CONCENTRATION AND DISTRIBUTION OF LINEAR ALKYLBENZENES IN SURFACE SEDIMENTS OF SOUTH CHINA SEA AS MOLECULAR MARKERS FOR SEWAGE POLLUTION

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By

NAJAT ABDULLAH EBRAHIM

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfillment of the Requirement for the Degree of Master of Science.

December 2011

DEDICATION

To my dear husband, close friends, my family, and my supervisor who have been the most important reasons of hopefulness during my study.

Abstract of thesis presented to the senate of Universiti Putra Malaysia in fulfillment of the requirement of the degree of Master of Science

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Chairman : Associate Professor Mohamad Pauzi Zakaria, PhD

Faculty : Environmental Studies

The coastal areas along the South China Sea (SCS) have been polluted by pollutants from various sources such as sewage outfalls and storm drains. Differentiating between these inputs is important in order to create better management of coastal resources. Linear alkylbenzenes (LABs), raw materials in the production of detergents, have been recognized as molecular markers for domestic waste inputs for more than a decade. Due to the hydrophobic characteristic of LABs, its residues will remain in detergents, survive wastewater treatment, and can be transported into the environment with treated sewage. Hence, a study was carried out at selected coastal areas along the SCS to determine the concentration of LABs in sediment. Thirty sampling stations were chosen from the location in the east coast of Peninsular Malaysia area onward to SCS region. Gas chromatography-mass spectrometry (GC-MS) was used to quantitate LABs of different sediment as well as sediment from different locations. The types of LABs compounds found in the samples were 1-pentylhexyl, 1-butylhexyl, 1-propylhexyl, 1-propylheptyl, 1-ethyloctyl, 1-methylnonyl, 1-propyloctyl, 1-ethylnonyl, 1-methyldecyl, 1-

pentylheptyl, 1-butyloctyl, 1-propylnonyl, 1-ethyldecyl, 1-methylundecyl, 1-pentyloctyl, 1-hexylheptyl, C-19 LABs compound 1, C-19 LABs compound 2, C-19 LABs compound 3. Total LABs concentration in the surface sediments ranged from 1191.73 to 206.06 ng/g dry weight. Among the 30 stations, Terengganu, seems to be the most concentration with LABs, followed by Pahang, Johor and finally Kelantan. I/E ratios (a ratio of internal to external isomers of LABs) for SCS ranged from 0.12 to 5.68. *I/E* ratios at Kelantan were much lower than the others, indicating that sewage discharged at Kelantan is poorly treated. *I/E* ratios can be used to determine the degree of biodegradation of LABs in a range of environments, making it a powerful yet simple tool for monitoring biodegradation of LABs in the environment.

Keywords: Molecular markers, Sewage pollution, LABs, *I/E* ratios, South China Sea

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

PENUMPUAN DAN PENGAGIHAN ALKYLBENZENES LINEAR (LABS) DALAM SEDIMEN PERMUKAAN LAUT CHINA SELATAN SEBAGAI PENANDA MOLEKUL BAGI PENCEMARAN KUMBAHAN

