

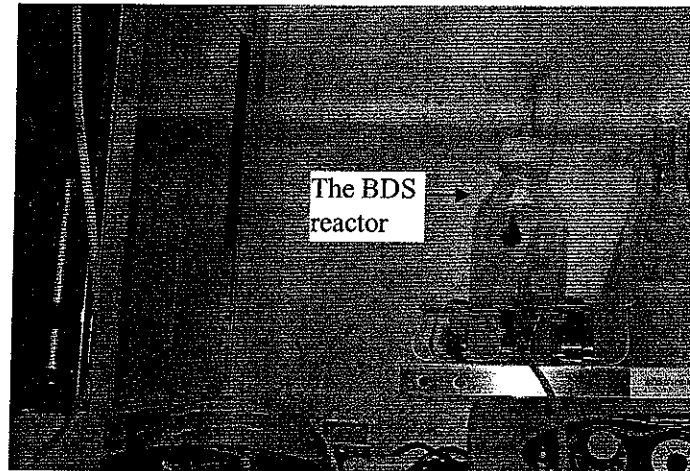


Figure 1. The setup of reactor system

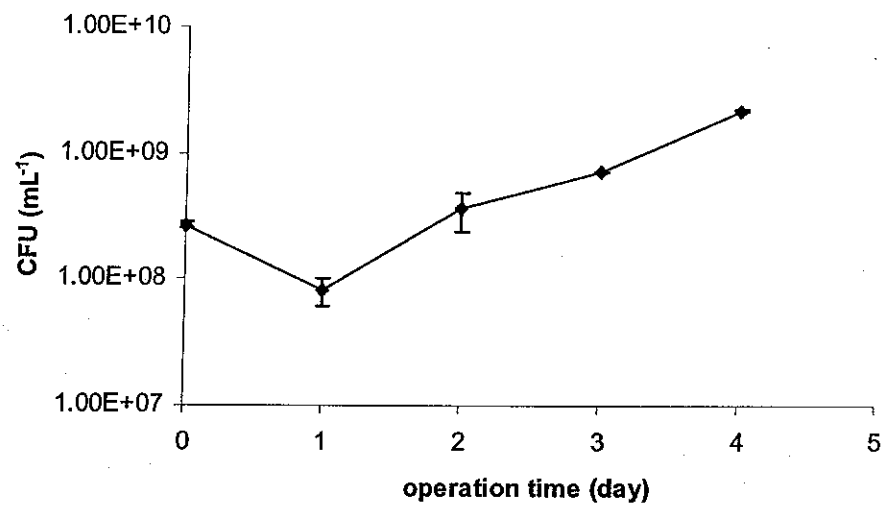


Figure 2. Change of plate counting result in the seed reactor with operation time.

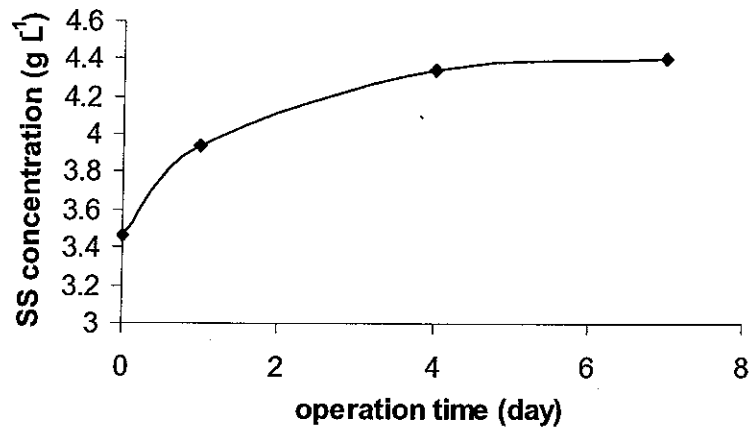


Figure 3. Change of suspended solids (SS) concentration with operation in the seed reactor.

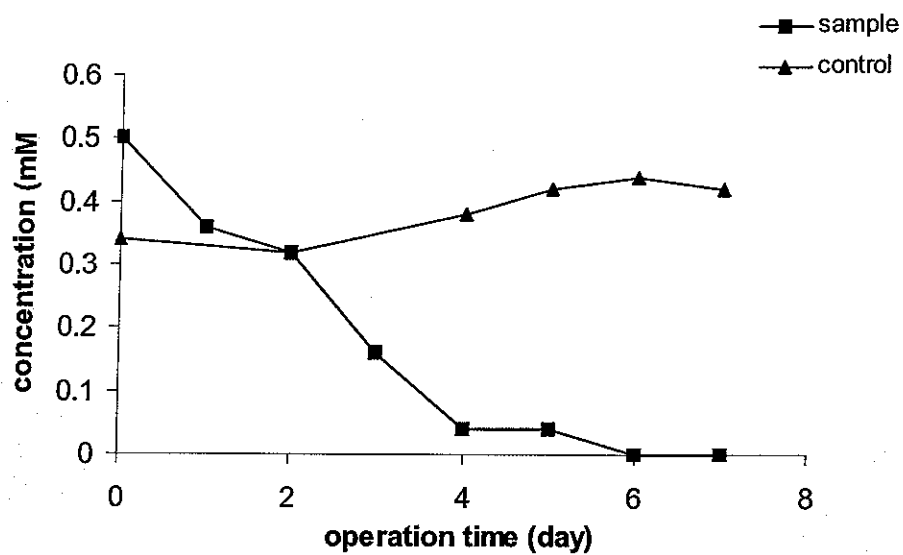


Figure 4. Change of DBT concentration in the seed and control reactor.

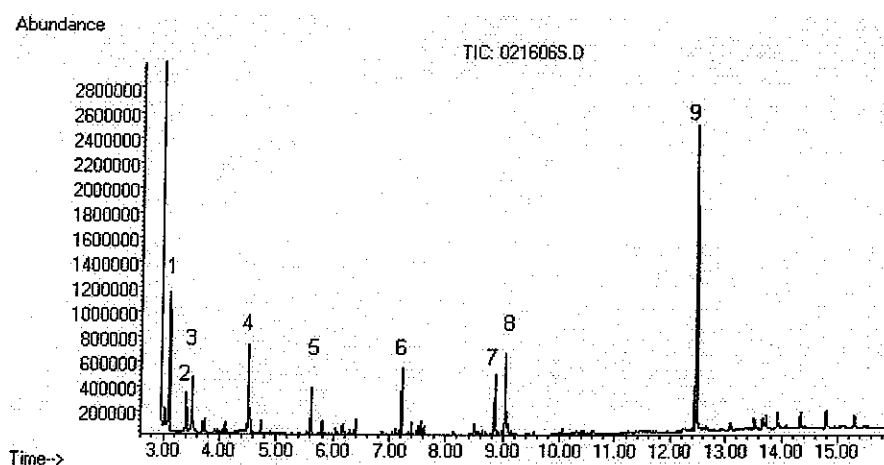


Figure 5. The GC total ion chromatograph of the n-hexane extract from the seed reactor on day 6.

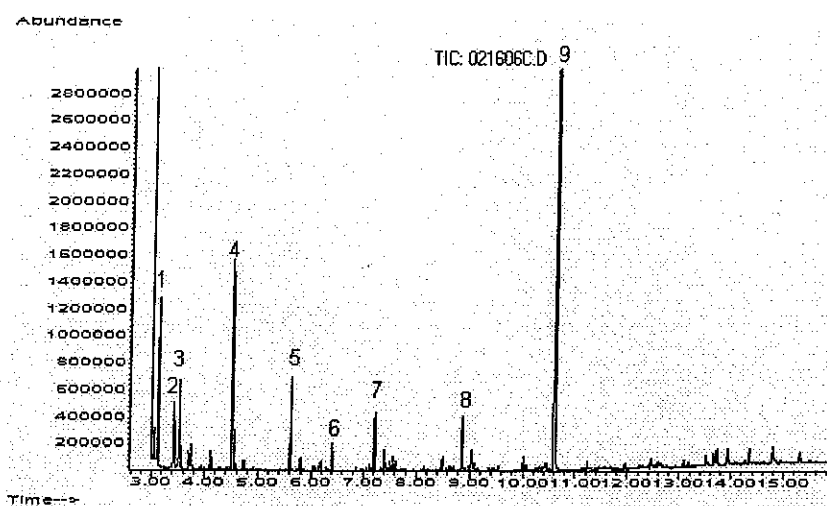


Figure 6. The GC total ion chromatograph of the n-hexane extract from the control reactor on day 6.

