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Long-Term Programme for Pollution Monitoring and Research
in the Mediterranean Sea (MED POL - PHASE II)

REPORT ON THE IOC/UNEP MUSSEL HOMOGENATE INTERCALIBRATION EXERCISE
FOR PETROLEUM HYDROCARBONS (Mediterranean region)

In co-operation with:



INTERGOVERNMENTAL OCEANOGRAPHIC COMMISSION

C O N T E N T S

	<u>Page</u>
BACKGROUND	1
INTRODUCTION	2
PREPARATION OF MUSSEL HOMOGENATE SAMPLES	2
STANDARDS	3
METHODS	3
DISTRIBUTION OF SAMPLE KITS	3
RESULTS	4
Ultraviolet Fluorescence Spectrometry	4
Gas Chromatography	4
Gravimetry	5
DISCUSSION	5
APPENDIX A: Working Secondary Standards	

BACKGROUND

As part of the Long-term Programme for Pollution Monitoring and Research in the Mediterranean Sea (MED POL - PHASE II), an intercalibration exercise was to be organised by the secretariat in collaboration with the Intergovernmental Oceanographic Commission (IOC) for the analysis of petroleum hydrocarbons in environmental samples.

Since a global exercise was being organised jointly by the IOC and the International Commission for the Exploration of the Sea (ICES), the resources of the MED POL programme joined those made by the two organisations and as a result a Mussel Homogenate Intercomparison Exercise was carried out.

Preparation of the samples and review of the results were done under contract with IOC by the Bermuda Biological Station (BBS) and the Woods Hole Oceanographic Institution (WHOI).

The present document contains the report submitted to the IOC by Anthony H. Knap, Director, Marine Atmospheric Programme and John W. Farrington, W.H.O.I..

INTRODUCTION

The need for quality control and intercalibration of chemical pollutants is an essential part of any regional or global monitoring programme. Within the International Oceanographic Commission (IOC) countries, data have been reported and collected, but there has not been a major intercomparison of petroleum hydrocarbon measurements in marine environmental samples. The Group of Experts for Methods, Standards, and Intercomparison (GEMSI) has called for an intercalibration exercise for the analysis of petroleum hydrocarbons in seawater. This analysis has been delayed due to the lack of funding but will be carried out in Bermuda in late 1984. The impracticality of mailing seawater samples, however, has ruled out an international intercalibration exercise of this type.

GEMSI felt that an intercomparison exercise was still necessary to determine the state of analytical expertise in certain geographical areas. Since a co-operative research agreement exists between the IOC and the International Council for the Exploration of the Sea (ICES), a joint exercise was proposed. The ICES Marine Chemical Working Group was scheduled to carry out the second round of an intercalibration exercise involving the determination of petroleum hydrocarbons in biological tissue. The groups felt that a joint exercise would be mutually advantageous. The full IOC/ICES report is forthcoming and involved contacting 267 laboratories. One hundred and twenty-two laboratories replied; 91 sample kits were sent out, and 47 laboratories submitted data.

This report discusses the response and data for the participating laboratories from the MED POL region. Within that area, 129 laboratories were contacted and 34 replied. Sample kits were sent to the 22 laboratories that requested them. To date, 12 have submitted data, and one investigator has reported that he was unable to complete the analysis. Ninety-five laboratories did not respond. It should be stated that all laboratories having any ability to carry out analytical chemistry were contacted. So, as with other similar exercises, the number of laboratories actually submitting data was low. Approximately 9.3% of the laboratories contacted were able to analyse the samples.

PREPARATION OF MUSSEL HOMOGENATE SAMPLES

Approximately 4,000 mussels, *Mytilus edulis*, were collected near a sewage outfall of Deer Island, Massachusetts. The mussels were shucked and homogenised, and the liquid and solid material was freeze-dried in batches. These batches were then combined and rehomogenised. Samples of the mussel homogenate, 5 to 6 g dry weight, were drawn into clean glass jars for distribution to the exercise participants. These jars were randomly numbered, although a record of the order in which they were drawn has been kept. Three randomly selected jars were sent to each participant who requested them. Homogeneity was assessed by randomly selecting two sets of five jars and analysing them by gas chromatography.

STANDARDS

N-Alkanes - a sealed ampoule containing a mixture of n-alkanes and androstane in methylene chloride was included to be used for G.C. detector response calibration. Concentrations were in the range of 4.8 to 6.9 ng/ l. The actual concentrations are given in Table 1 of Appendix A.