Oleh

NAJAT ABDULLAH EBRAHIM

Disember 2011

Pengerusi : Profesor Madya Mohamad Pauzi Zakaria, PhD

Fakulti : Pengajian Alam Sekitar

Kawasan persisiran pantai di sepanjang Laut China Selatan (SCS) telah dicemari oleh bahan pencemar yang berpunca dari pelbagai sumber seperti sisa kumbahan dan sisa saliran ribut. Mengenalpasti jenis punca-punca ini adalah penting untuk menjadikan sistem pengurusan sumber persisir pantai lebih terurus. Linear alkilbenzens (LABs), iaitu bahan mentah dalam penghasilan detergen, telah pun dikenali sebagai penanda molekul bagi mengenalpasti punca sisa domestik untuk tempoh lebih dari satu dekad. Oleh kerana sifat hidrofobik LABs, sisa bahan ini akan kekal dalam detergen, kekal wujud dalam rawatan sisa kumbahan dan akhirnya terlepas ke alam sekitar bersama dengan sisa terawat. Sehubungan itu, satu kajian telah dijalankan di kawasan persisir pantai yang terpilih di sepanjang SCS untuk mengetahui jumlah kepekatan LABs di dalam sedimen. Tiga puluh stesen kajian telah dipilih dari kawasan Timur Laut Semenanjung Malaysia sehingga ke kawasan SCS. Kromatografi Gas gandingan Spektrometri Jisim (GCMS) digunakan untuk menganalisis LABs dari pelbagai jenis sedimen dan sedimen dari lokasi yang berlainan. Jenis-jenis LABs yang dikenalpasti di dalam sampel ialah 1-pentilheksil, 1-butilheksil, 1-propilheksil, 1-propilheptil, 1-etiloktil, 1-metilnonil, 1-propiloktil, 1-etilnonil, 1-metildekil, 1-pentilheptil, 1-butiloktil, 1-propilnonil, 1-etildekil, 1-metilundekil, 1-pentiloktil, 1-heksilheptil, C-19 LABs sebatian 1, C-19 LABs sebatian 2, C-19 LABs sebatian 3. Jumlah kepekatan LABs di permukaan sedimen adalah di antara 1191.73 ke 206.06 ng/g berat kering. Di antara 30 stesen, Terangganu dikenalpasti sebagai kawasan yang mempunyai kepekatan LABs yang paling tinggi, diikuti dengan Pahang, Johor dan Kelantan. Nisbah I/E (nisbah internal kepada eksternal LABs) untuk SCS adalah di antara 0.12 ke 5.68. Nisbah *I/E* di Kelantan adalah paling rendah berbanding kawasan lain, menunjukkan bahawa sisa kumbahan yang dibuang adalah sangat kurang dirawat. Nisbah *I/E* boleh digunakan untuk mengenalpasti darjah biodegradasi LABs di alam sekitar, menjadikan ia alat yang berkesan lagi mudah untuk mengawasi tahap biodegradasi LABs di dalam alam sekitar.

Kata kunci: Penanda molekul, Kumbahan pencemaran, LABs, *I/E* Nisbah, Laut China Selatan

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APPROVAL

i certify that a thesis examination committee has met on 1st december 2011 to conduct the final examination of najat abdullah ebrahim on her thesis entitled “concentration and distribution of linear alkylbenzenes in surface sediments of south china sea as molecular markers for sewage pollution” in accordance with the universities and university colleges act 1971 and the constitution of the universiti putra malaysia [p.u.(a) 106] 15 march 1998. the committee recommends that the student be awarded the master of science.

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DECLARATION

I declare that the thesis is my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously, and is not concurrently, submitted for any other degree at Universiti Putra Malaysia or at any other institution.

NAJAT ABDULLAH EBRAHIM

Date: 1 December 2011

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LIST OF ABBREVIATIONS

ABS	Alkybenzene sulfonates
a-TA	a-Tocopheryl acetate
APR	Aminopropanone
BASs	Branched alkylbenzene sulphonates
Biphe-d_{10}	Biphenyl-deuterated -10
DATs	Dialkyltetralinsulfonates
DSBP	(2-sulfostyryl) biphenyl
I/E Ratio	A ratio of (6-C_{12}AB+5-C-$_{12}$AB) relative to (4-C_{12}AB+3-C_{12}AB+2-C_{12}AB)
FWAs	Fluorescent whitening agents
IIS	Internal Injection Standard
LABs	Linear Alkylbenzenes
LANs	Long chain alkylnitriles
LASs	Linear alkylbenzenes sulfonates
LOD	Limit of detection
LOQ	Limit of quantification
NPs	Nonylphenols
PAHs	Polycyclic Aromatic Hydrocarbons
PCBs	Polychlorinated biphenyls
POPs	Persistent organic pollutant
SIS	Surrogate Internal Standard
SCS	South China Sea
Silicones	Polyorganosiloxanes
TABs	Tetrapropylene based Alkylbenzenes

α-TA	α-Tocopheryl acetate
TAMs	Trialkylamines
TSQ	Thermo Scientific Quantum
UKM	Universiti Kebangsaan Malaysia

