TECHNICAL REPORT

PRELIMINARY RESULTS OF THE OIL SPILL IMPACT ON LEBANESE COASTAL WATERS

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(Received 16 October 2006 - Accepted 11 December 2006)

ABSTRACT

Immediately after 13th July, 2006, date of the oil spill from the Jieh power plant, the National Center for Marine Sciences (CNSM) - National Council for Scientific Research in Lebanon (CNRS), and in coordination with Ifremer-France, began the rapid assessment plan in order to evaluate the direct impact of pollution by hydrocarbons on the whole marine ecosystem.

The CNSM has carried out several excursions on field and has also conducted detailed submarine cartography of the polluted sites. The fuel oil, which reached the coast of Batroun, is being sampled and analyzed every 15 days. These analyses have allowed us to determine the degree of alteration and the chemical composition of the fuel oil.

In this study the preliminary results issued from the campaign between July and October 2006 concerning the chemical and biological parameters are presented. Many comparisons are made with pre-spill data obtained from the same period in previous years.

Surface water samples obtained from 14 sites along the Lebanese coast showed relatively high concentrations of nitrates and nitrites ions 2 months after the oil spill, compared to previous years.

Primary production evaluated by counting the phytoplankton population abundance (3 sites), and the measurement of chlorophyll a concentration (13 sites), showed a serious qualitative and quantitative impact in the 2 months following the oil spill.

The specific diversity and the meiofaunal population abundance studied in the Antelias sandy beach site were negatively affected.

Analyses of PAHs levels in 5 species of fish captured in 3 different sites and in the tissues of a mussel species (Brachidontes variabilis) collected in 3 other sites, showed the different responses of the two organisms. The mussel tissues were heavily contaminated, while the fish muscle did not show significant contamination levels.

Keywords: Lebanon, Jieh oil spill, PAHs, coastal water, chemical contamination, nutrients, primary production, meiofauna, fish, bioindicators

INTRODUCTION

On 13th and 15th July 2006, the Jieh power plant located 30 km south of Beirut, directly on the coastline, was hit by Israeli bombs. About 15000 to 20000 tons of heavy fuel oil spilt into the Mediterranean Sea (MoE, 2006).

Due to prevailing winds blowing South West to North East and general water current movement in the Levantine basin, the oil spill was partly carried out to sea and partly dispersed along the coast of Lebanon and it eventually reached the Syrian coast and perhaps beyond. It has affected about 140 km of both public and private rocky, sandy and gravel beaches along the Lebanese coast, including public and private marinas/ports.

In response to this major fuel oil spill, the CNSM immediately suggested an initial National Resource Damage Assessment (NRDA) program. The potential for environmental damage was significant. By the end of July 2006, the CNSM, in collaboration with Ifremer-Nantes, elaborated a monitoring strategy divided into 3 phases: short term phase (2006), mid-term phase (2007) and long term phase (2008-2010). Each phase includes several activities related to oil spill impact on coastal ecosystems.

The National Center for Marine Sciences located in Batroun city is the only public institute responsible for the monitoring of the Lebanese coastal zone. Many national programs have been implemented in addition to international cooperation programs in order to create a National Observatory Net covering the totality of the Lebanese coast. A large database, concerning major contaminants such as heavy metals in water, sediment and biota, nutrients, pre-spill data on PAH along with 10 years' results on primary production, allowed us to compare the after-spill results to the previous situation.

This paper presents the preliminary results of the short term phase including:

- visual observation,
- fuel oil composition,
- nutrients analysis and primary production,
- meiofauna quantitative and qualitative study,
- PAHs and trace elements contamination levels in fish muscles,
- PAHs levels in quantitative bioindicators (mussels).

Other analyses concerning some of these parameters, such as trace elements in fish, mussels and fuel oil are still ongoing.

MATERIAL AND METHODS

Sampling sites designation was obtained by combining pre-established sites already in use in the monitoring network established by the CNSM with new fixed points chosen in relation to the degree of contamination of the shoreline (Figure 1, Table 1).

Visual and submarine observation

Directly after the ceasefire (15th August, 2006), the CNSM team began to investigate the coastline, starting from the Jieh thermal power station up to the Syrian border in the extreme north. All the contaminated sites were fixed on the map and photographed. These sites were classified by contamination levels as non-contaminated, slightly contaminated, moderately contaminated and heavily contaminated.