Chrysene - the MARPOLMON measurement procedure (UNESCO) requires the use of chrysene as a primary standard. Each sample kit contained an ampoule of chrysene.

Aromatics - a sealed ampoule containing a mixture of aromatic compounds in methylene chloride was also included. Concentrations ranged from 0.9 to 3.5 ng/ l. A detailed list is presented in Table 2 of Appendix A.

Reference oil - an ampoule of reference oil was also provided. This is an Arabian Light Crude oil obtained via the courtesy of the U.S. E.P.A. and the American Petroleum Institute. It was provided in order to calibrate the U.V. fluorescence measurements in terms of oil equivalents as well as chrysene equivalents.

METHODS

A Mussel Watch report describing some methods for analysing a mussel homogenate and a full set of instructions for reporting data were included in the sample kit mailed to each participating laboratory. Participants were urged to analyse the entire homogenate subsample of each jar separately to minimize subsampling artifacts. If desired, one subsample could be used for preliminary analysis, but laboratories were requested to analyse at least two of the subsamples and report results for these duplicates.

The protocol for the exercise asked the laboratories to provide a description of their analytical methods, including extraction and isolation procedures, analytical instrument operating parameters and calibration, the sources for the chemicals and calibration standards used, blank and recovery values, and how precision and accuracy were determined. If U.V. -fluorescence analyses were conducted, participants were requested to use the IOC Marine Pollution Monitoring Programme (MARPOLMON) procedure for seawater extracts in addition to the procedure routinely employed in their laboratories. Data were to be reported both in terms of chrysene equivalents and Arabian Light Crude Oil equivalents. If gas chromatography, high pressure liquid chromatography, or gas chromatography mass spectrometry was used, the protocol requested that copies of the standard and sample chromatograms and of representative mass spectra be submitted with the report.

DISTRIBUTION OF SAMPLE KITS

Sample kits were sent by air after request from the participating laboratories.

RESULTS

Original estimates predicted that 15 laboratories from the MEDPOL region would participate in the intercalibration exercise. We received data from 12 laboratories including some French laboratories which are not actually sited on the Mediterranean. They have been included in the report for this region, however, because they have been carrying out measurements in the Mediterranean and have an active interest in the area. Two laboratories requested kits after the deadline date. The kits have now been sent, and when the analysis is complete, their data will be appended to the report. Eight laboratories analysed n-alkanes by gas chromatography. Four of the laboratories reported data on the aromatic fraction and quantitated individual aromatic hydrocarbons. Nine laboratories measured total hydrocarbons by fluorescence spectrophotometry. Only one laboratory reported data by using high pressure liquid chromatography. None utilized gas chromatography mass spectrometry of infrared and ultraviolet spectrometry.

Ultraviolet Fluorescence Spectrometry

Nine laboratories utilized ultraviolet fluorescence spectrometry at the MARPOLMON wavelengths to analyse total hydrocarbons. They reported concentration differences related to calibration techniques. The results in terms of Arabian Light Crude Oil Equivalents are given in Table 1. They show a range of 30 to 658 g/g dry weight and a mean of 195 g/g with a coefficient of variation of 103%. Removal of Laboratory No. 12 from the group reduces the mean to 137 g/g dry weight and the coefficient of variation to 81%. When chrysene was used as the calibration mixture (Table 2), the total hydrocarbon concentrations ranged from 4.4 to 45.0 g/g dry weight. The average of the nine laboratories was 16.7 g/g dry weight as chrysene equivalents with a coefficient of variation of 82%. The precision of each laboratory was reported to be quite good in terms of chrysene equivalents with coefficients of variation ranging from 6% to 53%. The precision was somewhat better using crude oil equivalents and ranged from 8% to 24%.

Gas Chromatography

Eight laboratories reported gas chromatographic data. Laboratories No. 2 and 7 analysed only one subsample, and Laboratory No. 4 reported the averages and standard deviations for the three subsamples but did not provide the individual subsample data. The available subsample data from each laboratory is listed separately in Table 3 , and then synthesized in Table 4. Generally, the laboratories were more precise in determining the higher molecular weight components (i.e., C₂₀). The average coefficient of variation for all n-alkanes for all laboratories was 91%. When outliers were discarded, it dropped to 53%.

