saronikos Gulf in two periods prior and three periods after the incident of the Agia Zoni II sinking and the oil spill that followed, aimed at the examination of potential contamination using as tracers the elements vanadium and nickel, often found in crude oils. In all five sampling campaigns the levels of the metals were normal and the their variability is attributed mostly to grain-size variations, with fine sediments being more enriched in metals over the coarser ones, which are generally of biogenic origin, rich in carbonates. The estimated Enrichment Factors show with reliability that there was no contamination of the sediments in the aforementioned metals and therefore it appears that there is no impact on the sediments associated to the Agia Zoni II incident.

Potential bioaccumulation of contaminants from the incident and related biological effects in marine organisms

From the study of the potential bioaccumulation of contaminants from the incident and related biological effects in mussels (*Mytilus galloprovincialis*) no bioaccumulation of aliphatic hydrocarbons, polycyclic aromatic hydrocarbons and metals has been observed due to the incident. The results on biomarkers indicative of oxidative stress, biotransformation and neurotoxicity do not show oil spill effects in these bio-indicator organisms. Levels of biomarkers in the caged mussels fall within the range of values reported by previous studies in caged or native mussels in the Saronikos Gulf. From the determination of aliphatic hydrocarbons in the tissue of selected fish (*Mullus barbatus, Merluccius merluccius, Parapenaeus longirostris, Illex coidentii*, depending on availability) a cause-effect relationship cannot be securely established between the presence of an oil trace from the Agia Zoni II wreck in the sampling net and the bioaccumulation of petroleum products in the tissue of *Mullus barbatus*, which being a benthic fish potentially constitutes an indicator of oil burden in the sediments in which it inhabits. It should be noted however that petroleum compounds are being metabolized by the fish organism and therefore are detected in their flesh only in cases of high petroleum pollution.

Impacts on the zoobenthic communities of the sublittoral zone

Based on the examination of benthic samples in the wider area of the Saronikos Gulf and specifically in the depth zone between 20 and 60 m (sublittoral or subtidal zone) over two sampling periods with a time interval from the accident of 0 and 4 months, it seems that there are no oil spill impacts on the sublittoral benthic communities. Specifically, the short and long-term indices of benthic communities' response to oil pollution as well as the ecological quality of benthic communities at the sampling stations after the accident, were found at comparable levels that those of the respective sampling areas before the accident without statisticall significant differences. The composition of benthic communities corresponds with the expected according to the depth the type of sediment which are the basic factors that define the type of communities is soft bottoms.

Impacts on macroalgae of the upper sublittoral zone

In the network of stations examined in March 2018, no major differences were observed in the community structure and composition, when compared to the results of previous years. No significant changes in the distribution patterns, species abundances and number of species per sampling station were noticed. No intense cover of opportunistic algae (*Ulva* spp.) was observed, other than the "normal" presence and coverage documented in previous samplings. The expected fluctuations in the abundance of certain species (*Ulva* spp. and *Dictyota dichotoma* var. *intricata*) were recorded but were attributed to natural variability. In the sampling stations no traces of oil tars were observed on the soft or rocky substrate.

Mapping of the seabed on selected coastal regions affected by the oil spill by conducting visual observations

According to the results of the on-site seabed inspection, as well as the further examination of the recorded digital material (photos and video) on parts of the coasts of Salamis Island and Attica mainland from -20 m to 3 m depth, no macroscopic oil residues or other evidence of oil pollution were detected along the transects performed, regardless of the benthic habitat types examined (sandy and muddy bottoms, rocky reefs, Posidonia seagrass meadows, as well mixed phases thereof). Special attention was given at sites with high potential of trapping of suspended and drifting material (e.g. innermost parts of sheltered bays, seagrass meadows interstices and their lower and upper boundary zones, rocky reef recesses, etc.). Particular emphasis was placed on the critical examination of the Posidonia meadows and the vegetation of shallow reefs, in order to identify indirect signs of disturbance. However, the ecosystem was found to reflect the natural ecological conditions, as anticipated on the basis of our background knowledge of the study area and the season of the survey.

Considerations

The results presented in this report concerning the sediments collected from the open sea areas of the Saronikos Gulf should be considered as indicative as the dimensions of the sample (40x40 cm) are limited. Therefore, taking into account the direction of the dispersal of the oil spill caused by the incident, the accumulation of petroleum residues on the seabed in a position adjacent to the sampling points cannot be ruled out. Mapping of the seabed in open sea areas of the Saronikos Gulf by underwater visual systems equipped with external artificial lighting (e.g. ROV) can give more reliable information.

The general conclusion of the study is that the main effects of the incident were confined to the coastal zone, especially in the areas of Salamina, Glyfada and Elliniko and only for the first three months after the oil spill. After December 2017, there appears to be no significant findings across the coastline regarding the presence of petroleum hydrocarbons. Marine organisms appear to be unaffected by the incident, while no evidence of bioaccumulation was found. With respect to the seabed, both visual observations at depths from -20 m to 3 m and the analysis of sediment samples collected in the open Saronikos Gulf (from 22 to 92 m depth) showed no major petroleum burden related to the incident.

10. OUTREACH

Up to date, the results of the Institute of Oceanography of the Hellenic Centre for Marine Research (H.C.M.R.) survey on the possible short- and medium-term environmental impacts of the Agia Zoni II sinking on the marine ecosystem of the Saronikos Gulf have been presented twice (December 8th 2017 and April 27th 2018) at dedicated sessions of the Permanent Committee on Environmental Protection of the Hellenic Parliament which were broadcasted live on Pan-Hellenic TV-network.

The December 8th 2017 session (in Greek) can be reached at the following link:

https://www.hellenicparliament.gr/Vouli-ton-Ellinon/ToKtirio/Fotografiko-Archeio/#a26933f2-5c73-43e6-849d-a84600abb66e

while the April 27th 2018 session (in Greek) can be reached at the following link:

https://www.hellenicparliament.gr/Vouli-ton-Ellinon/ToKtirio/Fotografiko-Archeio/#1a71bfce-9be0-40d2-bba2-a8d2010b60d1

Moreover, during the 12th Panhellenic Symposium of Oceanography & Fisheries Ionian University, Corfu, 30 May – 3 June 2018, the following related scientific papers were submitted and finally published in the conference proceedings:

(https://www.symposia.gr/wp-content/uploads/2018/07/Book_of_Abstracts.pdf)

1. Parinos C, Hatzianestis I, Karageorgis AP, Simboura N, Salomidi M, Panagiotidis P, Kanellopoulos TD, Tsangaris C, Strogyloudi E, Gogou A, Zervoudaki T, Arvanitakis G, Bordbar L, Chourdaki S, Gerakaris V, Issaris Y, Katsiaras N, Kikaki K, Kouerinis N, Kyriakidou H, Lardi P, Papageorgiou A, Pappas G, Plakidi E, Stavrakaki I, Voutsina E, Study of the environmental consequenses of the AGIA ZONI II tanker sinking on the marine ecosystem of the Saronikos Gulf.

2. Chourdaki S, Plakidi E, Parinos C, Hatzianestis I. Evaluating the AGIA ZONI II oil spill imprint on seawater and sediment samples of the Saronikos Gulf.

3. Karageorgis AP, Kanellopoulos TD, Papageorgiou A, Stavrakaki I, Parinos C. Vanadium and nickel contents in surface sediments of the Saronikos Gulf during 2016-2017.

4. Tsangaris C, Strogyloudi E, Hatzianestis I, Parinos C, Kouerinis N, Plakidi E, Chourdaki S, Papas G. Contaminant levels and biomarkers in caged mussels following the AGIA ZONI II oil spill in Saronikos Gulf, Greece.

5. Simboura N, Katsiaras N, Voutsinas E, Arvanitakis G. Impact of the shipwreck AGIA ZONI II on the zoobenthic communities of the sublittoral zone of the wider Saronikos Gulf area.

6. Lardi P-I, Panayotidis P. Study of macroalgae in the upper sublittoral zone of Saronikos Gulf: six months after the AGIA ZONI II oil spill.

The above studies were presented during a dedicated 3.5 h session of the conference which was video-recorded and can be freely accessed at the following link:

https://www.youtube.com/watch?v=2vDTRbpkKIc

To the above the numerous opinion articles/interviews in TV/radio networks and journals of pan-Hellenic broadcast/circulation should also be considered.

11. SUPPLEMENTARY INFORMATION

Following the release, on April 5th 2018, of the final scientific report on the short- and medium term environmental consequences of the sinking of the Agia Zoni II tanker on the marine ecosystem of the Saronikos Gulf, and in order to fully ensure the good quality of seawater in the coastal zone of the Saronikos Gulf in view of the summer season, monitoring of seawater quality has been conducted on April 2018, June 2018, July 2018 and August 2018 on the existing network of coastal sampling stations (see Annex II). Seawater samplings (sea surface) from the coastal zone of the Saronikos Gulf have been conducted on April 23rd 2018, June 20th 2018, July 17th 2018 and August 31st 2018. In total, the survey effort included 46 sampling sites, while a total of 178 seawater samples have been collected and subsequently analyzed. All collected seawater samples have been analyzed for total petroleum hydrocarbons by gas chromatography - flame ionization detector (GC - FID) after proper pre-treatment (in-house variant of the ISO 9377-2 standard) and polycyclic aromatic hydrocarbons by gas chromatography - mass spectrometry (Agilent 5973C GC-MSD) according to the in-house methodology of the accredited by ISO/IEC 17025 for the analysis of polycyclic aromatic hydrocarbons in seawater samples organic chemistry laboratory of HCMR.

Total petroleum hydrocarbons concentrations at all sampling sites are considered as normal, with the exception of the sampling site vicinal to the 2nd marina of Glyfada on July 17th and August 31st 2018. In these cases, laboratory analysis of the collected sea water samples by means of gas chromatography - mass spectrometry (identification of the molecular identity of the samples' hydrocarbon content) shows that the slightly increased total petroleum hydrocarbons concentration is not related to the incident of the Agia Zoni II sinking. More specifically, the molecular profile of aliphatic hydrocarbons, hopanes and polycyclic aromatic hydrocarbons of the samples did not match the one of the petroleum sample drawn from the shipwreck of Agia Zoni II on September 16th 2017, which H.C.M.R. holds for analysis. This fact, combined with the low concentrations of total petroleum hydrocarbons at all other sampling sites within the jurisdiction of the Municipality of Glyfada on July 17th and August 31st 2018, indicates a local mild oil pollution burden on the days of sampling due to, with an increased probability, the operation of the neighboring 2nd marina of Glyfada.

Regarding polycyclic aromatic hydrocarbons (PAHs), in no case values higher than the maximum allowable concentration (MAC) for PAHs were recorded. However, in a few cases (14 out of 178 samples) values higher than the annual average concentration (AA) were recorded for benzo(a)pyrene (i.e., Kinosoura on August 31st 2018, Afrodite Voe on August 31st 2018, Phloisbos on August 31st 2018, Batis on July 17th 2018 and on August 31st 2018, Edem on April 23rd 2018 and on August 31st 2018, Yacht club of Alimos on April 23rd 2018, Agios Kosmas and HCMR Facilities on August 31st 2018, Glyfada 4 on August 31st 2018, and Asteras Glyfadas on April 23rd 2018, June 20th 2018 and August 31st 2018) in accordance to the environmental quality standards for priority substances for the determination of chemical and ecological status of waters (Directive 2013/39/EC). Total PAHs concentrations fluctuated at low levels, in accordance to those previously reported in various Greek seas (Hatzianestis and Sklivagou, 2002, Parinos and Gogou, 2016, and references therein).

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ANNEX I: Final scientific report of the Institute of Oceanography H.C.M.R. on the short- and medium term environmental consequences of the sinking of the Agia Zoni II tanker on the marine ecosystem of the Saronikos Gulf. 182 pages (released on April 5th 2018).

ANNEX II: Supplementary to the final scientific report of the Institute of Oceanography H.C.M.R. on the short- and medium term environmental consequences of the sinking of the Agia Zoni II tanker on the marine ecosystem of the Saronikos Gulf, regarding seawater quality in coastal areas of the Saronikos Gulf for the period of April to August 2018. 31 pages (released on September 25th 2018).

ANNEX I

MINISTRY OF EDUCATION, RESEARCH AND RELIGIOUS AFFAIRS
GENERAL SECRETARIAT OF RESEARCH AND TECHNOLOGY

HELLENIC CENTRE FOR MARINE RESEARCH (H.C.M.R.)
INSTITUTE OF OCEANOGRAPHY

STUDY OF THE SHORT AND MEDIUM TERM ENVIRONMENTAL CONSEQUENSES OF THE SINKING OF THE AGIA ZONI II TANKER ON THE MARINE ECOSYSTEM OF THE SARONIKOS GULF

FINAL SCIENTIFIC REPORT

ANAVYSSOS

APRIL 2018

ANNEX I

STUDY OF THE SHORT AND MEDIUM TERM ENVIRONMENTAL CONSEQUENSES OF THE SINKING OF THE AGIA ZONI II TANKER ON THE MARINE ECOSYSTEM OF THE SARONIKOS GULF

Project Leader

Dr. Constantine Parinos	Chemist Oceanographer, Assistant Researcher

H.C.M.R. Scientific and Technical Staff

Dr. Ioannis Hatzianestis	Chemist Oceanographer, Research Director
Dr. Aristomenis Karageorgis	Geologist Oceanographer, Research Director
Dr. Nomiki Simboura	Biologist Oceanographer, Research Director
Dr. Panagiotis Panayotidis	Biologist Oceanographer, Research Director
Dr. Caterina Tsangaris	Biologist Oceanographer, Senior Researcher
Dr. Evangelia Strogyloudi	Biologist Oceanographer, Assistant Researcher
Dr. Maria Salomidi	Environmentalist, Assistant Researcher
Dr. Theodoros Kanellopoulos	Geologist Oceanographer, Associated Research Scientist
Dr. Ioannis Issaris	Marine Scientist, Oceanographer
Stella Chourdaki	Chemical Engineer, MSc
Elvira Plakidi	Technical Scientist, MSc
Nikolaos Katsiaras	Biologist Oceanographer, MSc
Emmanouela Voutsina	Biologist Oceanographer, MSc
Katerina Kikaki	Geomatics Engineer, MSc in Oceanography
Politimi Lardi	Marine Scientist, MSc in Oceanography
Giorgos Arvanitakis	Technical Scientist Biologist
Alkiviadis Parageorgiou	Technical Scientist Geologist
Ioanna Stavrakaki	Technical Scientist Geologist
Nikolaos Kouerinis	Technical Scientist
Giorgos Pappas	Technical Scientist
Vassilis Mpampas	Technical Staff (Driver)
Constantine Fostiropoulos	Technical Staff (Driver)

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ANNEX I

1. INTRODUCTION

Following the sinking of the Agia Zoni II tanker on September 10th 2017 southwest of Atalanti Island in the Saronikos Gulf, H.C.M.R., under the direction of the Ministry of Shipping and Island Policy, taking into account the provisions of paragraphs 3.5.13 and 3.15.1 of the National Emergency Plan on oil pollution incidents (Presidential Decree 11/2002, Government Gazette Issue 6 A'/2002), has carried out a series of systematic surveys to monitor the possible short- and medium- term impacts of the incident on the marine ecosystem of the Saronikos Gulf. The study of the Institute of Oceanography, from September 18th 2017 till March 30th 2018, has been pursued on the following axes:

(a) Recording of chemical pollution in seawater and sediments. Between September 18th 2017 and March 21st 2018 a series of seawater samplings were conducted in order to record the levels of environmental burden caused by the oil spill and its development in the coastal zone as well as open sea areas of the Saronikos Gulf. The seawater sampling network included **70 stations, 56 coastal and 14 open sea**, and a total of **247 seawater samples** were collected. The collected seawater samples were analyzed for total petroleum hydrocarbons and polycyclic aromatic hydrocarbons.

Regarding sediments, three samplings have been conducted with R/V Aegaeo on September 2017, November 2017 and January 2018, in the open Saronikos Gulf. The monitoring network included **22 stations**, with a total of **59 sediment samples** being collected. Aliphatic and polycyclic aromatic hydrocarbons, as well as the metals vanadium and nickel, were determined in the sediment samples.

(b) Assessment of the ecological status of the Saronikos area following the incident based on the indicators related to the bio-communities of the zoo- and phytobenthos, as provided by the relevant European directives (WFD, MSFD). To this, **two samplings of benthos** were conducted in the open Saronikos Gulf (September 2017 and January 2018) in orderr to investigate the possible impacts of the incident on the **zoobenthic communities** of the sublittoral zone. Furthermore, in order to assess **the status of macroalgae of the upper sublittoral zone** a macrobenthos sampling has been conducted in March 19-22nd 2018 at the coasts of Salamina and Attica.

(c) In order to investigate the potential bioaccumulation of contaminants related to the incident and the possible biological effects on marine organisms the following sub-actions have been taken: On January 23-24th 2018 **mussels *Mytilus galloprovincialis*** were immersed in cages at four sites, Salamina, Agios Kosmas, Glyfada and Asteras Vouliagmenis. The mussel cages were immersed at two depths in each site (5 and 20 m below the sea surface) and were collected after approximately six weeks on March 7th 2018. In the collected mussels: (i) the concentrations of hydrocarbons and heavy metals were determined in their tissue, (ii) a set of biomarkers indicative of oxidative stress (catalase), phase II biotransformation (glutathione S-transferase) and neurotoxicity (acetylcholinesterase) were measured, (iii) condition index (CI) was determined as a measure of the health status of the animals that summarizes their physiological activity (e.g., growth, reproduction, secretion) under given environmental conditions and (iv) metallothioneins (MTs) were determined.
Furthermore, determination of aliphatic hydrocarbons was carried out **in the tissue of selected fish** (*Mullus barbatus, Merluccius merluccius, Parapenaeus longirostris, Illex coidentii*, depending on availability) which were sampled by demersal towed gears (trawlers) in October and November 2017 by the Institute of Marine Biological Resources and Inland Waters of H.C.M.R. in the wider area of the Saronikos Gulf.

Finally, **(d) in order to inspect the present condition and investigate the potential presence of macroscopic oil residues on coastal benthic habitats** of the Saronikos gulf, after the completion of the cleaning operations and the removal of the Agia Zoni II wreck, **underwater visual surveys were conducted using drop camera**. The survey focused on parts of the coasts of Salamis Island and Attica mainland where the impact of the accident was mainly manifested. The visual survey was carried out along underwater transects running parallel and perpendicular to the shoreline at depths between 3-20 meters. **Particular emphasis was placed on the critical examination of the Posidonia meadows and the vegetation of shallow reefs**, in order to identify indirect signs of disturbance. This allowed for a systematic **seabed inspection of a total length of ~ 25 km** as well as the simultaneous production of **6 649 photographic files**.

2. SAMPLINGS

2.1. SEAWATER SAMPLINGS (COASTAL ZONE AND OPEN SEA AREAS OF THE SARONIKOS GULF)

Seawater samplings (sea surface) from the coastal zone of the Saronikos Gulf have been conducted on September 18th, 22nd, 29th, October 3rd, 10th, 23rd, November 2nd and December 4th 2017, January 19th and March 21st 2018. Regarding open sea areas of the Saronikos Gulf, seawater samplings have been conducted on September 21-22nd 2017 and November 13-14th 2017 with *R/V* Aegaeo (HCMR) from the sea surface and various water depths along the water column in the sampling stations. In the vicinity of the Agia Zoni II shipwreck (approx. 60 m from the antipollution barrier) water samples were collected from six depths of the water column. In total, the survey effort includes 70 sampling sites, of which 56 coastal and 14 open sea areas. The collected seawater samples, 239 in total, were analyzed for total petroleum hydrocarbons and polycyclic aromatic hydrocarbons after proper pre-treatment.

The sampling sites at the coastal and open sea areas of the Saronikos Gulf are presented in Figure 2.1 that follows, while detailed sampling positions and sampling dates are depicted in Tables 2.1 and 2.2 respectively.

Figure 2.1. Seawater sampling sites at the coastal zone and open sea areas of the Saronikos Gulf.

ANNEX I

Table 2.1: Sampling sites and sampling dates along the coastal zone of the Saronikos Gulf.

SAMPLING AREA	COORDINATES		SAMPLING DATES	SAMPLING AREA	COORDINATES		SAMPLING DATES
	LAT.	LONG.			LAT.	LONG.	
MUNICIPALITY OF SALAMINA				**MUNICIPALITY OF GLYFADA**			
KINOSOURA	37° 56.56'N	23° 32.57'E	29/09/17, 23/10/17, 04/12/17, 21/03/18	GLYFADA 1 (VICINAL TO 4th MARINA)	37° 52.40'N	23° 43.96'E	18/09/17, 22/09/17, 03/10/17, 23/10/17, 02/11/17, 04/12/17, 19/01/18
SELINIA I	37° 56.43'N	23° 32.33'E	29/09/17, 23/10/17, 04/12/17, 21/03/18	GLYFADA 2	37° 52.08'N	23° 44.19'E	18/09/17, 22/09/17, 03/10/17, 10/10/17, 23/10/17, 02/11/17, 04/12/17, 19/01/18
SELINIA II	37° 55.96'N	23° 32.23'E	29/09/17	GLYFADA 3 (VICINAL TO 3rd MARINA)	37° 51.91'N	23° 44.45'E	18/09/17, 22/09/17, 03/10/17, 23/10/17, 02/11/17, 04/12/17, 19/01/18
KAKH VIGLA	37° 54.74'N	23° 30.72'E	29/09/17, 23/10/17, 04/12/17	GLYFADA 4 (VICINAL TO 2nd MARINA)	37° 51.75'N	23° 44.76'E	18/09/17, 22/09/17, 03/10/17, 10/10/17, 23/10/17, 02/11/17, 04/12/17, 19/01/18
CHAROUPIAS	37° 54.22'N	23° 30.83'E	29/09/17, 23/10/17, 04/12/17	GLYFADA 5 (VICINAL TO 1st MARINA)	37° 51.63'N	23° 44.93'E	18/09/17, 22/09/17, 03/10/17, 10/10/17, 23/10/17, 02/11/17, 04/12/17, 19/01/18
NTOULAPI	37° 54.08'N	23° 30.77'E	29/09/17, 23/10/17, 04/12/17	ASTERAS GLYFADAS	37° 51.40'N	23° 44.99'E	10/10/17, 23/10/17, 02/11/17, 04/12/17, 19/01/18
GIALA	37° 54.16'N	23° 30.18'E	29/09/17, 23/10/17, 04/12/17	**MUNICIPALITY OF VARI-VOULA-VOULIAGMENI**			
KIRIZA	37° 53.92'N	23° 29.20'E	29/09/17, 23/10/17, 04/12/17	ASKLIPIEIO VOULAS (VICINAL TO EL. VENIZELOS SQUARE)	37° 50.75'N	23° 45.23'E	18/09/17, 03/10/17
MAROUDI	37° 53.39'N	23° 28.76'E	29/09/17, 23/10/17, 04/12/17	VOULA CITY HALL	37° 50.19'N	23° 45.95'E	18/09/17, 22/09/17
PERISTERIA	37° 52.74'N	23° 27.53'E	29/09/17, 23/10/17, 04/12/17	MEGALO KAVOURI	37° 49.07'N	23° 46.05'E	18/09/17, 22/09/17, 03/10/17
MUNICIPALITY OF PIRAEUS				VOULIAGMENI NAUTICAL CLUB	37° 48.60'N	23° 46.47'E	18/09/17, 03/10/17
AEGEAN SEA NAVAL COMMAND-ROCKY SHORE	37° 55.98'N	23° 37.47'E	10/10/17, 23/10/17, 02/11/17	VOULIAGMENI BEACH CLUB	37° 48.78'N	23° 46.79'E	18/09/17, 22/09/17, 03/10/17
THEMISTOKLES TOMB SITE	37° 55.98'N	23° 37.45'E	10/10/17, 23/10/17, 02/11/17	LIMANAKIA	37° 48.00'N	23° 47.33'E	18/09/17
HELLENIC NAVAL ACADEMY	37° 56.00'N	23° 37.69'E	10/10/17, 02/11/17	VARKIZA NAVAL ATHLETIC CLUB	37° 49.23'N	23° 48.77'E	18/09/17, 22/09/17, 03/10/17
AFRODITE VOE	37° 55.74'N	23° 37.82'E	29/09/17, 10/10/17, 23/10/17, 02/11/17				

ANNEX I

SAMPLING AREA	COORDINATES		SAMPLING DATES	SAMPLING AREA	COORDINATES		SAMPLING DATES
	LAT.	LONG.			LAT.	LONG.	
MUNICIPALITY OF PIRAEUS				**MUNICIPALITY OF KROPIA**			
FREATTYDA	37° 55.82'N	23° 38.84'E	29/09/17, 10/10/17, 23/10/17, 02/11/17	LOUBARDAS	37° 49.11'N	23° 50.07'E	18/09/17
YACHT CLUB OF GREECE	37° 56.14'N	23° 39.23'E	29/09/17, 10/10/17, 23/10/17, 02/11/17	AGIA MARINA	37° 48.85'N	23° 50.58'E	18/09/17
MUNICIPALITY OF KALLITHEA				BLUE BEACH (MUNICIPALITY LIMITS KROPIA-SARONIKOS)	37° 48.09'N	23° 51.95'E	18/09/17, 22/09/17, 03/10/17
KALLITHEA MARINA	37° 56.22'N	23° 41.16'E	29/09/17	**MUNICIPALITY OF SARONIKOS**			
STAVROS NIARXOS FOUNDATION	37° 56.15'N	23° 41.29'E	29/09/17	BLUE BEACH (TREXANTHRI)	37° 47.74'N	23° 52.29'E	18/09/17
MUNICIPALITY OF PALAIO FALIRO				GRAND RESORT - ΚΟΧΥΛΙΑ	37° 46.87'N	23° 53.33'E	18/09/17
PHLOISBOS	37° 55.55'N	23° 41.41'E	22/09/17, 03/10/17, 10/10/17, 23/10/17, 02/11/17, 19/01/18	GRAND RESORT - GRAND BEACH	37° 46.75'N	23° 53.50'E	18/09/17
BATIS	37° 55.27'N	23° 41.74'E	02/11/17, 19/01/18, 21/03/18	SARONIDA	37° 44.87'N	23° 54.29'E	18/09/17, 22/09/17, 03/10/17
EDEM	37° 55.09'N	23° 42.02'E	22/09/17, 03/10/17, 10/10/17, 23/10/17, 02/11/17	MAYRO LITHARI	37° 44.17'N	23° 54.30'E	18/09/17, 03/10/17
MUNICIPALITY OF ALIMOS				ST. NIKOLAS	37° 43.11'N	23° 55.32'E	22/09/17
AKTI ILIOU	37° 54.41'N	23° 42.93'E	22/09/17, 03/10/17, 10/10/17, 23/10/17	ANAVYSSOS	37° 43.52'N	23° 56.18'E	18/09/17, 03/10/17
YACHT CLUB OF ALIMOS	37° 54.07'N	23° 43.06'E	22/09/17	PALAIA FOKAIA	37° 43.29'N	23° 56.71'E	22/09/17
MUNICIPALITY OF ELLINIKO-ARGYROUPOLI				THIMARI	37° 42.19'N	23° 56.36'E	18/09/17, 03/10/17
AGIOS KOSMAS	37° 53.45'N	23° 43.20'E	22/09/17, 29/09/17, 03/10/17, 10/10/17, 23/10/17, 02/11/17, 04/12/17, 19/01/18	ORMOS - KATAFYGI	37° 40.80'N	23° 56.51'E	22/09/17
H.C.M.R. FACILITIES	37° 53.56'N	23° 43.07'E	18/09/17, 03/10/17, 10/10/17, 23/10/17, 02/11/17, 04/12/17, 19/01/18	**MUNICIPALITY OF LAVRIO**			
PHAROS AKROTIRI OPEN SEA - SURFACE	37° 53.43'N	23° 42.51'E	18/09/17, 10/10/17	CHARAKAS	37° 39.99'N	23° 58.31'E	22/09/17
PHAROS AKROTIRI OPEN SEA - 8 M DEPTH	37° 53.43'N	23° 42.51'E	18/09/17, 10/10/17	LEGRENA (NAUTICAL CLUB)	37° 39.75'N	23° 59.47'E	22/09/17
AIGYPTIOTES NAVAL CLUB	37° 53.62'N	23° 43.04'E	23/10/17, 02/11/17, 04/12/17, 19/01/18, 21/03/18				

Table 2.2: Sampling sites and sampling dates in open sea areas of the Saronikos Gulf.

STATION/ SAMPLING DEPTH	STATION DEPTH (in m)	COORDINATES		SAMPLING DATES
		LAT.	LONG.	
OS1	51	37° 55.29'N	23° 32.43'E	
2 meters				21-22/09/2017, 13-14/11/2017
48 meters				21-22/09/2017, 13-14/11/2017
OS2	56	37° 55.26'N	23° 37.87'E	
2 meters				21-22/09/2017, 13-14/11/2017
54 meters				21-22/09/2017, 13-14/11/2017
OS3	22	37° 55.49'N	23° 40.47'E	
2 meters				21-22/09/2017, 13-14/11/2017
20 meters				21-22/09/2017, 13-14/11/2017
OS4	45	37° 53.52'N	23° 41.14'E	
2 meters				21-22/09/2017, 13-14/11/2017
42 meters				21-22/09/2017, 13-14/11/2017
OS5	70	37° 50.80'N	23° 40.25'E	
2 meters				21-22/09/2017, 13-14/11/2017
67 meters				21-22/09/2017, 13-14/11/2017
OS6	35	37° 51.38'N	23° 43.16'E	
2 meters				21-22/09/2017, 13-14/11/2017
34 meters				21-22/09/2017, 13-14/11/2017
OS7	92	37° 50.30'N	23° 35.78'E	
2 meters				21-22/09/2017, 13-14/11/2017
50 meters				21-22/09/2017, 13-14/11/2017
90 meters				21-22/09/2017, 13-14/11/2017
OS8	53	37° 48.23'N	23° 45.00'E	
2 meters				21-22/09/2017, 13-14/11/2017
52 meters				21-22/09/2017, 13-14/11/2017
OS9	57	37° 47.15'N	23° 48.12'E	
2 meters				21-22/09/2017
56 meters				21-22/09/2017

STATION/ SAMPLING DEPTH	STATION DEPTH (in m)	COORDINATES		SAMPLING DATES
		LAT.	LONG.	
OS10	54	37° 43.81'N	23° 52.90'E	
2 meters				21-22/09/2017
52 meters				21-22/09/2017
S7	69	37° 55.70'N	23° 35.75'E	
2 meters				21-22/09/2017, 13-14/11/2017
42 meters				21-22/09/2017, 13-14/11/2017
68 meters				21-22/09/2017, 13-14/11/2017
S11	72	37° 52.60'N	23° 38.50'E	
2 meters				21-22/09/2017, 13-14/11/2017
71 meters				21-22/09/2017, 13-14/11/2017
S16	85	37° 47.38'N	23° 42.07'E	
2 meters				21-22/09/2017, 13-14/11/2017
40 meters				21-22/09/2017, 13-14/11/2017
60 meters				21-22/09/2017, 13-14/11/2017
84 meters				21-22/09/2017, 13-14/11/2017
AGIA ZONI II SHIPWRECK	50	37° 55.77'N	23° 34.17'E	
2 meters				21-22/09/2017, 13-14/11/2017
18.3 meters				21-22/09/2017, 13-14/11/2017
27.2 meters				21-22/09/2017, 13-14/11/2017
34.5 meters				21-22/09/2017, 13-14/11/2017
45 meters				21-22/09/2017, 13-14/11/2017
49 meters				21-22/09/2017, 13-14/11/2017

2.2. SEDIMENT SAMPLINGS (OPEN SEA)

Sediment samplings in open sea areas of the Saronikos Gulf have been conducted on September 21-22nd 2017, November 13-14th 2017 and January 23-24th 2018 with *R/V* Aegaeo (HCMR), in order to investigate any possible burden regarding petroleum hydrocarbons released from the Agia Zoni II shipwreck on sediments of the study area. On September 21-22nd 2017 and January 23-24th 2018 benthos sampling has also been conducted in order to investigate any possible impacts of the incident on the zoobenthic communities of the sublittoral zone of the Saronikos Gulf.

The sediment sampling sites at the open sea areas of the Saronikos Gulf are presented in Figure 2.2 that follows, while detailed sampling positions, sampling dates and laboratory analyses that have been conducted are summarized in Table 2.3.

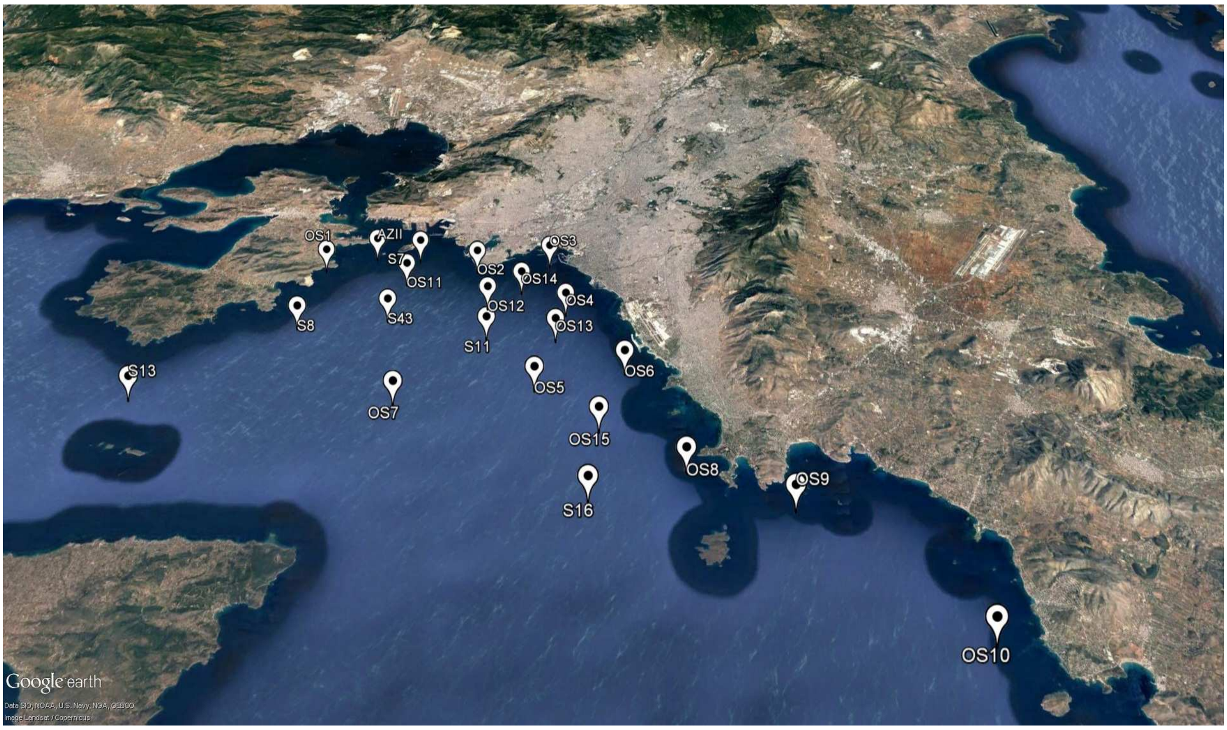

Figure 2.2. Sediment sampling sites in open sea areas of the Saronikos Gulf.

Table 2.3. Sediment sampling positions in open sea areas of the Saronikos Gulf, sampling dates and laboratory analyses that have been conducted. **H/C:** Hydrocarbons.

STATION	DEPTH (in m)	COORDINATES		SAMPLING DATES							
		LAT.	LONG.	21-22/09/2017			13-14/11/2017		23-24/01/2018		
				H/C	Metals	Benthos	H/C	Metals	H/C	Metals	Benthos
OS1	51	37° 55.29'N	23° 32.43'E	+	+	+	+	+	+	+	
OS2	56	37° 55.26'N	23° 37.87'E	+	+	+	+	+	+	+	+
OS3	22	37° 55.49'N	23° 40.47'E	+	+	+	+	+	+	+	+
OS4	45	37° 53.52'N	23° 41.14'E	+	+	+	+	+	+	+	+

ANNEX I

STATION	DEPTH (in m)	COORDINATES		SAMPLING DATES							
		LAT.	LONG.	21-22/09/2017			13-14/11/2017		23-24/01/2018		
				H/C	Metals	Benthos	H/C	Metals	H/C	Metals	Benthos
OS5	70	37° 50.80'N	23° 40.25'E	+	+		+	+			
OS6	35	37° 51.38'N	23° 43.16'E	+	+	+	+	+	+	+	+
OS7	92	37° 50.30'N	23° 35.78'E	+	+		+	+			
OS8	53	37° 48.23'N	23° 45.00'E	+	+	+	+	+	+	+	
OS9	57	37° 47.15'N	23° 48.12'E	+	+						
OS10	54	37° 43.81'N	23° 52.90'E	+	+						
OS11	90	37° 54.72'N	23° 35.43'E				+	+	+	+	
OS12	71	37° 53.77'N	23° 38.41'E				+	+	+	+	
OS13	47	37° 52.54'N	23° 40.84'E				+	+	+	+	
OS14	58	37° 54.38'N	23° 39.54'E				+	+	+	+	
OS15	52	37° 49.47'N	23° 42.35'E				+	+	+	+	
S7	69	37° 55.70'N	23° 35.75'E	+	+	+	+	+	+	+	
S8	92	37° 53.00'N	23° 32.00'E	+	+		+	+	+	+	
S11	72	37° 52.60'N	23° 38.50'E	+	+		+	+	+	+	
S13	89	37° 50.45'N	23° 27.30'E	+	+		+	+	+	+	
S16	85	37° 47.38'N	23° 42.07'E	+	+		+	+	+	+	
S43	91	37° 53.28'N	23° 35.03'E	+	+		+	+	+	+	
AZ II	50	37° 55.77'N	23° 34.17'E	+	+	+	+	+	+	+	+

Sampling stations S7, S8, S11, S13, S16 and S43 belong to the Saronikos Gulf systematic monitoring network, for which a time series of data is available covering the past years. They are therefore a reliable basis for comparing data gathered before and after the sinking of the Agia Zoni II in order to examine any possible impact of the incident on the marine ecosystem of the area. OS1-OS15 sampling stations are new stations added to the existing monitoring network, taking into account the direction of the oil spill caused by the incident, in order to examine its possible impact on affected areas.

2.3. CONTAMINANT BIOACCUMULATION AND EFFECTS IN MARINE ORGANISMS

In order to investigate the potential bioaccumulation of contaminants related to the Agia Zoni II incident and the possible biological effects on marine organisms the following actions have been taken:

(a) On January 23-24th 2018 mussels *Mytilus galloprovincialis* were immersed in cages at four sites, Salamina (MUS1), Agios Kosmas (MUS2), Glyfada (MUS3) and Asteras Vouliagmenis (MUS4) (Figure 2.3 and Table 2.4). Asteras Vouliagmenis (MUS4) was used as a reference site. The mussel cages were immersed at two depths in each site (5 and 20 m below the sea surface) and were collected after approximately six weeks on March 7th 2018.

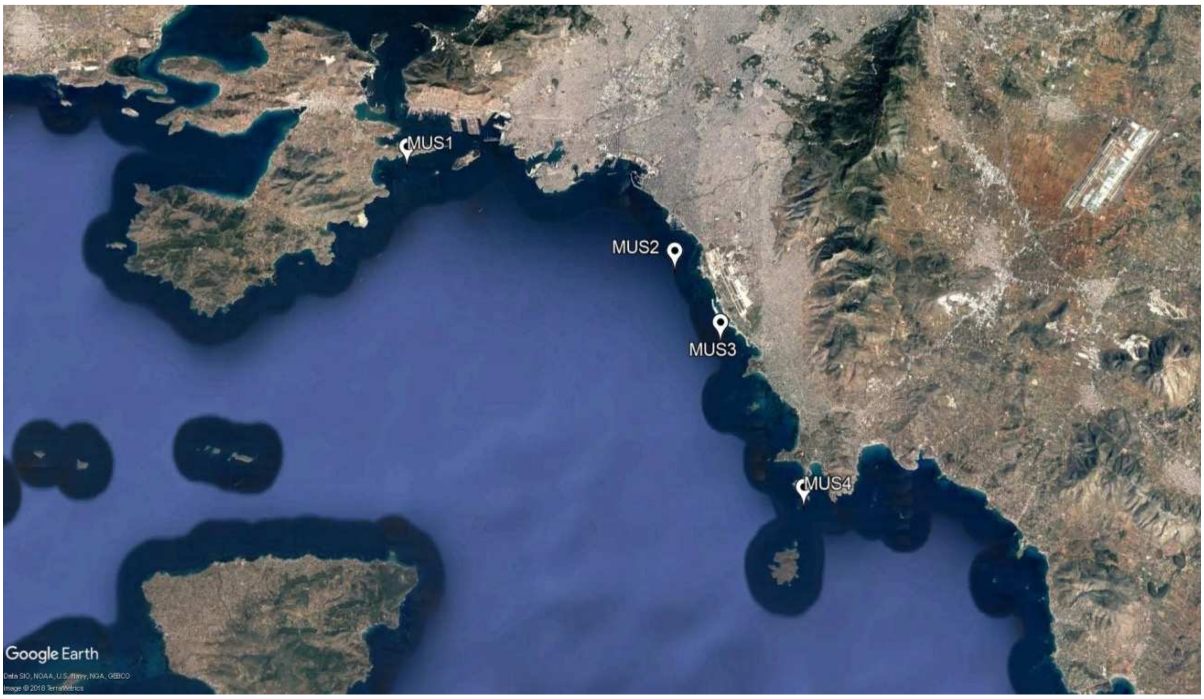

Figure 2.3. Sites of mussel cages immersion in January 2018.

In the collected mussels: (i) the concentrations of hydrocarbons and heavy metals were determined in their tissue, (ii) a set of biomarkers indicative of oxidative stress (catalase), phase II biotransformation (glutathione S-transferase) and neurotoxicity (acetylcholinesterase) were measured, (iii) condition index (CI) was determined as a measure of the health status of the animals that summarizes their physiological activity (e.g., growth, reproduction, secretion) under given environmental conditions and (iv) metallothioneins (MTs) were determined.

Table 2.4. Mussel cages immersion sites in January 2018.

STATION	AREA	LAT.	LONG.	DEPTH (m)
MUS1	SALAMINA	37° 56.22'N	23° 33.34'E	25
MUS2	AGIOS KOSMAS	37° 53.55'N	23° 42.18'E	26
MUS3	GLYFADA	37° 51.74'N	23° 43.66'E	24
MUS4	VOULIAGMENI	37° 47.62'N	23° 46.30'E	25

During the initial immersion of the mussel cages a sediment sample was taken at the studied sites and seawater at the immersion depths in order to estimate the sediment and seawater quality of the study areas. When the cages were retrieved seawater sampling was repeated at the immersion depths. In the collected seawater samples total petroleum hydrocarbons and polycyclic aromatic hydrocarbons were determined, while aliphatic and polycyclic aromatic hydrocarbons were determined in the collected sediment samples.

(b) determination of aliphatic hydrocarbons was carried out in the tissue of selected fish (*Mullus barbatus, Merluccius merluccius, Parapenaeus longirostris, Illex coidentii*, depending on availability) allocated to the Institute of Oceanography of H.C.M.R. for analysis. The sampling was carried out by demersal towed gears (trawlers) in October and November 2017 by the Institute of Marine Biological Resources and Inland Waters of H.C.M.R. in the wider area of the Saronikos Gulf. The routes taken are presented in Figure 2.4.

Figure 2.4. Sampling routes carried out by demersal towed gears (trawlers) in October and November 2017 in the wider area of the Saronikos Gulf.

2.4. STUDY OF MACROALGAE IN THE UPPER SUBLITTORAL ZONE

In order to evaluate the macroalgal assemblages in the upper sublittoral zone of the coasts of Salamina and Attica a macroalgae sampling has been conducted in March 19-22nd 2018 at four sites, Ampelakia-Limnionas on the eastern coasts of Salamina, Peiriaki, Agios Kosmas and Kavouri on the southern coasts of Attica. All sampling stations are characterized by rocky substrate and the macroalgae assemblages were examined in shallow waters (<1 m = upper sublittoral zone). The sampling stations were examined by free diving and the sampling method was photographic (non-destructive sampling). Also, representative macroalgae were collected in order to confirm the photographic speciments.

2.5. UNDERWATER VISUAL SURVEYS TO INVESTIGATE MACROSCOPIC SEABED CONDITIONS

In order to inspect the present condition and investigate the potential presence of macroscopic oil residues on coastal benthic habitats of the Saronikos gulf, after the completion of the cleaning operations and the removal of the Agia Zoni II wreck, underwater visual surveys were conducted on parts of the coasts of Salamis Island and Attica mainland. Particular emphasis was placed on the critical examination of the Posidonia meadows and the vegetation of shallow reefs, in order to identify indirect signs of disturbance. The survey focused on parts of the coasts of Salamis Island and Attica mainland where the impact of the accident was mainly manifested (Figure 2.5). The visual survey was carried out along underwater transects running parallel and perpendicular to the shoreline at depths between 3-20 meters of: (a) the Selinia bay and around the Agia Zoni II wreck site (29/03/2018), (b) Phloisbos to Agios Kosmas coasts (30/03/2018)and (c) Agios Kosmas to Voula coasts (08/12/2017).

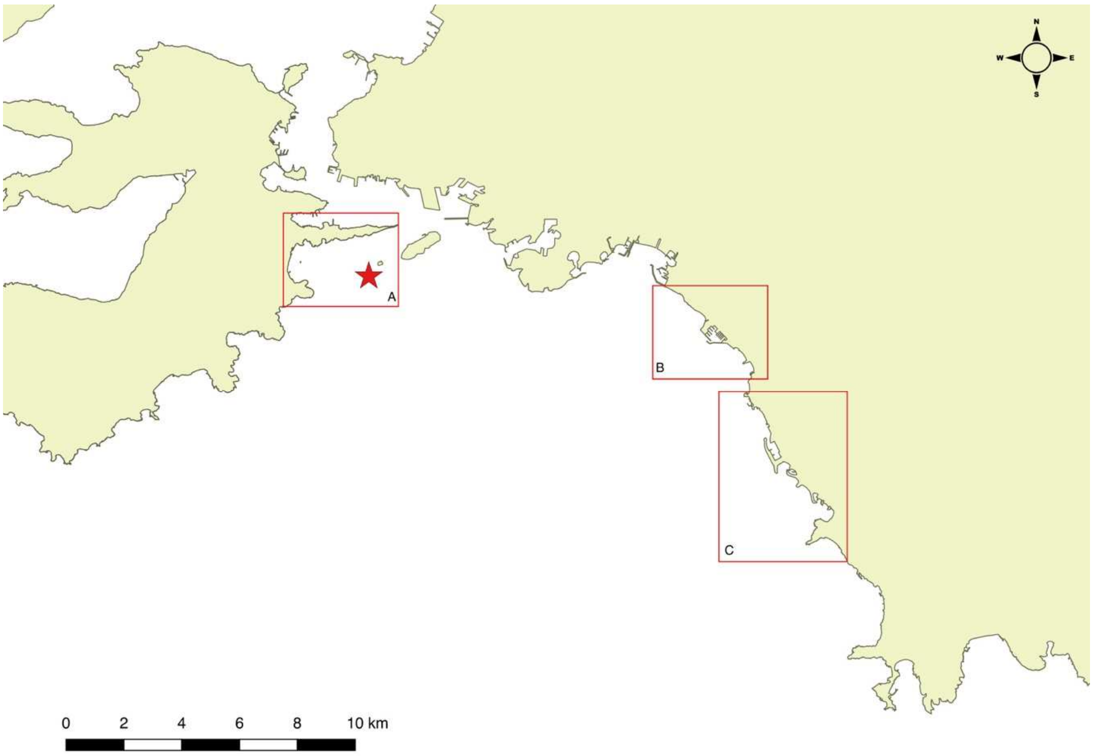

Figure 2.5. Map of the wider study area indicating visual surveys focus sub-areas.

3. RESULTS AND DISCUSSION

3.1. TOTAL PETROLEUM HYDROCARBONS AND POLYCYCLIC AROMATIC HYDROCARBONS IN SEAWATER SAMPLES (COASTAL ZONE AND OPEN SEA AREAS)

Parinos, C., Hatzianestis, I., Chourdaki, S., Plakidi, E.

3.1.1. Methodology

All seawater samples collected from coastal and open sea areas of the Saronikos Gulf have been analyzed for total petroleum hydrocarbons by gas chromatography - flame ionization detector (GC - FID) after proper pre-treatment (in-house variant of the ISO 9377-2 standard) and polycyclic aromatic hydrocarbons by gas chromatography - mass spectrometry (Agilent 5973C GC-MSD) according to the in-house methodology of the accredited by ISO/IEC 17025 for the analysis of polycyclic aromatic hydrocarbons in seawater samples organic chemistry laboratory of HCMR.

3.1.2. Results and Discussion

For the interpretation of the results the following remarks are taken into account:

(a) Although the background values for total petroleum hydrocarbons in marine waters range from 0.5 to 2 μg/L, in the inner Saronikos Gulf, according to the H.C.M.R. database over the last decade (98 observations), values up to 20 μg/L have often been reported which are therefore considered as being normal. Also, under the Greek and European legislation there are no limit values regarding total petroleum hydrocarbons concentrations in seawater.

(b) Regarding polycyclic aromatic hydrocarbons, for determining the chemical status of the considered seawater samples the annual mean concentration (AA) and the maximum allowable concentration (MAC) for naphthalene, anthracene, fluoranthene, benzo(b)fluoranthene, benzo(k) fluoranthene, benzo(a)pyrene and benzo(ghi)perylene have been considered, according to the environmental quality standards for priority substances for the determination of chemical and ecological status of waters (Directive 2013/39/EC).

3.1.2.1. Total petroleum hydrocarbons and polycyclic aromatic hydrocarbons in the coastal zone of the Saronikos Gulf

The results from the determination of total petroleum hydrocarbons in seawater samples collected along the coastal zone of the Saronikos Gulf during the conducted samplings (from September 18th 2017 till March 21st 2018) are summarized in Table 3.1.1 that follows. The results from the determination of polycyclic aromatic hydrocarbons for the corresponding seawater samples are presented in detail for each of the sampling sites in Table A.1 of the Annex.

Table 3.1.1: Total petroleum hydrocarbons in seawater samples collected along the coastal zone of the Saronikos Gulf. **N.D:** Not detected, detection limit 0.5 μg/L.

SAMPLING AREA	TOTAL PETROLEUM HYDROCARBONS (in μg/L)									
	18/09/2017	22/09/2017	29/09/2017	03/10/2017	10/10/2017	23/10/2017	02/11/2017	04/12/2017	19/01/2018	21/03/2018
MUNICIPALITY OF SALAMINA										
KINOSOURA			>1500			NOT CONSIDERED		2.5		3.1
SELINIA I			>1500			NOT CONSIDERED		2.9		N.D
SELINIA II			N.D							
KAKH VIGLA			N.D			3.1		N.D		
CHAROUPIAS			N.D			0.7		N.D		
NTOULAPI			1.3			N.D		N.D		
GIALA			N.D			N.D		N.D		
KIRIZA			N.D			1.5		0.6		
MAROUDI			N.D			1.1		0.7		
PERISTERIA			4.4			N.D		N.D		
MUNICIPALITY OF PIRAEUS										
AEGEAN SEA NAVAL COMMAND-ROCKY SHORE					N.D	N.D	N.D			
THEMISTOKLES TOMB SITE					1200	344	34.2			
HELLENIC NAVAL ACADEMY					N.D		N.D			
AFRODITE VOE			5.4		0.7	6.7	N.D			
FREATTYDA			N.D		N.D	N.D	N.D			

ANNEX I

SAMPLING AREA	TOTAL PETROLEUM HYDROCARBONS (in µg/L)									
	18/09/2017	**22/09/2017**	**29/09/2017**	**03/10/2017**	**10/10/2017**	**23/10/2017**	**02/11/2017**	**04/12/2017**	**19/01/2018**	**21/03/2018**
YACHT CLUB OF GREECE			1.3		1.2	2.2	3.4			
MUNICIPALITY OF KALLITHEA										
KALLITHEA MARINA			8.7							
STAVROS NIARXOS FOUNDATION (WATER PUMPING SITE)			2.1							
MUNICIPALITY OF PALAIO FALIRO										
PHLOISBOS		34.2		NOT CONSIDERED	100	14.1	2.2		1.5	
BATIS							17.2		45.4	10.5
EDEM		16.4		8.6	5.7	N.D	3.2			
MUNICIPALITY OF ALIMOS										
AKTI ILIOU		9.8		4.9	N.D	1.2				
YACHT CLUB OF ALIMOS		8.2								
MUNICIPALITY OF ELLINIKO-ARGYROUPOLI										
AGIOS KOSMAS		529	157	159	NOT CONSIDERED	269	14.8	6.5	1.7	
H.C.M.R. FACILITIES	>1500			110	19.3	2.5	NOT CONSIDERED	2.4	5.3	
PHAROS AKROTIRI OPEN SEA - SURFACE	>1500				3.2					
PHAROS AKROTIRI OPEN SEA - 8 M DEPTH	>1500				6.5					
AIGYPTIOTES NAVAL CLUB						284	10.0	7.0	34.9	2.6
MUNICIPALITY OF GLYFADA										
GLYFADA 1 (VICINAL TO 4th MARINA)	97.8	16.8		1.5		N.D	3.3	N.D	N.D	
GLYFADA 2	>1500	38.5		5.8	NOT CONSIDERED	2.0	0.7	N.D	N.D	
GLYFADA 3 (VICINAL TO 3rd MARINA)	352	47.7		2.9		9.0	N.D	0.6	N.D	
GLYFADA 4 (VICINAL TO 2nd MARINA)	>1500	>1500		331	66.8	61.4	7.5	6.3	N.D	
GLYFADA 5 (VICINAL TO 1st MARINA)	>1500	>1500		85.5	11.3	40.9	2.8	N.D	N.D	
ASTERAS GLYFADAS					6.9	3.5	16.5	18.3	18.1	

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SAMPLING AREA	TOTAL PETROLEUM HYDROCARBONS (in µg/L)									
	18/09/2017	22/09/2017	29/09/2017	03/10/2017	10/10/2017	23/10/2017	02/11/2017	04/12/2017	19/01/2018	21/03/2018
MUNICIPALITY OF VARI-VOULA-VOULIAGMENI										
ASKLIPIEIO VOULAS (VICINAL TO EL. VENIZELOS SQUARE)	139			N.D						
VOULA CITY HALL	7.7	8.4								
MEGALO KAVOURI	89	9.1		2.0						
VOULIAGMENI NAUTICAL CLUB	4.6			1.1						
VOULIAGMENI BEACH CLUB	67	5.5		2.4						
LIMANAKIA	6.2									
VARKIZA NAVAL ATHLETIC CLUB	4.2	5.8		1.1						
MUNICIPALITY OF KROPIA										
LOUBARDAS	2.2									
AGIA MARINA	N.D									
BLUE BEACH (MUNICIPALITY LIMITS KROPIA-SARONIKOS)	11.7	N.D		2.3						
MUNICIPALITY OF SARONIKOS										
BLUE BEACH (TREXANTHRI)	15.4									
GRAND RESORT - ΚΟΧΥΛΙΑ	5.4									
GRAND RESORT - GRAND BEACH	6.6									
SARONIDA	1.9	N.D		1.8						
MAYRO LITHARI	28.6			2.3						
ST. NIKOLAS		5.4								
ANAVYSSOS		3.2		N.D						
PALAIA FOKAIA		2.1								
THIMARI		0.8		0.6						
ORMOS - KATAFYGI		7.8								
MUNICIPALITY OF LAVRIO										
CHARAKAS		3.1								
LEGRENA (NAUTICAL CLUB)		1.9								

Regarding total petroleum hydrocarbons, at 37 out of 56 considered coastal sampling stations their concentrations were recorded within normal levels in all cases (Figure 3.1.1, Table 3.1.1).

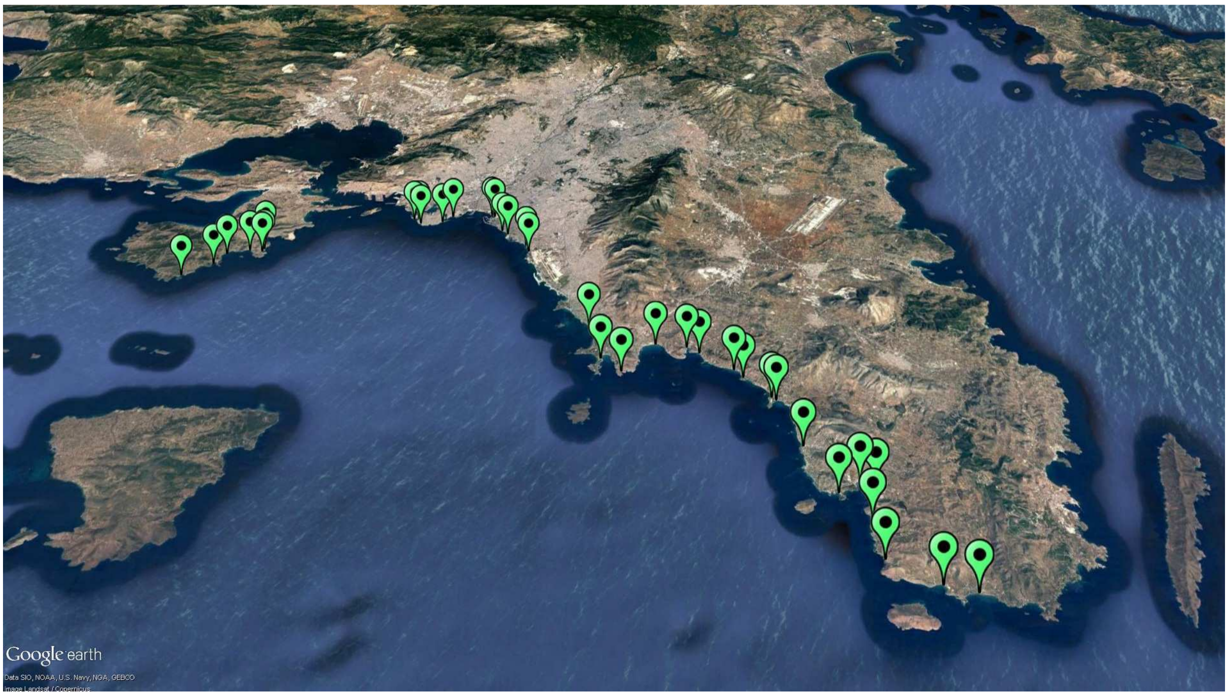

Figure 3.1.1. Sampling stations at the coastal zone of the Saronikos Gulf where total petroleum hydrocarbons concentrations were recorded within normal levels in all cases.

On the contrary, extended petroleum pollution was initially recorded (September 2017) in the regions of Elliniko, Glyfada, Selinia and Kinousoura. A smaller burden of petroleum hydrocarbons was also recorded at the areas of Phloisvos (till October 10th 2017), Asklipieio Voulas (on September 18th 2017), Megalo Kavouri (on September 18th 2017), Vouliagmeni beach club (on September 18th 2017), Mavro Lithari at Anavyssos (on September 18th 2017), locally within the Tomb of Themistocles in Piraeus (on October 10th and October 23rd 2017) and Batis (on January 19th 2018 after a severe weather event followed by rough sea) (Table 3.1.1).

In Figure 3.1.2 that follows the sampling sites where an extended or smaller burden of petroleum hydrocarbons was initially recorded are depicted.

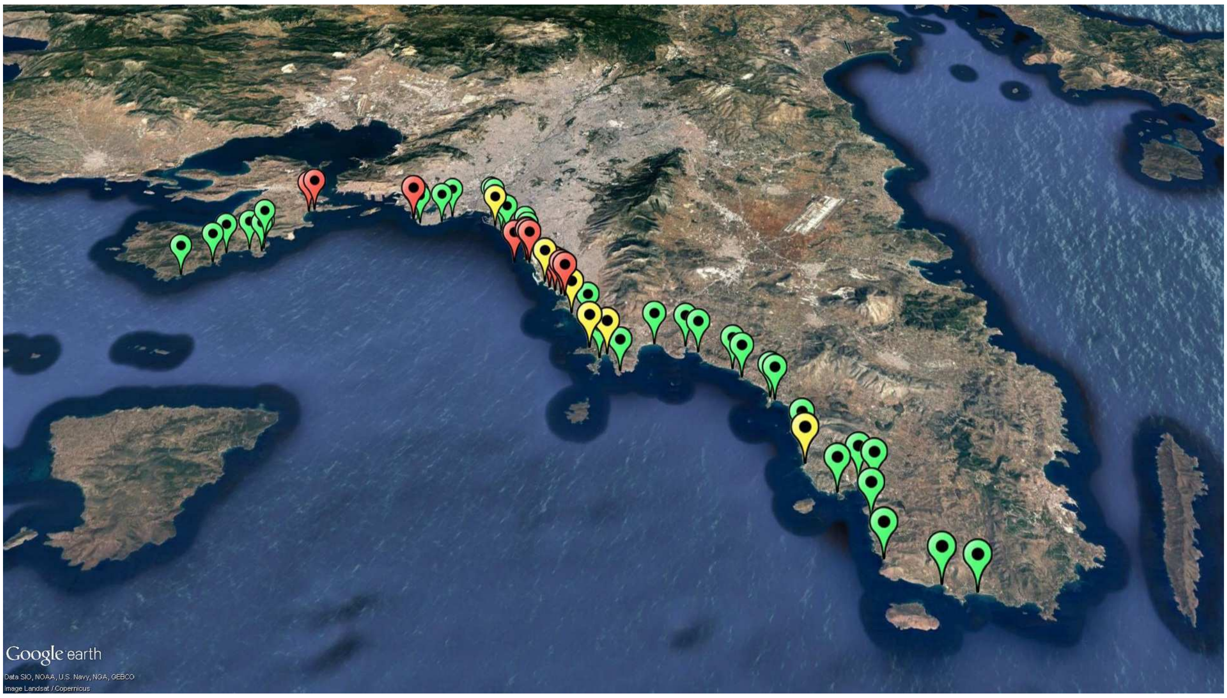

Figure 3.1.2. The sampling sites along the coastal zone of the Saronikos Gulf, in total, where marked green are the ones where total petroleum hydrocarbons concentrations were recorded at normal levels in all cases, while marked red and yellow respectively are the areas where an extended or smaller burden of petroleum hydrocarbons was initially recorded.

Specifically, at the sampling sites of Elliniko and Glyfada, extended petroleum pollution was observed during the sampling of September 18th 2017 with the exception of the 4th Marina of Glyfada. On September 22nd 2017 high concentrations of total petroleum hydrocarbons were observed at Agios Kosmas and at the 1st and 2nd Marina of Glyfada. In the following samplings (October 3rd and October 23rd 2017) total petroleum hydrocarbons levels were declining but still remaining high in some cases, presenting various fluctuations as a result of extensive rocky and beach clean up operations that prevented a representative sample being obtained in some cases (see Table 3.1.1 - "Not considered"). On November 2nd 2017, December 4th 2017 and January 19th 2018 total petroleum hydrocarbons levels were recorded at normal levels with the exception of Aigyptiotes Naval Club were a slightly elevated value was recorded on January 19th 2018 (after a severe weather event followed by rough sea). The following figures summarize the time evolution of the levels of total petroleum hydrocarbons concentrations at the sampling sites of Elliniko and Glyfada.

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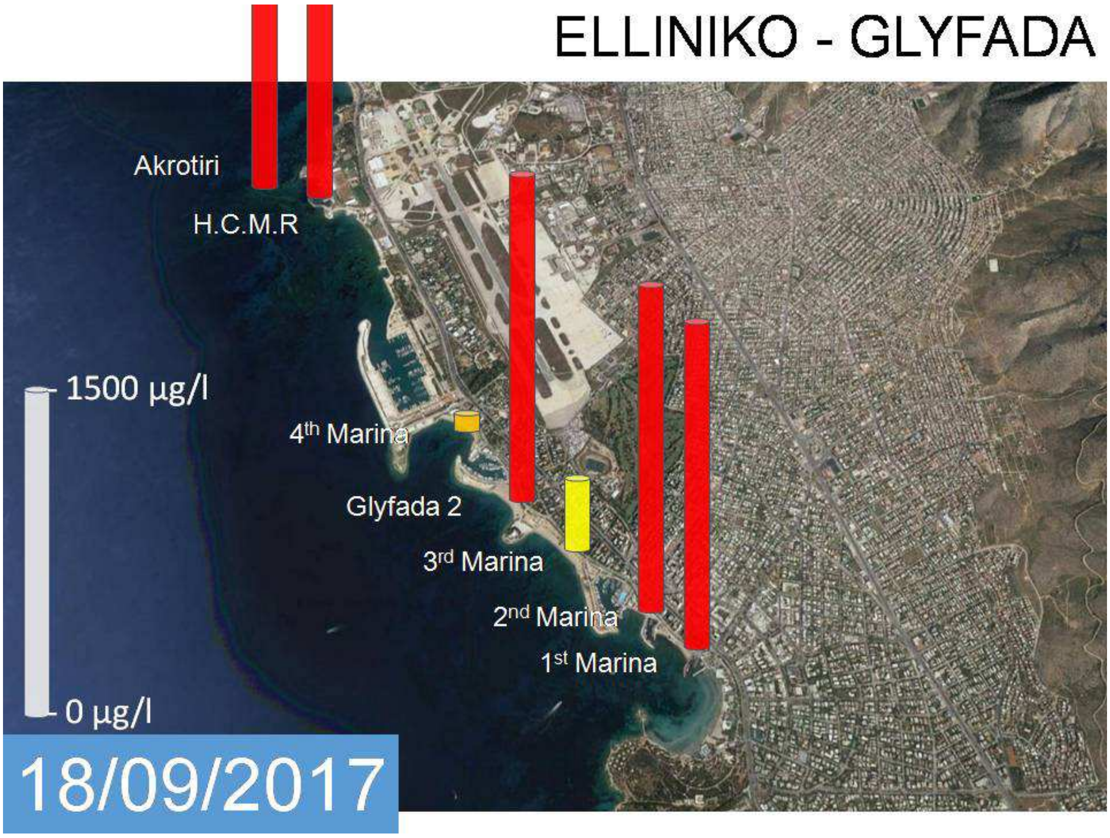
ELLINIKO - GLYFADA
Akrotiri
H.C.M.R
1500 μg/l
0 μg/l
4th Marina
Glyfada 2
3rd Marina
2nd Marina
1st Marina
18/09/2017


ELLINIKO - GLYFADA
Agios Kosmas
1500 μg/l
0 μg/l
4th Marina
Glyfada 2
3rd Marina
2nd Marina
1st Marina
22/09/2017

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ELLINIKO - GLYFADA

ELLINIKO - GLYFADA

ANNEX I


ELLINIKO - GLYFADA
Aigyptiotes naval club
H.C.M.R.
Agios Kosmas
1500 μg/l
0 μg/l
4th Marina
Glyfada 2
3rd Marina
2nd Marina
1st Marina
Asteras
02/11/2017


ELLINIKO - GLYFADA
Aigyptiotes naval club
H.C.M.R.
Agios Kosmas
1500 μg/l
0 μg/l
4th Marina
Glyfada 2
3rd Marina
2nd Marina
1st Marina
Asteras
04/12/2017

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Regarding polycyclic aromatic hydrocarbons at the sampling sites of Elliniko and Glyfada (see Table A.1 of the Annex), following the evolution of total petroleum hydrocarbons values above the maximum allowable concentration for benzo(a)pyrene (Agios Kosmas on September 22nd 2017) and benzo(ghi)perylene (on September 18th 2017 at Glyfada 1, September 18th and 22nd 2017 at Glyfada 3, October 3rd 2017 at H.C.M.R facilities and Glyfada 5, October 23rd 2017 at the Aigyptiotes naval club, until October 23rd 2017 at Agios Kosmas and Glyfada 4) were recorded. On November 2nd 2017, December 4th 2017 and January 19th 2018 their concentrations were recorded within limits at all sampling sites.

Regarding the sampling sites of Selinia and Kinosoura, on September 29th 2017 extended petroleum pollution was evident at both stations. On October 23rd 2017 both sampling sites were not considered since extended beach cleanup was being performed, resulting in the presence of petroleum residues at the adjacent coastal area. Thus, the collection of a representative seawater sample was not possible in any case. On December 4th 2017, following the conclusion of cleanup activities in the areas total petroleum hydrocarbons were recorded at normal levels at both sites.

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On March 21st 2018 total petroleum hydrocarbons were also recorded at normal levels at both sites (see figures that follow).