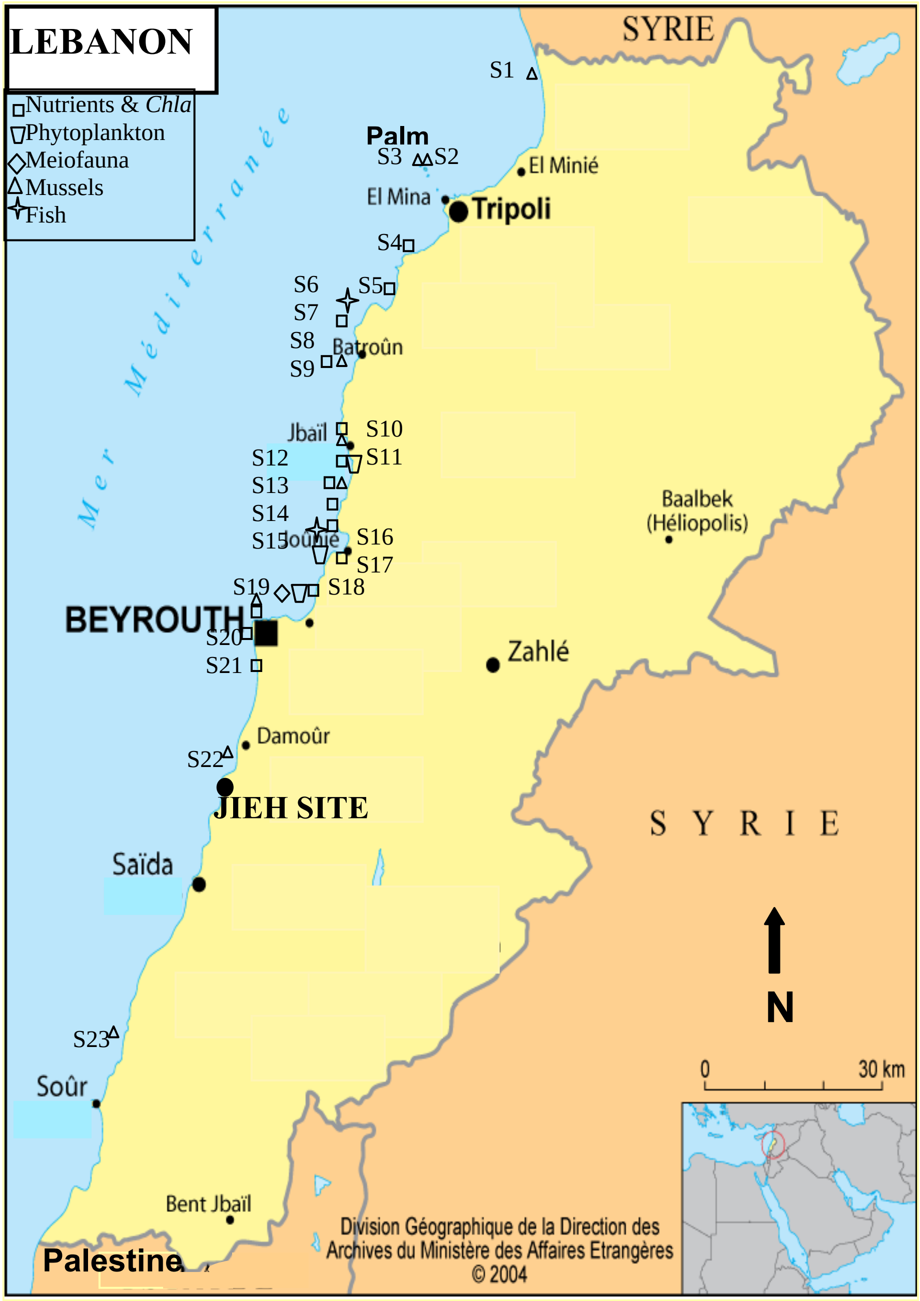

Figure 1. Sampling sites and analyzed parameters.

TABLE 1
Coordinates and Characteristics of Sampling Sites

NO_2^- = Nitrites, NO_3^- = Nitrates, PO_4^{---}= Orthophosphates, Chl *a* = Chlorophyll *a*,
Phy = Phytoplankton, Mf = Meiofauna

Location	Sites	Code	Coordinates	Sample	Parameters	Description
Akkar	S1	AKK-9	35º 59'269E 34º 35'663N	bivalves, fuel	PAHs*, trace elements*	Terraces
Palm isles	S2	PAL-7	35º 46'241E 34º 29'714N	bivalves	PAHs*, trace elements*	Rocky
	S3	PAL-8	35º 46'541E 34º 29'715N	bivalves, fuel	PAHs*, trace elements*	Rocky
Tripoli	S4	TRI-20	35º 44'160E 34º 22'054N	water	NO_2^-, NO_3^-, PO_4^{---}, Chl*a*	Rocky
Heri	S5	TRI-21	35º 42'851E 34º 18'592N	water	NO_2^-, NO_3^-, PO_4^{---}, Chl*a*	Sandy beach
Batroun	S6	BAT-9	35º 39'189E 34º 16'570N	water	NO_2^-, NO_3^-, PO_4^{---}, Chl*a*	Rocky
	S7	BAT-30	35º 40'129E 34º 17'588N	fish	PAHs, trace elements*	Offshore
	S8	BAT-40	35º 39'704E 34º 17'167N	fish	PAHs, trace elements*	Offshore
	S9	BAT-14	35º 39'413E 34º 15'090N	water, fuel, bivalves	NO_2^-, NO_3^-, PO_4^{---}, Chl*a*, PAHs*, trace elements*	Rocky
Byblos	S10	BYB-10	35º 38'578E 34º 07'406N	water	NO_2^-, NO_3^-, PO_4^{---}, Chl*a*	Pebbles
	S11	BYB-11	35º 39'554E 34º 07'316N	bivalves	PAHs*, trace elements*	Terraces
	S12	BYB-13	35º 38'878E 34º 04'894N	bivalves	PAHs*, trace elements*	Rocky
	S13	BYB-14	35º 38'896E 34º 06'864N	water	NO_2^-, NO_3^-, PO_4^{---}, Chl*a* , Phy	Sandy
	S14	BYB-20	35º 39'035E 34º 06'142N	water	NO_2^-, NO_3^-, PO_4^{---}, Chl*a*	Sandy
	S15	BYB-22	35º 38'539E 34º 03'625N	water	NO_2^-, NO_3^-, PO_4^{---}, Chl*a*	River mouth
Jounieh	S16	JUN-13	35º 37'424E 34º 01'777N	water, fish	NO_2^-, NO_3^-, PO_4^{---}, Chl*a* PAHs, trace elements*	Rocky
	S17	JUN-20	35º 38'630E 34º 00'635N	water	NO_2^-, NO_3^-, PO_4^{---}, Chl*a*, Phy	Sandy/pebbles
Antelias	S18	JUN-40	35º 34'970E 33º 55'020N	water, sediment	NO_2^-, NO_3^-, PO_4^{---}, Chl*a*, Mf, Phy	Sandy
Beirut	S19	BEY-11	35º 28'518E 33º 54'120N	water, bivalves	NO_2^-, NO_3^-, PO_4^{---}, Chl*a* PAHs, trace elements*	Rocky
	S20	BEY-12	35º 28'225E 33º 54'024N	water	NO_2^-, NO_3^-, PO_4^{---}	Rocky
	S21	BEY-20	35º 28'760E 33º 52'767N	water	NO_2^-, NO_3^-, PO_4^{---}, Chl*a*	Sandy
Jieh	S22	DAM-11	35º 24'957E 33º 39'381N	bivalves	PAHs, trace elements*	Sandy
Sour - Itanieh	S23	SUR-10	35º 14'846E 33º 21'298N	bivalves	PAHs, trace elements*	Rocky

Along with the on-shore observation, Ifremer also provided their expertise in submarine video observation. A rapid survey was performed towards the coastline of Beirut and in the port of Byblos using submarine video camera (Sony) linked to a GPS *via* a digital recorder. The overall system is guided by GIS and Arc-Pad programs.