Pristane and phytane were analysed by all laboratories except No. 3. For the other laboratories, the coefficients of variation for pristane and phytane were 98% and 90%, respectively. These values were quite close to the n-alkane average coefficient of variation, 91%. The coefficient for pristane dropped to 60% when the outlier was discarded. Two laboratories, Nos. 2 and 6, did not provide data on the Unresolved Complex Mixture (UCM). The quantitation by the other six laboratories, however, was fairly constant with a 72% coefficient of variation.

Four laboratories analysed the individual aromatic hydrocarbons (Table 5). However, the only aromatics measured by all four laboratories were phenanthrene, anthracene, and fluoranthene. Reported phenanthrene concentrations ranged from 300 to 560 ng/g dry weight and were quite consistent showing a coefficient of variation of 25%. There was a fairly wide variation in anthracene concentrations, however, with a range of 37 to 920 ng/g dry weight. Removal of the outlier, Laboratory No. 4, dropped the coefficient of variation considerably from 157% to 60%. Fluoranthene concentrations varied from 57 to 240 ng/g dry weight with a coefficient of variation of 57%.

The recovery data using the internal standard were somewhat ambiguous (Table 6). Only two laboratories, Nos. 5 and 6, indicated recovery in the range of 86% to 108%. Two laboratories stated that their results had been corrected, and four did not mention the internal standard.

Gravimetry

Only two laboratories, Nos 1 and 8, performed gravimetric analysis (Table 7). The coefficient of variation for the two was 49%.

DISCUSSION

The response from Mediterranean laboratories was not as good as had been hoped. Twelve laboratories, or 55% , submitted data out of the 22 that originally agreed to participate. In the first round of the ICES inter-calibration exercise, 72% of the participants were able to submit data. Many MEDPOL laboratories, however, indicated that they were just beginning to analyse petroleum hydrocarbons in tissue. Some still required staff training, and others were experiencing equipment problems, as well as financial constraints. It appears that there is an encouraging trend towards the improvement of analytical capabilities in the region.

Ultraviolet fluorescence was the analytical method chosen by ten of the twelve MEDPOL laboratories submitting data; it was surprising, however, that 67% of the respondents quantitated by gas chromatography as well. In contrast, seven laboratories in round one of the ICES exercise analysed a mussel homogenate for total hydrocarbons by UVF, and two others used gas chromatography, but none used both methods. The coefficient of variation for the seven ICES laboratories using UVF was 51% as compared to 81% for this exercise.

A significant outcome of the exercise is that a great many laboratories have now been identified in the Mediterranean area. Responses indicate that more and more of these laboratories are going to be willing and able to participate in similar exercises in the future. As far as pollution monitoring is concerned - the results reported have a confidence limit of about 80% for a polluted mussel. This should be borne in mind when designing and interpreting results of any future pollution monitoring programmes.

Table 1. Total hydrocarbon analysis by U.V. fluorescence
EPA/API Arabian Light Crude Oil Equivalents
(10^{-6} g/g dry weight)

Laboratory No.	No. of Samples	Av. \pm s.d.	C.V. %
1	2	336 \pm 1	
2	1	80	
3	2	101	
4	3	116 \pm 17	15
5	3	285 \pm 36	13
8	3	92 \pm 7	8
9	2	58 \pm 19	
11	2	30	
12	3	658 \pm 159	24
Average of 9 Laboratories		195 \pm 202	103
Average Excluding Laboratory No. 12		137 \pm 111	81

Table 2. Total hydrocarbon analysis by U.V. Fluorescence
Chrysene equivalents
(10^{-6} g/g dry weight)

Laboratory No.	No. of Samples	Av. \pm s.d.	C.V. %
1	2	27.5 \pm 0.1	
2	1	6.0	
3	2	12.4 \pm 1.0	
4	3	27.8 \pm 4.0	14
5	3	45.0 \pm 2.5	6
8	3	9.9 \pm 1.0	10
9	2	4.4 \pm 1.4	
10	3	9.8 \pm 5.2	53
11	2	7.2 \pm 1.5	
Average of 9 Laboratories		16.7 \pm 13.7	82

Table 3. N-alkane analysis by gas chromatography
(10⁻⁹ g/g dry weight)