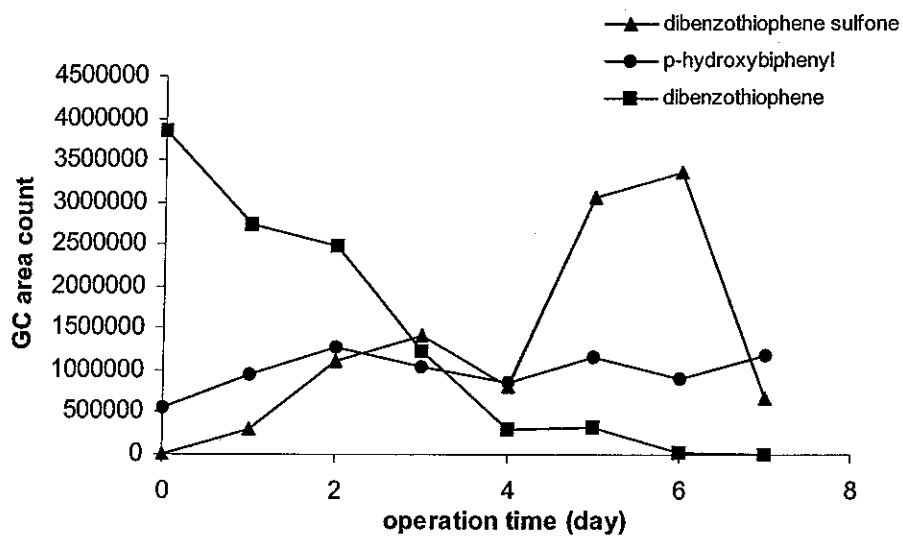


Figure 7. Change of abundance of DBT and its metabolites with operation time.

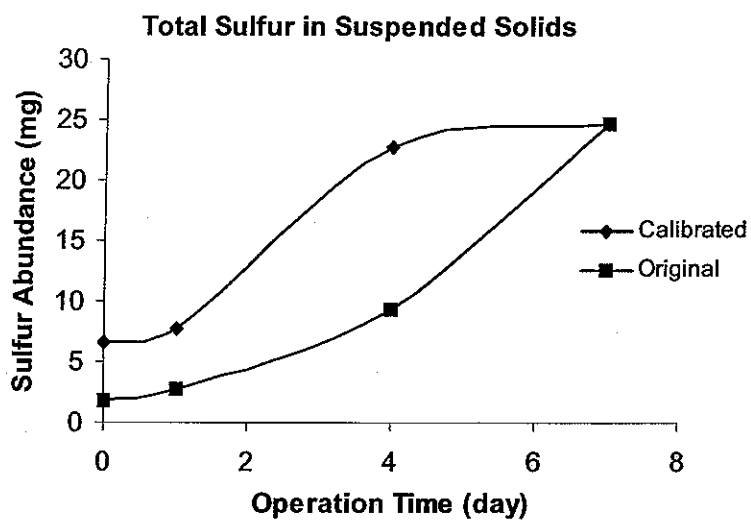


Figure 8. Total sulfur quantity in the biomass of the seed reactor.

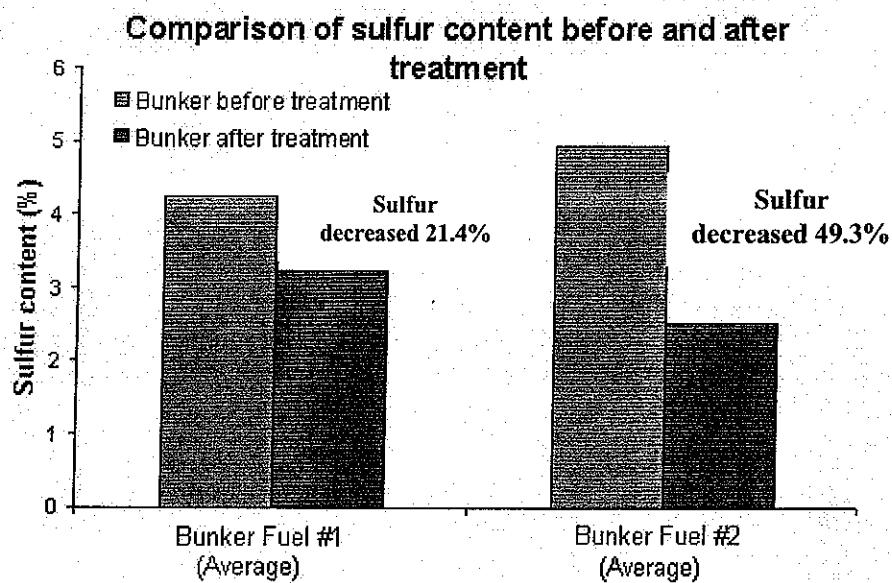


Figure 9. Comparison of the average sulfur content in bunker fuel #1 and #2 before and after treatment.

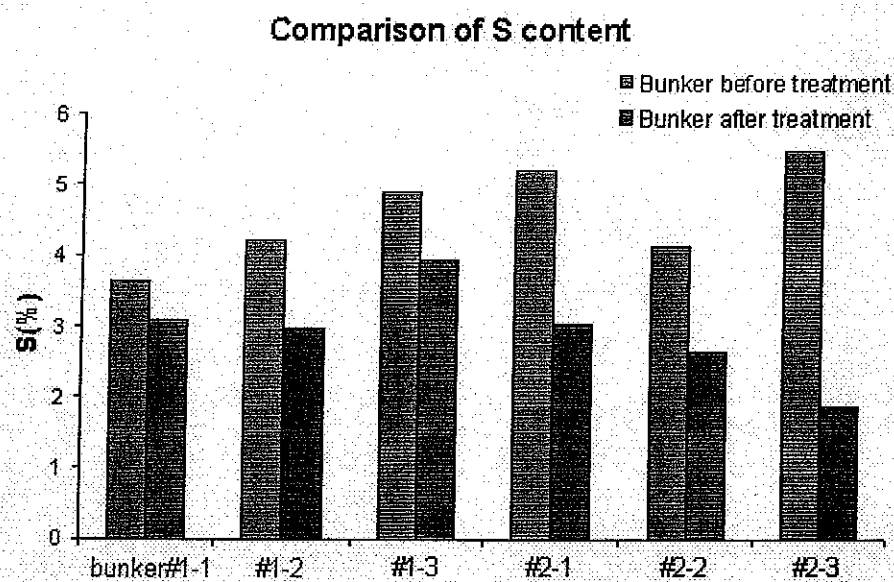


Figure 10. Comparison of the sulfur content in two bunker fuels before and after treatment.

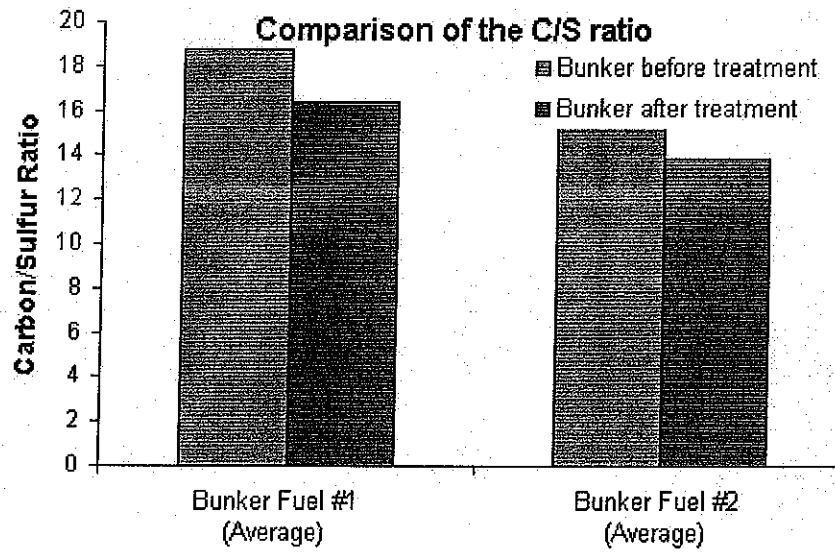


Figure 11. Comparison of the average carbon/sulfur ratio in bunker fuel #1 and #2 before and after treatment.

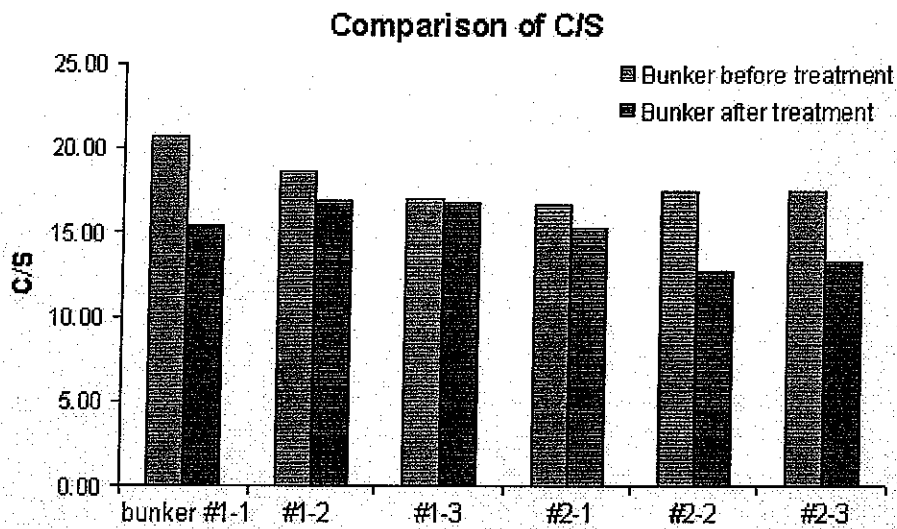


Figure 12. Comparison of the carbon/sulfur ration in bunker fuels before and after treatment.