Fuel oil

Dating from 28th August, 2006, fuel samples were collected every 15 days from the site of Batroun (S9), near the CNSM.

The fuel analysis was conducted in the Ifremer organic contaminants laboratory (LBCO). Three replicates were analyzed for quantitative and qualitative composition concerning polycyclic aromatic hydrocarbons (PAHs), identification of heterocyclic nitrogen compounds and aliphatic hydrocarbons, chlorinated compounds, trace elements and elementary composition of carbon, hydrogen, nitrogen and sulfur.

Hydrocarbon analyses were performed on gas chromatography coupled with mass spectrometry according to Tronczynski *et al*. (2004), Munschy *et al*. (2005) and Tronczynski *et al*. (2005). The focus was especially on the 16 PAHs compounds required by the EPA (Environmental Protection Agency-USA) and the 6 PAHs required by the WHO (World Healh Organization).

Nutrients

Surface water samples for nutrients analysis (nitrates, nitrites and orthophosphates) were collected from 14 sites with a frequency of one sampling each 15 days dating from 23rd August 2006. Nitrate ions are measured according to Wood *et al*. (1967). The wave length used in spectral analysis is 543 nm. Nitrite ions are measured according to the reaction of Griess, applied to sea water by Bendschneider and Robinson (1952). Orthophosphates are analyzed according to the colorimetric method of Murphy and Riley (1962). The wave length used in spectral analysis is 885 nm.

Primary production

Samples for primary production variability were taken from 13 sites for Chl *a* and from 3 for phytoplankton population studies for the period between August and October 2006. The comparison was made with previous results. Primary production biomass was estimated by the measuring of Chl *a* (Lorenzen, 1967) and by the counting of nano and microphytoplankton populations in water samples (Utermöhl , 1958).

Meiofauna

The sediments were sampled from the Antelias site (S18) on 24th August 2006 for meiofauna study. Three cores were collected at the wave–washed zone and at 10 m depth. The point in the wave-washed zone is about 50 cm from the highest point reached by the surging waves.

In the laboratory, the meiofauna were extracted from the sediment by adding water to each sample, followed by a process of agitation and decantation using a 45 µm sieve. All meiofauna taxa were counted after staining with Rose Bengal.

PAHs and trace elements in fish muscles and mussel tissue

The fish were caught in a net (except for mullet) between 20 – 30 meters water depth on 11th October 2006, in the area of Hannouch (S7 and S8). The five species of fish that were caught are: *Trachinotus ovatus* (Derbio), *Fistularia commersonii* (Bluespotted cornetfish) *Seriola dumerili* (Greater amberjack), *Diplodus sargus*, (White seabream), and *Mugil cephalus* (Flathead mullet).

The fifth sample (flathead mullet) was caught on 12th October 2006 from the heavily polluted site of Tabarja (S16).

Upon recovery of the net, each fish specimen was manipulated with clean gloves and wrapped separately into aluminum foil and protected in polyethylene bags, stored in the cooler. The dissection of fish muscle samples was carried out in laboratory conditions. The muscle samples were stored in pre-baked (at 450°C) glass jars and frozen at –20°C.

The mussel (*Brachidontes variabilis*) samples were taken on 11th and 12th October 2006 at 9 sampling sites located along the coastal line of Lebanon, beginning from south of the Jieh plant on the S23 site up to the north, near the Syrian border (S1). Temporal survey started in August 2006, on the S9 site and several mussel samples have been collected since then with a frequency of one sample each 15 days.

Mussel samples were collected by hand and stored in pre-baked glass jars at -20°C until further analyses. Shellfish sampling was performed so as to avoid contamination by coated fuel. About 150 specimens of controlled shell sizes (20-25 mm) were pooled as a composite sample representative of each sampling location.

Fish muscles and mussel wet tissue were both sampled, homogenized, lyophilized then extracted and analyzed for PAHs by GC-MS according to Munschy *et al*. (2005) and for trace elements according to Chiffoleau *et al*. (2003).

RESULTS AND DISCUSSION

Visual and submarine observation

The onshore and submarine visual observation carried out on different sites affected by the oil spill shows (Khalaf *et al.*, 2006b):

- the presence of fish and crab carcasses on different beaches, especially in Batroun (S9), Byblos (S11), Tabarja (S16) and Ramlet el Baida (S21),
- the disappearance of bivalve species and sea urchins from the visited reference sites, such as Batroun (S9) and Hannouch (S7),
- a massive mortality of fauna (Gastropods, Crustaceans, Echinoderms,) and macroscopic algae of the medio-littoral vermetid terraces in Byblos (S11), Batroun (S9), Heri (S5),
- a massive mortality of infra-littoral benthic Gastropods in Ramlet el Baida (S21), Heri (S5) and on Byblos sandy beaches (S14).

The underwater video observation showed some fuel nodules in the northern part of Ramlet el Baida (S21). The sea bottom of the ancient port of Byblos seemed to be preserved.

Fuel oil analyses

The fuel oil that reached the coast contains water and solid debris. These residues can introduce significant error if the results of hydrocarbon analysis are expressed in bulk weight of fuel. Our results show that the fuel sampled on the 28th August 2006 contains 26% of water and solid debris; this percentage must be taken into consideration during the result correction.