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SELINIA-KINOSOURA

SELINIA-KINOSOURA

As earlier mentioned a smaller burden of petroleum hydrocarbons was also initially recorded in other sampling sites. Specifically:

At Phloisvos sampling site total petroleum hydrocarbons concentration was slightly elevated on September 22nd 2017, while at the same day a value above the maximum allowable concentration for benzo(ghi)perylene was also recorded. The sample collected on October 3rd 2017 at the same sampling site was not considered since sand clean up (flushing method) was performed, resulting in the presence of petroleum residues at the adjacent coastal area. Thus, the collected seawater sample was not considered as not being representative. The elevated total petroleum hydrocarbons levels as well as the value above the maximum allowable concentration for benzo(ghi)perylene on October 10th 2017 could be likely attributed to the shore clean up operations conducted during the previous days. On October 23rd and November 2nd 2017, following the conclusion of cleanup activities in the area, total petroleum hydrocarbons were recorded at normal levels. On January 19th 2018 (after a severe weather event followed by rough sea) total petroleum hydrocarbons were also recorded at normal levels.

Traces of petroleum hydrocarbons were also recorded on September 18th 2017 at **Asklipieio Voulas, Megalo Kavouri and Vouliagmeni Beach Club**, the levels of which rapidly declined (up to and/or higher than 90% of the initial values) on September 22nd 2017 and furthermore on October 3rd 2017 at normal levels. At **Asklipieio Voulas and Megalo Kavouri** sites values above the maximum allowable concentration for benzo(ghi)perylene were also recorded on September 18th 2017 which declined within limits on September 22nd 2017. A similar trend was also recorded at the **Mavro Lithari** of the Municipality of Saronikos, where the slightly elevated value of total petroleum hydrocarbons concentrations and the value above the maximum allowable concentration recorded for benzo(ghi)perylene on September 18th 2017 decreased to normal levels/within limits respectively at the sampling round of October 3rd 2017.

During the samplings of October 10th and October 23rd 2017 a burden of petroleum hydrocarbons was recorded locally within the **Tomb of Themistokles**, with their levels clearly declining on November 2nd 2017. It should be noticed that in the adjacent coastal sampling site "Aegean Sea Naval Command - Rocky Shore" on the corresponding sampling dates the total petroleum hydrocarbons concentration was below the limit of detection in all cases.

Finally, a slightly elevated value of total petroleum hydrocarbons was recorded on January 19th 2018 **at Batis** (after a severe weather event followed by rough sea). On March 21st 2018 total petroleum hydrocarbons were recorded at normal levels.

3.1.2.2. Total petroleum hydrocarbons and polycyclic aromatic hydrocarbons in open sea areas of the Saronikos Gulf

The results from the determination of total petroleum hydrocarbons and polycyclic aromatic hydrocarbons in seawater samples collected during the conducted samplings in open sea areas of the Saronikos Gulf (September 21-22nd 2017 and November 13-14th 2017; Figure 3.1.3) are presented in detail in Table 3.1.2 that follows.

Figure 3.1.3. Seawater sampling sites in open sea areas of the Saronikos Gulf.

Table 3.1.2. Total petroleum hydrocarbons (TPH in μg/L) and polycyclic aromatic hydrocarbons (PAHs; in ng/L) in seawater samples collected during the conducted samplings in open sea areas of the Saronikos Gulf (September 21-22nd 2017 and November 13-14th 2017). AA: annual mean concentration (in ng/L) and MAC: maximum allowable concentration (in ng/L) for naphthalene, anthracene, fluoranthene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene and benzo(ghi)perylene according to the environmental quality standards for priority substances for the determination of chemical and ecological status of waters (Directive 2013/39/EC). **N.D.:** Not detected, detection limit: TPH 0.5 μg/L, PAHs (for each individual compound) 0.02 ng/L.

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STATION	OS 1 (37° 55.29'N - 23° 32.43'E)				OS 2 (37° 55.26'N - 23° 37.87'E)					
DEPTH	**2 meters**		**48 meters**		**2 meters**		**54 meters**			
DATE	**21-22/09**	**13-14/11**	**21-22/09**	**13-14/11**	**21-22/09**	**13-14/11**	**21-22/09**	**13-14/11**		
TPH (μg/L)	3.9	0.6	1.0	N.D	3.5	3.9	3.4	1.1	**AA (ng/L)**	**MAC (ng/L)**
PAHs (ng/L)										
Naphthalene	2.51	4.24	2.16	3.58	2.91	5.63	4.88	2.92	2000	130000
Methylnapthalenes	6.51	6.99	4.23	5.60	6.87	14.2	7.51	5.07		
Acenaphthylene	0.03	0.14	0.12	0.12	0.11	0.12	0.03	0.10		
Acenaphthene	0.37	0.63	0.22	0.28	0.65	0.47	0.16	0.10		
Dimethylnapthalenes	8.17	8.08	4.81	4.89	10.4	11.5	5.04	2.41		
Trimethylnapthalenes	7.04	14.1	4.99	4.25	9.59	10.4	2.36	1.67		
Fluorene	0.44	1.24	0.30	0.44	0.83	0.54	0.18	0.17		
Dibenzothiophene	0.28	0.65	0.10	0.14	0.44	0.19	0.05	0.07		
Methyldibenzothiophenes	0.92	1.58	1.68	0.34	1.53	0.43	0.09	0.11		
Dimethyldibenzothiophenes	1.66	5.21	0.72	0.60	2.85	0.90	0.16	0.21		
Phenanthrene	1.32	7.54	0.65	0.86	1.76	1.77	0.39	0.39		
Anthracene	0.05	0.27	0.05	0.05	0.12	0.18	0.02	0.03	100	100
Methylphenanthrenes	3.88	11.3	1.67	2.51	6.23	3.73	0.51	0.57		
Dimethylphenanthrenes	4.02	4.89	1.96	1.96	7.54	4.74	0.43	0.72		
Trimethylphenanthrenes	2.82	1.94	1.09	1.11	4.43	2.98	0.20	0.42		
Fluoranthene	0.21	1.24	0.23	0.24	0.39	0.59	0.13	0.22	6.3	120
Pyrene	0.12	1.04	0.32	0.24	0.37	0.52	0.06	0.21		
Methylpyrenes	0.35	0.66	0.40	0.32	0.73	0.63	0.06	0.28		
Dimethylpyrenes	0.64	0.36	0.39	0.25	0.84	0.71	0.04	0.31		
Retene	0.04	0.30	N.D	N.D	0.11	0.07	0.02	N.D		
Benz[a]anthracene	0.04	0.07	0.08	0.08	0.08	0.19	N.D	0.34		
Chrysene	0.23	0.16	0.13	0.13	0.41	0.21	0.03	0.26		
Methylchrysenes	0.59	0.17	0.20	0.18	0.56	0.28	0.03	0.31		
Dimethylchrysenes	0.90	0.16	0.16	0.14	0.54	0.28	0.05	0.20		
Benzo[b]fluoranthene	0.13	0.40	0.27	0.15	0.26	0.23	0.05	0.70		17
Benzo[k]fluoranthene	0.03	0.02	0.09	0.04	0.06	0.05	N.D	0.19		17
Benzo[e]pyrene	0.13	0.10	0.16	0.08	0.15	0.13	0.02	0.31		
Benzo[a]pyrene	0.02	0.02	0.13	0.05	0.05	0.12	0.02	0.49	0.17	27
Perylene	0.02	0.02	0.03	0.02	0.02	0.03	N.D	0.11		
Indeno[1,2,3-cd]pyrene	0.02	0.02	0.12	0.07	0.06	0.14	0.02	0.38		
Benzo[ghi]perylene	0.05	0.04	0.12	0.11	0.06	0.17	0.02	0.38		0.82
Dibenz[a,h]anthracene	0.02	0.15	0.02	0.02	0.02	0.03	N.D	0.11		
ΣPAHs (ng/L)	**43.5**	**73.7**	**27.6**	**28.8**	**60.9**	**62.2**	**22.6**	**19.8**		

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STATION	OS 3 (37° 55.49'N - 23° 40.47'E)				OS 4 (37° 53.52'N - 23° 41.14'E)					
DEPTH	2 meters		20 meters		2 meters		42 meters			
DATE	21-22/09	13-14/11	21-22/09	13-14/11	21-22/09	13-14/11	21-22/09	13-14/11		
TPH (μg/L)	3.0	1.2	N.D	N.D	2.9	N.D	1.0	1.6	**AA (ng/L)**	**MAC (ng/L)**
PAHs (ng/L)										
Naphthalene	4.37	6.23	3.62	2.65	9.46	3.19	3.65	2.95	2000	130000
Methylnapthalenes	9.87	17.2	6.63	3.98	19.6	4.70	5.66	4.39		
Acenaphthylene	0.09	0.12	0.05	0.07	0.14	0.11	0.03	0.10		
Acenaphthene	0.56	0.54	0.32	0.13	1.29	0.20	0.15	0.14		
Dimethylnapthalenes	12.9	18.2	7.51	3.28	20.2	3.97	4.08	3.48		
Trimethylnapthalenes	11.4	15.0	6.85	2.29	19.0	2.87	3.67	2.66		
Fluorene	0.69	0.72	0.46	0.28	1.19	0.25	0.28	0.32		
Dibenzothiophene	0.47	0.19	0.28	0.09	0.71	0.11	0.10	0.10		
Methyldibenzothiophenes	1.58	0.42	0.91	0.15	2.60	0.18	0.27	0.17		
Dimethyldibenzothiophenes	2.64	0.74	1.73	0.25	5.50	0.31	0.53	0.26		
Phenanthrene	2.31	1.70	1.34	0.64	2.60	0.02	0.53	0.74		
Anthracene	0.10	0.15	0.06	0.04	0.16	0.04	0.04	0.05	100	100
Methylphenanthrenes	7.57	4.00	4.31	0.87	13.5	1.11	1.52	1.00		
Dimethylphenanthrenes	8.14	4.61	5.08	0.89	13.6	1.14	1.79	0.91		
Trimethylphenanthrenes	3.91	2.57	3.18	0.49	8.53	0.62	0.73	0.42		
Fluoranthene	0.27	0.43	0.19	0.18	0.44	0.24	0.16	0.20	6.3	120
Pyrene	0.32	0.49	0.23	0.10	0.41	0.15	0.15	0.11		
Methylpyrenes	0.65	0.52	0.51	0.13	1.12	0.16	0.18	0.11		
Dimethylpyrenes	0.69	0.54	0.50	0.12	1.31	0.16	0.13	0.07		
Retene	0.04	0.05	0.06	N.D	0.11	0.02	0.02	0.02		
Benz[a]anthracene	0.08	0.11	0.05	0.05	0.14	0.07	0.04	0.03		
Chrysene	0.32	0.16	0.24	0.08	0.63	0.11	0.07	0.06		
Methylchrysenes	0.44	0.20	0.37	0.08	0.94	0.09	0.07	0.05		
Dimethylchrysenes	0.38	0.19	0.38	0.09	0.99	0.09	0.06	0.05		
Benzo[b]fluoranthene	0.20	0.12	0.13	0.08	0.31	0.12	0.12	0.07		17
Benzo[k]fluoranthene	0.05	0.02	0.04	0.02	0.28	0.03	0.04	0.02		17
Benzo[e]pyrene	0.12	0.08	0.10	0.04	0.21	0.06	0.05	0.03		
Benzo[a]pyrene	0.05	0.05	0.04	0.03	0.08	0.04	0.03	N.D	0.17	27
Perylene	0.02	N.D	N.D	N.D	0.04	N.D	N.D	N.D		
Indeno[1,2,3-cd]pyrene	0.05	0.02	0.04	0.02	0.09	0.05	0.02	N.D		
Benzo[ghi]perylene	0.05	0.07	0.06	0.04	0.09	0.06	0.03	0.03		0.82
Dibenz[a,h]anthracene	N.D	N.D	N.D	N.D	0.04	0.02	0.02	N.D		
ΣPAHs (ng/L)	**70.3**	**75.5**	**45.3**	**17.2**	**125.3**	**20.3**	**24.2**	**18.6**		

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STATION	OS 5 (37° 50.80'N - 23° 40.25'E)				OS 6 (37° 51.38'N - 23° 43.16'E)					
DEPTH	**2 meters**		**67 meters**		**2 meters**		**34 meters**			
DATE	**21-22/09**	**13-14/11**	**21-22/09**	**13-14/11**	**21-22/09**	**13-14/11**	**21-22/09**	**13-14/11**		
TPH (μg/L)	0.6	N.D	2.7	1.0	N.D	N.D	0.6	1.6	**AA (ng/L)**	**MAC (ng/L)**
PAHs (ng/L)										
Naphthalene	5.58	1.80	3.57	2.71	5.32	4.04	3.40	2.97	2000	130000
Methylnapthalenes	17.1	2.06	5.75	2.98	12.3	3.94	4.62	3.51		
Acenaphthylene	0.08	0.07	0.03	0.06	0.06	0.07	0.02	0.07		
Acenaphthene	0.90	0.11	0.13	0.11	0.58	0.37	0.11	0.14		
Dimethylnapthalenes	24.3	1.87	4.66	2.11	14.8	2.68	3.29	2.69		
Trimethylnapthalenes	18.7	1.36	2.69	1.54	10.9	1.77	2.43	1.89		
Fluorene	1.34	0.24	0.18	0.59	1.02	0.42	0.20	0.29		
Dibenzothiophene	0.93	0.08	0.05	0.05	0.57	0.08	0.07	0.09		
Methyldibenzothiophenes	2.84	0.13	0.13	0.08	1.80	0.14	0.20	0.24		
Dimethyldibenzothiophenes	4.30	0.20	0.26	0.14	3.04	0.21	0.40	0.43		
Phenanthrene	4.01	0.52	0.47	0.39	2.71	0.49	0.40	0.58		
Anthracene	0.13	0.02	0.02	0.02	0.08	0.02	0.02	0.02	100	100
Methylphenanthrenes	11.3	0.63	0.78	0.30	8.07	1.24	1.07	0.87		
Dimethylphenanthrenes	12.0	0.56	0.59	0.38	8.64	0.60	1.13	0.74		
Trimethylphenanthrenes	6.73	0.25	0.27	0.16	4.93	0.31	0.48	0.34		
Fluoranthene	0.27	0.14	0.21	0.14	0.23	0.12	0.09	0.15	6.3	120
Pyrene	0.13	0.05	0.07	0.07	0.21	0.06	0.09	0.10		
Methylpyrenes	0.66	0.06	0.08	0.05	0.59	0.10	0.12	0.10		
Dimethylpyrenes	0.88	0.05	0.08	0.03	0.77	0.06	0.08	0.08		
Retene	0.10	N.D	0.03	N.D	0.17	N.D	0.02	0.02		
Benz[a]anthracene	0.06	N.D	N.D	N.D	0.05	0.02	0.02	N.D		
Chrysene	0.51	0.05	0.06	0.04	0.36	0.05	0.06	0.05		
Methylchrysenes	0.84	0.04	0.04	0.03	0.67	0.05	0.06	0.06		
Dimethylchrysenes	0.87	0.04	0.06	0.03	0.68	0.04	0.06	0.05		
Benzo[b]fluoranthene	0.09	0.05	0.07	0.03	0.08	0.04	0.06	0.04		17
Benzo[k]fluoranthene	0.02	N.D	0.02	N.D	0.02	N.D	0.02	N.D		17
Benzo[e]pyrene	0.11	0.02	0.03	N.D	0.08	0.02	0.05	0.02		
Benzo[a]pyrene	0.02	N.D	N.D	0.02	0.02	0.04	0.03	N.D	0.17	27
Perylene	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D		
Indeno[1,2,3-cd]pyrene	0.03	N.D	0.03	N.D	0.03	N.D	0.04	N.D		
Benzo[ghi]perylene	0.05	N.D	0.02	N.D	0.03	0.02	0.04	N.D		0.82
Dibenz[a,h]anthracene	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D		
ΣPAHs (ng/L)	**114.9**	**10.4**	**20.4**	**12.1**	**78.9**	**17.0**	**18.7**	**15.6**		

ANNEX I

STATION	OS 7 (37° 50.30'N - 23° 35.78'E)									
DEPTH	**2 meters**		**50 meters**		**90 meters**					
DATE	**21-22/09**	**13-14/11**	**21-22/09**	**13-14/11**	**21-22/09**	**13-14/11**				
TPH (μg/L)	N.D	N.D	4.1	N.D	1.5	0.5			**AA (ng/L)**	**MAC (ng/L)**
PAHs (ng/L)										
Naphthalene	3.46	3.77	1.98	2.67	3.53	2.95			2000	130000
Methylnapthalenes	10.9	3.82	3.65	3.40	6.71	3.84				
Acenaphthylene	0.08	0.11	0.07	0.10	0.05	0.10				
Acenaphthene	0.52	0.34	0.16	0.15	0.18	0.17				
Dimethylnapthalenes	11.7	3.18	3.17	2.84	6.92	2.20				
Trimethylnapthalenes	7.72	2.28	2.62	2.24	3.20	2.26				
Fluorene	0.54	0.48	0.32	0.22	0.15	0.24				
Dibenzothiophene	0.30	0.11	0.10	0.10	0.04	0.06				
Methyldibenzothiophenes	0.78	0.25	0.30	0.21	0.11	0.08				
Dimethyldibenzothiophenes	1.20	0.50	0.55	0.32	0.25	0.23				
Phenanthrene	1.42	0.67	0.78	0.65	0.47	0.45				
Anthracene	0.06	0.03	0.04	0.03	0.02	0.02			100	100
Methylphenanthrenes	3.78	1.92	2.88	0.89	0.61	0.39				
Dimethylphenanthrenes	3.83	1.00	1.28	0.85	0.51	0.42				
Trimethylphenanthrenes	2.20	0.50	0.58	0.40	0.30	0.28				
Fluoranthene	0.12	0.17	0.21	0.17	0.24	0.19			6.3	120
Pyrene	0.11	0.10	0.19	0.08	0.08	0.09				
Methylpyrenes	0.14	0.13	0.15	0.09	0.08	0.09				
Dimethylpyrenes	0.27	0.04	0.09	0.05	0.09	0.04				
Retene	N.D	0.03	0.25	0.02	0.02	N.D				
Benz[a]anthracene	N.D	0.02	0.03	N.D	0.02	0.03				
Chrysene	0.08	0.06	0.06	0.06	0.06	0.05				
Methylchrysenes	0.07	0.07	0.05	0.04	0.05	0.03				
Dimethylchrysenes	0.05	0.05	0.05	0.05	0.06	0.04				
Benzo[b]fluoranthene	0.03	0.07	0.11	0.04	0.07	0.15				17
Benzo[k]fluoranthene	N.D	0.02	0.05	N.D	0.03	0.02				17
Benzo[e]pyrene	0.03	0.03	0.07	0.02	0.05	0.03				
Benzo[a]pyrene	N.D	0.05	0.02	N.D	0.02	0.11			0.17	27
Perylene	N.D	N.D	0.04	N.D	N.D	N.D				
Indeno[1,2,3-cd]pyrene	0.02	N.D	0.04	N.D	0.03	0.02				
Benzo[ghi]perylene	N.D	0.02	0.03	N.D	0.03	0.12				0.82
Dibenz[a,h]anthracene	N.D	N.D	0.02	N.D	N.D	0.02				
ΣPAHs (ng/L)	**49.5**	**19.8**	**19.9**	**15.7**	**24.0**	**14.7**				

ANNEX I

STATION	OS 8 (37° 48.23'N - 23° 45.00'E)				OS 9 (37° 47.15'N - 23° 48.12'E)					
DEPTH	**2 meters**		**52 meters**		**2 meters**		**56 meters**			
DATE	**21-22/09**	**13-14/11**	**21-22/09**	**13-14/11**	**21-22/09**	**13-14/11**	**21-22/09**	**13-14/11**		
TPH (μg/L)	1.7	0.5	2.0	1.2	5.4	-	1.6	-	**AA (ng/L)**	**MAC (ng/L)**
PAHs (ng/L)										
Naphthalene	4.75	4.06	3.20	2.03	9.46	-	4.69	-	2000	130000
Methylnapthalenes	12.1	4.95	3.54	2.52	14.0	-	6.99	-		
Acenaphthylene	0.08	0.05	0.03	0.04	0.07	-	0.04	-		
Acenaphthene	0.74	0.13	0.10	0.09	0.65	-	0.11	-		
Dimethylnapthalenes	18.6	2.86	2.20	2.01	17.8	-	4.53	-		
Trimethylnapthalenes	18.4	1.68	1.75	1.30	14.9	-	2.56	-		
Fluorene	0.87	0.24	0.17	0.22	0.91	-	0.23	-		
Dibenzothiophene	0.83	0.07	0.06	0.08	0.71	-	0.07	-		
Methyldibenzothiophenes	3.36	0.12	0.16	0.26	2.65	-	0.14	-		
Dimethyldibenzothiophenes	6.08	0.17	0.32	0.53	4.46	-	0.25	-		
Phenanthrene	4.15	0.43	0.39	0.44	3.68	-	0.54	-		
Anthracene	0.15	0.02	0.02	N.D	0.14	-	0.03	-	100	100
Methylphenanthrenes	16.5	1.42	0.77	0.58	13.5	-	0.66	-		
Dimethylphenanthrenes	19.2	0.49	0.80	0.58	14.5	-	0.55	-		
Trimethylphenanthrenes	10.5	0.23	0.36	0.22	7.67	-	0.21	-		
Fluoranthene	0.30	0.12	0.15	0.11	0.28	-	0.18	-	6.3	120
Pyrene	0.18	0.06	0.07	0.04	0.25	-	0.12	-		
Methylpyrenes	0.68	0.05	0.09	0.06	0.90	-	0.07	-		
Dimethylpyrenes	0.87	0.04	0.08	0.05	1.05	-	0.05	-		
Retene	0.10	N.D	N.D	0.02	0.08	-	0.05	-		
Benz[a]anthracene	0.05	N.D	0.02	N.D	0.08	-	N.D	-		
Chrysene	0.52	0.04	0.05	0.04	0.43	-	0.04	-		
Methylchrysenes	0.71	0.03	0.05	0.04	0.75	-	0.03	-		
Dimethylchrysenes	0.66	0.03	0.05	0.04	0.83	-	0.04	-		
Benzo[b]fluoranthene	0.09	0.03	0.06	0.04	0.10	-	0.04	-		17
Benzo[k]fluoranthene	0.02	N.D	0.02	N.D	0.02	-	0.02	-		17
Benzo[e]pyrene	0.08	N.D	0.03	0.02	0.11	-	0.03	-		
Benzo[a]pyrene	N.D	0.03	N.D	N.D	0.04	-	N.D	-	0.17	27
Perylene	N.D	N.D	N.D	N.D	0.02	-	N.D	-		
Indeno[1,2,3-cd]pyrene	0.02	N.D	0.02	N.D	0.02	-	N.D	-		
Benzo[ghi]perylene	0.02	0.02	0.02	0.02	0.04	-	0.02	-		0.82
Dibenz[a,h]anthracene	N.D	N.D	N.D	N.D	N.D	-	N.D	-		
ΣPAHs (ng/L)	**120.7**	**17.4**	**14.6**	**11.4**	**110.2**	**-**	**22.3**	**-**		

ANNEX I

STATION	OS 10 (37° 43.81'N - 23° 52.90'E)				S 11 (37° 52.60'N - 23° 38.50'E)					
DEPTH	2 meters		52 meters		2 meters		71 meters			
DATE	21-22/09	13-14/11	21-22/09	13-14/11	21-22/09	13-14/11	21-22/09	13-14/11		
TPH (µg/L)	0.7	-	N.D	-	N.D	0.8	1.3	N.D	AA (ng/L)	MAC (ng/L)
PAHs (ng/L)										
Naphthalene	1.93	-	1.57	-	5.27	4.01	1.24	2.01	2000	130000
Methylnapthalenes	3.02	-	3.01	-	15.3	5.24	1.84	2.28		
Acenaphthylene	0.02	-	0.03	-	0.05	0.10	0.05	0.04		
Acenaphthene	0.09	-	0.06	-	0.66	0.16	0.09	0.08		
Dimethylnapthalenes	1.96	-	1.13	-	17.2	3.59	1.64	1.78		
Trimethylnapthalenes	1.19	-	1.00	-	11.5	2.18	1.57	1.19		
Fluorene	0.15	-	0.10	-	0.86	0.30	0.17	0.14		
Dibenzothiophene	0.04	-	0.11	-	0.51	0.09	0.07	0.04		
Methyldibenzothiophenes	0.07	-	0.26	-	1.28	0.13	0.33	0.05		
Dimethyldibenzothiophenes	0.16	-	0.41	-	1.62	0.17	0.77	0.09		
Phenanthrene	0.33	-	1.31	-	2.28	0.59	0.77	0.30		
Anthracene	N.D	-	0.06	-	0.07	0.03	0.03	N.D	100	100
Methylphenanthrenes	0.47	-	1.37	-	5.55	0.68	3.50	0.42		
Dimethylphenanthrenes	0.44	-	1.20	-	4.61	0.55	1.74	0.27		
Trimethylphenanthrenes	0.28	-	0.49	-	2.18	0.21	0.78	0.10		
Fluoranthene	0.13	-	0.15	-	0.16	0.15	0.37	0.12	6.3	120
Pyrene	0.05	-	0.09	-	0.07	0.08	0.22	0.05		
Methylpyrenes	0.05	-	0.21	-	0.20	0.06	0.16	0.04		
Dimethylpyrenes	0.06	-	0.11	-	0.21	0.04	0.08	0.03		
Retene	N.D	-	0.07	-	0.05	N.D	0.50	N.D		
Benz[a]anthracene	N.D	-	N.D	-	N.D	N.D	0.02	N.D		
Chrysene	0.03	-	0.11	-	0.16	0.05	0.07	0.03		
Methylchrysenes	0.03	-	N.D	-	0.15	0.04	0.05	N.D		
Dimethylchrysenes	0.05	-	0.09	-	0.09	0.03	0.04	0.02		
Benzo[b]fluoranthene	0.02	-	0.10	-	0.04	0.03	0.07	0.02		17
Benzo[k]fluoranthene	N.D	-	0.02	-	N.D	N.D	N.D	N.D		17
Benzo[e]pyrene	N.D	-	0.04	-	0.03	0.02	0.02	N.D		
Benzo[a]pyrene	N.D	-	N.D	-	N.D	N.D	N.D	N.D	0.17	27
Perylene	N.D	-	N.D	-	N.D	N.D	N.D	N.D		
Indeno[1,2,3-cd]pyrene	N.D	-	0.02	-	0.02	N.D	N.D	N.D		
Benzo[ghi]perylene	N.D	-	N.D	-	N.D	0.02	0.02	N.D		0.82
Dibenz[a,h]anthracene	N.D	-	N.D	-	N.D	N.D	N.D	N.D		
ΣPAHs (ng/L)	**10.7**	**-**	**13.1**	**-**	**70.1**	**18.6**	**16.2**	**9.18**		

ANNEX I

STATION	S 7 (37° 55.70'N - 23° 35.75'E)									
DEPTH	2 meters		42 meters		68 meters					
DATE	21-22/09	13-14/11	21-22/09	13-14/11	21-22/09	13-14/11				
TPH (μg/L)	1.6	0.8	0.5	N.D	N.D	N.D			**AA (ng/L)**	**MAC (ng/L)**
PAHs (ng/L)										
Naphthalene	4.76	2.39	1.61	3.32	1.70	3.39			2000	130000
Methylnapthalenes	14.3	3.54	2.68	5.20	2.96	6.50				
Acenaphthylene	0.06	0.10	0.06	0.05	0.04	0.06				
Acenaphthene	0.69	0.17	0.12	0.30	0.09	0.13				
Dimethylnapthalenes	17.6	3.15	2.58	4.73	2.48	2.44				
Trimethylnapthalenes	13.2	3.02	2.33	6.90	1.76	2.16				
Fluorene	0.91	0.33	0.21	0.52	0.16	0.21				
Dibenzothiophene	0.47	0.13	0.08	0.15	0.05	0.23				
Methyldibenzothiophenes	1.28	0.63	0.21	0.23	0.16	0.55				
Dimethyldibenzothiophenes	1.64	1.48	0.40	0.24	0.30	0.88				
Phenanthrene	2.37	1.48	0.47	1.59	0.42	2.84				
Anthracene	0.08	0.06	0.02	0.05	0.03	0.13			100	100
Methylphenanthrenes	5.64	6.73	1.31	2.59	0.80	2.97				
Dimethylphenanthrenes	4.87	3.35	1.19	0.30	0.73	2.61				
Trimethylphenanthrenes	2.24	1.50	0.53	0.11	0.44	1.06				
Fluoranthene	0.20	0.71	0.14	0.13	0.20	1.63			6.3	120
Pyrene	0.12	0.42	0.12	0.10	0.15	1.50				
Methylpyrenes	0.24	0.31	0.13	0.05	0.16	0.46				
Dimethylpyrenes	0.23	0.15	0.11	0.01	0.16	0.24				
Retene	0.12	0.96	0.08	0.01	0.03	0.15				
Benz[a]anthracene	N.D	N.D	0.02	0.01	0.07	N.D				
Chrysene	0.16	0.13	0.05	0.02	0.11	0.23				
Methylchrysenes	0.16	0.10	0.05	N.D	0.15	N.D				
Dimethylchrysenes	0.12	N.D	0.05	0.01	0.16	0.20				
Benzo[b]fluoranthene	0.07	0.13	0.08	0.03	0.28	0.21				17
Benzo[k]fluoranthene	0.02	N.D	0.03	N.D	0.10	0.04				17
Benzo[e]pyrene	0.05	0.04	0.04	N.D	0.17	0.10				
Benzo[a]pyrene	N.D	N.D	0.02	0.05	0.13	0.09			0.17	27
Perylene	N.D	N.D	N.D	N.D	0.03	0.02				
Indeno[1,2,3-cd]pyrene	0.02	N.D	0.03	N.D	0.10	0.08				
Benzo[ghi]perylene	0.02	0.04	0.02	0.07	0.11	0.18				0.82
Dibenz[a,h]anthracene	N.D	2.39	N.D	3.32	0.02	0.03				
ΣPAHs (ng/L)	**71.7**	**31.1**	**14.8**	**26.7**	**14.3**	**31.3**				

ANNEX I

STATION	S 16 (37° 47.38'N - 23° 42.07'E)									
DEPTH	2 meters		40 meters		60 meters		84 meters			
DATE	21-22/09	13-14/11	21-22/09	13-14/11	21-22/09	13-14/11	21-22/09	13-14/11		
TPH (μg/L)	2.8	N.D	6.8	1.1	2.9	3.4	1.4	N.D	**AA (ng/L)**	**MAC (ng/L)**
PAHs (ng/L)										
Naphthalene	9.10	1.89	1.34	2.18	1.62	2.24	3.96	5.72	2000	130000
Methylnapthalenes	27.6	2.12	2.51	1.94	2.12	2.59	5.58	8.96		
Acenaphthylene	0.07	0.02	0.03	0.03	0.03	0.23	0.03	0.08		
Acenaphthene	0.80	0.07	0.09	0.07	0.08	0.06	0.12	0.52		
Dimethylnapthalenes	23.4	1.52	2.25	1.56	1.92	1.81	3.55	8.15		
Trimethylnapthalenes	14.7	0.94	1.46	1.08	1.11	1.38	2.26	11.9		
Fluorene	1.06	0.18	0.18	0.21	0.15	0.15	0.16	0.90		
Dibenzothiophene	0.61	0.05	0.06	0.05	0.04	0.09	0.05	0.25		
Methyldibenzothiophenes	1.53	0.06	0.10	0.08	0.11	0.65	0.13	0.39		
Dimethyldibenzothiophenes	1.92	0.10	0.20	0.11	0.15	1.62	0.29	0.42		
Phenanthrene	2.76	0.28	0.32	0.33	0.35	0.36	0.50	2.74		
Anthracene	0.08	N.D	0.02	N.D	0.06	0.02	0.02	0.08	100	100
Methylphenanthrenes	6.85	0.32	0.48	0.37	0.34	0.82	0.69	4.46		
Dimethylphenanthrenes	5.42	0.28	0.43	0.32	0.30	0.99	0.62	0.52		
Trimethylphenanthrenes	2.46	0.12	0.23	0.13	0.13	0.43	0.35	0.19		
Fluoranthene	0.20	0.08	0.13	0.08	0.14	0.11	0.22	0.22	6.3	120
Pyrene	0.13	0.04	0.07	0.03	0.06	0.05	0.10	0.17		
Methylpyrenes	0.20	0.03	0.07	0.04	0.05	0.08	0.10	0.09		
Dimethylpyrenes	0.25	0.02	0.10	0.03	0.03	0.08	0.09	0.02		
Retene	0.11	N.D	N.D	N.D	N.D	0.04	0.03	0.02		
Benz[a]anthracene	N.D	N.D	0.02	N.D	N.D	0.02	N.D	0.02		
Chrysene	0.18	0.03	0.05	0.03	0.03	0.04	0.06	0.03		
Methylchrysenes	0.17	0.02	0.06	0.02	0.03	0.07	0.07	N.D		
Dimethylchrysenes	0.12	0.02	0.08	0.02	0.04	0.09	0.10	0.02		
Benzo[b]fluoranthene	0.04	N.D	0.09	N.D	0.02	0.02	0.04	0.06		17
Benzo[k]fluoranthene	N.D	N.D	0.03	N.D	N.D	N.D	N.D	N.D		17
Benzo[e]pyrene	0.03	N.D	0.05	N.D	0.02	0.02	0.03	N.D		
Benzo[a]pyrene	N.D	N.D	0.02	N.D	N.D	N.D	N.D	0.09	0.17	27
Perylene	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D		
Indeno[1,2,3-cd]pyrene	0.02	N.D	0.04	N.D	N.D	N.D	N.D	N.D		
Benzo[ghi]perylene	N.D	N.D	0.03	N.D	N.D	N.D	N.D	0.12		0.82
Dibenz[a,h]anthracene	N.D	N.D	N.D	N.D	N.D	N.D	N.D	0.02		
ΣPAHs (ng/L)	**99.8**	**8.23**	**10.6**	**8.75**	**8.99**	**14.1**	**19.2**	**46.2**		

ANNEX I

STATION	AGIA ZONI II SHIPWRECK (37° 55.77'N - 23° 34.17'E)									
DEPTH	**2 meters**		**18.3 meters**		**27.2 meters**		**34.5 meters**			
DATE	**21-22/09**	**13-14/11**	**21-22/09**	**13-14/11**	**21-22/09**	**13-14/11**	**21-22/09**	**13-14/11**		
TPH (μg/L)	0.5	N.D	1.7	1.4	1.2	0.5	0.6	N.D		
PAHs (ng/L)									**AA (ng/L)**	**MAC (ng/L)**
Naphthalene	6.78	3.73	N.D	3.32	4.60	3.01	5.25	2.82	2000	130000
Methylnapthalenes	15.4	6.11	N.D	4.80	11.6	4.49	7.34	3.74		
Acenaphthylene	0.04	0.15	N.D	0.17	0.11	0.13	0.04	0.14		
Acenaphthene	0.62	0.21	N.D	0.18	0.60	0.18	0.21	0.19		
Dimethylnapthalenes	16.6	4.45	N.D	3.83	13.5	3.67	5.57	3.55		
Trimethylnapthalenes	11.1	3.36	N.D	2.76	10.8	2.71	3.87	2.83		
Fluorene	0.84	0.37	0.11	0.32	0.87	0.32	0.26	0.36		
Dibenzothiophene	0.43	0.13	0.45	0.13	0.45	0.11	0.11	0.12		
Methyldibenzothiophenes	1.11	0.32	1.51	0.42	1.40	0.18	0.30	0.21		
Dimethyldibenzothiophenes	1.61	0.57	6.4	0.84	2.48	0.32	0.54	0.40		
Phenanthrene	1.97	0.80	2.55	0.75	1.91	0.70	0.57	0.79		
Anthracene	0.08	0.05	0.63	0.04	0.11	0.04	0.03	0.05	100	100
Methylphenanthrenes	4.73	1.41	7.51	1.28	6.31	1.03	1.37	1.21		
Dimethylphenanthrenes	4.46	1.77	9.61	1.52	7.64	1.10	1.48	1.23		
Trimethylphenanthrenes	2.19	1.10	6.94	0.76	4.54	0.55	0.91	0.64		
Fluoranthene	0.29	0.25	0.24	0.21	0.26	0.22	0.12	0.25	6.3	120
Pyrene	0.16	0.27	0.33	0.17	0.27	0.17	0.19	0.20		
Methylpyrenes	0.31	0.29	1.16	0.21	0.79	0.18	0.26	0.22		
Dimethylpyrenes	0.33	0.30	1.62	0.21	0.96	0.16	0.26	0.22		
Retene	0.05	0.03	2.30	0.03	0.05	N.D	0.04	0.02		
Benz[a]anthracene	0.03	0.06	0.10	0.04	0.09	0.04	0.04	0.05		
Chrysene	0.21	0.11	0.37	0.09	0.32	0.08	0.09	0.09		
Methylchrysenes	0.24	0.17	0.69	0.11	0.57	0.07	0.16	0.09		
Dimethylchrysenes	0.23	0.19	0.77	0.11	0.66	0.07	0.15	0.09		
Benzo[b]fluoranthene	0.06	0.14	0.13	0.11	0.12	0.13	0.17	0.17		17
Benzo[k]fluoranthene	0.02	0.04	0.03	0.03	0.03	0.03	0.06	0.04		17
Benzo[e]pyrene	0.04	0.07	0.10	0.05	0.09	0.06	0.11	0.08		
Benzo[a]pyrene	N.D	0.04	0.05	0.02	0.04	0.02	0.06	0.04	0.17	27
Perylene	N.D	N.D	0.02	N.D	N.D	N.D	0.02	N.D		
Indeno[1,2,3-cd]pyrene	0.02	0.04	0.03	0.02	0.04	0.02	0.06	0.04		
Benzo[ghi]perylene	0.02	0.07	0.05	0.04	0.04	0.03	0.08	0.07		0.82
Dibenz[a,h]anthracene	N.D	N.D	0.02	N.D	N.D	N.D	N.D	N.D		
ΣPAHs (ng/L)	**70.0**	**26.6**	**43.7**	**22.6**	**71.4**	**19.8**	**29.7**	**20.0**		

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STATION	AGIA ZONI II SHIPWRECK (37° 55.77'N - 23° 34.17'E)									
DEPTH	45 meters		49 meters							
DATE	21-22/09	13-14/11	21-22/09	13-14/11						
TPH (μg/L)	1.4	N.D	1.7	0.8					AA (ng/L)	MAC (ng/L)
PAHs (ng/L)										
Naphthalene	1.99	3.76	5.85	4.89					2000	130000
Methylnapthalenes	3.18	5.50	9.72	8.69						
Acenaphthylene	0.05	0.18	0.07	0.17						
Acenaphthene	0.16	0.28	0.32	0.23						
Dimethylnapthalenes	3.41	4.51	7.03	4.35						
Trimethylnapthalenes	3.55	4.20	4.94	3.18						
Fluorene	0.24	0.48	0.24	0.37						
Dibenzothiophene	0.10	0.16	0.09	0.13						
Methyldibenzothiophenes	0.89	0.29	0.28	0.20						
Dimethyldibenzothiophenes	0.57	0.44	0.60	0.39						
Phenanthrene	0.56	1.21	0.60	0.86						
Anthracene	0.04	0.07	0.06	0.05					100	100
Methylphenanthrenes	1.35	2.40	1.61	1.20						
Dimethylphenanthrenes	1.42	1.53	1.82	1.26						
Trimethylphenanthrenes	0.82	0.84	1.21	0.66						
Fluoranthene	0.17	0.35	0.22	0.30					6.3	120
Pyrene	0.24	0.35	0.27	0.24						
Methylpyrenes	0.30	0.28	0.32	0.23						
Dimethylpyrenes	0.27	0.27	0.35	0.24						
Retene	0.02	0.04	0.03	0.02						
Benz[a]anthracene	0.07	0.11	0.09	0.09						
Chrysene	0.12	0.15	0.12	0.13						
Methylchrysenes	0.23	0.12	0.21	0.13						
Dimethylchrysenes	0.17	0.12	0.15	0.12						
Benzo[b]fluoranthene	0.31	0.22	0.33	0.24						17
Benzo[k]fluoranthene	0.09	0.06	0.10	0.06						17
Benzo[e]pyrene	0.17	0.10	0.18	0.11						
Benzo[a]pyrene	0.14	0.11	0.18	0.09					0.17	27
Perylene	0.04	0.03	0.04	0.03						
Indeno[1,2,3-cd]pyrene	0.10	0.09	0.12	0.11						
Benzo[ghi]perylene	0.10	0.11	0.11	0.11						0.82
Dibenz[a,h]anthracene	0.02	0.04	0.03	0.03						
ΣPAHs (ng/L)	**20.9**	**28.4**	**37.3**	**28.9**						

In both seawater samplings conducted in open sea areas of the Saronikos Gulf, total petroleum hydrocarbons levels were normal. Furthermore, in no case values higher than the annual average concentration (AA) and maximum allowable concentration (MAC) for PAHs were recorded, in accordance with the environmental quality standards for priority substances for the determination of chemical and ecological status of waters (Directive 2013/39/EC). Total PAHs concentrations fluctuated at low levels, in accordance to those previously reported in various Greek seas (Hatzianestis and Sklivagou, 2002, Parinos and Gogou, 2016, and references therein).

During the sampling of September 21-22nd 2017, total petroleum hydrocarbons concentrations ranged from not detected to 6.8 μg/L, with an average of 2.1 μg/L, while during the sampling of November 13-14th 2017 total petroleum hydrocarbons concentrations ranged from not detected to 3.9 μg/L, with an average of 1.3 μg/L. These minor variations can be interpreted in the context of the physical variability of the total petroleum hydrocarbons content of the water column of the study area. In all cases, however, they clearly indicate the absence of a petroleum residues burden at the sampling sites and the corresponding sampling depths in open sea areas of the Saronikos Gulf during the sampling dates.

References

Hatzianestis, I., and Sklivagou, E., 2002. Dissolved and suspended polycyclic aromatic hydrocarbons (PAH) in the north Aegean Sea. Mediter. Mar. Sci. 3, 89-98.

Parinos, C., and Gogou, A., 2016. Suspended particle-associated PAHs in the open eastern Mediterranean Sea: Occurrence, sources and processes affecting their distribution patterns. Marine Chemistry 180, 42-50.

3.2. HYDROCARBONS IN SURFACE SEDIMENTS

Parinos, C., Hatzianestis, I., Chourdaki, S., Plakidi, E.

3.2.1. Methodology

All sediment samples were collected by using a stainless steel Box Corer with dimensions of 40x40 cm. Using this particular sampler it is possible to sample undisturbed sediment from the upper 0-1 cm which is considered herein. All collected samples were wrapped in pre-combusted aluminum foil and kept frozen at -20 ^{o}C till further laboratory analysis.

In the laboratory, the samples were initially freeze-dried and subsequently homogenized. The analytical determination of hydrocarbons was based on the methodology proposed by IOC (IOC, 1993). Briefly, 5 g of sediment is extracted into a Soxhlet apparatus for 24 hours with a methanol-dichloromethane mixture (2:1, *v/v*), and subsequently the extract is saponified with a methanolic potassium hydroxide solution and the non-saponified components are extracted with *n*-hexane. The extract is then fractionated on an activated silica gel column and two fractions are collected, the first one with 10 mL of *n*-hexane containing the aliphatic hydrocarbons and the second one with 10 mL of hexane-ethyl acetate (9:1, *v/v*) containing the polycyclic aromatic hydrocarbons. Quantitation of the compounds was performed by gas chromatography - mass spectrometry (Agilent 5973C GC-MSD) on a full scan mode. The organic chemistry laboratory of H.C.M.R. is accredited by ISO/IEC 17025 for the analysis of polycyclic aromatic hydrocarbons in marine sediments. Results are reported per dry weight of sediment in all cases.

3.2.2. Results and Discussion

Figures 3.2.1, 3.2.2 and 3.2.3 below show photographs of the collected sediments at the time of their sampling on September 21-22nd 2017, November 13-14th 2017 and January 23-24th 2018. Macroscopically no large sized tar aggregates or traces of extensive petroleum pollution were observed either in the surface or in the sub-surface layers of the collected sediment samples.

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Figure 3.2.1. Photographs of the collected sediments at the time of their sampling on September 21-22nd 2017 in the open sea of the Saronikos Gulf.

Figure 3.2.2. Photographs of the collected sediments at the time of their sampling on November 13-14th 2017 in the open sea of the Saronikos Gulf.

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Figure 3.2.3. Photographs of the collected sediments at the time of their sampling on January 23-24th 2018 in the open sea of the Saronikos Gulf.

Very limited 1-2 mm sized tar balls were visually observed during the sampling of November 13-14th 2017 at the sampling site of the shipwreck of Agia Zoni II and the sampling site south of Psittaleia (Figure 3.2.4).

Figure 3.2.4. Limited 1-2 mm sized tar balls visually observed during the sampling of November 13-14th 2017 at the sampling site of the shipwreck of Agia Zoni II (left) and the sampling site south of Psittaleia (right).

Table 3.2.1 below summarizes the results of the determination of total aliphatic hydrocarbons and total polycyclic aromatic hydrocarbons in the collected sediment samples together with the corresponding time series data for sampling stations S7, S8, S11, S13, S16 and S43 belonging to the Saronikos Gulf systematic monitoring network. In Table 3.2.2 the analytical results of the determination of all individual polycyclic aromatic hydrocarbons and other diagnostic ratios used in this chapter for the interpretation of the reported results are depicted.

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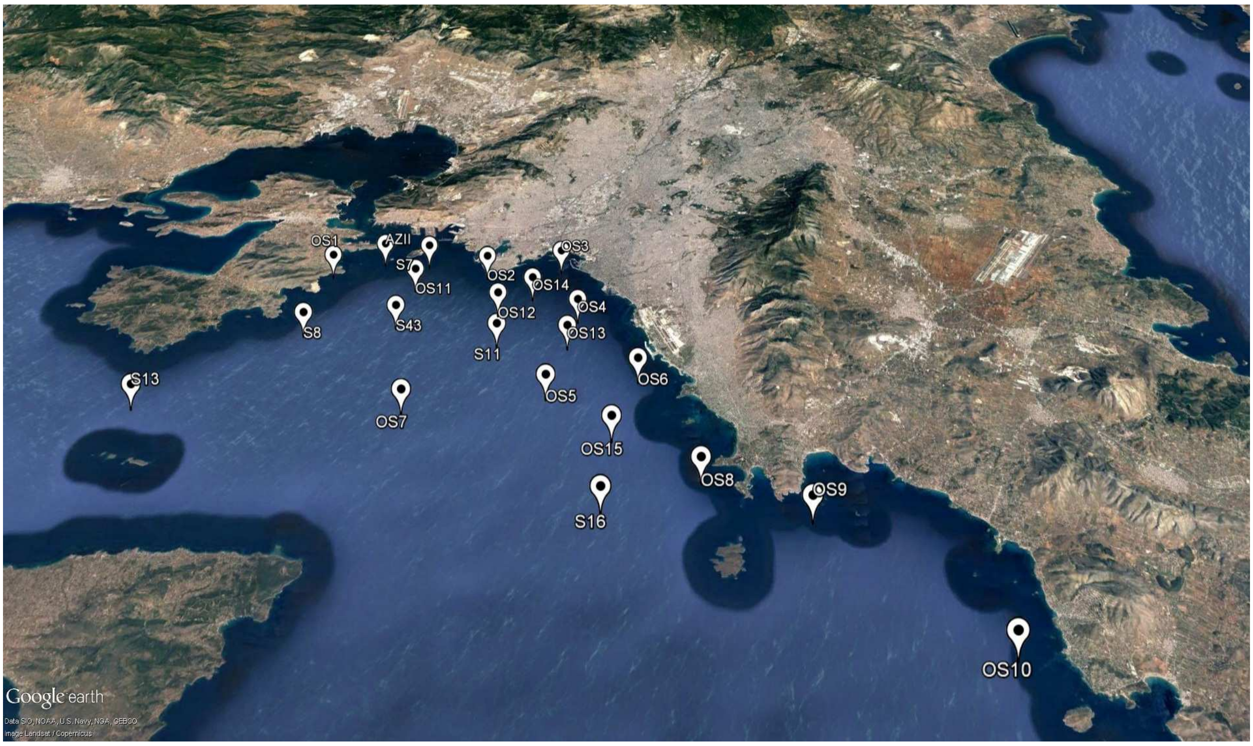

Figure 3.2.5. Sediment sampling sites in the open Saronikos Gulf.

Table 3.2.1. Total aliphatic hydrocarbons (in μg/g) and total polycyclic aromatic hydrocarbons (PAHs; in ng/g) concentrations for the collected sediment samples in the open Saronikos Gulf along with the corresponding time series data for sampling stations belonging to the Saronikos Gulf systematic monitoring network.

STATION	**∑aliphatic hydrocarbons (in μg/g)**				**∑PAHs (in ng/g)**			
	2000-2012	**09/2017**	**11/2017**	**01/2018**	**2000-2012**	**09/2017**	**11/2017**	**01/2018**
S7	1800 - 4700	1220	1140	1160	7900-9100	4430	4570	4330
S8	236-368	69.8	108	215	790-930	446	1530	1130
S11	145-177	64.2	63.5	70.0	390-410	422	705	1510
S13	46-57	116	59.8	91.7	190-220	491	245	337
S16	49-75	48.5	37.3	39.5	220-530	809	331	144
S43	156-247	98.9	120	169	890-1270	646	789	990
AZ II		282	354	248		1260	3490	2540
OS1		419	225	377		1010	627	1040

STATION	∑aliphatic hydrocarbons (in μg/g)				∑PAHs (in ng/g)			
	2000-2012	09/2017	11/2017	01/2018	2000-2012	09/2017	11/2017	01/2018
OS2		555	179	494		3750	1820	4420
OS3		129	117	94.0		1240	2140	1890
OS4		103	66.7	79.7		840	307	437
OS5		64.5	41.0			592	184	
OS6		85.3	75.8	63.0		466	388	209
OS7		121	80.2			654	453	
OS8		44.2	25.3	51.5		153	141	261
OS9		28.8				98.6		
OS10		23.4				53.1		
OS11			196	288			1430	1950
OS12			58.8	69.0			328	347
OS13			96.9	84.3			423	284
OS14			158	271			2210	3600
OS15			22.9	53.9			112	165
Saronikos Gulf (Outer)	40-52				110-190			
Background values	< 30				< 50			

Table 3.2.2. Concentrations of total aliphatic (**∑H/C** in μg/g) and polycyclic aromatic hydrocarbons (PAHs; in ng/g) for the collected sediment samples on September 21-22nd 2017, November 13-14th 2017 and January 23-24th 2018 in the open Saronikos Gulf. **UCM:** Unresolved complex mixture of aliphatic hydrocarbons, **U/R:** ratio of unresolved to resolved aliphatic compounds concentrations.

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STATION	S7			S8			S11			S13		
DATE	09/2017	11/2017	01/2018	09/2017	11/2017	01/2018	09/2017	11/2017	01/2018	09/2017	11/2017	01/2018
∑H/C (μg/g)	1220	1140	1160	69.8	108	215	64.2	63.5	70.0	116	59.8	91.7
UCM (μg/g)	1140	1080	1090	63.8	97.7	198	58.1	58.3	64.1	106	54.8	84.4
U/R	13.6	16.4	15.1	10.8	9.1	11.9	9.6	11.2	10.8	10.8	11.1	11.5
PAHs (ng/g)												
Naphthalene	59.4	46.5	54.0	7.1	18.3	15.5	5.2	5.3	9.1	7.1	5.3	8.7
Methylnapthalenes	79.5	60.6	88.4	8.6	30.6	20.6	11.9	11.2	14.3	11	6.7	9.8
Acenaphthylene	55.6	46.0	42.7	4.8	6.4	11.8	2.9	6.1	5.4	4	2.9	3.7
Acenaphthene	9.1	9.8	9.3	1.3	6.7	2.2	1.6	2.5	3	1.5	0.7	0.7
Dimethylnapthalenes	62.6	49.8	52.6	8.7	26.8	17.2	10.3	7.2	14	8.5	6.9	7.8
Trimethylnapthalenes	100.5	75.2	80.9	8.3	20.4	17.9	14.6	12.3	19.6	8.3	6.3	7.2
Fluorene	9.3	8.6	8.9	0.9	4.2	1.9	1.1	1	2.3	0.9	0.6	0.7
Dibenzothiophene	9.4	8.9	9.3	0.5	2.7	2.2	1.2	0.9	1.7	0.8	0.5	0.6
Methyldibenzothiophenes	27.2	21.8	20.2	1.4	2.9	4.7	2.2	1.2	4.2	1.7	1.2	1.1
Dimethyldibenzothiophenes	64.2	64.5	56.5	3.5	5.5	10.6	4.5	2.4	9.7	3.8	2.4	2.6
Phenanthrene	83.1	82.7	78.8	10.6	62.8	25.3	14.1	29.6	29.6	10.6	5.4	7.8
Anthracene	40.3	34.4	33.4	3.0	9.7	7.8	2.5	4.4	10.2	3	1.6	2.3
Methylphenanthrenes	153.1	131.5	119.2	17.6	54.9	38.3	22.5	24.3	80.9	14.5	11	13.3
Dimethylphenanthrenes	188.6	149.9	134.3	20.9	51.6	39.5	32.7	22.2	101.9	17.6	13.3	16.1
Trimethylphenanthrenes	133.6	128.2	106.3	13.5	28.3	23.9	24.3	13.1	53.7	12.1	9.2	10.9
Fluoranthene	168.8	176.2	175.2	20.2	115.7	58.5	21.8	53.8	110	22.2	10.4	15.6
Pyrene	179.9	194.5	187.2	24.3	109.5	62.5	21.7	50.3	119.7	24.2	12.1	17.5
Methylpyrenes	197.2	201.9	189.1	22.6	77.6	52.2	17.3	34.1	102.8	18.6	11.3	14.1
Dimethylpyrenes	182.2	179.4	162.7	17.7	46.3	33.9	15.6	20.2	66.1	12.2	8.1	10.0
Retene	12.6	8.4	8.1	1.9	7	2.2	2.5	3.1	5.2	3.8	1	1.5
Benz[a]anthracene	170.2	190.7	175.5	18.8	75.2	54.4	16	37.1	91.3	24	9.9	13.9
Chrysene	198.8	215.3	197.3	23.0	98	63.6	19.9	50.9	89.3	28.1	12.1	18.1
Methylchrysenes	267.3	256.5	226.6	17.8	58.6	53.3	18.7	26.4	76.5	17.8	9.6	14.2
Dimethylchrysenes	210.0	194.2	178.9	12.0	31.3	36.5	16.4	13.8	39.6	11.5	5.9	10.6
Benzo[b]fluoranthene	397.8	484.2	435.3	40.9	150.4	105	29.2	72.1	114.6	54	21.7	28.7
Benzo[k]fluoranthene	146.3	171.5	156.2	16.1	56.7	38	10.6	25.9	42.9	20.3	8.3	11.6
Benzo[e]pyrene	254.9	290.2	271.8	26.8	91.9	68.7	18.7	42.2	65.4	32.9	13.5	19.8
Benzo[a]pyrene	321.9	377.0	355.8	31.9	105.9	90.2	20.2	49.1	91	38.3	14.9	22.2
Perylene	81.5	83.9	83.7	7.7	26.3	21.3	5.8	13.5	20.6	9.5	3.8	5.2
Indeno[1,2,3-cd]pyrene	235.3	299.8	294.9	25.1	65	68.8	14.8	30.2	54.3	34	12.9	18.2
Benzo[ghi]perylene	266.5	268.2	272.7	24.2	66.6	67.8	18.5	32.1	49.9	28.5	12.7	19.3
Dibenz[a,h]anthracene	62.8	61.6	59.6	3.8	12.5	12.2	3.3	6.5	10.6	6.1	2.4	2.9
ΣPAHs (ng/g)	**4430**	**4570**	**4330**	**446**	**1530**	**1130**	**422**	**705**	**1510**	**491**	**245**	**337**

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STATION	S16			S43			AZ II			OS1		
DATE	09/2017	11/2017	01/2018	09/2017	11/2017	01/2018	09/2017	11/2017	01/2018	09/2017	11/2017	01/2018
∑H/C (μg/g)	48.5	37.3	39.5	98.9	120	169	282	354	248	419	225	377
UCM (μg/g)	44.2	33.8	36.2	90.2	111	157	264	330	231	391	208	351
U/R	10.1	9.8	11.0	10.3	12.0	12.9	13.9	13.8	13.8	14.5	12.6	13.5
PAHs (ng/g)												
Naphthalene	8.9	8.6	5.3	9	6.8	11.5	10.3	24.3	14.0	12.4	9.5	19.5
Methylnapthalenes	9.5	16.6	7.5	10.8	8.4	14.7	27.0	79.0	37.5	15.0	17.0	20.5
Acenaphthylene	1.2	2.6	1.7	9.1	8	12	9.20	18.2	8.3	8.7	8.3	12.5
Acenaphthene	3.6	1.6	0.6	1.1	1.3	1.8	3.60	12.6	9.5	2.3	1.7	2.6
Dimethylnapthalenes	10.2	19.2	6.7	9.8	8.9	13.8	29.7	98.3	44.9	16.0	10.9	16.3
Trimethylnapthalenes	11.1	19.4	5.9	10.3	9.4	15.4	45.9	117.1	61.3	23.3	13.2	15.4
Fluorene	2.1	1.2	0.5	1.1	1.5	1.9	2.5	15.7	5.4	2.3	0.9	2
Dibenzothiophene	1.6	0.4	0.2	1	1.8	1.4	3.5	8.3	5.8	2.1	1.0	2.2
Methyldibenzothiophenes	1.8	1.6	0.5	2.2	3.5	3.2	9.1	17.6	12.3	6.7	2.8	4.5
Dimethyldibenzothiophenes	4	2.2	0.9	7	7.7	8.4	25.8	42.9	33.4	18.3	6.9	10.5
Phenanthrene	31.3	10.4	5.2	11.3	23.6	23.6	33.4	159.5	76.9	18.3	10.9	22.9
Anthracene	4	2	1.1	4.3	5.6	7.6	8.0	27.2	20.5	6.3	3.9	8
Methylphenanthrenes	22	16.4	7.5	22.9	29.3	35.1	61.6	182.4	89.7	34.9	19.3	31.8
Dimethylphenanthrenes	24.7	19.2	8.9	29.7	28.4	39	88.1	180.3	95.2	55.8	27.9	40.5
Trimethylphenanthrenes	22.2	13.4	6.2	18.7	18.6	22.4	71.9	141.4	72.1	45.1	20.5	27.5
Fluoranthene	64.4	11.8	5.9	26.7	47.2	52.4	54.0	205.4	157.4	37.7	24.0	45.7
Pyrene	58.6	12	5.7	33.1	51.9	56.7	57.3	197.2	142.2	40.8	28.0	48
Methylpyrenes	34.2	12.6	5.5	27.1	37.6	46.2	54.8	170.5	113.2	39.9	25.2	44.7
Dimethylpyrenes	18	15.4	5.4	19.4	22.4	27.7	48.9	134.4	80.3	39.0	20.7	34.1
Retene	2.3	3.4	0.9	2	1.2	2.2	5.4	11.2	7.9	2.5	0.4	2.3
Benz[a]anthracene	46.2	9.8	4.6	28.1	38.5	47.7	43.9	148.6	136.4	37.2	23.6	44.2
Chrysene	63.2	13.8	5.5	36.9	48.5	56.1	57.2	173.9	154.7	47.5	29.6	52.4
Methylchrysenes	33.1	14	4.9	27	38.9	44.1	61.6	142.8	115.1	51.9	29.2	51.9
Dimethylchrysenes	17.5	12.4	4.4	16	20.8	26.3	57.9	126.9	65.8	45.1	23.6	39.6
Benzo[b]fluoranthene	81.5	23.4	10.4	64.9	76.6	94.7	87.7	264.5	235.2	86.2	61.5	98.6
Benzo[k]fluoranthene	28.9	7.8	3.9	26.6	29.3	37.2	31.4	94.6	81.5	31.2	23.9	38.4
Benzo[e]pyrene	47.7	15.6	6.5	42.4	48.7	61.8	60.6	161.7	145.2	56.8	38.3	63.7
Benzo[a]pyrene	55.9	13.8	6.1	53	59.5	82.7	66.4	198.5	189.9	69.2	47.5	76.5
Perylene	18.4	3.2	1.7	12.5	13.6	19.8	19.0	47.2	49.6	18.6	11.2	19.8
Indeno[1,2,3-cd]pyrene	33.7	12.8	6.6	39.1	42	57.6	49.0	134.4	130.4	56.9	38.9	65.6
Benzo[ghi]perylene	39.3	13	6.1	36.1	41.3	56.6	61.3	122.6	116.3	71.8	39.7	67
Dibenz[a,h]anthracene	8.1	2.2	1.0	6.4	7.7	9.7	12.1	28.3	27.0	12.5	7.3	11.6
ΣPAHs (ng/g)	**809**	**331**	**144**	**646**	**789**	**990**	**1260**	**3490**	**2540**	**1010**	**627**	**1040**

ANNEX I

STATION	OS2			OS3			OS4			OS5		
DATE	09/2017	11/2017	01/2018	09/2017	11/2017	01/2018	09/2017	11/2017	01/2018	09/2017	11/2017	01/2018
∑H/C (μg/g)	555	179	494	129	117	94.0	103	66.7	79.7	64.5	41.0	-
UCM (μg/g)	519	165	455	118	108	87.6	94.6	60.9	73.4	59.3	37.4	-
U/R	14.1	12.0	11.7	11.5	11.8	13.7	11.5	10.5	11.7	11.5	10.4	-
PAHs (ng/g)												
Naphthalene	36.5	18.1	44.4	4.1	19.7	32.6	4.3	5.6	6.7	7.8	3.4	-
Methylnapthalenes	46.6	28.6	42	5.1	15	20.9	5.8	8.6	7	15.9	6.6	-
Acenaphthylene	44.3	24.2	52.2	3.8	21.3	37.2	2.7	4.9	4.6	2.3	1.3	-
Acenaphthene	3.7	3.7	4.6	0.4	4.9	1.3	0.8	0.7	0.5	2.3	0.6	-
Dimethylnapthalenes	34.3	23.1	40.2	5.5	12	16.3	6.9	4.6	5.8	19.7	8	-
Trimethylnapthalenes	61.3	26.0	54.4	22.7	13.6	15.0	30	6.1	6.5	25.4	7.8	-
Fluorene	4.2	2.7	5.2	0.6	3.1	3.3	1	0.5	0.6	2.3	0.6	-
Dibenzothiophene	5.5	2.7	5.4	1.3	2.3	2.0	1.6	0.4	0.3	1.9	0.3	-
Methyldibenzothiophenes	15.2	4.9	13.9	15.2	4.1	3.9	11	1.1	0.9	2.9	0.7	-
Dimethyldibenzothiophenes	41.8	13.2	42	67.2	13.6	13.1	38.9	3.2	2.7	4.3	1.1	-
Phenanthrene	61.5	40.2	76	9.2	30.8	26.8	13.4	5.8	5	30.9	5.6	-
Anthracene	23.5	12.9	28.2	2.9	15.2	12.4	2.7	1.8	2.5	5.5	1.2	-
Methylphenanthrenes	116.6	59.3	139.7	87.7	42.7	43.7	73.5	11.1	14.7	35.3	9.1	-
Dimethylphenanthrenes	159	71.3	190.6	241.9	72.5	54.2	151.5	17.6	23.1	34.4	11.1	-
Trimethylphenanthrenes	116.6	51.3	119.5	285.6	70.1	42.4	153	19.9	21.3	19.9	8	-
Fluoranthene	184.1	89.6	225.7	15.1	102.1	100.5	15.8	11.9	17.6	33.4	7.7	-
Pyrene	189.4	89.6	217.6	19.1	91.6	99.9	18	13.5	19.8	28.9	7.5	-
Methylpyrenes	167.6	78.6	212.5	48	97	72.5	29.5	12.5	24.6	28.2	7.5	-
Dimethylpyrenes	148.5	64.6	175.1	69.1	78.8	56.8	35.7	13.8	19.6	22.1	7.5	-
Retene	8.8	4.3	7	4.3	0.9	3.9	3.6	0.4	1.5	4.8	1.3	-
Benz[a]anthracene	180.9	87.9	230.7	18.6	125.1	109.7	15	12.3	21.9	25.2	6.7	-
Chrysene	215.5	102.1	268.2	28.6	146.2	108.4	22.3	15	24.5	30.7	8.5	-
Methylchrysenes	199.9	88.4	250.5	63.5	112.1	67.9	36.2	13	22	31.2	8.3	-
Dimethylchrysenes	147.2	61.8	164.2	88.3	63.3	49.0	45.1	12.2	19	23.8	7.1	-
Benzo[b]fluoranthene	359.4	193.1	431.8	32.7	258.3	225.2	28.9	27.2	41.4	39.2	14	-
Benzo[k]fluoranthene	132.7	70.1	161	12	97.2	85.5	11.2	9.9	16.1	15.2	5.3	-
Benzo[e]pyrene	208.7	110.3	255.7	21.4	136	117.5	18.6	16.1	23.3	23.4	8.4	-
Benzo[a]pyrene	284.7	143.7	351.4	22.9	198	158.0	20.6	18.6	29.7	26.7	8.9	-
Perylene	76.6	35.6	88.4	7.2	47.9	45.7	6.1	4.3	7.1	7	2.4	-
Indeno[1,2,3-cd]pyrene	209.7	105.7	248	16.2	116.2	124.7	14.9	15.9	22.3	16.7	7.9	-
Benzo[ghi]perylene	216.1	93.4	222.9	18.9	103.8	116.2	17.9	15.6	20.2	20.5	8.1	-
Dibenz[a,h]anthracene	54	21.4	51.2	4.3	25.7	23.5	3.7	3	4.4	4.3	1.4	-
ΣPAHs (ng/g)	**3750**	**1820**	**4420**	**1240**	**2140**	**1890**	**840**	**307**	**437**	**592**	**184**	**-**

ANNEX I

STATION	OS6			OS7			OS8			OS9		
DATE	09/2017	11/2017	01/2018	09/2017	11/2017	01/2018	09/2017	11/2017	01/2018	09/2017	11/2017	01/2018
∑H/C (μg/g)	85.3	75.8	63.0	121	80.2	-	44.2	25.3	51.5	28.8	-	-
UCM (μg/g)	77.9	69.8	57.5	111	73.9	-	37.0	22.7	47.0	24.5	-	-
U/R	10.5	11.6	10.5	11.3	11.8	-	5.2	8.9	10.5	5.6	-	-
PAHs (ng/g)												
Naphthalene	3.2	9.7	4.7	10.1	6.6	-	3.4	3.1	5.8	2.5	-	-
Methylnapthalenes	4.9	14.9	6.1	15.9	8.3	-	8.2	4.6	13.4	3.4	-	-
Acenaphthylene	1.5	4.8	2.6	5.1	4.9	-	0.8	1.5	2.2	0.9	-	-
Acenaphthene	0.5	1.8	0.5	3.8	1.2	-	0.4	0.5	0.9	0.5	-	-
Dimethylnapthalenes	5.2	13.6	5	14.2	9	-	8.9	5.1	15.1	3.6	-	-
Trimethylnapthalenes	8.4	10.5	4.1	12.9	9.2	-	10.9	4.7	14	3.5	-	-
Fluorene	0.3	0.9	0.4	1.7	1	-	0.4	0.4	0.7	0.3	-	-
Dibenzothiophene	0.7	0.9	0.2	1.6	0.9	-	0.3	0.2	0.4	0.2	-	-
Methyldibenzothiophenes	4.7	2.6	0.5	2.3	1.9	-	0.8	0.7	1	0.7	-	-
Dimethyldibenzothiophenes	22.9	5.7	2	5.3	4.4	-	2.0	1	2.1	1.5	-	-
Phenanthrene	4.7	7.0	4	20.9	10.7	-	3.6	3.8	8.4	3.1	-	-
Anthracene	1.0	2.2	1.4	4.8	3	-	0.7	0.8	1.3	0.7	-	-
Methylphenanthrenes	33.0	15.8	8.4	26.9	15	-	8.8	7.2	17.7	3.5	-	-
Dimethylphenanthrenes	91.9	31.2	12.6	29.8	17.2	-	17.1	8.9	22.3	6.1	-	-
Trimethylphenanthrenes	97.7	28.1	12.5	18.6	11.2	-	15.9	7.3	16.6	5.4	-	-
Fluoranthene	6.8	10.1	9.4	38.3	20.7	-	2.9	7	9.5	3.8	-	-
Pyrene	7.4	11.0	9	39.9	25.3	-	2.8	7.1	9.1	3.7	-	-
Methylpyrenes	17.5	14.9	9.3	31.5	20.8	-	5.5	6.4	10.4	3.7	-	-
Dimethylpyrenes	24.0	20.6	8.2	24.1	15.1	-	7.1	6.6	11.2	4.0	-	-
Retene	4.0	1.8	1.9	1.3	1.2	-	0.8	0.6	1.7	0.8	-	-
Benz[a]anthracene	6.9	11.4	8.7	31.2	18	-	2.5	5.8	7.6	3.2	-	-
Chrysene	11.3	14.5	9.7	38.9	24.6	-	4.0	7.4	9.9	4.2	-	-
Methylchrysenes	20.3	17.6	7.5	32.5	20.1	-	6.9	6.3	10	4.2	-	-
Dimethylchrysenes	28.4	20.2	9	25.2	13.4	-	8.9	5.9	12.4	4.8	-	-
Benzo[b]fluoranthene	14.7	28.1	18.1	52.1	45.5	-	2.0	9.9	14.3	7.4	-	-
Benzo[k]fluoranthene	5.1	10.1	6.6	19.5	17.5	-	3.7	3.8	5.8	3.2	--	-
Benzo[e]pyrene	9.5	18.0	10.2	32.7	28.7	-	5.5	6.4	9.1	5.0	-	-
Benzo[a]pyrene	8.5	17.6	11.4	37.5	34.7	-	4.3	6.7	9.2	4.5	-	-
Perylene	2.6	4.8	3.3	9.4	8.3	-	1.8	1.7	2.5	1.4	-	-
Indeno[1,2,3-cd]pyrene	7.4	16.7	9.9	28	24.9	-	3.4	4.6	7.6	4.3	-	-
Benzo[ghi]perylene	9.4	18.0	9.6	32	25.7	-	3.3	4.8	7.4	3.9	-	-
Dibenz[a,h]anthracene	1.7	3.1	1.7	6.5	4.4	-	0.6	0.9	1.2	0.6	-	-
ΣPAHs (ng/g)	**466**	**388**	**209**	**654**	**453**	**-**	**153**	**141**	**261**	**98.6**	**-**	**-**