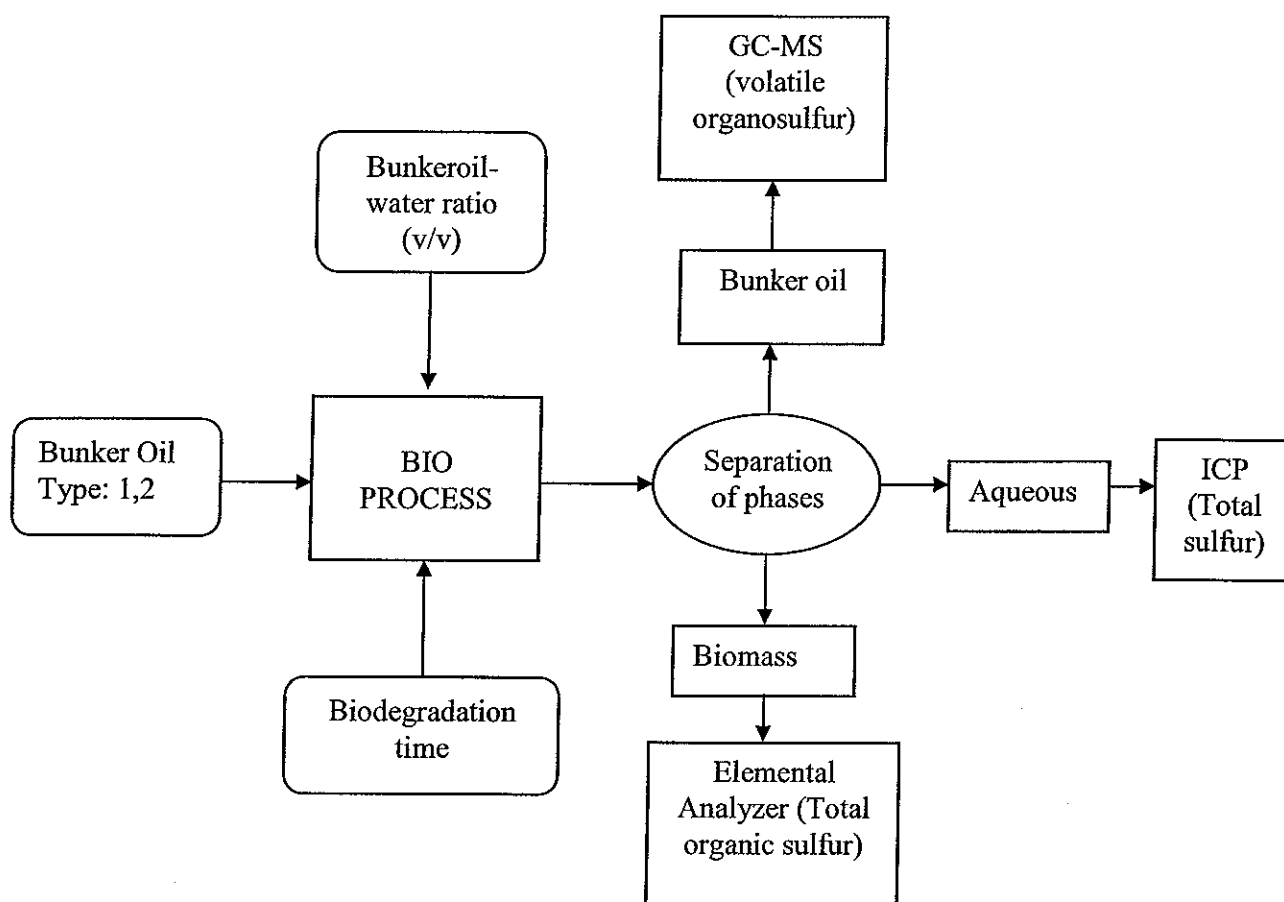


Figure 13. Schematic of experimental approach.

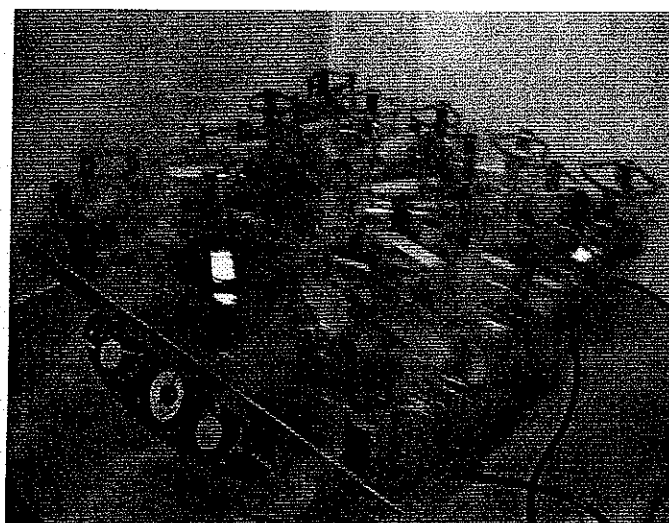


Figure 14. Schematic of the bioreactor setup.

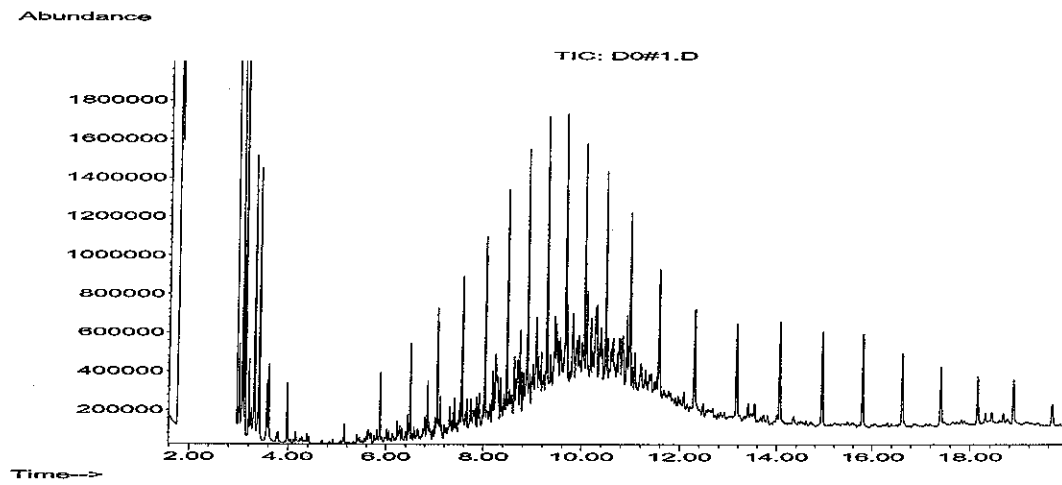


Figure 15. TIC of Bunker Oil #1 sample before bioprocess (0 hr).

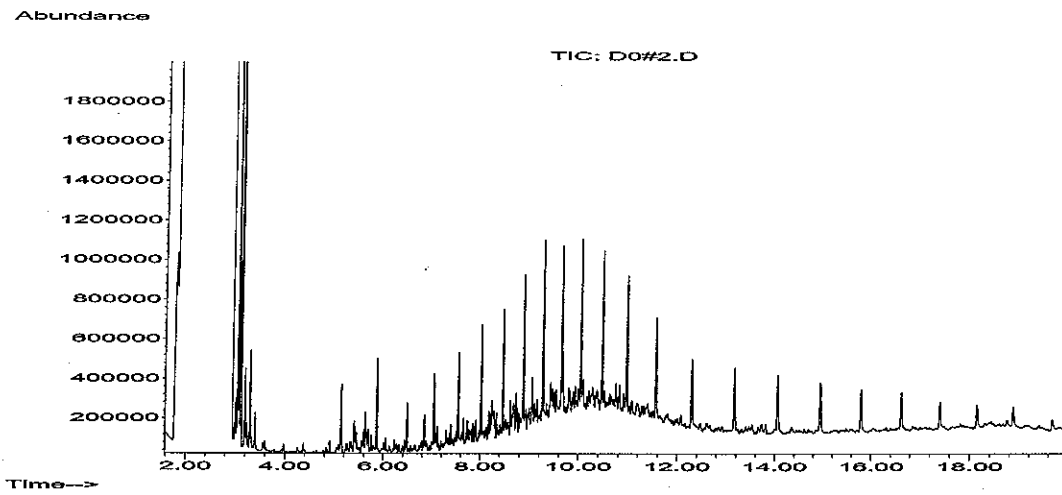


Figure 16. TIC of Bunker Oil #2 sample before bioprocess (0 hr).

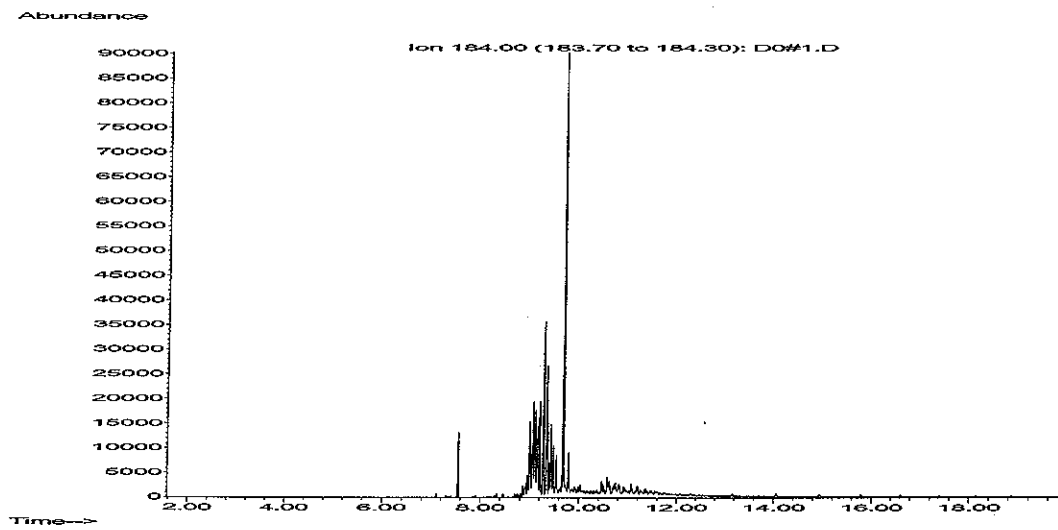


Figure 17. Extracted Ion Chromatogram for DBT in Bunker Oil#1 (0 hr).