CHAPTER 1

INTRODUCTION

1.1 Background of study

In recent years, untreated sewage flows into coastal waters, carrying organic wastes. This is especially true in many developing countries, which lack proper sewage collection and treatment facilities. Generally, much of the untreated sewage enters waterways when rainstorms overload combined storm-water and sewage systems. This results in a very significant contribution to the pollution of waterways and the surrounding area. Since the mid-1960s, the use of synthetic organic chemicals has increased drastically, both in industry and homes. This is reflected in the contents of the sewage. The long list of organic contaminants that have been found in sewage and sewage sludge include mineral oils, lipids, phthalate esters, organochlorine pesticides, nitrosamines and nitroaromatics, organophosphorus compounds, chlorophenols and chlorophenoxy acids, chlorobenzenes, various pharmaceutical chemicals, polycyclic aromatic hydrocarbons and surfactants. These ultimately find their way into waterways and the sea. Hence it has been determined that one of the major sources of pollution in aquatic environments is municipal wastewater (from both industrial and domestic sources) (Takada and Eganhouse, 1998). Synthetic detergents were first used in the 1930's but it was after the second world war that they grew in popularity and began to displace the natural detergents or soaps made from sodium palmitate, sodium oleate and sodium stearate. By the mid 50's the detergents used were mainly of the synthetic type. The first signs of trouble soon appeared in the form of masses of foam on rivers. Also, where water was being drawn from wells located close to household discharge points, the water tended to foam when coming out of the tap. This was caused by the presence of residual detergent, which had remained undegraded in sewage treatment. Comparatively, linear alkylbenzenes were found to be more biodegradable, and were used instead. Pollutants are defined as any elements or compounds that existed in excess concentrations in the wrong place. Pollutants can be naturally generated or anthropogenic synthesized substances in the environment (Baudo *et al.*, 1990). Much of the pollution in the world comes from sewage and trade waste, which has been going on since the days of the industrial revolution.

In the last 50 years the production of synthetic organic chemicals for industrial and domestic use has increased dramatically from 7 million tons in 1950 to 63 million tons in 1970 (Maugh, 1978). Inevitably, the occurrence and concentration of organic contaminants in effluents, sewage and sewage sludge has also increased. During sewage treatment it is likely that many organic compounds, particularly hydrophobic/lipophilic compounds are absorbed into sludge where they occur in much higher concentrations than in the sewage from which the sludge was derived (Rogers, 1996). Analytical investigations into organic contaminants in sewage sludge could potentially result in the identification of numerous residues of anthropogenic synthetic organic chemicals and their degradation products. One of the major sources of pollution to the aquatic environment is municipal wastewater. Municipal wastes generally consist of domestic and industrial components (Takada and Eganhouse, 1998). Organic contaminants in sewage sludge could cause environmental effects when sludge is applied to agricultural land or when it is disposed of to sea (Rogers, 1996).

Persistent organic pollutants (POPs) are organic compounds that, to a varying degree, resist photolytic, biological and chemical degradation. POPs are often halogenated and characterized by low water solubility and high lipid solubility, leading to their bioaccumulation in fatty tissues. They are also semi-volatile, enabling them to move long distances in the atmosphere before deposition occurs. POPs are also noted for their semi-volatility; that property of their physico-chemical characteristics that permit these compounds to occur either in the vapour phase or be adsorbed by atmospheric particles, thereby facilitating their long range transport through the atmosphere. Humans can be exposed to POPs through diet, occupational accidents and the environment (including indoor). Exposure to POPs, either acute or chronic, can be associated with a wide range of adverse health effects, including illness and death.

Coastal areas are recipients of increasing amounts of land-based wastes transported by rivers and sewage outfalls, and domestic effluents are the major point sources of coastal pollution (Richard and Shieh, 1986). The discharge of wastewaters into semi-enclosed systems, where dilution processes are quite restricted and anaerobic condition often prevail, can lead to an accumulation of persistent contaminants in sediments, depending upon their phase-association in the water column (Chalaux *et al.*, 1995).

The effect of a chemical on the environment (open ocean, coastal waters estuary, aquatic fauna, aquatic flora, etc.) depends on the toxicity of the chemical and on the amount of the chemical the environment is exposed to (such as, the amount of chemical discharged, the concentration of the chemical, and the length of exposure). Accordingly, to determine the effects, two factors have to be investigated: toxicity and exposure. Identification of hazards requires studies of toxicity, whereas exposure data are needed for the estimation of risk. Risk is the probability that the exposure conditions are such that the hazards may materialize and result in an effect. In any case, although a better understanding of the marine environment, natural changes, and fluctuations will help, it will not guarantee a separation of the effects of natural processes from those resulting from anthropogenic causes (Zitko, 2000).

Pollutants, which come from various types of anthropogenic activities, are finally discharged as wastewater. This waste is treated at sewage treatment plants before it is discharged into the environment. Therefore, sewage treatment plants play an important role in the protection of the marine environment from pollution. However, when these treatment plants fail to treat the wastewater to the required water quality standards, they will cause marine pollution once the untreated or partially treated sewage reaches the water body (Tsutsumi, 2002).