Alkane No	Laboratory No. 1		Laboratory No. 2		Laboratory No. 3				
	Av. ±	s.d.	Av. ±	s.d.	Av. ±	s.d.			
n-C ₁₅	1879	1292	2411	1861 ± 560	350	690	440	565 ± 177	(31)
n-C ₁₆	16130	2804	3662	7532 ± 7458	370	570	340	455 ± 163	(36)
n-C ₁₇	3379	3811	4364	3851 ± 494	538	620	440	530 ± 127	(24)
n-C ₁₈	3556	4944	5023	4508 ± 825	229	900	310	605 ± 417	(69)
n-C ₁₉	1538	3071	2936	2515 ± 849	170	3100*	2450*	2775 ± 460	(17)
n-C ₂₀	1573	2479	1096	1716 ± 703	110	4290*	3710*	4000 ± 410	(10)
n-C ₂₁	864	1287	1264	1138 ± 238	100	330	280	305 ± 35	(12)
n-C ₂₂	788	548	689	675 ± 121	250	600	490	545 ± 78	(14)
n-C ₂₃	719	469	1007	732 ± 269	160	830	700	765 ± 92	(12)
n-C ₂₄	381	1208	249	613 ± 520	180	640	440	540 ± 141	(26)
n-C ₂₅	510	1134	787	810 ± 313	300	880	720	800 ± 113	(14)
n-C ₂₆	273	691	306	423 ± 232	160	520	430	475 ± 64	(13)
n-C ₂₇	147	279	68	165 ± 107	180	450	440	445 ± 7	(2)
n-C ₂₈	63	438	390	297 ± 204	150	520	530	525 ± 7	(1)
n-C ₂₉	96	132	74	101 ± 29	300	550	570	560 ± 14	(3)
n-C ₃₀	575	388	237	400 ± 169	250	330	360	345 ± 21	(6)
pristane	1390	1220	1320	1310 ± 85	123	---	---	---	---
phytane	660	1070	1170	967 ± 270	65	---	---	---	---
UCM (10 ⁻⁶ g/g)	528	408	428	455 ± 64	---	456	456	456	---

* Interferences Reported

Table 3 (Continued). N-alkane analysis by gas chromatography
(10⁻⁹g/g dry weight)

Alkane No	Laboratory No. 4 Av. ± s.d.	C.V. %	Laboratory No. 5	Av. ± s.d.	C.V. %	Laboratory No. 6 Av. ± s.d.	C.V. %
n-C ₁₅	180 ± 30 (17)	(17)	380	730	670	531	449 ± 116 (26)
n-C ₁₆	200 ± 15 (8)	(8)	280	650	540	557	443 ± 161 (36)
n-C ₁₇	370 ± 10 (3)	(3)	360	610	720	566	501 ± 92 (18)
n-C ₁₈	250 ± 30 (12)	(12)	200	420	360	649	632 ± 24 (4)
n-C ₁₉	270 ± 20 (7)	(7)	170	270	310	112	137 ± 35 (25)
n-C ₂₀	240 ± 50 (21)	(21)	120	310	310	264	284 ± 28 (10)
n-C ₂₁	150 ± 10 (7)	(7)	330	780	720	162	199 ± 52 (26)
n-C ₂₂	210 ± 30 (14)	(14)	360	850	670	242	239 ± 5 (2)
n-C ₂₃	140 ± 20 (14)	(14)	180	400	450	264	267 ± 4.2 (2)
n-C ₂₄	190 ± 20 (11)	(11)	170	360	380	186	183 ± 4.2 (2)
n-C ₂₅	160 ± 20 (13)	(13)	230	490	430	187	243 ± 78 (32)
n-C ₂₆	200 ± 5 (3)	(3)	240	290	360	170	170 (2)
n-C ₂₇	150 ± 10 (7)	(7)	100	270	320	245	232 ± 19 (8)
n-C ₂₈	260 ± 30 (12)	(12)	140	310	280	208	196 ± 17 (9)
n-C ₂₉	190 ± 20 (11)	(11)	240	410	410	318	290 ± 40 (14)
n-C ₃₀	110 ± 10 (9)	(9)	210	400	320	---	---
pristane	160 ± 10 (6)	(6)	130	230	250	289	291 ± 2.1 (1)
phytane	160 ± 10 (6)	(6)	170	270	310	836	795 ± 59 (7)
UCM (10 ⁻⁶ g/g)	91 ± 7 (8)	(8)	364	427	395	---	---

* Individual Sample Results Not Reported/ Average of 3 Samples

Table 3 (Continued). n-Alkane analysis by gas chromatography
(10⁻⁹g/g dry weight)