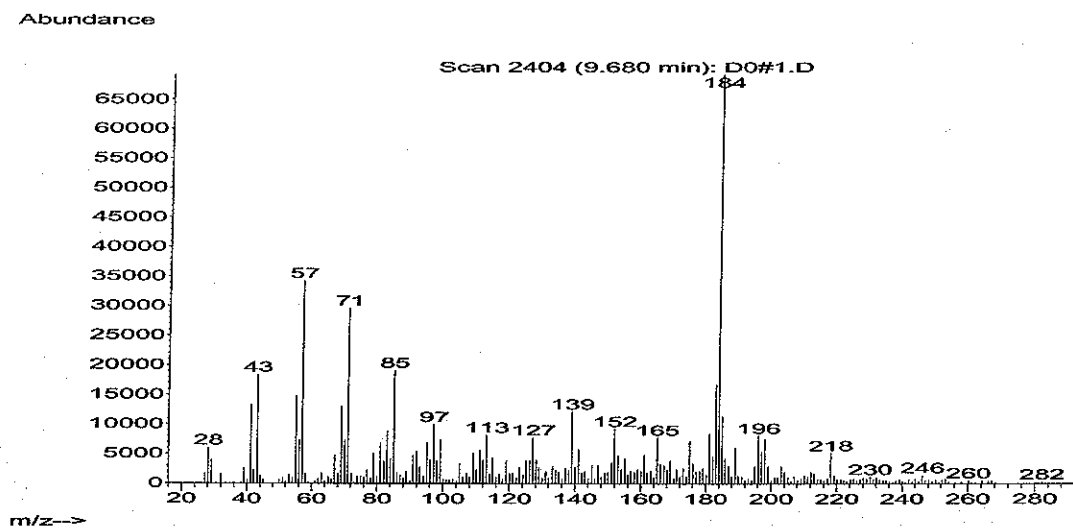


Figure 18. MS Spectra of DBT in Bunker Oil#1 (0 hr).

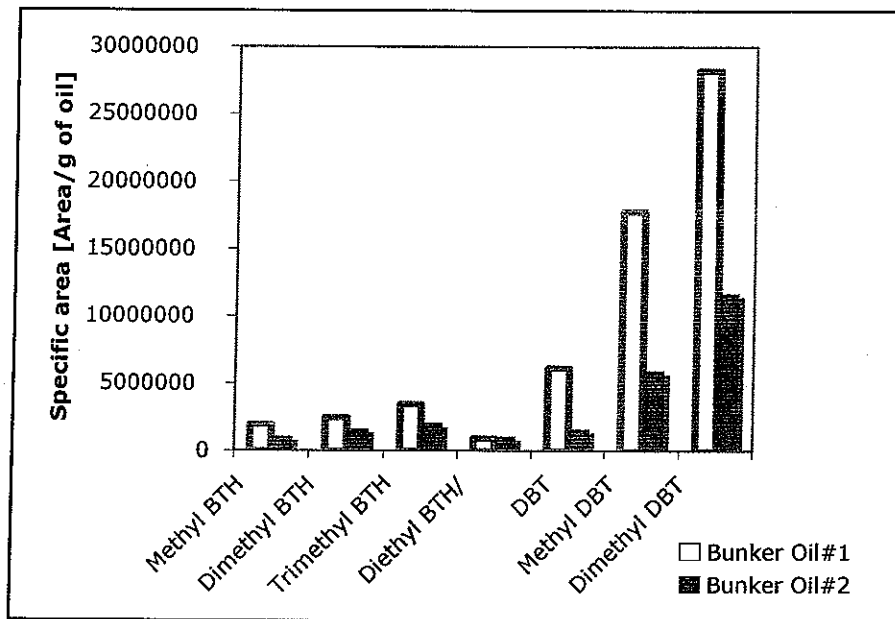


Figure 19. Comparison of intensities of organosulfur compounds in bunker oils.

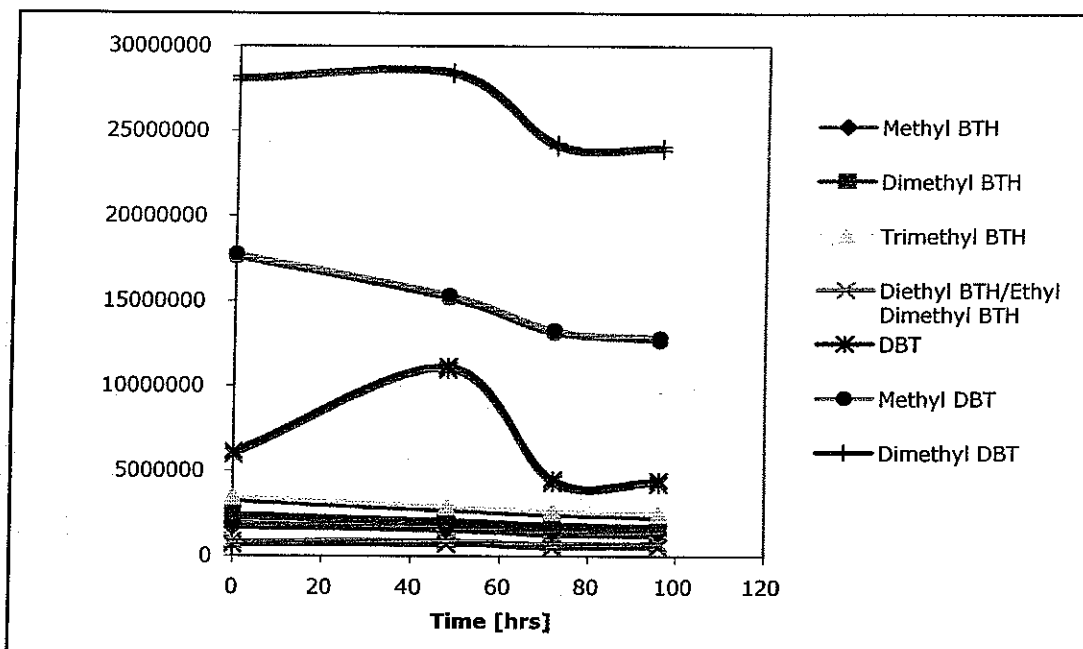


Figure 20. Change in intensity of organosulfur species over time course for Bunker Oil #1 (Vol. Oil/Water 1:3).

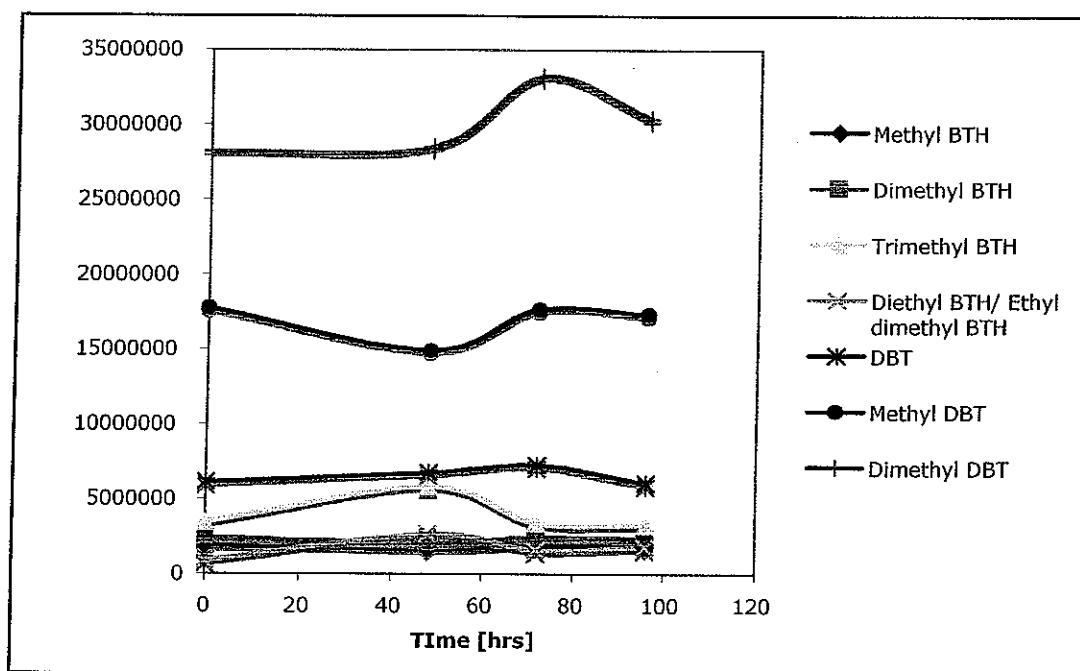


Figure 21. Change in intensity of organosulfur species over time course for Bunker Oil #1 (Vol. Oil/Water 1:10).