ANNEX I

STATION	OS10			OS11			OS12			OS13		
DATE	09/2017	11/2017	01/2018	09/2017	11/2017	01/2018	09/2017	11/2017	01/2018	09/2017	11/2017	01/2018
∑H/C (μg/g)	23.4	-	-	-	196	288	-	58.8	69.0	-	96.9	84.3
UCM (μg/g)	20.7	-	-	-	180	268	-	53.9	63.3	-	89.2	78.1
U/R	7.7	-	-	-	11.5	13.3	-	11.1	11.2	-	11.5	12.7
PAHs (ng/g)												
Naphthalene	2.4	-	-	-	20.0	18.2	-	2.15	9.5	-	5.8	5.3
Methylnapthalenes	3.2	-	-	-	28.0	19.6	-	7.95	10.6	-	10.4	9.5
Acenaphthylene	0.3	-	-	-	15.2	23.3	-	0.47	3.1	-	3.1	2.3
Acenaphthene	0.1	-	-	-	3.5	3.8	-	2.26	1	-	0.9	0.8
Dimethylnapthalenes	2.8	-	-	-	23.2	22	-	2.54	10.6	-	11.6	9.4
Trimethylnapthalenes	2.2	-	-	-	23.8	24.8	-	1.59	9.8	-	11.4	9.3
Fluorene	0.2	-	-	-	2.4	3	-	0.87	0.8	-	0.8	0.7
Dibenzothiophene	0.1	-	-	-	2.1	3.2	-	0.91	0.7	-	0.7	0.5
Methyldibenzothiophenes	0.2	-	-	-	5.2	8.2	-	0.62	0.9	-	1.6	1.1
Dimethyldibenzothiophenes	0.5	-	-	-	13.7	24.1	-	0.87	1.6	-	3.5	2.6
Phenanthrene	1.1	-	-	-	28.7	45.2	-	18.35	8.8	-	12.7	9.0
Anthracene	0.2	-	-	-	10.1	15.8	-	1.68	1.9	-	2.5	1.9
Methylphenanthrenes	2.5	-	-	-	51.7	74.6	-	10.49	15.8	-	16.7	12.9
Dimethylphenanthrenes	3.6	-	-	-	68.4	82.4	-	6.76	16.6	-	16.8	13.6
Trimethylphenanthrenes	2.8	-	-	-	50.4	52.4	-	3.26	9.7	-	13	9.7
Fluoranthene	2.3	-	-	-	61.0	98.8	-	1.67	14.2	-	22.8	14.5
Pyrene	2.2	-	-	-	66.6	106.6	-	1.42	14.6	-	29.3	13.2
Methylpyrenes	1.9	-	-	-	63.6	93.7	-	19.33	13	-	17.5	11.5
Dimethylpyrenes	1.8	-	-	-	50.3	61.3	-	10.35	12.6	-	14.6	9.2
Retene	5.8	-	-	-	4.1	5	-	0.04	1.5	-	1	1.4
Benz[a]anthracene	1.1	-	-	-	60.4	93.3	-	24.16	13.4	-	18.8	11.6
Chrysene	1.5	-	-	-	73.1	107.7	-	32.52	16.4	-	22.4	13.3
Methylchrysenes	1.2	-	-	-	60.3	94.9	-	15.85	13.1	-	16.4	11.0
Dimethylchrysenes	2.1	-	-	-	44.1	62.7	-	6.18	12	-	15.4	11.2
Benzo[b]fluoranthene	2.3	-	-	-	139.0	176.5	-	43.87	31.9	-	36.5	24.4
Benzo[k]fluoranthene	0.8	-	-	-	51.2	65.4	-	15.6	12.2	-	12.9	9.0
Benzo[e]pyrene	2.5	-	-	-	88.0	118.4	-	23.27	18.8	-	22.7	14.1
Benzo[a]pyrene	1.9	-	-	-	110.0	160.5	-	27.88	21.6	-	26.4	15.3
Perylene	0.4	-	-	-	25.7	36.9	-	6.44	5.7	-	6.1	4.5
Indeno[1,2,3-cd]pyrene	1.3	-	-	-	86.4	114.4	-	19.47	21.5	-	25.3	14.2
Benzo[ghi]perylene	1.6	-	-	-	82.9	110.2	-	15.3	19.8	-	19.4	14.3
Dibenz[a,h]anthracene	0.2	-	-	-	13.8	19.7	-	4.19	3.5	-	3.7	2.5
ΣPAHs (ng/g)	**53.1**	**-**	**-**	**-**	**1430**	**1950**	**-**	**328**	**347**	**-**	**423**	**284**

ANNEX I

STATION	OS14			OS15								
DATE	09/2017	11/2017	01/2018	09/2017	11/2017	01/2018						
∑H/C (μg/g)	-	158	271	-	22.9	53.9						
UCM (μg/g)	-	144	253	-	20.5	49.6						
U/R	-	10.4	13.7	-	8.55	11.6						
PAHs (ng/g)												
Naphthalene	-	39.7	178.8	-	2.2	3.7						
Methylnapthalenes	-	19.2	32.9	-	4.3	6.3						
Acenaphthylene	-	23.4	37.3	-	0.8	2.1						
Acenaphthene	-	2.7	6.7	-	0.4	0.5						
Dimethylnapthalenes	-	20.6	28.5	-	5.2	6.2						
Trimethylnapthalenes	-	32.1	43.7	-	5.1	5.6						
Fluorene	-	2.6	5.2	-	0.4	0.4						
Dibenzothiophene	-	3.1	6.6	-	0.2	0.3						
Methyldibenzothiophenes	-	8	11.1	-	0.4	0.7						
Dimethyldibenzothiophenes	-	26.8	26.6	-	1	1.2						
Phenanthrene	-	32.6	92.4	-	3.2	4.3						
Anthracene	-	16.4	30.2	-	0.7	1.1						
Methylphenanthrenes	-	57.1	92.7	-	4.5	7.8						
Dimethylphenanthrenes	-	82.4	93	-	5.7	8.5						
Trimethylphenanthrenes	-	60.4	61	-	4.2	6.1						
Fluoranthene	-	92.2	184.8	-	4	7.2						
Pyrene	-	112.6	189.3	-	4.4	6.7						
Methylpyrenes	-	116.5	158.4	-	4.9	6.1						
Dimethylpyrenes	-	83	111.9	-	4.7	5.8						
Retene	-	7.9	11.1	-	0.6	1.2						
Benz[a]anthracene	-	120.8	175.7	-	4	6.4						
Chrysene	-	136.1	197.5	-	5.1	7.7						
Methylchrysenes	-	116.5	185.8	-	4.8	5.4						
Dimethylchrysenes	-	69.9	119.7	-	3.8	6						
Benzo[b]fluoranthene	-	238.7	385.1	-	8.9	15.3						
Benzo[k]fluoranthene	-	87	146.3	-	3.3	5.2						
Benzo[e]pyrene	-	129.9	208.3	-	6.4	8.6						
Benzo[a]pyrene	-	180.7	293.6	-	6.4	8.1						
Perylene	-	47.3	80	-	1.6	2.4						
Indeno[1,2,3-cd]pyrene	-	127	198.3	-	4.5	8.5						
Benzo[ghi]perylene	-	94.6	159.7	-	5.9	7.8						
Dibenz[a,h]anthracene	-	25.6	41.4	-	0.8	1.5						
ΣPAHs (ng/g)	**-**	**2210**	**3600**	**-**	**112**	**165**						

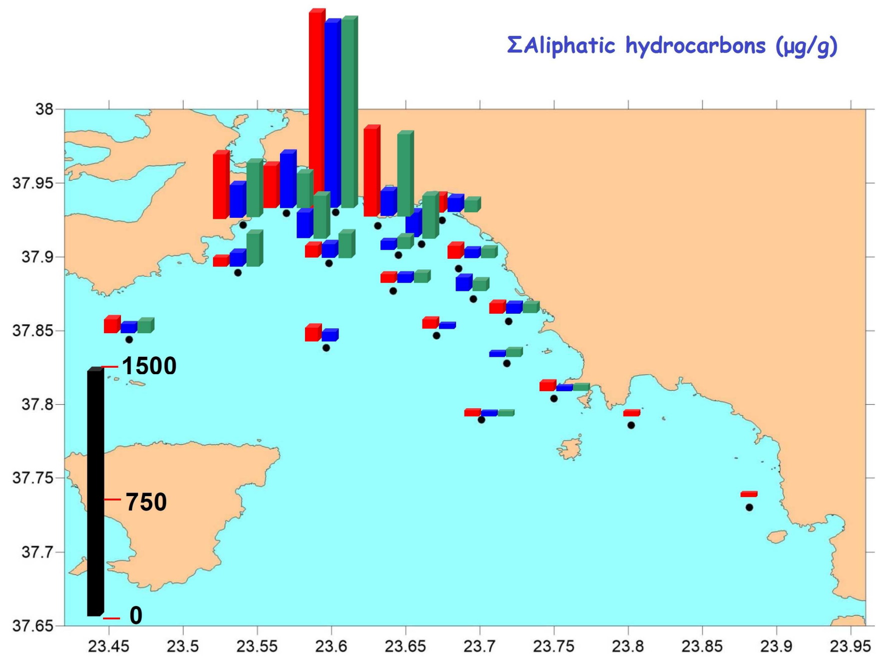

Figure 3.2.6. Concentrations of total aliphatic hydrocarbons (in μg/g) for the collected sediment samples on September 21-22nd 2017 (red color), November 13-14th 2017 (blue color) and January 23-24th 2018 (green color) in the open Saronikos Gulf.

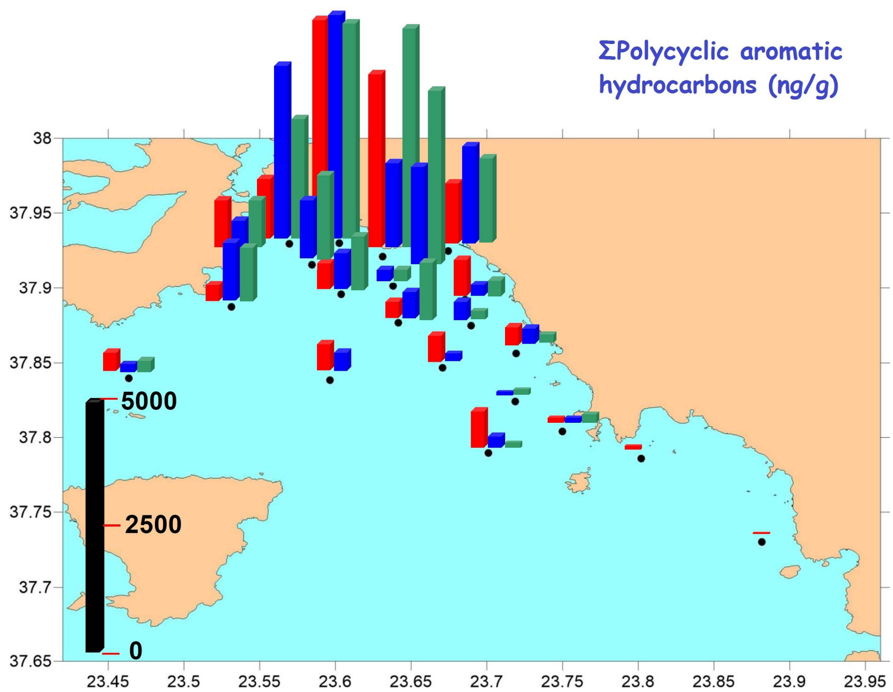

Figure 3.2.7. Concentrations of total polycyclic aromatic hydrocarbons (in ng/g) for the collected sediment samples on September 21-22nd 2017 (red color) November 13-14th 2017 (blue color) and January 23-24th 2018 (green color) in the open Saronikos Gulf.

Total aliphatic hydrocarbons concentrations in the considered sediment samples ranged from 22.9 to 1220 μg/g, with an average of 193 μg/g. Their concentrations in all three sampling rounds showed an increasing trend from southeast to northwest with the highest concentrations being recorded at station S7 in Psittaleia (Figure 3.2.6). Compared to the stations S7, S8, S11, S13, S16 and S43 belonging to the Saronikos Gulf systematic monitoring network, total aliphatic hydrocarbon concentrations after the incident varied at lower levels in almost all cases (Table 3.2.1).

The presence of aliphatic hydrocarbons in marine sediments does not necessarily imply pollution since a significant proportion of them may be of biogenic origin, either marine or terrestrial (Bouloubassi and Saliot, 1993). Typically in the gas chromatography analysis the chromatographs of the aliphatic fractions have two characteristics: compounds which are sufficiently resolved and are predominantly *n*-alkanes; and a mixture of unresolved compounds, the so-called "unresolved complex mixture" (UCM: unresolved complex mixture). This mixture consists of branched, alicyclic and partially degraded hydrocarbons which cannot be separated by existing gas chromatography techniques. The existence of this mixture is to a large extent considered as an indication of the presence of residues of degraded petroleum products. The ratio of non-resolved to resolved aliphatic compounds (U/R) is often being used as a criterion for the origin of hydrocarbons and values for this ratio greater than 4 indicate chronic pollution from petroleum products (Mazurek and Simoneit, 1984).

The U/R ratio values for the considered surface sediment samples (Table 3.2.2) were greater than 5.2 in all cases, and greater than 7.7 in 96% of the cases, which clearly indicates chronic pollution from petroleum residues in the sediments, which can be rather attributed to the anthropogenic background associated with the petroleum burden of the Saronikos Gulf and not to the recent incident of the sinking of the Agia Zoni II. However, as discussed below, in some stations a mild petroleum burden associated to the Agia Zoni II incident is recorded, which however is very small in relation to the chronic petroleum-associated anthropogenic background of the area.

A typical gas chromatograph of the aliphatic fraction (full scan mode) of the considered sediment samples is presented below in Figure 3.2.8.

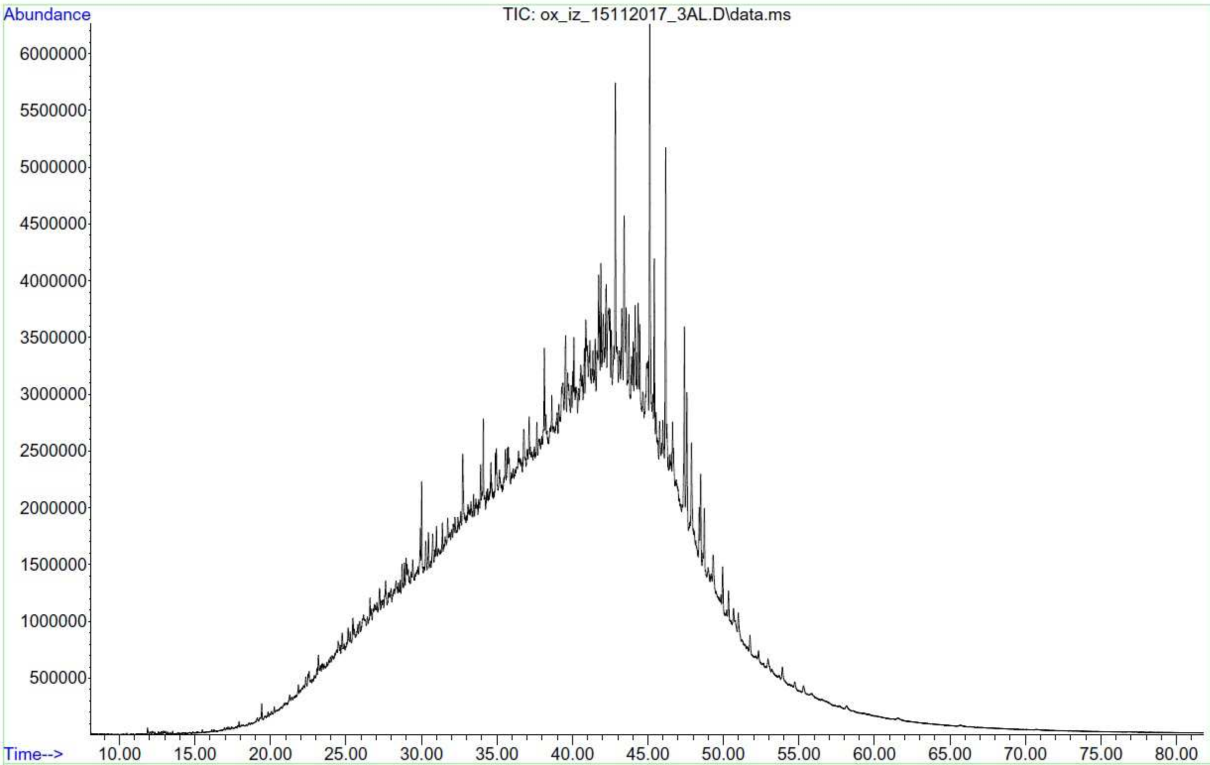

Figure 3.2.8. A typical gas chromatograph of the aliphatic fraction (full scan mode) of the considered sediment samples. The high ratio of non-resolved to resolved aliphatic compounds indicates chronic pollution from petroleum residues in the sediments, which can be rather attributed to the chronic petroleum-associated anthropogenic background of the Saronikos Gulf.

A similar distribution was observed for the concentrations of total polycyclic aromatic hydrocarbons in the considered sediments, which ranged from 53.1 to 4570 ng/g, with an average of 1180 ng/g, with the highest concentrations being recorded at S7 station in Psittaleia (Figure 3.2.7). Compared to the S7, S8, S11, S13, S16, and S43 stations belonging to the Saronikos Gulf systematic monitoring network, concentrations of total polycyclic aromatic hydrocarbons showed mixed trends. They were lower, after the incident, at S7 station in Psittaleia, higher at station S11 and S13, while in all other cases mixed trends were recorded (Table 3.2.1).

Polycyclic aromatic hydrocarbons (PAHs), with the exception of perylene that can be of biogenic origin and retene produced by coniferous trees on land, are purely anthropogenic compounds with primary sources being all kinds of combustion of organic materials (pyrolytic PAHs) but also petroleum products. As for the distribution of the individual compounds, Table 3.2.3 shows the percentage distributions of the concentrations of hydrocarbons of pyrolytic origin (sum of compounds with a molecular weight of 202, 228, 252, 276 and 278) and of petrogenic-petroleum origin (phenanthrene and its methylated derivatives) to the total sum of determined PAHs for the considered sediment samples. In marine sediments, the predominance of pyrolytic PAHs is common due to their greater stability and only in the case of recent petroleum pollution higher rates of petrogenic-petroleum PAHs are recorded.

Table 3.2.3. The percentage distributions of the concentrations of polycyclic aromatic hydrocarbons of pyrolytic origin and of petrogenic-petroleum origin to the total sum of determined PAHs for the considered sediment samples.

STATION	POLYCYCLIC AROMATIC HYDROCARBONS					
	21-22/09/2017		13-14/11/2017		23-24/01/2018	
	PETROGENIC (%)	PYROLYTIC (%)	PETROGENIC (%)	PYROLYTIC (%)	PETROGENIC (%)	PYROLYTIC (%)
S7	12.6	56.1	10.8	61.5	10.1	61.6
S8	14.1	58.9	12.9	63.8	11.3	63.0
S11	19.4	56.5	12.7	65.8	17.6	56.9
S13	11.1	65.5	15.9	55.1	14.3	57.3
S16	12.4	67.5	13.3	59.5	14.3	62.5
S43	12.8	62.9	12.7	64.0	12.1	63.9
AZ II	**25.6**	41.3	**19.0**	51.0	13.2	61.8
OS1	15.2	55.9	12.5	59.5	11.8	60.7
OS2	12.1	61.6	12.2	62.7	11.9	62.3
OS3	**50.2**	17.4	10.1	67.6	8.9	69.6
OS4	**46.6**	22.9	17.7	53.2	14.7	56.8
OS5	20.3	45.8	18.4	47.2	-	-
OS6	**48.7**	19.6	**21.2**	42.1	17.9	59.6
OS7	14.7	55.9	11.9	61.4	-	-
OS8	16.2	60.7	19.2	46.6	17.6	59.2
OS9	18.4	52.7	-	-	-	-
OS10	20.3	56.5	-	-	-	-
OS11	-	-	14.0	60.1	13.1	62.1

STATION	POLYCYCLIC AROMATIC HYDROCARBONS					
	21-22/09/2017		13-14/11/2017		23-24/01/2018	
	PETROGENIC (%)	PYROLYTIC (%)	PETROGENIC (%)	PYROLYTIC (%)	PETROGENIC (%)	PYROLYTIC (%)
OS12	-	-	11.8	65.7	14.7	55.8
OS13	-	-	14.0	58.3	15.9	53.2
OS14	-	-	10.5	62.9	9.5	62.8
OS15	-	-	15.7	59.2	16.2	54.8

As shown in Table 3.2.3 on September 21-22nd 2017, high percentages of petrogenic PAHs are recorded at stations OS3 (off Palaio Faliro), OS4 (off Agios Kosmas), OS6 (off Glyfada) and AZII (near the shipwreck). This suggests that a recent oil pollution imprint was recorded at these stations.

This observation is confirmed by GC.MS ion analysis (m/z 71) of the aliphatic fraction for the corresponding sediment samples (Figure 3.2.9) where an increase in the presence of normal alkanes in the *n*-C17 to *n*-C26 range is observed. The same molecular profile is found in samples of tar balls (24 in total) collected from the coastal zone of the Saronikos Gulf during the early days of coastal samplings, as well as, and most importantly, in the molecular profile of a petroleum sample drawn from the shipwreck of Agia Zoni II on September 16th 2017 and was distributed for analysis to H.C.M.R. (Figure 3.2.10). This fact clearly demonstrates that the recent petroleum pollution imprint encountered in these sediments is due to the Agia Zoni II incident.

In all cases this recent burden is very mild in respect to the chronic petroleum-associated anthropogenic background of the Saronikos Gulf, to the extent that it is not clearly reflected in the full scan chromatographic analysis of the aliphatic fractions.

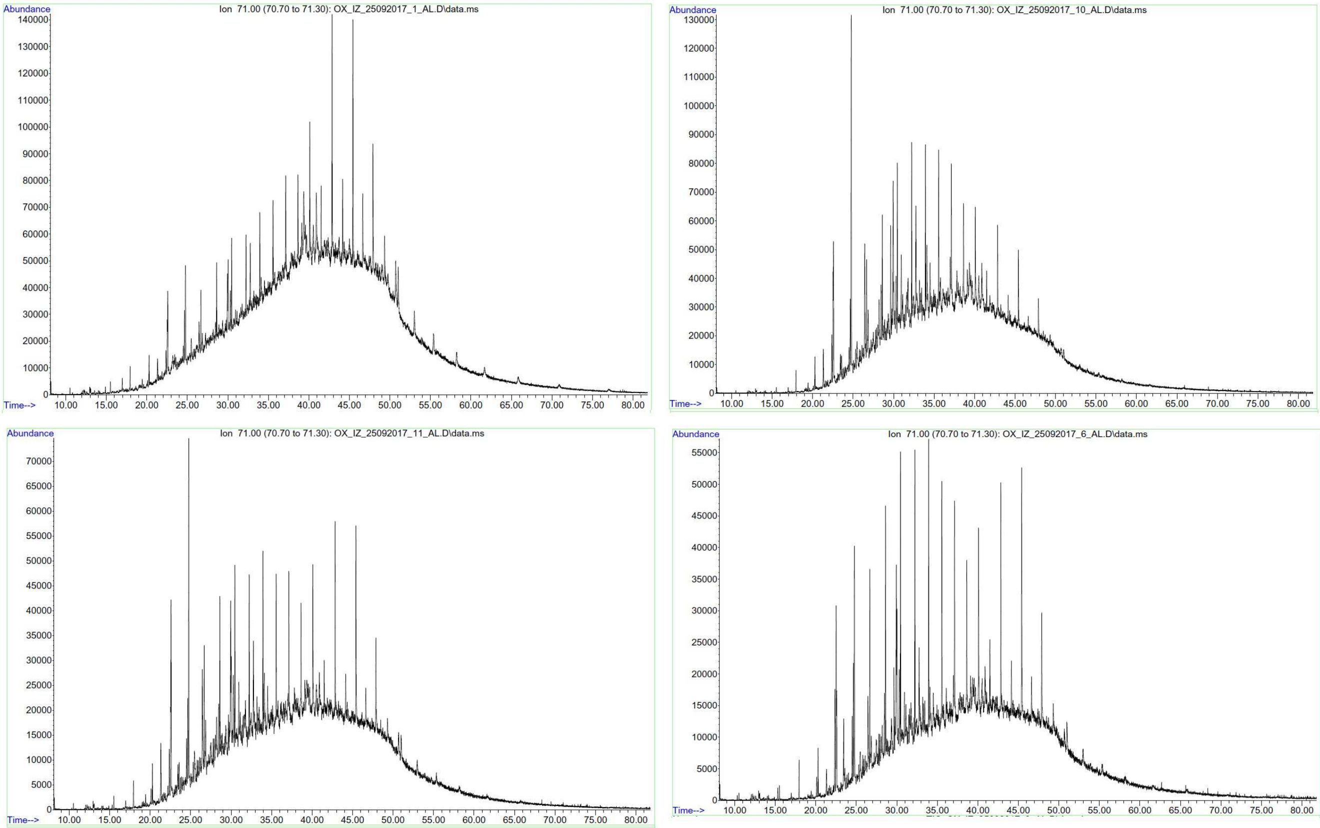

Figure 3.2.9. GC.MS trace (m/z 71) of the aliphatic fraction of the collected sediments at stations AZII (upper left), OS3 (upper right), OS4 (down left) and OS6 (down right) during the September 21-22nd 2017 sampling in the open Saronikos Gulf.

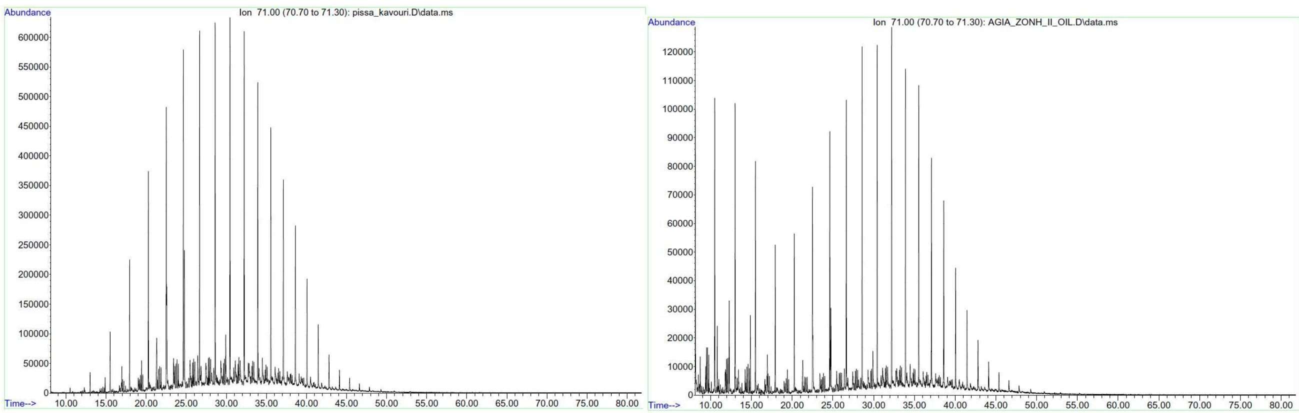

Figure 3.2.10. GC.MS trace (m/z 71) of the aliphatic fraction of a representative tar ball collected along the coastal zone of the Saronikos Gulf (left) and of a petroleum sample drawn from the shipwreck of Agia Zoni II and was distributed for analysis to H.C.M.R (right).

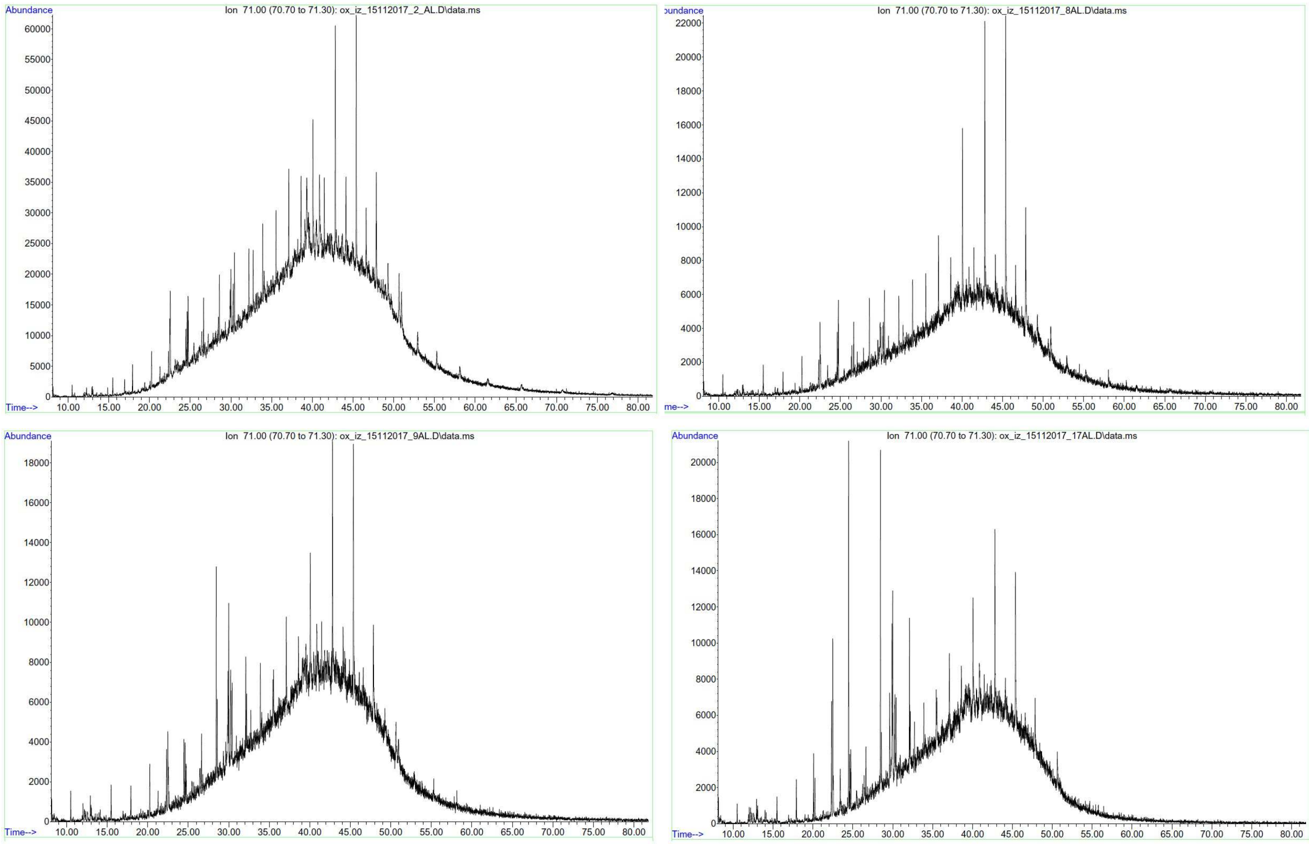

Figure 3.2.11. GC.MS trace (m/z 71) of the aliphatic fraction of the collected sediments at stations AZII (upper left), OS3 (upper right), OS4 (down left) and OS6 (down right) during the November 13-14th 2017 sampling in the open Saronikos Gulf.

On November 13-14th 2017 and furthermore on January 23-24th 2018 in the corresponding sediments the recent imprint associated to the Agia Zoni II incident appears to be reduced (Table 3.2.3, Figures 3.2.11 and 3.2.12). This could be likely attributed to the degradation of the petroleum-associated compounds (aliphatic and polycyclic aromatic hydrocarbons) during their residence in the sediment. However, the limitations in the sampling procedure associated with the use of a Box Corer sampler with a surface area of 40x40 cm should be considered, as discussed in Chapter 4 of this report.

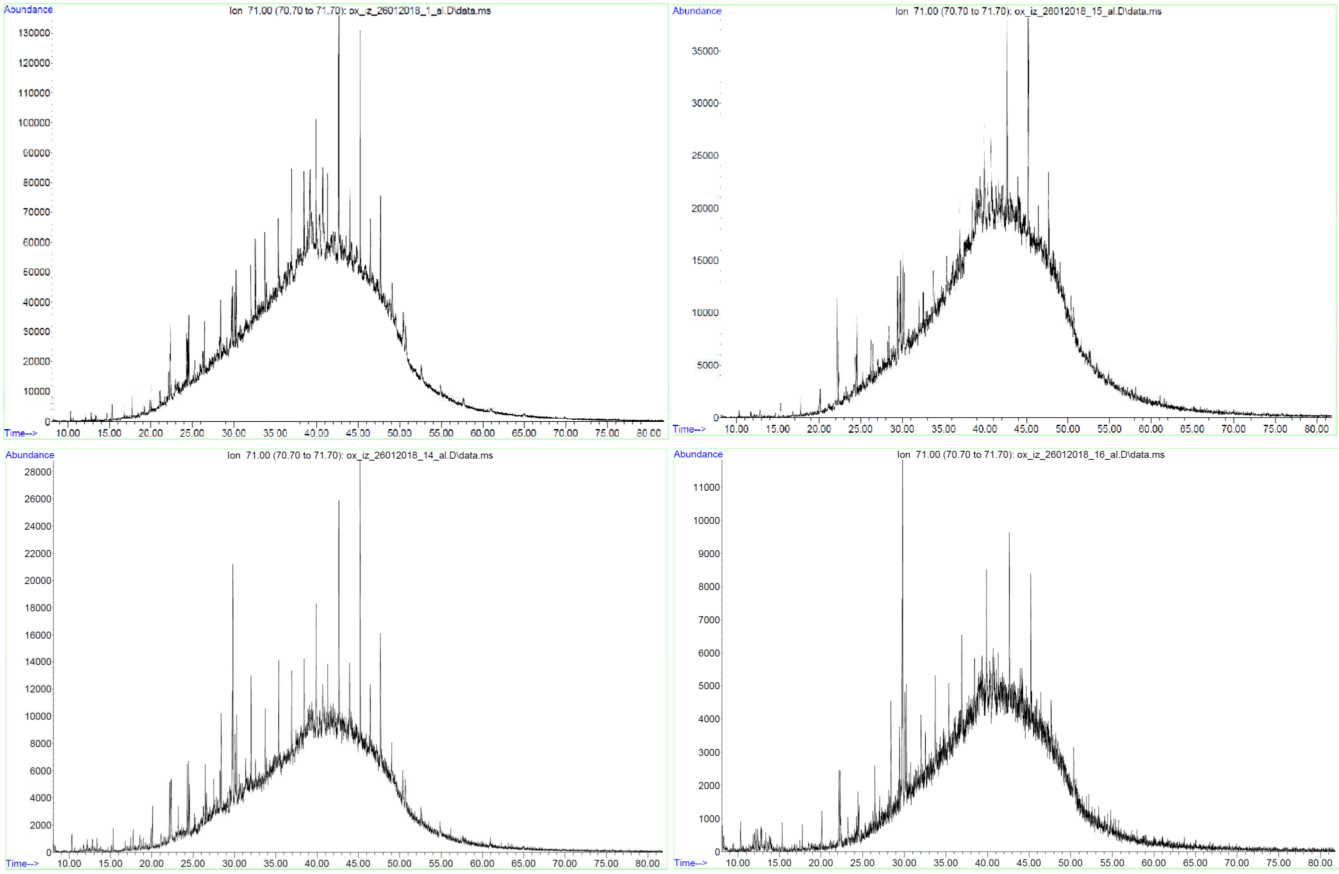

Figure 3.2.12. GC.MS trace (m/z 71) of the aliphatic fraction of the collected sediments at stations AZII (upper left), OS3 (upper right), OS4 (down left) and OS6 (down right) during the January 23-24th 2018 sampling in the open Saronikos Gulf

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3.3. GEOCHEMICAL STUDY OF SURFACE SEDIMENTS OF THE SARONIKOS GULF IN RESPECT TO POTENTIAL OIL CONTAMINATION

A.P. Karageorgis, Th. Kanellopoulos, A. Papageorgiou, I. Stavrakaki, A. Kikaki

The presence of several metals in crude oil is known since decades. Crude oil may be enriched in cadmium, chromium, cobalt, copper, iron, manganese, molybdenum, zinc, and mainly vanadium and nickel, which can be found to be > 400 and > 1500 mg kg^{-1}, respectively. Since the study area is regularly monitored in respect to the sediment content in heavy metals, is way possible to compare data collected prior and after the Agia Zoni II incident. The assessment of potential contamination was made on one hand by comparing absolute metal contents and secondly by the estimation of Enrichment Factors (EFs; Karageorgis et al., 2009), as described here after.

3.3.1. Methodology

In the present report we present results of sampling and analyses conducted in February 2016, March 2017, September 2017, November 2017 and January 2018 (Table 3.3.1 and Fig. 3.3.1). During the two sampling campaigns carried out prior to the accident, samples were collected from the regular monitoring network of stations of the Saronikos Gulf, whereas during the following three campaigns additional stations were occupied to describe in finer detail potential problems associated with the oil spill and its impact on the seabed.

All samples were collected with a stainless steel Box Corer with dimensions 40x40 cm. Using his particular sampler it is possible to sample undisturbed sediment from the upper 0-1 cm. The sampling stations network is illustrated in Figure 3.3.1. Bulk (not sieved and unwashed) samples were oven dried, ground to a fine powder in a twin swinging motorized mill with agate mortar and balls and were analyzed for their chemical composition in a Philips PW-2400 wavelength X-Ray fluorescence analyzer, equipped with Rh-tube. Major elements were determined in fused beads (SiO_2, Al_2O_3, TiO_2, Fe_2O_3, K_2O, Na_2O, CaO, MgO, P_2O_5). Fused bead preparation involved a complete fusion of 0.6 g of sample, with 5.4 g of flux (50:50 lithium meta-borate, lithium tetra-borate) and 0.5 g of lithium nitrate, the latter being used as an oxidizer. Loss on ignition (LOI) was determined after burning 1 g of sample for 1 h at 1000 °C.

Minor elements were determined according to the following procedure: 5 g of powdered sample were mixed with 1.5 g of wax and subsequently pressed in a 31 mm aluminium cup. The powder pellets were analyzed in the XRF to determine minor element contents; herein we report results for V and Ni only. Analytical accuracy was checked by parallel analysis of certified sediment standards (MESS-2, PACS-2, MAG-1) and was found to be satisfactory for all elements analyzed (for details see Karageorgis et al. 2005).

Recent participation of the XRF laboratory in a blind inter-laboratory exercise organized by the International Atomic Energy Agency showed excellent performance of the method (Table 3.3.2) (IAEA, 2013; laboratory code No. 11).

Table 3.3.1. Sampling stations in Saronikos gulf during February 2016, March 2017, September 2017, November 2017 and January 2018. Coordinates in decimal degrees and depths in meters.

February 2016				**March 2017**			
Station	**Latitude**	**Longitude**	**Depth**	**Station**	**Latitude**	**Longitude**	**Depth**
S1	38.01765	23.55448	20	S1	38.01817	23.55483	20
S1W	38.03143	23.57030	12.6	S1W	38.03100	23.56900	13
S1E	38.03002	23.57645	12.2	S1E	38.03000	23.57667	12
S2	38.00055	23.45268	30	S2	38.00067	23.45233	31
S3	37.57300	23.36000	29.3	S3	37.94967	23.58333	27
S7	37.55420	23.35450	68	S7	37.92433	23.59000	70
S7W	37.55880	23.32880	29				
S7N	37.55956	23.35059	61				
S8	37.53000	23.32000	93	S8	37.88267	23.54083	95
S11	37.52360	23.38300	77	S11	37.87350	23.63800	77
S13	37.50410	23.27300	89	S13	37.84083	23.45417	90
S16	37.47230	23.42040	85	S16	37.78833	23.70167	91
S26	37.54100	23.37080	84	S26	37.90167	23.61800	85
S43	37.87783	23.58717	92	S43	37.87983	23.58683	93
September 2017				**November 2017**			
Station	**Latitude**	**Longitude**	**Depth**	**Station**	**Latitude**	**Longitude**	**Depth**
S1	38.01823	23.55432	20	S1	38.02046	23.5554	20
S1W	38.03110	23.56933	12	S1W	38.0315	23.5700	12
S1E	38.03027	23.57655	12	S1E	38.0316	23.5554	20
S2	38.00090	23.45325	54	S2	38.0011	23.4495	30
S3	37.94993	23.58342	32	S3	37.9496	23.5828	30
S7	37.92345	23.59112	70	S7	37.9245	23.5916	70
S8	37.88752	23.52953	91	S8	37.8669	23.5341	92
S11	37.87542	23.63487	75	S11	37.8732	23.6383	76
S13	37.84472	23.45608	92	S13	37.8413	23.4530	89

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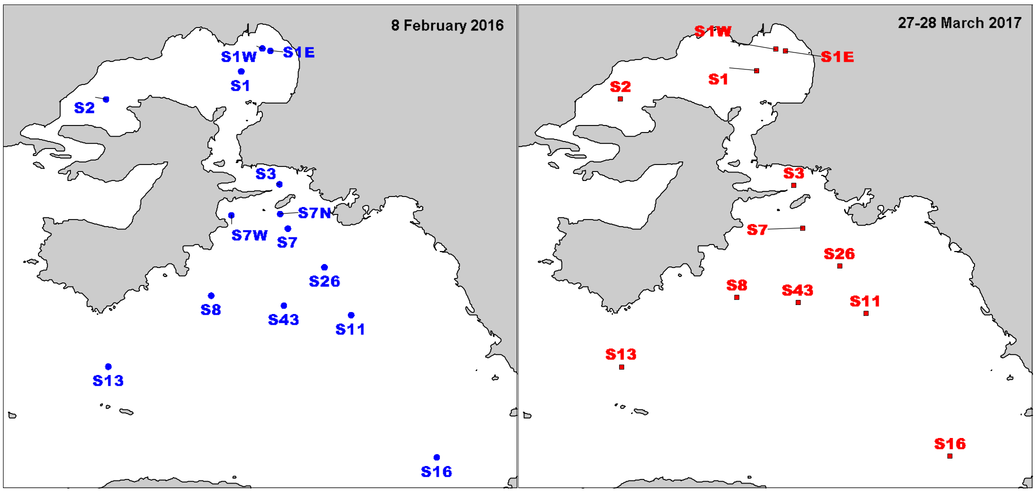
September 2017				November 2017			
Station	**Latitude**	**Longitude**	**Depth**	**Station**	**Latitude**	**Longitude**	**Depth**
S16	37.78913	23.70005	86	S16	37.7896	23.7065	83
S43	37.87950	23.58463	91	S43	37.8732	23.5860	91
AZII	37.92952	23.56952	50	AZII	37.9295	23.5691	49
OS1	37.92345	23.54012	49	OS1	37.9221	23.5454	52
OS2	37.92242	23.63137	54	OS2	37.9199	23.6325	63
OS3	37.92617	23.67332	20	OS3	37.9245	23.6730	20
OS4	37.89498	23.68200	46	OS4	37.8928	23.6862	45
OS5	37.84700	23.67100	70	OS5	37.8466	23.6712	69
OS6	37.85797	23.71625	34	OS6	37.8546	23.7187	36
OS7	37.84293	23.59390	90	OS7	37.8384	23.5967	92
OS8	37.80358	23.75105	53	OS8	37.8040	23.7497	50
OS9	37.78522	23.80167	56	OS11	37.9107	23.5913	90
OS10	37.73020	23.88172	53	OS12	37.8965	23.6389	71
				OS13	37.8577	23.6798	47
				OS14	37.9062	23.6601	58
				OS15	37.8256	23.7067	52
January 2018							
Station	**Latitude**	**Longitude**	**Depth**				
S1	38.02046	23.5554	20				
S1W	38.0315	23.5700	13				
S1E	38.0316	23.5554	23				
S2	38.0011	23.4495	30				
S3	37.9496	23.5828	30				
S7	37.9245	23.5916	75				
S8	37.8669	23.5341	90				
S11	37.8732	23.6383	75				
S13	37.8413	23.4530	90				
S16	37.7896	23.7065	90				
S43	37.8732	23.5860	93				
OS1	37.9221	23.5454	23				
OS2	37.9199	23.6325	70				
OS3	37.9245	23.6730	20				
OS4	37.8928	23.6862	45				
OS6	37.8546	23.7187	34				
OS8	37.8040	23.7497	46				
OS11	37.9107	23.5913	95				
OS12	37.8965	23.6389	79				
OS13	37.8577	23.6798	45				
OS14	37.9062	23.6601	65				
OS15	37.8256	23.7067	53				
AZII	37.9295	23.5691	23				

Table 3.3.2. Results of the inter-laboratory exercise IAEE-458 for the analysis of major and minor elements in marine sediment (IAEA, 2013).

IAEA-458 Sediment Reference values				HCMR-IO XRF Laboratory Results		
Element	**Unit**	**Reference value**	**Expanded uncertainty**	**Element**	**Mean Value**	**Expanded uncertainty**
Al	g·kg^{-1}	82.8	4.2	Al	84.70	8.20
As	mg·kg^{-1}	10	0.8	As	11	3
Co	mg·kg^{-1}	15.6	1.2	Co	15	3.1
Cr	mg·kg^{-1}	91.5	8.6	Cr	87	15
Cu	mg·kg^{-1}	48.1	3.1	Cu	45	15
Fe	mg·kg^{-1}	40.7	2	Fe	40.50	0.52
Mn	mg·kg^{-1}	886	38	Mn	885	100
Ni	mg·kg^{-1}	40	2.8	Ni	38	4
Pb	mg·kg^{-1}	35.5	2	Pb	35	6
Sn	mg·kg^{-1}	5.58	0.71	Sn	7.2	2.4
Sr	mg·kg^{-1}	124	6	Sr	125	33
V	mg·kg^{-1}	99.8	10	V	95	21
Zn	mg·kg^{-1}	154	7	Zn	144	24



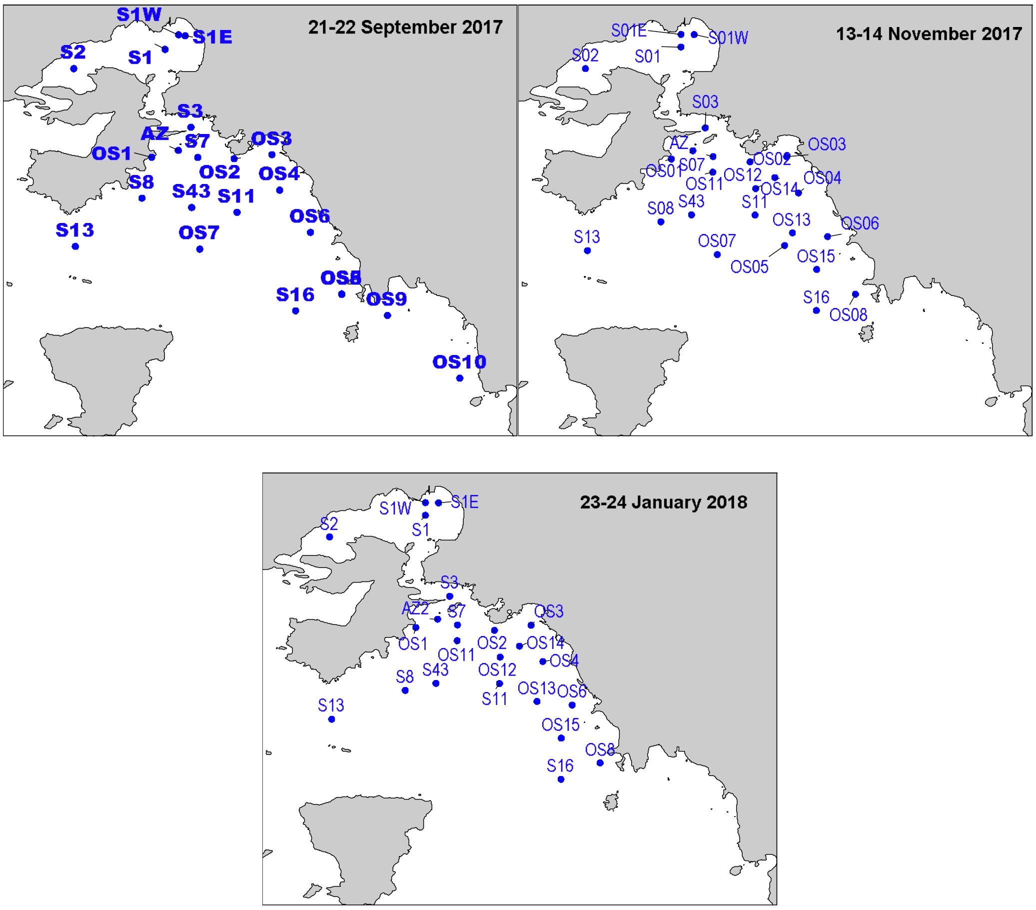


Figure 3.3.1. Saronikos sampling sites in February 2016, March 2017, September 2017, November 2017 and January 2018.

3.3.2. Results and Discussion

The contents of Saronikos Gulf sediments in V and Ni (mg kg^{-1}) are presented in Table 3.3.3 and the spatial distribution of the two elements in Figure 3.3.2. Initially we observe that mean values of metal contents prior to the incident and approximately at the same network of stations are very similar, i.e. 46 and 45 mg kg^{-1} for vanadium and 69 and 66 mg kg^{-1} for nickel. In the following months mean values decrease to 32, 29 and 34 mg kg^{-1} for vanadium and 52, 50 and 59 mg kg^{-1} for nickel. This decrease is due to the fact that the additional stations occupied for the detailed coverage of the area (named OS) are generally sandier and therefore have naturally lower metal contents. Estimating mean metal values for September 2017, November 2017 and January 2018 only for the regular monitoring network stations, values similar to the previous months, February 2016 and March 2017, derive (in chronological order; V: 46, 45, 46, 39, 51 and 39 mg kg^{-1}, Ni: 69, 66, 70, 69 and 88 mg kg^{-1}). Nevertheless, the values of the examined metals don't show any enrichment after the incident, indicating that there is no impact associated with oil contamination.

Table 3.3.3. Content of surface sediments in vanadium and nickel (in mg kg^{-1}) prior to and after the incident in all stations of the network of regular and additional stations.

February 2016			March 2017			September 2017			November 2017			January 2018		
Station	V	Ni	Station	V	Ni	Station	V	Ni	Station	V	Ni	Station	V	Ni
S1	97	92	S1	88	90	S1	84	86	S01	76	79	S01	83	92
S1W	79	72	S1W	59	54	S1W	76	73	S01W			S01W	110	186
S1E	76	62	S1E	72	62	S1E	56	51	S01E			S01E	96	153
S2	79	163	S2	76	139	S2	78	139	S02	76	138	S02	78	139
S3	31	67	S3	36	54	S3	41	75	S03	32	61	S03	36	65
S7	55	85	S7	49	85	S7	52	90	S07	50	91	S07	43	78
S7W	18	37												
S7N	32	67												
S8	46	87	S8	45	93	S8	44	94	S08	43	90	S08	39	79
S11	14	25	S11	9	18	S11	14	21	S11	10	25	S11	12	28
S13	21	45	S13	19	41	S13	21	48	S13	18	43	S13	15	42
S16	22	34	S16	11	21	S16	7	15	S16	9	19	S16	10	22
S26	34	54	S26	28	53									
S43	43	81	S43	42	86	S43	37	75	S43	39	79	S43	41	89
						AZ2	20	43	AZ2	24	46	AZ2	16	122
						OS1	17	34	OS1	17	35	OS1	18	37
						OS2	50	88	OS2	49	87	OS2	50	86
						OS3	15	20	OS3	30	44	OS3	13	18
						OS4	13	22	OS4	13	22	OS4	13	21
						OS5	16	29	OS5	10	18	OS5		
						OS6	12	16	OS6	10	10	OS6	10	43
						OS7	29	60	OS7	33	71	OS7		
						OS8	6	13	OS8	9	17	OS8	10	48
						OS9	22	32						
						OS10	7	10						
									OS11	36	67	OS11	37	71
									OS12	15	23	OS12	14	23
									OS13	7	10	OS13	11	16
									OS14	45	67	OS14	28	40
									OS15	11	14	OS15	7	9
min	14	25		9	18		6	10		7	10		7	9
max	97	163		88	139		84	139		76	138		110	186
mean	46	69		45	66		32	52		29	50		34	59
st. dev	27	34		26	34		24	35		21	34		30	48

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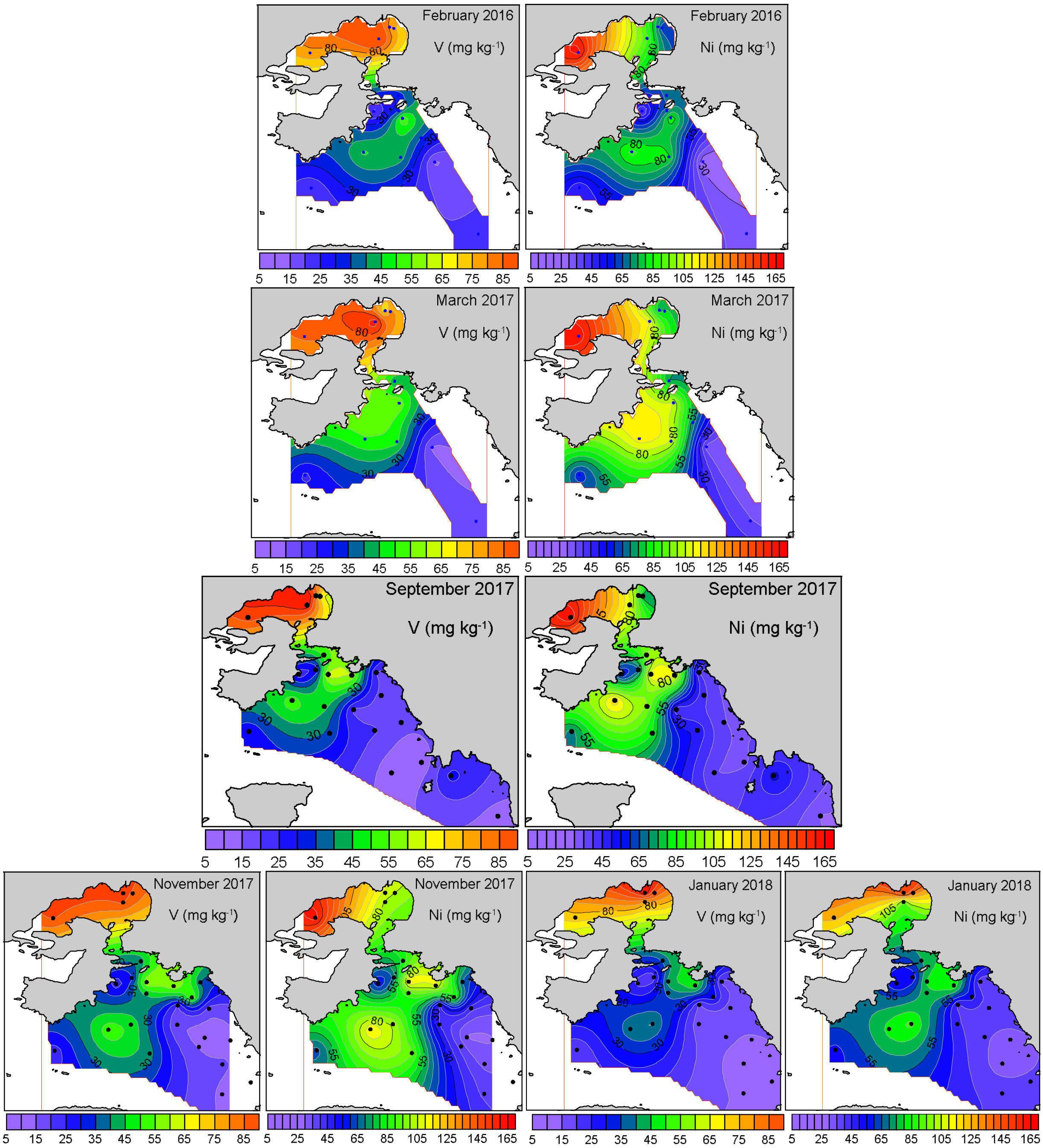


Figure 3.3.2. Spatial distribution of vanadium and nickel contents in February 2016, March 2017, September 2017, November 2017 and January 2018.

Looking into the spatial distributions of the metals in the five sampling periods, we observe no significant variations in the study area. Elefsis Gulf and the area south-southwest of the Psyttaleia Island in the outer Saronikos gulf exhibit locally increased values of the specific elements, which are due to the fine texture of the sediments, rather than anthropogenic influence, as we will explain below. By contrast, the east and southeast sector of the Saronikos Gulf exhibits low metal contents, which are associated with the sandier texture of the sediments and shows overall good conditions. From this examination, absence of impact in respect to the Agia Zoni II incident and the subsequent oil spill is derived.

A reliable method to estimate the degree of contamination of a sediment in respect to the considered pristine sample of the same study area are the Enrichment Factors (EF; Ackermann, 1980; Luoma, 1990; Grousset et al., 1995). Enrichments Factors are calculated as follows:

$$EF = \frac{\left(\frac{El}{Al}\right) sed}{\left(\frac{El}{Al}\right) rs}$$

where $[El]_{sed}$ is the content of a minor element in the sediment, $[Al]_{sed}$ is the Al content in the sediment, and $[El]_{rs}$ and $[Al]_{rs}$ the contents of the element and Al in the reference sediment. The use of element rations to a lithogenic element as Al, aims at compensating for variations due to salts, organic carbon, and carbonates, and mostly to smooth grain-size variations between samples. It is a common normalization technique applied according to the literature (Förstner and Wittmann, 1983, Van Der Weijden, 2002). Al is used very often as a normalizer as it belongs to the lithogenic fraction of the sediment. Other elements often used as normalizers are Ti, Rb, Sc, Zr and other. The selection of Al a normalizer was based on the coefficient of variation *V* (standard deviation divided by the mean), after Van Der Weijden (2002).

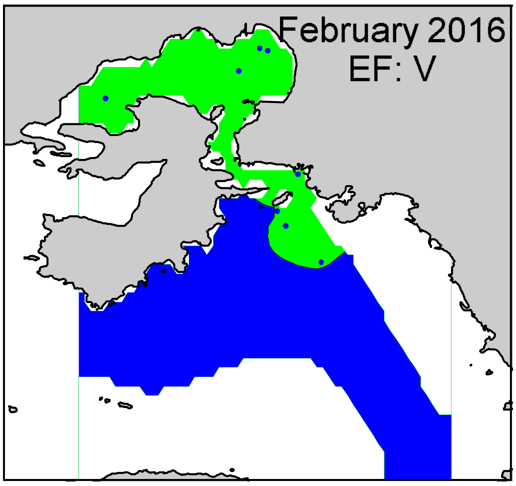
As a reference sediment we used the mean value of 7 samples (30-47 cm) obtained from a core sediment (S07, depth 70 m, south of Psyttaleia Island) collected in 2009 and analyzed with the same methods. Moreover, the samples have sandy mud texture, and are rich in carbonates, therefore have similar composition to the other samples from the study area. After radiocarbon AMS dating of shells from a depth 45-46 cm, we estimated the sedimentation rate in the vicinity of station S07 to 0.45 cm 100 y^{-1}, therefore the reference sediment is definitely dated at a pre-industrial period. EF values from 0 to 1 indicate background values, values 1-2 are also considered as similar to the reference sediment and are therefore lying within natural (non-anthropogenic) variability (GROUSSET *et al.*, 1995, SHUMILIN *et al.*, 2002). EF values 5>EF>2 indicate moderate enrichment and >5 high enrichment. The results are presented in Table 3.3.4 and the spatial distribution of EFs for the 4 sampling periods in Figure 3.3.3.

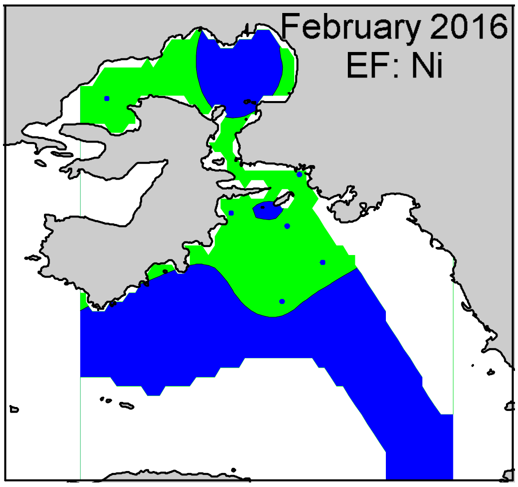
Table 3.3.4. Enrichment Factors for vanadium and nickel before and after the incident in all stations of the regular and extended monitoring network.

February 2016			March 2017			September 2017			November 2017			January 2018		
Station	V	Ni	Station	V	Ni	Station	V	Ni	Station	V	Ni	Station	V	Ni
S1	1.2	0.6	S1	1.4	0.9	S1	1.4	0.9	S1	1.0	0.7	S1	1.3	0.9
S1W	1.3	0.8	S1W	1.5	0.9	S1W	1.5	0.9	S1W			S1W	1.2	1.3
S1E	1.6	1.0	S1E	1.7	0.9	S1E	1.5	0.9	S1E			S1E	1.2	1.2
S2	1.3	1.9	S2	1.8	2.1	S2	1.9	2.2	S2	1.8	2.0	S2	1.6	1.8
S3	1.4	1.7	S3	0.8	0.8	S3	1.6	1.8	S3	1.6	1.9	S3	1.1	1.3
S7	1.1	1.4	S7	1.4	1.6	S7	1.5	1.6	S7	1.4	1.7	S7	1.4	1.6
S7W	0.9	1.0												
S7N	1.0	0.9												
S8	1.0	0.9	S8	1.2	1.6	S8	1.1	1.4	S8	1.2	1.6	S8	0.9	1.1
S11	0.3	0.3	S11	2.2	2.7	S11	1.4	1.3	S11	0.5	0.8	S11	0.8	1.2
S13	0.7	0.8	S13	1.5	2.1	S13	1.2	1.8	S13	0.9	1.3	S13	0.8	1.4
S16	0.9	0.6	S16	1.8	2.0	S16	0.9	1.2	S16	1.3	1.7	S16	0.6	0.9
S26	1.1	1.5	S26	1.3	1.6									
S43	0.8	1.1	S43	1.2	1.6	S43	1.1	1.4	S43	1.2	1.6	S43	1.0	1.4
						AZII	1.6	2.2	AZII	1.8	2.1	AZII	1.6	2.4
						OS1	1.2	1.5	OS1	1.5	1.9	OS1	1.3	1.6
						OS2	1.2	1.4	OS2	1.0	1.2	OS2	1.2	1.3
						OS3	1.5	1.3	OS3	1.4	1.3	OS3	1.3	1.1
						OS4	1.3	1.3	OS4	1.2	1.3	OS4	0.9	0.9
						OS5	1.3	1.6	OS5	1.9	2.3	OS5		
						OS6	1.7	1.4	OS6	1.1	0.7	OS6	1.9	1.7
						OS7	1.1	1.5	OS7	1.2	1.7	OS7		
						OS8	2.3	3.2	OS8	0.7	0.9	OS8	0.9	1.0
						OS9	1.1	1.1	OS11	1.1	1.3	OS11	1.1	1.3
						OS10	1.1	0.9	OS12	1.0	1.0	OS12	1.1	1.1
									OS13	2.0	1.7	OS13	2.1	1.9
									OS14	1.2	1.1	OS14	1.5	1.3
									OS15	0.9	0.7	OS15	0.9	0.7

We observe that in February 2016 all EF values are within natural limits for vanadium and nickel, whereas in March 2017 a minor enrichment in the vicinity of stations S11, S13 and S16 is observed, which are however sandy, with high biogenic carbonates abundance, and in parallel low values of the normalizing element Al; therefore, those results are not alarming. The situation after the incident, in September 2017, November 2017 and January 2018 is similar. i.e. absence of high EFs for vanadium and nickel, except for stations AZII, OS5, OS8 and OS13, which are also sandy, with high percentages of biogenic carbonates and low Al.

The spatial distribution of EFs in February 2016 and March 2017 shows that the entire area exhibits values within normal limits. Relatively high values observed in the southwestern and southeastern sector of the outer Saronikos gulf are attributed to the sandy, biogenic texture of the sediments. Similar patterns occur for the EF values in September 2017, November 2017 and January 2018, which vary almost entirely between 1 and 2, i.e. within natural limits. Small exceptions in two coastal stations are associated with the coarse texture of the sediments. In any case, Enrichment Factors show there is no metal enrichment of the sediments in vanadium and nickel either before or after the incident.





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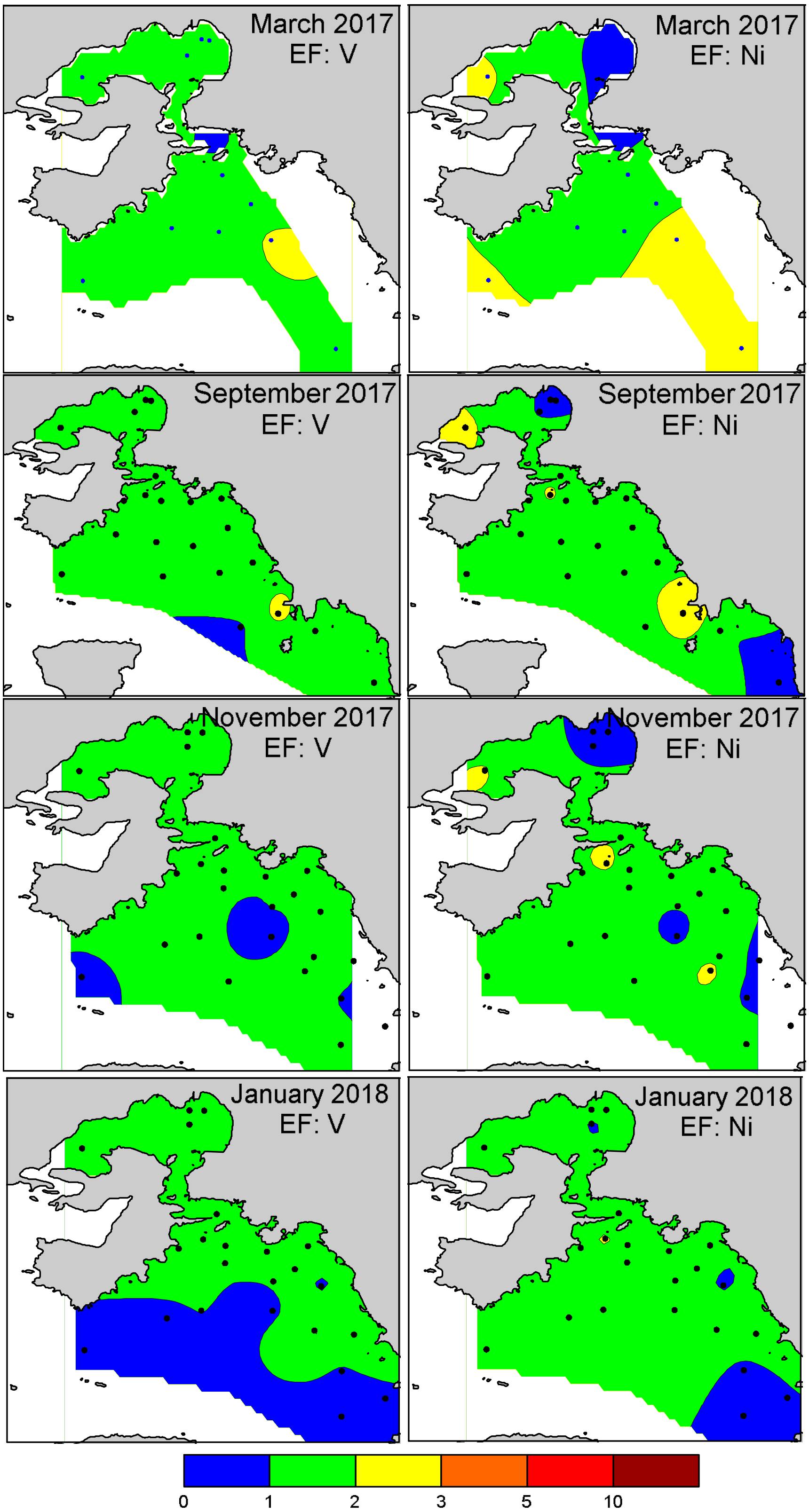

Figure 3.3.3. Spatial distributions of Enrichment Factors (EF) for vanadium and nickel in February 2016, March 2017, September 2017, November 2017 and January 2018.