The analyses revealed that the volatile compounds are quasi absent in the fuel sampled two months after the spill; these compounds have entirely evaporated from the fuel that lies on the rocky shores of Batroun (S9). A relative abundance of methyl phenanthrene/anthracene and heavy PAHs was also noticed in our sample (Figure 2); for example, the concentrations of the 6 most toxic compounds according to WHO and the 16 most toxic compounds according to EPA are higher than those found in the Erika and Prestige oil spill (respectively off the French and Spanish coasts) (Table 2).

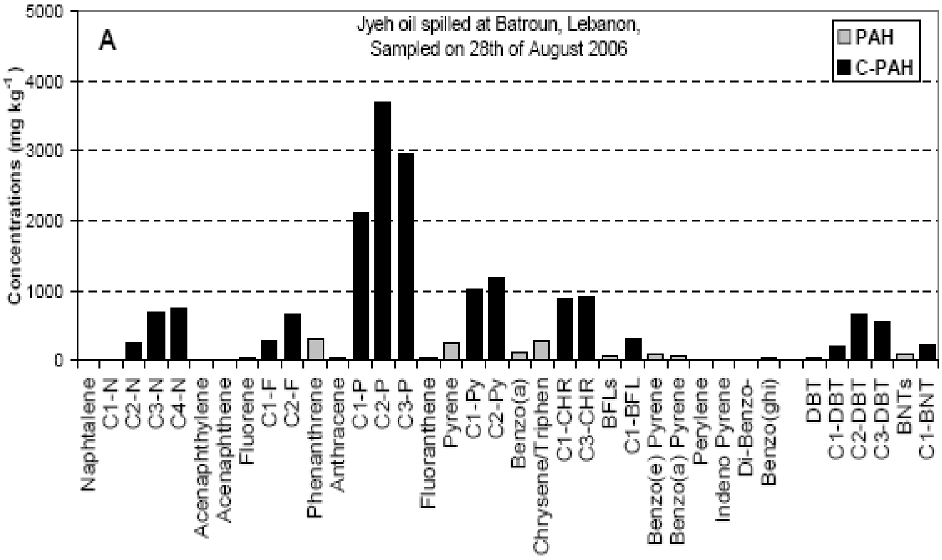

Figure 2. Chemical composition of the fuel oil sample collected from Batroun site (S9) on the 28th of August 2006.

TABLE 2
Comparison of the ΣEPA PAH and the ΣWHO PAH Levels in Fuel Oil Samples from Lebanese, French and Spanish Oil Spills

Abreviation	JIEH , Lebanon	ERIKA, France	PRESTIGE, Spain
	28-Augt-06	**27-Dec-99**	**24-Nov-02**
	mg/kg	mg/kg	mg/kg
ΣEPA PAH "16 PAH"	1416	949	902
ΣWHO PAH "6 PAH"	290	194	98

Nutrients

Higher levels of nitrates and nitrites were noticed in August 2006 compared to August 2004 and 2005, especially in the moderately and heavily polluted sites like S4, S9, S10, S13, S14, S15, S16, S17, S18 and S21 (Table 3). This tendency was also observed during the first half of September 2006/1. The nitrates and nitrites levels returned to normal levels in the second half of September 2006/2 (Abboud-Abi Saab *et al*., 2005; Khalaf *et al*., 2006a). These changes could be explained by the low primary production noticed directly after the oil spill (*cf*. Primary production).

The orthophosphate levels seemed not to be affected by the oil spill; the concentrations recorded in 2006 are roughly comparable with those found in the same period of the years 2004 and 2005 (Table 4).

Primary production

Chlorophyll a:

Comparing the results of 2005 and 2006, a net decrease in the concentration of chlorophyll *a* was noted at most sites for August and September 2006, while in October, concentrations were higher in 2006 at most of the sites, indicating a recovery situation in water column (Table 5).

It can be concluded that the effect of the fuel in the sea was not restricted to a small area. In fact, oil spill occurred most frequently at the surface of the sea and is found there not only in the immediate vicinity of its accidental or deliberate discharge, but also as a permanent and widespread feature of the waters according to the water current movement. Phytoplankton communities are delicate plants and may be affected and contaminated by the oil. Plankton is almost entirely at the mercy of winds and currents so that, once in the vicinity of a path of floating oil, they are likely to remain with it.

The decrease of chlorophyll *a* is justified theoretically and according to the literature; possible harmful effects on plankton can be summarized as follows: 1) a layer of oil on the surface will, by occluding light, cause a serious drop in photosynthesis by phytoplankton; 2) oil will exert serious toxic effects on plankton.

TABLE 3

Pre-spill and After Spill Concentrations of Nitrates and Nitrites in the Surface Water in Different sites along the Lebanese Coast

Sites	Code	NITRATES									
		AUG			SEPT				OCT		
		2004	2005	2006	2004	2005	2006/1	2006/2	2004	2005	2006
S4	TRI-20	0.113	0.225	0.724	0.26	0.136	0.519	0.172		0.214	0.214
S5	TRI-21	0.346	0.254	0.138	2.473	0.191	0.216	0.105	3.352	1.445	0.09
S6	BAT-9	0.669	0.315	0.286	0.553	0.269	0.286	0.2	0.497	9.389	0.483
S9	BAT-14	0.172	0.368	0.738	0.258	0.500	0.656	0.739	0.689	3.701	0.833
S10	BYB-10	0.352	0.793	0.865	0.303	0.548	0.601	0.493	1.735	3.719	0.35
S13	BYB-14	0.336	1.470	2.425	1.294	1.968	0.394	1.936	8.433	17.877	1.793
S14	BYB-20	0.672	1.655	2.03	0.363	1.697	2.492	0.659	3.437	11.087	0.701
S15	BYB-22	0.821	4.625	5.813	1.508	2.898	1.145	1.102	5.09	7.494	0.93
S16	JUN-13	0.483	1.067	1.279	0.947	0.827	1.042	0.861	1.334	0.794	1.115
S17	JUN-20	6.28	0.821	2.681	0.203	1.623	1.398	2.713	4.281	8.999	2.625
S18	JUN-40	3.054	9.005	18.03	0.345	0.825	3.006	0.596	4.61	3.231	1.491
S19	BEY-11	0.368	1.086	0.705	0.513	1.123	0.712	0.945	0.506	0.481	0.968
S20	BEY-12	1.22	2.334	0.483	1.524	2.330	1.546	1.058	1.557	1.146	1.434
S21	BEY-20	2.311	1.191	2.257	0.783	4.476	0.37	0.268	5.474	3.707	1.227