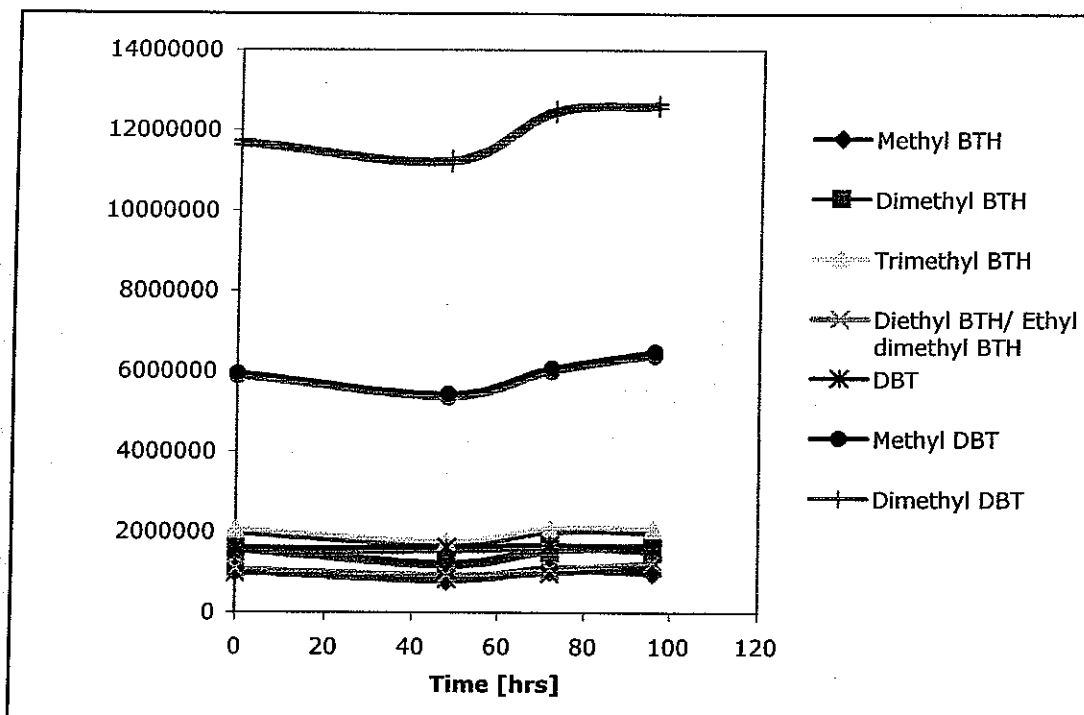


Figure 22. Change in intensity of organosulfur species over time course for Bunker Oil #2 (Vol. Oil/Water 1:3).

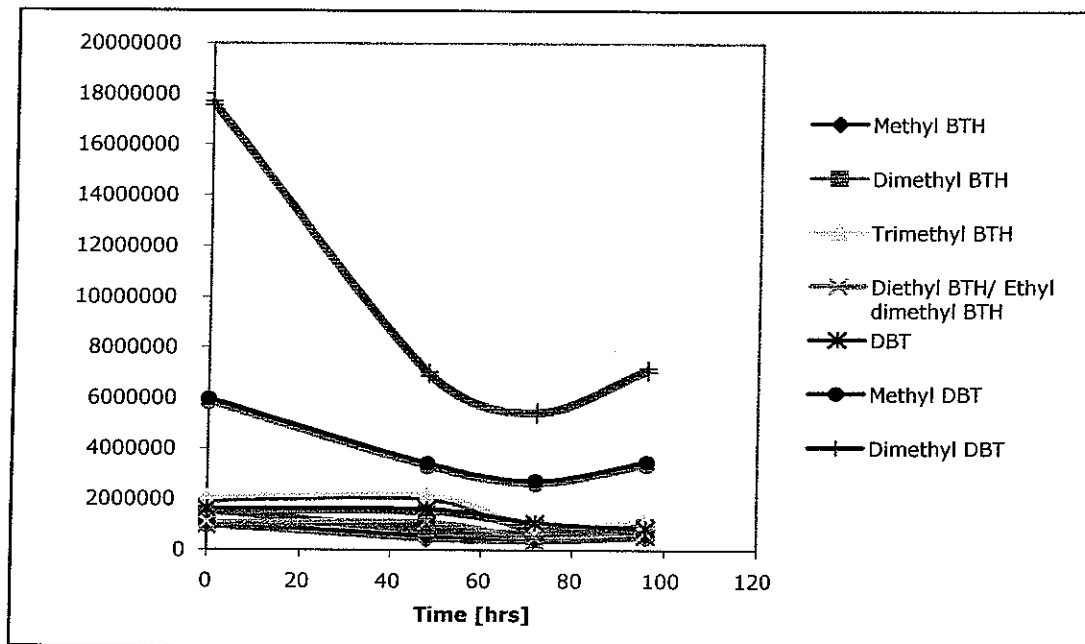


Figure 23. Change in intensity of organosulfur species over time course for Bunker Oil #2 (Vol. Oil/Water 1:10).

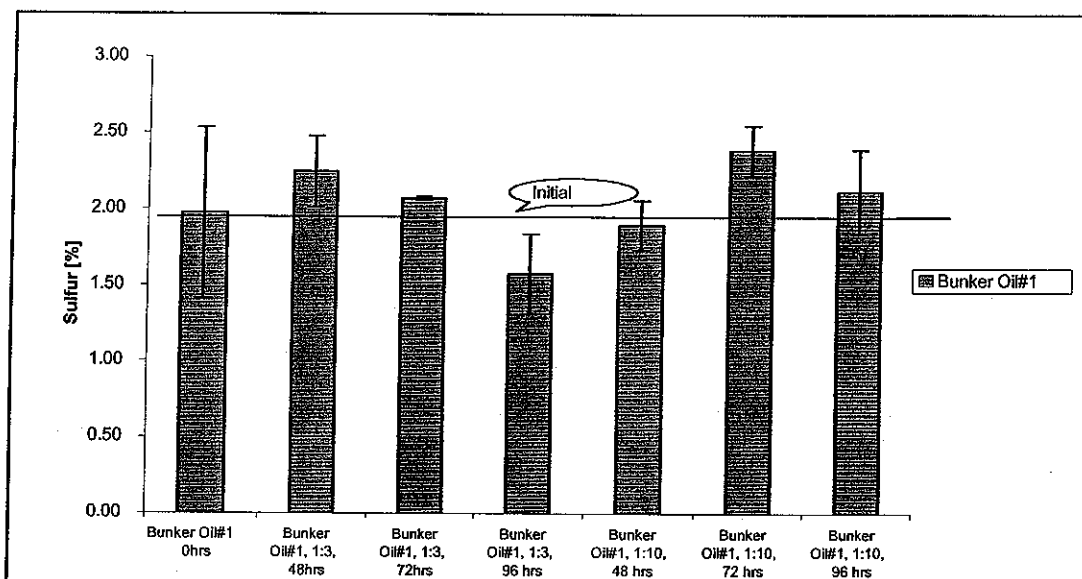


Figure 24a. Sulfur measurements as weight percentage for Bunker Oil #1 using Elemental Analyzer.

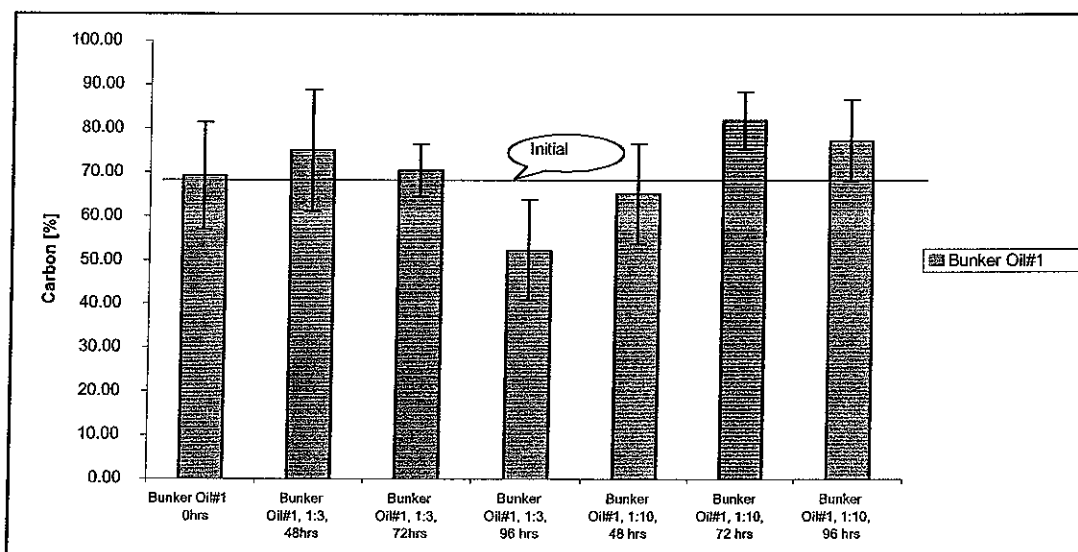


Figure 24b. Carbon measurements as weight percentage for Bunker Oil #1 using Elemental Analyzer.