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3.4. CONTAMINANT BIOACCUMULATION AND EFFECTS IN MARINE ORGANISMS

3.4.1. Assessment of bioaccumulation and biological effects of contaminants in mussels (*Mytilus galloprovincialis)*

Tsangaris, C., Strogyloudi, E., Hatzianestis, I., Parinos, C., Kouerinis, N., Plakidi, E., Chourdaki, S., Pappas G.

3.4.1.1. Introduction

In order to investigate potential bioaccumulation of petroleum hydrocarbons and of other organic and inorganic contaminants from the incident, and to assess related biological effects of pollution in the study area, bivalves and specifically mussels of the genus *Mytilus* (Cardellicchio et al., 2008; Pellerin and Amiard, 2009) were used as bioindicator organisms. The benthic species *Mytilus galloprovincialis* is a bivalve mollusc, which flourishes in coastal waters, attached to the hard bottom where its natural populations are covering large surfaces. Under natural conditions, it is the dominant species in its ecological niche. It is a cosmopolitan sedentary species, it has a long life, it is easy to collect and identify, tolerant of exposure to environmental variations in physicochemical parameters and resistant to handling stress caused by laboratory experiments or field transplantation.

Due to their feeding behavior (they are filter feeders) mussels take up large amounts of the available contaminants in their ambient waters even if polluting substances are at low concentrations. They are used as indicator species in pollution monitoring studies worldwide (M*ussel Watch*). Active biomonitoring using transplanted mussels is considered as a useful approach to measure bioavailability and effects of contaminants for the assessment of the quality of the marine environment and is widely used in the Mediterranean Sea (http://mytilos.tvt.fr/; http://mytimed.tvt.fr/).

The genetic uniformity of the transplanted individuals eliminates fluctuations originating from genetic variability. The selection of individuals of certain size from the parental population ensures similarity in age and sexual maturity of the transplanted specimens. In addition, this approach provides the potential to transport mussels in a wide network of areas where natural mussel populations are not present. The study of contaminant concentrations in bioindicator organisms represents an integrated measure of the bioavailable contaminant levels in the environment which is not affected by short-term fluctuations (Wang and Rainbow, 2008).

Biological effects of pollution are among the tools proposed for the evaluation of pollution effects, one of the criteria used for the assessment of Good Environmental Status of Marine Waters according to the Marine Strategy Framework Directive (2008/56/EC) (JRC, 2010). Biomarkers are methods developed in the few last decades for assessing biological effects of pollution used in environmental monitoring programmes for risk assessment and monitoring of pollution impacts (Walker et al, 2016). Biomarkers detect early responses of indicator organisms to environmental stress before disturbances such as disease, mortality and population changes occur, thus provide early warning signals of environmental disturbance. Biomarkers have been applied in several studies assessing the impact of oil spills and have been clearly proven useful particularly for the assessment of sublethal effects (Martinez-Gomez et al., 2010).

Catalase (CAT) is an enzyme of the antioxidant defense against oxidative stress that can arise from exposure to various contaminants. Glutathione S-transferase (GST) is an enzyme of the phase II biotransformation of organic contaminants and also a component of the antioxidant defense. Catalase and glutathione S-transferase can be induced or inhibited by contaminant exposure (Viarengo et al., 2007). AChE is an enzyme involved in nerve impulse transmission, and its inhibition is an established biomarker of neurotoxicity (Fulton and Key, 2001). CAT, GST and AChE are among the biomarkers proposed as suitable for assessing oil spill impacts (Martnez-Gomez et al., 2010). Metallothioneins (MTs) are metal-binding storage non-enzymatic proteins with different metal affinity (Hg^{2+}>Cu^{+}>Cd^{2+}>Zn^{2+}). Their induction is considered as metal exposure biomarker while they are part of the antioxidant defence system of the organisms (Amiard et al., 2006).

3.4.1.2. Methodology

In order to investigate the potential bioaccumulation of petroleum hydrocarbons and of other organic and inorganic contaminants and to assess the possible biological effects of the Agia Zoni II incident in the study area, mussels *Mytilus galloprovincialis* were immersed in cages on January 23-24th 2018 at four sites, Salamina (MUS1), Agios Kosmas (MUS2), Glyfada (MUS3) and Asteras Vouliagmenis (MUS4) (Figure 3.4.1). Asteras Vouliagmenis (MUS4) was used as a reference site. The mussel cages were immersed at two depths in each site (5 and 20 m below the sea surface) and were collected after approximately six weeks on March 7th 2018.

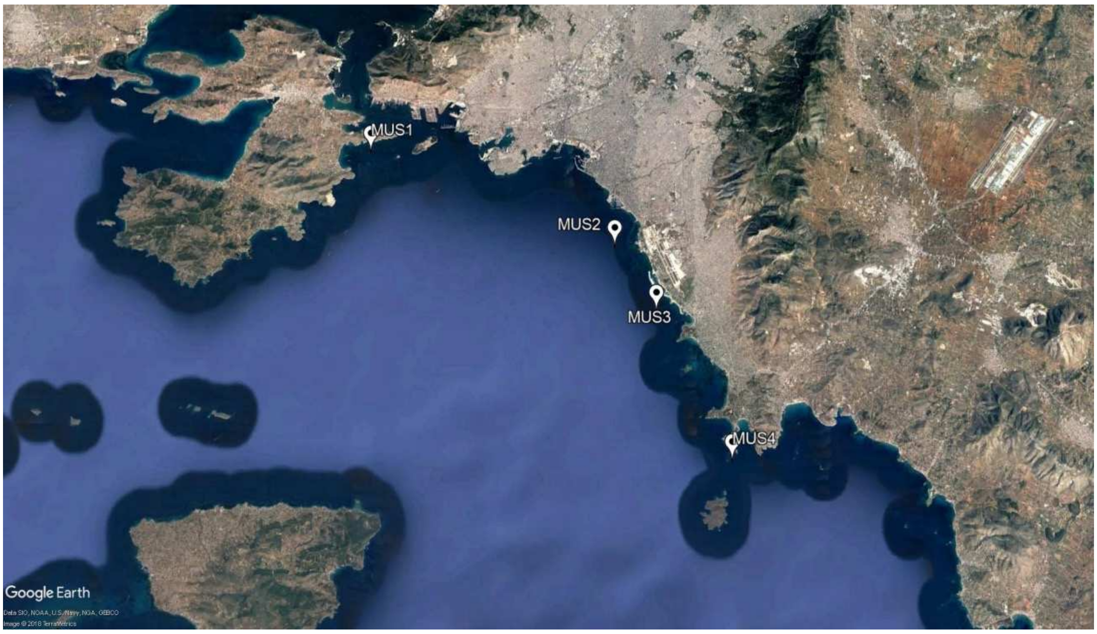


Figure 3.4.1. Sites of mussel cages immersion in January 2018.

In the collected mussels: (a) the concentrations of hydrocarbons and heavy metals were determined in their tissue, (b) a set of biomarkers indicative of oxidative stress (catalase), phase II biotransformation (glutathione S-transferase) and neurotoxicity (acetylcholinesterase) were measured, (c) condition index (CI) was determined as a measure of the health status of the animals that summarizes their physiological activity (e.g., growth, reproduction, secretion) under given environmental conditions (Pampanin et al., 2005) and (d) metallothioneins (MTs) were determined.

After their collection, the mussels were transported to the laboratory where, after their body characteristics were recorded, their tissue was isolated, freeze-dried under low pressure and temperature and then homogenized, before the determination of hydrocarbons and heavy metals. The mean wet to dry weight ratio of the mussels whole body soft tissue was 10.1 and this ratio can be used to convert the concentration units from the dry to the wet weight basis. Mean mussels hell length was 6-7 cm.

For the determination of hydrocarbons, after the addition of internal standards, the fresh tissue is saponified with a methanolic potassium hydroxide solution and the non-saponified components are extracted with *n*-hexane, followed by purification and fractionation by column chromatography on silica. The determination of aliphatic and polycyclic aromatic hydrocarbons in the two fractions collected was carried out by gas chromatography - mass spectrometry (see Chapter 3.2.1).

For the study of mussel metal concentrations, 30 pooled samples were prepared from the whole body soft tissue of the organisms of 20 individuals each, per station and depth for MUS1, MUS3 and MUS4 stations. Due to the limited remaining available mussels at station MUS2, only 3 pooled samples were prepared for this station (of 6 individuals each) from mussels placed near the bottom at 20 m depth. Nitric acid digestion of the homogenized dry tissue was performed into Teflon vessels in an ETHOSEZ/Milestone microwave digestion system. Cu, Zn, Fe and Mn concentrations were determined by flame Atomic Absorption Spectroscopy using the AA7000 Shimadzu spectrophotometer. Concentrations are expressed as μg of the metal per g of dry weight of the tissue. The accuracy and precision of metal chemical analysis in organisms were verified with certified reference materials of known metal concentrations and the measurement of control samples in random order amongst the mussel samples.

For the study of metallothionein (MT) concentrations, 40 pooled samples were prepared from the mussel digestive gland (5 pooled samples per station and depth of 6 individuals each). MTs content was evaluated according to the spectrophotometric method (Viarengo et al., 1997) in these mussel digestive gland samples. The MTs containing fraction was gradually isolated. Measurements were performed in a PerkinElmer (UV/VIS, Lamda 20) spectrophotometer at 412 nm. Concentrations are expressed as μg MT/g ww of the tissue.

For mussel metal and MTs concentrations, the Kolmogorov-Smirnov test was applied to determine whether data can be adequately modelled by the normal distribution. One-way analysis of variance (One-Way ANOVA) was performed to determine which means are significantly different from which others at the 95.0% confidence level. Post hoc comparisons assessed by the LSD test. Tests were performed using the statistical package Statgraphics Plus.

For CAT, GST and AChE biomarker analyses, gills and digestive glands of 30 individuals per site were dissected just after collection. Tissue samples were pooled (samples of six individuals) and five pooled samples per site were frozen in liquid nitrogen and stored at -70 ºC. CAT and GST activities were measured in digestive glands while AChE activities were measured in the gills.

For CAT and GST activity measurements, digestive glands were weighed, cut in small pieces and then homogenized using a Potter-Elvehjem homogenizer (Heidolph Electro GmbH, Kelheim, Germany) in 1:4 (w/v) 100 mM KH_2PO_4/K_2HPO_4, pH 7.4, 1 mM EDTA. Homogenates were centrifuged at 10,000×g for 30 min. All preparation procedures were carried out at 4 °C. CAT activity was measured through the loss of H_2O_2 that was measured colorimetrically with ferrous ions and thiocyanate on a microplate reader (BIOTEK Synergy HTX Multi-Mode Microplate Reader) (Cohen et al. 1996). CAT activity was determined by the difference in the absorbance at 490 nm per unit of time. CAT activity results are expressed in terms of the first-order reaction rate constant (k) and protein content as follows: U/mg proteins=k/mg proteins=[ln (A1/A2)/(t_2 −t_1)]/mg proteins where U represents units, ln is the natural log, and A1 and A2 are the observed mean absorbance at 490 nm at two time points, t_1 = 1 min and t_2 = 4 min. GST was measured by the method of Habig and Jacoby (1981) with 1-chloro-2,4-dinitrobenzene (CDNB) as a conjugation substrate, adapted to microplate reading by McFarland et al. (1999). Activity was expressed as nanomoles of conjugate per minute per milli- gram of proteins.

For AChE measurements, gill tissues were homogenized using a Potter-Elvehjem homogenizer in 1:2 (w/v) 0.1 M Tris–HCl buffer containing 0.1 % TRITON X 100, pH 7. Homogenates were centrifuged at 10,000×g for 20 min. All preparation procedures were carried out at 4°C. AChE activity was assayed by the method of Ellman et al. (1961) adapted to microplate reading by Bocquené et al. (1993). Enzyme activity was expressed as nanomoles of acetylthiocholine hydrolyzed per minute per milligram of proteins. Total protein content in the tissue extracts was measured using bovine serum albumin (BSA) as a standard (Bradford 1976).

For CI measurements, whole soft tissues of 30 to 50 individuals per sitewere stored at -20 °C. The whole soft tissues were dissected and lyophilized; shells were dried at 60 °C for 48 h and then weighed. The ratio of dry flesh weight to dry shell weight (FW/SW × 100) was used to determine CI for each sample.

CAT, GST, AChE and CI data are presented as mean ± SD. To assess for significant differences of CAT, GST, AChE and CI among sites, two-way analysis of variance (Two-Way ANOVA) (factors: site and depth) followed by the Tukey HSD multiple comparison test was applied.

Finally, during the initial immersion of the mussel cages a sediment sample was taken at the studied sites and seawater at the immersion depths in order to estimate the sediment and seawater quality of the study areas. When the cages were retrieved seawater sampling was repeated at the immersion depths. In the collected seawater samples total petroleum hydrocarbons and polycyclic aromatic hydrocarbons were determined, while aliphatic and polycyclic aromatic hydrocarbons were determined in the collected sediment samples. The methodology followed for the analysis of seawater and sediment samples is described in detail in Chapters 3.1.1 and 3.2.1 respectively.

3.4.1.3. Results

(A). Sediment and seawater quality of the study areas

The results from the determination of total petroleum hydrocarbons and polycyclic aromatic hydrocarbons in seawater samples collected at the study areas during the initial immersion (January 23-24th 2018) and recovery of the mussel cages (March 7th 2018) are presented in detail in Table 3.4.1 that follows

Table 3.4.1. Total petroleum hydrocarbons (TPH in μg/L) and polycyclic aromatic hydrocarbons (PAHs; in ng/L) in seawater samples collected during the initial immersion and recovery of the mussel cages. AA: annual mean concentration (in ng/L) and MAC: maximum allowable concentration (in ng/L) for naphthalene, anthracene, fluoranthene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene and benzo(ghi)perylene according to the environmental quality standards for priority substances for the determination of chemical and ecological status of waters (Directive 2013/39/EC). **N.D.:** Not detected, detection limit: TPH 0.5 μg/L, PAHs (for each individual compound) 0.02 ng/L.

ANNEX I

STATION	MUS 1				MUS 2					
DEPTH	2 meters		20 meters		2 meters		20 meters			
DATE	23-24/01	07/03	23-24/01	07/03	23-24/01	07/03	23-24/01	07/03		
TPH (μg/L)	N.D	2.6	0.6	0.5	0.8	N.D	1.1	0.9	**AA (ng/L)**	**MAC (ng/L)**
PAHs (ng/L)										
Naphthalene	1.48	85.27	2.51	6.32	3.98	2.85	2.72	7.08	2000	130000
Methylnapthalenes	1.67	55.30	3.64	5.80	5.06	2.73	3.37	8.52		
Acenaphthylene	0.08	3.05	0.10	0.16	0.14	0.15	0.12	0.18		
Acenaphthene	0.21	0.93	0.26	0.25	0.20	0.19	0.15	0.30		
Dimethylnapthalenes	1.31	6.37	2.88	3.26	3.76	1.82	2.49	2.45		
Trimethylnapthalenes	1.49	16.90	2.56	3.01	2.53	1.44	1.68	7.12		
Fluorene	0.26	1.24	0.33	0.49	0.31	0.35	0.27	0.44		
Dibenzothiophene	0.05	0.15	0.09	0.09	0.07	0.07	0.07	0.14		
Methyldibenzothiophenes	0.18	1.32	0.64	0.12	0.13	0.18	0.12	0.79		
Dimethyldibenzothiophenes	0.52	0.76	1.72	0.33	0.21	0.37	0.17	0.70		
Phenanthrene	0.40	2.16	0.56	0.91	0.77	0.89	0.70	1.16		
Anthracene	0.03	0.59	0.03	0.04	0.02	0.03	0.04	0.06	100	100
Methylphenanthrenes	0.55	3.05	1.05	1.32	0.68	0.83	0.71	1.09		
Dimethylphenanthrenes	1.85	4.08	3.08	1.18	0.82	0.82	0.69	0.64		
Trimethylphenanthrenes	1.58	1.83	2.68	0.61	0.50	0.44	0.49	0.41		
Fluoranthene	0.52	0.73	0.64	0.34	0.34	0.26	0.32	0.28	6.3	120
Pyrene	0.54	0.85	0.72	0.22	0.21	0.07	0.16	0.13		
Methylpyrenes	0.35	0.71	0.54	0.18	0.12	0.10	0.11	0.10		
Dimethylpyrenes	0.31	0.39	0.47	0.15	0.08	0.07	0.11	0.12		
Retene	0.03	N.D	0.05	N.D	N.D	N.D	N.D	N.D		
Benz[a]anthracene	0.08	0.21	0.11	0.05	0.03	0.02	0.03	0.03		
Chrysene	0.14	0.10	0.15	0.07	0.08	0.06	0.07	0.05		
Methylchrysenes	0.07	0.13	0.13	0.04	0.03	0.05	0.06	0.04		
Dimethylchrysenes	0.08	0.13	0.15	0.05	0.02	0.06	0.04	0.04		
Benzo[b]fluoranthene	0.19	0.16	0.25	0.11	0.10	0.06	0.12	0.16		17
Benzo[k]fluoranthene	0.07	N.D	0.07	N.D	0.03	N.D	0.03	N.D		17
Benzo[e]pyrene	0.09	0.12	0.11	0.04	0.05	N.D	0.06	0.15		
Benzo[a]pyrene	0.02	**0.89**	0.03	0.05	0.03	N.D	0.04	N.D	0.17	27
Perylene	N.D	1.89	N.D	N.D	N.D	N.D	N.D	0.02		
Indeno[1,2,3-cd]pyrene	0.03	0.03	0.04	N.D	N.D	N.D	0.03	N.D		
Benzo[ghi]perylene	0.04	0.07	0.07	0.06	0.03	N.D	0.04	N.D		0.82
Dibenz[a,h]anthracene	N.D	0.06	N.D	N.D	N.D	N.D	N.D	0.06		
ΣPAHs (ng/L)	**14.2**	**189.4**	**25.7**	**25.2**	**20.4**	**13.9**	**15.0**	**32.2**		

ANNEX I

STATION	MUS 3				MUS 4					
DEPTH	2 meters		20 meters		2 meters		20 meters			
DATE	23-24/01	07/03	23-24/01	07/03	23-24/01	07/03	23-24/01	07/03		
TPH (μg/L)	1.2	N.D	N.D	0.8	N.D	2.4	N.D	1.4	AA (ng/L)	MAC (ng/L)
PAHs (ng/L)										
Naphthalene	2.61	2.60	3.81	6.29	2.14	6.44	2.19	5.53	2000	130000
Methylnapthalenes	2.62	2.79	4.10	5.64	1.80	5.50	1.82	3.29		
Acenaphthylene	0.16	0.11	0.16	0.16	0.06	0.24	0.06	0.08		
Acenaphthene	0.16	0.15	0.22	0.26	0.07	0.29	0.09	0.10		
Dimethylnapthalenes	1.89	2.18	2.98	3.80	1.19	1.84	1.38	1.08		
Trimethylnapthalenes	2.18	1.37	3.59	3.82	1.17	4.99	1.27	0.84		
Fluorene	0.35	0.35	1.17	0.38	0.32	0.42	0.51	0.27		
Dibenzothiophene	0.07	0.06	0.09	0.08	0.04	0.10	0.05	0.05		
Methyldibenzothiophenes	0.14	0.08	0.18	0.32	0.06	1.50	0.06	0.06		
Dimethyldibenzothiophenes	0.27	0.14	0.35	0.43	0.07	0.66	0.08	0.10		
Phenanthrene	0.71	0.75	0.87	0.97	0.45	0.78	0.55	0.72		
Anthracene	0.02	N.D	0.05	0.03	0.04	0.02	0.03	N.D	100	100
Methylphenanthrenes	0.79	0.56	1.46	0.67	0.77	0.36	0.56	0.44		
Dimethylphenanthrenes	1.12	0.61	1.67	0.50	0.37	0.37	0.44	0.27		
Trimethylphenanthrenes	0.72	0.25	2.06	0.33	0.14	0.25	0.31	0.11		
Fluoranthene	0.40	0.26	0.40	0.25	0.20	0.28	0.25	0.25	6.3	120
Pyrene	0.22	0.05	0.20	0.07	0.05	0.07	0.10	0.06		
Methylpyrenes	0.19	0.08	0.16	0.06	0.05	0.09	0.06	0.06		
Dimethylpyrenes	0.15	0.07	0.16	0.06	0.06	0.07	0.04	0.04		
Retene	N.D	N.D	N.D	N.D	N.D	0.02	N.D	N.D		
Benz[a]anthracene	0.10	0.03	0.07	N.D	N.D	0.04	N.D	N.D		
Chrysene	0.11	0.06	0.10	0.04	0.05	0.05	0.06	0.04		
Methylchrysenes	0.06	0.05	0.06	0.03	N.D	0.05	0.02	N.D		
Dimethylchrysenes	0.05	0.06	0.05	0.04	0.04	0.10	0.03	N.D		
Benzo[b]fluoranthene	0.17	0.08	0.15	0.04	0.06	0.14	0.06	0.04		17
Benzo[k]fluoranthene	0.06	N.D	0.04	N.D	N.D	N.D	0.02	N.D		17
Benzo[e]pyrene	0.07	N.D	0.06	N.D	0.02	0.02	0.03	N.D		
Benzo[a]pyrene	0.06	N.D	0.07	N.D	0.04	N.D	N.D	0.04	0.17	27
Perylene	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D		
Indeno[1,2,3-cd]pyrene	0.04	N.D	0.04	N.D	N.D	N.D	N.D	N.D		
Benzo[ghi]perylene	0.06	N.D	0.05	N.D	0.03	N.D	N.D	N.D		0.82
Dibenz[a,h]anthracene	N.D	N.D	N.D	0.03	N.D	0.03	N.D	N.D		
ΣPAHs (ng/L)	**15.5**	**12.7**	**24.4**	**24.3**	**9.3**	**24.7**	**10.1**	**13.5**		

In both seawater samplings conducted at the studied areas during the initial immersion and recovery of the mussel cages, total petroleum hydrocarbons levels were normal. Furthermore, in no case a value higher than the maximum allowable concentration (MAC) for PAHs was recorded while in only one case (station MUS1, 2m depth on March 7th 2018) a value higher than the annual average concentration (AA) was recorded for benzo(a)pyrene, following with the environmental quality standards for priority substances for the determination of chemical and ecological status of waters (Directive 2013/39/EC).

The results from the determination of aliphatic hydrocarbons and polycyclic aromatic hydrocarbons in the collected sediment samples at the studied areas during the initial immersion of the mussel cages (January 23-24th 2018) are presented in Table 3.4.2. Total aliphatic and total polycyclic aromatic hydrocarbons concentrations in the considered sediment samples were low, while in all cases the ratio of unresolved to resolved aliphatic compounds concentrations (U/R) was higher than 8.9, which clearly indicates chronic pollution from petroleum residues in the sediments which can be rather attributed to the anthropogenic background associated with the petroleum burden of the Saronikos Gulf and not to the recent incident of the sinking of the Agia Zoni II. Macroscopically no large sized tar aggregates or traces of extensive petroleum pollution were observed either in the surface or in the sub-surface layers of the collected sediment samples at the time of their sampling.

Table 3.4.2. Concentrations of total aliphatic (**∑H/C** in μg/g) and polycyclic aromatic hydrocarbons (PAHs; in ng/g) for the collected sediment samples during the initial immersion of the mussel cages (January 23-24th 2018). **UCM:** Unresolved complex mixture of aliphatic hydrocarbons, **U/R:** ratio of unresolved to resolved aliphatic compounds concentrations.

ANNEX I

STATION	MUS 1	MUS 2	MUS 3	MUS 4
∑H/C (µg/g)	**121.3**	**64.9**	**52.6**	**47.9**
UCM (µg/g)	**113.1**	**60.4**	**48.4**	**43.0**
U/R	**13.7**	**13.6**	**11.37**	**8.91**
PAHs (ng/g)				
Naphthalene	3.20	3.00	2.90	3.20
Methylnapthalenes	3.50	3.60	2.90	5.80
Acenaphthylene	2.30	2.30	1.80	1.70
Acenaphthene	0.90	0.00	0.00	0.00
Dimethylnapthalenes	3.80	2.30	2.90	4.50
Trimethylnapthalenes	4.70	2.90	3.00	4.30
Fluorene	0.50	N.D	N.D	N.D
Dibenzothiophene	0.50	N.D	N.D	N.D
Methyldibenzothiophenes	0.90	1.00	0.80	0.50
Dimethyldibenzothiophenes	2.80	3.10	2.90	1.10
Phenanthrene	6.40	2.40	4.90	3.60
Anthracene	1.70	0.80	1.40	1.10
Methylphenanthrenes	8.00	7.00	8.40	7.40
Dimethylphenanthrenes	11.9	16.8	14.9	9.10
Trimethylphenanthrenes	13.9	17.2	14.3	5.60
Fluoranthene	11.0	7.50	14.8	12.6
Pyrene	11.1	8.30	13.2	11.7
Methylpyrenes	9.50	8.40	10.6	9.4
Dimethylpyrenes	12.4	8.80	10.1	6.7
Retene	0.90	0.60	1.70	0.70
Benz[a]anthracene	8.80	7.00	13.2	11.2
Chrysene	10.9	9.00	15.9	11.6
Methylchrysenes	11.4	6.50	9.40	8.70
Dimethylchrysenes	12.2	7.60	9.80	6.30
Benzo[b]fluoranthene	20.7	14.7	24.5	19.0
Benzo[k]fluoranthene	7.9	5.60	9.30	7.00
Benzo[e]pyrene	13.1	8.60	13.5	10.7
Benzo[a]pyrene	14.5	9.90	16.0	13.1
Perylene	4.00	2.80	4.50	3.80
Indeno[1,2,3-cd]pyrene	12.5	9.00	12.4	9.10
Benzo[ghi]perylene	12.6	8.50	11.4	9.00
Dibenz[a,h]anthracene	2.40	1.50	2.10	1.60
ΣPAHs (ng/g)	**240.9**	**186.7**	**253.5**	**200.1**

(B). Hydrocarbons in mussels

The results from the determination of aliphatic and polycyclic aromatic hydrocarbons in mussel samples are given in Table 3.4.3 that follows.

The concentrations of aliphatic hydrocarbons were relatively small in all cases, did not exceed 30 μg/g of wet tissue, and indicate that there was no significant burden with petroleum products. Concentrations for mussels caged at 5m depth at stations MUS1 and MUS2 were slightly elevated compared to mussels caged at 20m depth, as well as to the mussels of the reference site in the area of Vouliagmeni but also to the initial values before the immersion of the mussel cages. This trend could be likely attributed to the increased hydrocarbons background in these areas of the Saronikos Gulf.

Concentrations of polycyclic aromatic hydrocarbons were in all cases less than the initial values of mussels prior to their immersion indicating that there was no PAH burden either. As in the case of aliphatic hydrocarbons the highest concentrations were determined in mussels caged at stations MUS1 and MUS2. According to the legislation (EC Regulation 1881/2006) for hydrocarbons, the maximum allowable concentration for benzo(a)pyrene is 10 ng/g of wet tissue. In the caged mussels, concentrations of benzo(a)pyrene were in all cases well below this limit, with the highest value of 0.4 ng/g being recorded at station MUS1.

From the above results it appears that bioaccumulation of aliphatic and polycyclic aromatic hydrocarbons in the caged mussels has not been observed due to the incident.

Table 3.4.3. Concentrations of hydrocarbons (expressed as wet tissue weight) in the *Mytilus galloprovincialis* mussels caged at the Saronikos Gulf. **N.D.**: Not detected, detection limit 0.1 ng/g.

Station	**MUS1**		**MUS2**		**MUS3**		**MUS4**		**Initial value**
Depth (m)	**5m**	**20m**	**5m**	**20m**	**5m**	**20m**	**5m**	**20m**	
Total hydrocarbons (μg/g)	25.2	20.8	26.7	18.2	12.1	15.6	4.0	3.0	9.0
Aliphatic hydrocarbons (μg/g)	25.1	20.7	26.6	18.2	12.1	15.5	4.0	3.4	9.1
U/R	10.2	11.6	10.0	8.0	5.8	7.2	3.9	4.0	2.6
PAHs (ng/g)									
Naphthalene	0.8	0.7	1.4	0.6	0.6	0.5	0.6	0.7	0.9
Methylnapthalenes	1.3	1.0	2.3	0.7	0.7	0.5	0.7	0.5	1.5
Acenaphthylene	0.2	0.2	0.1	0.2	0.1	0.1	0.1	0.1	0.1
Acenaphthene	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Dimethylnapthalenes	1.9	1.6	2.9	1.1	1.0	0.4	0.6	0.6	5.8
Trimethylnapthalenes	5.1	3.0	4.1	1.6	1.2	1.0	0.6	0.6	4.4
Fluorene	0.2	0.2	0.2	0.1	0.2	0.1	0.1	0.2	0.3
Dibenzothiophene	0.1	0.1	0.1	0.1	N.D	N.D	N.D	N.D	0.2
Methyldibenzothiophenes	0.6	0.6	0.4	0.2	0.1	0.3	0.1	N.D	1.4
Dimethyldibenzothiophenes	3.6	2.7	2.0	1.2	0.5	0.9	0.4	0.3	7.5
Phenanthrene	1.6	1.4	1.8	1.4	1.5	1.5	1.1	1.1	2.3
Anthracene	0.4	0.3	0.2	0.1	0.1	0.1	0.1	0.1	0.2
Methylphenanthrenes	4.6	3.7	3.3	2.4	2.0	2.2	1.3	1.1	3.7
Dimethylphenanthrenes	14.3	10.2	8.1	5.1	3.9	6.0	2.2	1.6	16.4
Trimethylphenanthrenes	16.7	13.9	9.1	6.8	4.4	6.4	3.1	2.4	17.2
Fluoranthene	1.1	0.9	1.0	0.8	0.6	0.6	0.4	0.3	1.2
Pyrene	0.6	0.6	0.4	0.3	0.2	0.2	0.1	0.1	1.0
Methylpyrenes	2.2	1.8	1.4	1.1	0.8	0.7	0.4	0.5	2.1
Dimethylpyrenes	3.0	2.8	1.7	1.2	0.5	0.9	0.3	0.3	1.8
Retene	0.7	0.6	0.6	0.5	0.4	0.4	0.3	0.3	0.9
Benz[a]anthracene	0.4	0.4	0.3	0.2	0.2	0.2	0.1	0.1	0.5
Chrysene	1.7	1.5	1.5	1.2	1.0	1.1	0.7	0.7	2.8
Methylchrysenes	1.8	1.6	1.2	0.8	0.6	0.8	0.3	0.3	1.6
Dimethylchrysenes	2.3	2.7	1.3	1.1	0.6	1.1	0.4	0.4	0.3
Benzo[b]fluoranthene	2.3	2.2	0.9	1.1	0.7	1.0	0.6	0.5	2.0
Benzo[k]fluoranthene	0.8	0.7	0.4	0.3	0.3	0.4	0.2	0.2	0.6
Benzo[e]pyrene	1.9	1.8	0.7	0.9	0.7	0.8	0.3	0.3	1.4
Benzo[a]pyrene	0.4	0.4	0.1	0.1	0.1	0.1	N.D	N.D	0.2
Perylene	0.2	0.2	0.1	0.1	0.1	0.1	0.1	N.D	0.1
Indeno[1,2,3-cd]pyrene	0.5	0.6	0.2	0.3	0.1	0.2	0.1	0.1	0.4
Benzo[ghi]perylene	0.8	0.8	0.3	0.5	0.1	0.3	0.1	N.D	0.5
Dibenz[a,h]anthracene	0.1	0.1	N.D	N.D	N.D	N.D	N.D	N.D	0.1
ΣPAHs (ng/g)	**72.3**	**59.4**	**48.2**	**32.2**	**23.4**	**29.0**	**15.5**	**13.5**	**79.5**

(C). Biomarkers in mussels

CAT, GST και AChE activities in the caged mussels are shown in Figures 3.4.2, 3.4.3 και 3.4.4. CAT, GST και AChE activities were similar in caged mussels at sites MUS1, MUS2, MUS3 and at the reference site MUS4 (Two-WayANOVA, $p>0.05$). CAT and AChE activities did not vary with respect to caging depth (Two-WayANOVA, $p>0.05$), while GST activities were higher in the mussels caged at 5 m depth (Two-WayANOVA, $p<0.05$).

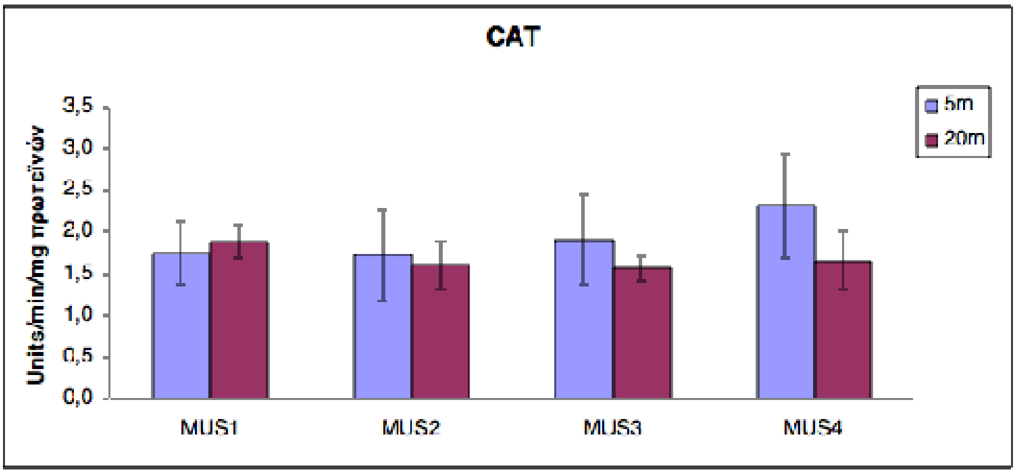


Figure 3.4.2. Catalase (CAT) activity in caged mussels at MUS1, MUS2, MUS3 and MUS4 sites. Mean ± SD, n=5.

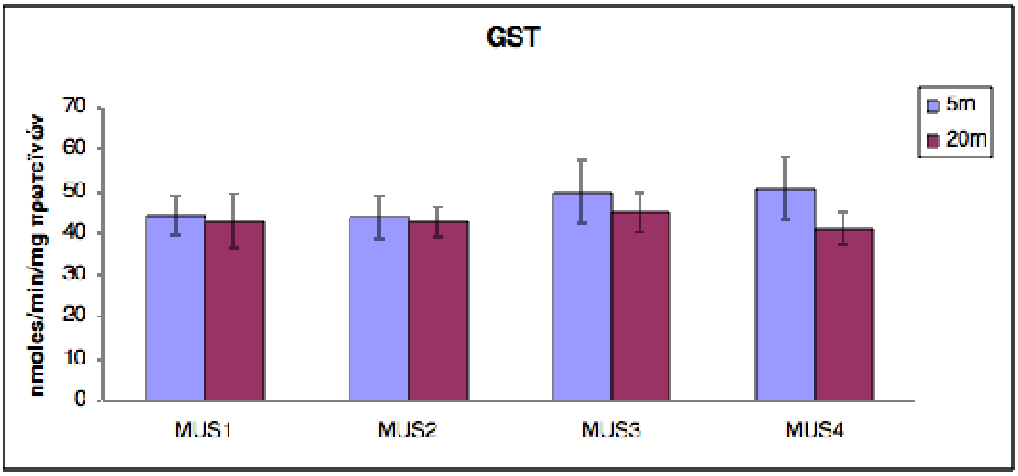


Figure 3.4.3. Glutathione S-trensferase (GST) activity in caged mussels at MUS1, MUS2, MUS3 and MUS4 sites. Mean ± SD, n=5.

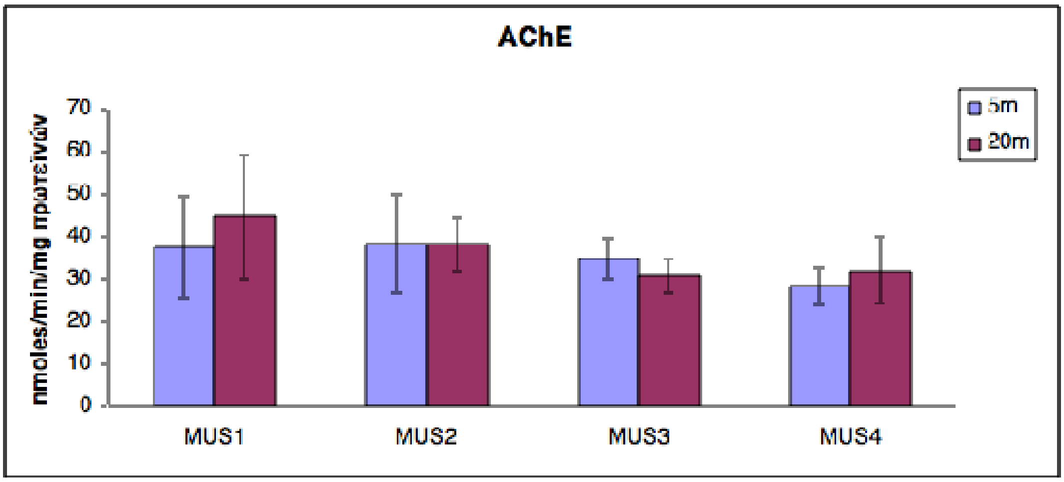


Figure 3.4.4. Acetylcholinesterase (AChE) activity in caged mussels at MUS1, MUS2, MUS3 and MUS4 sites. Mean ± SD, n=5.

Condition index results are shown in Figure 3.4.5. At MUS2 site, part of the mussels were lost during the caging period, thus the mussel samples were not enough to measure CI at 5 m depth. In contrast to CAT, GST and ACHE activities, CI values varied among sites (Two-WayANOVA, $p<0.05$). CI was significantly lower in caged mussels at the reference site MUS4 with respect to those caged at MUS1 in Salamina and MUS2 in Agios Kosmas (TukeyHSDtest, $p<0,05$). Condition index is influenced by environmental conditions, primarily food availability and/or reproductive condition (gamete release) (Bayneetal. 1985). In the present study, the caged mussels were taken from the same population and were in the same stage of the reproductive cycle, thus the lower CI value at MUS4 is possibly related to lower food availability with respect to sites MUS1 and MUS2.

In conclusion, the set of biomarkers applied to assess effects of the oil spill in caged mussels showed no variations among the four studied sites in the Saronikos Gulf. Thus, our results on biomarkers indicative of oxidative stress, biotransformation and neurotoxicity do not show oil spill effects in these bio-indicator organisms. Levels of CAT, GST and AChE activities in the caged mussels at the four studied sites fall within the range of values reported by previous studies in caged or native mussels in the Saronikos Gulf (Tsangaris et al., 2004, 2010, 2014, 2016).

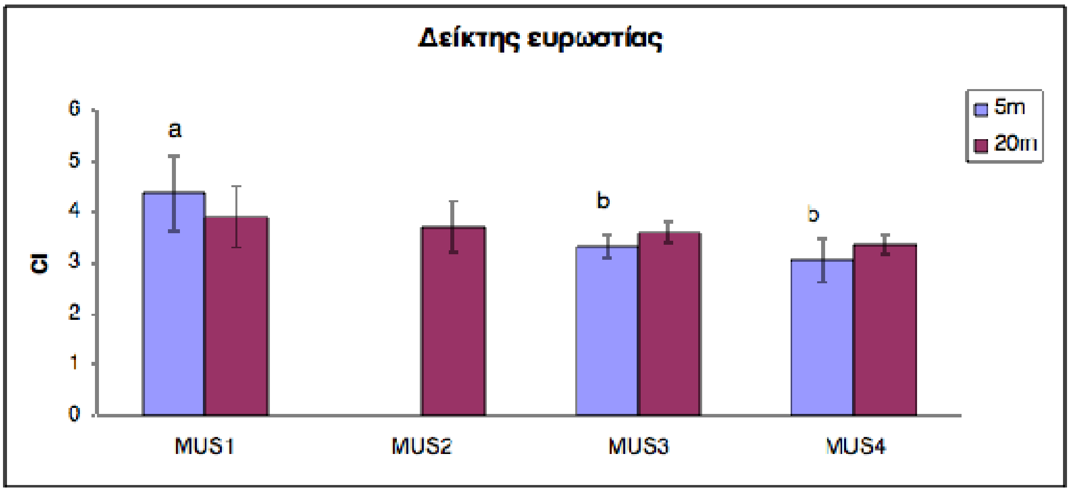


Figure 3.4.5. Condition index (CI) in caged mussels at MUS1, MUS2, MUS3 and MUS4 sites. Mean ± SD, n=5. Significant differences between sites are shown by different letters (TukeyHSDtest, $p<0.05$).

(D). Metal concentrations and metallothionein induction in mussels

Mussel metal concentrations (whole body soft tissue) and MTs (digestive gland) are summarized in Table 3.4.4.

Table 3.4.4. Concentrations of metals (μg/g dw) and MTs (μg/g ww) in the whole body soft tissue and digestive gland respectively of transplanted mussels in the Saronikos gulf per station and depth (sur: surface & bot: bottom)

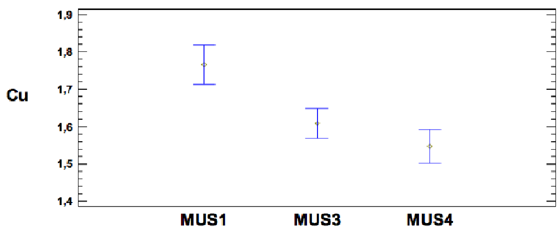
Station/depth		Cu	Zn	Fe	Mn	MTs
MUS 1 sur	*avg±std*	5.89±0.35	314±70	282±27	4.38±0.27	194±26
n=5	*min-max*	5.42-6.41	236-403	256-319	4.05-4.65	155-224
MUS 1 bot	*avg±std*	5.30±0.39	268±119	294±39	4.66±0.79	322±118
n=5	*min-max*	4.71-5.58	115-445	249-339	3.75-5.53	189-484
MUS 2 sur	*avg±std*					225±66
	min-max					142-315

MUS 2 bot	*avg±std*	4.90±0.37	244±87	299±7	3.88±0.52	384±160
n=3	*min-max*	4.48-5.15	158-332	291-304	3.28-4.21	209-554
MUS 3 sur	*avg±std*	4.99±0.23	350±65	349±10	4.68±0.18	302±98
n=5	*min-max*	4.75-5.36	266-436	337-364	4.44-4.93	215-441
MUS 3 bot	*avg±std*	5.31±0.42	322±82	373±58	5.03±0.71	262±90
n=5	*min-max*	4.84-5.93	195-405	324-472	4.60-6.29	165-368
MUS 4 sur	*avg±std*	4.68±0.23	432±43	259±18	3.76±0.16	275±16
n=5	*min-max*	4.41-4.95	382-501	236-285	3.66-4.03	248-294
MUS 4 bot	*avg±std*	4.71±0.30	369±37	248±20	3.71±0.34	321±130
n=5	*min-max*	4.40-5.15	308-400	224-275	3.31-4.05	247-553

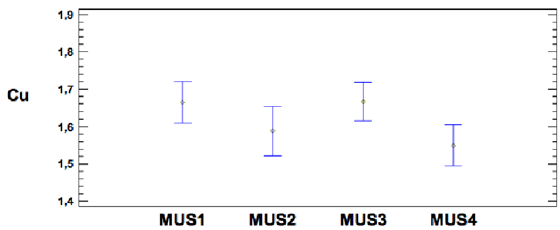
(***n*** number of samples, ***avg±std*** average ± standard deviation, ***min-max*** minimum–maximum values)

According to the statistical analysis, no differences were observed between surface and bottom in mussel metal concentrations for all examined metals while MTs values were higher in mussels transplanted near the bottom in relation to mussels placed near the surface (ANOVA, LSD test for $p<0.05$). A spatial decreasing gradient of Cu, Fe and Mn mussel concentrations was observed along the north-west (station MUS1) to the south-east geographical axis (stationMUS4) for mussels placed near the surface. Spatial variation was not significant for Cu and Zn for mussels placed near the bottom and was limited for Fe and Mn (higher values of Fe at station MUS3, Figure 3.4.6). Differences of MTs among stations at both depths were not significant (Figure 3.4.7).

SURFACE (5m)



BOTTOM (20m)



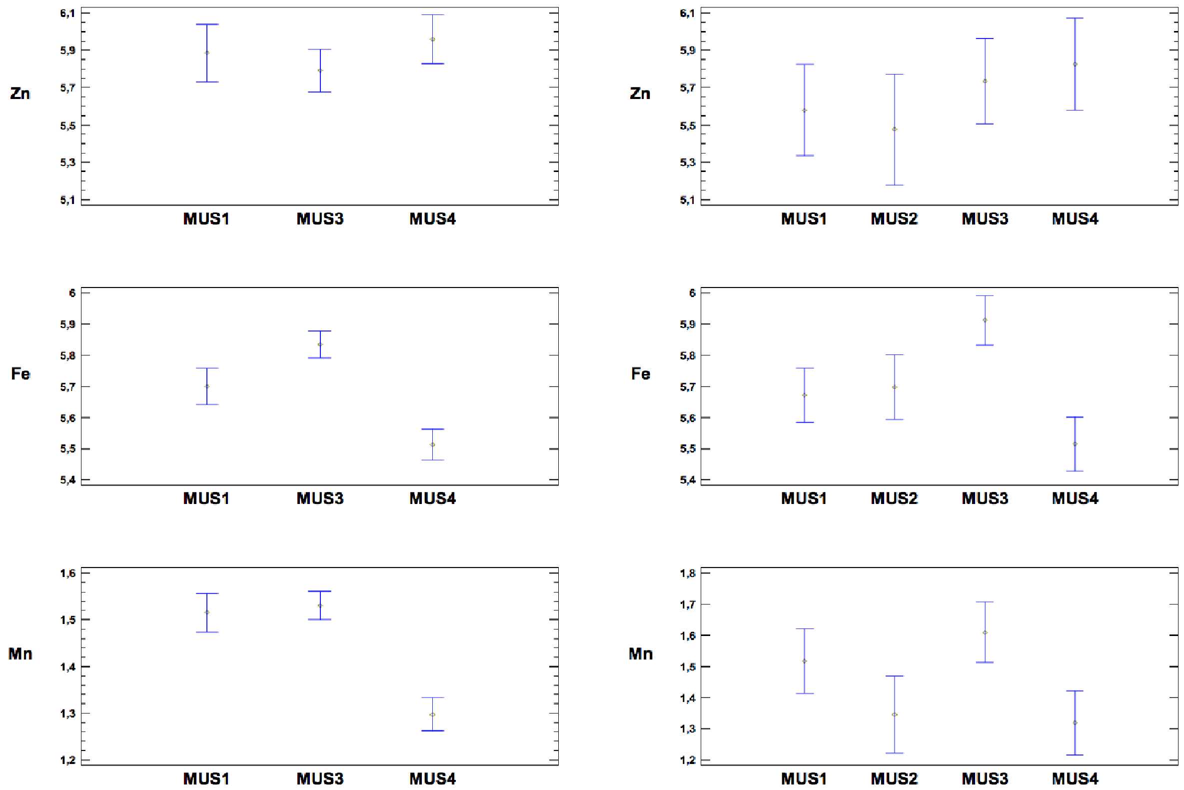


Figure 3.4.6. Spatial variation of Cu, Zn, Fe, Mn concentrations (μg/g dw) in the whole body soft tissue of the transplanted mussels in the studied areas of the Saronikos Gulf (ANOVA, LSD test for p<0.05). Values are log transformed and the flesh condition index was used as covariate.

SURFACE (5m) **BOTTOM (20m)**

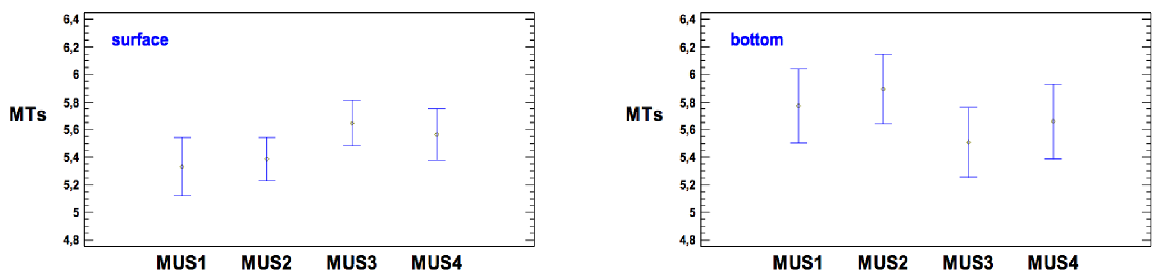


Figure 3.4.7. Spatial variation of MTs concentrations (μg/g ww) in the digestive gland of the transplanted mussels in the studied areas of the Saronikos Gulf (ANOVA, LSD test for p<0.05). Values are log transformed and the flesh condition index was used as covariate.

3.4.2. Determination of aliphatic hydrocarbons in the tissue of selected fish

Hatzianestis, I., Parinos, C., Plakidi, E., Chourdaki, S.

In order to study the possible bioaccumulation of petroleum hydrocarbons from the incident, further determination of aliphatic hydrocarbons was carried out in the tissue of selected fish (*Mullus barbatus, Merluccius merluccius, Parapenaeus longirostris, Illex coidentii*, depending on availability) allocated to the Institute of Oceanography of H.C.M.R. for analysis. The sampling was carried out by demersal towed gears (trawlers) in October and November 2017 by the Institute of Marine Biological Resources and Inland Waters of H.C.M.R. in the wider area of the Saronikos Gulf. The routes taken are presented in Figure 3.4.8.

Figure 3.4.8. Sampling routes carried out by demersal towed gears (trawlers) in October and November 2017 in the wider area of the Saronikos Gulf.

The determination of total aliphatic hydrocarbons was carried out on a mixed sample of wet fish tissue following the methodology described in Section 3.4.1.2. Table 3.4.5 below summarizes the results of the determination of total aliphatic hydrocarbons (THC) (expressed in wet weight of the tissue) for the case-by-case samples analyzed from the corresponding bottom trawl routes (Figure 3.4.8).

Table 3.4.5. Total aliphatic hydrocarbons (THC) (expressed as wet weight of the tissue) for the case-by-case samples analyzed from the corresponding bottom trawl routes in the wider Saronikos Gulf.

Route	Date	Fish species	THC (μg/g)
1	**10/2017**	*Mullus barbatus*	8.9
	10/2017	*Merluccius merluccius*	1.1
2	**11/2017**	*Mullus barbatus*	7.3
3	**11/2017**	*Mullus barbatus*	7.7
4	**11/2017**	*Mullus barbatus*	5.4
5	**10/2017**	*Mullus barbatus*	6.7
	10/2017	*Merluccius merluccius*	1.2
6	**10/2017**	*Merluccius merluccius*	2.0
	10/2017	*Mullus barbatus*	8.7
7	**10/2017**	*Mullus barbatus*	3.0
8	**10/2017**	*Illex coidentii*	2.0
9	**10/2017**	*Merluccius merluccius*	1.6
		Parapenaeus longirostris	3.5
10	**10/2017**	*Parapenaeus longirostris*	3.1
		Parapenaeus longirostris	6.2
11	**10/2017**	*Illex coidentii*	2.5

It should be noted that at routes no. 1, 2 and 4 (located within the direction of the oil spill caused by the incident) traces of oil, of small diameter, were observed on the nets. These traces were extracted with a suitable organic solvent and the ion analysis (m/z 71) of the chromatographs showed an increased presence of *n*-alkanes in the range *n*-C_{17} to *n*-C_{26}. This molecular profile is in line with the molecular profile of a sample of oil pumped out from the Agia Zoni II wreck and was allocated for analysis at H.C.M.R. However, higher concentrations of total aliphatic hydrocarbons were determined in samples of *Mullus barbatus*, a benthic fish species, on routes no. 1 (south of Piraiki) and no. 6 (northeast of Aegina), while the lowest concentrations of total aliphatic hydrocarbons for the same species on routes no. 4 (off Glyfada) and no. 7 (northwest of Aegina).

Taking into account the above observations, a cause-effect relationship cannot be securely established between the presence of an oil trace from the Agia Zoni II wreck in the sampling net and the bioaccumulation of petroleum products in the tissue of *Mullus barbatus*, which being a benthic fish potentially constitutes an indicator of oil burden in the sediments in which it inhabits. It should be noted however that petroleum compounds are being metabolized by the fish organism and therefore are detected in their flesh only in cases of extended petroleum pollution.

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3.5. IMPACTS ON THE ZOOBENTHIC COMMUNITIES OF THE SUBLITTORAL ZONE

Simboura, N., Katsiaras, N., Voutsinas, E., Arvanitakis, G.

Herein we examine the possible impacts of the Agia Zoni II incident on the zoobenthic communities of the sublittoral zone of the Saronikos Gulf. Studies on the effects of oil spill events show significant impacts on benthic organisms (HCMR, 2016a and references within). The substances of oil and especially its water soluble clusters are toxic to marine organisms and can cause detrimental effects, increased mortality, reduce of species number, destabilization of communities and even disappearance of communities locally in the more affected areas. However, through adaptive mechanisms, communities may recover after a period (Teal and Howarth, 1984).

In the case of the Eurobulker ship-wreck in the Southern Evvoikos Gulf in 2000 and at 30 m depth, the effects on the benthic communities were directly evident one month after the accident through the drop of the number of species mostly and indirectly through the increase of certain opportunistic pollution indicator species towards the coastal areas. Eight months after the accident the benthic communities in the area had been fully recovered (HCMR, 2001; Zenetos et al., 2004). The case of the SEA DIAMOND wreck which was studied by H.C.M.R. for a period of seven years showed that the short term effects on the benthos included reductions in the number of species and specimens. The recovery process of the benthic communities started six months after the accident and continued throughout the monitoring period. Recovery was reflected in the number of species and specimens on the site of the wreck as well as recolonization of benthic species on the site and over the whole caldera area. Five years after the wreck, the rest of the benthic indices such as the indices of diversity, eveness of distribution and ecological quality BENTIX had increased indicating a long term recovery (HCMR, 2007-2012; Simboura et al., 2008, 2012).

3.5.1. Methodology

The first phase sampling for the monitoring of the impacts of the Agia Zoni II incident on the benthic communities of the Saronikos Gulf was conducted on September 21-22nd 2017 using the *R/V* Aegaeo (HCMR). A Van Veen benthic sampler was used (0.16 m^2 sampling surface).

Sampling was repeated 4 months after the incident on January 23-24th 2018 in a subset of stations at which a recent imprint of oil pollution attributed to the Agia Zoni II was recorded in

September 2017 (see Section 3.2 above) and specifically at stations AZII, OS2 (Peiraiki), OS3 (Faliro), OS4 (Agios Kosmas) and OS6 (Glyfada), in order to detect possible short- and medium term impacts of the oil spill on the zoobenthic communities of the sublittoral zone.

The aim of the sampling was to examine the sublittoral zone within 20-60m depth in the area of the incident in Salamina coasts (ship wreck and Selinia) and in the coastal areas where the oil spill was beached: Peiraiki, Faliro, Glyfada, Agios Kosmas, Vouliagmeni. Psittalia station (S7) was also sampled, belonging to the regular monitoring network of the Saronikos Gulf for which a long time series of data is available (HCMR, 2016b). It is noted that in all the new areas sampled (named OS) there exist time series of data from stations with similar or slightly lower depths. Recent data from these areas-stations will be used for comparisons of benthic indices before and after the Agia Zoni II incident. The stations are given in Table 3.5.1.

Two replicate samples were collected at each station for the analysis of zoobenthos. Samples for fauna analysis were sieved on board through a 1 mm sieve and stored in 4 % formalin solution, stained with Rose Bengal. A third replicate sample was retained for sedimentological analysis. Samples were sorted in the lab and were grouped into the main benthic groups. Subsequently most of the specimens were identified to the species level and only when this was not possible to a higher taxonomic level (genus or family).

Based on the qualitative and quantitative composition of the macrofauna, the following ecological-biological parameters were calculated: a) number of species over the sampling surface of 0.1 m^2 (S), b) abundance (N) or population density expressed as number of individuals found, c) community diversity (H’) using the Shannon-Wiener Index (Shannon and Weaver, 1963) and d) evenness of distribution (J) of individuals among species (Pielou, 1969). For the calculation of each index the average value of the two replicate samples was taken into account. Finally for the evaluation of the ecological quality status of the benthic communities the biotic index BENTIX (Simboura and Zenetos, 2002) was used. This index was developed for the purposes of the European Water Framework Directive for water policy (EEC, 2000) that consists the new European framework for water management policy. A classification analysis was carried out (clustering analysis and multidimentional scaling MDS) on log(x+1) transformed data using the “group average” technique. Table 3.5.1 presents the characteristics of the stations.

Sedimentological analysis was performed with a Sedigraph 5100E device after the separation of the sand fraction (> 63 μm) with liquid sieving and subsequently the percentages of sand, silt and clay were calculated. Sediment granulometric classification followed Folk (1954).

Total carbon, nitrogen and organic carbon were measured in an elemental EA 1108 CHN analyzer after the methodology of Cutter and Radford-Knoery (1991) and Verardo et al. (1990).

Table 3.5.1. Sampling stations during September 2017/January 2018 cruises (OS) and respective stations of the Saronikos Gulf regular monitoring network (shaded) for comparison. Field data.

STATIONS	Area	Sampling period	latitude	longitude	Depth (m)	Mud sediment content %	Sdiment type
AZII	Ship-wreck	Sept. 2017 Januar. 2018	37.92952	23.56952	50	15	Muddy sand
OS1	Selinia	Sept. 2017	37.92345	23.56952	49	36	Muddy sand
S7W 2012	Selinia	Febr. 2012	37.92066	23.54057	30	26	Muddy sand
OS2	Peiraiki	Sept. 2017 Januar. 2018	37.92242	23.56952	54	91	Mud
S7	Psittaleia	Sept. 2017	37.92345	23.59112	70	85	Sandy mud
S7 February 2016	Psittaleia	Febr. 2016	37.92366	23.59083	75	70	Sandy mud
S7 March 2017	Psittaleia	March 2017	37.92366	23.59083	75	70	Sandy mud
OS3	Faliro	Sept. 2017 Januar. 2018	37.92617	23.67332	22	11	Muddy sand
S26 February 2016	Faliro	Febr. 2016	37.85090	23.71705	70	55	Sandy mud
S26 March 2017	Faliro	March 2017	37.85090	23.71705	70	55	Sandy mud
OS4	Ag. Kosmas	Sept. 2017 Januar. 2018	37.89498	23.68200	46	29	Muddy sand
OS6	Ag. Kosmas	Sept. 2017 Januar. 2018	37.85797	23.71625	34	19	Muddy sand
S11 February 2016	Ag. Kosmas	Febr. 2016	37.86753	23.63405	82	13	Muddy sand
S11 March 2017	Ag. Kosmas	March 2017	37.86753	23.63405	82	13	Muddy sand
OS8	Vouliagme ni	Sept. 2017	37.80358	23.75105	53	13	Muddy sand
S16 February 2016	Kavouri	Febr. 2016	37.78388	23.70009	92	17	Muddy sand
S16 March 2017	Kavouri	March 2017	37.78388	23.70009	92	17	Muddy sand

3.5.2. Results and Discussion

3.5.2.1. Benthic indices

Recent data from adjacent stations (at slightly lower depths) from the same areas (Psittaleia, Faliron, Agions Kosmas, Vouliagmeni-Kavouri) available from the Saronikos gulf monitoring network, were used for the comparative analysis of the benthic indices' levels at the oil spill sampling stations (OS) (HCMR, 2016β; HCMR, 2017). According to HCMR experience from similar accidental occassions ex. the Sea Diamond oil spill at Santorini (Simboura et al., 2008) and the international literature (see introduction), the most direct and short term indicators of the response of the benthic communities to oil spill incidences are the number of species and the number of specimens, while the indices of Shannon diversity, eveness of distribution and the ecological quality index BENTIX are among the the medium and long term indicators of such a response. These indices levels were evaluated and also in comparison with reference levels before the accident in the same areas. Alos the sediment content in organic carbon and nitrogen were evaluated as indicators of organic pollution in sediment. Figures 3.5.1 and 3.5.2 show the variance of the indices using comparative data from the 2016-2017 regular monitoring network.

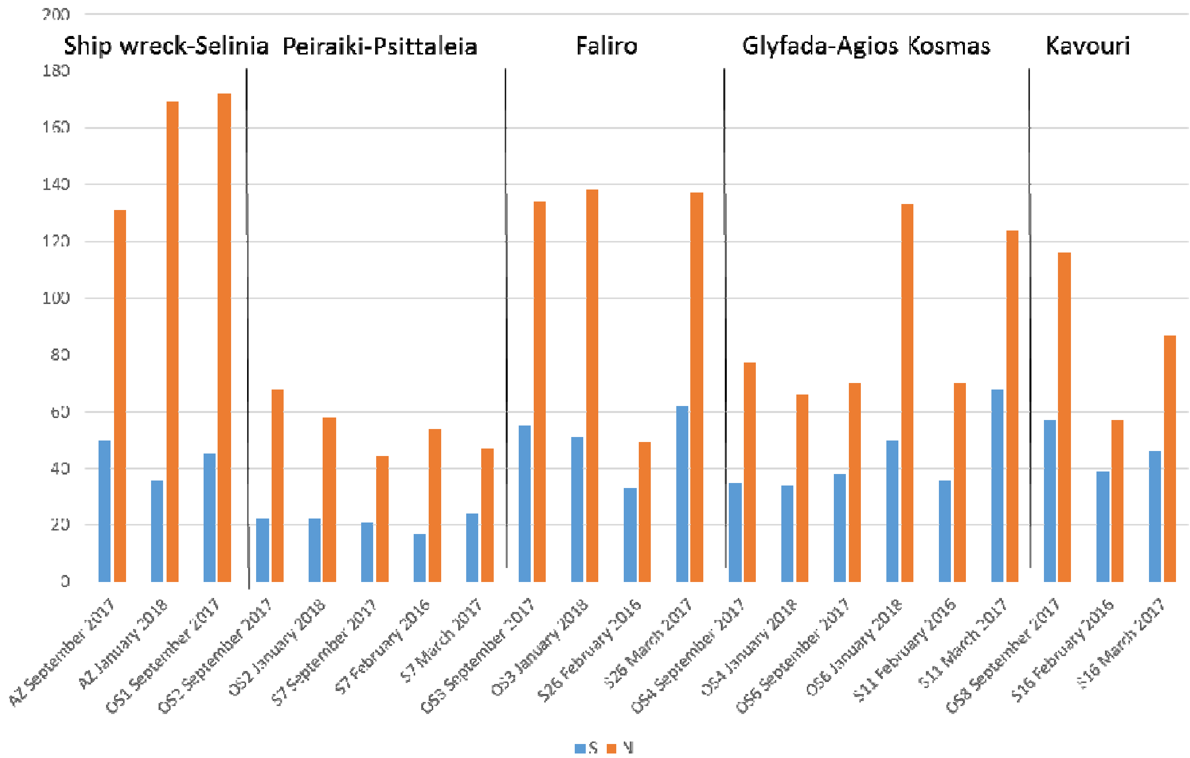

Figure 3.5.1. Number of Species (S) and number of individuals (N) in the sampling stations and comparative data before the Agia Zoni II incident (HCMR, 2016β; HCMR, 2017).

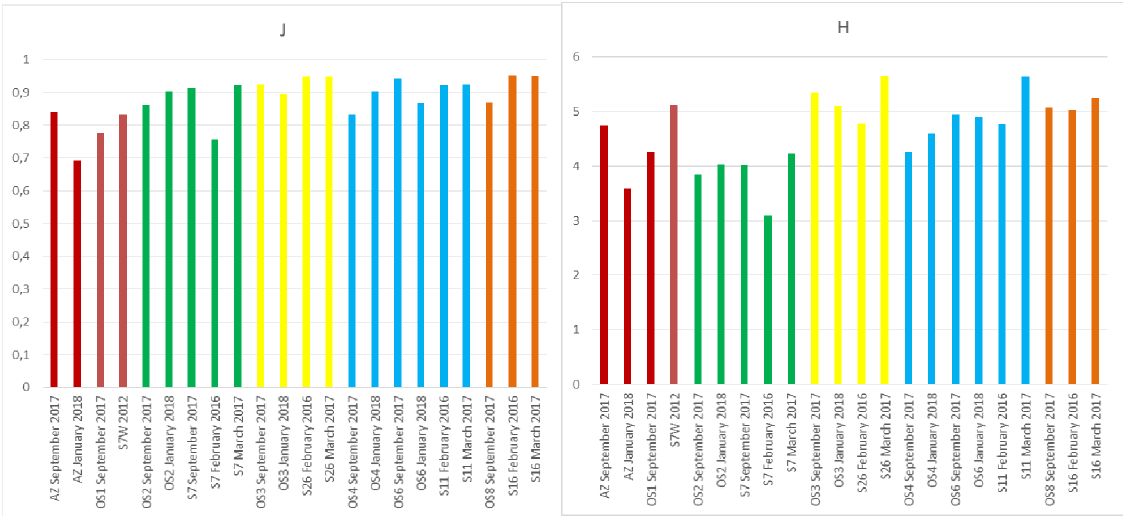

Figure 3.5.2. Shannon Diversity index (H’) and eveness index (J) in the sampling stations and comparative data before the Agia Zoni II incident (HCMR, 2016b; HCMR, 2017).

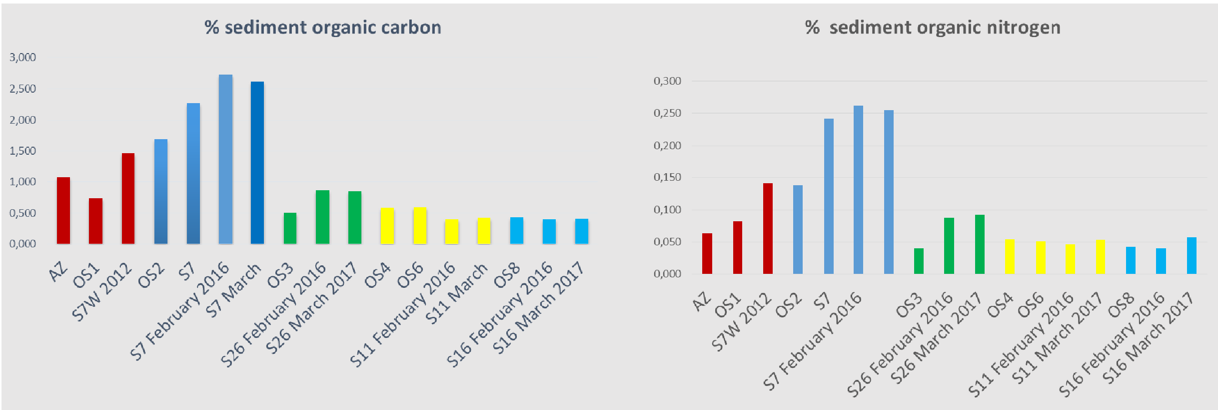

Figure 3.5.3. Sediment content in organic carbon and nitrogen in the sampling stations and comparative data before the Agia Zoni II incident (HCMR, 2016b; HCMR, 2017).