Alkane No.	Laboratory No. 7	Laboratory No. 8			C.V. %	
		Av.	±	s.d.		
n-C ₁₅	1560	485	730	850	688 ± 186	(27)
n-C ₁₆	770	395	654	568	539 ± 132	(24)
n-C ₁₇	770	624	846	957	809 ± 170	(21)
n-C ₁₈	1200	181	294	100	192 ± 97	(51)
n-C ₁₉	1270	149	191	94	145 ± 49	(34)
n-C ₂₀	880	160	147	82	130 ± 42	(32)
n-C ₂₁	710	261	228	86	192 ± 93	(48)
n-C ₂₂	1170	320	331	155	269 ± 99	(37)
n-C ₂₃	470	171	164	99	145 ± 40	(27)
n-C ₂₄	800	160	186	123	156 ± 32	(20)
n-C ₂₅	610	208	257	271	245 ± 33	(14)
n-C ₂₆	420	107	164	120	130 ± 30	(23)
n-C ₂₇	400	*	142	132	137 ± 7	(5)
n-C ₂₈	1240	117	153	130	133 ± 18	(14)
n-C ₂₉	940	142	255	263	220 ± 68	(31)
n-C ₃₀	660	*	196	164	180 ± 23	(13)
pristane	570	272	460	248	327 ± 116	(36)
phytane	1370	278	287	185	250 ± 56	(23)
UCM	1100	260	307	368	312 ± 54	(17)

* Interferences Reported

Table 4. Mean N-Alkane concentrations
(10-9 g/g dry weight)

Alkane No	Lab 1	Lab 2	Lab 3	Lab 4	Lab 5	Lab 6	Lab 7	Lab 8	All Labs		Excluding Outliers	
									Av. \pm s.d.	C.V. %	Av. \pm s.d.	C.V. %
n-C ₁₅	1861 ^m	350	565	180	593	449	560	688	656 \pm 512	(78)	483 \pm 172 ^m	(36)
n-C ₁₆	7532 ^m	370	455	200	490	443	770	539	1350 \pm 2503	(185)	466 \pm 173 ^m	(37)
n-C ₁₇	3851 ^m	538	530	370	563	501	770	809	992 \pm 1164	(117)	583 \pm 154 ^m	(27)
n-C ₁₈	4508 ^m	229	605	250	326	632	1200*	192	993 \pm 1459	(147)	372 \pm 196 ^m	(53)
n-C ₁₉	2515 ^m	170	2775*	270	250	137	1270*	145	942 \pm 1118	(119)	194 \pm 62 ^{m*}	(32)
n-C ₂₀	1716 ^m	110	4000*	240	246	284	880	130	951 \pm 1348	(142)	315 \pm 285 ^{m*}	(91)
n-C ₂₁	1138 ^m	100	305	150	610	199	710	192	426 \pm 363	(85)	323 \pm 240 ^m	(74)
n-C ₂₂	675	250	545	210	626	239	1170*	269	498 \pm 331	(66)	402 \pm 204 ^m	(51)
n-C ₂₃	732	160	765	140	343	267	470	145	411 \pm 256	(62)		
n-C ₂₄	613	180	540	190	303	193	800	156	371 \pm 247	(67)		
n-C ₂₅	810	300	800	160	383	243	610	245	444 \pm 260	(59)		
n-C ₂₆	423	160	475	200	296	170	420	130	284 \pm 138	(49)		
n-C ₂₇	165	180	445	150	230	232	400	137	242 \pm 117	(48)		
n-C ₂₈	297	150	525	260	243	196	1240 ^m	133	381 \pm 368	(97)	258 \pm 132 ^m	(51)
n-C ₂₉	101	300	560	190	353	290	940 ^m	220	369 \pm 267	(72)	288 \pm 146 ^m	(51)
n-C ₃₀	400	250	345	110	310	--	660	180	322 \pm 179	(55)		
pristane	1310 ^m	123	---	160	203	291	570	327	426 \pm 417	(98)	299 \pm 162	(60)
phytane	967	65	---	160	250	795	1370	250	551 \pm 496	(90)		
UCM (10 ⁻⁶ g/g)	455	---	456	91	395	---	1100	312	468 \pm 338	(72)		

^m Excluding Lab 1

* Excluding Lab 3

' Excluding Lab 7

Table 5. Aromatic hydrocarbon analysis by gas chromatography
(10^{-9} g/g dry weight)