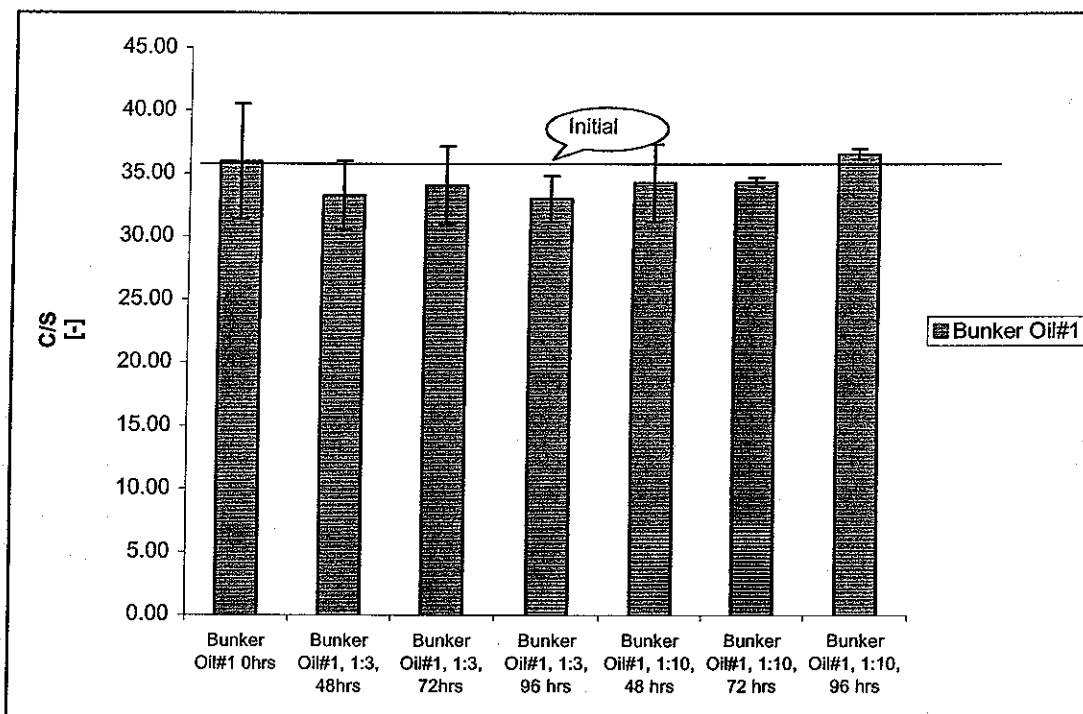


Figure 24c. C/S ratio for Bunker Oil #1 using Elemental Analyzer.

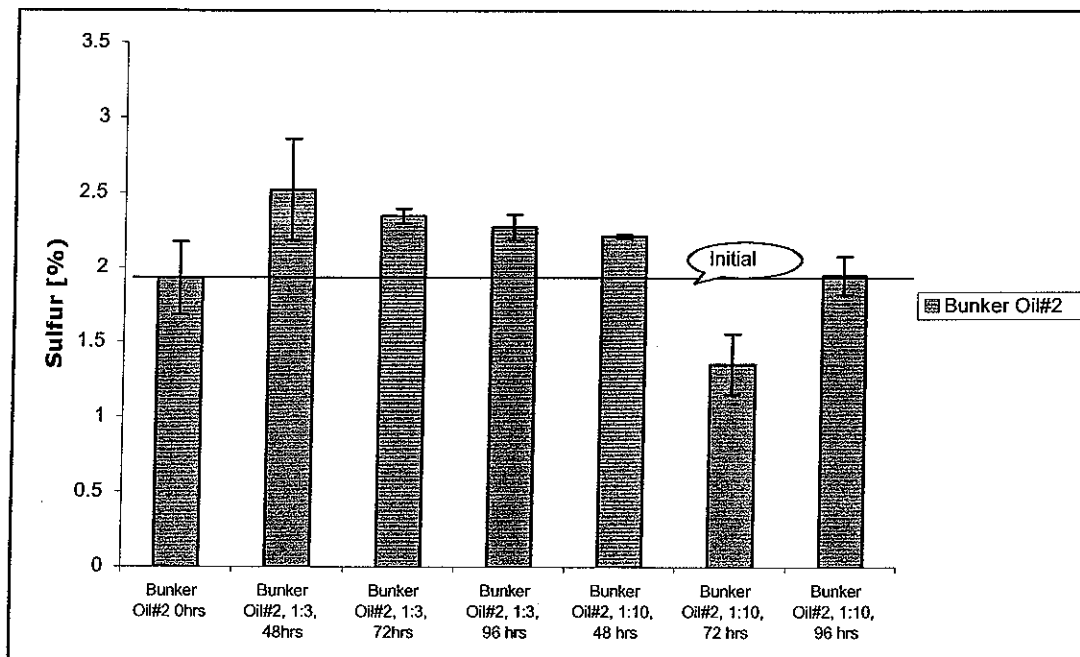


Figure 25a. Sulfur measurements as weight percentage for Bunker Oil #2 using Elemental Analyzer.

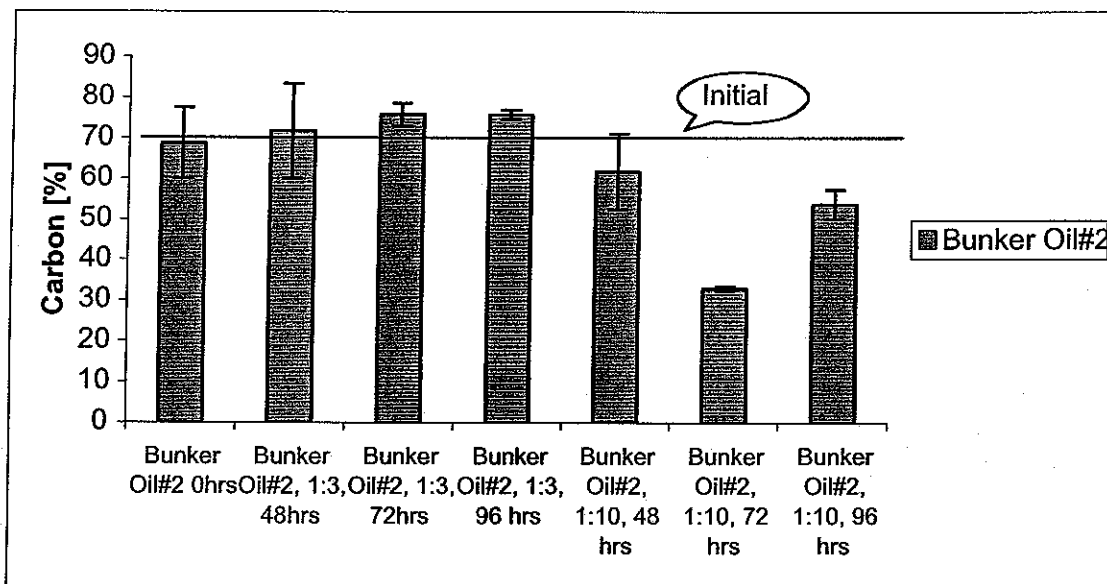


Figure 25b. Carbon measurements as weight percentage for Bunker Oil #2 using Elemental Analyzer.

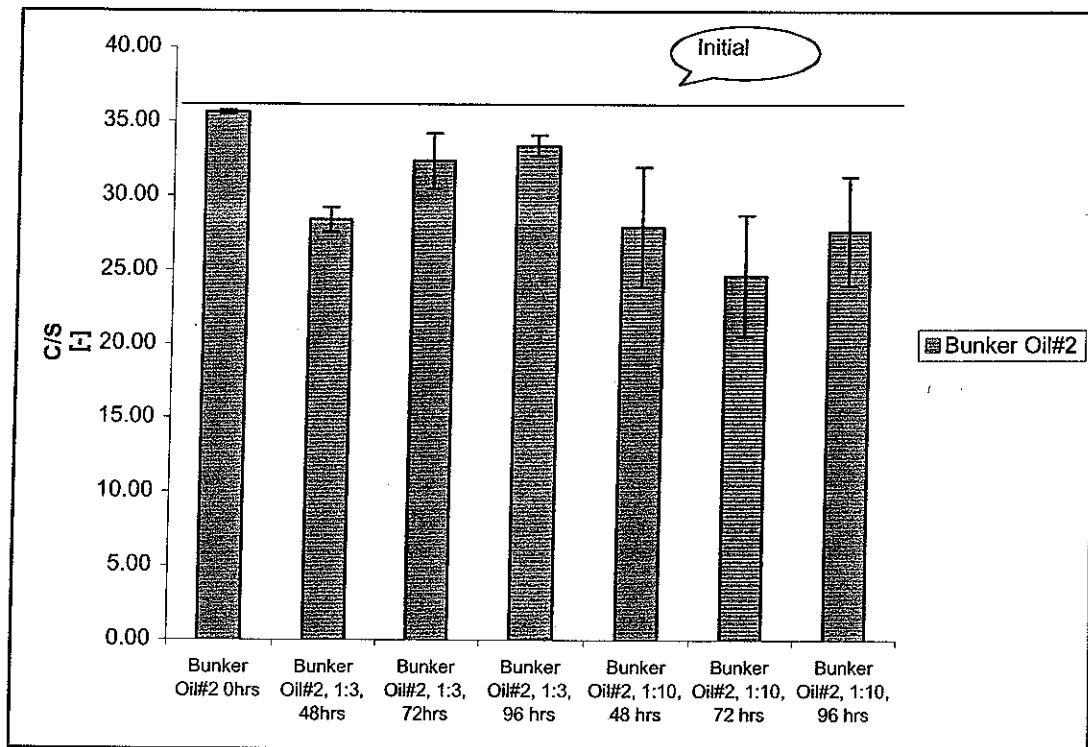


Figure 25c. C/S ratio for Bunker Oil #2 using Elemental Analyzer.