The values of the Species richness (number of species), the number of individuals, diversity and evenness after the incident were similar of even higher than those of the respective areas based on recent data (2016-2017) available before the incident. The values of indices in the sampling of January 2018 do not present significant variation in relation to the values of the September 2017 sampling period. An exception is stations AZII and OS3 at which communities structural indices S, N, J, H´ present a slight decrease in 2018 which however is not accompanied by any decrease of the ecological status index BENTIX; on the contrary the value of BENTIX is increased in January at these two stations without however a change in quality class. These changes are attributed to the significant increase in density of two sensitive species of polychaetes: *Aponuphis brementi* and *Marphysa bellii* at these two stations in the second sampling together with the absence of some mainly sensitive species. On the contrary the BENTIX index is positively influenced by the increase of these two sensitive species. The higher values of the structural indices (species richness) in some shallower stations (OS8) in relation to deeper stations of the respective region (S16), are attributed to the variability of these indices depending on the type of sediment and the depth that aldo define in a great extent the benthic ecotypes (Simboura et al., 2012b).

Figure 3.5.4 shows the ecological quality at the OS stations also in comparison with the stations of the wider monitoring network of Saronikos Gulf. The ecological quality in the stations after the incident are of the same class or even with higher BENTIX values compared to the respective areas based on recent data before the incident. The lower ecological quality class among OS stations corresponds to that of station OS2. The values of indices in 2018 are comparable with those of 2017 at the stations where the sampling was repeated and fall within the range of variance of the indices. Analysis of variance (ANOVA) run for testing differences of indices values before and after the incident and between periods of sampling did not show any statistical significance for all indices tested (p>0,05).

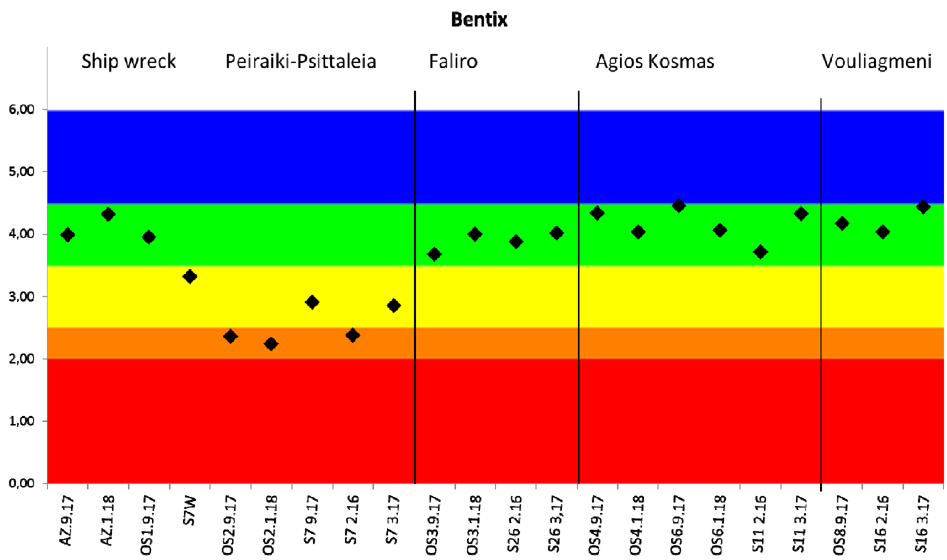

Figure 3.5.4. BENTIX index values and resulted quality classes in the sampling stations and in comparison to those of the respective regular monitoring network stations before the incident (HCMR, 2016b-2017). Blue=high quality class, green=good, yellow= moderate, orange=poor and red=bad.

3.5.2.2. Benthic communities' composition

Table 3.5.2 shows the most abundant benthic indices and their respective abundance values over the two sub-samples taken at each stations, the sediment content in fine material (mud), the depth, and the ecological group of each species according to the BENTIX index methodology, where GT are the generally tolerant species and GS the generally sensitive ones. Table 3.5.2 also gives the type of biocoenosis according to Peres and Picard (1964) that the species characterize or are typical of (Simboura and Nicolaidou, 2001).

Based on Table 3.5.2, the benthic communities correspond to the community type of the biogenic detritus with mud (DE) with the exception of station at Peiraiki (OS2) and Psittaleia S7 where the dominant community type is that of the coastal terrigenous muds (VTC). Both types of communities belong to the circalittoral benthic zone (lower than 30-35m depth).

Table 3.5.2. Dominant species (10) at each station. The abundance values refer to the total number of individuals found at each station and over the two sub-samples. GS: Sensitive, GT: Tolerant. SVMC=biocoenosis of the calm water muddy sand. DE=the muddy detritus bottoms, DC=the coastal detritic, SFBC=of the well sorted fine sands, VTC=the coastal terrigenous mud community.

Ecolog. group	Community type	Species	S7 9.17	AZ 9.17	AZ 1.18	OS1 9.17	OS2 9.17	OS2 1.18	OS3 9.17	OS3 1.18	OS4 9.17	OS4 1.18	OS6 9.17	OS6 1.18	OS8 9.17
		% of fines in sediment	85	15		36	91		11		29		19		13
		DEPTH (m)	91	50	50	51	56	56	22	22	45	45	35	35	53
GT	DC	*Ditrupa arietina*												23	
GS	DC	*Drilloneris filum*										2			
GT	DC	*Pista cristata*									6				
GS	DE	*Aponuphis bilineata*				3			4						
GS	DE	*Aponuphis brementi*		30	70	54			7	12	17	13	4		4
GT	DE	*Atlantella distorta*		3											
GT	DE	*Eunice vittata*								6		2	5	4	
GT	DE	*Glycera alba*				3		2							
GT	DE	*Hilbigneris gracilis*													
GT	DE	*Kirkegaardia heterochaeta*	5	5	5	11	10	9		6					
GT	DE	*Loimia medusae*			6										
GT	DE	*Lumbrineris pinaster*				4		3							
GT	DE	*Lysidice unicornis*		10	11	5			5			4		4	
GT	DE	*Melinna palmata*										2			
GT	DE	*Myrtea spinifera*						3							
GT	DE	*Nepthys hombergii*	2											4	
GT	DE	*Notomastus sp.*		3	7				11	4					

GT	DE	*Paralacydonia paradoxa*				13		3			3	4	7	5	24
GT	DE	*Pseudoleiocapitella fauveli*	4	4					11	6					
GT	DE	*Spiophanes sp.*								13					
GT	DL	*Lanice conchylega*		10	15				4		6	4			3
GT	DL	*Poecilochaetus serpens*	2	3	6	6	4								
GS	SFBC	*Paradoneis harpagonea*													4
GT	SFBC	*Protodorvillea kefersteini*												6	
GT	SVMC	*Loripes lacteus*				3			4						
GT	VTC	*Aphaelochaeta marioni*	3				3	3							
GT	VTC	*Chaetozone sp.*					2	6							
GT	VTC	*Cossura coasta*					7								
GT	VTC	*Glycera unicornis*			6				4	8		2			
GT	VTC	*Labioleanira yhleni*	2												
GT	VTC	*Levinsenia demiri*				9		7				2			
GS	VTC	*Marphysa bellii*		3					4	12	2	3			
GS	VTC	*Nepthys hystricis*				3									
GT	VTC	*Spiochaetopterus costarum*													
GT	VTC	*Sternaspis scutata*					4	5							
GT	VTC	*Thyasira flexuosa*					2								
GS	SAND	*Lygdamis muratus*			6					6					
GT		*Nemertea*			5			4							
GS		*Syllis gerlachi*												17	

3.5.2.3. Multivariate analysis

Figure 3.5.5 shows the hierarchical clustering and two-dimensional scaling of the stations superimposed with the mud content in sediment, depth and the hydrocarbon concentrations at the OS stations sampled on September 2017 and January 2018. The similarity is calculated on the basis of their qualitative and quantitative faunal composition. Data were transformed using the (Log 1+x) transformation.

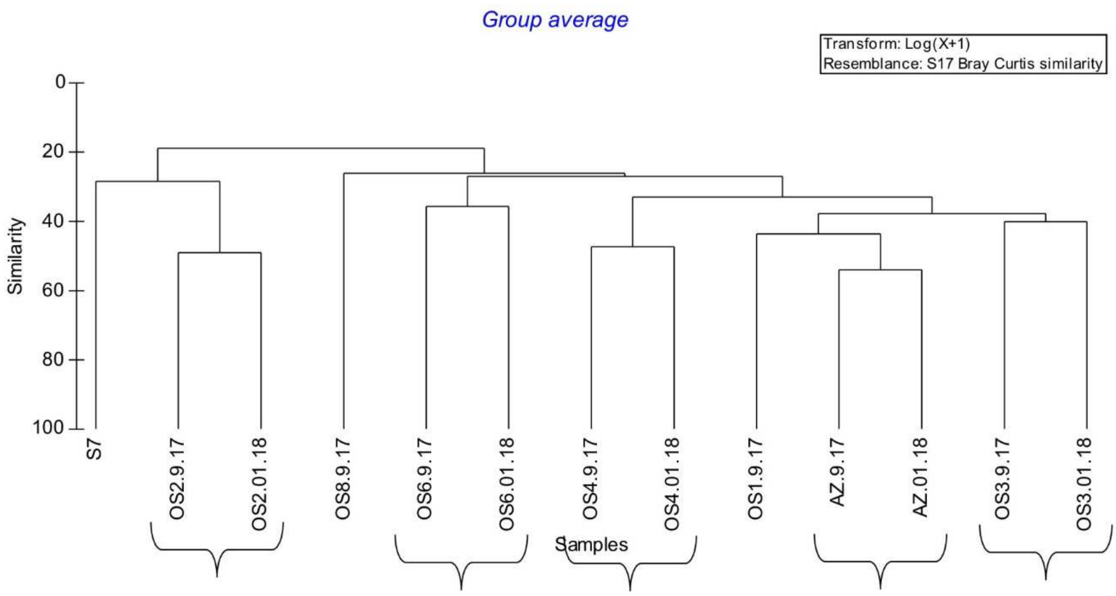

Figure 3.5.5. Hierarchical clustering of stations sampled in September 2017 and January 2018 after the incident.

The dendrogramm of Figure 3.5.5 shows a high similarity level without significant differences between the two sampling periods of September 2017 and January 2018 for those statiosn sampled twice. The multidimensional scaling (nMDS) ordination plot based on the faunal similarities (Figure 3.5.6) and the superimposition of the ordination plot with environmental factors including hydrocarbon concentrations provides a visual representation of possible correlations.

The comparative similarity among stations (Figure 3.5.6) seems to be governed by the type of sediment (mud sediment content) and depth that define the ecotype. Most of the OS stations are characterized by more coarse sediment compared with the regular monitoring stations with the exception of stations OS2 και S7. Regarding hydrocarbons (pertrogenic related to oil pollution and pyrolytic) it seems that there is no association to the patterns of benthic communities based on their structure and composition.

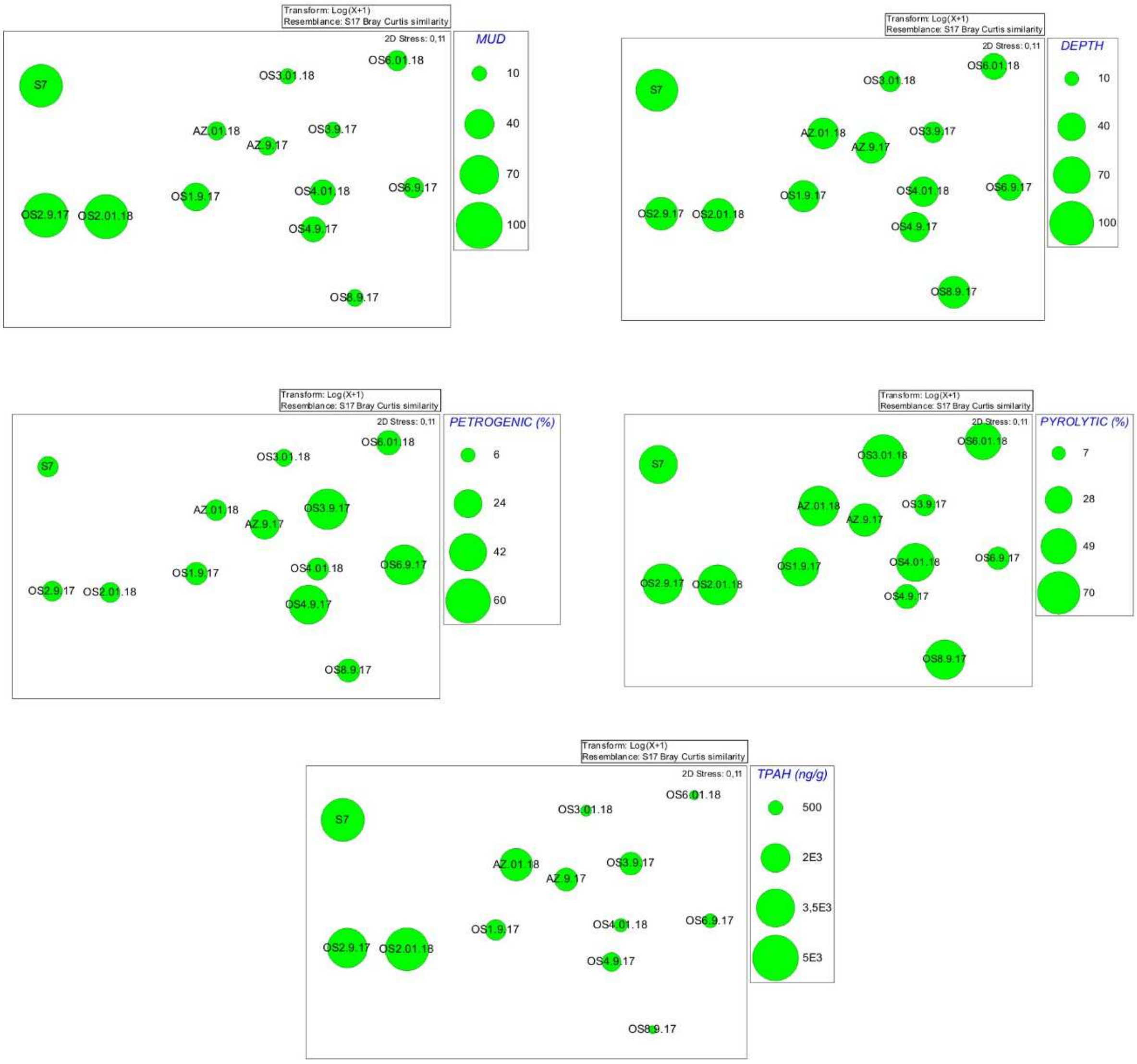

Figure 3.5.6. Two-dimensional scaling of stations sampled in September 2017 and January 2018 after the incident. Superimposition with mud sediment content and depth and total polyaromatic hydrocarbons (TPAH - ng/g), and their pyrolytic and petrogenic fractions.

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3.6. STUDY OF MACROALGAE IN THE UPPER SUBLITTORAL ZONE

P. Lardi, P. Panayotidis

3.6.1. Introduction

3.6.1.1. Basic concepts

Macroalgae are marine plants that form well organized communities on hard substrata. They can be found in shallow waters and up to 100-120 meters depth, depending on water transparency, as they are photosynthetic organisms and need light to survive. Macroalgal communities present typical composition, structure and function, depending on the environmental conditions of a given area. Therefore, they are a reliable indicator of the ecological status of the coastal ecosystems. Particularly, macroalgae that dominate hard substrata in shallow waters (<1 m = upper sublittoral zone) are considered among the best indicators worldwide (LITTLER & MURRAY, 1975; TEWARI & JOSHI, 1988). The macroalgal flora of the Mediterranean Sea is characterized by high biodiversity (COLL *et al.,* 2010).

In the Mediterranean coasts, the pristine sublittoral zone is dominated by species of the genus *Cystoseira* (PERGENT, 1991). These brown algae are canopy-forming perennial erect species. They form extensive communities of high biodiversity, which have long been considered according to PÉRÈS & PICARD (1964), as the climax stage of the shallow-water Mediterranean rocky shores. Most *Cystoseira* species show high sensitivity to natural (intense grazing, high hydrodynamic conditions) and human disturbances (THIBAUT *et al*., 2005; BALLESTEROS *et al.,* 2007; SALES & BALLESTEROS, 2009).

On the contrary, in disturbed environments opportunistic green algae prevail, such as species of the genera *Ulva* and *Cladophora*, which commonly thrive in organically enriched ecosystems (DIEZ *et al.,* 1999).

Therefore, replacing Cystoseira species with opportunistic green algae is a sign of degradation, a phenomenon that has frequently been observed on the Mediterranean coasts (SOLTAN *et al*., 2001; PANAYOTIDIS *et al*., 2004). On these grounds, macroalgae of the upper sublittoral zone, have been commonly used as indicators of marine ecosystem quality (CHRYSSOVERGIS & PANAYOTIDIS, 1995; ORLANDO-BONACA ET *al*., 2008), while their use is widespread in the implementation of the European Water Framework Directive (WFD, 2000/60/EC).

3.6.1.2. Macroalgae and Oil spills– A literature review

The wide range of the effects of an oil spill at sea depend on various factors, such as the accident size, the composition of the oil, the physico-chemical (currents, sea temperature) and geomorphological (rocky or sandy substrate, level of exposure to waves) characteristics of the area, the weather conditions (wind speed) and the response of the state (O' BRIEN & DIXON 1976; Kotrikla 2015; IPIECA-IOGP 2016). Additionally, sensitivity, resilience and the community's restoration ability is influenced by ecological and biological factors, such as life cycle, growth rate, mobility, feeding method and geographical distribution (IPIECA-IOGP 2016).

Most studies on the effects of oil on marine life have been focused on fish, mammals, birds and benthic macroinvertebrates. However, there are reports and some scientific studies (O' BRIEN & DIXON 1976; LOBON *et al.*, 2008) on the response of macroalgal communities.

The complexity of ecosystems and the interactions between organisms, may cause direct or indirect effects and thus prolong the recovery process of a community (PETERSON 2001). Typically, macroalgae are less sensitive to elevated concentrations of hydrocarbons than other groups of organisms such as macroinvertebrates and juvenile fish (IPIECA-IOGP 2015, 2016). Limpets and other molluscs, which feed on macroalgae on rocky substrates, exhibit high levels of sensitivity to oil (SOUTHWARD & SOUTHWARD 1978; SUCHANEK 1993). In some cases of oil spills, habitat changes have been recorded due to high mortality rates of macroalgae (perennial species of the genera *Fucus* and *Laminaria*) combined with the loss of important grazing gastropods (limpets). In these cases, the free space on the rocks is usually covered by ephemeral green algae (*Ulva* spp. and *Enteromorpha* spp.). These r-selected species, have high growth rates and reproduction potential by producing large quantities of spores that enables them to exploit every opportunity of vegetation (ephemeral – opportunistic species). Therefore, in several impact studies of oil spills in the coastal ecosystems, the blooms of ephemeral green algae are associated with the limited number of grazers due to mortality (HAWKINS and SOUTHWARD 1992; EDWARDS and WHITE 1999; PETERSON 2003; IPIECA-IOGP 2016).

As mentioned previously, some macroalgae species are relatively resilient to oil components. However, there are species sensitive to the toxicity of hydrocarbons. In particular, in cases of exposure of Coralline algae in oil, the upper pink layer of the living cells may die, and the white calcium carbonate remains *in situ*. If the levels and duration of the pollution are low, there may be a chance of recovery (EDWARDS and WHITE 1999).

In an oil spill impact study in California (O' BRIEN & DIXON 1976), a normal state of the macroalgal flora was initially recorded in the affected area. But then, significant mortality levels were observed in some algal species. In contrast, in the case of the «Prestige» (2002) oil spill the response of macroalgal assemblages was studied, without observing differences in the community structure. There was not significant decrease in dominant macroalgae abundances, nor an increase in opportunistic species. Some differences in species abundances were observed, but no common pattern emerged and the results were attributed to natural variability of the macroalgal communities (LOBON *et al*., 2008).

3.6.2. Purpose of the study

The present study concerns the evaluation of macroalgal assemblages in the upper sublittoral zone of the coasts of Salamina and Attica, which were affected by the "Agia Zoni II" oil spill in September 2017.

This is a comparative study between results obtained six months after the oil spill and a time series of 3 years prior to the oil spill. At the framework of the program "Monitoring of Saronikos & Elefsina gulfs under the influence of Psyttalia wastewater treatment plant" samplings are performed by the Institute of Oceanography-HCMR on a network of selected points (sampling stations) (Figure 3.6.1). The current sampling took place in 19-22 March 2018 on the eastern coast of Salamina and the southern shores of Attica.

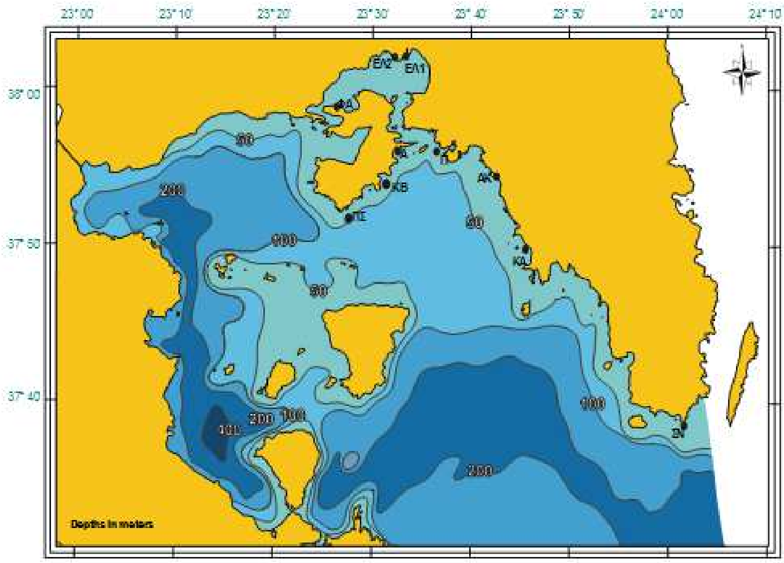

Figure 3.6.1. Network of sampling stations. Peristeria (PS-ΠΣ), Kaki Vigla (KV-KB), Ampelakia-Limnionas (A), Peiriaki (P-Π), Agios Kosmas (AK), Kavouri (KA), Sounio (SN-ΣΝ).

3.6.3. Materials and Methods

3.6.3.1. The study region

For the purposes of the present study, four sites were selected from the given network of sampling stations and in particular those that received the largest oil quantities (Ampelakia-Limnionas (A) on the eastern coasts of Salamina, as well as Peiriaki (P-Π), Agios Kosmas (AK), Kavouri (KA) on the southern coasts of Attica). All sampling stations are characterized by rocky substrate and the macroalgae assemblages were examined in shallow waters (<1 m = upper sublittoral zone), where the coast was covered by oil.

3.6.3.2. Macroalgal sampling and laboratory analysis

The sampling stations were examined by free diving and the sampling method was photographic (non-destructive sampling). In some cases, representative macroalgae were collected in order to confirm the photographic speciments. The samples collected in the field were placed in labeled plastic bags and transferred to the laboratory for further processing.

The study and taxonomy of macroalgae was carried out in the Phytobenthos Lab of HCMR, by using an OLYMPUS SZX10 stereoscope and an OLYMPUS BX43 microscope. Nomenclature and systemic classification of macroalgae were based on the following catalogs: GALLARDO *et al.* (1993) for green algae, RIBERA *et al.* (1992) for brown algae, ATHANASIADIS (1987) and GOMEZ-GARRETA *et al.* (2001) for red algae. In cases where species level recognition was not possible, macroalgae were identified at genus level.

For estimating macroalgae abundances, the Braun-Blanquet scale was applied (WIKUM D.A. and SHANHOLTZER G.F. 1978). This methodology is used for rapid assessment and description of the vegetation on a given area. Two scales are used, one concerns the coverage percentage of recorded species and the "values" given range from + (insignificant presence) to 5 (covering more than 75% of the area). The second scale, which was not used in the current study, concerns to how macroalgae species develop on rocky substrate (individual species, clusters or solid populations).

3.6.4. Results and Discussion

3.6.4.1. Marine Macroalgae

In total, 29 taxa of macroalgae were identified: 5 green algae, 10 brown algae και 14 red algae. The presence of macroalgae in the four sampling stations during March 2018 is noted with a + sign (Table 3.6.1). Species number for each station ranged from 14 to 18, corresponding to previous studies in the Saronikos Gulf (SIOKOU-FRANGOU *et al.*, 2002), as well as other areas of the Aegean Sea (CHRYSSOVERGIS & PANAYOTIDIS, 1995 and PANAYOTIDIS *et al.,* 1999).

In all the studied stations a common core of predominant species was observed. Among them, the brown algae *Dictyota dichotoma* var. *intricata, Colpomenia sinuosa* and *Sphacelaria cirrosa*, with the red algae *Jania* spp. and the green alga *Cladophora* spp.

Regarding the seasonality of macroalgae, species of the cold period were recorded, such as the brown algae *Colpomenia sinuosa* and *Scytosiphon lomentaria.* The expected fluctuations in the abundance of certain species due to their natural seasonal cycle was observed, such as the increase in the abundance of the green algae *Ulva* spp. and the brown algae *Dictyota dichotoma* var. *intricata* during the cold period. The nitrophilous *Ulva* spp. species are typically known to thrive in early spring, sometimes forming extensive blooms, and usually decline again during the warm season.

The perennial brown alga *Cystoseira compressa*, which has re-occurred in the Saronikos Gulf after the operation of the Psyttalia wastewater treatment plant, was found in most sampling stations apart from Ampelakia-Limniona. The absence of the species is not related to the oil spill.

The presence of alien species, such as *Asparagopsis taxiformis, Caulerpa cylindracea* and *Stypopodium shimperi,* was noteworthy but not related to the oil spill.

Table 3.6.1. Qualitative analysis of macroalgae during March in the sampling station Ampelakia-Limnionas (A), Peiraiki (P), Agios Kosmas (AK) and Kavouri (KA). Species presence is noted with (+).

	A	P	AK	KA
CHLOROPHYTA				
Acetabularia acetabulum			+	
Caulerpa cylindracea		+	+	+
Cladophora spp.	+	+	+	+
Halimeda tuna			+	
Ulva spp.	+	+		
FUCOPHYCEAE				
Colpomenia sinuosa	+	+	+	+
Cystoseira compressa		+	+	+
Cystoseira crinitophylla			+	+
Dictyopteris polypodioides		+	+	
Dictyota dichotoma var. *intricata*	+	+	+	+
Halopteris scoparia	+		+	+
Padina pavonica		+	+	+
Sargassum vulgare		+	+	+
Sphacelaria cirrosa	+	+	+	+
Stypopodium schimperi	+			
RHODOPHYCEAE				
Asparagopsis taxiformis	+	+		+
Ceramium virgatum		+		
Chondracanthus acicularis	+	+		
Corallina spp.	+	+		
Hypnea musciformis	+	+	+	
Jania spp.	+	+	+	+
Laurencia spp.	+			
Lithophyllum spp.				+
Osmundea truncata	+	+		
Palisada spp.		+	+	
Plocamium cartilagineum	+			
Pterocladiella capillacea	+	+		

	A	P	AK	KA
Rytiphlaea tinctroria				+
Schizymenia dubyi		+		
Total species number	**16**	**18**	**16**	**14**

3.6.4.2. Community structure

According to data collected over the past 2o years at the Phytobenthos Lab of the Institute of Oceanography-HCMR, the vegetation of the sublittoral zone in the Saronikos Gulf can be subdivided into the following main floors:

a) The **canopy**-forming floor, which is characterized by perennial photophilic algae that act as ecosystem-engineers forming “forests” in the sublittoral zone, represented mostly by large brown algae of the genera *Cystoseira* and *Sargassum*. The canopy-forming floor takes its typical form during the warm period (August-September). During the cold period, lower biomass levels are observed. At the samplings of March 2018, the canopy-forming species where present in most stations, except for Ampelakia-Limnionas in Salamina. However, this fact should not be attributed to the effects of the oil spill because it has been observed in the past.

b) The **bushy** floor, which is characterized by species who occupy the free space between the canopy-forming floor, such as the brown algae *Dictyota* spp., *Halopteris scoparia*, *Padina pavonica*, the red algae *Jania* spp. και *Corallina* spp. and the green alga *Ulva* spp. During the cold period (February-March) some typical species may occur, which may be dominant in some cases, such as the brown algae *Scytosyphon lomentaria* and *Colpomenia sinuosa*. At the same time, a seasonal bloom of nitrophilous green algae (“green tide” *Ulva spp*.) may be observed.

Finally, it’s worth noting that in the past 5-10 years various alien species, such as *Caulerpa cylindracea*, *Asparagopsis armata* and *Stypopodium shimperi*, have a permanent presence in the bushy floor. During the samplings of March 2018 all the aforementioned species were observed, with minor variations between the stations. The presence of alien species is not related to the oil spill.

c) The **crustose** floor, which is characterized by sciophilic crustose coralline algae that grow below the canopy-forming and bushy floors. These rock-hard calcareous red algae were present with some variations between the stations which were not related to the oil spill.

d) The **epiphytic** floor, which includes relatively small sized species that grow upon other larger algae. Typical species of the epiphytic floor are the brown algae of the *Sphacelaria* genus, the red algae of the genera *Polysiphonia* and *Ceramium* and the green algae of the genera *Chaetomorpha* and *Cladophora*. During the samplings of March, some of the above mentioned species were observed, but no visible differences possibly related to the oil spill were recorded.

In most of the sampling stations, no traces of oil tars were observed on the soft or rocky substrate. However, in Ampelakia-Limniona station (Figure 2.3) traces of oil tars were noticed on marine litter (plastic bottles) that is being washed out on the coast due to waves.

The presence and abundance of macroalgae in the sampling stations (Ampelakia-Limnionas, Peiraiki, Agios Kosmas, Kavouri), before (March 2017, 2016 and 2014) and after (March 2018) the oil spill, are listed in Table 3.6.2. Because marine algae exhibit seasonal variations, just like terrestrial vegetation, they are usually examined during the warm (September) and cold (March) period. Thus, it is important that the comparison of the data is made between the same sampling periods.

In the network of stations examined in March 2018, no major differences were observed in the community structure and composition, when compared to the results of previous years (March 2017, March 2016 and March 2014). No significant changes in the distribution patterns, species abundances and number of species per sampling station were noticed. No intense cover of opportunistic algae (*Ulva* spp.) was observed, other than the "normal" presence and coverage documented in previous samplings. As mentioned, the expected fluctuations in the abundance of certain species (*Ulva* spp. and *Dictyota dichotoma* var. *intricata*) were recorded but were attributed to natural variability.

Figure 3.6.2. Salamina coast: Ampelakia-Limnionas.

Figure 3.6.2.1: General view of the station

Figure 3.6.2.2: No visible traces of oil on the rocky shores

Figure 3.6.2.3: Traces of oil on marine litter

Figure 3.6.2.4: Brown algae washed out on the splash zone, without visible traces of oil

Figure 3.6.2.5: Bushy floor with Dictyota spp. and Ulva spp.

Figure 3.6.2.6: Sample of macroalgae diversity

Figure 3.6.3. Attica coasts: Peiraiki

Figure 3.6.3.1: General view of the station

Figure 3.6.3.2: No visible traces of oil on the rocky shores

Figure 3.6.3.3: Bushy floor with *Corallina* spp.

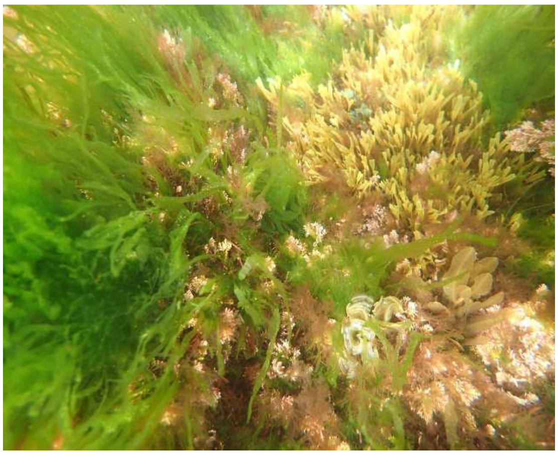

Figure 3.6.3.4: Bushy floor with *Ulva* spp., *Dictyota* spp. and *Padina pavonica*

Figure 3.6.3.5: Typical zone with *Cystoseira compressa*

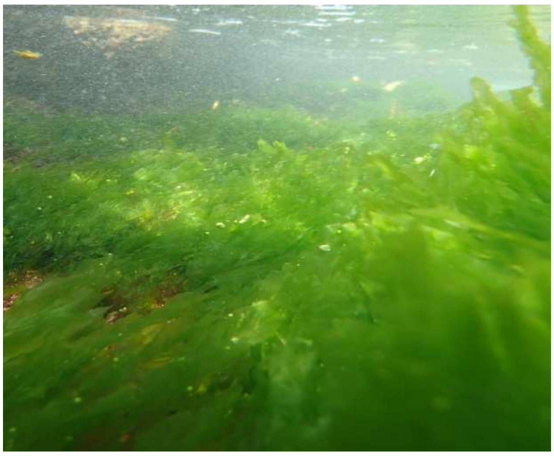

Figure 3.6.3.6: Green tide

Figure 3.6.4. Attica coasts: Agios Kosmas

Figure 3.6.4.1: General view of the station

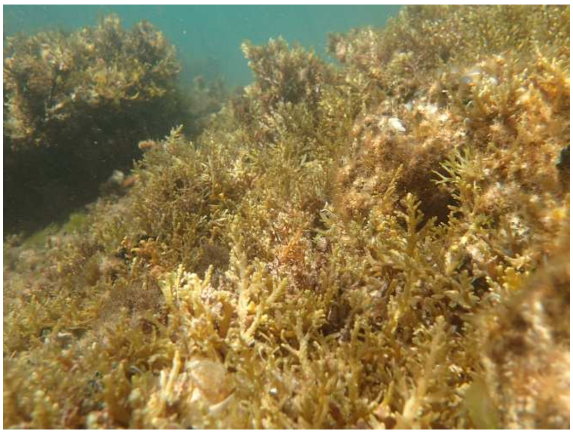

Figure 3.6.4.2: Canopy-forming floor with Cystoseira spp.

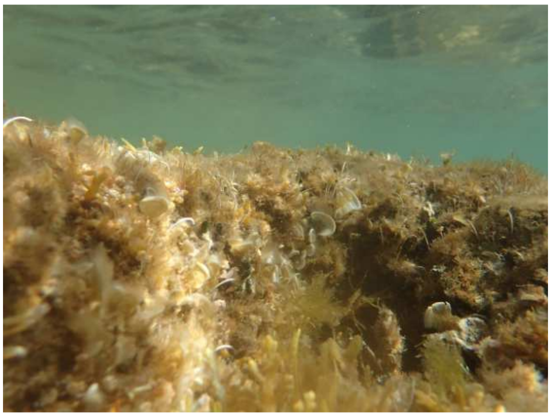

Figure 3.6.4.3: Bushy floor with *Padina pavonica* and *Halopteris scoparia*

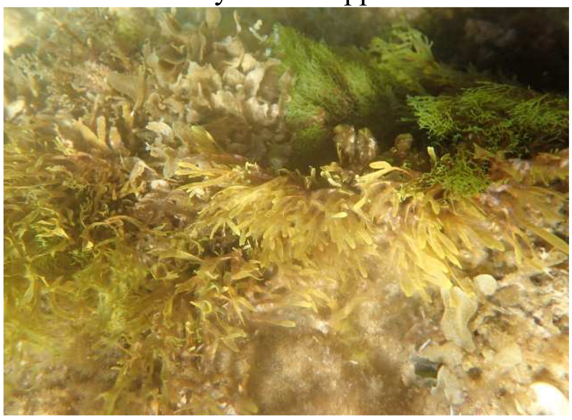

Figure 3.6.4.4: Bushy floor with *Dictyota* spp.

Figure 3.6.4.5: Bushy floor with *Jania* spp.

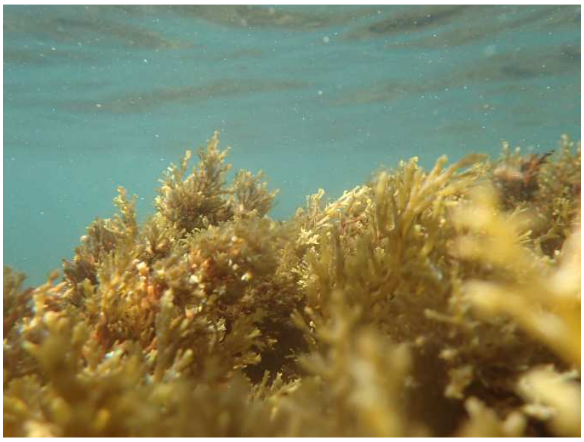

Figure 3.6.4.6: Canopy-forming floor with *Cystoseira* spp.

Figure 3.6.5. Attica coasts: Kavouri

Figure 3.6.5.1: General view of the station

Figure 3.6.5.2: Sea urchin overgrazing

Figure 3.6.5.3: Bushy algal floor, grazing by sea urchins, Posidonia meadow

Figure 3.6.5.4: Grazing by limpets. Only crustose floor remains

Figure 3.6.5.5: Canopy-forming floor with *Cystoseira* spp.

Figure 3.6.5.6: Bushy floor with *Dictyota* spp. and *Jania* spp.

Table 3.6.2. Braun-Blanquet cover-abundance scale of macroalgae during the cold period (March 2018, March 2017, March 2016 and March 2014) at the sampling stations of Ampelakia-Limnionas, Peiraiki, Agios Kosmas and Kavouri.

	Ampelakia-Limnionas				**Peiraiki**				**Agios Kosmas**		**Kavouri**			
	2018	**2017**	**2016**	**2014**	**2018**	**2017**	**2016**	**2014**	**2018**	**2017**	**2018**	**2017**	**2016**	**2014**
CHLOROPHYTA														
Acetabularia acetabulum									+					
Caulerpa cylindracea				1	+	1		+	+		1	1	1	1
Chaetomorpha aerea			+	+						+				
Cladophora spp.	2	2	+		+		+		1	1	2	2	2	2
Halimeda tuna									+	+				
Ulva spp.	2	2	2	2	1		+						+	
Valonia utricularis										+				+
FUCOPHYCEAE														
Colpomenia sinuosa	1	1	+	2	1	+	1	1	+	+	1	1	+	
Cystoseira compressa		+			3	3	3	3	3	3	2	1	2	2
Cystoseira crinitophylla									2	2	3	3	2	3
Dictyopteris polypodioides					+	+	+		+	+				
Dictyota dichotoma var. *intricata*	4	4	4	2	2	2	2	1	2	2	2	2	2	2
Halopteris scoparia	2	2	1	2		+	1	+	1	2	2	2	1	2
Hydroclathrus clathratus													+	
Padina pavonica					+	1	+		1	1	2	2	2	2
Sargassum vulgare					2	2	2	2	1	1	2	2	2	2
Sphacelaria cirrosa	+		+	+	+	+		+	+	+	1	1	1	1
Stypopodium schimperi	+													
Taonia atomaria				2						+				
RHODOPHYCEAE														
Amphiroa beauvoisii		+	+	1										
Asparagopsis taxiformis	+	1	1	+	+	+	+				+		+	
Ceramium virgatum					2	2	2	2						
Champia parvula				1										
Chondracanthus acicularis	+	+	1	2	1	2	1	2						
Corallina spp.	2	2	2	3	2	2	3	3				1	1	2

Hypnea musciformis	+	1	1	2	1	1	1	2	1					1
Jania spp.	+	+	1	2	1	1	1	1	2	2	2	2	2	2
Laurencia spp.	+													
Lithophyllum spp.											+	+		
Osmundea truncata	+		1	1	+									
Palisada spp.					+	+	1	2	1				+	+
Plocamium cartilagineum	+	+		1										
Pterocladiella capillacea	1	+	2	2	2	2	2	2						
Rytiphlaea tinctroria											+		+	
Schizymenia dubyi					2	2	2	2						
Total Species Number	**16**	**14**	**15**	**18**	**18**	**18**	**18**	**15**	**16**	**15**	**14**	**13**	**17**	**14**

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3.7. UNDERWATER VISUAL SURVEYS TO INVESTIGATE MACROSCOPIC SEABED CONDITIONS

M. Salomidi, Y. Issaris

The aim of the underwater visual survey was to inspect the present condition and investigate the potential presence of macroscopic oil residues on coastal benthic habitats of the Saronikos gulf, after the completion of the cleaning operations and the removal of the Agia Zoni II wreck. The survey focused on parts of the coasts of Salamis Island and Attica mainland, where the impact of the accident was mainly manifested (Figure 3.7.1).

The visual survey was carried out along underwater transects running parallel and perpendicular to the shoreline, at depths between 3-20 meters of: (a) the Selinia bay and around the Agia Zoni II wreck site (29/03/2018) (Figures 3.7.1.A and 3.7.2), (b) Phloisbos to Agios Kosmas coasts (30/03/2018) (Figures 3.7.1.B and 3.7.3) and (c) Agios Kosmas to Voula coasts (08/12/2017) (Figures 3.7.1.C and 3.7.4).

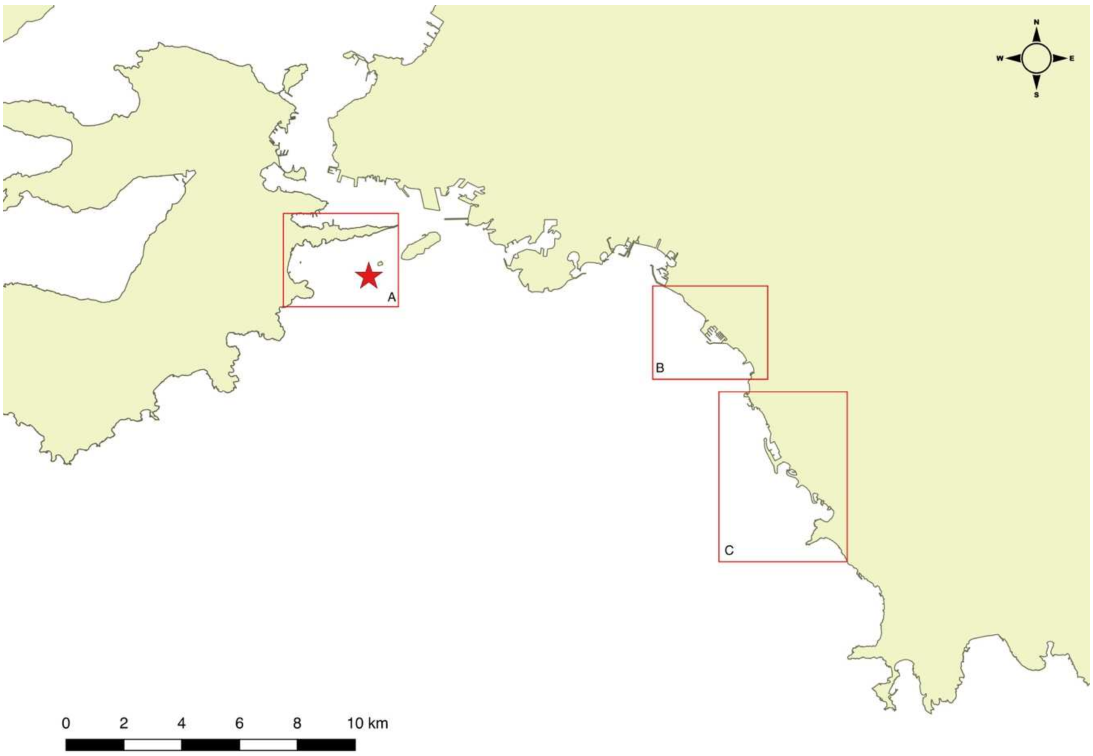

Figure 3.7.1. Map of the wider study area, indicating focus sub-areas A, B and C.

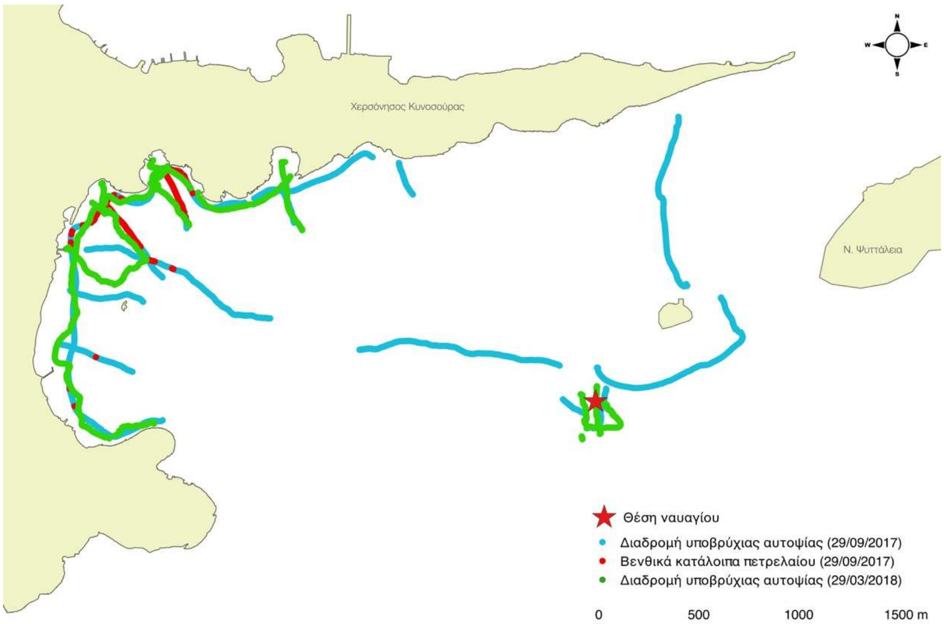

Figure 3.7.2. Map of study sub-area A, Selinia bay, Salamina island. The transects performed during the recent survey (29/03/2018) are highlighted in green, while the transects highlighted in blue refer to those performed during the initial survey and before the removal of the wreck (29/09/2017), when oil residues were detected on the seabed (red highlights).

Figure 3.7.3. Map of study sub-area B, Phloisbos to Agios Kosmas coasts, depicting locations of the underwater visual transects performed.

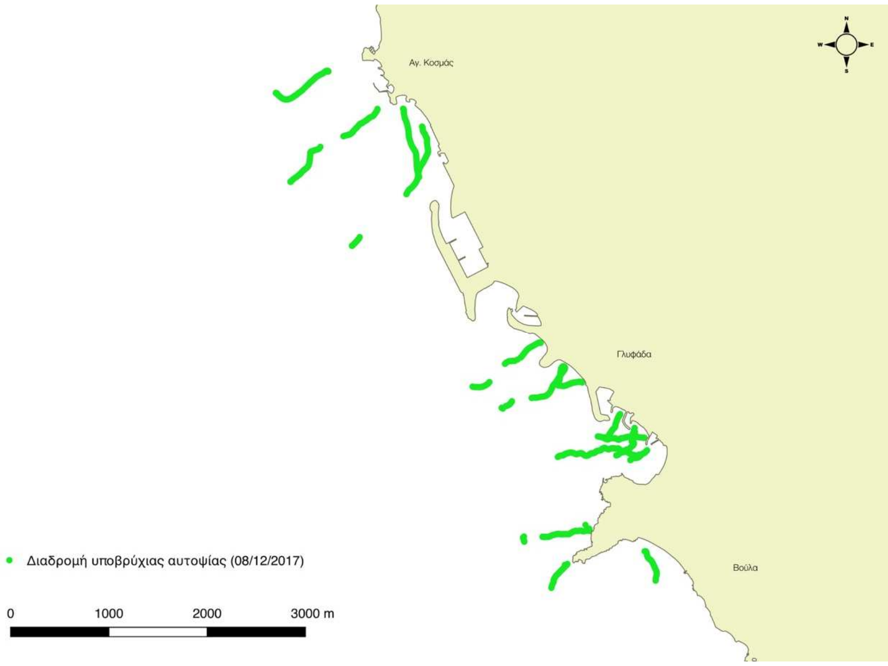

Figure 3.7.4. Map of study sub-area C, Agios Kosmas to Voula coasts, depicting locations of underwater visual transects performed.

The survey was carried out by an HCMR team using RIB boats suitable for the safe handling and successful navigation of the underwater tow camera system. This allowed for a systematic seabed inspection of a total length of ~ 25 km as well as the simultaneous HD video recording of a total duration of 9.21 hours (Table 3.7.1).

Table 3.7.1. Length of underwater visual transects, underwater video recording duration and number of underwater photographs captured per sub-area.

STUDY SUB-AREA (SURVEY DATE)	VISUAL TRANSECT LENGTH (m)	DURATION OF VIDEO RECORDING (min)	NUMBER OF PHOTOGRAPHS CAPTURED
Selinia bay (29/03/2018)	5,871	138	1,667
Phloisbos – Agios Kosmas (30/03/2018)	10,266	232	2,786
Agios Kosmas – Voula Coast A (08/12/2017)	8,609	183	2,196
TOTAL	**24,746**	**553**	**6,649**

According to the results of the on-site seabed inspection, as well as the further examination of the recorded digital material (photos and video), no macroscopic oil residues or other evidence of oil pollution were detected along the transects performed, regardless of the benthic habitat types examined (sandy and muddy bottoms, rocky reefs, Posidonia seagrass meadows, as well mixed phases thereof) in the wider study area, despite the fact that special attention was given at sites with high potential of trapping of suspended and drifting material (e.g. innermost parts of sheltered bays, seagrass meadows interstices and their lower and upper boundary zones, rocky reef recesses, etc.). The presence of plastic and other litter was however recorded in the majority of the inspected area.

Particular emphasis was placed on the critical examination of the Posidonia meadows and the vegetation of shallow reefs, in order to identify indirect signs of disturbance. However, the ecosystem was found to reflect the natural ecological conditions, as anticipated on the basis of our background knowledge of the study area and the season of the survey (Zervoudaki et al., 2015; 2016; 2017).

Particularly for the Selinia bay sub-area, where macroscopic petroleum residues were found during the initial phase of our survey (29/09/2018), this latter inspection (29/03/2018) rather implies their successful removal or degradation. However, since the area is characterized by significant accumulations of macroalgal drifts (predominantly *Dictyota* spp., *Stypopodium* sp., and Cladophorales) - typical of this region and season - the presence of smaller residues or tarballs between or below this drifting biomass is difficult to exclude with certainty.

Similar caution should be expressed for the seabed around the Agia Zoni II (ex) wreck site, where particularly dimmed light conditions, due to increased depth (30-50 m) and high turbidity, did not allow the recording of high quality underwater images so as to safely detect or exclude the presence of oil residues on the seabed. The area should therefore be revisited by means of more suitable underwater visual systems equipped with external artificial lighting (e.g. ROV).

Figures 3.7.5, 3.7.6 and 3.7.7 below present typical sea bottom aspects in the study sub-areas.

Figure 3.7.5. Characteristic sea bottom aspects of study sub-area A, Selinia bay, Salamina Island.

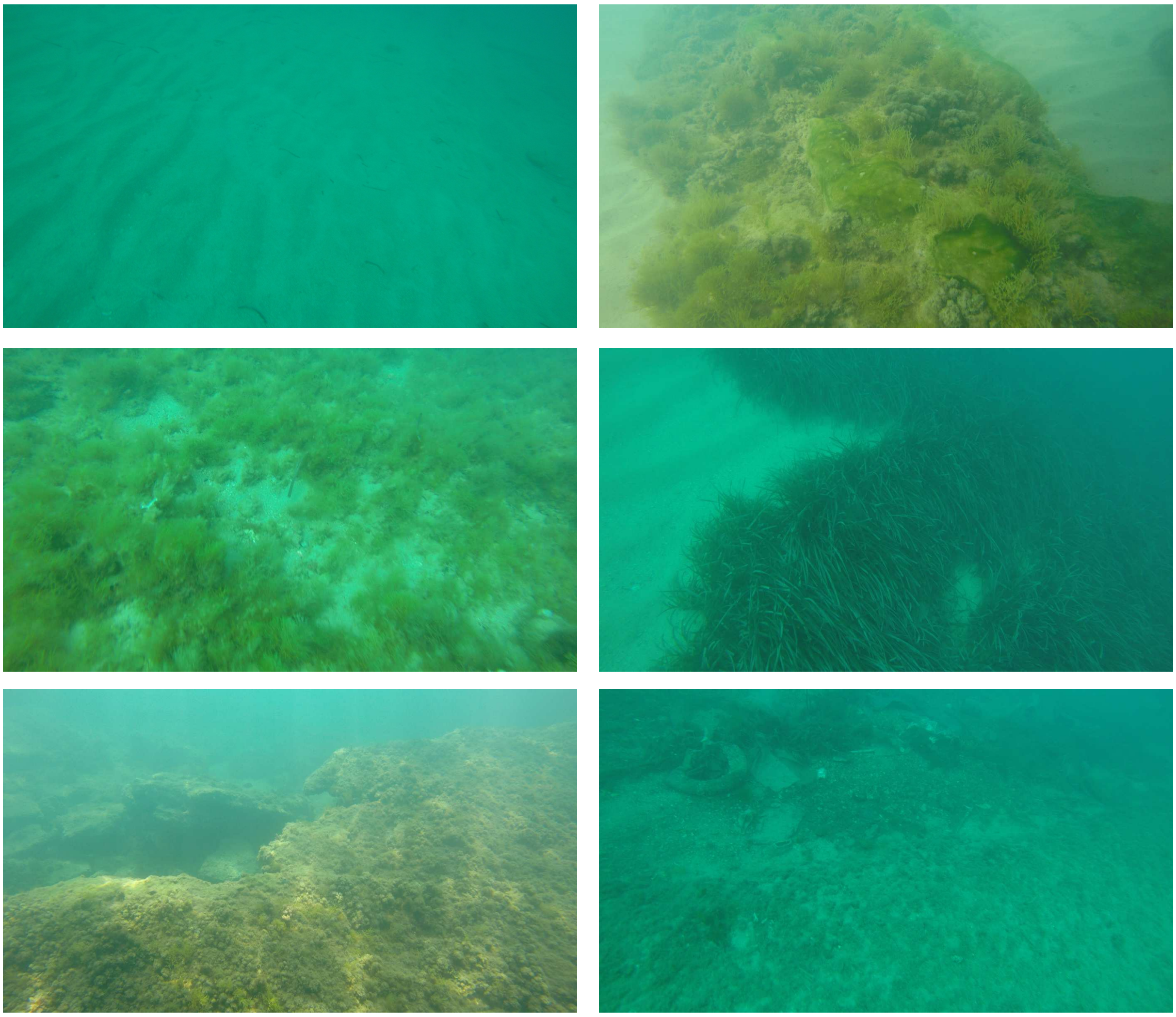

Figure 3.7.6. Characteristic sea bottom aspects of study sub-area B, Phloisvos to Agios Kosmas coasts.

Figure 3.7.7. Characteristic sea bottom aspects of study sub-area C, Agios Kosmas to Voula coasts.

References

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4. CONCLUSIONS

From the results presented in this report the following concluding remarks can be drawn:

Regarding seawater samples collected from the coastal zone of the Saronikos Gulf

Regarding total petroleum hydrocarbons, at 37 out of 56 considered coastal sampling stations their concentrations were recorded within normal levels in all cases. On the contrary, extended petroleum pollution was initially recorded (September 2017) in the regions of Elliniko, Glyfada, Selinia and Kinousoura. A smaller burden of petroleum hydrocarbons was also recorded at the areas of Phloisvos (till October 10th 2017), Asklipieio Voulas (on September 18th 2017), Megalo Kavouri (on September 18th 2017), Vouliagmeni beach club (on September 18th 2017), Mavro Lithari at Anavyssos (on September 18th 2017) and locally within the Tomb of Themistocles in Piraeus (on October 10th and October 23rd 2017).

On November 2nd 2017, December 4th 2017 and January 19th 2018 total petroleum hydrocarbons concentrations were recorded within normal levels at all sampling locations. A slightly elevated value of total petroleum hydrocarbons concentrations was recorded at Aigyptiotes Naval Club and Batis on January 19th 2018 (after a severe weather event followed by rough sea) with their levels recorded at normal values on March 21st 2018.

Regarding seawater samples collected from open sea areas of the Saronikos Gulf

In both seawater samplings conducted in open sea areas of the Saronikos Gulf, total petroleum hydrocarbons levels were normal. Furthermore, in no case values higher than the annual average concentration and maximum allowable concentration for PAHs were recorded, in accordance with the environmental quality standards for priority substances for the determination of chemical and ecological status of waters (Directive 2013/39/EC).

Minor variations in total petroleum hydrocarbons levels can be interpreted in the context of the physical variability of the total petroleum hydrocarbons content of the water column of the study area. In all cases they clearly indicate the absence of a petroleum residues burden at the sampling sites and the corresponding sampling depths in open sea areas of the Saronikos Gulf during the sampling dates.

Regarding sediment samples collected in the open Saronikos Gulf

Macroscopically no large sized tar aggregates or traces of extensive petroleum pollution were observed on the collected sediments at the time of their sampling (September 2017, November 2017 and January 2018) either in the surface or in the sub-surface layers. Very limited 1-2 mm sized tar balls were visually observed during the sampling of November 13-14th 2017 at the sampling site of the shipwreck of Agia Zoni II and the sampling site south of Psittaleia. Compared to the stations belonging to the Saronikos Gulf systematic monitoring network, for which a time series of data is available covering the past years, total aliphatic and polycyclic aromatic hydrocarbons concentrations after the incident were on general terms recorded in the same or in many cases at lower levels compared to data before the incident.

However, the molecular analysis and the use of diagnostic indices showed that at stations OS3 (off Palaio Faliro), OS4 (off Agios Kosmas), OS6 (off Glyfada) and AZII (near the shipwreck) a recent oil pollution imprint associated to the Agia Zoni II incident was recorded on September 21-22nd 2017. This recent burden is very mild in respect to the chronic petroleum-associated anthropogenic background of the Saronikos Gulf. On November 13-14th 2017 and furthermore on January 23-24th 2018 in the corresponding sediments the recent imprint associated to the Agia Zoni II incident appears to be reduced. This could be likely attributed to the degradation of the petroleum-associated compounds (aliphatic and polycyclic aromatic hydrocarbons) during their residence in the sediment. However, the limitations in the sampling procedure associated with the use of a Box Corer sampler with a surface area of 40x40 cm should be considered.

Geochemical composition of open sea surface sediments

The study on the geochemical composition of surface sediments of the Saronikos Gulf in two periods prior and three periods after the incident of the Agia Zoni II sinking and the oil spill that followed, aimed at the examination of potential contamination using as tracers the elements vanadium and nickel, often found in crude oils. In all five sampling campaigns the levels of the metals were normal and the their variability is attributed mostly to grain-size variations, with fine sediments being more enriched in metals over the coarser ones, which are generally of biogenic origin, rich in carbonates. The estimated Enrichment Factors show with reliability that there was no contamination of the sediments in the aforementioned metals and therefore it appears that there is no impact on the sediments associated to the Agia Zoni II incident.

Potential bioaccumulation of contaminants from the incident and related biological effects in marine organisms

From the study of the potential bioaccumulation of contaminants from the incident and related biological effects in mussels (*Mytilus galloprovincialis*) no bioaccumulation of aliphatic hydrocarbons, polycyclic aromatic hydrocarbons and metals has been observed due to the incident. The results on biomarkers indicative of oxidative stress, biotransformation and neurotoxicity do not show oil spill effects in these bio-indicator organisms. Levels of biomarkers in the caged mussels fall within the range of values reported by previous studies in caged or native mussels in the Saronikos Gulf.

From the determination of aliphatic hydrocarbons in the tissue of selected fish (*Mullus barbatus, Merluccius merluccius, Parapenaeus longirostris, Illex coidentii*, depending on availability) a cause-effect relationship cannot be securely established between the presence of an oil trace from the Agia Zoni II wreck in the sampling net and the bioaccumulation of petroleum products in the tissue of *Mullus barbatus*, which being a benthic fish potentially constitutes an indicator of oil burden in the sediments in which it inhabits. It should be noted however that petroleum compounds are being metabolized by the fish organism and therefore are detected in their flesh only in cases of extended petroleum pollution.

Impacts on the zoobenthic communities of the sublittoral zone

Based on the examination of benthic samples in the wider area of the Saronikos Gulf and specifically in the depth zone between 20 and 60 m (sublittoral or subtidal zone) over two sampling periods with a time interval from the accident of 0 and 4 months, it seems that there are no oil spill impacts on the sublittoral benthic communities. Specifically, the short and long-term indices of benthic communities’ response to oil pollution as well as the ecological quality of benthic communities at the sampling stations after the accident, were found at comparable levels that those of the respective sampling areas before the accident without statisticall significant differences. The composition of benthic communities corresponds with the expected according to the depth the type of sediment which are the basic factors that define the type of communities is soft bottoms.

Impacts on macroalgae of the upper sublittoral zone

In the network of stations examined in March 2018, no major differences were observed in the community structure and composition, when compared to the results of previous years. No significant changes in the distribution patterns, species abundances and number of species per sampling station were noticed. No intense cover of opportunistic algae (*Ulva* spp.) was observed, other than the "normal" presence and coverage documented in previous samplings. The expected fluctuations in the abundance of certain species (*Ulva* spp. and *Dictyota dichotoma* var. *intricata*) were recorded but were attributed to natural variability. In the sampling stations no traces of oil tars were observed on the soft or rocky substrate.

Mapping of the seabed on selected coastal regions affected by the oil spill by conducting visual observations

According to the results of the on-site seabed inspection, as well as the further examination of the recorded digital material (photos and video) on parts of the coasts of Salamis Island and Attica mainland from -20 m to 3 m depth, no macroscopic oil residues or other evidence of oil pollution were detected along the transects performed, regardless of the benthic habitat types examined (sandy and muddy bottoms, rocky reefs, Posidonia seagrass meadows, as well mixed phases thereof). Special attention was given at sites with high potential of trapping of suspended and drifting material (e.g. innermost parts of sheltered bays, seagrass meadows interstices and their lower and upper boundary zones, rocky reef recesses, etc.). Particular emphasis was placed on the critical examination of the Posidonia meadows and the vegetation of shallow reefs, in order to identify indirect signs of disturbance. However, the ecosystem was found to reflect the natural ecological conditions, as anticipated on the basis of our background knowledge of the study area and the season of the survey.

Considerations

The results presented in this report concerning the sediments collected from the open sea areas of the Saronikos Gulf should be considered as indicative as the dimensions of the sample (40x40 cm) are limited. Therefore, taking into account the direction of the dispersal of the oil spill caused by the incident, the accumulation of petroleum residues on the seabed in a position adjacent to the sampling points cannot be ruled out. Mapping of the seabed in open sea areas of the Saronikos Gulf by underwater visual systems equipped with external artificial lighting (e.g. ROV) can give more reliable information.

The general conclusion of the study is that the main effects of the incident were confined to the coastal zone, especially in the areas of Salamina, Glyfada and Elliniko and only for the first three months after the oil spill. After December 2017, there appears to be no significant findings across the coastline regarding the presence of petroleum hydrocarbons. Marine organisms appear to be unaffected by the incident, while no evidence of bioaccumulation was found. With respect to the seabed, both visual observations at depths from -20 m to 3 m and the analysis of sediment samples collected in the open Saronikos Gulf (from 22 to 92 m depth) showed no major petroleum burden related to the incident.

However it is obvious that the accumulation of individual petroleum residues on the seabed cannot be ruled out. Considering the limitations in the sampling procedure associated with the use of a Box Corer sampler with a surface area of 40x40 cm, **<u>the mapping of the seabed in open sea areas of the Saronikos Gulf by optical means (ROV) is proposed</u>** since it can give more reliable information regarding the potential accumulation of petroleum residues on the seabed (Figure 4.1).

Moreover, in order to fully ensure the good quality of seawater in the coastal zone in view of the summer season, and also taking into account the fact that there were individual cases of detection of traces of oil following severe weather events **<u>it is proposed to monitor the quality of seawater in April and May 2018</u>** on the existing network of coastal sampling stations by conducting water samplings and determination of total petroleum and polycyclic aromatic hydrocarbons.

ANNEX I

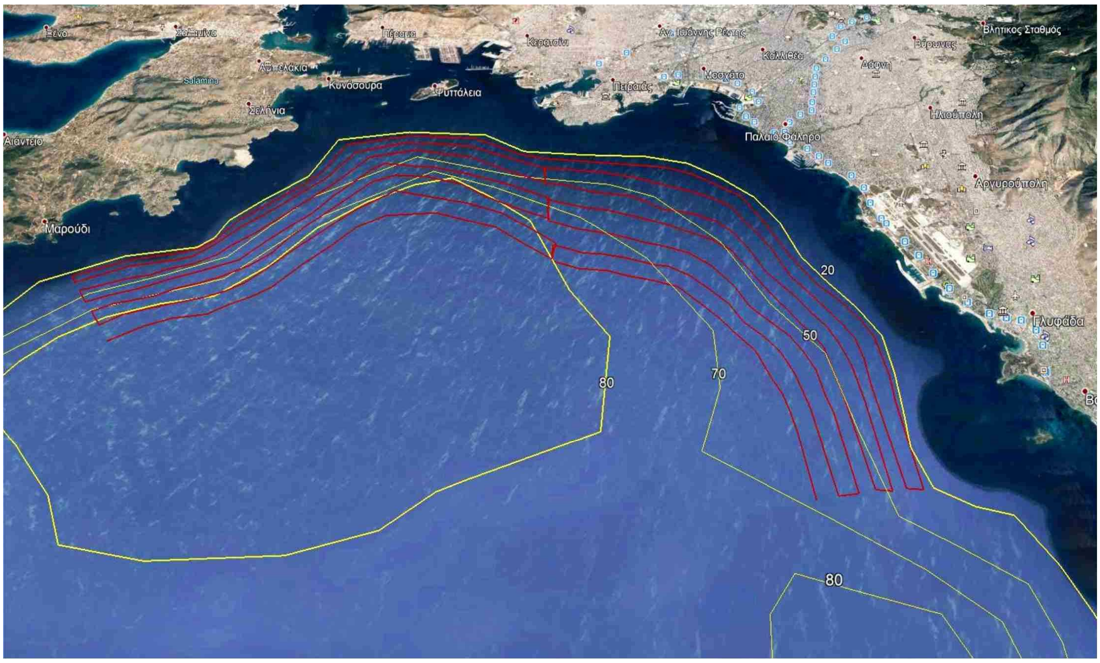

Figure 4.1. Recommended ROV routes (red lines) in order to visualize (video) the seabed and possibly identify areas where accumulation of petroleum residues has occurred.