There are broad ranges of anthropogenic pollution, especially the anthropogenic organic micro pollutants from various land-based and marine-based sources (Law, 1994) from industrial and municipal effluent, agricultural effluent and also oil spills. There are many types of pollutants being discharged into the marine environment. Molecular markers can be used to detect sewage input into the marine sediment. In this thesis, linear alkylbenzenes (LABs) are used as tracers of the pollutants. LABs are proposed as a marker for municipal wastewater. LABs are a group of secondary phenyl alkanes with contain side chains ranging from 10-14 carbon atoms. LABs are used as raw materials for the industrial production of linear alkylsulphonates (LAS). LAS have been widely used as surfactants in the manufacture of detergents. LABs are present as minor constituents in commercial LAS formation. A significant amount of LABs is not sulphonated during the synthesis, and the unsolphonated residue is carried over in LAS type synthesis detergents (Takada and Ishiwatari, 1990). LABs are introduced as replacements for tetrapropylene-based alkylbenzenes (TABs). TABs are feedstock used for producing branched chain alkylbenzene sulphonates with tetrapropylene-based alkyl chains (ABS). ABS and TABs were first synthesized industrially in the 1950s. ABS were found to be poorly biodegradable and were subsequently replaced by LAS during the 1960s. Because of wide branching of the tetrapropylene side chains, TABs are an extremely complex mixture, comprising up to 80,000 theoretically possible congeners. Because of their highly branched alkyl chain, TABs are more resistant to microbial degradation than the LABs (Eganhouse, 1986).

Although LABs had been observed in municipal wastewater effluents and sediments during the mid-1970s, it was not until the early 1980s that their synthetic origin and potential uses as molecular markers were recognized (Eganhouse *et al.*, 1983 and Ishiwatari *et al.*, 1983). Because of their hydrophobicity (log octanol-water partition coefficient ~7-10 (Sherblom *et al.*, 1992)), LABs sorb strongly to the organicrich particles in sewage and suspended matter (Murray *et al.*, 1991 and Takada *et al.*, 1994). Consequently, their transport to bottom sediments and uptake by aquatic organisms (e.g., refs Murray *et al.*, 1991, Albaiges *et al.*, 1987 and Tsutsumi *et al.*, 2002) is expected. One of the principal criteria for a molecular marker is persistence (Takada *et al.*, 1997). Unfortunately, our knowledge of the persistence of the LABs (both LABs and tetrapropylene-based alkylbenzenes (TABs)) is incomplete. Under aerobic conditions, LABs appear to undergo degradation through selective depletion of the "external" isomers (where benzene is attached near the end of the alkyl chain (Bayona and Albaiges, 1986 and Takada, 1987). This led Takada and Ishiwatari (1987) to propose an index of biodegradation, the *I/E* ratio, based on the relative abundance of phenyldodecane isomers. The *I/E* ratio is defined as [6-C12 + 5-C12]/[4-C12 + 3-C12 + 2-C12], where j-C_k indicates substitution of benzene at the j position of an alkyl chain having k carbon atoms. LAB concentrations have sometimes been found to decrease and *I/E* ratios to increase in sediments collected at greater distance from a point source (Eganhouse *et al.*, 1983 and Murray *et al.*, 1991), suggesting that significant LAB degradation may occur during transportn through the oxygenated water column. However, this pattern is not always observed (Chalaux, 1992 and Luo, 2008). Microcosm experiments in which untreated sewage or LAB-amended anaerobic sludge was incubated in the absence of oxygen showed little or no degradation of the LABs (Steber, 1995 and Takada, 1990). In general, this has been taken as substantiation of the persistence of LABs in anoxic sediments (Eganhouse *et al.*, 1983, Ishiwatari *et al.*, 1983, Takada, 1990 Chalaux, 1992 and Chalaux, 1995). Conversely, it is sometimes tacitly assumed that little or no change in *I/E* ratio means that no biodegradation has occurred (Raymundo and Preston, 1992 and Kumata *et al.*, 2000).

Gas chromatography-mass spectrometry (GC-MS) is used to determine the concentration of LABs in the sediment, which was collected from different locations along the South China Sea (SCS). The SCS encompasses a portion of the Pacific Ocean stretching roughly from Singapore and the Straits of Malacca in the southwest, to the Strait of Taiwan (between Taiwan and China) in the northeast. Lots of anthropogenic activities around the SCS come from developing countries such as Malaysia, Thailand and Vietnam.