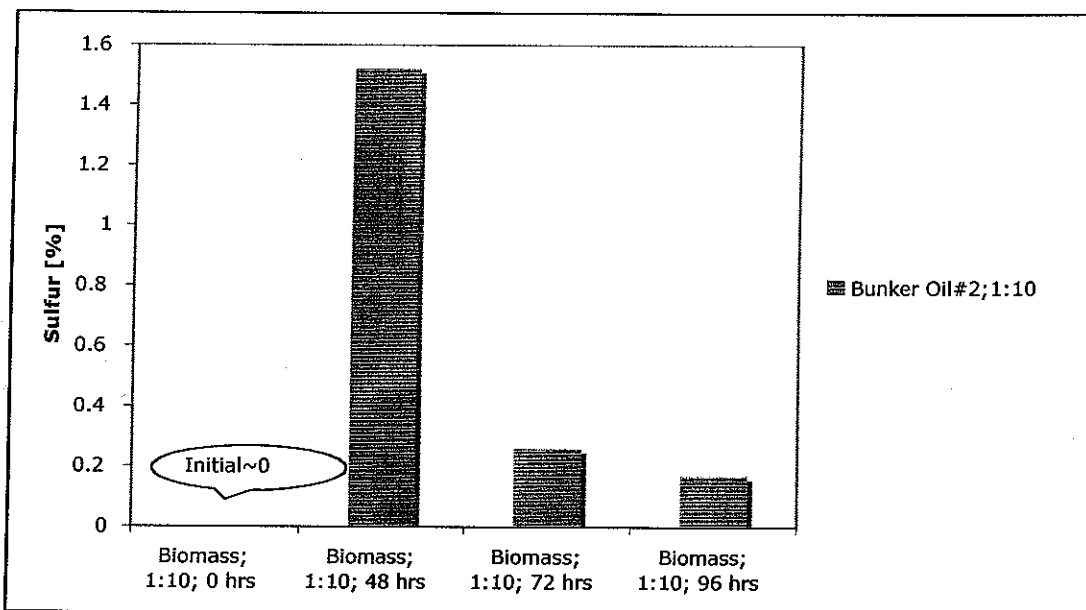


Figure 26. Sulfur content in biomass degrading bunker oil #2 with oil/water ratio of 1:10.

Appendix I. Quality of the bunker oils used in this study

Test description	Test method	Standard (max.)	Result		Units
			#1	#2	
Sample point			PF23	F0018	
Sample name			05077994	05066318	
Sample date			24-Jun-05	30-May-05	
Density @ 15°C	ASTM D4052	991.0	986.7	984.3	Kg/m ³
Viscosity @ 50°C	ASTM D445	380.0	357.4	344.2	CST
Ash	ASTM D482	0.15	0.02	0.03	Masspct
Water by distillation	ASTM D95	0.5	0.1	0.2	Volpct
Sulfur	ASTM D4292	4.5	4.3	4.1	Masspct

Appendix II. Analysis of bunker oil component by GC-MS

Table 1 Identities of the main peaks in GC chromatograms of bunker oil #1 and #2

Bunker oil #1		Bunker oil #2	
Retention time (min)	Identity	Retention time (min)	Identity
0~5.132	hexane and impurities	0~4.907	hexane and impurities
5.143	nonane	5.139	nonane
5.870	decane	5.449	heptane, 3-ethyl-2-methyl
6.493	undecane	5.628	benzene, 1,3,5-trimethyl
6.834	tetradecane, 1-chloro	5.870	decane
7.046	dodecane	6.490	undecane
7.551	tridecane	6.851	benzene, 1,2,4,5-tetramethyl
8.020	tetradecane	7.046	dodecane

8.461	pentadecane	7.551	tridecane
8.879	hexadecane	8.020	tetradecane
9.269	heptadecane	8.461	pentadecane
9.647	octadecane	8.875	hexadecane
10.041	docasane	8.950	octadecane
10.967	dotriacontane	10.038	docosane
11.564	dotriacontane	10.469	docosane
12.291	dotriacontane	10.967	dotriacontane
13.164	docasane	11.557	dotriacontane
14.057	docasane	12.291	dotriacontane
14.936	docasane	13.167	dotriacontane
15.798	docasane	14.057	dotriacontane
16.614	dotriacontane	14.939	dotriacontane
17.395	docasane	15.795	dotriacontane
18.150	dotriacontane	16.617	dotriacontane
18.878	dotriacontane	17.399	dotriacontane
19.676	dotriacontane	18.147	dotriacontane
		18.874	dotriacontane
		19.673	dotriacontane

Table 2 Identification of sulfur-containing substances in the bunker oils

Retention time (min)	Isomer	Main mass fragments	Identity
7.733	1	147,74,45	methyl BTH
8.208	1	162,28,147	dimethyl BTH
8.616	1	176,161,115	trimethyl BTH
8.933	2	175,190,147,160	diethyl BTH
9.700	1	184,139,152	DBT
10.085, 10.172	2	198,99,165	methyl DBT
10.513~10.822	6	212,197,92, 105	dimethyl DBT

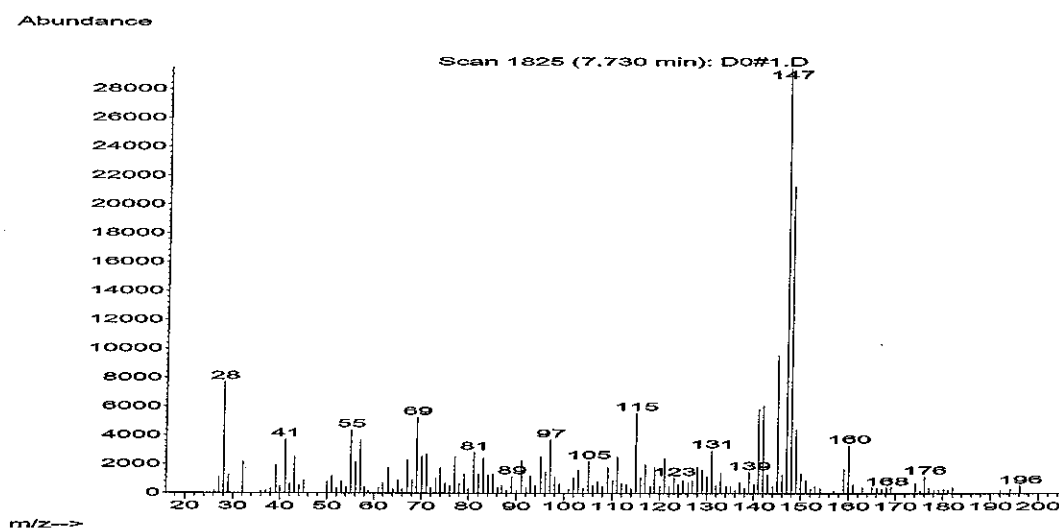
Appendix III. Mass spectra of the sulfur containing substances in bunker oils

Figure 1. MS spectrum of methyl BTH.

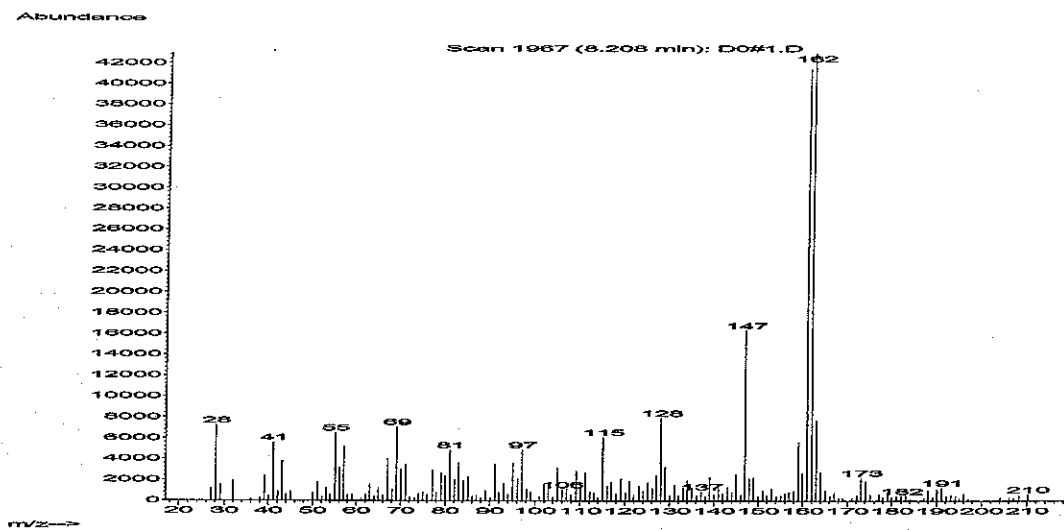


Figure 2. MS spectrum of dimethyl BTH.