ANNEX

Table A.1. Polycyclic aromatic hydrocarbons (PAHs; in ng/L) in seawater samples collected during the conducted samplings in coastal areas of the Saronikos Gulf (September 18th to March 21st 2018). AA: annual mean concentration (in ng/L) and MAC: maximum allowable concentration (in ng/L) for naphthalene, anthracene, fluoranthene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene and benzo(ghi)perylene according to the environmental quality standards for priority substances for the determination of chemical and ecological status of waters (Directive 2013/39/EC). **N.D.:** Not detected, detection limit (for each individual compound): 0.02 ng/L**.**

ANNEX I

MUNICIPALITY OF SALAMINA						
KINOSOURA						
	29/09/2017	**23/10/2017**	**04/12/2017**	**21/03/2018**	**AA (ng/L)**	**MAC (ng/L)**
PAHs (ng/L)						
Naphthalene	EXTENDED PETROLEUM POLLUTION	NOT CONSIDERED	1.79	1.51	2000	130000
Methylnapthalenes			3.71	2.09		
Acenaphthylene			0.10	0.28		
Acenaphthene			0.51	0.35		
Dimethylnapthalenes			11.9	5.20		
Trimethylnapthalenes			21.5	9.96		
Fluorene			0.63	0.53		
Dibenzothiophene			0.59	0.42		
Methyldibenzothiophenes			4.75	2.93		
Dimethyldibenzothiophenes			13.0	13.53		
Phenanthrene			2.57	1.60		
Anthracene			0.28	0.22	100	100
Methylphenanthrenes			18.0	8.94		
Dimethylphenanthrenes			33.6	28.09		
Trimethylphenanthrenes			24.8	45.72		
Fluoranthene			0.46	0.43	6.3	120
Pyrene			1.72	1.52		
Methylpyrenes			6.68	10.49		
Dimethylpyrenes			8.29	18.56		
Retene			0.25	1.17		
Benz[a]anthracene			1.06	2.19		
Chrysene			2.28	2.44		
Methylchrysenes			5.38	11.05		
Dimethylchrysenes			6.46	19.63		
Benzo[b]fluoranthene			0.37	1.37		17
Benzo[k]fluoranthene			0.05	0.13		17
Benzo[e]pyrene			0.63	2.31		
Benzo[a]pyrene			0.29	1.29	0.17	27
Perylene			0.13	0.43		
Indeno[1,2,3-cd]pyrene			0.05	0.52		
Benzo[ghi]perylene			0.25	0.20		0.82
Dibenz[a,h]anthracene			0.10	0.46		
ΣPAHs (ng/L)			**172.2**	**195.5**		

ANNEX I

MUNICIPALITY OF SALAMINA					
SELINIA I					
	29/09/2017	**23/10/2017**	**04/12/2017**	**AA (ng/L)**	**MAC (ng/L)**
PAHs (ng/L)					
Naphthalene	EXTENDED PETROLEUM POLLUTION	NOT CONSIDERED	1.84	2000	130000
Methylnapthalenes			5.76		
Acenaphthylene			0.07		
Acenaphthene			0.77		
Dimethylnapthalenes			18.1		
Trimethylnapthalenes			22.7		
Fluorene			0.75		
Dibenzothiophene			0.83		
Methyldibenzothiophenes			6.85		
Dimethyldibenzothiophenes			19.8		
Phenanthrene			3.10		
Anthracene			0.40	100	100
Methylphenanthrenes			24.2		
Dimethylphenanthrenes			49.6		
Trimethylphenanthrenes			43.0		
Fluoranthene			0.53	6.3	120
Pyrene			2.56		
Methylpyrenes			11.7		
Dimethylpyrenes			15.2		
Retene			0.55		
Benz[a]anthracene			1.91		
Chrysene			3.80		
Methylchrysenes			10.2		
Dimethylchrysenes			12.7		
Benzo[b]fluoranthene			0.95		17
Benzo[k]fluoranthene			0.14		17
Benzo[e]pyrene			1.40		
Benzo[a]pyrene			**0.94**	0.17	27
Perylene			0.34		
Indeno[1,2,3-cd]pyrene			0.33		
Benzo[ghi]perylene			**1.01**		0.82
Dibenz[a,h]anthracene			0.28		
ΣPAHs (ng/L)			**262.5**		

MUNICIPALITY OF SALAMINA				
SELINIA II				
	29/09/2017	**21/03/2018**	**AA (ng/L)**	**MAC (ng/L)**
PAHs (ng/L)				
Naphthalene	6.20	1.04	2000	130000
Methylnapthalenes	29.4	1.13		
Acenaphthylene	0.15	0.07		
Acenaphthene	2.84	0.11		
Dimethylnapthalenes	54.2	1.64		
Trimethylnapthalenes	42.1	2.13		
Fluorene	2.50	0.26		
Dibenzothiophene	2.06	0.08		
Methyldibenzothiophenes	6.82	0.40		
Dimethyldibenzothiophenes	11.0	1.01		
Phenanthrene	6.76	0.57		
Anthracene	0.57	0.04	100	100
Methylphenanthrenes	24.8	1.49		
Dimethylphenanthrenes	32.5	2.59		
Trimethylphenanthrenes	21.9	2.95		
Fluoranthene	0.46	0.16	6.3	120
Pyrene	1.80	0.25		
Methylpyrenes	5.84	0.97		
Dimethylpyrenes	5.56	1.58		
Retene	0.27	0.05		
Benz[a]anthracene	0.69	0.12		
Chrysene	2.13	0.28		
Methylchrysenes	4.12	0.65		
Dimethylchrysenes	4.21	0.84		
Benzo[b]fluoranthene	0.29	0.11		17
Benzo[k]fluoranthene	0.04	N.D		17
Benzo[e]pyrene	0.46	0.14		
Benzo[a]pyrene	**0.18**	0.06	0.17	27
Perylene	0.08	0.02		
Indeno[1,2,3-cd]pyrene	0.04	N.D		
Benzo[ghi]perylene	0.12	0.05		0.82
Dibenz[a,h]anthracene	0.07	0.02		
ΣPAHs (ng/L)	**270.3**	**20.9**		

ANNEX I

MUNICIPALITY OF SALAMINA					
KAKH VIGLA					
	29/09/2017	**23/10/2017**	**04/12/2017**	**AA (ng/L)**	**MAC (ng/L)**
PAHs (ng/L)					
Naphthalene	1.05	1.49	2.07	2000	130000
Methylnapthalenes	2.30	2.64	2.26		
Acenaphthylene	0.10	0.05	0.11		
Acenaphthene	0.21	0.08	0.20		
Dimethylnapthalenes	5.27	1.24	3.18		
Trimethylnapthalenes	6.9	1.50	3.27		
Fluorene	0.50	0.11	0.30		
Dibenzothiophene	0.51	0.06	0.15		
Methyldibenzothiophenes	0.23	0.12	0.47		
Dimethyldibenzothiophenes	0.4	0.21	0.81		
Phenanthrene	2.88	0.33	0.83		
Anthracene	0.46	0.02	0.05	100	100
Methylphenanthrenes	9.0	0.54	1.99		
Dimethylphenanthrenes	9.6	0.63	2.44		
Trimethylphenanthrenes	6.3	0.38	1.62		
Fluoranthene	0.46	0.08	0.23	6.3	120
Pyrene	1.49	0.04	0.15		
Methylpyrenes	8.25	0.08	0.33		
Dimethylpyrenes	12.1	0.08	0.37		
Retene	0.91	N.D.	0.03		
Benz[a]anthracene	1.54	N.D.	0.05		
Chrysene	2.49	0.05	0.15		
Methylchrysenes	2.75	0.07	0.21		
Dimethylchrysenes	4.0	0.07	0.20		
Benzo[b]fluoranthene	0.69	0.03	0.05		17
Benzo[k]fluoranthene	0.10	N.D.	N.D.		17
Benzo[e]pyrene	1.21	0.02	0.04		
Benzo[a]pyrene	**0.89**	N.D.	N.D.	0.17	27
Perylene	0.37	N.D.	N.D.		
Indeno[1,2,3-cd]pyrene	0.09	N.D.	N.D.		
Benzo[ghi]perylene	0.46	N.D.	0.02		0.82
Dibenz[a,h]anthracene	0.25	N.D.	N.D.		
ΣPAHs (ng/L)	**123.8**	**9.98**	**21.6**		

ANNEX I

MUNICIPALITY OF SALAMINA				
CHAROUPIAS				
	23/10/2017	**04/12/2017**	**AA (ng/L)**	**MAC (ng/L)**
PAHs (ng/L)				
Naphthalene	0.90	2.18	2000	130000
Methylnapthalenes	1.10	2.72		
Acenaphthylene	0.04	0.11		
Acenaphthene	0.06	0.20		
Dimethylnapthalenes	0.73	3.57		
Trimethylnapthalenes	0.69	3.83		
Fluorene	0.15	0.32		
Dibenzothiophene	0.06	0.15		
Methyldibenzothiophenes	0.08	0.47		
Dimethyldibenzothiophenes	0.11	0.92		
Phenanthrene	0.29	0.83		
Anthracene	N.D.	0.04	100	100
Methylphenanthrenes	0.35	2.10		
Dimethylphenanthrenes	0.33	2.86		
Trimethylphenanthrenes	0.14	1.67		
Fluoranthene	0.07	0.26	6.3	120
Pyrene	0.02	0.19		
Methylpyrenes	0.03	0.32		
Dimethylpyrenes	0.03	0.34		
Retene	N.D.	0.02		
Benz[a]anthracene	N.D.	0.05		
Chrysene	0.03	0.15		
Methylchrysenes	0.03	0.19		
Dimethylchrysenes	0.03	0.17		
Benzo[b]fluoranthene	N.D.	0.06		17
Benzo[k]fluoranthene	N.D.	N.D.		17
Benzo[e]pyrene	N.D.	0.04		
Benzo[a]pyrene	N.D.	N.D.	0.17	27
Perylene	N.D.	N.D.		
Indeno[1,2,3-cd]pyrene	N.D.	N.D.		
Benzo[ghi]perylene	N.D.	0.02		0.82
Dibenz[a,h]anthracene	N.D.	N.D.		
ΣPAHs (ng/L)	**5.34**	**23.8**		

ANNEX I

MUNICIPALITY OF SALAMINA					
NTOULAPI					
	29/09/2017	**23/10/2017**	**04/12/2017**	**AA (ng/L)**	**MAC (ng/L)**
PAHs (ng/L)					
Naphthalene	2.11	1.16	3.64	2000	130000
Methylnapthalenes	4.19	1.51	4.31		
Acenaphthylene	0.04	0.07	0.16		
Acenaphthene	0.19	0.06	0.23		
Dimethylnapthalenes	4.48	1.24	4.78		
Trimethylnapthalenes	3.29	0.94	4.20		
Fluorene	0.33	0.14	0.36		
Dibenzothiophene	0.15	0.07	0.17		
Methyldibenzothiophenes	0.36	0.12	0.57		
Dimethyldibenzothiophenes	0.56	0.18	1.16		
Phenanthrene	0.72	0.32	0.97		
Anthracene	0.03	0.02	0.07	100	100
Methylphenanthrenes	1.66	0.53	2.67		
Dimethylphenanthrenes	1.81	0.57	3.84		
Trimethylphenanthrenes	1.02	0.27	2.60		
Fluoranthene	0.12	0.08	0.30	6.3	120
Pyrene	0.07	0.04	0.24		
Methylpyrenes	0.16	0.08	0.52		
Dimethylpyrenes	0.19	0.07	0.57		
Retene	0.03	N.D.	0.02		
Benz[a]anthracene	0.02	0.02	0.09		
Chrysene	0.11	0.04	0.22		
Methylchrysenes	0.15	0.05	0.33		
Dimethylchrysenes	0.15	0.05	0.34		
Benzo[b]fluoranthene	0.06	0.03	0.10		17
Benzo[k]fluoranthene	N.D.	N.D.	0.02		17
Benzo[e]pyrene	0.04	0.02	0.07		
Benzo[a]pyrene	N.D.	N.D.	0.02	0.17	27
Perylene	N.D.	N.D.	N.D.		
Indeno[1,2,3-cd]pyrene	0.02	N.D.	0.02		
Benzo[ghi]perylene	0.02	N.D.	0.03		0.82
Dibenz[a,h]anthracene	N.D.	N.D.	N.D.		
ΣPAHs (ng/L)	**22.1**	**7.72**	**32.6**		

MUNICIPALITY OF SALAMINA					
GIALA					
	29/09/2017	**23/10/2017**	**04/12/2017**	**AA (ng/L)**	**MAC (ng/L)**
PAHs (ng/L)					
Naphthalene	1.45	0.97	5.00	2000	130000
Methylnapthalenes	2.67	1.26	2.77		
Acenaphthylene	0.07	0.03	1.19		
Acenaphthene	0.18	0.06	0.22		
Dimethylnapthalenes	3.71	1.08	2.42		
Trimethylnapthalenes	4.84	0.93	2.17		
Fluorene	0.45	0.16	0.57		
Dibenzothiophene	0.26	0.06	0.13		
Methyldibenzothiophenes	1.36	0.13	0.31		
Dimethyldibenzothiophenes	4.12	0.37	0.54		
Phenanthrene	1.44	0.37	2.14		
Anthracene	0.13	0.02	0.16	100	100
Methylphenanthrenes	6.61	0.78	1.80		
Dimethylphenanthrenes	12.6	1.11	1.83		
Trimethylphenanthrenes	12.1	1.00	0.76		
Fluoranthene	0.25	0.09	0.59	6.3	120
Pyrene	0.60	0.07	0.38		
Methylpyrenes	2.54	0.26	0.30		
Dimethylpyrenes	3.05	0.38	0.22		
Retene	0.22	0.03	0.12		
Benz[a]anthracene	0.29	0.04	0.07		
Chrysene	0.84	0.10	0.16		
Methylchrysenes	2.32	0.26	0.14		
Dimethylchrysenes	3.11	0.36	0.14		
Benzo[b]fluoranthene	0.22	0.04	0.15		17
Benzo[k]fluoranthene	0.03	N.D.	0.03		17
Benzo[e]pyrene	0.38	0.05	0.06		
Benzo[a]pyrene	0.15	0.02	0.03	0.17	27
Perylene	0.07	N.D.	N.D.		
Indeno[1,2,3-cd]pyrene	0.04	N.D.	0.04		
Benzo[ghi]perylene	0.11	0.03	0.06		0.82
Dibenz[a,h]anthracene	0.05	N.D.	0.02		
ΣPAHs (ng/L)	**66.4**	**10.09**	**24.5**		

MUNICIPALITY OF SALAMINA					
KIRIZA					
	29/09/2017	**23/10/2017**	**04/12/2017**	**AA (ng/L)**	**MAC (ng/L)**
PAHs (ng/L)					
Naphthalene	0.90	0.90	1.75	2000	130000
Methylnapthalenes	2.01	1.10	1.73		
Acenaphthylene	0.04	0.04	0.11		
Acenaphthene	0.13	0.06	0.13		
Dimethylnapthalenes	2.39	1.03	2.07		
Trimethylnapthalenes	2.83	0.69	1.95		
Fluorene	0.26	0.15	0.23		
Dibenzothiophene	0.11	0.06	0.11		
Methyldibenzothiophenes	0.27	0.08	0.24		
Dimethyldibenzothiophenes	0.45	0.11	0.42		
Phenanthrene	0.53	0.29	0.67		
Anthracene	0.03	N.D.	0.04	100	100
Methylphenanthrenes	1.25	0.35	1.16		
Dimethylphenanthrenes	1.44	0.33	1.29		
Trimethylphenanthrenes	1.03	0.14	0.73		
Fluoranthene	0.09	0.07	0.21	6.3	120
Pyrene	0.06	0.02	0.12		
Methylpyrenes	0.19	0.03	0.17		
Dimethylpyrenes	0.25	0.03	0.19		
Retene	0.02	N.D.	0.03		
Benz[a]anthracene	0.03	N.D.	0.03		
Chrysene	0.09	0.03	0.09		
Methylchrysenes	0.18	0.03	0.11		
Dimethylchrysenes	0.18	0.03	0.10		
Benzo[b]fluoranthene	0.03	N.D.	0.09		17
Benzo[k]fluoranthene	N.D.	N.D.	0.02		17
Benzo[e]pyrene	0.03	N.D.	0.05		
Benzo[a]pyrene	N.D.	N.D.	N.D.	0.17	27
Perylene	N.D.	N.D.	N.D.		
Indeno[1,2,3-cd]pyrene	N.D.	N.D.	0.02		
Benzo[ghi]perylene	N.D.	N.D.	0.02		0.82
Dibenz[a,h]anthracene	N.D.	N.D.	N.D.		
ΣPAHs (ng/L)	**14.9**	**5.64**	**13.9**		

MUNICIPALITY OF SALAMINA					
MAROUDI					
	29/09/2017	**23/10/2017**	**04/12/2017**	**AA (ng/L)**	**MAC (ng/L)**
PAHs (ng/L)					
Naphthalene	1.29	1.00	1.43	2000	130000
Methylnapthalenes	2.26	1.31	1.61		
Acenaphthylene	0.08	0.05	0.08		
Acenaphthene	0.15	0.06	0.12		
Dimethylnapthalenes	2.75	1.05	2.03		
Trimethylnapthalenes	2.81	0.72	1.82		
Fluorene	0.37	0.15	0.23		
Dibenzothiophene	0.14	0.06	0.10		
Methyldibenzothiophenes	0.37	0.09	0.24		
Dimethyldibenzothiophenes	0.76	0.13	0.46		
Phenanthrene	0.76	0.31	0.65		
Anthracene	0.06	0.02	0.04	100	100
Methylphenanthrenes	2.03	0.54	1.22		
Dimethylphenanthrenes	2.81	0.38	1.42		
Trimethylphenanthrenes	2.27	0.18	0.84		
Fluoranthene	0.14	0.08	0.24	6.3	120
Pyrene	0.10	0.03	0.14		
Methylpyrenes	0.27	0.04	0.19		
Dimethylpyrenes	0.36	0.03	0.21		
Retene	0.08	0.02	0.05		
Benz[a]anthracene	0.05	N.D.	0.04		
Chrysene	0.15	0.03	0.11		
Methylchrysenes	0.33	0.03	0.13		
Dimethylchrysenes	0.39	0.03	0.13		
Benzo[b]fluoranthene	0.06	N.D.	0.06		17
Benzo[k]fluoranthene	N.D.	N.D.	N.D.		17
Benzo[e]pyrene	0.04	N.D.	0.04		
Benzo[a]pyrene	0.03	N.D.	N.D.	0.17	27
Perylene	N.D.	N.D.	N.D.		
Indeno[1,2,3-cd]pyrene	0.02	N.D.	N.D.		
Benzo[ghi]perylene	0.02	N.D.	0.03		0.82
Dibenz[a,h]anthracene	N.D.	N.D.	N.D.		
ΣPAHs (ng/L)	**21.0**	**6.40**	**13.7**		

ANNEX I

MUNICIPALITY OF SALAMINA					
PERISTERIA					
	29/09/2017	**23/10/2017**	**04/12/2017**	**AA (ng/L)**	**MAC (ng/L)**
PAHs (ng/L)					
Naphthalene	1.09	1.04	2.70	2000	130000
Methylnapthalenes	1.54	1.25	2.73		
Acenaphthylene	0.08	0.04	1.50		
Acenaphthene	0.12	0.07	0.16		
Dimethylnapthalenes	2.16	1.16	11.2		
Trimethylnapthalenes	2.25	0.67	9.35		
Fluorene	0.33	0.14	0.11		
Dibenzothiophene	0.12	0.05	0.08		
Methyldibenzothiophenes	0.28	0.09	1.62		
Dimethyldibenzothiophenes	0.48	0.15	8.53		
Phenanthrene	0.82	0.29	0.83		
Anthracene	0.05	0.02	0.12	100	100
Methylphenanthrenes	1.76	0.41	10.9		
Dimethylphenanthrenes	1.37	0.42	25.5		
Trimethylphenanthrenes	0.68	0.23	18.1		
Fluoranthene	0.17	0.08	0.22	6.3	120
Pyrene	0.09	0.03	0.12		
Methylpyrenes	0.14	0.06	0.23		
Dimethylpyrenes	0.15	0.05	0.24		
Retene	0.08	N.D.	0.94		
Benz[a]anthracene	0.03	N.D.	0.03		
Chrysene	0.07	0.03	0.09		
Methylchrysenes	0.10	0.03	0.11		
Dimethylchrysenes	0.10	0.04	0.10		
Benzo[b]fluoranthene	0.04	0.02	0.06		17
Benzo[k]fluoranthene	N.D.	N.D.	N.D.		17
Benzo[e]pyrene	0.04	N.D.	0.03		
Benzo[a]pyrene	0.03	N.D.	N.D.	0.17	27
Perylene	N.D.	N.D.	N.D.		
Indeno[1,2,3-cd]pyrene	N.D.	N.D.	N.D.		
Benzo[ghi]perylene	N.D.	N.D.	0.02		0.82
Dibenz[a,h]anthracene	N.D.	N.D.	N.D.		
ΣPAHs (ng/L)	**14.21**	**6.43**	**95.7**		

MUNICIPALITY OF PIRAEUS					
AEGEAN SEA NAVAL COMMAND-ROCKY SHORE					
	10/10/2017	**23/10/2017**	**02/11/2017**	**AA (ng/L)**	**MAC (ng/L)**
PAHs (ng/L)					
Naphthalene	1.39	2.45	1.27	2000	130 000
Methylnapthalenes	1.67	2.71	1.21		
Acenaphthylene	0.10	0.12	0.06		
Acenaphthene	0.20	0.15	0.06		
Dimethylnapthalenes	3.60	2.16	1.01		
Trimethylnapthalenes	7.11	2.60	0.86		
Fluorene	0.29	0.22	0.10		
Dibenzothiophene	0.23	0.10	0.05		
Methyldibenzothiophenes	1.35	0.43	0.13		
Dimethyldibenzothiophenes	4.09	0.37	0.41		
Phenanthrene	1.01	0.54	0.27		
Anthracene	0.14	0.05	0.02	100	100
Methylphenanthrenes	6.37	3.49	0.52		
Dimethylphenanthrenes	3.60	3.08	1.12		
Trimethylphenanthrenes	1.73	2.32	1.09		
Fluoranthene	0.21	0.17	0.08	6.3	120
Pyrene	0.78	0.20	0.08		
Methylpyrenes	2.84	0.58	0.29		
Dimethylpyrenes	4.14	0.80	0.49		
Retene	0.13	0.03	0.02		
Benz[a]anthracene	0.41	0.10	0.04		
Chrysene	0.85	0.33	0.12		
Methylchrysenes	2.05	0.71	0.27		
Dimethylchrysenes	2.41	1.00	0.38		
Benzo[b]fluoranthene	0.33	0.16	0.06		17
Benzo[k]fluoranthene	0.03	0.19	N.D.		17
Benzo[e]pyrene	0.41	0.19	0.07		
Benzo[a]pyrene	0.15	0.08	0.03	0.17	27
Perylene	0.07	0.03	N.D.		
Indeno[1,2,3-cd]pyrene	0.03	0.05	N.D.		
Benzo[ghi]perylene	0.11	0.10	0.03		0.82
Dibenz[a,h]anthracene	0.08	0.03	N.D.		
ΣPAHs (ng/L)	**47.9**	**25.5**	**10.2**		

ANNEX I

MUNICIPALITY OF PIRAEUS					
HELLENIC NAVAL ACADEMY					
	10/10/2017		02/11/2017	AA (ng/L)	MAC (ng/L)
PAHs (ng/L)					
Naphthalene	2.37		1.14	2000	130 000
Methylnapthalenes	5.43		1.45		
Acenaphthylene	0.06		0.04		
Acenaphthene	0.56		0.08		
Dimethylnapthalenes	3.66		1.55		
Trimethylnapthalenes	1.70		1.41		
Fluorene	0.69		0.15		
Dibenzothiophene	0.49		0.07		
Methyldibenzothiophenes	2.53		0.17		
Dimethyldibenzothiophenes	7.15		0.40		
Phenanthrene	2.92		0.38		
Anthracene	0.25		0.02	100	100
Methylphenanthrenes	4.49		0.84		
Dimethylphenanthrenes	5.49		1.39		
Trimethylphenanthrenes	2.35		1.21		
Fluoranthene	0.34		0.10	6.3	120
Pyrene	1.52		0.08		
Methylpyrenes	5.03		0.26		
Dimethylpyrenes	5.81		0.42		
Retene	0.21		N.D.		
Benz[a]anthracene	0.62		0.04		
Chrysene	1.68		0.12		
Methylchrysenes	3.18		0.24		
Dimethylchrysenes	3.22		0.29		
Benzo[b]fluoranthene	0.54		0.06		17
Benzo[k]fluoranthene	0.04		N.D.		17
Benzo[e]pyrene	0.63		0.05		
Benzo[a]pyrene	0.14		0.02	0.17	27
Perylene	0.08		N.D.		
Indeno[1,2,3-cd]pyrene	0.04		N.D.		
Benzo[ghi]perylene	0.14		0.03		0.82
Dibenz[a,h]anthracene	0.09		N.D.		
ΣPAHs (ng/L)	**63.5**		**12.1**		

ANNEX I

MUNICIPALITY OF PIRAEUS						
AFRODITE VOE						
	29/09/2017	**10/10/2017**	**23/10/2017**	**02/11/2017**	**AA (ng/L)**	**MAC (ng/L)**
PAHs (ng/L)						
Naphthalene	2.70	1.69	1.21	1.37	2000	130 000
Methylnapthalenes	15.8	10.5	5.63	6.18		
Acenaphthylene	0.10	0.21	0.08	0.08		
Acenaphthene	1.34	1.27	1.08	0.91		
Dimethylnapthalenes	29.6	30.6	22.1	22.2		
Trimethylnapthalenes	31.5	36.7	41.2	24.0		
Fluorene	1.36	1.43	1.13	0.94		
Dibenzothiophene	1.06	1.32	1.31	0.73		
Methyldibenzothiophenes	5.18	6.78	9.25	3.49		
Dimethyldibenzothiophenes	14.6	17.6	27.3	8.56		
Phenanthrene	4.37	5.04	5.47	3.01		
Anthracene	0.57	0.49	0.99	0.40	100	100
Methylphenanthrenes	22.7	28.6	41.1	15.2		
Dimethylphenanthrenes	44.8	55.9	84.3	27.3		
Trimethylphenanthrenes	42.3	44.4	77.0	22.6		
Fluoranthene	0.51	0.58	0.78	0.35	6.3	120
Pyrene	2.31	2.95	3.71	1.62		
Methylpyrenes	9.31	9.12	14.4	5.21		
Dimethylpyrenes	12.2	10.6	19.8	7.50		
Retene	0.74	0.44	0.97	0.34		
Benz[a]anthracene	1.04	1.51	2.62	0.69		
Chrysene	2.89	2.79	4.37	1.33		
Methylchrysenes	8.11	6.12	14.1	3.68		
Dimethylchrysenes	11.5	6.72	20.1	4.62		
Benzo[b]fluoranthene	0.81	0.89	1.21	0.34		17
Benzo[k]fluoranthene	0.12	0.07	0.14	0.04		17
Benzo[e]pyrene	1.24	1.00	1.75	0.49		
Benzo[a]pyrene	**0.70**	**0.32**	**1.16**	**0.30**	0.17	27
Perylene	0.29	0.13	0.43	0.10		
Indeno[1,2,3-cd]pyrene	0.19	0.07	0.25	0.06		
Benzo[ghi]perylene	0.48	0.28	0.81	0.22		0.82
Dibenz[a,h]anthracene	0.22	0.17	0.44	0.11		
ΣPAHs (ng/L)	**270.6**	**286.1**	**406.2**	**164.1**		

ANNEX I

MUNICIPALITY OF PIRAEUS						
FREATTYDA						
	29/09/2017	10/10/2017	23/10/2017	02/11/2017	AA (ng/L)	MAC (ng/L)
PAHs (ng/L)						
Naphthalene	1.41	1.15	0.96	3.19	2000	130 000
Methylnapthalenes	2.54	5.14	1.27	2.54		
Acenaphthylene	0.10	0.07	0.10	0.08		
Acenaphthene	0.23	0.17	0.12	0.11		
Dimethylnapthalenes	4.52	2.85	1.68	1.61		
Trimethylnapthalenes	6.86	7.76	2.98	1.68		
Fluorene	0.41	0.20	0.17	0.18		
Dibenzothiophene	0.27	0.22	0.10	0.10		
Methyldibenzothiophenes	1.41	1.49	0.74	0.36		
Dimethyldibenzothiophenes	5.00	4.86	2.14	0.81		
Phenanthrene	1.51	1.15	0.58	0.63		
Anthracene	0.20	0.13	0.08	0.05	100	100
Methylphenanthrenes	6.56	6.72	3.74	1.59		
Dimethylphenanthrenes	14.7	14.9	7.48	1.89		
Trimethylphenanthrenes	14.4	13.5	6.15	1.45		
Fluoranthene	0.48	0.33	0.19	0.35	6.3	120
Pyrene	0.74	0.69	0.50	0.29		
Methylpyrenes	4.02	3.17	1.83	0.59		
Dimethylpyrenes	5.59	4.41	2.30	0.89		
Retene	0.28	0.15	0.10	0.03		
Benz[a]anthracene	0.44	0.62	0.21	0.19		
Chrysene	1.58	1.10	0.61	0.33		
Methylchrysenes	3.37	2.47	1.19	0.48		
Dimethylchrysenes	4.16	2.98	1.54	0.55		
Benzo[b]fluoranthene	0.57	0.57	0.16	0.21		17
Benzo[k]fluoranthene	0.11	0.07	0.02	0.05		17
Benzo[e]pyrene	0.78	0.51	0.22	0.19		
Benzo[a]pyrene	0.35	0.20	0.10	0.10	0.17	27
Perylene	0.14	0.07	0.03	0.03		
Indeno[1,2,3-cd]pyrene	0.12	0.08	0.04	0.04		
Benzo[ghi]perylene	0.20	0.17	0.10	0.08		0.82
Dibenz[a,h]anthracene	0.09	0.09	0.04	0.02		
ΣPAHs (ng/L)	**83.2**	**78.0**	**37.5**	**20.7**		

ANNEX I

MUNICIPALITY OF PIRAEUS						
YACHT CLUB OF GREECE						
	29/09/2017	10/10/2017	23/10/2017	02/11/2017	AA (ng/L)	MAC (ng/L)
PAHs (ng/L)						
Naphthalene	1.43	1.37	0.60	1.33	2000	130 000
Methylnapthalenes	1.97	1.56	0.92	1.36		
Acenaphthylene	0.11	0.10	0.18	0.08		
Acenaphthene	0.17	0.17	0.11	0.08		
Dimethylnapthalenes	3.03	2.50	1.66	1.20		
Trimethylnapthalenes	4.73	3.03	1.87	1.25		
Fluorene	0.29	0.36	0.22	0.18		
Dibenzothiophene	0.17	0.14	0.07	0.07		
Methyldibenzothiophenes	0.66	0.45	0.16	0.32		
Dimethyldibenzothiophenes	2.07	1.08	0.46	0.78		
Phenanthrene	1.11	0.84	0.52	0.48		
Anthracene	0.11	0.06	0.05	0.04	100	100
Methylphenanthrenes	4.12	2.73	0.97	1.09		
Dimethylphenanthrenes	6.90	3.60	1.63	1.40		
Trimethylphenanthrenes	6.12	2.69	1.34	0.98		
Fluoranthene	0.50	0.42	0.36	0.26	6.3	120
Pyrene	0.49	0.35	0.32	0.17		
Methylpyrenes	1.64	0.64	0.41	0.25		
Dimethylpyrenes	2.51	0.83	0.59	0.26		
Retene	0.16	0.03	0.02	0.03		
Benz[a]anthracene	0.29	0.22	0.21	0.10		
Chrysene	0.72	0.32	0.27	0.14		
Methylchrysenes	1.42	0.44	0.32	0.17		
Dimethylchrysenes	1.60	0.46	0.37	0.18		
Benzo[b]fluoranthene	0.37	0.31	0.24	0.11		17
Benzo[k]fluoranthene	0.07	0.05	0.06	0.02		17
Benzo[e]pyrene	0.38	0.16	0.15	0.07		
Benzo[a]pyrene	**0.19**	0.08	0.12	0.04	0.17	27
Perylene	0.06	0.02	0.03	N.D.		
Indeno[1,2,3-cd]pyrene	0.09	0.08	0.08	0.02		
Benzo[ghi]perylene	0.11	0.09	0.11	0.04		0.82
Dibenz[a,h]anthracene	0.05	0.03	0.02	N.D.		
ΣPAHs (ng/L)	**43.6**	**25.2**	**14.46**	**12.5**		

ANNEX I

MUNICIPALITY OF KALLITHEA				
	KALLITHEA MARINA	**STAVROS NIARXOS FOUNDATION**		
	29/09/2017	**29/09/2017**	**AA (ng/L)**	**MAC (ng/L)**
PAHs (ng/L)				
Naphthalene	1.82	1.89	2000	130 000
Methylnapthalenes	8.12	7.68		
Acenaphthylene	0.55	0.59		
Acenaphthene	1.15	1.44		
Dimethylnapthalenes	25.8	30.2		
Trimethylnapthalenes	27.1	33.6		
Fluorene	2.00	2.59		
Dibenzothiophene	1.09	1.56		
Methyldibenzothiophenes	3.68	4.89		
Dimethyldibenzothiophenes	4.91	5.76		
Phenanthrene	5.75	7.71		
Anthracene	0.38	0.60	100	100
Methylphenanthrenes	18.2	24.7		
Dimethylphenanthrenes	15.6	22.2		
Trimethylphenanthrenes	6.56	10.0		
Fluoranthene	0.77	0.94	6.3	120
Pyrene	0.92	1.46		
Methylpyrenes	1.49	2.51		
Dimethylpyrenes	1.21	2.34		
Retene	0.13	0.09		
Benz[a]anthracene	0.33	0.52		
Chrysene	0.63	0.98		
Methylchrysenes	0.69	1.21		
Dimethylchrysenes	0.48	0.99		
Benzo[b]fluoranthene	1.11	1.35		17
Benzo[k]fluoranthene	0.35	0.37		17
Benzo[e]pyrene	0.45	0.61		
Benzo[a]pyrene	**0.56**	**0.71**	0.17	27
Perylene	0.14	0.19		
Indeno[1,2,3-cd]pyrene	0.42	0.58		
Benzo[ghi]perylene	0.40	0.57		0.82
Dibenz[a,h]anthracene	0.10	0.14		
ΣPAHs (ng/L)	**133.0**	**170.9**		

ANNEX I

MUNICIPALITY OF PALAIO FALIRO								
PHLOISBOS								
	22/09/2017	**03/10/2017**	**10/10/2017**	**23/10/2017**	**02/11/2017**	**19/01/2018**	**AA (ng/L)**	**MAC (ng/L)**
PAHs (ng/L)								
Naphthalene	2.74	NOT CONSIDERED	7.61	3.21	1.48	1.93	2000	130 000
Methylnapthalenes	25.8		83.1	19.5	5.05	2.79		
Acenaphthylene	0.23		0.30	0.17	0.07	0.18		
Acenaphthene	7.51		8.01	1.86	0.47	0.38		
Dimethylnapthalenes	79.1		183.2	46.4	11.7	5.90		
Trimethylnapthalenes	191.3		265.8	55.6	12.1	9.84		
Fluorene	7.62		7.35	1.76	0.49	0.44		
Dibenzothiophene	5.93		8.72	1.51	0.40	0.25		
Methyldibenzothiophenes	46.7		59.4	8.52	1.93	1.70		
Dimethyldibenzothiophenes	160.3		187.2	24.1	5.11	5.02		
Phenanthrene	16.2		38.7	6.74	1.89	1.50		
Anthracene	4.98		4.43	0.95	0.18	0.19	100	100
Methylphenanthrenes	169.8		245.7	41.3	9.23	7.75		
Dimethylphenanthrenes	434.8		480.5	76.5	17.2	18.65		
Trimethylphenanthrenes	349.7		498.0	81.2	16.1	15.05		
Fluoranthene	2.11		1.62	0.77	0.29	0.66	6.3	120
Pyrene	8.73		7.65	3.76	1.04	1.17		
Methylpyrenes	39.1		39.9	18.7	5.61	4.18		
Dimethylpyrenes	37.8		55.9	24.5	8.34	8.33		
Retene	4.07		6.91	1.11	0.23	0.54		
Benz[a]anthracene	9.96		12.0	2.38	0.49	1.07		
Chrysene	18.9		33.9	7.23	2.37	1.20		
Methylchrysenes	45.2		100.5	16.8	4.34	2.78		
Dimethylchrysenes	55.2		151.2	23.3	5.49	5.09		
Benzo[b]fluoranthene	2.73		7.62	1.67	0.43	1.05		17
Benzo[k]fluoranthene	0.34		1.20	0.20	0.05	0.16		17
Benzo[e]pyrene	4.78		14.1	2.85	0.98	0.89		
Benzo[a]pyrene	**3.36**		**6.41**	**1.11**	**0.28**	**0.70**	0.17	27
Perylene	1.13		2.51	0.41	0.11	0.22		
Indeno[1,2,3-cd]pyrene	0.40		1.41	0.35	0.06	0.29		
Benzo[ghi]perylene	**1.49**		**5.11**	0.81	0.27	0.54		0.82
Dibenz[a,h]anthracene	0.84		2.03	0.65	0.13	0.04		
ΣPAHs (ng/L)	**1739**		**2528**	**476**	**113.9**	**100.6**		

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MUNICIPALITY OF PALAIO FALIRO							
EDEM							
	22/09/2017	**03/10/2017**	**10/10/2017**	**23/10/2017**	**02/11/2017**	**AA (ng/L)**	**MAC (ng/L)**
PAHs (ng/L)							
Naphthalene	2.32	1.67	1.64	1.34	2.12	2000	130 000
Methylnapthalenes	17.4	3.90	2.29	1.66	2.31		
Acenaphthylene	0.21	0.12	0.10	0.09	0.13		
Acenaphthene	3.73	0.96	0.73	0.21	0.27		
Dimethylnapthalenes	63.9	14.9	11.14	3.37	3.95		
Trimethylnapthalenes	116.5	23.2	31.58	4.91	8.12		
Fluorene	3.69	1.00	0.89	0.27	0.28		
Dibenzothiophene	4.11	0.85	1.32	0.17	0.28		
Methyldibenzothiophenes	31.0	5.53	9.96	0.86	2.40		
Dimethyldibenzothiophenes	100.8	19.6	26.55	2.35	9.90		
Phenanthrene	15.73	3.16	5.05	0.69	1.15		
Anthracene	2.55	0.52	0.72	0.10	0.25	100	100
Methylphenanthrenes	124.4	23.9	40.23	3.79	10.3		
Dimethylphenanthrenes	280.2	61.9	84.45	6.99	33.9		
Trimethylphenanthrenes	236.8	52.1	63.20	6.96	31.7		
Fluoranthene	1.70	0.57	1.14	0.20	0.49	6.3	120
Pyrene	6.29	2.20	4.78	0.63	1.62		
Methylpyrenes	32.9	13.0	18.80	2.45	7.90		
Dimethylpyrenes	37.3	14.8	19.32	2.80	11.2		
Retene	2.45	0.76	0.62	0.09	0.46		
Benz[a]anthracene	7.60	1.93	3.30	0.24	1.23		
Chrysene	14.7	4.23	5.44	0.68	2.24		
Methylchrysenes	37.8	11.5	11.80	1.31	5.70		
Dimethylchrysenes	46.0	14.3	12.92	1.64	7.62		
Benzo[b]fluoranthene	2.67	0.95	1.20	0.20	0.61		17
Benzo[k]fluoranthene	0.45	0.11	0.11	0.03	0.08		17
Benzo[e]pyrene	4.06	1.60	1.71	0.24	0.90		
Benzo[a]pyrene	**2.44**	**0.88**	0.80	0.13	**0.46**	0.17	27
Perylene	0.87	0.33	0.29	0.04	0.16		
Indeno[1,2,3-cd]pyrene	0.39	0.17	0.12	0.06	0.13		
Benzo[ghi]perylene	**1.20**	0.60	0.59	0.13	0.38		0.82
Dibenz[a,h]anthracene	0.67	0.27	0.31	0.06	0.21		
ΣPAHs (ng/L)	**1203**	**281.5**	**363.1**	**44.7**	**148.4**		

ANNEX I

MUNICIPALITY OF PALAIO FALIRO				MUNICIPALITY OF ALIMOS		
BATIS				YACHT CLUB OF ALIMOS		
	02/11/2017	19/01/2018	21/03/2018	22/09/2017	AA (ng/L)	MAC (ng/L)
PAHs (ng/L)						
Naphthalene	1.56	2.25	1.68	2.65	2000	130 000
Methylnapthalenes	5.35	1.98	25.21	10.1		
Acenaphthylene	0.12	0.42	0.13	0.09		
Acenaphthene	1.15	0.48	3.18	1.78		
Dimethylnapthalenes	43.7	4.85	92.65	33.5		
Trimethylnapthalenes	94.1	82.31	127.01	60.3		
Fluorene	1.63	1.30	3.40	2.09		
Dibenzothiophene	2.35	1.23	1.55	2.35		
Methyldibenzothiophenes	16.3	38.41	6.45	15.2		
Dimethyldibenzothiophenes	43.9	165.36	10.89	38.9		
Phenanthrene	10.2	5.46	11.45	10.4		
Anthracene	1.14	2.14	0.80	1.27	100	100
Methylphenanthrenes	71.7	144.44	42.28	66.3		
Dimethylphenanthrenes	146.1	504.95	50.24	117.3		
Trimethylphenanthrenes	107.0	473.49	44.61	90.9		
Fluoranthene	0.76	1.40	1.63	2.03	6.3	120
Pyrene	2.84	5.48	1.74	4.45		
Methylpyrenes	14.7	30.66	4.93	17.9		
Dimethylpyrenes	20.4	47.08	3.01	22.3		
Retene	1.57	9.37	N.D	1.27		
Benz[a]anthracene	4.52	14.43	1.58	3.18		
Chrysene	4.59	11.83	0.56	6.53		
Methylchrysenes	16.5	49.05	1.40	16.8		
Dimethylchrysenes	22.6	84.96	1.90	23.5		
Benzo[b]fluoranthene	1.09	5.76	1.25	1.50		17
Benzo[k]fluoranthene	0.13	0.59	0.20	0.24		17
Benzo[e]pyrene	1.53	8.03	0.55	2.11		
Benzo[a]pyrene	**1.16**	**2.64**	**0.42**	**1.14**	0.17	27
Perylene	0.40	1.44	0.16	0.39		
Indeno[1,2,3-cd]pyrene	0.16	0.89	0.27	0.25		
Benzo[ghi]perylene	0.65	0.79	0.41	0.73		0.82
Dibenz[a,h]anthracene	0.46	0.48	0.09	0.39		
ΣPAHs (ng/L)	**640.2**	**1704**	**441.7**	**557.7**		

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MUNICIPALITY OF ALIMOS						
AKTI ILIOU						
	22/09/2017	**03/10/2017**	**10/10/2017**	**23/10/2017**	**AA (ng/L)**	**MAC (ng/L)**
PAHs (ng/L)						
Naphthalene	3.71	2.80	2.12	1.61	2000	130 000
Methylnapthalenes	21.9	3.55	2.06	1.66		
Acenaphthylene	0.12	0.11	0.11	0.11		
Acenaphthene	2.35	0.23	0.18	0.12		
Dimethylnapthalenes	65.2	4.49	3.64	2.21		
Trimethylnapthalenes	80.0	4.60	3.79	2.79		
Fluorene	2.78	0.36	0.29	0.24		
Dibenzothiophene	3.24	0.19	0.19	0.13		
Methyldibenzothiophenes	16.9	0.67	0.72	0.59		
Dimethyldibenzothiophenes	38.1	1.54	1.74	1.45		
Phenanthrene	13.0	0.97	0.87	0.72		
Anthracene	1.44	0.06	0.06	0.07	100	100
Methylphenanthrenes	69.7	3.41	3.29	2.88		
Dimethylphenanthrenes	109.8	5.37	6.06	4.71		
Trimethylphenanthrenes	81.1	3.58	7.72	4.02		
Fluoranthene	0.90	0.23	0.16	0.29	6.3	120
Pyrene	4.07	0.32	0.28	0.39		
Methylpyrenes	17.0	0.98	1.22	1.02		
Dimethylpyrenes	19.5	1.27	2.00	1.22		
Retene	1.14	0.04	0.10	0.04		
Benz[a]anthracene	2.47	0.12	0.20	0.23		
Chrysene	5.49	0.53	0.68	0.47		
Methylchrysenes	13.4	0.84	1.47	0.78		
Dimethylchrysenes	17.0	0.80	2.02	0.87		
Benzo[b]fluoranthene	0.92	0.18	0.23	0.21		17
Benzo[k]fluoranthene	0.12	0.03	0.03	0.04		17
Benzo[e]pyrene	1.52	0.20	0.27	0.19		
Benzo[a]pyrene	**0.92**	0.07	0.08	0.10	0.17	27
Perylene	0.34	0.02	0.03	0.03		
Indeno[1,2,3-cd]pyrene	0.14	0.07	0.04	0.06		
Benzo[ghi]perylene	0.43	0.06	0.11	0.09		0.82
Dibenz[a,h]anthracene	0.25	0.02	0.05	0.04		
ΣPAHs (ng/L)	**594.9**	**37.7**	**41.8**	**29.4**		

ANNEX I

MUNICIPALITY OF ELLINIKO-ARGYROUPOLI										
AGIOS KOSMAS										
	22/09/17	29/09/17	03/10/17	10/10/17	23/10/17	02/11/17	04/12/17	19/01/18	AA (ng/L)	MAC (ng/L)
PAHs (ng/L)										
Naphthalene	19.2	4.63	2.65	NOT CONSIDERED	14.42	2.12	2.16	3.02	2000	130 000
Methylnapthalenes	581.9	122.8	47.3		127.3	8.68	10.5	4.00		
Acenaphthylene	51.8	0.32	0.24		0.47	0.11	0.09	0.24		
Acenaphthene	411.5	24.0	12.6		19.6	1.31	1.62	0.42		
Dimethylnapthalenes	7494	493.8	189.7		401.3	23.0	37.6	8.00		
Trimethylnapthalenes	13398	621.6	360.9		586.7	30.3	64.4	13.15		
Fluorene	220.7	24.2	11.5		16.7	1.35	1.55	0.63		
Dibenzothiophene	201.8	23.9	12.7		17.6	1.04	1.98	0.41		
Methyldibenzothiophenes	1130	117.6	109.9		115.1	5.63	15.4	2.95		
Dimethyldibenzothiophenes	2767	248.7	403.7		367.6	18.8	48.9	12.00		
Phenanthrene	765.3	93.9	46.5		71.6	3.78	9.23	2.20		
Anthracene	6.22	8.30	7.64		9.01	0.51	1.04	0.25	100	100
Methylphenanthrenes	4010	436.8	422.5		461.6	23.1	70.0	11.50		
Dimethylphenanthrenes	7271	612.4	1013		1050	61.8	146.1	37.98		
Trimethylphenanthrenes	5624	513.4	1107		950.7	60.2	120.5	42.81		
Fluoranthene	2.52	2.60	1.48		1.84	0.74	0.92	0.93	6.3	120
Pyrene	13.6	10.0	7.41		10.3	4.26	3.74	2.37		
Methylpyrenes	32.0	35.3	38.9		45.7	19.0	15.6	9.23		
Dimethylpyrenes	84.3	41.8	56.7		47.2	23.1	18.9	14.27		
Retene	122.3	4.77	12.3		12.1	1.20	1.40	1.50		
Benz[a]anthracene	97.2	10.9	23.8		20.7	2.42	2.41	1.38		
Chrysene	303.8	25.7	49.8		49.6	6.44	5.05	2.04		
Methylchrysenes	767.6	73.9	177.4		168.7	14.1	12.9	2.67		
Dimethylchrysenes	1007	101.4	265.8		207.0	17.7	15.2	8.48		
Benzo[b]fluoranthene	101.3	4.37	13.1		13.2	1.82	0.91	1.32		17
Benzo[k]fluoranthene	9.60	0.73	2.17		2.09	0.23	0.12	0.19		17
Benzo[e]pyrene	175.0	7.99	23.8		23.3	2.19	1.21	1.30		
Benzo[a]pyrene	**114.9**	**3.83**	**11.9**		**10.3**	**0.96**	**0.58**	**0.54**	0.17	27
Perylene	46.14	1.54	4.80		4.69	0.34	0.25	0.20		
Indeno[1,2,3-cd]pyrene	5.08	0.65	1.95		2.19	0.35	0.13	0.27		
Benzo[ghi]perylene	**21.42**	**2.67**	**8.69**		**8.34**	**0.84**	0.46	0.68		0.82
Dibenz[a,h]anthracene	10.53	1.23	4.07		3.89	0.50	0.22	0.24		
ΣPAHs (ng/L)	**46867**	**3676**	**4452**		**4841**	**337.9**	**611.1**	**187.2**		

ANNEX I

MUNICIPALITY OF ELLINIKO-ARGYROUPOLI									
H.C.M.R. FACILITIES									
	18/09/17	03/10/17	10/10/17	23/10/17	02/11/17	04/12/17	19/01/18	AA (ng/L)	MAC (ng/L)
PAHs (ng/L)									
Naphthalene	EXTENDED PETROLEUM POLLUTION	7.34	43.52	6.74	NOT CONSIDERED	1.08	2.29	2000	130 000
Methylnapthalenes		46.7	18.85	4.30		2.28	10.93		
Acenaphthylene		0.28	2.10	0.46		0.05	0.24		
Acenaphthene		7.69	2.53	0.64		0.29	1.46		
Dimethylnapthalenes		131.2	12.40	5.32		6.23	32.27		
Trimethylnapthalenes		247.3	8.95	10.6		11.0	57.12		
Fluorene		8.92	7.26	1.50		0.34	1.80		
Dibenzothiophene		11.0	1.43	0.47		0.38	1.77		
Methyldibenzothiophenes		90.8	3.34	3.24		3.38	10.50		
Dimethyldibenzothiophenes		288.4	11.8	10.5		13.1	27.33		
Phenanthrene		45.6	13.4	3.42		1.79	8.66		
Anthracene		6.60	2.64	0.78		0.20	0.89	100	100
Methylphenanthrenes		348.6	20.1	16.4		15.1	44.18		
Dimethylphenanthrenes		735.9	42.9	34.6		39.0	87.91		
Trimethylphenanthrenes		692.6	34.8	32.2		32.5	75.54		
Fluoranthene		1.90	2.34	0.74		0.45	1.29	6.3	120
Pyrene		8.44	2.44	2.69		1.65	3.53		
Methylpyrenes		40.4	6.06	9.44		7.31	12.58		
Dimethylpyrenes		55.4	7.99	10.7		8.22	20.35		
Retene		8.50	0.41	0.35		0.39	2.63		
Benz[a]anthracene		18.5	1.35	1.04		1.03	2.80		
Chrysene		38.6	2.13	2.82		2.63	2.90		
Methylchrysenes		129.9	5.51	6.17		6.02	9.46		
Dimethylchrysenes		192.7	7.19	7.48		6.80	14.75		
Benzo[b]fluoranthene		7.31	0.99	0.56		0.45	1.52		17
Benzo[k]fluoranthene		1.12	0.09	0.05		0.08	0.18		17
Benzo[e]pyrene		14.0	0.92	0.92		0.66	1.78		
Benzo[a]pyrene		**6.99**	0.48	**0.37**		**0.29**	**0.87**	0.17	27
Perylene		2.95	0.15	0.13		0.11	0.33		
Indeno[1,2,3-cd]pyrene		1.14	0.14	0.07		0.07	0.30		
Benzo[ghi]perylene		**5.03**	0.47	0.26		0.25	0.78		0.82
Dibenz[a,h]anthracene		2.39	0.24	0.17		0.12	0.16		
ΣPAHs (ng/L)		**3204**	**265**	**6.74**		**163.1**	**439.1**		

ANNEX I

MUNICIPALITY OF ELLINIKO-ARGYROUPOLI						
	PHAROS AKROTIRI OPEN SEA - SURFACE		PHAROS AKROTIRI OPEN SEA - 8 M DEPTH			
	18/09/2017	10/10/2017	18/09/2017	10/10/2017	AA (ng/L)	MAC (ng/L)
PAHs (ng/L)						
Naphthalene	EXTENDED PETROLEUM POLLUTION	4.19	EXTENDED PETROLEUM POLLUTION	5.83	2000	130 000
Methylnapthalenes		28.7		4.79		
Acenaphthylene		0.09		0.09		
Acenaphthene		0.64		0.16		
Dimethylnapthalenes		18.0		3.27		
Trimethylnapthalenes		9.77		2.97		
Fluorene		0.68		0.41		
Dibenzothiophene		0.53		0.19		
Methyldibenzothiophenes		1.31		0.58		
Dimethyldibenzothiophenes		3.41		1.48		
Phenanthrene		3.83		1.28		
Anthracene		0.16		0.11	100	100
Methylphenanthrenes		17.1		3.58		
Dimethylphenanthrenes		9.60		5.71		
Trimethylphenanthrenes		9.69		5.81		
Fluoranthene		0.49		0.36	6.3	120
Pyrene		0.50		0.35		
Methylpyrenes		2.18		1.12		
Dimethylpyrenes		3.83		1.74		
Retene		0.18		0.12		
Benz[a]anthracene		0.45		0.27		
Chrysene		0.98		0.44		
Methylchrysenes		3.68		1.20		
Dimethylchrysenes		7.17		1.97		
Benzo[b]fluoranthene		1.63		0.29		17
Benzo[k]fluoranthene		0.74		0.05		17
Benzo[e]pyrene		1.79		0.21		
Benzo[a]pyrene		0.63		0.10	0.17	27
Perylene		1.43		0.03		
Indeno[1,2,3-cd]pyrene		0.21		0.06		
Benzo[ghi]perylene		0.46		0.13		0.82
Dibenz[a,h]anthracene		0.22		0.06		
ΣPAHs (ng/L)		**134.3**		**44.7**		

ANNEX I

MUNICIPALITY OF ELLINIKO-ARGYROUPOLI							
AIGYPTIOTES NAVAL CLUB							
	23/10/2017	**02/11/2017**	**04/12/2017**	**19/01/2018**	**21/03/2018**	**AA (ng/L)**	**MAC (ng/L)**
PAHs (ng/L)							
Naphthalene	3.93	1.93	1.83	3.84	1.04	2000	130 000
Methylnapthalenes	20.7	3.94	7.11	25.88	1.06		
Acenaphthylene	0.39	0.08	0.09	0.24	0.06		
Acenaphthene	23.76	0.34	1.14	2.62	0.08		
Dimethylnapthalenes	921.4	7.94	29.9	68.73	1.13		
Trimethylnapthalenes	1902	12.4	47.8	96.14	1.23		
Fluorene	18.2	0.45	1.18	2.71	0.17		
Dibenzothiophene	22.2	0.34	1.36	1.92	0.05		
Methyldibenzothiophenes	140.9	2.20	10.2	10.33	0.29		
Dimethyldibenzothiophenes	400.0	7.67	24.4	27.47	1.19		
Phenanthrene	96.8	1.62	6.43	14.05	0.41		
Anthracene	15.3	0.24	0.60	1.62	0.04	100	100
Methylphenanthrenes	653.7	10.2	42.1	68.90	1.27		
Dimethylphenanthrenes	1051	28.0	68.7	130.69	3.23		
Trimethylphenanthrenes	775.3	31.1	42.8	127.27	4.11		
Fluoranthene	1.55	0.34	0.74	1.75	0.20	6.3	120
Pyrene	7.75	1.56	2.95	4.90	0.26		
Methylpyrenes	38.6	8.29	9.80	20.07	1.05		
Dimethylpyrenes	48.4	13.2	8.68	30.99	1.81		
Retene	10.5	0.58	0.43	5.55	0.10		
Benz[a]anthracene	20.3	1.16	1.06	4.10	0.20		
Chrysene	35.0	2.96	3.36	4.13	0.37		
Methylchrysenes	132.9	7.13	5.81	13.15	0.86		
Dimethylchrysenes	177.3	9.53	5.63	20.54	1.33		
Benzo[b]fluoranthene	10.6	0.63	0.35	2.56	0.25		17
Benzo[k]fluoranthene	1.68	0.06	0.04	0.27	0.04		17
Benzo[e]pyrene	18.7	1.06	0.55	3.14	0.21		
Benzo[a]pyrene	**14.5**	**0.34**	**0.20**	**1.49**	0.15	0.17	27
Perylene	5.29	0.15	0.09	0.44	0.04		
Indeno[1,2,3-cd]pyrene	1.75	0.12	0.05	0.30	0.04		
Benzo[ghi]perylene	**7.64**	0.39	0.18	0.61	0.11		0.82
Dibenz[a,h]anthracene	4.06	0.27	0.08	0.14	0.04		
ΣPAHs (ng/L)	**6582.2**	**156.1**	**325.6**	**696.6**	**22.4**		

ANNEX I

MUNICIPALITY OF GLYFADA									
GLYFADA 1 (VICINAL TO 4th MARINA)									
	18/09/17	22/09/17	03/10/17	23/10/17	02/11/17	04/12/17	19/01/18	AA (ng/L)	MAC (ng/L)
PAHs (ng/L)									
Naphthalene	N.D.	3.38	1.34	1.82	1.35	1.54	2.93	2000	130 000
Methylnapthalenes	N.D.	17.92	2.58	2.06	1.38	1.24	2.04		
Acenaphthylene	0.16	0.10	0.07	0.18	0.09	0.17	0.19		
Acenaphthene	1.61	1.79	0.15	0.10	0.06	0.23	0.12		
Dimethylnapthalenes	25.1	36.98	2.78	1.93	1.17	1.32	1.95		
Trimethylnapthalenes	100.9	54.28	4.59	2.71	0.98	1.65	2.21		
Fluorene	1.10	2.54	0.27	0.23	0.15	0.19	0.42		
Dibenzothiophene	2.48	2.52	0.15	0.11	0.05	0.11	0.09		
Methyldibenzothiophenes	20.6	12.72	0.73	0.52	0.12	0.48	0.39		
Dimethyldibenzothiophenes	68.5	25.14	3.65	1.39	0.30	1.71	1.23		
Phenanthrene	11.1	10.79	1.06	0.60	0.35	0.74	1.00		
Anthracene	0.91	0.54	0.15	0.06	0.02	0.05	0.06	100	100
Methylphenanthrenes	93.7	58.08	4.49	2.58	0.73	2.35	1.88		
Dimethylphenanthrenes	199.1	85.75	12.6	4.82	1.15	5.41	4.26		
Trimethylphenanthrenes	208.1	46.53	11.5	4.27	0.77	4.63	4.37		
Fluoranthene	0.73	0.96	0.32	0.20	0.11	0.43	0.46	6.3	120
Pyrene	2.71	1.97	0.44	0.23	0.07	0.41	0.33		
Methylpyrenes	16.2	7.38	1.98	0.76	0.21	0.81	0.71		
Dimethylpyrenes	24.5	7.98	2.59	0.96	0.29	1.01	1.09		
Retene	4.70	0.42	0.22	0.06	N.D.	0.06	0.07		
Benz[a]anthracene	2.96	1.12	0.33	0.13	0.03	0.23	0.20		
Chrysene	9.82	3.21	0.79	0.43	0.12	0.49	0.29		
Methylchrysenes	33.7	5.36	2.12	0.83	0.16	0.79	0.46		
Dimethylchrysenes	46.1	5.36	2.77	1.18	0.20	0.86	0.78		
Benzo[b]fluoranthene	2.82	0.57	0.29	0.18	0.08	0.30	0.30		17
Benzo[k]fluoranthene	0.39	0.06	0.04	0.02	0.02	0.08	0.06		17
Benzo[e]pyrene	4.34	0.74	0.36	0.18	0.08	0.20	0.20		
Benzo[a]pyrene	**1.27**	**0.20**	0.18	0.05	0.03	0.14	0.09	0.17	27
Perylene	0.48	0.08	0.05	0.02	N.D.	0.04	0.02		
Indeno[1,2,3-cd]pyrene	0.26	0.07	0.07	0.04	0.02	0.12	0.07		
Benzo[ghi]perylene	**1.05**	0.24	0.12	0.07	0.03	0.22	0.12		0.82
Dibenz[a,h]anthracene	0.39	0.14	0.07	0.04	N.D.	0.03	0.03		
ΣPAHs (ng/L)	**885.7**	**394.9**	**58.8**	**28.8**	**10.1**	**28.0**	**28.4**		

ANNEX I

MUNICIPALITY OF GLYFADA

GLYFADA 2

	18/09/17	22/09/17	03/10/17	10/10/17	23/10/17	02/11/17	04/12/17	19/01/18	AA (ng/L)	MAC (ng/L)
PAHs (ng/L)										
Naphthalene	EXTENDED PETROLEUM POLLUTION	25.5	1.20	NOT CONSIDERED	1.13	1.56	1.36	3.24	2000	130 000
Methylnapthalenes		90.6	2.05		1.48	1.28	1.06	2.68		
Acenaphthylene		0.22	0.07		0.11	0.08	0.05	0.31		
Acenaphthene		4.76	0.38		0.16	0.08	0.05	0.16		
Dimethylnapthalenes		134.0	7.22		3.30	1.48	1.07	2.08		
Trimethylnapthalenes		139.9	15.7		11.1	2.74	1.85	2.23		
Fluorene		4.16	0.54		0.26	0.18	0.15	0.38		
Dibenzothiophene		3.09	0.74		0.24	0.13	0.09	0.15		
Methyldibenzothiophenes		20.04	5.74		2.70	0.90	0.53	0.34		
Dimethyldibenzothiophenes		53.59	21.1		12.1	2.80	3.06	1.22		
Phenanthrene		15.35	3.32		1.07	0.61	0.44	2.75		
Anthracene		1.54	0.56		0.31	0.07	0.08	0.42	100	100
Methylphenanthrenes		133.3	26.4		12.8	3.84	2.54	4.42		
Dimethylphenanthrenes		211.2	66.8		37.2	9.34	8.67	7.54		
Trimethylphenanthrenes		100.6	59.5		38.7	6.51	9.85	8.78		
Fluoranthene		1.78	1.10		0.40	0.20	0.19	2.48	6.3	120
Pyrene		3.97	2.51		1.81	0.59	0.36	2.42		
Methylpyrenes		18.7	14.7		10.9	2.97	2.36	3.09		
Dimethylpyrenes		16.1	16.4		10.5	3.35	3.34	3.77		
Retene		1.36	0.86		0.57	0.10	0.20	0.44		
Benz[a]anthracene		2.29	2.38		1.00	0.18	0.24	2.61		
Chrysene		6.34	5.23		3.06	1.11	0.72	2.03		
Methylchrysenes		13.0	12.9		6.25	1.41	1.84	1.65		
Dimethylchrysenes		13.9	15.1		6.78	1.25	2.27	2.45		
Benzo[b]fluoranthene		0.97	1.40		0.62	0.15	0.17	3.10		17
Benzo[k]fluoranthene		0.21	0.23		0.06	0.02	0.02	0.80		17
Benzo[e]pyrene		1.49	1.87		0.91	0.29	0.27	1.66		
Benzo[a]pyrene		**0.58**	**1.10**		**0.41**	0.06	0.13	**1.26**	0.17	27
Perylene		0.23	0.39		0.16	0.02	0.05	0.29		
Indeno[1,2,3-cd]pyrene		0.16	0.29		0.08	0.03	0.03	0.88		
Benzo[ghi]perylene		0.44	0.60		0.25	0.05	0.10	0.37		0.82
Dibenz[a,h]anthracene		0.24	0.32		0.16	0.03	0.04	0.27		
ΣPAHs (ng/L)		**1020**	**288.8**		**166.4**	**43.4**	**43.2**	**66.3**		

ANNEX I

MUNICIPALITY OF GLYFADA									
GLYFADA 3 (VICINAL TO 3rd MARINA)									
	18/09/17	22/09/17	03/10/17	23/10/17	02/11/17	04/12/17	19/01/18	AA (ng/L)	MAC (ng/L)
PAHs (ng/L)									
Naphthalene	2.90	3.71	1.50	1.68	1.29	0.89	2.04	2000	130 000
Methylnapthalenes	39.1	19.6	2.21	2.68	1.22	0.74	1.57		
Acenaphthylene	0.68	0.20	0.08	2.16	0.07	0.04	0.22		
Acenaphthene	19.7	3.36	0.20	0.59	0.13	0.06	0.20		
Dimethylnapthalenes	149.6	78.5	3.96	7.69	2.59	1.38	1.81		
Trimethylnapthalenes	647.7	159.0	8.93	19.8	5.16	1.97	2.53		
Fluorene	17.7	4.03	0.31	0.98	0.24	0.14	0.40		
Dibenzothiophene	19.2	5.27	0.28	1.21	0.22	0.10	0.20		
Methyldibenzothiophenes	201.8	39.5	2.23	7.03	1.77	0.61	0.59		
Dimethyldibenzothiophenes	727.4	118.1	8.92	26.1	5.70	1.97	1.93		
Phenanthrene	35.7	23.0	1.42	9.62	0.99	0.54	2.72		
Anthracene	12.4	2.92	0.22	3.81	0.20	0.06	0.71	100	100
Methylphenanthrenes	727.9	156.0	11.6	43.4	7.47	2.83	3.71		
Dimethylphenanthrenes	1777	301.7	29.7	62.4	19.1	5.95	7.09		
Trimethylphenanthrenes	1706	246.2	27.1	92.4	16.2	5.07	5.68		
Fluoranthene	1.47	2.43	0.38	19.8	0.44	0.20	3.13	6.3	120
Pyrene	6.67	5.47	0.95	14.3	1.35	0.29	2.76		
Methylpyrenes	37.8	26.1	5.75	25.1	6.81	1.13	3.21		
Dimethylpyrenes	58.8	33.3	6.87	29.0	7.86	1.48	3.99		
Retene	51.5	2.96	0.50	1.25	0.26	0.06	0.22		
Benz[a]anthracene	23.4	6.97	0.64	24.4	0.91	0.20	3.16		
Chrysene	46.1	14.4	1.91	14.4	2.00	0.47	1.59		
Methylchrysenes	175.3	41.4	4.47	22.0	3.42	0.94	1.73		
Dimethylchrysenes	249.1	57.7	4.90	27.0	3.76	1.03	2.05		
Benzo[b]fluoranthene	14.0	3.82	0.50	22.8	0.51	0.17	3.04		17
Benzo[k]fluoranthene	2.00	0.82	0.08	5.68	0.09	0.03	0.76		17
Benzo[e]pyrene	24.7	5.03	0.76	8.99	0.64	0.16	1.41		
Benzo[a]pyrene	**14.6**	**3.13**	**0.35**	16.6	0.32	0.08	**1.37**	0.17	27
Perylene	6.38	1.21	0.11	3.39	0.11	0.03	0.32		
Indeno[1,2,3-cd]pyrene	1.99	0.78	0.09	8.36	0.11	0.04	0.97		
Benzo[ghi]perylene	**9.40**	**1.85**	0.20	**7.58**	0.20	0.07	0.45		0.82
Dibenz[a,h]anthracene	4.35	0.76	0.09	3.32	0.15	0.02	0.07		
ΣPAHs (ng/L)	**6813**	**1369**	**127.3**	**535.4**	**91.3**	**28.8**	**61.6**		

ANNEX I

MUNICIPALITY OF GLYFADA										
GLYFADA 4 (VICINAL TO 2nd MARINA)										
	18/09/17	22/09/17	03/10/17	10/10/17	23/10/17	02/11/17	04/12/17	19/01/18	AA (ng/L)	MAC (ng/L)
PAHs (ng/L)										
Naphthalene	EXTENDED PETROLEUM POLLUTION	EXTENDED PETROLEUM POLLUTION	3.6	1.81	1.00	1.85	0.88	3.96	2000	130 000
Methylnapthalenes			7.7	14.1	2.33	5.95	0.88	4.13		
Acenaphthylene			0.57	0.32	0.52	0.11	0.12	0.32		
Acenaphthene			19.7	5.92	1.39	0.44	0.16	0.94		
Dimethylnapthalenes			395.2	121.6	27.3	10.1	2.64	7.15		
Trimethylnapthalenes			1455	281.6	90.8	15.5	8.54	12.22		
Fluorene			11.7	6.35	1.71	0.60	0.26	0.55		
Dibenzothiophene			11.8	5.38	1.82	0.24	0.24	0.29		
Methyldibenzothiophenes			121.6	43.0	23.4	1.55	2.09	1.98		
Dimethyldibenzothiophenes			413.0	135.8	87.5	6.08	12.2	5.83		
Phenanthrene			38.15	25.5	10.4	1.43	0.96	1.93		
Anthracene			11.45	3.12	1.84	0.33	0.35	0.20	100	100
Methylphenanthrenes			435.6	180.8	121.7	10.3	9.00	8.46		
Dimethylphenanthrenes			1016	362.8	265.9	22.9	36.8	22.17		
Trimethylphenanthrenes			826.2	281.4	252.1	23.6	40.6	20.75		
Fluoranthene			2.23	1.66	1.13	0.35	0.57	0.89	6.3	120
Pyrene			7.88	5.19	4.81	1.42	1.84	1.92		
Methylpyrenes			35.7	25.1	21.5	8.45	7.46	4.56		
Dimethylpyrenes			39.1	25.5	26.5	11.4	9.74	5.83		
Retene			10.7	3.53	3.07	0.53	0.63	0.28		
Benz[a]anthracene			23.1	3.49	3.41	0.53	0.82	0.69		
Chrysene			18.5	18.1	12.0	2.90	2.78	1.20		
Methylchrysenes			74.8	36.3	29.7	3.97	5.99	1.69		
Dimethylchrysenes			51.8	44.5	39.0	4.27	7.72	2.05		
Benzo[b]fluoranthene			7.69	2.84	1.85	0.44	0.69	0.82		17
Benzo[k]fluoranthene			1.13	0.39	0.24	0.05	0.09	0.15		17
Benzo[e]pyrene			13.1	5.00	3.42	0.77	0.96	0.68		
Benzo[a]pyrene			**8.50**	**1.22**	**1.09**	0.21	**0.42**	**0.35**	0.17	27
Perylene			3.26	0.51	0.49	0.09	0.15	0.09		
Indeno[1,2,3-cd]pyrene			1.19	0.36	0.28	0.07	0.17	0.28		
Benzo[ghi]perylene			**4.79**	**1.37**	**0.98**	0.20	0.47	0.36		0.82
Dibenz[a,h]anthracene			2.21	0.52	0.49	0.13	0.18	0.09		
ΣPAHs (ng/L)			**5073**	**1645**	**1040**	**136.8**	**156.4**	**112.8**		