Sites	Code	NITRITES									
		AUG			SEPT				OCT		
		2004	2005	2006	2004	2005	2006/1	2006/2	2004	2005	2006
S4	TRI-20	0.059	0.008	0.061	0.036	0.059	0.023	0.055	0.038	0.011	0.04
S5	TRI-21	0.078	0.044	0.078	0.113	0.069	0.04	0.086	0.061	0.05	0.034
S6	BAT-9	0.074	0.017	0.025	0.067	0.082	0.048	0.067	0.057	0.172	0.015
S9	BAT-14	0.082	0.025	0.155	0.08	0.113	0.116	0.17	0.071	0.179	0.097
S10	BYB-10	0.076	0.137	0.065	0.065	0.153	0.111	0.166	0.298	0.076	0.074
S13	BYB-14	0.025	0.082	0.353	0.088	0.128	0.298	0.158	0.153	0.185	0.204
S14	BYB-20	0.101	0.111	0.155	0.164	0.143	0.391	0.059	0.019	0.191	0.08
S15	BYB-22	0.16	0.103	0.462	0.246	0.134	0.109	0.019	0.592	0.011	0.038
S16	JUN-13	0.151	0.155	0.298	0.296	0.227	0.235	0.08	0.237	0.176	0.235
S17	JUN-20	0.122	0.08	0.16	0.158	0.179	0.179	0.065	0.023	0.202	0.05
S18	JUN-40	0.353	0.641	1.111	0.716	0.395	0.45	0.143	0.542	1.285	0.216
S19	BEY-11	0.128	0.212	0.311	0.193	0.246	0.206	0.13	0.086	0.09	0.227
S20	BEY-12	0.395	0.443	0.191	0.244	0.405	0.382	0.288	0.281	0.074	0.284
S21	BEY-20	0.827	0.508	0.817	0.227	0.909	0.51	0.305	0.504	0.3	0.464

TABLE 4

Pre-spill and After Spill Concentrations of Orthophosphates in the Surface Water in Different Sites along the Lebanese Coast

Sites	Code	ORTHOPHOSPHATES									
		AUG			SEPT				OCT		
		2004	2005	2006	2004	2005	2006/1	2006/2	2004	2005	2006
S4	**TRI-20**	0.346	0.888	0.178	0.451	0.883	0.187	0.442	0.35	0.245	0.398
S5	**TRI-21**	1.618	1.109	0.408	0.826	0.71	0.341	1.133	0.662	0.518	0.413
S6	**BAT-9**	0.216	0.446	0.278	5.256	0.936	0.144	0.288	1.994	3.720	0.595
S9	**BAT-14**	0.154	0.235	0.197	3.014	0.514	0.163	0.23	0.278	0.490	0.374
S10	**BYB-10**	0.221	0.259	0.178	0.187	0.298	0.197	0.283	0.221	0.134	0.389
S13	**BYB-14**	0.187	0.178	0.494	0.182	0.274	0.206	0.25	0.245	0.115	0.442
S14	**BYB-20**	0.197	0.269	0.23	0.197	0.379	0.154	0.206	0.211	0.158	0.341
S15	**BYB-22**	0.25	0.350	0.197	0.331	0.278	0.125	0.307	0.293	0.149	0.346
S16	**JUN-13**	0.245	0.312	0.25	0.202	0.293	0.182	0.293	0.269	0.139	0.331
S17	**JUN-20**	0.274	0.202	0.221	0.245	0.254	0.187	0.466	0.25	0.259	0.61
S18	**JUN-40**	0.566	4.954	5.006	4.406	0.888	1.8	1.046	1.57	5.170	3.59
S19	**BEY-11**	0.254	0.355	0.182	0.226	0.307	0.221	0.346	0.206	0.168	0.346
S20	**BEY-12**	0.787	0.946	0.322	0.307	0.725	0.398	0.773	0.341	0.250	0.605
S21	**BEY-20**	1.349	1.070	3.082	0.278	3.211	1.21	0.648	1.594	0.470	2.338

TABLE 5

Comparison of Concentrations of Chlorophyll *a* (mg/m^{-3}) during 3 Months (August-October) between 2006 and 2005

Sites	Code	AUG		SEPT			OCT	
		2005	2006	2005	5/9/2006	25/9/2006	2005	2006
S4	**TRI-20**	0.31	0.22	0.36	0.08	0.11	0.01	0.09
S5	**TRI-21**	0.73	0.37	0.70	0.37	0.17	0.20	0.11
S6	**BAT-9**	0.36	0.28	0.30	0.20	0.17	0.13	0.08
S9	**BAT-14**	0.23	0.12	0.15	0.06	0.14	0.03	0.14
S10	**BYB-10**	0.12	0.20	0.31	0.45	0.08	0.06	0.30
S13	**BYB-14**	0.99	0.20	1.02	0.13	0.52	0.13	0.28
S14	**BYB-20**	0.55		0.52		0.14	0.18	0.37
S15	**BYB-22**	0.35		0.20		0.15	0.09	0.13
S16	**JUN-13**	0.43		0.23		0.13	0.06	0.13
S17	**JUN-20**	0.74	0.19	0.50	0.21	0.67	0.06	0.30
S18	**JUN-40**	5.89	2.18	1.54	0.61	2.67	0.33	2.47
S19	**BEY-11**	0.33		0.30		0.07	0.10	0.17
S21	**BEY-20**	1.61		0.50	1.23	1.51	0.45	1.74

Phytoplanktonic populations:

The following remarks can be drawn from the first samples collected at 3 sites after the oil spill:

- the count was difficult because of the presence of small particles of tar which cover up the cells,
- most microphytoplanktonic cells were distorted,
- most of the cells were empty and without chloroplasts, particularly at site S13 (sandy site near Byblos which was very highly contaminated by the oil spill),
- quantitative studies did not show, in general, a decrease in the total number of phytoplanktonic populations (Table 6), but a decrease in specific diversity. It seems that some species did not resist these situations and disappeared from the environment, others took hold and developed.