Choosing the SCS as astudy area refers to the reality that SCS is in a very fast trend of development especially in the past decade to reach as one of the developed areas in the world. As a highly urbanized/industrialized area, the SCS and adjacent area have been subjected to heavy anthropogenic influences, including discharge of municipal and industrial wastewater. However, there have been few applications of molecular markers to trace the pollution of domestic waste inputs in these areas (Peng *et al.*, 2005). The aim of this study was to comprehensively assess anthropogenic impacts on the aquatic environment of the east of Peninsular Malaysia and adjacent SCS. Via determining the concentration and distribution of LABs in surface sediments from thirty samples. This study could provide valuable information about whether municipal wastewater released in these areas. In addition, the present study will also provide an insight into the degradation of LABs in the environment due to the inclusion of wide sampling areas that cover riverine environments directly affected by municipal wastewater to marine environments. The present study is the first report on sewage pollution monitoring using LABs as molecular markers in sediments in SCS. Use of hydrophobic molecular marker such as LABs is beneficial in extensive monitoring studies which require transport of samples to distant laboratories. Moreover, estimation of the quality or type of sewage treatment based on the information obtained from the isomer distribution of LABs is significant for evaluation of water quality control rule in the future.

1.2 Problem Statement

Rapid urbanization and industrialization are the main sources of pollution cause higher health risks due to increasing of sewage input which is discharged as municipal waste in SCS. It is surrounded by developing country. Therefore, their wastewater treatment system still didn't achieve the high quality performance. As a result, lots of untreated wastewater was being discharged into the aquatic environment. Determination of LABs concentration in the sediments can determine the severity of habitat in terms of sewage pollution. Besides solving water quality problems in and around SCS, the efficiency of sewage treatment at SCS also can be studied based on determination of the *I/E* ratio (internal divide external) in sediment samples (Takada and Ishiwatari, 1990).

1.3 Significance of the Study

The purpose of this study is to obtain data on the types of LABs and their concentration of the sediments in the selected location. LABs occur in the aquatic environment because of their release in domestic waters along with the linear alkylbenzene sulphonates (LASs). In order to efficiently control coastal zone organic pollution, the results from this study will provide data on the distribution and levels of LABs to monitor the marine ecosystem environment (Zakaria *et al.*, 2000). The detection of sewage sludge and domestic waste with molecular markers is extremely useful for identifying the source and transport pathways of sewage in coastal sediments.

1.4 The Objectives of the Study

1. To identify the compositions and concentration of LABs in selected sediment of the SCS.
2. To determine effectiveness of sewage treatment by using *I/E* ratio of LABs.
3. To determine the spatial distribution of LABs in selected sediment of the SCS.

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APPENDICES A

PHOTOGRAPHS OF SAMPLING AND ANALYTICAL PROCEDURE

Figure A-1 Sample Storage at -20 ° C

Figure A-2 Dried with anhydrous Na_2SO_4 &Transferred the sediments into cellulose thimble