ANNEX I

MUNICIPALITY OF GLYFADA										
GLYFADA 5 (VICINAL TO 1st MARINA)										
	18/09/17	22/09/17	03/10/17	10/10/17	23/10/17	02/11/17	04/12/17	19/01/18	AA (ng/L)	MAC (ng/L)
PAHs (ng/L)										
Naphthalene	EXTENDED PETROLEUM POLLUTION	EXTENDED PETROLEUM POLLUTION	2.14	1.50	1.88	2.12	1.40	2.62	2000	130 000
Methylnapthalenes			31.4	1.95	2.27	2.31	1.35	3.95		
Acenaphthylene			0.25	0.15	0.11	0.11	0.14	0.24		
Acenaphthene			11.0	0.33	0.28	0.24	0.17	0.56		
Dimethylnapthalenes			155.4	4.02	4.21	4.74	3.16	11.46		
Trimethylnapthalenes			223.5	19.9	11.3	6.94	7.13	22.81		
Fluorene			9.79	0.59	0.33	0.34	0.23	0.68		
Dibenzothiophene			8.80	0.71	0.34	0.24	0.22	0.49		
Methyldibenzothiophenes			45.1	6.21	3.04	1.31	1.74	3.23		
Dimethyldibenzothiophenes			135.0	22.2	16.4	4.19	6.76	8.95		
Phenanthrene			32.7	3.20	1.69	1.20	1.16	3.01		
Anthracene			3.99	0.61	0.28	0.17	0.19	0.28	100	100
Methylphenanthrenes			173.7	33.2	20.4	8.01	8.27	15.24		
Dimethylphenanthrenes			333.0	72.8	34.9	16.7	22.2	33.52		
Trimethylphenanthrenes			345.8	72.8	36.6	13.8	19.6	28.75		
Fluoranthene			1.58	0.69	0.29	0.21	0.38	0.58	6.3	120
Pyrene			11.2	3.17	1.85	1.03	1.33	1.35		
Methylpyrenes			37.4	13.8	7.67	3.76	4.20	3.50		
Dimethylpyrenes			44.8	16.0	9.12	4.87	4.44	5.17		
Retene			5.26	1.05	0.59	0.21	0.21	0.81		
Benz[a]anthracene			6.74	1.34	0.43	0.31	0.28	0.45		
Chrysene			21.5	6.26	3.29	1.52	1.34	0.76		
Methylchrysenes			62.7	11.2	6.02	2.32	2.03	1.55		
Dimethylchrysenes			95.2	12.9	7.42	2.25	1.92	1.88		
Benzo[b]fluoranthene			3.95	1.20	0.40	0.20	0.17	0.31		17
Benzo[k]fluoranthene			0.53	0.11	0.57	0.02	0.02	0.05		17
Benzo[e]pyrene			7.93	1.62	0.84	0.34	0.26	0.35		
Benzo[a]pyrene			**3.41**	**0.39**	0.14	0.08	0.07	0.11	0.17	27
Perylene			1.48	0.15	0.10	0.03	0.03	0.04		
Indeno[1,2,3-cd]pyrene			0.54	0.19	0.06	0.03	0.03	0.10		
Benzo[ghi]perylene			**2.50**	0.52	0.18	0.08	0.08	0.15		0.82
Dibenz[a,h]anthracene			1.14	0.28	0.08	0.05	0.03	0.02		
ΣPAHs (ng/L)			**1819**	**311.1**	**173.2**	**79.7**	**90.6**	**153.1**		

ANNEX I

MUNICIPALITY OF GLYFADA							
ASTERAS GLYFADAS							
	10/10/2017	**23/10/2017**	**02/11/2017**	**04/12/2017**	**19/01/2018**	**AA (ng/L)**	**MAC (ng/L)**
PAHs (ng/L)							
Naphthalene	1.21	1.19	3.83	1.82	2.21	2000	130 000
Methylnapthalenes	5.28	2.76	20.29	9.21	4.35		
Acenaphthylene	0.12	0.24	0.11	0.22	0.16		
Acenaphthene	1.25	0.68	2.03	2.26	0.98		
Dimethylnapthalenes	17.0	13.4	41.88	50.0	20.45		
Trimethylnapthalenes	58.5	24.9	61.47	95.7	62.59		
Fluorene	1.71	0.91	2.88	2.58	1.31		
Dibenzothiophene	1.73	0.72	2.85	2.73	1.45		
Methyldibenzothiophenes	12.5	5.00	14.41	19.2	13.15		
Dimethyldibenzothiophenes	41.2	14.2	28.47	52.8	45.06		
Phenanthrene	8.24	3.86	12.22	14.3	8.21		
Anthracene	0.98	0.42	0.61	1.26	0.61	100	100
Methylphenanthrenes	62.9	25.9	65.78	93.6	60.17		
Dimethylphenanthrenes	134.3	47.7	97.11	167.4	146.55		
Trimethylphenanthrenes	127.7	41.0	52.70	115.6	137.59		
Fluoranthene	1.02	0.59	1.09	1.20	1.00	6.3	120
Pyrene	2.71	2.00	2.23	4.10	3.60		
Methylpyrenes	10.7	7.20	8.36	14.8	14.83		
Dimethylpyrenes	11.5	7.83	9.04	16.2	21.91		
Retene	1.10	0.46	0.48	1.56	5.10		
Benz[a]anthracene	1.33	0.59	1.27	2.27	3.02		
Chrysene	5.79	3.08	3.64	6.54	3.96		
Methylchrysenes	9.58	5.45	6.07	14.7	12.07		
Dimethylchrysenes	9.27	6.06	6.07	19.2	18.22		
Benzo[b]fluoranthene	0.87	0.49	0.65	0.99	1.67		17
Benzo[k]fluoranthene	0.09	0.05	0.07	0.13	0.18		17
Benzo[e]pyrene	1.01	0.70	0.84	1.48	2.10		
Benzo[a]pyrene	0.17	**0.20**	**0.23**	**0.47**	**0.85**	0.17	27
Perylene	0.07	0.07	0.09	0.21	0.32		
Indeno[1,2,3-cd]pyrene	0.09	0.07	0.08	0.16	0.32		
Benzo[ghi]perylene	0.30	0.24	0.27	0.65	0.53		0.82
Dibenz[a,h]anthracene	0.17	0.11	0.16	0.27	0.46		
ΣPAHs (ng/L)	**530.5**	**218.0**	**447.2**	**713.4**	**594.9**		

ANNEX I

MUNICIPALITY OF VARI-VOULA-VOULIAGMENI						
	ASKLIPIEIO VOULAS		**VOULA CITY HALL**			
	18/09/2017	**03/10/2017**	**18/09/2017**	**22/09/2017**	**AA (ng/L)**	**MAC (ng/L)**
PAHs (ng/L)						
Naphthalene	4.95	1.28	3.12	1.60	2000	130 000
Methylnapthalenes	42.3	1.73	14.2	6.01		
Acenaphthylene	0.96	0.05	0.30	0.13		
Acenaphthene	5.48	0.09	1.33	1.23		
Dimethylnapthalenes	134.0	1.76	32.2	22.0		
Trimethylnapthalenes	223.7	2.51	34.6	32.8		
Fluorene	4.88	0.23	1.72	2.38		
Dibenzothiophene	9.93	0.08	1.53	1.73		
Methyldibenzothiophenes	77.9	0.32	7.72	7.22		
Dimethyldibenzothiophenes	263.3	0.82	16.4	11.0		
Phenanthrene	50.4	0.60	8.69	8.79		
Anthracene	3.83	0.04	0.31	0.41	100	100
Methylphenanthrenes	383.6	1.94	39.2	37.9		
Dimethylphenanthrenes	791.5	2.38	59.0	42.4		
Trimethylphenanthrenes	748.6	1.62	38.7	23.9		
Fluoranthene	1.00	0.15	0.74	0.64	6.3	120
Pyrene	4.40	0.14	0.93	0.66		
Methylpyrenes	24.0	0.32	4.24	2.80		
Dimethylpyrenes	32.4	0.25	5.11	3.61		
Retene	8.48	0.05	0.47	0.32		
Benz[a]anthracene	8.37	0.05	0.43	0.31		
Chrysene	20.8	0.19	1.71	1.32		
Methylchrysenes	73.8	0.28	3.30	2.97		
Dimethylchrysenes	113.6	0.26	3.25	4.21		
Benzo[b]fluoranthene	6.45	0.06	0.42	0.31		17
Benzo[k]fluoranthene	1.10	N.D.	0.07	0.06		17
Benzo[e]pyrene	12.6	0.05	0.53	0.40		
Benzo[a]pyrene	**3.95**	N.D.	0.13	0.13	0.17	27
Perylene	1.64	N.D.	0.06	0.06		
Indeno[1,2,3-cd]pyrene	0.64	0.03	0.06	0.06		
Benzo[ghi]perylene	**2.75**	0.02	0.11	0.17		0.82
Dibenz[a,h]anthracene	1.05	N.D.	0.05	0.07		
ΣPAHs (ng/L)	**3062**	**17.3**	**280.6**	**217.5**		

ANNEX I

MUNICIPALITY OF VARI-VOULA-VOULIAGMENI							
	MEGALO KAVOURI			VOULIAGMENI NAUTICAL CLUB			
	18/09/17	22/09/17	03/10/17	18/09/17	03/10/17	AA (ng/L)	MAC (ng/L)
PAHs (ng/L)							
Naphthalene	6.49	2.29	1.03	1.89	N.D.	2000	130 000
Methylnapthalenes	85.5	20.5	1.76	5.66	N.D.		
Acenaphthylene	0.42	0.11	0.06	0.73	N.D.		
Acenaphthene	7.66	2.49	0.15	0.25	N.D.		
Dimethylnapthalenes	186.3	62.3	3.79	4.22	N.D.		
Trimethylnapthalenes	237.5	77.8	5.16	3.25	N.D.		
Fluorene	6.72	4.10	0.33	0.43	0.25		
Dibenzothiophene	14.2	4.27	0.24	0.16	0.13		
Methyldibenzothiophenes	92.6	20.4	1.59	0.54	1.21		
Dimethyldibenzothiophenes	290.0	40.9	5.73	1.77	11.2		
Phenanthrene	65.4	18.2	1.11	1.00	1.15		
Anthracene	4.02	1.13	0.12	0.06	0.31	100	100
Methylphenanthrenes	429.3	89.0	7.36	2.47	18.3		
Dimethylphenanthrenes	904.9	129.3	18.8	4.80	39.0		
Trimethylphenanthrenes	746.1	89.7	16.1	4.47	48.4		
Fluoranthene	1.83	1.04	0.39	0.47	0.29	6.3	120
Pyrene	5.62	2.28	0.69	0.33	0.12		
Methylpyrenes	28.3	10.92	3.30	1.01	0.25		
Dimethylpyrenes	34.1	13.78	4.08	1.52	0.24		
Retene	16.8	0.99	0.35	0.12	2.37		
Benz[a]anthracene	11.2	1.98	0.87	0.38	0.04		
Chrysene	29.5	4.63	1.29	0.51	0.10		
Methylchrysenes	87.0	12.2	3.77	0.90	0.09		
Dimethylchrysenes	124.9	16.1	4.65	1.18	0.06		
Benzo[b]fluoranthene	11.0	0.88	0.68	0.70	0.07		17
Benzo[k]fluoranthene	1.61	0.14	0.15	0.17	0.02		17
Benzo[e]pyrene	16.5	1.30	0.61	0.37	0.03		
Benzo[a]pyrene	4.47	0.60	0.54	0.36	0.02	0.17	27
Perylene	1.63	0.25	0.15	0.07	N.D.		
Indeno[1,2,3-cd]pyrene	1.52	0.16	0.29	0.18	0.02		
Benzo[ghi]perylene	4.51	0.51	0.39	0.14	0.02		0.82
Dibenz[a,h]anthracene	1.91	0.25	0.14	0.06	N.D.		
ΣPAHs (ng/L)	3460	630.6	85.7	40.2	123.7		

ANNEX I

MUNICIPALITY OF VARI-VOULA-VOULIAGMENI						
	VOULIAGMENI BEACH CLUB			**LIMANAKIA**		
	18/09/17	**22/09/17**	**03/10/17**	**18/09/17**	**AA (ng/L)**	**MAC (ng/L)**
PAHs (ng/L)						
Naphthalene	1.61	6.02	1.18	2.19	2000	130 000
Methylnapthalenes	5.17	7.42	1.68	3.80		
Acenaphthylene	0.37	0.14	0.05	0.05		
Acenaphthene	0.21	0.14	0.07	0.10		
Dimethylnapthalenes	3.76	2.66	1.09	2.41		
Trimethylnapthalenes	3.53	3.64	2.34	1.98		
Fluorene	0.28	0.19	0.15	0.13		
Dibenzothiophene	0.14	0.22	0.05	0.08		
Methyldibenzothiophenes	0.35	0.29	0.09	0.32		
Dimethyldibenzothiophenes	5.20	0.50	0.16	0.84		
Phenanthrene	0.83	0.62	0.30	0.39		
Anthracene	0.04	0.04	0.02	0.05	100	100
Methylphenanthrenes	1.53	1.52	0.66	1.38		
Dimethylphenanthrenes	1.63	1.86	0.44	2.61		
Trimethylphenanthrenes	1.21	0.97	0.18	2.32		
Fluoranthene	0.51	0.34	0.16	0.07	6.3	120
Pyrene	0.30	0.19	0.10	0.09		
Methylpyrenes	0.40	0.14	0.09	0.40		
Dimethylpyrenes	0.05	0.22	0.06	0.54		
Retene	0.02	0.02	0.03	0.05		
Benz[a]anthracene	0.18	0.17	0.06	0.05		
Chrysene	0.26	0.14	0.09	0.11		
Methylchrysenes	0.47	0.06	0.05	0.41		
Dimethylchrysenes	1.98	0.11	0.04	0.61		
Benzo[b]fluoranthene	1.34	0.25	0.15	0.06		17
Benzo[k]fluoranthene	0.46	0.06	0.04	N.D.		17
Benzo[e]pyrene	0.25	0.09	0.06	0.07		
Benzo[a]pyrene	**0.25**	0.11	0.05	0.03	0.17	27
Perylene	0.06	0.03	N.D.	N.D.		
Indeno[1,2,3-cd]pyrene	0.16	0.07	0.05	0.02		
Benzo[ghi]perylene	0.17	0.08	0.04	0.03		0.82
Dibenz[a,h]anthracene	0.03	0.02	N.D.	N.D.		
ΣPAHs (ng/L)	**32.7**	**28.3**	**9.55**	**21.3**		

ANNEX I

MUNICIPALITY OF VARI-VOULA-VOULIAGMENI					
VARKIZA NAVAL ATHLETIC CLUB					
	18/09/2017	**22/09/2017**	**03/10/2017**	**AA (ng/L)**	**MAC (ng/L)**
PAHs (ng/L)					
Naphthalene	4.39	1.95	1.05	2000	130 000
Methylnapthalenes	6.95	2.83	1.61		
Acenaphthylene	0.20	0.07	0.03		
Acenaphthene	0.20	0.12	0.08		
Dimethylnapthalenes	3.85	1.94	1.25		
Trimethylnapthalenes	2.44	2.05	1.85		
Fluorene	0.24	0.22	0.25		
Dibenzothiophene	0.12	0.11	0.05		
Methyldibenzothiophenes	0.25	0.16	0.09		
Dimethyldibenzothiophenes	0.60	0.31	0.15		
Phenanthrene	0.68	0.52	0.29		
Anthracene	0.04	0.03	0.02	100	100
Methylphenanthrenes	1.28	1.02	0.51		
Dimethylphenanthrenes	1.73	1.07	0.46		
Trimethylphenanthrenes	1.20	0.58	0.29		
Fluoranthene	0.23	0.15	0.10	6.3	120
Pyrene	0.14	0.07	0.05		
Methylpyrenes	0.25	0.11	0.07		
Dimethylpyrenes	0.23	0.13	0.06		
Retene	0.07	0.04	N.D.		
Benz[a]anthracene	0.10	0.03	0.02		
Chrysene	0.14	0.08	0.05		
Methylchrysenes	0.15	0.10	0.05		
Dimethylchrysenes	0.26	0.14	0.05		
Benzo[b]fluoranthene	0.30	0.07	0.04		17
Benzo[k]fluoranthene	0.05	0.02	N.D.		17
Benzo[e]pyrene	0.11	0.06	0.03		
Benzo[a]pyrene	0.10	0.03	N.D.	0.17	27
Perylene	0.03	N.D.	N.D.		
Indeno[1,2,3-cd]pyrene	0.08	0.03	N.D.		
Benzo[ghi]perylene	0.07	0.05	N.D.		0.82
Dibenz[a,h]anthracene	0.02	N.D.	N.D.		
ΣPAHs (ng/L)	**26.5**	**14.1**	**8.58**		

ANNEX I

	MUNICIPALITY OF KROPIA			
	LOUBARDAS	**AGIA MARINA**		
	18/09/2017	**18/09/2017**	**AA (ng/L)**	**MAC (ng/L)**
PAHs (ng/L)				
Naphthalene	2.77	3.46	2000	130 000
Methylnapthalenes	6.75	6.55		
Acenaphthylene	0.11	0.12		
Acenaphthene	0.12	0.14		
Dimethylnapthalenes	4.64	4.23		
Trimethylnapthalenes	2.39	2.12		
Fluorene	0.17	0.22		
Dibenzothiophene	0.11	0.09		
Methyldibenzothiophenes	0.51	0.18		
Dimethyldibenzothiophenes	1.40	0.28		
Phenanthrene	0.61	0.54		
Anthracene	0.06	0.04	100	100
Methylphenanthrenes	2.40	1.00		
Dimethylphenanthrenes	4.33	1.01		
Trimethylphenanthrenes	3.65	0.39		
Fluoranthene	0.13	0.11	6.3	120
Pyrene	0.19	0.06		
Methylpyrenes	0.58	0.14		
Dimethylpyrenes	0.82	0.09		
Retene	0.11	0.04		
Benz[a]anthracene	0.10	0.02		
Chrysene	0.16	0.05		
Methylchrysenes	0.50	0.05		
Dimethylchrysenes	0.58	0.04		
Benzo[b]fluoranthene	0.11	0.04		17
Benzo[k]fluoranthene	0.03	N.D.		17
Benzo[e]pyrene	0.10	0.03		
Benzo[a]pyrene	0.06	0.02	0.17	27
Perylene	0.02	N.D.		
Indeno[1,2,3-cd]pyrene	0.03	0.02		
Benzo[ghi]perylene	0.05	0.02		0.82
Dibenz[a,h]anthracene	0.02	N.D.		
ΣPAHs (ng/L)	**33.6**	**21.1**		

ANNEX I

MUNICIPALITY OF KROPIA					
BLUE BEACH (MUNICIPALITY LIMITS OF KROPIA-SARONIKOS)					
	18/09/2017	**22/09/2017**	**03/10/2017**	**AA (ng/L)**	**MAC (ng/L)**
PAHs (ng/L)					
Naphthalene	2.06	1.48	0.90	2000	130 000
Methylnapthalenes	5.13	3.00	1.50		
Acenaphthylene	0.04	0.03	0.02		
Acenaphthene	0.13	0.11	0.07		
Dimethylnapthalenes	3.99	2.66	1.19		
Trimethylnapthalenes	2.13	2.28	1.55		
Fluorene	0.17	0.23	0.11		
Dibenzothiophene	0.14	0.11	0.04		
Methyldibenzothiophenes	1.03	0.25	0.09		
Dimethyldibenzothiophenes	3.85	0.40	0.15		
Phenanthrene	0.77	0.69	0.26		
Anthracene	0.07	0.04	N.D.	100	100
Methylphenanthrenes	5.05	1.54	0.45		
Dimethylphenanthrenes	12.2	1.42	0.32		
Trimethylphenanthrenes	12.7	0.67	0.18		
Fluoranthene	0.12	0.11	0.07	6.3	120
Pyrene	0.29	0.08	0.04		
Methylpyrenes	1.78	0.18	0.07		
Dimethylpyrenes	3.01	0.15	0.02		
Retene	0.27	0.04	N.D.		
Benz[a]anthracene	0.18	0.02	N.D.		
Chrysene	0.58	0.07	0.04		
Methylchrysenes	1.83	0.07	0.04		
Dimethylchrysenes	2.52	0.04	0.04		
Benzo[b]fluoranthene	0.18	0.03	0.06		17
Benzo[k]fluoranthene	0.03	N.D.	0.05		17
Benzo[e]pyrene	0.30	0.02	N.D.		
Benzo[a]pyrene	0.07	0.02	N.D.	0.17	27
Perylene	0.03	N.D.	N.D.		
Indeno[1,2,3-cd]pyrene	0.03	N.D.	N.D.		
Benzo[ghi]perylene	0.09	N.D.	N.D.		0.82
Dibenz[a,h]anthracene	0.04	N.D.	N.D.		
ΣPAHs (ng/L)	**60.7**	**15.8**	**7.32**		

ANNEX I

	MUNICIPALITY OF SARONIKOS				
	BLUE BEACH (TREXANTHRI)	GRAND RESORT - ΚΟΧΥΛΙΑ	GRAND RESORT - GRAND BEACH		
	18/09/2017	18/09/2017	18/09/2017	AA (ng/L)	MAC (ng/L)
PAHs (ng/L)					
Naphthalene	4.12	4.36	17.0	2000	130 000
Methylnapthalenes	13.2	7.71	76.0		
Acenaphthylene	0.36	0.13	0.21		
Acenaphthene	0.30	0.19	0.24		
Dimethylnapthalenes	10.7	4.03	4.01		
Trimethylnapthalenes	5.66	2.70	14.6		
Fluorene	0.35	0.26	0.14		
Dibenzothiophene	0.21	0.23	0.15		
Methyldibenzothiophenes	0.66	2.04	0.77		
Dimethyldibenzothiophenes	1.13	9.62	2.38		
Phenanthrene	1.22	1.17	0.84		
Anthracene	0.12	0.08	0.05	100	100
Methylphenanthrenes	3.66	9.44	3.37		
Dimethylphenanthrenes	4.32	29.7	6.65		
Trimethylphenanthrenes	2.16	37.0	6.21		
Fluoranthene	0.16	0.24	0.15	6.3	120
Pyrene	0.15	0.53	0.13		
Methylpyrenes	0.35	4.26	0.69		
Dimethylpyrenes	0.33	7.96	1.25		
Retene	0.13	0.89	0.14		
Benz[a]anthracene	0.05	0.59	0.10		
Chrysene	0.11	1.06	0.30		
Methylchrysenes	0.19	3.97	0.80		
Dimethylchrysenes	0.16	5.91	1.14		
Benzo[b]fluoranthene	0.07	0.36	0.09		17
Benzo[k]fluoranthene	N.D.	0.06	0.02		17
Benzo[e]pyrene	0.06	0.57	0.10		
Benzo[a]pyrene	0.04	**0.31**	0.03	0.17	27
Perylene	N.D.	0.10	0.02		
Indeno[1,2,3-cd]pyrene	0.02	0.07	0.02		
Benzo[ghi]perylene	0.03	0.17	0.03		0.82
Dibenz[a,h]anthracene	N.D.	0.08	0.02		
ΣPAHs (ng/L)	**50.0**	**135.9**	**137.6**		

MUNICIPALITY OF SARONIKOS					
SARONIDA					
	18/09/2017	**22/09/2017**	**03/10/2017**	**AA (ng/L)**	**MAC (ng/L)**
PAHs (ng/L)					
Naphthalene	3.17	1.83	1.47	2000	130 000
Methylnapthalenes	7.03	6.46	1.78		
Acenaphthylene	0.06	0.09	0.09		
Acenaphthene	0.29	0.48	0.12		
Dimethylnapthalenes	5.55	8.21	2.03		
Trimethylnapthalenes	5.29	12.9	4.33		
Fluorene	0.35	0.40	0.38		
Dibenzothiophene	0.48	0.62	0.22		
Methyldibenzothiophenes	2.39	2.79	0.88		
Dimethyldibenzothiophenes	6.65	5.53	1.79		
Phenanthrene	2.16	3.12	1.48		
Anthracene	0.07	0.17	0.11	100	100
Methylphenanthrenes	10.1	13.4	4.32		
Dimethylphenanthrenes	21.3	17.5	4.40		
Trimethylphenanthrenes	20.5	11.6	3.19		
Fluoranthene	0.25	0.33	0.34	6.3	120
Pyrene	0.42	0.51	0.29		
Methylpyrenes	2.68	1.79	0.73		
Dimethylpyrenes	4.53	2.05	0.99		
Retene	0.46	0.14	0.17		
Benz[a]anthracene	0.32	0.27	0.13		
Chrysene	1.16	0.69	0.27		
Methylchrysenes	3.20	1.61	0.72		
Dimethylchrysenes	4.27	1.62	0.97		
Benzo[b]fluoranthene	0.29	0.14	0.10		17
Benzo[k]fluoranthene	0.04	0.03	0.02		17
Benzo[e]pyrene	0.45	0.17	0.10		
Benzo[a]pyrene	0.10	0.07	0.06	0.17	27
Perylene	0.04	0.03	0.03		
Indeno[1,2,3-cd]pyrene	0.04	0.02	0.02		
Benzo[ghi]perylene	0.12	0.05	0.04		0.82
Dibenz[a,h]anthracene	0.06	0.03	0.02		
ΣPAHs (ng/L)	**103.9**	**94.6**	**31.6**		

ANNEX I

	MUNICIPALITY OF SARONIKOS				
	MAYRO LITHARI		ST. NIKOLAS		
	18/09/2017	03/10/2017	22/09/2017	AA (ng/L)	MAC (ng/L)
PAHs (ng/L)					
Naphthalene	3.57	0.89	2.36	2000	130 000
Methylnapthalenes	7.18	1.45	4.80		
Acenaphthylene	0.33	0.05	0.06		
Acenaphthene	0.24	0.07	0.18		
Dimethylnapthalenes	5.18	1.28	4.31		
Trimethylnapthalenes	14.7	2.01	3.91		
Fluorene	0.34	0.21	0.38		
Dibenzothiophene	0.86	0.08	0.21		
Methyldibenzothiophenes	14.7	0.23	0.54		
Dimethyldibenzothiophenes	65.9	0.59	0.73		
Phenanthrene	4.39	0.68	1.07		
Anthracene	0.36	0.03	0.04	100	100
Methylphenanthrenes	59.7	1.68	2.64		
Dimethylphenanthrenes	181.7	1.26	2.35		
Trimethylphenanthrenes	195.7	0.89	0.27		
Fluoranthene	0.55	0.14	0.12	6.3	120
Pyrene	2.59	0.09	0.08		
Methylpyrenes	18.4	0.19	0.16		
Dimethylpyrenes	29.9	0.24	0.17		
Retene	4.79	0.11	0.04		
Benz[a]anthracene	4.07	0.03	0.02		
Chrysene	8.94	0.10	0.09		
Methylchrysenes	30.6	0.22	0.10		
Dimethylchrysenes	44.7	0.24	0.08		
Benzo[b]fluoranthene	2.56	0.04	0.03		17
Benzo[k]fluoranthene	0.33	N.D.	N.D.		17
Benzo[e]pyrene	4.46	0.03	N.D.		
Benzo[a]pyrene	**1.90**	N.D.	N.D.	0.17	27
Perylene	0.64	N.D.	N.D.		
Indeno[1,2,3-cd]pyrene	0.34	N.D.	N.D.		
Benzo[ghi]perylene	**1.39**	N.D.	N.D.		0.82
Dibenz[a,h]anthracene	0.65	N.D.	N.D.		
ΣPAHs (ng/L)	**711.7**	**12.9**	**24.8**		

ANNEX I

	MUNICIPALITY OF SARONIKOS				
	ANAVYSSOS		PALAIA FOKAIA		
	22/09/2017	03/10/2017	22/09/2017	AA (ng/L)	MAC (ng/L)
PAHs (ng/L)					
Naphthalene	0.86	0.85	0.71	2000	130 000
Methylnapthalenes	1.68	1.87	1.69		
Acenaphthylene	0.07	0.05	0.06		
Acenaphthene	0.08	0.08	0.07		
Dimethylnapthalenes	1.51	1.38	1.83		
Trimethylnapthalenes	1.80	1.82	1.77		
Fluorene	0.15	0.08	0.16		
Dibenzothiophene	0.08	0.04	0.10		
Methyldibenzothiophenes	0.17	0.09	0.17		
Dimethyldibenzothiophenes	0.30	0.16	0.30		
Phenanthrene	0.42	0.29	0.50		
Anthracene	0.04	N.D.	0.04	100	100
Methylphenanthrenes	0.78	1.02	1.14		
Dimethylphenanthrenes	0.72	0.34	1.12		
Trimethylphenanthrenes	0.32	0.15	0.63		
Fluoranthene	0.21	0.08	0.20	6.3	120
Pyrene	0.12	0.03	0.13		
Methylpyrenes	0.15	0.05	0.18		
Dimethylpyrenes	0.17	0.02	0.20		
Retene	0.03	0.02	0.03		
Benz[a]anthracene	0.05	N.D.	0.09		
Chrysene	0.09	0.04	0.11		
Methylchrysenes	0.07	0.04	0.13		
Dimethylchrysenes	0.08	0.04	0.13		
Benzo[b]fluoranthene	0.10	0.03	0.13		17
Benzo[k]fluoranthene	0.03	N.D.	0.04		17
Benzo[e]pyrene	0.05	0.02	0.07		
Benzo[a]pyrene	0.04	N.D.	0.09	0.17	27
Perylene	N.D.	N.D.	0.02		
Indeno[1,2,3-cd]pyrene	0.03	N.D.	0.08		
Benzo[ghi]perylene	0.02	N.D.	0.12		0.82
Dibenz[a,h]anthracene	N.D.	N.D.	N.D.		
ΣPAHs (ng/L)	**10.2**	**8.63**	**12.0**		

ANNEX I

	MUNICIPALITY OF SARONIKOS			
	THIMARI	ORMOS - KATAFYGI		
	22/09/2017	22/09/2017	AA (ng/L)	MAC (ng/L)
PAHs (ng/L)				
Naphthalene	1.19	0.98	2000	130 000
Methylnapthalenes	4.78	4.65		
Acenaphthylene	0.06	0.07		
Acenaphthene	0.28	0.42		
Dimethylnapthalenes	9.35	10.6		
Trimethylnapthalenes	8.44	11.0		
Fluorene	0.49	0.71		
Dibenzothiophene	0.22	0.75		
Methyldibenzothiophenes	0.43	3.13		
Dimethyldibenzothiophenes	0.55	6.40		
Phenanthrene	2.01	3.15		
Anthracene	0.06	0.20	100	100
Methylphenanthrenes	2.43	13.6		
Dimethylphenanthrenes	1.91	19.6		
Trimethylphenanthrenes	0.80	14.9		
Fluoranthene	0.17	0.24	6.3	120
Pyrene	0.12	0.57		
Methylpyrenes	0.21	2.81		
Dimethylpyrenes	0.22	3.60		
Retene	0.04	0.24		
Benz[a]anthracene	0.03	0.45		
Chrysene	0.07	1.00		
Methylchrysenes	0.10	2.87		
Dimethylchrysenes	0.10	3.82		
Benzo[b]fluoranthene	0.03	0.20		17
Benzo[k]fluoranthene	N.D.	0.03		17
Benzo[e]pyrene	0.03	0.33		
Benzo[a]pyrene	0.02	0.12	0.17	27
Perylene	N.D.	0.06		
Indeno[1,2,3-cd]pyrene	N.D.	0.03		
Benzo[ghi]perylene	0.02	0.11		0.82
Dibenz[a,h]anthracene	N.D.	0.06		
ΣPAHs (ng/L)	**34.2**	**106.6**		

ANNEX I

	MUNICIPALITY OF LAVRIO			
	CHARAKAS	LEGRENA (NAUTICAL CLUB)		
	22/09/2017	22/09/2017	AA (ng/L)	MAC (ng/L)
PAHs (ng/L)				
Naphthalene	1.03	2.54	2000	130 000
Methylnapthalenes	1.96	5.80		
Acenaphthylene	0.12	0.09		
Acenaphthene	0.07	0.12		
Dimethylnapthalenes	1.67	2.57		
Trimethylnapthalenes	1.76	5.45		
Fluorene	0.15	0.09		
Dibenzothiophene	0.07	0.06		
Methyldibenzothiophenes	0.15	0.14		
Dimethyldibenzothiophenes	0.23	0.59		
Phenanthrene	0.46	0.42		
Anthracene	0.02	0.04	100	100
Methylphenanthrenes	0.83	1.19		
Dimethylphenanthrenes	0.58	1.18		
Trimethylphenanthrenes	0.26	0.63		
Fluoranthene	0.07	0.08	6.3	120
Pyrene	0.04	0.05		
Methylpyrenes	0.08	0.15		
Dimethylpyrenes	0.10	0.15		
Retene	0.02	0.04		
Benz[a]anthracene	0.02	N.D.		
Chrysene	0.05	0.05		
Methylchrysenes	0.06	0.05		
Dimethylchrysenes	0.06	0.03		
Benzo[b]fluoranthene	0.03	N.D.		17
Benzo[k]fluoranthene	N.D.	N.D.		17
Benzo[e]pyrene	0.03	N.D.		
Benzo[a]pyrene	0.02	N.D.	0.17	27
Perylene	N.D.	N.D.		
Indeno[1,2,3-cd]pyrene	0.02	N.D.		
Benzo[ghi]perylene	0.02	N.D.		0.82
Dibenz[a,h]anthracene	N.D.	N.D.		
ΣPAHs (ng/L)	**10.0**	**21.6**		

ANNEX II

MINISTRY OF EDUCATION, RESEARCH AND RELIGIOUS AFFAIRS
GENERAL SECRETARIAT OF RESEARCH AND TECHNOLOGY

HELLENIC CENTRE FOR MARINE RESEARCH (H.C.M.R.)
INSTITUTE OF OCEANOGRAPHY

STUDY OF THE SHORT AND MEDIUM TERM ENVIRONMENTAL CONSEQUENSES OF THE SINKING OF THE AGIA ZONI II TANKER ON THE MARINE ECOSYSTEM OF THE SARONIKOS GULF

SUPPLEMENTARY

SEAWATER QUALITY IN COASTAL AREAS OF THE SARONIKOS GULF FOR THE PERIOD OF APRIL TO AUGUST 2018

ANAVYSSOS
SEPTEMBER 2018

ANNEX II

STUDY OF THE SHORT AND MEDIUM TERM ENVIRONMENTAL CONSEQUENSES OF THE SINKING OF THE AGIA ZONI II TANKER ON THE MARINE ECOSYSTEM OF THE SARONIKOS GULF

SUPPLEMENTARY

SEAWATER QUALITY IN COASTAL AREAS OF THE SARONIKOS GULF FOR THE PERIOD OF APRIL TO AUGUST 2018

Project Leader

Dr. Constantine Parinos	Chemist Oceanographer, Assistant Researcher

H.C.M.R. Scientific and Technical Staff

Dr. Ioannis Hatzianestis	Chemist Oceanographer, Research Director
Alexandros Papaioannou	Chemical Engineer
Stella Chourdaki	Chemical Engineer, MSc
Elvira Plakidi	Technical Scientist, MSc
Vassilis Mpampas	Technical Staff (Driver)
Constantine Fostiropoulos	Technical Staff (Driver)

1. SAMPLING / METHODOLOGY

Following the release, on April 5th 2018, of the final scientific report on the short- and medium term environmental consequences of the sinking of the Agia Zoni II tanker on the marine ecosystem of the Saronikos Gulf, and in order to fully ensure the good quality of seawater in the coastal zone of the Saronikos Gulf in view of the summer season, monitoring of seawater quality has been conducted on April 2018, June 2018, July 2018 and August 2018 on the existing network of coastal sampling stations.

Seawater samplings (sea surface) from the coastal zone of the Saronikos Gulf have been conducted on April 23rd 2018, June 20th 2018, July 17th 2018 and August 31st 2018. In total, the survey effort included 46 sampling sites, while a total of 178 seawater samples have been collected and subsequently analyzed. All collected seawater samples have been analyzed for total petroleum hydrocarbons by gas chromatography - flame ionization detector (GC - FID) after proper pre-treatment (in-house variant of the ISO 9377-2 standard) and polycyclic aromatic hydrocarbons by gas chromatography - mass spectrometry (Agilent 5973C GC-MSD) according to the in-house methodology of the accredited by ISO/IEC 17025 for the analysis of polycyclic aromatic hydrocarbons in seawater samples organic chemistry laboratory of HCMR.

2. RESULTS AND DISCUSSION

For the interpretation of the results the following remarks are taken into account:

(a) Although the background values for total petroleum hydrocarbons in marine waters range from 0.5 to 2 μg/L, in the inner Saronikos Gulf, according to the H.C.M.R. database over the last decade, values up to 20 μg/L have often been reported which are therefore considered as being normal. Also, under the Greek and European legislation there are no limit values regarding total petroleum hydrocarbons concentrations in seawater.

(b) Regarding polycyclic aromatic hydrocarbons, for determining the chemical status of the considered seawater samples the annual mean concentration (AA) and the maximum allowable concentration (MAC) for naphthalene, anthracene, fluoranthene, benzo(b)fluoranthene, benzo(k) fluoranthene, benzo(a)pyrene and benzo(ghi)perylene have been considered, according to the environmental quality standards for priority substances for the determination of chemical and ecological status of waters (Directive 2013/39/EC).

The results from the determination of total petroleum hydrocarbons in seawater samples collected along the coastal zone of the Saronikos Gulf during the conducted samplings are summarized in Table 1 that follows. The results from the determination of polycyclic aromatic hydrocarbons for the corresponding seawater samples are presented in detail for each of the sampling sites in Table S.A.1 of the Annex.

Table 1: Total petroleum hydrocarbons in seawater samples collected along the coastal zone of the Saronikos Gulf. **N.D:** Not detected, detection limit 0.5 μg/L.

SAMPLING AREA	COORDINATES		TOTAL PETROLEUM HYDROCARBONS (in μg/L)			
	LAT.	LONG.	23/04/2018	20/06/2018	17/07/2018	31/08/2018
MUNICIPALITY OF SALAMINA						
KINOSOURA	37° 56.56'N	23° 32.57'E	2.7	0.8	0.7	4.3
SELINIA	37° 56.43'N	23° 32.33'E	1.3	1.2	5.5	3.0
KAKH VIGLA	37° 54.74'N	23° 30.72'E	N.D	3.0	1.1	0.7
CHAROUPIAS	37° 54.22'N	23° 30.83'E	1.0	0.6	N.D	0.9
NTOULAPI	37° 54.08'N	23° 30.77'E	N.D	N.D	0.8	N.D
GIALA	37° 54.16'N	23° 30.18'E	N.D	0.5	0.6	1.3
KIRIZA	37° 53.92'N	23° 29.20'E	0.9	1.4	0.9	0.8
MAROUDI	37° 53.39'N	23° 28.76'E	N.D	N.D	N.D	4.6
PERISTERIA	37° 52.74'N	23° 27.53'E	N.D	0.5	N.D	1.1
MUNICIPALITY OF PIRAEUS						
AFRODITE VOE	37° 55.74'N	23° 37.82'E	6.9	1.3	0.8	5.6
FREATTYDA	37° 55.82'N	23° 38.84'E	5.8	N.D	1.8	4.9
YACHT CLUB OF GREECE	37° 56.14'N	23° 39.23'E	6.1	2.0	1.0	3.2
MUNICIPALITY OF PALAIO FALIRO						
PHLOISBOS	37° 55.55'N	23° 41.41'E	1.2	N.D	0.8	8.6
BATIS	37° 55.27'N	23° 41.74'E	0.6	0.7	3.8	6.8
EDEM	37° 55.09'N	23° 42.02'E	6.1	4.1	0.7	11.2
MUNICIPALITY OF ALIMOS						
AKTI ILIOU	37° 54.41'N	23° 42.93'E	0.7	1.8	1.5	3.4
YACHT CLUB OF ALIMOS	37° 54.07'N	23° 43.06'E	0.8	N.D	1.7	2.1

ANNEX II

SAMPLING AREA	COORDINATES		TOTAL PETROLEUM HYDROCARBONS (in μg/L)			
	LAT.	LONG.	23/04/2018	20/06/2018	17/07/2018	31/08/2018
MUNICIPALITY OF ELLINIKO-ARGYROUPOLI						
AGIOS KOSMAS	37° 53.45'N	23° 43.20'E	1.0	1.3	7.2	1.9
H.C.M.R. FACILITIES	37° 53.56'N	23° 43.07'E	0.5	1.4	1.1	2.3
AIGYPTIOTES NAVAL CLUB	37° 53.62'N	23° 43.04'E	0.8	N.D	0.5	4.0
MUNICIPALITY OF GLYFADA						
GLYFADA 1 (VICINAL TO 4th MARINA)	37° 52.40'N	23° 43.96'E	1.1	N.D	0.7	1.4
GLYFADA 2	37° 52.08'N	23° 44.19'E	N.D	0.7	1.2	0.9
GLYFADA 3 (VICINAL TO 3rd MARINA)	37° 51.91'N	23° 44.45'E	N.D	0.5	1.0	2.1
GLYFADA 4 (VICINAL TO 2nd MARINA)	37° 51.75'N	23° 44.76'E	1.2	N.D	**56.8**	**99.5**
GLYFADA 5 (VICINAL TO 1st MARINA)	37° 51.63'N	23° 44.93'E	N.D	N.D	N.D	11.5
ASTERAS GLYFADAS	37° 51.40'N	23° 44.99'E	2.7	8.0	4.5	18.3
MUNICIPALITY OF VARI-VOULA-VOULIAGMENI						
ASKLIPIEIO VOULAS (VICINAL TO EL. VENIZELOS SQUARE)	37° 50.75'N	23° 45.23'E	N.D	0.5	5.2	8.0
VOULA CITY HALL	37° 50.19'N	23° 45.95'E	N.D	0.6	2.8	3.2
MEGALO KAVOURI	37° 49.07'N	23° 46.05'E	1.4	N.D	3.3	4.6
VOULIAGMENI NAUTICAL CLUB	37° 48.60'N	23° 46.47'E	N.D	11.6	1.4	4.2
VOULIAGMENI BEACH CLUB	37° 48.78'N	23° 46.79'E	N.D	0.6	1.8	3.2
LIMANAKIA	37° 48.00'N	23° 47.33'E	N.D	N.D	N.D	0.8
VARKIZA NAVAL ATHLETIC CLUB	37° 49.23'N	23° 48.77'E	1.0	0.5	N.D	2.9
MUNICIPALITY OF KROPIA						
LOUBARDAS	37° 49.11'N	23° 50.07'E	3.5	1.6	10.7	2.4
AGIA MARINA	37° 48.85'N	23° 50.58'E	1.1	0.8	N.D	3.7
BLUE BEACH (MUNICIPALITY LIMITS KROPIA-SARONIKOS)	37° 48.09'N	23° 51.95'E	2.7	N.D	0.5	1.5
MUNICIPALITY OF SARONIKOS						
BLUE BEACH (TREXANTHRI)	37° 47.74'N	23° 52.290'E	1.9	2.3	0.7	N.D
SARONIDA	37° 44.87'N	23° 54.29'E	N.D	N.D	0.6	1.8
MAYRO LITHARI	37° 44.17'N	23° 54.30'E	N.D	0.5	N.D	1.4
ST. NIKOLAS	37° 43.11'N	23° 55.32'E	1.7	0.7	1.0	13.7

SAMPLING AREA	COORDINATES		TOTAL PETROLEUM HYDROCARBONS (in μg/L)			
	LAT.	LONG.	23/04/2018	20/06/2018	17/07/2018	31/08/2018
MUNICIPALITY OF SARONIKOS						
ANAVYSSOS	37° 43.52'N	23° 56.18'E	1.6	2.4	N.D	4.5
PALAIA FOKAIA	37° 43.29'N	23° 56.71'E	N.D	3.4	0.7	2.4
THIMARI	37° 42.19'N	23° 56.36'E	4.0	2.1	1.1	1.2
ORMOS - KATAFYGI	37° 40.80'N	23° 56.51'E	0.9	0.5	N.D	N.D
MUNICIPALITY OF LAVRIO						
CHARAKAS	37° 39.99'N	23° 58.31'E	1.1			
LEGRENA (NAUTICAL CLUB)	37° 39.75'N	23° 59.47'E	0.5			

Considering the above, total petroleum hydrocarbons concentrations at all sampling sites are considered as normal, **with the exception of the sampling site vicinal to the 2nd marina of Glyfada on July 17th and August 31st 2018**. In these cases, laboratory analysis of the collected sea water samples by means of gas chromatography - mass spectrometry (identification of the molecular identity of the samples' hydrocarbon content) shows that the slightly increased total petroleum hydrocarbons concentration is not related to the incident of the Agia Zoni II sinking. More specifically, the molecular profile of aliphatic hydrocarbons, hopanes and polycyclic aromatic hydrocarbons of the samples did not match the one of the petroleum sample drawn from the shipwreck of Agia Zoni II on September 16th 2017, which H.C.M.R. holds for analysis. This fact, combined with the low concentrations of total petroleum hydrocarbons at all other sampling sites within the jurisdiction of the Municipality of Glyfada on July 17th and August 31st 2018, indicates a local mild oil pollution burden on the days of sampling due to, with an increased probability, the operation of the neighboring 2nd marina of Glyfada.

Regarding polycyclic aromatic hydrocarbons (PAHs), in no case values higher than the maximum allowable concentration (MAC) for PAHs were recorded. However, in a few cases (14 out of 178 samples) values higher than the annual average concentration (AA) were recorded for benzo(a)pyrene (i.e., Kinosoura on August 31st 2018, Afrodite Voe on August 31st 2018, Phloisbos on August 31st 2018, Batis on July 17th 2018 and on August 31st 2018, Edem on April 23rd 2018 and on August 31st 2018, Yacht club of Alimos on April 23rd 2018, Agios Kosmas and HCMR Facilities on August 31st 2018, Glyfada 4 on August 31st 2018, and Asteras Glyfadas on April 23rd 2018, June 20th 2018 and August 31st 2018– see Table S.A.1) in accordance to the environmental quality standards for priority substances for the determination of chemical and ecological status of waters (Directive 2013/39/EC). Total PAHs concentrations fluctuated at low levels, in accordance to those previously reported in various Greek seas (Hatzianestis and Sklivagou, 2002, Parinos and Gogou, 2016, and references therein).

References

Hatzianestis, I., and Sklivagou, E., 2002. Dissolved and suspended polycyclic aromatic hydrocarbons (PAH) in the north Aegean Sea. Mediter. Mar. Sci. 3, 89-98.

Parinos, C., and Gogou, A., 2016. Suspended particle-associated PAHs in the open eastern Mediterranean Sea: Occurrence, sources and processes affecting their distribution patterns. Marine Chemistry 180, 42-50.

ANNEX

Table S.A.1. Polycyclic aromatic hydrocarbons (PAHs; in ng/L) in seawater samples collected during the conducted samplings in coastal areas of the Saronikos Gulf (April to August 2018). AA: annual mean concentration (in ng/L) and MAC: maximum allowable concentration (in ng/L) for naphthalene, anthracene, fluoranthene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene and benzo(ghi)perylene according to the environmental quality standards for priority substances for the determination of chemical and ecological status of waters (Directive 2013/39/EC). **N.D.:** Not detected, detection limit (for each individual compound): 0.02 ng/L**.**

ANNEX II

MUNICIPALITY OF SALAMINA										
	KINOSOURA				SELINIA					
DATE	23/04/2018	20/06/2018	17/07/2018	31/08/2018	23/04/2018	20/06/2018	17/07/2018	31/08/2018		
PAHs (ng/L)									**AA (ng/L)**	**MAC (ng/L)**
Naphthalene	1.15	1.97	1.04	4.50	1.44	1.13	1.30	2.07	2000	130000
Methylnapthalenes	1.45	2.36	1.34	5.11	1.91	1.42	1.31	3.51		
Acenaphthylene	0.04	0.09	0.08	0.22	0.05	0.07	0.07	0.19		
Acenaphthene	0.14	0.24	0.11	2.60	0.16	0.13	0.06	2.90		
Dimethylnapthalenes	1.35	3.10	1.76	4.72	1.90	2.42	1.14	4.43		
Trimethylnapthalenes	1.83	3.82	1.69	4.05	1.82	2.63	1.11	3.41		
Fluorene	0.30	0.68	0.24	1.76	0.32	0.37	0.17	1.83		
Dibenzothiophene	0.10	0.18	0.12	0.44	0.12	0.13	0.07	0.35		
Methyldibenzothiophenes	0.12	0.57	0.31	0.82	0.24	0.39	0.44	0.87		
Dimethyldibenzothiophenes	0.26	1.31	0.76	2.15	0.51	0.88	1.07	1.98		
Phenanthrene	0.40	0.87	0.56	2.59	0.52	0.55	0.36	2.08		
Anthracene	0.02	0.07	0.05	0.09	0.04	0.05	0.03	0.07	100	100
Methylphenanthrenes	0.52	3.35	1.09	3.06	1.06	2.10	0.96	2.10		
Dimethylphenanthrenes	0.78	4.98	1.76	4.69	2.03	3.68	1.40	2.98		
Trimethylphenanthrenes	0.48	2.85	1.50	5.97	1.18	2.22	1.05	2.78		
Fluoranthene	0.10	0.29	0.20	1.34	0.14	0.19	0.11	1.04	6.3	120
Pyrene	0.10	0.37	0.23	0.79	0.14	0.26	0.14	0.32		
Methylpyrenes	0.15	0.93	0.55	2.93	0.38	0.93	0.48	1.03		
Dimethylpyrenes	0.17	1.16	0.69	5.48	0.55	1.55	0.60	1.54		
Retene	N.D.	0.03	N.D.	0.16	0.02	0.02	0.02	0.04		
Benz[a]anthracene	0.04	0.13	0.08	0.28	0.08	0.10	0.05	0.10		
Chrysene	0.09	0.35	0.24	1.04	0.17	0.25	0.17	0.42		
Methylchrysenes	0.14	0.53	0.34	3.07	0.29	0.51	0.26	0.75		
Dimethylchrysenes	0.17	0.59	0.32	4.92	0.40	0.84	0.30	1.16		
Benzo[b]fluoranthene	0.05	0.08	0.07	0.41	0.07	0.07	0.05	0.15		17
Benzo[k]fluoranthene	N.D.	0.02	N.D.	0.07	N.D.	0.02	N.D.	0.03		17
Benzo[e]pyrene	0.03	0.10	0.08	0.69	0.07	0.09	0.07	0.22		
Benzo[a]pyrene	N.D.	0.04	0.04	**0.35**	0.04	N.D.	0.02	0.06	0.17	27
Perylene	N.D.	N.D.	N.D.	0.11	N.D.	0.02	N.D.	0.02		
Indeno[1,2,3-cd]pyrene	0.02	0.02	N.D.	0.12	0.02	N.D.	N.D.	0.03		
Benzo[ghi]perylene	N.D.	0.04	0.04	0.35	0.03	0.06	0.02	0.06		0.82
Dibenz[a,h]anthracene	N.D.	N.D.	N.D.	0.09	N.D.	0.03	N.D.	0.02		
ΣPAHs (ng/L)	**10.1**	**31.2**	**15.4**	**64.9**	**15.7**	**23.1**	**12.9**	**38.5**		

ANNEX II

MUNICIPALITY OF SALAMINA										
	KAKH VIGLA				CHAROUPIAS					
DATE	23/04/2018	20/06/2018	17/07/2018	31/08/2018	23/04/2018	20/06/2018	17/07/2018	31/08/2018		
PAHs (ng/L)									AA (ng/L)	MAC (ng/L)
Naphthalene	2.62	N.D.	0.92	2.16	1.25	0.17	1.04	0.80	2000	130000
Methylnapthalenes	2.69	N.D.	1.04	4.84	1.62	1.44	0.94	0.54		
Acenaphthylene	0.08	N.D.	0.05	0.10	0.03	0.07	0.05	0.05		
Acenaphthene	0.20	N.D.	0.05	0.63	0.10	0.07	0.04	0.07		
Dimethylnapthalenes	0.92	N.D.	0.87	3.11	0.99	1.12	0.57	0.92		
Trimethylnapthalenes	3.78	N.D.	0.70	1.42	1.07	0.99	0.31	0.58		
Fluorene	0.34	0.05	0.44	0.59	0.18	0.18	0.07	0.14		
Dibenzothiophene	0.08	0.08	0.05	0.13	0.03	0.07	0.03	0.04		
Methyldibenzothiophenes	0.36	2.09	0.06	0.20	0.20	0.10	0.04	0.11		
Dimethyldibenzothiophenes	0.29	8.48	0.07	0.34	0.13	0.13	0.04	0.10		
Phenanthrene	0.57	0.57	0.28	0.83	0.27	0.47	0.23	0.32		
Anthracene	0.02	0.10	N.D.	0.02	N.D.	0.05	0.02	0.03	100	100
Methylphenanthrenes	0.41	4.09	0.20	0.65	0.16	0.73	0.22	0.36		
Dimethylphenanthrenes	0.39	7.35	0.21	0.55	0.16	1.30	0.19	0.54		
Trimethylphenanthrenes	0.19	4.41	0.06	0.22	0.12	0.30	0.06	0.16		
Fluoranthene	0.13	0.10	0.07	0.32	0.06	0.26	0.07	0.13	6.3	120
Pyrene	0.06	0.08	0.03	0.07	0.04	0.31	0.08	0.14		
Methylpyrenes	0.06	0.19	0.03	0.09	0.03	0.42	0.09	0.18		
Dimethylpyrenes	0.05	0.09	0.02	0.07	0.03	0.56	0.06	0.19		
Retene	N.D.	0.42	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.		
Benz[a]anthracene	N.D.	N.D.	N.D.	N.D.	N.D.	0.13	0.04	0.08		
Chrysene	0.03	0.04	0.03	0.05	N.D.	0.17	0.03	0.06		
Methylchrysenes	0.02	0.05	N.D.	0.05	N.D.	0.20	0.03	0.08		
Dimethylchrysenes	0.03	0.06	N.D.	0.04	N.D.	0.25	0.04	0.14		
Benzo[b]fluoranthene	N.D.	0.02	N.D.	0.04	N.D.	0.23	0.03	0.13		17
Benzo[k]fluoranthene	N.D.	N.D.	N.D.	N.D.	N.D.	0.06	0.04	0.05		17
Benzo[e]pyrene	0.04	N.D.	N.D.	0.03	N.D.	0.13	0.03	N.D.		
Benzo[a]pyrene	N.D.	N.D.	N.D.	N.D.	N.D.	0.13	0.04	N.D.	0.17	27
Perylene	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	0.04	N.D.		
Indeno[1,2,3-cd]pyrene	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	0.05	N.D.		
Benzo[ghi]perylene	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	0.03	0.03		0.82
Dibenz[a,h]anthracene	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	0.03	0.03		
ΣPAHs (ng/L)	**13.4**	**28.4**	**5.31**	**16.6**	**6.57**	**10.1**	**4.58**	**6.00**		

ANNEX II

MUNICIPALITY OF SALAMINA										
	NTOULAPI				GYALA					
DATE	23/04/2018	20/06/2018	17/07/2018	31/08/2018	23/04/2018	20/06/2018	17/07/2018	31/08/2018		
PAHs (ng/L)									AA (ng/L)	MAC (ng/L)
Naphthalene	1.38	0.42	1.17	1.07	2.70	0.93	0.39	1.53	2000	130000
Methylnapthalenes	1.85	0.62	1.11	0.98	2.41	0.74	0.53	1.40		
Acenaphthylene	0.05	0.06	0.04	0.05	0.11	0.06	0.04	0.08		
Acenaphthene	0.11	0.15	0.05	0.10	0.11	0.02	0.03	0.06		
Dimethylnapthalenes	1.28	0.37	0.52	0.51	1.38	0.66	0.51	0.84		
Trimethylnapthalenes	1.00	0.70	0.27	0.42	1.02	0.48	0.49	0.92		
Fluorene	0.29	0.25	0.38	0.28	0.25	0.11	0.06	0.18		
Dibenzothiophene	0.04	0.04	0.14	0.07	0.04	0.03	0.04	0.03		
Methyldibenzothiophenes	0.07	0.05	0.23	0.11	0.05	0.04	0.07	0.05		
Dimethyldibenzothiophenes	0.12	0.09	0.25	0.12	0.09	0.02	0.27	0.14		
Phenanthrene	0.52	0.36	0.21	0.22	0.38	0.28	0.10	0.29		
Anthracene	N.D.	0.03	N.D.	0.03	0.02	0.04	N.D.	0.03	100	100
Methylphenanthrenes	0.49	0.64	0.89	0.54	0.36	0.14	0.38	0.35		
Dimethylphenanthrenes	0.48	0.76	0.77	0.68	0.34	0.23	1.11	0.68		
Trimethylphenanthrenes	0.16	0.78	0.19	0.22	0.18	0.08	0.97	0.42		
Fluoranthene	0.13	0.18	0.12	0.12	0.12	0.04	0.04	0.08	6.3	120
Pyrene	0.04	0.15	0.08	0.09	0.06	0.02	0.06	0.05		
Methylpyrenes	0.05	0.23	0.06	0.11	0.06	0.03	0.22	0.12		
Dimethylpyrenes	0.05	0.28	0.04	0.12	0.04	0.02	0.37	0.16		
Retene	0.03	0.03	N.D.	N.D.	0.02	N.D.	N.D.	N.D.		
Benz[a]anthracene	N.D.	0.08	0.06	N.D.	N.D.	0.02	0.03	N.D.		
Chrysene	0.03	0.10	0.05	0.06	0.03	N.D.	0.08	0.06		
Methylchrysenes	N.D.	0.14	0.03	N.D.	N.D.	N.D.	0.16	0.18		
Dimethylchrysenes	0.02	0.20	0.05	0.09	N.D.	N.D.	0.21	0.24		
Benzo[b]fluoranthene	0.02	0.11	0.08	0.07	0.02	0.03	0.03	0.03		17
Benzo[k]fluoranthene	N.D.	0.04	0.05	N.D.	N.D.	N.D.	0.03	N.D.		17
Benzo[e]pyrene	N.D.	0.06	0.02	N.D.	N.D.	N.D.	0.03	N.D.		
Benzo[a]pyrene	N.D.	0.07	0.06	0.06	N.D.	N.D.	0.02	0.02	0.17	27
Perylene	N.D.	0.04	0.04	0.04	N.D.	N.D.	0.02	0.02		
Indeno[1,2,3-cd]pyrene	N.D.	0.05	0.02	0.03	N.D.	N.D.	N.D.	N.D.		
Benzo[ghi]perylene	N.D.	0.05	0.03	0.04	N.D.	N.D.	N.D.	N.D.		0.82
Dibenz[a,h]anthracene	N.D.	N.D.	N.D.	0.02	N.D.	N.D.	N.D.	N.D.		
ΣPAHs (ng/L)	**8.30**	**7.14**	**7.01**	**6.26**	**9.89**	**4.02**	**6.30**	**7.98**		

ANNEX II

MUNICIPALITY OF SALAMINA										
	KIRIZA				MAROUDI					
DATE	23/04/2018	20/06/2018	17/07/2018	31/08/2018	23/04/2018	20/06/2018	17/07/2018	31/08/2018		
PAHs (ng/L)									**AA (ng/L)**	**MAC (ng/L)**
Naphthalene	1.61	N.D.	1.40	1.75	6.53	N.D.	0.89	3.44	2000	130000
Methylnapthalenes	1.58	N.D.	1.32	3.75	2.90	N.D.	1.18	7.08		
Acenaphthylene	0.06	N.D.	0.07	0.07	0.12	N.D.	0.12	0.21		
Acenaphthene	0.09	N.D.	0.05	0.53	0.19	N.D.	0.05	1.23		
Dimethylnapthalenes	1.11	N.D.	0.86	2.40	1.87	N.D.	1.02	4.81		
Trimethylnapthalenes	1.24	N.D.	0.50	1.13	4.89	N.D.	0.71	1.99		
Fluorene	0.33	0.25	0.21	0.51	0.19	N.D.	0.26	1.01		
Dibenzothiophene	0.04	0.07	0.07	0.12	0.04	N.D.	0.06	0.21		
Methyldibenzothiophenes	0.08	0.17	0.06	0.14	0.06	N.D.	0.07	0.47		
Dimethyldibenzothiophenes	0.15	0.61	0.08	0.24	0.08	N.D.	0.10	0.89		
Phenanthrene	0.40	0.54	0.30	0.77	0.43	N.D.	0.39	1.27		
Anthracene	0.02	0.04	0.02	0.03	0.03	N.D.	0.02	0.04	100	100
Methylphenanthrenes	0.51	0.80	0.19	0.52	0.50	N.D.	0.36	1.03		
Dimethylphenanthrenes	0.27	1.35	0.20	0.44	0.28	N.D.	0.26	0.82		
Trimethylphenanthrenes	0.14	0.51	0.10	0.20	0.12	N.D.	0.09	0.45		
Fluoranthene	0.12	0.10	0.07	0.28	0.12	0.03	0.10	0.44	6.3	120
Pyrene	0.06	0.06	0.05	0.06	0.05	0.02	0.03	0.15		
Methylpyrenes	0.07	0.05	0.05	0.08	0.04	0.03	0.04	0.23		
Dimethylpyrenes	0.05	N.D.	0.03	0.06	0.03	0.02	0.03	0.16		
Retene	0.03	0.16	N.D.	N.D.	0.03	N.D.	N.D.	N.D.		
Benz[a]anthracene	N.D.	N.D.	0.02	N.D.	N.D.	N.D.	N.D.	0.04		
Chrysene	0.04	0.03	0.03	0.05	0.03	N.D.	0.03	0.08		
Methylchrysenes	0.03	0.03	N.D.	0.03	N.D.	N.D.	N.D.	0.10		
Dimethylchrysenes	0.03	N.D.	0.02	0.03	N.D.	N.D.	N.D.	0.08		
Benzo[b]fluoranthene	0.03	N.D.	0.40	0.03	0.02	N.D.	N.D.	0.06		17
Benzo[k]fluoranthene	N.D.	N.D.	0.17	N.D.	N.D.	N.D.	N.D.	N.D.		17
Benzo[e]pyrene	N.D.	N.D.	N.D.	0.02	N.D.	N.D.	N.D.	0.05		
Benzo[a]pyrene	N.D.	N.D.	0.15	N.D.	N.D.	N.D.	N.D.	0.03	0.17	27
Perylene	N.D.	N.D.	0.09	N.D.	N.D.	N.D.	N.D.	N.D.		
Indeno[1,2,3-cd]pyrene	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	0.02		
Benzo[ghi]perylene	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	0.03		0.82
Dibenz[a,h]anthracene	N.D.	N.D.	0.03	N.D.	N.D.	N.D.	N.D.	N.D.		
ΣPAHs (ng/L)	**8.20**	**4.88**	**6.61**	**13.2**	**18.6**	**0.17**	**5.95**	**26.4**		

ANNEX II

	MUNICIPALITY OF SALAMINA				MUNICIPALITY OF PIRAEUS					
	PERISTERIA				AFRODITE VOE					
DATE	23/04/2018	20/06/2018	17/07/2018	31/08/2018	23/04/2018	20/06/2018	17/07/2018	31/08/2018		
PAHs (ng/L)									**AA (ng/L)**	**MAC (ng/L)**
Naphthalene	2.11	0.83	0.91	2.81	1.67	N.D.	1.14	3.77	2000	130000
Methylnapthalenes	1.83	0.94	0.82	5.95	1.99	N.D.	1.10	5.49		
Acenaphthylene	0.08	0.04	0.04	0.15	0.09	N.D.	0.06	0.23		
Acenaphthene	0.09	0.03	0.05	1.13	0.17	N.D.	0.06	1.58		
Dimethylnapthalenes	1.05	0.56	0.55	4.05	1.59	N.D.	0.83	5.04		
Trimethylnapthalenes	1.03	0.43	0.44	1.70	1.53	N.D.	0.87	4.33		
Fluorene	0.27	0.12	0.19	0.91	0.39	N.D.	0.15	1.07		
Dibenzothiophene	0.04	0.03	0.04	0.16	0.07	N.D.	0.06	0.26		
Methyldibenzothiophenes	0.06	0.03	0.05	0.18	0.12	N.D.	0.13	0.62		
Dimethyldibenzothiophenes	0.07	0.05	0.09	0.24	0.35	N.D.	0.36	1.84		
Phenanthrene	0.38	0.18	0.27	1.05	0.58	N.D.	0.39	1.44		
Anthracene	N.D.	N.D.	N.D.	N.D.	0.04	N.D.	0.04	0.10	100	100
Methylphenanthrenes	0.32	0.14	0.24	0.64	1.01	N.D.	0.63	2.55		
Dimethylphenanthrenes	0.20	0.20	0.19	0.49	1.81	N.D.	1.00	3.78		
Trimethylphenanthrenes	0.10	0.06	0.08	0.24	2.24	N.D.	0.85	4.88		
Fluoranthene	0.11	0.04	0.07	0.40	0.28	0.15	0.22	0.77	6.3	120
Pyrene	0.05	0.02	0.03	0.10	0.24	0.26	0.26	0.82		
Methylpyrenes	0.04	0.03	0.04	0.10	0.36	0.57	0.35	1.68		
Dimethylpyrenes	0.04	N.D.	0.07	0.09	0.45	0.80	0.47	2.34		
Retene	0.02	N.D.	N.D.	N.D.	0.05	N.D.	N.D.	0.09		
Benz[a]anthracene	N.D.	N.D.	0.02	N.D.	0.13	0.04	0.11	0.22		
Chrysene	0.02	N.D.	0.03	0.07	0.16	0.10	0.14	0.55		
Methylchrysenes	N.D.	N.D.	0.05	0.06	0.23	0.16	0.17	1.30		
Dimethylchrysenes	N.D.	N.D.	0.15	0.05	0.32	0.19	0.21	1.82		
Benzo[b]fluoranthene	N.D.	N.D.	0.04	0.06	0.17	0.04	0.19	0.39		17
Benzo[k]fluoranthene	N.D.	N.D.	N.D.	N.D.	0.07	N.D.	0.05	0.10		17
Benzo[e]pyrene	N.D.	N.D.	0.03	0.03	0.10	0.04	0.11	0.40		
Benzo[a]pyrene	N.D.	N.D.	0.02	N.D.	0.11	0.02	0.11	**0.25**	0.17	27
Perylene	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	0.03	0.08		
Indeno[1,2,3-cd]pyrene	N.D.	N.D.	N.D.	N.D.	0.08	N.D.	0.06	0.17		
Benzo[ghi]perylene	N.D.	N.D.	0.02	0.02	0.08	0.03	0.08	0.27		0.82
Dibenz[a,h]anthracene	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	0.02	0.05		
ΣPAHs (ng/L)	**8.03**	**3.86**	**4.59**	**20.7**	**16.5**	**2.47**	**10.3**	**48.3**		