TABLE 6

Comparison of Phytoplankton Populations (Cells/L) between 2006 and 2005 for a Period of 3 Months after the Oil Spill (August –October)

Sites	Code	Nanophytoplankton			Microphytoplankton			Total phytoplankton		
		AUG								
		2005	2006		2005	2006		2005	2006	
S18	JUN-40	2573025	3879330		930600	3099880		3503625	6979210	
S17	JUN-20	284940	colmatage		424908	colmatage		709848	colmatage	
S13	BYB-14	22167	253344		112794	471240		134961	724584	
		SEPT								
		2005	2006		2005	2006		2005	2006	
			5 SEPT	25 SEPT		5 SEPT	25 SEPT		5 SEPT	25 SEPT
S18	JUN-40	395850	1068795	1227135	591360	4163140	3741915	987210	5231935	4969050
S17	JUN-20	118725	167798	134555	133848	753192	549583	252573	920990	684138
S13	BYB-14	45918		245365	566610		773744	612528		1019110
		OCT								
		2005	2006		2005	2006		2005	2006	
S18	JUN-40	498771	348348		588060	613800		1086831	962148	
S17	JUN-20	50656	110810		19008	280368		69664	391178	
S13	BYB-14	38001	31660		117942	108504		155943	140168	

During September and October 2006, results showed that phytoplankton populations at sites S17 and S18 had rapidly recovered, due, perhaps, to the relatively protected geographical position of these sites; the situation at S13 was more closely related to the state of the sea; in calm sea, phytoplankton showed normal development and an increase in the density of cells due to the high growth rate of these primary producers (2-3 times/day)**;** in stormy conditions, waves and mixed water help the re-suspension of tar in water column which contributes to the breakdown of the phytoplankton cells. In shallow coastal areas, wind induces re-suspension of particles from the bottom (Abboud-Abi Saab, 1992) and more tar will be present in the water, contributing to the increase of water turbidity.

Meiofauna

Benthic meiofauna have frequently been used as potential bio-indicators of pollution due to oil spill. Many studies have been carried out in order to monitor the effect of the fuel oil spill on meiofauna assemblages : the Agip Abruzzo at Ligurian Sea (Danovaro *et al.*, 1995), Goa in India "M V Sea Transporter" (Ansari & Ingole, 2002) and the Southern Bay of Bourgneuf in France “ERIKA” (Morvan *et al*., 2004).

Before the fuel oil spill on the Lebanese coast, the meiofauna assemblages were surveyed during 3 periods (May 2002, August 2002 and January 2003) at the Antelias site (S18).

Meiofaunal response to oil pollution at the wave-washing zone was extremely rapid (Table 7). Meiofaunal groups appeared to be highly sensitive to hydrocarbon pollution since the oil spill determined an observable decline in Nematodes (1221 and 53 ind./10 cm^2) and Oligochaetes (381 ; 0 ind./10 cm^2) densities and mostly the disappearance of all other meiofaunal groups (Polychaetes, Harpacticoides, Cyclopoides, Nauplii, bivalve larvae) (Mouawad, 2005). Such patterns were unusual since they were reported in a period (summer) in which, we would expect an increase in density, because of the usual seasonality of Mediterranean meiofauna.

The results indicate that the changes in the total density of the major meiofaunal groups at 10 m depth, between the two sampling periods (before and after pollution) were not important (2550 and 2721 ind./10 cm^2). Meiobenthos and specifically Nematode total densities were almost indistinguishable from pre-pollution conditions (Table 7), indicating that sediments at this depth were not affected by the oil spill.

PAHs in fish muscle samples

Table 8 shows a comparison of the concentrations of the most toxic compounds found in 5 fish muscle samples to some advisory levels for these compounds in subsistence seafood samples. This comparison should be considered as an exercise, because only five fish samples were analyzed and they are not sufficient for more general hazard and risk assessment.

In this Table are presented benz(a)pyrene concentrations and summed concentrations of EPA-PAH (called 16 parent compounds) and WHO-PAH (6 parent compounds) in the fish muscle samples. For comparison, the concentrations in hake muscle and liver caught in the Biscay Bay (Tronczynski *et al.*, 2004) after the Erika oil spill (December 1999) are given.

TABLE 7

Summary of the Mean Meiofaunal Densities (ind./10 cm^2) at Antelias Site, S18 (0 m and 10 m Depths) before and after the Oil Spill

Meiofauna taxa	0 m		10 m	
	29-AUG-02	24- AUG -06	29- AUG -02	24- AUG -06
Nematodes	1221	53	2314	2554
Oligochaetes	381	0	3	1
Polychaetes	1	0	24	152
Harpacticoides	1	0	179	14
Nauplii	4	0	22	0
Cyclopoides	3	0	1	0
Bivalves larvae	1	0	7	0
Total	1611	53	2550	2721

The advisory levels for fish proposed by AFSSA (French Food Sanitary Safety Agency) for the Erika oil spill are also reported, as well as a European Union maximum admissible concentration of benzo(a)pyrene in fish muscle. It appears that none of PAH levels in fish samples exceeded the "advisory/admissible levels".