Figure A-3 Soxhlet Extraction with DCM for 10 hour

Figure A-4 Rotary evaporator

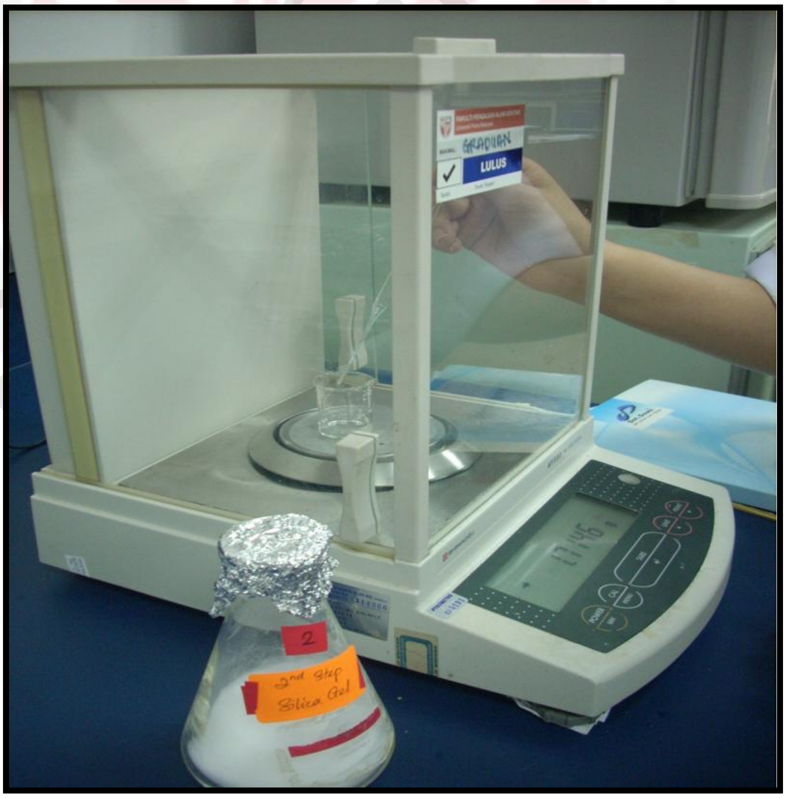


Figure A-5 Preparation of silica gel

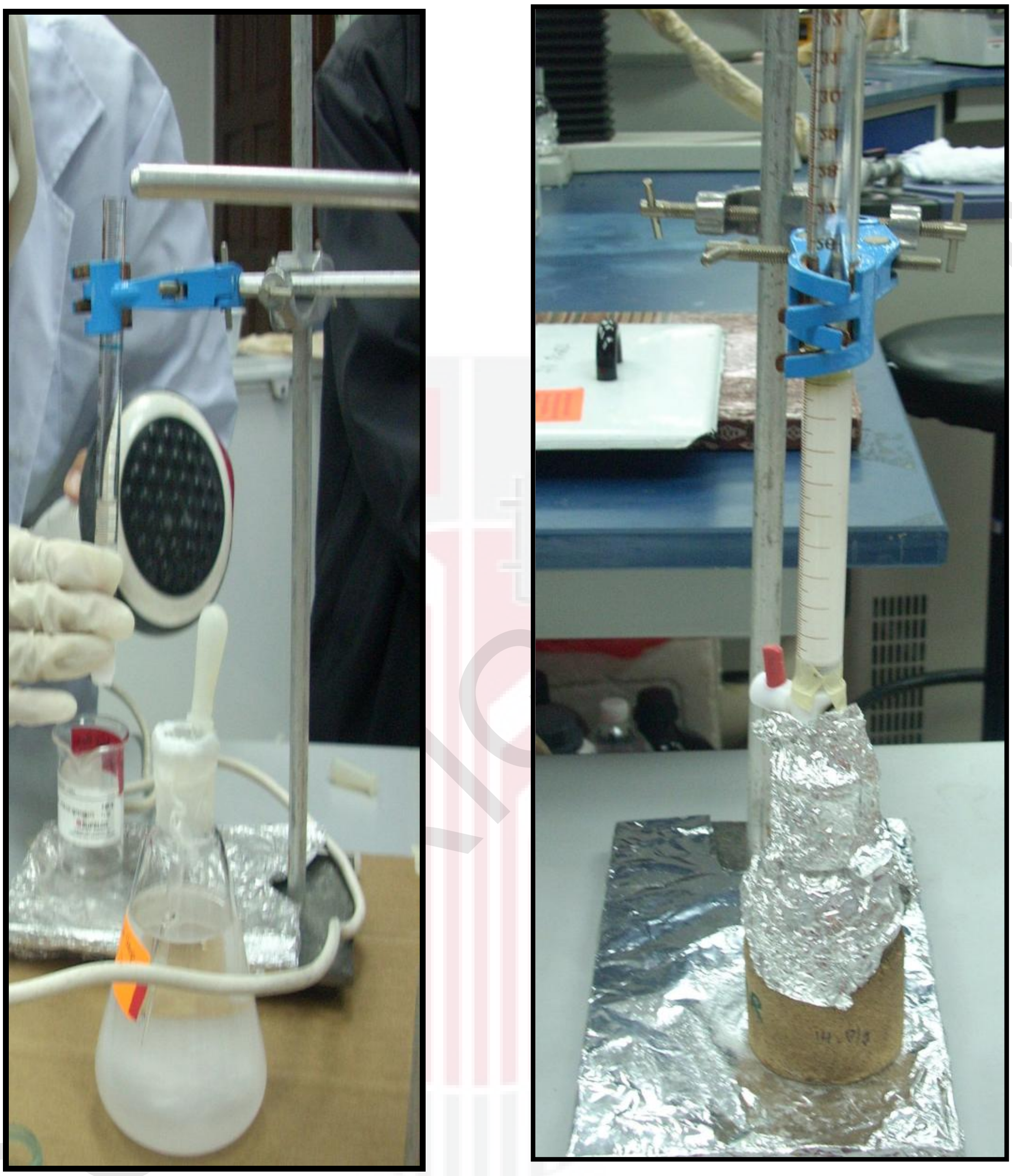


Figure A-6 Column Chromatography