ANNEX II

MUNICIPALITY OF PIRAEUS										
	FREATTYDA				YACHT CLUB OF GREECE					
DATE	23/04/2018	20/06/2018	17/07/2018	31/08/2018	23/04/2018	20/06/2018	17/07/2018	31/08/2018		
PAHs (ng/L)									**AA (ng/L)**	**MAC (ng/L)**
Naphthalene	1.30	N.D.	0.82	4.06	2.12	1.01	0.57	2.29	2000	130000
Methylnapthalenes	1.53	N.D.	1.00	4.63	3.28	1.22	0.81	3.44		
Acenaphthylene	0.07	N.D.	0.07	0.22	0.16	0.05	0.15	0.33		
Acenaphthene	0.08	N.D.	0.04	1.35	0.17	0.11	0.06	0.25		
Dimethylnapthalenes	1.08	N.D.	0.81	3.19	2.78	0.74	1.25	2.09		
Trimethylnapthalenes	1.05	N.D.	0.72	2.20	2.03	0.67	1.45	2.41		
Fluorene	0.20	0.08	0.15	1.03	0.35	0.31	0.23	0.54		
Dibenzothiophene	0.07	0.12	0.05	0.20	0.07	0.08	0.06	0.11		
Methyldibenzothiophenes	0.56	0.42	0.20	0.39	0.12	0.12	0.12	0.22		
Dimethyldibenzothiophenes	1.44	3.49	0.45	0.89	0.30	0.16	0.22	0.45		
Phenanthrene	0.41	0.47	0.34	1.46	0.73	0.37	0.64	1.13		
Anthracene	N.D.	0.18	0.03	0.05	0.03	0.02	0.05	0.06	100	100
Methylphenanthrenes	1.07	4.59	0.55	1.80	1.08	0.69	0.75	2.63		
Dimethylphenanthrenes	1.74	8.58	0.52	1.31	1.70	0.69	0.81	2.07		
Trimethylphenanthrenes	0.69	4.85	0.25	0.82	1.37	0.39	0.40	1.12		
Fluoranthene	0.12	0.13	0.18	0.89	0.29	0.15	0.33	0.50	6.3	120
Pyrene	0.07	0.10	0.13	0.37	0.16	0.09	0.19	0.28		
Methylpyrenes	0.05	0.10	0.12	0.32	0.16	0.12	0.15	0.28		
Dimethylpyrenes	0.08	0.07	0.07	0.25	0.15	0.13	0.12	0.26		
Retene	0.04	0.22	N.D.	N.D.	0.04	N.D.	0.02	N.D.		
Benz[a]anthracene	0.03	0.04	0.09	0.16	0.08	0.07	0.08	0.15		
Chrysene	0.04	0.05	0.08	0.25	0.10	0.06	0.11	0.17		
Methylchrysenes	0.09	0.03	0.06	0.45	0.07	0.09	0.06	0.14		
Dimethylchrysenes	0.10	0.02	0.05	0.13	0.07	0.09	0.06	0.14		
Benzo[b]fluoranthene	0.04	0.04	0.10	0.21	0.12	0.07	0.10	0.19		17
Benzo[k]fluoranthene	N.D.	0.02	0.04	0.06	0.03	0.05	0.03	0.07		17
Benzo[e]pyrene	0.02	0.03	0.05	0.11	0.05	0.04	0.05	0.09		
Benzo[a]pyrene	N.D.	0.02	0.07	0.09	0.04	0.07	0.05	0.10	0.17	27
Perylene	N.D.	N.D.	N.D.	0.02	N.D.	0.04	N.D.	N.D.		
Indeno[1,2,3-cd]pyrene	N.D.	N.D.	0.03	0.05	0.04	N.D.	0.02	N.D.		
Benzo[ghi]perylene	N.D.	N.D.	0.03	0.08	0.03	0.04	0.03	0.06		0.82
Dibenz[a,h]anthracene	N.D.	N.D.	N.D.	N.D.	N.D.	0.02	N.D.	0.04		
ΣPAHs (ng/L)	**12.1**	**23.7**	**7.13**	**27.0**	**17.7**	**7.74**	**9.02**	**21.6**		

ANNEX II

MUNICIPALITY OF PALAIO FALIRO										
	PHLOISBOS				BATIS					
DATE	23/04/2018	20/06/2018	17/07/2018	31/08/2018	23/04/2018	20/06/2018	17/07/2018	31/08/2018		
PAHs (ng/L)									**AA (ng/L)**	**MAC (ng/L)**
Naphthalene	4.14	0.63	1.82	4.52	1.76	0.49	0.92	6.86	2000	130000
Methylnapthalenes	3.73	0.80	1.80	4.10	1.68	0.61	1.00	2.37		
Acenaphthylene	0.13	0.04	0.09	0.46	0.08	0.03	0.08	0.35		
Acenaphthene	0.20	0.04	0.08	1.08	0.11	0.06	0.10	1.48		
Dimethylnapthalenes	2.61	0.59	1.05	3.96	1.15	0.80	1.04	4.46		
Trimethylnapthalenes	3.68	0.77	0.90	5.34	1.05	0.87	1.03	5.92		
Fluorene	0.30	0.08	0.11	0.83	0.36	0.11	0.31	0.98		
Dibenzothiophene	0.07	0.03	0.06	0.53	0.05	0.03	0.09	0.44		
Methyldibenzothiophenes	0.81	0.06	0.07	1.15	0.07	0.05	0.11	1.29		
Dimethyldibenzothiophenes	0.27	0.15	0.09	3.48	0.13	0.08	0.23	4.27		
Phenanthrene	0.74	0.22	0.29	2.79	0.51	0.25	0.86	2.25		
Anthracene	0.03	0.03	N.D.	1.04	0.03	0.03	0.08	0.64	100	100
Methylphenanthrenes	1.73	0.45	0.42	7.16	0.60	0.37	0.97	6.35		
Dimethylphenanthrenes	1.89	0.83	0.34	8.85	0.68	0.46	0.98	10.1		
Trimethylphenanthrenes	1.45	0.46	0.13	12.14	0.23	0.23	0.46	9.82		
Fluoranthene	0.25	0.19	0.12	4.86	0.25	0.15	0.91	3.17	6.3	120
Pyrene	0.21	0.13	0.18	5.87	0.14	0.10	0.61	4.76		
Methylpyrenes	0.43	0.17	0.12	5.01	0.11	0.07	0.36	2.10		
Dimethylpyrenes	0.43	0.15	0.10	8.73	0.11	0.05	0.32	4.01		
Retene	0.03	N.D.	N.D.	0.38	N.D.	N.D.	N.D.	0.32		
Benz[a]anthracene	0.07	0.12	0.06	2.46	0.06	0.06	0.48	2.19		
Chrysene	0.13	0.08	0.04	2.58	0.08	0.05	0.33	2.34		
Methylchrysenes	0.22	0.07	0.06	5.06	0.06	0.03	0.19	3.87		
Dimethylchrysenes	0.24	0.08	0.10	9.34	0.06	0.04	0.14	4.81		
Benzo[b]fluoranthene	0.74	0.06	0.05	1.72	0.06	0.05	0.47	0.96		17
Benzo[k]fluoranthene	0.61	0.03	N.D.	0.50	0.03	0.02	0.31	0.44		17
Benzo[e]pyrene	0.10	0.04	0.03	1.65	0.04	0.03	0.16	1.40		
Benzo[a]pyrene	0.02	0.04	0.06	**1.23**	0.03	0.03	**0.25**	**1.26**	0.17	27
Perylene	N.D.	N.D.	N.D.	0.40	N.D.	N.D.	0.06	0.38		
Indeno[1,2,3-cd]pyrene	N.D.	0.03	N.D.	0.44	0.02	N.D.	0.12	0.54		
Benzo[ghi]perylene	0.02	0.03	0.03	0.84	0.02	N.D.	0.13	0.81		0.82
Dibenz[a,h]anthracene	0.03	N.D.	N.D.	0.24	N.D.	N.D.	0.04	0.22		
ΣPAHs (ng/L)	**25.3**	**6.41**	**8.25**	**108.7**	**9.60**	**5.22**	**13.2**	**91.2**		

ANNEX II

MUNICIPALITY OF PALAIO FALIRO					MUNICIPALITY OF ALIMOS					
	EDEM				AKTI ILIOU					
DATE	23/04/2018	20/06/2018	17/07/2018	31/08/2018	23/04/2018	20/06/2018	17/07/2018	31/08/2018		
PAHs (ng/L)									**AA (ng/L)**	**MAC (ng/L)**
Naphthalene	1.96	N.D.	1.33	12.2	4.22	N.D.	1.24	2.30	2000	130000
Methylnapthalenes	2.01	N.D.	1.20	5.18	6.03	N.D.	1.21	5.03		
Acenaphthylene	0.10	N.D.	0.06	0.29	0.13	N.D.	0.06	0.18		
Acenaphthene	0.16	N.D.	0.04	1.83	0.30	N.D.	0.05	0.34		
Dimethylnapthalenes	1.83	N.D.	0.67	4.88	1.97	N.D.	0.68	3.57		
Trimethylnapthalenes	1.74	N.D.	0.41	6.17	6.56	N.D.	0.42	6.42		
Fluorene	0.35	0.03	0.12	1.40	0.32	N.D.	0.09	0.40		
Dibenzothiophene	0.13	0.04	0.03	0.51	0.10	0.02	0.05	0.11		
Methyldibenzothiophenes	0.21	1.25	0.03	1.81	1.11	0.05	0.04	0.78		
Dimethyldibenzothiophenes	0.57	5.78	0.06	7.73	0.92	0.13	0.06	0.62		
Phenanthrene	1.26	0.52	0.22	4.11	0.74	0.19	0.23	0.64		
Anthracene	0.11	0.15	N.D.	0.54	N.D.	N.D.	N.D.	N.D.	100	100
Methylphenanthrenes	1.29	6.95	0.17	6.32	0.58	0.34	0.26	0.76		
Dimethylphenanthrenes	2.13	18.66	0.17	11.3	0.92	0.49	0.20	1.04		
Trimethylphenanthrenes	1.92	9.76	0.07	13.0	1.38	0.31	0.07	1.14		
Fluoranthene	0.95	0.18	0.09	4.62	0.22	0.11	0.08	0.27	6.3	120
Pyrene	0.71	0.16	0.04	3.71	0.14	0.07	0.06	0.17		
Methylpyrenes	0.90	0.19	0.04	3.70	0.36	0.09	0.07	0.34		
Dimethylpyrenes	1.19	0.13	0.04	4.04	0.71	0.10	0.05	0.56		
Retene	0.25	0.38	N.D.	0.30	0.05	N.D.	N.D.	0.10		
Benz[a]anthracene	0.38	0.05	0.03	2.20	0.09	0.05	0.05	0.12		
Chrysene	0.39	0.06	0.03	2.40	0.14	0.05	0.03	0.14		
Methylchrysenes	0.55	0.07	0.02	3.59	0.41	0.05	0.02	0.31		
Dimethylchrysenes	0.85	0.09	0.04	5.26	0.69	0.10	0.03	0.53		
Benzo[b]fluoranthene	0.31	0.03	0.03	2.01	0.14	0.05	0.05	0.16		17
Benzo[k]fluoranthene	0.09	N.D.	N.D.	0.69	N.D.	0.02	N.D.	N.D.		17
Benzo[e]pyrene	0.28	0.03	0.02	1.34	0.13	0.03	0.02	0.12		
Benzo[a]pyrene	0.22	N.D.	0.03	1.44	0.03	0.03	0.03	0.06	0.17	27
Perylene	0.07	N.D.	N.D.	0.40	N.D.	N.D.	N.D.	N.D.		
Indeno[1,2,3-cd]pyrene	0.08	N.D.	N.D.	0.70	0.03	N.D.	N.D.	N.D.		
Benzo[ghi]perylene	0.20	N.D.	N.D.	0.89	0.05	N.D.	N.D.	0.10		0.82
Dibenz[a,h]anthracene	0.04	N.D.	N.D.	0.23	0.06	N.D.	N.D.	0.12		
ΣPAHs (ng/L)	**23.2**	**44.6**	**5.07**	**114.7**	**28.6**	**2.39**	**5.23**	**26.4**		

ANNEX II

	MUNICIPALITY OF ALIMOS				MUNICIPALITY OF ELLINIKO-ARGYROUPOLI					
	YACHT CLUB OF ALIMOS				AGIOS KOSMAS					
DATE	**23/04/2018**	**20/06/2018**	**17/07/2018**	**31/08/2018**	**23/04/2018**	**20/06/2018**	**17/07/2018**	**31/08/2018**		
PAHs (ng/L)									**AA (ng/L)**	**MAC (ng/L)**
Naphthalene	4.79	0.28	1.34	3.01	0.35	N.D.	0.55	4.67	2000	130000
Methylnapthalenes	5.19	0.62	1.40	2.14	0.48	N.D.	1.00	3.76		
Acenaphthylene	0.19	0.10	0.06	0.09	N.D.	N.D.	0.10	0.14		
Acenaphthene	0.43	0.06	0.05	0.10	0.03	N.D.	0.09	0.60		
Dimethylnapthalenes	2.82	1.11	0.87	1.31	0.46	N.D.	2.01	4.91		
Trimethylnapthalenes	1.79	1.48	0.65	1.22	0.44	N.D.	2.45	6.50		
Fluorene	0.64	0.10	0.12	0.24	0.05	0.02	0.21	0.54		
Dibenzothiophene	0.31	0.06	0.04	0.13	N.D.	0.05	0.11	0.40		
Methyldibenzothiophenes	1.82	0.28	0.03	0.77	0.06	0.41	0.34	0.94		
Dimethyldibenzothiophenes	1.99	1.01	0.08	1.01	0.24	1.89	0.82	1.93		
Phenanthrene	4.95	0.23	0.30	1.82	0.09	0.35	0.52	1.39		
Anthracene	0.67	0.07	N.D.	0.13	N.D.	0.08	0.06	0.14	100	100
Methylphenanthrenes	5.17	1.69	0.28	2.44	0.34	2.74	1.87	3.03		
Dimethylphenanthrenes	7.07	1.21	0.27	2.18	1.00	7.55	2.88	4.66		
Trimethylphenanthrenes	5.69	1.02	0.15	1.15	0.87	7.26	1.84	4.65		
Fluoranthene	5.40	0.17	0.10	1.68	0.04	0.16	0.31	1.51	6.3	120
Pyrene	4.62	0.19	0.07	1.42	0.05	0.22	0.30	1.40		
Methylpyrenes	1.00	0.48	0.11	N.D.	0.20	0.64	0.57	1.95		
Dimethylpyrenes	3.50	0.72	0.23	1.40	0.33	1.11	0.67	2.54		
Retene	0.50	N.D.	N.D.	N.D.	N.D.	0.11	0.03	0.09		
Benz[a]anthracene	3.91	0.14	0.07	1.29	0.03	0.09	0.29	0.61		
Chrysene	2.88	0.20	0.05	0.98	0.07	0.27	0.24	1.18		
Methylchrysenes	6.32	0.31	0.12	2.12	0.14	0.46	0.31	1.38		
Dimethylchrysenes	5.77	0.42	0.33	2.05	0.19	0.68	0.35	1.68		
Benzo[b]fluoranthene	2.67	0.15	0.07	0.91	0.03	0.14	0.26	1.25		17
Benzo[k]fluoranthene	1.16	0.06	N.D.	N.D.	N.D.	0.03	0.09	0.36		17
Benzo[e]pyrene	1.74	0.10	0.13	N.D.	0.03	0.14	0.11	0.78		
Benzo[a]pyrene	**2.33**	0.06	0.03	0.16	N.D.	0.07	0.04	**0.53**	0.17	27
Perylene	0.56	0.02	N.D.	0.27	N.D.	0.02	0.02	0.16		
Indeno[1,2,3-cd]pyrene	0.89	0.07	0.05	N.D.	N.D.	0.05	0.09	0.30		
Benzo[ghi]perylene	1.31	N.D.	0.15	N.D.	N.D.	0.07	0.08	0.30		0.82
Dibenz[a,h]anthracene	0.59	0.04	0.03	0.21	N.D.	0.03	0.04	0.07		
ΣPAHs (ng/L)	**88.7**	**12.4**	**7.24**	**30.2**	**5.63**	**24.6**	**18.6**	**54.3**		

ANNEX II

MUNICIPALITY OF ELLINIKO-ARGYROUPOLI										
	H.C.M.R. FACILITIES				AIGYPTIOTES NAVAL CLUB					
DATE	23/04/2018	20/06/2018	17/07/2018	31/08/2018	23/04/2018	20/06/2018	17/07/2018	31/08/2018		
PAHs (ng/L)									AA (ng/L)	MAC (ng/L)
Naphthalene	2.30	N.D.	0.70	3.67	3.36	N.D.	0.28	4.53	2000	130000
Methylnapthalenes	2.52	N.D.	0.88	2.31	4.28	N.D.	0.48	3.44		
Acenaphthylene	0.11	N.D.	0.10	0.25	0.15	N.D.	0.03	0.14		
Acenaphthene	0.16	N.D.	0.09	0.68	0.37	N.D.	0.06	0.53		
Dimethylnapthalenes	2.31	N.D.	0.77	2.71	4.42	N.D.	0.92	4.03		
Trimethylnapthalenes	2.23	N.D.	0.82	3.49	5.19	N.D.	1.57	7.13		
Fluorene	0.40	0.07	0.20	0.54	0.37	0.12	0.12	0.46		
Dibenzothiophene	0.11	0.03	0.08	0.29	0.14	0.11	0.09	0.48		
Methyldibenzothiophenes	0.39	0.17	0.10	0.87	0.79	2.45	0.22	1.34		
Dimethyldibenzothiophenes	1.16	0.95	0.19	2.44	0.87	6.18	0.50	5.06		
Phenanthrene	0.64	0.16	0.38	1.77	0.61	0.78	0.22	1.08		
Anthracene	0.05	0.03	0.04	0.47	0.04	0.66	0.04	0.16	100	100
Methylphenanthrenes	1.68	0.59	0.74	4.41	1.21	2.02	0.75	3.88		
Dimethylphenanthrenes	3.49	3.03	1.07	5.58	3.10	6.70	1.72	9.49		
Trimethylphenanthrenes	3.32	2.84	0.73	6.03	2.65	6.23	1.26	9.86		
Fluoranthene	0.18	0.08	0.22	4.47	0.23	0.10	0.11	1.24	6.3	120
Pyrene	0.28	0.11	0.23	4.31	0.29	0.20	0.16	1.67		
Methylpyrenes	0.94	0.32	0.33	2.53	0.81	0.72	0.39	3.71		
Dimethylpyrenes	1.21	0.41	0.38	3.71	1.10	0.97	0.50	4.24		
Retene	0.04	0.02	0.05	0.35	0.06	1.06	N.D.	0.20		
Benz[a]anthracene	0.09	0.04	0.12	1.52	0.11	0.06	0.10	0.43		
Chrysene	0.35	0.13	0.13	1.52	0.34	0.24	0.15	1.11		
Methylchrysenes	0.59	0.18	0.14	2.84	0.59	0.34	0.24	2.36		
Dimethylchrysenes	0.68	0.19	0.17	4.15	0.75	0.34	0.30	3.12		
Benzo[b]fluoranthene	0.07	0.04	0.13	0.93	0.14	0.04	0.05	0.26		17
Benzo[k]fluoranthene	N.D.	N.D.	0.05	0.33	0.41	N.D.	N.D.	0.40		17
Benzo[e]pyrene	0.11	0.04	0.08	1.05	0.15	0.07	0.06	0.45		
Benzo[a]pyrene	0.03	0.02	0.08	**0.68**	0.06	N.D.	N.D.	0.16	0.17	27
Perylene	N.D.	N.D.	0.05	0.27	0.03	N.D.	N.D.	0.06		
Indeno[1,2,3-cd]pyrene	0.02	N.D.	0.07	0.35	0.05	N.D.	N.D.	0.07		
Benzo[ghi]perylene	0.03	0.03	0.05	0.82	0.06	0.03	0.03	0.15		0.82
Dibenz[a,h]anthracene	N.D.	N.D.	0.03	0.18	0.03	N.D.	N.D.	0.04		
ΣPAHs (ng/L)	**25.5**	**9.52**	**9.20**	**65.5**	**32.8**	**29.1**	**10.4**	**71.3**		

ANNEX II

MUNICIPALITY OF GLYFADA										
	GLYFADA 1				**GLYFADA 2**					
DATE	**23/04/2018**	**20/06/2018**	**17/07/2018**	**31/08/2018**	**23/04/2018**	**20/06/2018**	**17/07/2018**	**31/08/2018**		
PAHs (ng/L)									**AA (ng/L)**	**MAC (ng/L)**
Naphthalene	2.04	0.82	0.65	1.32	2.48	1.31	0.42	3.59	2000	130000
Methylnapthalenes	2.62	0.72	0.36	1.16	2.04	1.34	0.45	3.76		
Acenaphthylene	0.08	0.15	0.09	0.10	0.10	0.06	0.17	0.12		
Acenaphthene	0.10	0.09	0.23	0.13	0.10	0.05	0.08	0.57		
Dimethylnapthalenes	1.17	0.63	0.57	0.64	1.28	0.85	1.42	2.60		
Trimethylnapthalenes	1.34	0.51	0.28	0.57	1.00	0.78	2.33	1.64		
Fluorene	0.19	0.18	0.38	0.22	0.26	0.25	0.27	0.53		
Dibenzothiophene	0.04	0.12	0.07	0.07	0.04	0.06	0.07	0.13		
Methyldibenzothiophenes	0.21	0.14	0.11	0.14	0.07	0.11	0.19	0.19		
Dimethyldibenzothiophenes	0.15	0.33	0.18	0.31	0.14	0.23	0.52	0.38		
Phenanthrene	0.83	0.43	0.16	0.45	0.47	0.48	0.60	1.06		
Anthracene	N.D.	0.05	0.04	0.04	0.03	0.05	0.07	0.06	100	100
Methylphenanthrenes	0.24	1.01	0.71	0.58	0.38	1.09	1.75	0.68		
Dimethylphenanthrenes	0.27	0.74	1.08	0.66	0.51	1.15	3.29	1.05		
Trimethylphenanthrenes	0.16	0.58	1.21	0.61	0.32	0.62	2.78	0.66		
Fluoranthene	0.10	0.25	0.27	0.19	0.22	0.27	0.27	0.98	6.3	120
Pyrene	0.06	0.27	0.23	0.18	0.12	0.20	0.39	0.62		
Methylpyrenes	0.05	0.55	0.08	0.21	0.14	0.18	0.70	0.42		
Dimethylpyrenes	0.06	0.61	0.06	0.23	0.16	0.16	0.83	0.34		
Retene	N.D.	N.D.	0.05	N.D.	N.D.	N.D.	0.05	N.D.		
Benz[a]anthracene	N.D.	0.15	0.13	0.13	0.05	0.06	0.07	0.21		
Chrysene	0.03	0.17	0.16	0.11	0.11	0.08	0.28	0.35		
Methylchrysenes	0.02	0.17	0.06	0.08	0.08	0.06	0.28	0.21		
Dimethylchrysenes	N.D.	0.19	0.09	0.13	0.09	0.06	0.24	0.16		
Benzo[b]fluoranthene	N.D.	0.14	N.D.	0.13	0.05	0.04	0.08	0.25		17
Benzo[k]fluoranthene	N.D.	0.05	N.D.	N.D.	0.03	N.D.	N.D.	0.07		17
Benzo[e]pyrene	N.D.	0.09	0.10	N.D.	0.04	0.03	0.10	0.15		
Benzo[a]pyrene	N.D.	0.06	0.11	N.D.	0.03	N.D.	0.02	0.11	0.17	27
Perylene	N.D.	N.D.	0.06	N.D.	N.D.	N.D.	N.D.	0.03		
Indeno[1,2,3-cd]pyrene	N.D.	0.08	0.08	N.D.	N.D.	N.D.	N.D.	0.06		
Benzo[ghi]perylene	N.D.	N.D.	N.D.	N.D.	0.02	N.D.	0.03	0.07		0.82
Dibenz[a,h]anthracene	N.D.	0.02	N.D.	0.02	N.D.	N.D.	N.D.	N.D.		
ΣPAHs (ng/L)	**9.87**	**9.29**	**7.59**	**8.42**	**10.4**	**9.66**	**17.8**	**21.0**		

ANNEX II

MUNICIPALITY OF GLYFADA										
	GLYFADA 3				GLYFADA 4					
DATE	23/04/2018	20/06/2018	17/07/2018	31/08/2018	23/04/2018	20/06/2018	17/07/2018	31/08/2018		
PAHs (ng/L)									**AA (ng/L)**	**MAC (ng/L)**
Naphthalene	1.63	N.D.	0.41	0.85	6.50	1.59	0.74	2.88	2000	130000
Methylnapthalenes	1.41	N.D.	0.66	0.82	6.49	1.73	1.08	3.70		
Acenaphthylene	0.06	0.11	0.08	0.08	0.90	0.13	0.09	0.58		
Acenaphthene	0.06	0.76	0.04	0.31	0.18	0.15	0.06	0.36		
Dimethylnapthalenes	0.95	4.86	0.69	1.02	3.67	1.73	1.15	4.57		
Trimethylnapthalenes	0.71	10.2	0.51	2.34	3.39	3.27	1.26	8.30		
Fluorene	0.18	0.24	0.11	0.16	0.44	0.33	0.15	0.50		
Dibenzothiophene	0.03	0.10	0.03	0.05	0.07	0.16	0.06	0.27		
Methyldibenzothiophenes	0.06	0.54	0.07	0.21	0.26	0.43	0.16	1.35		
Dimethyldibenzothiophenes	0.16	0.45	0.17	0.24	0.77	1.34	0.75	7.69		
Phenanthrene	0.38	0.55	0.36	0.40	0.99	0.67	0.45	1.79		
Anthracene	0.03	0.05	0.03	N.D.	0.08	0.11	0.05	0.31	100	100
Methylphenanthrenes	0.35	0.55	0.38	0.40	1.81	2.26	1.42	7.82		
Dimethylphenanthrenes	0.51	1.13	0.52	0.67	2.86	6.40	32.5	26.9		
Trimethylphenanthrenes	0.33	0.80	0.37	0.47	2.02	4.40	63.6	43.5		
Fluoranthene	0.20	0.31	0.28	0.25	0.31	0.55	0.33	1.11	6.3	120
Pyrene	0.14	0.22	0.20	0.17	0.31	0.62	0.35	1.53		
Methylpyrenes	0.21	0.24	0.17	0.19	0.51	0.99	0.83	4.69		
Dimethylpyrenes	0.17	0.23	0.13	0.16	0.64	1.15	0.79	6.75		
Retene	N.D.	0.02	N.D.	N.D.	0.06	0.08	1.51	1.16		
Benz[a]anthracene	0.05	0.12	0.12	0.09	0.05	0.31	0.23	0.61		
Chrysene	0.10	0.12	0.12	0.11	0.22	0.42	0.67	2.28		
Methylchrysenes	0.11	0.10	0.09	0.09	0.27	0.46	0.22	4.81		
Dimethylchrysenes	0.11	0.10	0.08	0.09	0.25	0.46	0.67	7.37		
Benzo[b]fluoranthene	0.06	N.D.	0.10	0.07	0.08	0.27	0.22	0.70		17
Benzo[k]fluoranthene	0.02	N.D.	0.04	N.D.	N.D.	0.10	0.04	1.64		17
Benzo[e]pyrene	0.05	0.05	0.06	0.05	0.09	0.17	0.05	0.71		
Benzo[a]pyrene	0.02	0.05	0.03	N.D.	0.02	0.17	0.05	**0.35**	0.17	27
Perylene	N.D.	N.D.	N.D.	N.D.	N.D.	0.04	N.D.	0.07		
Indeno[1,2,3-cd]pyrene	0.02	0.03	0.03	N.D.	0.02	0.13	0.03	0.49		
Benzo[ghi]perylene	0.02	0.03	0.03	N.D.	0.03	0.11	0.04	0.39		0.82
Dibenz[a,h]anthracene	N.D.	N.D.	N.D.	N.D.	N.D.	0.04	N.D.	0.13		
ΣPAHs (ng/L)	**8.18**	**22.0**	**5.94**	**9.30**	**33.3**	**30.8**	**109.6**	**145.3**		

ANNEX II

MUNICIPALITY OF GLYFADA										
	GLYFADA 5				ASTERAS GLYFADAS					
DATE	23/04/2018	20/06/2018	17/07/2018	31/08/2018	23/04/2018	20/06/2018	17/07/2018	31/08/2018		
PAHs (ng/L)									AA (ng/L)	MAC (ng/L)
Naphthalene	1.73	2.04	0.79	2.43	2.28	N.D.	0.37	1.24	2000	130000
Methylnapthalenes	1.70	1.86	0.99	3.48	3.25	N.D.	0.44	2.15		
Acenaphthylene	0.11	0.11	0.12	0.29	0.14	0.19	0.07	0.82		
Acenaphthene	0.09	0.10	0.07	0.27	0.42	0.24	0.17	0.93		
Dimethylnapthalenes	1.39	1.36	1.08	3.67	7.12	3.27	2.66	14.8		
Trimethylnapthalenes	2.86	1.71	1.13	3.65	10.4	18.5	4.87	31.0		
Fluorene	0.18	0.23	0.19	0.51	0.79	0.08	0.34	1.21		
Dibenzothiophene	0.04	0.08	0.06	0.19	0.52	0.16	0.21	1.52		
Methyldibenzothiophenes	0.15	0.16	0.12	0.58	2.62	1.01	0.79	5.09		
Dimethyldibenzothiophenes	0.44	0.36	0.23	2.23	5.72	4.59	1.64	14.2		
Phenanthrene	0.41	0.56	0.44	1.52	2.82	0.68	0.86	3.70		
Anthracene	0.03	0.06	0.05	0.16	0.22	0.06	0.06	1.10	100	100
Methylphenanthrenes	0.87	1.31	0.85	3.14	15.8	5.38	3.37	20.0		
Dimethylphenanthrenes	1.61	2.00	0.84	5.69	27.8	21.0	5.28	37.9		
Trimethylphenanthrenes	1.33	1.20	0.56	6.42	13.9	25.4	3.39	31.0		
Fluoranthene	0.18	0.28	0.22	1.52	0.71	0.46	0.33	5.76	6.3	120
Pyrene	0.18	0.27	0.20	1.44	1.09	0.72	0.29	6.49		
Methylpyrenes	0.32	0.29	0.20	1.79	3.44	2.91	0.88	6.38		
Dimethylpyrenes	0.36	0.32	0.17	3.06	4.56	5.01	1.20	3.61		
Retene	0.03	0.05	0.10	0.11	0.17	0.41	0.08	0.54		
Benz[a]anthracene	0.03	0.04	0.03	0.37	0.69	0.94	0.12	9.82		
Chrysene	0.16	0.10	0.07	0.84	1.38	1.05	0.31	8.34		
Methylchrysenes	0.21	0.09	0.06	1.76	2.36	3.27	0.49	9.41		
Dimethylchrysenes	0.23	0.11	0.06	2.46	3.68	5.08	0.87	6.66		
Benzo[b]fluoranthene	0.06	0.03	0.03	0.34	0.57	0.61	0.17	8.47		17
Benzo[k]fluoranthene	N.D.	N.D.	N.D.	0.09	0.14	0.18	0.05	2.93		17
Benzo[e]pyrene	0.07	0.03	0.03	0.59	0.62	0.62	0.21	4.23		
Benzo[a]pyrene	N.D.	N.D.	N.D.	0.16	**0.56**	**0.77**	0.12	**1.41**	0.17	27
Perylene	N.D.	N.D.	N.D.	0.15	0.15	0.14	0.03	1.83		
Indeno[1,2,3-cd]pyrene	N.D.	N.D.	N.D.	0.12	0.25	0.39	0.05	3.64		
Benzo[ghi]perylene	0.02	N.D.	N.D.	0.32	0.33	0.60	0.12	2.91		0.82
Dibenz[a,h]anthracene	N.D.	N.D.	N.D.	0.09	0.12	0.22	0.04	0.81		
ΣPAHs (ng/L)	**14.8**	**14.8**	**8.73**	**49.5**	**114.7**	**103.9**	**29.9**	**251.8**		

ANNEX II

MUNICIPALITY OF VARI-VOULA-VOULIAGMENI										
	ASKLIPIEIO VOULAS				VOULA CITY HALL					
DATE	23/04/2018	20/06/2018	17/07/2018	31/08/2018	23/04/2018	20/06/2018	17/07/2018	31/08/2018		
PAHs (ng/L)									**AA (ng/L)**	**MAC (ng/L)**
Naphthalene	6.66	N.D.	1.45	2.24	1.58	0.73	2.06	1.71	2000	130000
Methylnapthalenes	6.23	N.D.	1.41	2.47	1.58	0.66	1.97	2.12		
Acenaphthylene	0.49	2.37	0.11	0.15	0.07	0.04	0.11	0.15		
Acenaphthene	0.12	2.14	0.05	0.10	0.20	0.03	0.09	0.11		
Dimethylnapthalenes	3.54	5.85	0.98	1.56	1.26	0.37	1.16	1.40		
Trimethylnapthalenes	2.30	8.47	1.10	1.08	2.60	0.41	0.71	1.22		
Fluorene	0.38	N.D.	0.08	0.14	0.33	0.07	0.13	0.16		
Dibenzothiophene	0.06	0.04	0.08	0.15	0.10	0.03	0.08	0.10		
Methyldibenzothiophenes	0.09	0.07	0.10	0.09	0.27	0.02	0.12	0.06		
Dimethyldibenzothiophenes	0.15	0.18	0.17	0.12	0.37	0.08	0.23	0.26		
Phenanthrene	0.91	0.22	0.24	0.49	1.35	0.20	0.32	0.65		
Anthracene	0.09	N.D.	0.02	0.04	0.04	N.D.	N.D.	0.05	100	100
Methylphenanthrenes	1.30	0.46	0.50	0.77	1.04	0.20	0.38	0.80		
Dimethylphenanthrenes	1.61	0.77	0.76	0.56	0.63	0.25	0.39	0.87		
Trimethylphenanthrenes	0.74	0.37	0.43	0.31	0.35	0.10	0.15	0.59		
Fluoranthene	0.29	0.08	0.25	0.30	0.27	0.13	0.19	0.43	6.3	120
Pyrene	0.22	0.03	0.26	0.28	0.13	0.08	0.14	0.34		
Methylpyrenes	0.31	0.04	0.29	0.30	0.09	0.05	0.18	0.29		
Dimethylpyrenes	0.24	0.03	0.27	0.24	0.07	0.03	0.25	0.28		
Retene	N.D.	0.02	N.D.	N.D.	0.06	N.D.	N.D.	N.D.		
Benz[a]anthracene	0.09	N.D.	0.26	0.08	0.03	0.03	0.13	0.09		
Chrysene	0.11	0.03	0.12	0.14	0.06	0.04	0.06	0.15		
Methylchrysenes	0.12	N.D.	0.11	0.18	0.06	N.D.	0.09	0.17		
Dimethylchrysenes	0.08	0.02	0.16	0.44	0.03	N.D.	0.19	0.51		
Benzo[b]fluoranthene	0.08	N.D.	0.20	0.15	0.04	0.03	0.08	0.15		17
Benzo[k]fluoranthene	0.02	N.D.	0.05	0.04	N.D.	0.02	N.D.	0.03		17
Benzo[e]pyrene	0.06	N.D.	0.09	0.08	0.02	0.02	0.06	0.10		
Benzo[a]pyrene	N.D.	N.D.	0.05	0.06	N.D.	N.D.	0.03	0.06	0.17	27
Perylene	N.D.	N.D.	0.02	N.D.	N.D.	N.D.	N.D.	N.D.		
Indeno[1,2,3-cd]pyrene	0.03	N.D.	0.10	0.05	N.D.	N.D.	0.03	0.03		
Benzo[ghi]perylene	0.05	N.D.	0.08	0.07	N.D.	N.D.	0.05	0.06		0.82
Dibenz[a,h]anthracene	N.D.	N.D.	0.02	N.D.	N.D.	N.D.	0.02	N.D.		
ΣPAHs (ng/L)	**26.4**	**31.3**	**9.82**	**12.7**	**12.7**	**3.70**	**9.47**	**12.9**		

ANNEX II

MUNICIPALITY OF VARI-VOULA-VOULIAGMENI										
	MEGALO KAVOURI				VOULIAGMENI NAUTICAL CLUB					
DATE	23/04/2018	20/06/2018	17/07/2018	31/08/2018	23/04/2018	20/06/2018	17/07/2018	31/08/2018		
PAHs (ng/L)									AA (ng/L)	MAC (ng/L)
Naphthalene	3.17	1.01	1.47	1.36	5.81	4.59	1.47	0.98	2000	130000
Methylnapthalenes	3.82	1.04	1.24	1.73	4.51	10.9	1.16	1.28		
Acenaphthylene	0.06	0.04	0.11	0.14	0.79	0.09	0.04	0.10		
Acenaphthene	0.20	0.05	0.05	0.08	0.21	0.05	0.05	0.07		
Dimethylnapthalenes	1.75	0.70	0.76	1.49	2.29	0.59	0.62	0.87		
Trimethylnapthalenes	3.22	0.55	0.65	1.18	3.51	0.60	0.47	0.69		
Fluorene	0.23	0.13	0.06	0.16	0.34	0.14	0.28	0.15		
Dibenzothiophene	0.08	0.03	0.09	0.12	0.06	0.18	0.04	0.13		
Methyldibenzothiophenes	0.70	0.07	0.08	0.07	0.83	0.03	0.03	0.41		
Dimethyldibenzothiophenes	0.47	0.17	0.12	0.20	0.43	0.07	0.05	0.38		
Phenanthrene	0.50	0.32	0.15	0.46	0.81	0.21	0.21	0.43		
Anthracene	N.D.	N.D.	N.D.	0.03	N.D.	N.D.	N.D.	0.02	100	100
Methylphenanthrenes	0.47	0.56	0.24	0.61	0.49	0.28	0.10	0.56		
Dimethylphenanthrenes	0.84	1.04	0.37	0.69	0.48	0.48	0.17	0.60		
Trimethylphenanthrenes	0.67	0.56	0.30	0.44	0.27	0.09	0.09	0.39		
Fluoranthene	0.22	0.18	0.18	0.30	0.24	0.12	0.12	0.23	6.3	120
Pyrene	0.14	0.12	0.17	0.25	0.10	0.05	0.08	0.16		
Methylpyrenes	0.20	0.15	0.25	0.28	0.07	0.05	0.05	0.17		
Dimethylpyrenes	0.24	0.18	0.28	0.27	0.06	0.07	0.04	0.14		
Retene	0.02	0.10	N.D.	N.D.	0.04	N.D.	N.D.	N.D.		
Benz[a]anthracene	0.06	0.07	0.06	0.07	0.02	0.03	0.05	0.05		
Chrysene	0.11	0.09	0.09	0.14	0.04	0.03	0.05	0.10		
Methylchrysenes	0.15	0.12	0.12	0.19	0.02	0.02	0.03	0.12		
Dimethylchrysenes	0.16	0.17	0.18	0.39	0.03	0.06	0.06	0.14		
Benzo[b]fluoranthene	0.07	0.09	0.10	0.14	N.D.	0.08	0.08	0.09		17
Benzo[k]fluoranthene	N.D.	0.03	N.D.	0.05	N.D.	0.03	0.03	0.03		17
Benzo[e]pyrene	0.09	0.06	0.06	0.08	0.04	0.02	0.04	0.06		
Benzo[a]pyrene	0.03	0.04	0.03	0.05	N.D.	N.D.	0.03	0.03	0.17	27
Perylene	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.		
Indeno[1,2,3-cd]pyrene	0.03	0.03	0.02	0.05	0.02	0.02	0.03	0.03		
Benzo[ghi]perylene	0.03	0.04	0.03	0.07	0.02	0.04	0.03	0.04		0.82
Dibenz[a,h]anthracene	0.03	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.		
ΣPAHs (ng/L)	**17.8**	**7.79**	**7.32**	**11.1**	**21.6**	**19.0**	**5.53**	**8.44**		

ANNEX II

MUNICIPALITY OF VARI-VOULA-VOULIAGMENI										
	VOULIAGMENI BEACH CLUB				LIMANAKIA					
DATE	23/04/2018	20/06/2018	17/07/2018	31/08/2018	23/04/2018	20/06/2018	17/07/2018	31/08/2018		
PAHs (ng/L)									AA (ng/L)	MAC (ng/L)
Naphthalene	2.51	N.D.	2.08	1.48	2.65	0.35	0.85	1.33	2000	130000
Methylnapthalenes	2.33	N.D.	1.74	1.86	2.36	0.08	1.03	1.68		
Acenaphthylene	0.15	N.D.	0.09	0.17	0.05	0.12	0.04	0.13		
Acenaphthene	0.10	N.D.	0.09	0.08	0.17	0.10	0.09	0.09		
Dimethylnapthalenes	1.21	N.D.	0.91	1.21	1.15	0.12	0.62	1.24		
Trimethylnapthalenes	1.57	N.D.	0.62	0.90	3.13	0.21	0.57	1.10		
Fluorene	0.26	0.02	0.13	0.18	0.22	0.14	0.26	0.17		
Dibenzothiophene	0.05	2.16	0.08	0.10	0.09	0.18	0.06	0.08		
Methyldibenzothiophenes	0.16	0.07	0.06	0.05	0.75	0.10	0.10	0.20		
Dimethyldibenzothiophenes	0.11	0.42	0.09	0.21	0.55	0.21	0.13	0.17		
Phenanthrene	0.45	0.22	0.30	0.53	0.50	0.33	0.31	0.49		
Anthracene	0.03	0.05	0.03	0.04	N.D.	0.04	0.03	0.03	100	100
Methylphenanthrenes	0.24	0.87	0.27	0.63	0.44	0.47	0.58	0.52		
Dimethylphenanthrenes	0.23	1.39	0.29	0.66	0.35	0.65	0.58	0.45		
Trimethylphenanthrenes	0.07	0.48	0.14	0.40	0.18	0.24	0.32	0.29		
Fluoranthene	0.14	0.06	0.24	0.30	0.15	0.15	0.12	0.24	6.3	120
Pyrene	0.05	0.03	0.13	0.24	0.06	0.07	0.08	0.18		
Methylpyrenes	0.04	0.04	0.11	0.23	0.04	N.D.	0.10	0.18		
Dimethylpyrenes	0.04	N.D.	0.09	0.20	0.07	N.D.	0.11	0.14		
Retene	N.D.	N.D.	N.D.	N.D.	0.06	N.D.	0.03	0.02		
Benz[a]anthracene	N.D.	N.D.	0.08	0.07	N.D.	0.08	0.06	0.05		
Chrysene	0.03	N.D.	0.08	0.12	0.02	0.06	0.05	0.09		
Methylchrysenes	N.D.	N.D.	0.08	0.15	N.D.	0.08	0.07	0.08		
Dimethylchrysenes	0.02	N.D.	0.19	0.61	0.02	0.11	0.08	0.10		
Benzo[b]fluoranthene	N.D.	N.D.	0.09	0.10	0.04	0.09	0.06	0.11		17
Benzo[k]fluoranthene	N.D.	N.D.	0.04	0.08	N.D.	0.04	0.04	0.02		17
Benzo[e]pyrene	0.03	N.D.	0.05	0.07	0.07	0.04	0.03	0.07		
Benzo[a]pyrene	N.D.	N.D.	0.08	0.04	N.D.	0.08	0.06	0.04	0.17	27
Perylene	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.		
Indeno[1,2,3-cd]pyrene	N.D.	N.D.	0.04	0.04	N.D.	0.04	N.D.	0.02		
Benzo[ghi]perylene	N.D.	N.D.	0.05	0.05	N.D.	0.05	N.D.	0.05		0.82
Dibenz[a,h]anthracene	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.		
ΣPAHs (ng/L)	**9.91**	**5.95**	**8.30**	**10.8**	**13.2**	**4.24**	**6.47**	**9.37**		

ANNEX II

MUNICIPALITY OF VARI-VOULA-VOULIAGMENI					MUNICIPALITY OF KROPIA					
	VARKIZA NAVAL ATHLETIC CLUB				LOUBARDAS					
DATE	23/04/2018	20/06/2018	17/07/2018	31/08/2018	23/04/2018	20/06/2018	17/07/2018	31/08/2018		
PAHs (ng/L)									AA (ng/L)	MAC (ng/L)
Naphthalene	1.29	0.91	0.86	3.27	1.91	0.92	1.08	2.17	2000	130000
Methylnapthalenes	1.16	0.85	1.11	3.17	1.47	0.71	0.86	2.31		
Acenaphthylene	0.05	0.02	0.06	0.16	0.07	0.03	0.04	0.15		
Acenaphthene	0.07	0.03	0.07	0.12	0.05	0.03	0.03	0.10		
Dimethylnapthalenes	0.90	0.47	0.88	1.40	0.62	0.35	0.49	1.42		
Trimethylnapthalenes	0.84	0.34	0.86	1.39	0.54	0.32	0.27	1.08		
Fluorene	0.21	0.08	0.20	0.25	0.16	0.14	0.18	0.24		
Dibenzothiophene	0.11	N.D.	0.05	0.07	0.04	0.61	0.11	0.11		
Methyldibenzothiophenes	0.41	0.03	0.07	0.45	0.03	0.03	0.65	0.33		
Dimethyldibenzothiophenes	0.99	0.05	0.09	0.23	0.06	0.05	1.56	0.22		
Phenanthrene	0.52	0.14	0.44	0.55	0.34	0.17	0.31	0.53		
Anthracene	N.D.	N.D.	N.D.	0.04	N.D.	N.D.	0.02	0.04	100	100
Methylphenanthrenes	0.69	0.15	0.23	1.05	0.20	0.08	0.51	0.98		
Dimethylphenanthrenes	0.69	0.53	0.12	0.60	0.18	0.14	0.94	0.57		
Trimethylphenanthrenes	0.40	0.15	0.04	0.40	0.09	0.07	0.37	0.35		
Fluoranthene	0.24	0.06	0.15	0.25	0.10	0.05	0.11	0.28	6.3	120
Pyrene	0.18	0.03	0.13	0.21	0.05	N.D.	0.08	0.21		
Methylpyrenes	0.14	0.05	0.17	0.23	0.03	0.02	0.07	0.23		
Dimethylpyrenes	0.11	0.02	0.11	0.18	0.04	N.D.	0.11	0.17		
Retene	0.03	N.D.	0.03	N.D.	N.D.	N.D.	0.04	0.03		
Benz[a]anthracene	0.05	N.D.	0.08	0.06	N.D.	N.D.	0.04	0.07		
Chrysene	0.09	0.02	0.10	0.11	0.03	N.D.	0.04	0.12		
Methylchrysenes	0.10	N.D.	0.13	0.10	N.D.	N.D.	0.04	0.12		
Dimethylchrysenes	0.10	0.02	0.11	0.11	N.D.	N.D.	0.12	0.16		
Benzo[b]fluoranthene	0.09	N.D.	0.10	0.10	0.02	N.D.	0.06	0.14		17
Benzo[k]fluoranthene	0.03	N.D.	0.06	0.02	N.D.	N.D.	N.D.	0.04		17
Benzo[e]pyrene	0.05	N.D.	0.08	0.06	N.D.	N.D.	0.02	0.08		
Benzo[a]pyrene	0.03	N.D.	0.11	0.05	N.D.	N.D.	N.D.	0.05	0.17	27
Perylene	N.D.	N.D.	0.02	N.D.	N.D.	N.D.	N.D.	N.D.		
Indeno[1,2,3-cd]pyrene	0.05	N.D.	N.D.	0.03	N.D.	N.D.	N.D.	0.04		
Benzo[ghi]perylene	0.05	N.D.	N.D.	0.06	N.D.	N.D.	0.02	0.06		0.82
Dibenz[a,h]anthracene	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.		
ΣPAHs (ng/L)	**9.71**	**4.04**	**6.48**	**14.7**	**6.15**	**3.89**	**8.22**	**12.4**		

ANNEX II

MUNICIPALITY OF KROPIA										
	AGIA MARINA				BLUE BEACH					
DATE	23/04/2018	20/06/2018	17/07/2018	31/08/2018	23/04/2018	20/06/2018	17/07/2018	31/08/2018		
PAHs (ng/L)									**AA (ng/L)**	**MAC (ng/L)**
Naphthalene	1.66	N.D.	0.52	2.24	1.18	0.78	1.69	0.99	2000	130000
Methylnapthalenes	1.24	N.D.	0.61	2.37	1.00	0.80	1.48	1.26		
Acenaphthylene	0.05	N.D.	0.03	0.13	0.14	0.05	0.08	0.10		
Acenaphthene	0.07	N.D.	0.03	0.10	0.08	0.04	0.06	0.07		
Dimethylnapthalenes	0.84	N.D.	0.44	1.43	0.94	0.49	0.88	0.93		
Trimethylnapthalenes	0.74	N.D.	0.26	1.03	0.86	0.34	0.52	0.83		
Fluorene	0.23	N.D.	0.03	0.43	0.21	0.08	0.12	0.14		
Dibenzothiophene	0.02	N.D.	N.D.	0.07	0.07	0.03	0.05	0.08		
Methyldibenzothiophenes	0.03	N.D.	N.D.	0.30	0.18	0.05	0.03	0.27		
Dimethyldibenzothiophenes	0.06	N.D.	N.D.	0.20	0.57	0.13	0.07	0.17		
Phenanthrene	0.32	N.D.	0.10	0.50	0.50	0.18	0.36	0.40		
Anthracene	N.D.	N.D.	N.D.	0.04	N.D.	0.02	0.03	N.D.	100	100
Methylphenanthrenes	0.28	N.D.	0.10	0.37	0.53	0.25	0.29	0.46		
Dimethylphenanthrenes	0.14	N.D.	0.07	0.48	0.65	0.32	0.21	0.48		
Trimethylphenanthrenes	0.05	N.D.	0.02	0.30	0.23	0.38	0.08	0.26		
Fluoranthene	0.11	0.06	0.02	0.22	0.19	0.06	0.15	0.22	6.3	120
Pyrene	0.04	0.04	0.04	0.18	0.12	0.06	0.11	0.16		
Methylpyrenes	0.04	0.07	0.03	0.18	0.24	0.12	0.10	0.15		
Dimethylpyrenes	0.03	0.06	0.02	0.14	0.13	0.17	0.06	0.14		
Retene	N.D.	N.D.	N.D.	0.02	0.05	N.D.	N.D.	N.D.		
Benz[a]anthracene	N.D.	N.D.	N.D.	0.05	0.04	0.03	0.05	0.04		
Chrysene	0.02	N.D.	N.D.	0.10	0.09	0.04	0.06	0.09		
Methylchrysenes	N.D.	N.D.	N.D.	0.08	0.10	0.08	0.03	0.09		
Dimethylchrysenes	N.D.	N.D.	0.03	0.07	0.09	0.10	0.03	0.14		
Benzo[b]fluoranthene	N.D.	N.D.	N.D.	0.09	0.06	0.03	0.06	0.09		17
Benzo[k]fluoranthene	N.D.	N.D.	N.D.	0.03	N.D.	0.03	N.D.	0.03		17
Benzo[e]pyrene	N.D.	N.D.	N.D.	0.06	0.04	N.D.	0.04	0.06		
Benzo[a]pyrene	N.D.	N.D.	N.D.	0.04	0.05	0.02	0.03	0.02	0.17	27
Perylene	N.D.	N.D.	N.D.	N.D.	N.D.	0.05	N.D.	N.D.		
Indeno[1,2,3-cd]pyrene	N.D.	N.D.	N.D.	0.02	0.03	0.05	N.D.	0.02		
Benzo[ghi]perylene	N.D.	N.D.	N.D.	0.04	0.04	N.D.	0.03	0.04		0.82
Dibenz[a,h]anthracene	N.D.	N.D.	N.D.	N.D.	0.07	N.D.	N.D.	N.D.		
ΣPAHs (ng/L)	**6.10**	**0.34**	**2.52**	**11.3**	**8.54**	**4.75**	**6.75**	**7.72**		

ANNEX II

MUNICIPALITY OF SARONIKOS										
	BLUE BEACH (TREXANTIRI)				SARONIDA					
DATE	23/04/2018	20/06/2018	17/07/2018	31/08/2018	23/04/2018	20/06/2018	17/07/2018	31/08/2018		
									AA (ng/L)	**MAC (ng/L)**
PAHs (ng/L)										
Naphthalene	2.33	0.63	0.24	0.89	3.23	0.68	1.04	1.44	2000	130000
Methylnapthalenes	2.48	0.55	0.26	1.02	3.48	0.67	0.84	2.34		
Acenaphthylene	0.09	0.02	N.D.	0.05	0.06	0.03	0.05	0.89		
Acenaphthene	0.14	0.04	N.D.	0.08	0.15	0.03	0.05	0.15		
Dimethylnapthalenes	1.86	0.32	0.21	0.44	1.32	0.35	0.54	4.65		
Trimethylnapthalenes	1.88	0.28	0.15	0.32	3.05	0.30	0.29	3.01		
Fluorene	0.57	0.11	N.D.	0.22	0.29	0.10	0.07	0.48		
Dibenzothiophene	0.06	1.49	N.D.	0.64	0.10	0.04	0.03	0.07		
Methyldibenzothiophenes	0.07	0.02	N.D.	0.04	0.80	0.03	N.D.	0.20		
Dimethyldibenzothiophenes	0.11	0.07	N.D.	0.08	0.53	0.05	0.05	0.24		
Phenanthrene	0.80	0.20	0.05	0.38	0.83	0.16	0.23	0.97		
Anthracene	0.04	N.D.	N.D.	N.D.	0.06	N.D.	N.D.	0.18	100	100
Methylphenanthrenes	0.57	0.12	0.03	0.22	0.74	0.16	0.19	1.27		
Dimethylphenanthrenes	0.41	0.21	0.04	0.21	1.16	0.19	0.15	1.19		
Trimethylphenanthrenes	0.18	0.10	0.02	N.D.	0.73	0.07	0.07	0.59		
Fluoranthene	0.19	0.07	N.D.	0.12	0.41	0.06	0.08	0.48	6.3	120
Pyrene	0.10	0.03	N.D.	N.D.	0.23	0.03	0.07	0.46		
Methylpyrenes	0.13	0.05	N.D.	N.D.	0.17	0.04	0.09	0.39		
Dimethylpyrenes	0.06	0.04	N.D.	N.D.	0.15	N.D.	0.05	0.30		
Retene	N.D.	N.D.	N.D.	N.D.	0.05	N.D.	N.D.	N.D.		
Benz[a]anthracene	0.03	N.D.	N.D.	N.D.	0.03	N.D.	N.D.	0.09		
Chrysene	0.04	0.02	N.D.	N.D.	0.10	N.D.	0.03	0.12		
Methylchrysenes	0.04	N.D.	N.D.	0.04	0.10	N.D.	N.D.	0.12		
Dimethylchrysenes	0.06	N.D.	N.D.	0.06	0.15	N.D.	N.D.	0.10		
Benzo[b]fluoranthene	0.04	0.04	N.D.	0.04	0.04	N.D.	0.03	0.13		17
Benzo[k]fluoranthene	N.D.	0.03	N.D.	N.D.	N.D.	N.D.	N.D.	0.05		17
Benzo[e]pyrene	N.D.	N.D.	N.D.	N.D.	0.07	N.D.	N.D.	0.09		
Benzo[a]pyrene	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	0.02	0.03	0.17	27
Perylene	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.		
Indeno[1,2,3-cd]pyrene	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	0.03		
Benzo[ghi]perylene	0.02	N.D.	N.D.	0.02	N.D.	N.D.	N.D.	0.07		0.82
Dibenz[a,h]anthracene	N.D.	N.D.	N.D.	N.D.	0.03	N.D.	N.D.	N.D.		
ΣPAHs (ng/L)	**12.4**	**4.51**	**1.16**	**4.87**	**18.1**	**3.15**	**4.11**	**19.1**		

ANNEX II

MUNICIPALITY OF SARONIKOS										
	MAVRO LITHARI				AGIOS NIKOLAOS					
DATE	23/04/2018	20/06/2018	17/07/2018	31/08/2018	23/04/2018	20/06/2018	17/07/2018	31/08/2018		
									AA (ng/L)	**MAC (ng/L)**
PAHs (ng/L)										
Naphthalene	3.15	0.50	1.16	2.86	1.57	0.54	0.90	2.33	2000	130000
Methylnapthalenes	3.70	0.56	1.05	1.52	1.41	0.51	0.81	2.71		
Acenaphthylene	0.08	0.02	0.06	0.56	0.03	N.D.	0.06	0.12		
Acenaphthene	0.17	0.03	0.05	0.11	0.05	N.D.	0.04	0.11		
Dimethylnapthalenes	1.96	0.36	0.63	3.03	0.72	0.29	0.53	1.56		
Trimethylnapthalenes	2.50	0.33	0.34	2.02	0.45	0.23	0.39	0.85		
Fluorene	0.26	0.09	0.08	0.31	0.19	0.07	0.07	0.25		
Dibenzothiophene	0.08	N.D.	0.03	0.04	0.02	N.D.	0.03	0.23		
Methyldibenzothiophenes	0.58	0.02	N.D.	0.12	0.05	0.03	0.03	1.79		
Dimethyldibenzothiophenes	0.34	0.09	0.05	0.13	0.13	0.04	0.09	4.25		
Phenanthrene	0.49	0.13	0.26	0.64	0.28	0.12	0.20	0.75		
Anthracene	N.D.	N.D.	0.02	0.11	N.D.	N.D.	N.D.	0.05	100	100
Methylphenanthrenes	0.30	0.12	0.24	0.81	0.19	0.13	0.22	1.62		
Dimethylphenanthrenes	0.34	0.32	0.21	0.73	0.30	0.14	0.19	2.08		
Trimethylphenanthrenes	0.22	0.12	0.07	0.38	0.10	0.10	0.10	1.16		
Fluoranthene	0.15	0.05	0.08	0.30	0.10	0.04	0.05	0.18	6.3	120
Pyrene	0.06	0.03	0.09	0.29	0.03	N.D.	0.04	0.14		
Methylpyrenes	0.05	0.05	0.10	0.25	0.03	0.02	0.07	0.17		
Dimethylpyrenes	0.04	0.04	0.07	0.15	N.D.	N.D.	0.07	0.15		
Retene	0.03	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	0.02		
Benz[a]anthracene	N.D.	N.D.	0.04	0.06	N.D.	N.D.	0.03	0.03		
Chrysene	0.03	0.02	0.03	0.08	0.02	N.D.	0.03	0.08		
Methylchrysenes	0.03	0.03	0.03	0.07	N.D.	N.D.	0.05	0.09		
Dimethylchrysenes	N.D.	0.03	N.D.	0.07	0.03	N.D.	0.07	0.22		
Benzo[b]fluoranthene	0.02	N.D.	0.03	0.09	N.D.	N.D.	0.02	0.04		17
Benzo[k]fluoranthene	N.D.	N.D.	N.D.	0.04	N.D.	N.D.	N.D.	0.04		17
Benzo[e]pyrene	0.03	N.D.	0.03	0.06	N.D.	N.D.	N.D.	0.04		
Benzo[a]pyrene	N.D.	N.D.	0.04	0.03	N.D.	N.D.	0.03	0.02	0.17	27
Perylene	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.		
Indeno[1,2,3-cd]pyrene	N.D.	N.D.	N.D.	0.02	N.D.	N.D.	N.D.	N.D.		
Benzo[ghi]perylene	N.D.	N.D.	0.03	0.05	N.D.	N.D.	N.D.	0.03		0.82
Dibenz[a,h]anthracene	0.03	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.		
ΣPAHs (ng/L)	**14.7**	**3.06**	**4.88**	**14.9**	**5.80**	**2.43**	**4.19**	**21.1**		

ANNEX II

MUNICIPALITY OF SARONIKOS										
	ANAVYSSOS				PALAIA FOKAIA					
DATE	23/04/2018	20/06/2018	17/07/2018	31/08/2018	23/04/2018	20/06/2018	17/07/2018	31/08/2018		
PAHs (ng/L)									**AA (ng/L)**	**MAC (ng/L)**
Naphthalene	6.39	0.70	0.66	2.06	2.61	0.72	0.67	4.28	2000	130000
Methylnapthalenes	5.52	0.64	0.60	2.15	2.09	0.78	0.61	6.78		
Acenaphthylene	0.53	0.12	0.04	0.75	0.11	0.06	0.04	0.68		
Acenaphthene	0.15	0.03	0.02	0.15	0.08	0.03	0.03	0.12		
Dimethylnapthalenes	2.49	0.37	0.40	4.12	1.03	0.38	0.43	3.53		
Trimethylnapthalenes	1.40	0.34	0.32	2.58	0.70	0.37	0.32	2.05		
Fluorene	0.42	0.07	0.06	0.40	0.23	0.09	0.06	0.52		
Dibenzothiophene	0.06	0.04	0.02	0.10	0.03	0.04	0.02	0.08		
Methyldibenzothiophenes	0.06	0.26	0.02	0.24	N.D.	0.10	0.02	0.18		
Dimethyldibenzothiophenes	0.10	0.53	0.06	0.34	0.05	0.18	0.07	0.15		
Phenanthrene	0.73	0.18	0.14	0.89	0.41	0.26	0.15	0.77		
Anthracene	0.04	N.D.	N.D.	0.13	N.D.	N.D.	N.D.	0.12	100	100
Methylphenanthrenes	0.63	0.33	0.14	1.22	0.29	1.21	0.13	0.66		
Dimethylphenanthrenes	0.54	0.46	0.15	1.14	0.33	2.67	0.15	0.89		
Trimethylphenanthrenes	0.13	0.20	0.08	0.52	0.08	1.44	0.12	0.42		
Fluoranthene	0.27	0.15	0.04	0.39	0.15	0.11	0.04	0.35	6.3	120
Pyrene	0.12	0.11	0.03	0.37	0.05	0.10	0.04	0.36		
Methylpyrenes	0.12	0.08	0.05	0.32	0.05	0.14	0.12	0.30		
Dimethylpyrenes	0.05	0.07	0.04	0.24	0.05	0.16	0.29	0.20		
Retene	N.D.	0.02	N.D.	N.D.	N.D.	0.02	N.D.	N.D.		
Benz[a]anthracene	0.05	0.11	0.02	0.07	N.D.	0.04	0.03	0.07		
Chrysene	0.07	0.08	0.02	0.09	0.04	0.06	0.05	0.09		
Methylchrysenes	0.05	0.08	0.03	0.09	0.03	0.09	0.12	0.08		
Dimethylchrysenes	0.05	0.08	0.04	0.10	0.04	0.13	0.27	0.08		
Benzo[b]fluoranthene	0.07	0.13	0.02	0.10	0.03	0.03	0.02	0.08		17
Benzo[k]fluoranthene	0.02	0.05	N.D.	0.04	N.D.	N.D.	N.D.	0.03		17
Benzo[e]pyrene	0.04	0.07	N.D.	0.06	N.D.	0.02	0.05	0.06		
Benzo[a]pyrene	0.03	0.07	N.D.	0.03	N.D.	N.D.	0.03	0.03	0.17	27
Perylene	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.		
Indeno[1,2,3-cd]pyrene	0.03	0.04	N.D.	0.02	N.D.	N.D.	N.D.	0.02		
Benzo[ghi]perylene	0.03	0.03	N.D.	0.05	N.D.	N.D.	0.02	0.04		0.82
Dibenz[a,h]anthracene	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.		
ΣPAHs (ng/L)	**20.2**	**5.49**	**3.09**	**18.8**	**8.61**	**9.34**	**3.95**	**23.0**		

ANNEX II

MUNICIPALITY OF SARONIKOS										
	THIMARI				ORMOS-KATAFYGI					
DATE	23/04/2018	20/06/2018	17/07/2018	31/08/2018	23/04/2018	20/06/2018	17/07/2018	31/08/2018		
PAHs (ng/L)									**AA (ng/L)**	**MAC (ng/L)**
Naphthalene	2.18	0.74	0.85	3.55	1.88	0.87	0.92	1.34	2000	130000
Methylnapthalenes	1.86	0.80	0.83	6.26	1.62	0.81	0.91	2.28		
Acenaphthylene	0.09	0.03	0.05	0.63	0.06	0.05	0.04	0.09		
Acenaphthene	0.06	0.03	0.03	0.14	0.06	0.02	0.04	0.04		
Dimethylnapthalenes	0.91	0.39	0.50	3.53	0.96	0.42	0.38	0.35		
Trimethylnapthalenes	0.62	0.46	0.26	2.29	0.61	0.44	0.22	0.39		
Fluorene	0.22	0.09	0.06	0.37	0.24	0.12	0.11	0.15		
Dibenzothiophene	0.04	0.10	0.02	0.06	0.04	N.D.	0.02	N.D.		
Methyldibenzothiophenes	0.23	0.54	0.03	0.14	0.05	0.02	0.04	N.D.		
Dimethyldibenzothiophenes	0.56	1.07	0.09	0.13	0.10	0.04	0.08	0.07		
Phenanthrene	0.40	0.79	0.16	0.74	0.42	0.13	0.19	0.23		
Anthracene	N.D.	N.D.	N.D.	0.12	N.D.	N.D.	N.D.	N.D.	100	100
Methylphenanthrenes	0.43	5.37	0.23	0.89	0.27	0.10	0.15	0.16		
Dimethylphenanthrenes	0.66	8.96	0.17	0.81	0.30	0.19	0.20	0.21		
Trimethylphenanthrenes	0.26	4.61	0.08	0.39	0.11	0.06	0.10	0.08		
Fluoranthene	0.14	0.14	0.04	0.34	0.14	0.04	0.06	0.07	6.3	120
Pyrene	0.04	0.38	0.03	0.32	0.05	0.02	0.03	N.D.		
Methylpyrenes	0.09	1.07	0.05	0.29	0.06	0.03	0.04	N.D.		
Dimethylpyrenes	0.07	1.40	0.05	0.21	0.07	N.D.	0.07	0.07		
Retene	0.02	0.08	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.		
Benz[a]anthracene	N.D.	0.19	N.D.	0.06	N.D.	N.D.	0.03	N.D.		
Chrysene	0.03	0.49	0.02	0.09	0.03	N.D.	0.02	N.D.		
Methylchrysenes	0.04	1.24	0.03	0.08	N.D.	N.D.	0.05	0.05		
Dimethylchrysenes	0.04	1.73	0.03	0.06	0.03	N.D.	0.05	0.04		
Benzo[b]fluoranthene	0.02	0.14	N.D.	0.08	0.02	N.D.	0.02	N.D.		17
Benzo[k]fluoranthene	N.D.	0.02	N.D.	0.04	N.D.	N.D.	0.02	N.D.		17
Benzo[e]pyrene	N.D.	0.28	N.D.	0.12	N.D.	N.D.	N.D.	N.D.		
Benzo[a]pyrene	N.D.	0.05	N.D.	0.03	N.D.	N.D.	0.03	N.D.	0.17	27
Perylene	N.D.	0.02	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.		
Indeno[1,2,3-cd]pyrene	N.D.	0.02	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.		
Benzo[ghi]perylene	N.D.	0.08	N.D.	0.04	N.D.	N.D.	N.D.	N.D.		0.82
Dibenz[a,h]anthracene	N.D.	0.04	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.		
ΣPAHs (ng/L)	**9.10**	**31.4**	**3.72**	**21.8**	**7.21**	**3.48**	**3.84**	**5.62**		

ANNEX II

MUNICIPALITY OF LAVRIO										
	CHARAKAS				LEGRENA (NAUTICAL CLUB)					
DATE	23/04/2018	20/06/2018	17/07/2018	31/08/2018	23/04/2018	20/06/2018	17/07/2018	31/08/2018		
PAHs (ng/L)									**AA (ng/L)**	**MAC (ng/L)**
Naphthalene	2.18	-	-	-	1.36	-	-	-	2000	130000
Methylnapthalenes	1.89	-	-	-	1.37	-	-	-		
Acenaphthylene	0.09	-	-	-	0.03	-	-	-		
Acenaphthene	0.06	-	-	-	0.06	-	-	-		
Dimethylnapthalenes	0.93	-	-	-	0.82	-	-	-		
Trimethylnapthalenes	0.54	-	-	-	0.53	-	-	-		
Fluorene	0.21	-	-	-	0.16	-	-	-		
Dibenzothiophene	0.03	-	-	-	0.02	-	-	-		
Methyldibenzothiophenes	0.04	-	-	-	0.04	-	-	-		
Dimethyldibenzothiophenes	0.07	-	-	-	0.06	-	-	-		
Phenanthrene	0.36	-	-	-	0.31	-	-	-		
Anthracene	N.D.	-	-	-	N.D.	-	-	-	100	100
Methylphenanthrenes	0.28	-	-	-	0.23	-	-	-		
Dimethylphenanthrenes	0.39	-	-	-	0.23	-	-	-		
Trimethylphenanthrenes	0.14	-	-	-	0.07	-	-	-		
Fluoranthene	0.13	-	-	-	0.09	-	-	-	6.3	120
Pyrene	0.06	-	-	-	0.04	-	-	-		
Methylpyrenes	0.12	-	-	-	0.03	-	-	-		
Dimethylpyrenes	0.04	-	-	-	0.04	-	-	-		
Retene	N.D.	-	-	-	N.D.	-	-	-		
Benz[a]anthracene	0.02	-	-	-	N.D.	-	-	-		
Chrysene	0.04	-	-	-	0.02	-	-	-		
Methylchrysenes	0.03	-	-	-	N.D.	-	-	-		
Dimethylchrysenes	0.04	-	-	-	0.03	-	-	-		
Benzo[b]fluoranthene	0.03	-	-	-	N.D.	-	-	-		17
Benzo[k]fluoranthene	N.D.	-	-	-	N.D.	-	-	-		17
Benzo[e]pyrene	0.03	-	-	-	N.D.	-	-	-		
Benzo[a]pyrene	N.D.	-	-	-	N.D.	-	-	-	0.17	27
Perylene	N.D.	-	-	-	N.D.	-	-	-		
Indeno[1,2,3-cd]pyrene	N.D.	-	-	-	N.D.	-	-	-		
Benzo[ghi]perylene	N.D.	-	-	-	N.D.	-	-	-		0.82
Dibenz[a,h]anthracene	N.D.	-	-	-	N.D.	-	-	-		
ΣPAHs (ng/L)	**7.85**	**-**	**-**	**-**	**5.64**	**-**	**-**	**-**		