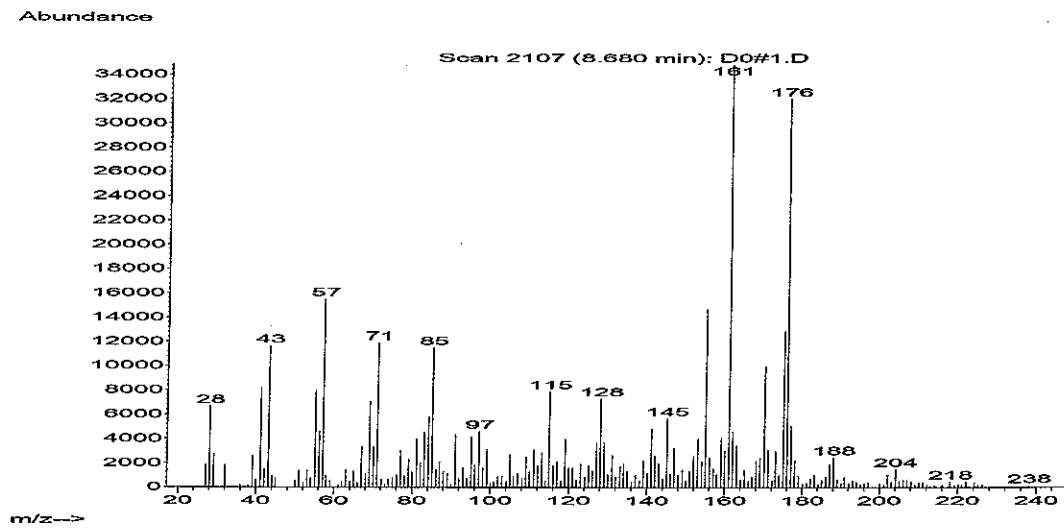


Figure 3. MS spectrum of trimethyl BTH.

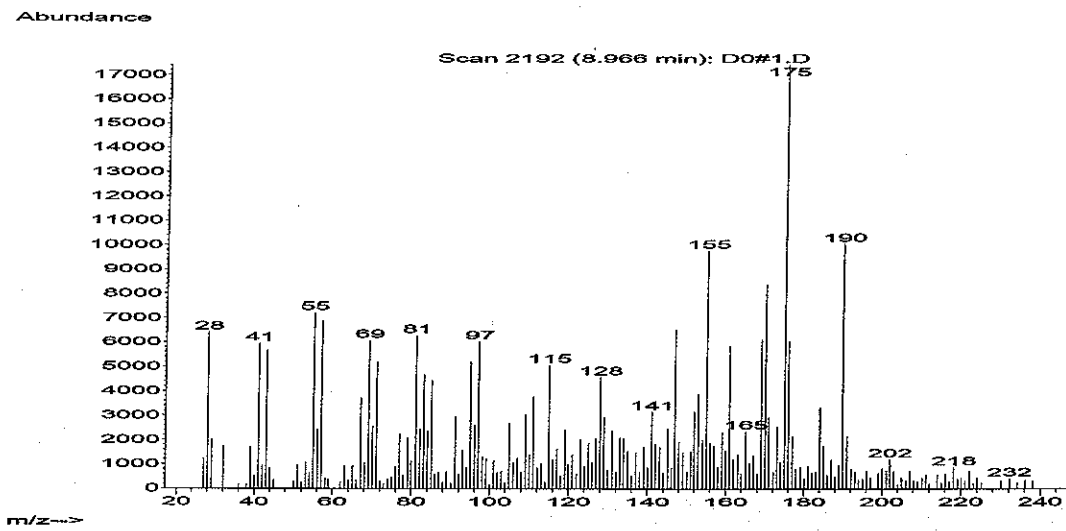


Figure 4. MS spectrum of diethyl BTH.

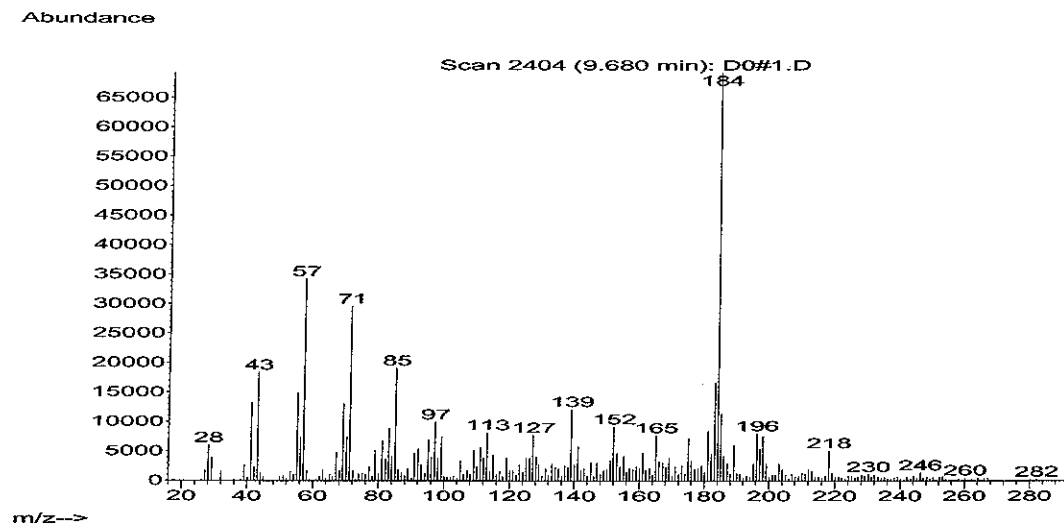


Figure 5. MS Spectrum of DBT.

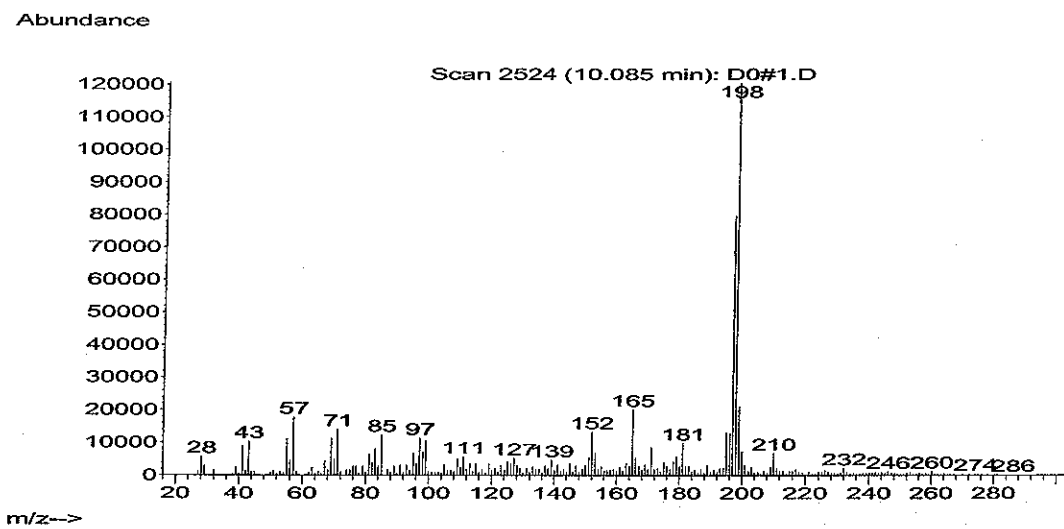


Figure 6. MS spectrum of methyl DBT.

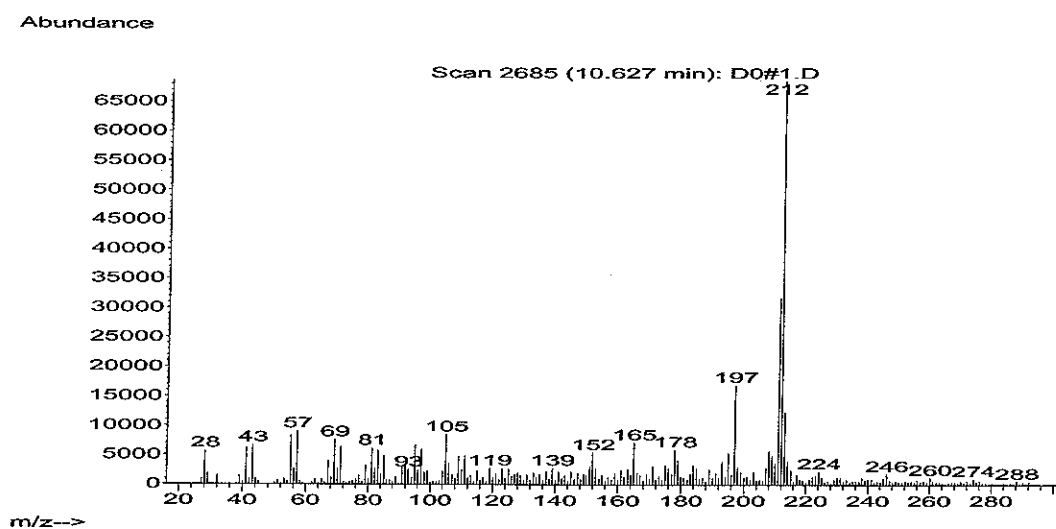


Figure 7. MS spectrum of dimethyl DBT.