Figure A-7 GC-MS analysis

APPENDICES B

CHROMATOGRAMS AND I/E RATIO

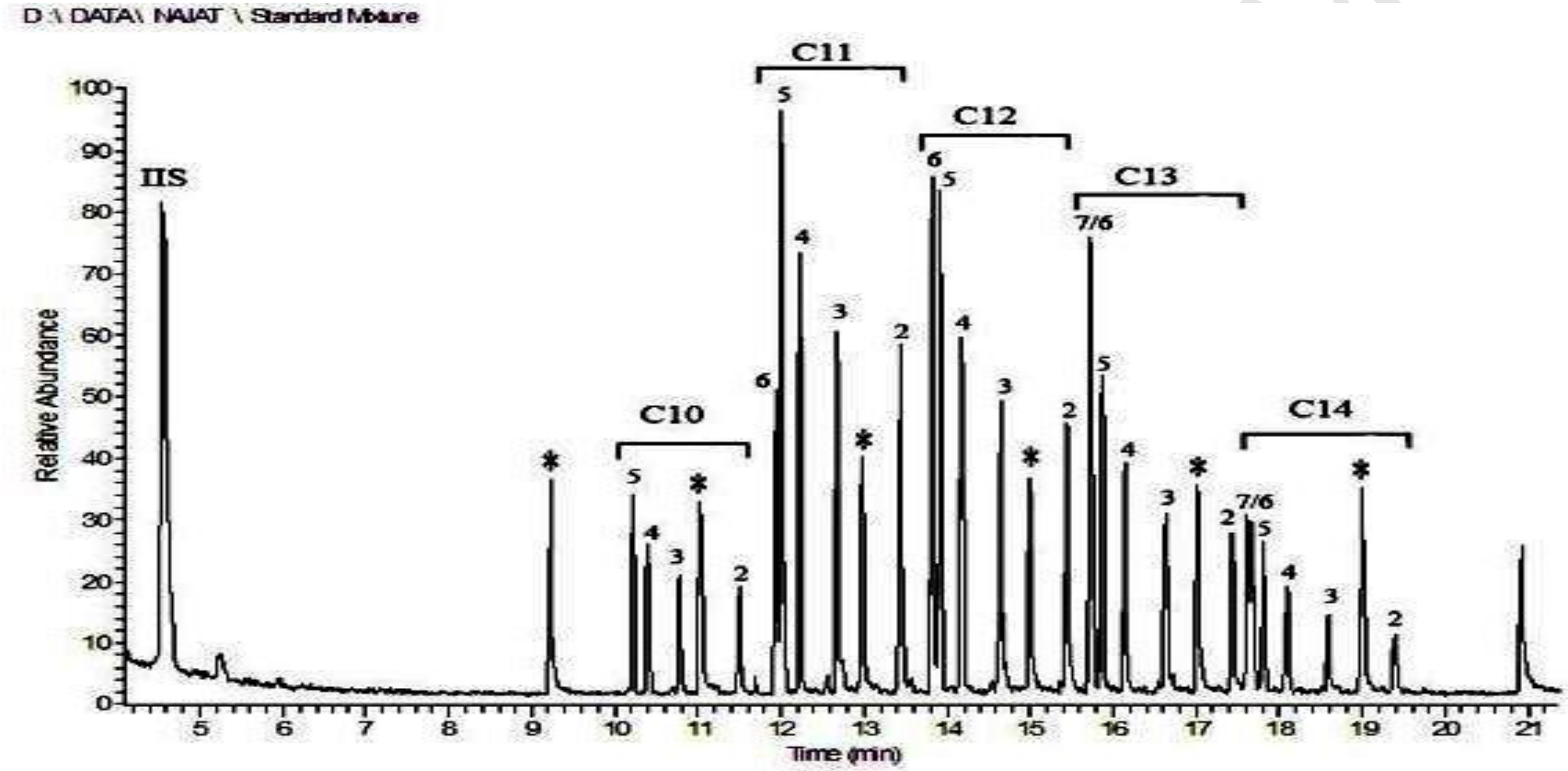


Figure B-1 Typical GC-MS chromatogram of LABs compounds in standard mixture that analyzed in the SIM MODE with the retention time.