Aromatic Hydrocarbons	Lab 2	Lab 3 (GC/HPLC)	Lab 4	Lab 8	Av.	\pm	s.d.	C.V. %
naphthalene	---	---	---	63				
C ₁ -naphthalene	---	---	---	93				
C ₂ -naphthalene	---	---	---	53				
C ₃ -naphthalene	---	---	---	--				
phenanthrene	300	405/13.5	470	560	434	\pm	109	25
anthracene	100	40/4.5	920	37	274	\pm	431	157
C ₁ -phen./anthracene	120	---	890	640	550	\pm	393	71
C ₂ -phen./anthracene	270	---	---	633	452	\pm	257	57
dibenzothiophene	70	---	60	460	197	\pm	228	116
C ₁ -dibenzothiophene	90	---	---	---				
C ₂ -dibenzothiophene	310	---	120	--	215	\pm	134	62
fluoranthene	120	57	240	120	134	\pm	77	57
pyrene	90	95/66	---	240	142	\pm	85	60
benz(a)anthracene	---	15	---	10	12.5	\pm	3.5	28
chrysene	120	---	180	40	113	\pm	70	62
benzo(e)pyrene	---	---	---	---				
benzo(a)pyrene	110	9	190	---	103	\pm	91	88
benzo(b)fluoranthene	50	---	---					
benzo(k)fluoranthene	---	---	---	90				
benzo(g,h,i)perylene	---	---	---	---				
indeno(1,2,3-cd)pyrene	---	---	---	---				

Table 6. Gas Chromatography Results
 Internal Standard Table

Laboratory No.	% Recovery
1	---
2	---
3	---
4	corrected
5	greater than 90
6	80 - 108
7	---
8	corrected

Table 7. Gravimetric Analysis
 (mg/g)

Laboratory No.				Av. \pm s.d.	C.V. %
1	1143	1014	959	1039 \pm 94	(9)
8	453	590	477	507 \pm 73	(14)
Average of the 2 Laboratories				773 \pm 376	(49)

Appendix

Working Secondary Standards

The following vials and ampules have been provided to act as secondary reference standards.

- CHRYSENE - a vial containing pure chrysene to be used for U.V. - fluorescence analysis
- n-ALKANE - a sealed ampule containing a mixture of n-alkanes and Androstanein methylene chloride to be used for G.C. detector response calibration. Compounds and concentrations are listed in Table 1 of this appendix.
- AROMATICS - a sealed amber ampule containing a mixture of aromatic compounds in methylene chloride to be used for G.C. detector response calibration. Compounds and concentrations are listed in Table 2 of this appendix.

IMPORTANT NOTE: If participating analysis wish to dilute, concentrate or change solvents for use in their own laboratory, they should first determine volume of solution in each ampule. Our choice of methylene chloride (CH₂-Cl₂) was dictated by international and United States air-freight rules and regulations.

Table 1

Compound	Concentration (ng/ l)
n-C ₁₁	4.86
n-C ₁₂	4.86
n-C ₁₃	4.86
n-C ₁₄	6.44
n-C ₁₆	4.96
n-C ₁₈	4.96
Androstane	5.93
n-C ₂₀	4.96
n-C ₂₂	4.96
n-C ₂₄	4.98
n-C ₂₆	4.91
n-C ₂₈	6.86
n-C ₃₀	5.30
n-C ₃₂	4.75
n-C ₃₄	4.89
n-C ₃₆	4.75
n-C ₄₀	4.80

Table 2

Compound	Concentration (ng/ l)
Naphthalene	3.09
Tri-ethyl Benzene	1.08
1-methyl Naphthalene	1.36
Biphenyl	3.34
1-ethyl Naphthalene	1.23
2,6-dimethyl Naphthalene	1.86
Acenaphthylene	3.36
Acenaphthene	0.924
2,3,6-trimethyl Naphthalene	1.61
d ₁₀ -Fluorene	2.97
Fluorene	3.09
Dibenzothiophene	2.85
Phenanthrene	3.20
Anthracene	3.06
2-methyl Phenanthrene	2.12
1-methyl Phenanthrene	1.41
3,6-dimethyl Phenanthrene	1.95
Fluoranthene	1.00
Pyrene	3.03
d ₁₄ -Terphenyl	2.76
1-methyl Pyrene	1.55
Benzo(c)phenanthrene	3.30
Chrysen	2.99
Naphthacene	2.66*
Benzo(b)fluoranthene	2.68
Benzo(k)fluoranthene	3.47
Benz(e)pyrene	3.60
Benz(a)pyrene	3.46
Perylene	1.34
Dibenzo(a,h)anthracene	3.22
Benzo(g,h,i)perylene	3.03

* - not quantitative, compound did not completely dissolve