It is known that the ability of fish to metabolize PAHs makes fish of considerably less concern as a dietary source of PAHs as compared, for instance, to mollusk bivalves. The US Food and Drug Administration (FDA) has concluded in its extensive hazard and risk assessment of crude oil contaminants in subsistence seafood after the *T/V Exxon Valdez* oil spill in Alaska that the risk of contracting cancer from eating fish collected in the spill area was, for practical reasons, equal to zero (Bolger *et al.,* 1996).
In spite of the absence of such risk in the case of the *Exxon Valdez* oil spill, the hazard and risk assessments should probably be conducted for each case of an oil spill and, furthermore, other considerations should be taken into account in marketing seafood from the areas of a given oil spill (such as the flavor, taint and smell of the seafood products). Finally, as was stated above, low concentration of PAHs in fish muscle does not indicate absence of ecological/physiological/biochemical pressures that the marine organisms suffer in the oil spill areas. Therefore, the ecological consequences and the damage to natural marine resources of the marine ecosystems resulting from oil spills are considered in individual studies.

PAHs in mussel (*Brachidontes variabilis*)

In this section, the preliminary results of PAHs concentrations in the mussels collected on 11th October 2006 from the Lebanese coast at three sites S19, S22 and S23 are reported. Samples collected from the 6 other sites showed in Figure 1 are still being analyzed in Ifremer's organic laboratory for PAHs and trace elements. The concentrations (µg/kg dry weight) of different suites of PAHs are presented in Table 9.

TABLE 8

PAH Concentrations in µg/kg Dry Weight in Five Fish Samples and AFSSA Advisory Levels for the Erika Oil Spill and EU and EPA Maximum Admissible Concentration (MAC) of Benzo [*a*] Pyrene in Fish Muscle

Site	**S7**	**S8**	**S8**	**S8**	**S16**		**Erika oil spill hake**	
Species	***T. ovatus***	***F. commersonii***	***S. dumerili***	***D. sargus***	***M. cephalus***			
Tissue	Muscle	Muscle	Muscle	Muscle	Muscle		Muscle	Liver
	.	.	.				Range	Range .
***EPA HAP (µg/kg d.w.)**	8.45	4.13	2.88	4.64	32.03		6.2 – 14.4	21 – 108
**** WHO PAH (µg/kg d.w.)**	0.31	0.12	0.11	0.05	1.56		0.1 – 0.5	0.1 – 0.7
benzo[*a*]pyrene (µg/kg d.w.)	0.00	0.12	0.11	0.00	0.37		0.0 – 0.1	0.0 – 0.2
AFSSA and EU advisory / regulatory criteria for PAH in fish								
			Affssa	EU MAC B(a)Py				
EPA HAP (µg/kg d.w.)			50					
WHO PAH (µg/kg d.w.)			20					
benzo[*a*]pyrene (µg/kg d.w.)				8				

*ΣEPA-PAH: 16 PAHs from the EPA list of priority PAHs: naphtalene, acenaphtylene, acenaphthene, fluorene, phenanthrene, anthracene, fluoranthene, pyrene, benz[*a*]anthracene, chrysene + triphenylene, benzo[*b*]fluoranthene + benzo[*j*]fluoranthene, benzo[*k*]fluoranthene benzo[*a*]pyrene, indeno[1,2,3-*cd*]pyrene, dibenz[a,h]anthracene, benzo[*ghi*]perylene.

**ΣWHO-PAH: 6 PAH: benz[*a*]anthracene, benzo[*b*]fluoranthene + benzo[*j*]fluoranthene, benzo[*k*]fluoranthene, benzo[*a*]pyrene, indeno[1,2,3-*cd*]pyrene, dibenz[a,h]anthracene, benzo[*ghi*]perylene.

The sample collected at site S23, located in southern Lebanon, came most probably from the area outside the influence of the oil spill. In this area there were no visible traces of the spilled oil. Two other sites (S19 and S22), were plainly located within the oil-impacted area. Indeed, the PAHs concentrations in mussels at site S23 are very low and do not show, either by their levels or by their chemical composition (fingerprints), contamination by PAHs from Jieh fuel oil (Figure 3). For instance, some set of PAHs in the mussels from the S23 site are up to 2000 times lower than the same set of compounds in the mussels at S22 site (*e.g*. for dimethl-chrysenes). This remarkable difference of PAHs concentrations in mussels living in the south and north of the Jieh site is certainly related to oil spill contamination. The compositional patterns of PAHs are also significantly different at two contaminated sites (S19, S22) showing higher relative abundances of alkyl-substituted phenanthrenes, pyrenes and chrysenes.

TABLE 9

PAH Concentrations in µg/kg Dry Weight in *Brachidontes variabilis* Tissue and AFSSA Advisory Levels for the Erika Oil Spill and EU and EPA Maximum Admissible Concentration (MAC) of Benzo [*a*] Pyrene in Mussel Tissue

Site	**S23**	**S22**	**S19**
Tissue	Mussel	Mussel	Mussel
***EPA HAP (µg/kg d.w.)**	15.93	2242.4	375.88
**** WHO PAH (µg/kg d.w.)**	4.51	1442.6	197.81
benzo[*a*]pyrene (µg/kg d.w.)	0.58	26.3	9.51
AFSSA and EU advisory / regulatory criteria for PAH in fish			
		Afssa	EU MAC B(a)Py
EPA HAP (µg/kg d.w.)		500	
WHO PAH (µg/kg d.w.)		200	
benzo[*a*]pyrene (µg/kg d.w.)			80

Furthermore, the pyrene/fluoranthene ratio changes from 0.42 in S23 site to 2.6 and 3.7 at S22 and S19 sites respectively. This ratio is about 5 in the Jieh fuel oil and can be considered as an indicator of chemical contamination of mussels by PAHs originating from Jieh oil. From this discussion, it appears that mussels from the S23 site located in the south of Lebanon may be considered as reference samples, being not contaminated by PAHs coming from the Jieh oil spill.

Six remaining samples collected from the sites covering the region to the north of Beirut up to the Syrian border are still under analysis for PAHs and trace elements.

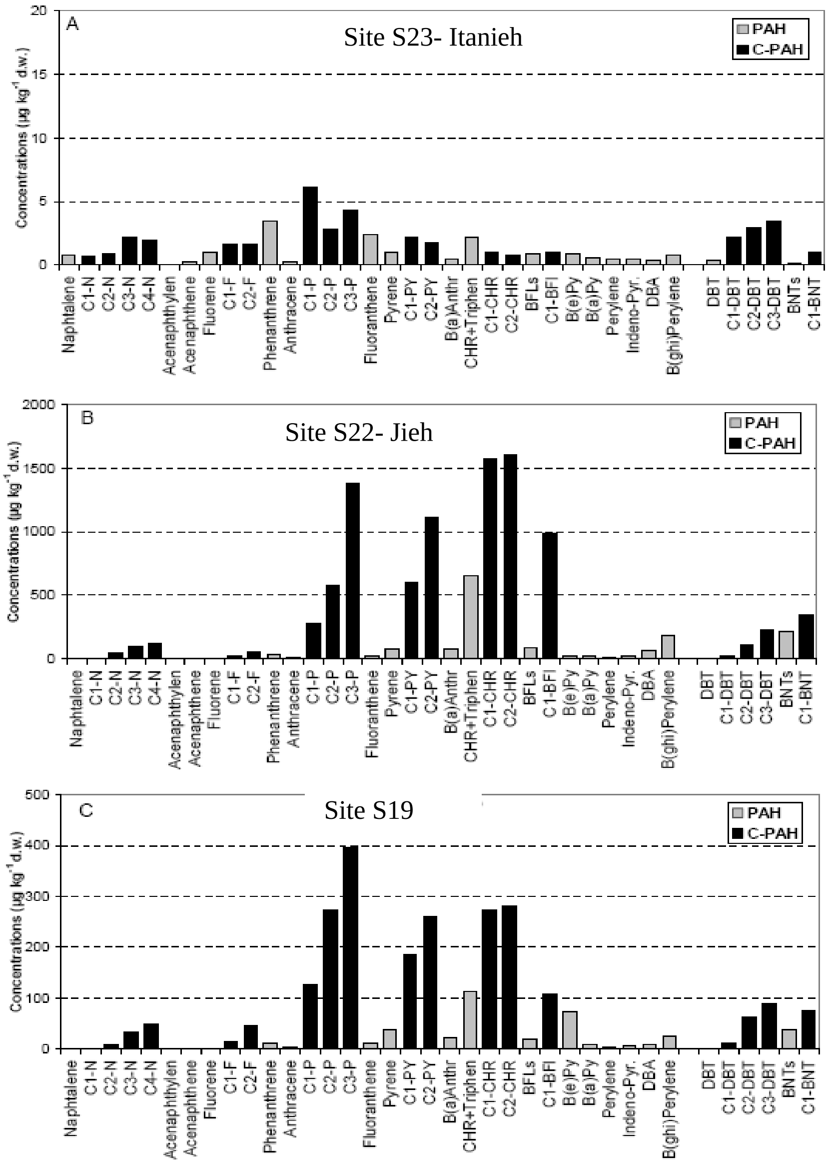

Figure 3. Chemical fingerprints of PAH and sulfur heterocyclic compounds in the three samples of mussels collected in the south of Lebanon (A, site S23 Itanieh), near the electric power plant in Jieh (B, site S22 Jieh) and in Beirut (C, site S19); note that the scales of the histogram vary.

CONCLUSION AND PERSPECTIVE

The fuel oil spilled from the Jieh power plant reservoirs has affected about 140 km of the Lebanese coast situated to the north of the spill site. Its impact on the marine ecosystem was obviously felt. The sandy beaches and vermetid terraces were the most polluted part of the coast where massive mortality of Gastropods, Crustaceans, Echinoderms, Fish and macroscopic algae was recorded, especially in the moderately and heavily polluted sites.

Volatile compounds have completely disappeared from the fuel oil sampled two months after the spill date on a basis of 15 days, but a relative abundance of methyl phenanthrene/anthracene was observed and the concentration of the 16 PAHs most toxic compounds was higher than those found in both the Erika and Prestige accidents.

Hydrobiological components of water suffered and presented notable modifications one month after the oil spill; the nitrate and nitrite ion levels increased in the most analyzed sites along with a disturbance of the phytoplanktonic population expressed by the destruction of cell organelles and the disappearance of chloroplast in most of them. This situation seems to be returning to normal since October 2006.

The meiobenthic fauna has been also affected by the oil spill impact, especially on the sandy beaches exposed to wave movement and constantly polluted by fuel oil. At 10 meters depth, the meiobenthic community seemed not to be affected.

The five species of fish collected from different sites exhibit PAHs concentrations less than the maximum admissible concentration recommended by AFSSA, WHO and EPA. This can be explained by the ability of fish to metabolise PAHs, which is why we chose to analyze a native species of mussel, *Brachidontes variabilis,* considered by several studies as a good quantitative bio-indicator. The mussels collected from the site situated to the south of the spill area presented very low levels of PAHs and therefore this site could be considered as a reference. However, the mussels from two other sites located to the north of the spill site were highly contaminated by PAHs in direct relation to their distance from the Jieh power plant.

Low concentration of PAHs in fish muscle does not indicate absence of ecological/physiological/biochemical pressures that the marine organisms suffered in the oil spill areas. Therefore, the ecological consequences and the damage to natural resources of the marine ecosystems resulting from oil spills are considered in individual studies. This was demonstrated in our case by the deep impact of the fuel oil spill on the phytoplankton and meiobenthic communities and the high contamination levels found in mussels whereas we did not observe alarming concentrations in fish muscles. For this reason, a long-term monitoring plan is underway in cooperation with Ifremer-France, Icram-Italie and other institutions worldwide. This project will allow us to observe long-term trends in order to return to normal conditions.

ACKNOWLEDGMENT

This was a collaborative study between CNSM - CNRSL and IFREMER-France, financially supported by both organizations. We are thankful to all colleagues at CNSM and LBCO who assisted in field and laboratory. Special thanks for Lebanese National Navy.

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