IIS (Internal Injection Standard), * (SIS, Surrogate 1-Cn, n= 8-14), Numbers on the peaks indicate the phenyl substituted position on the alkyl chain

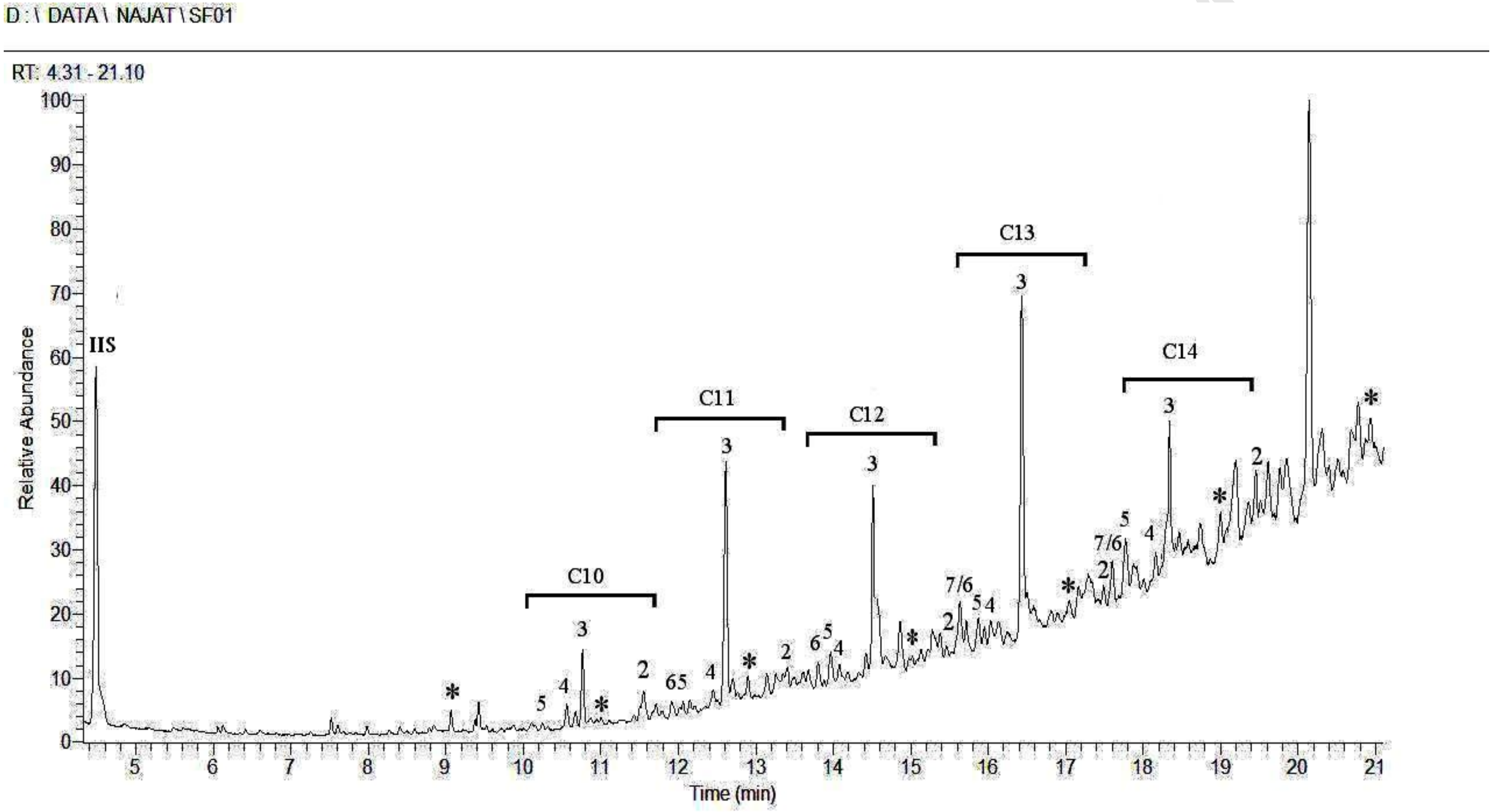


Figure B-2 Example of GC-MS chromatogram in sediments sample

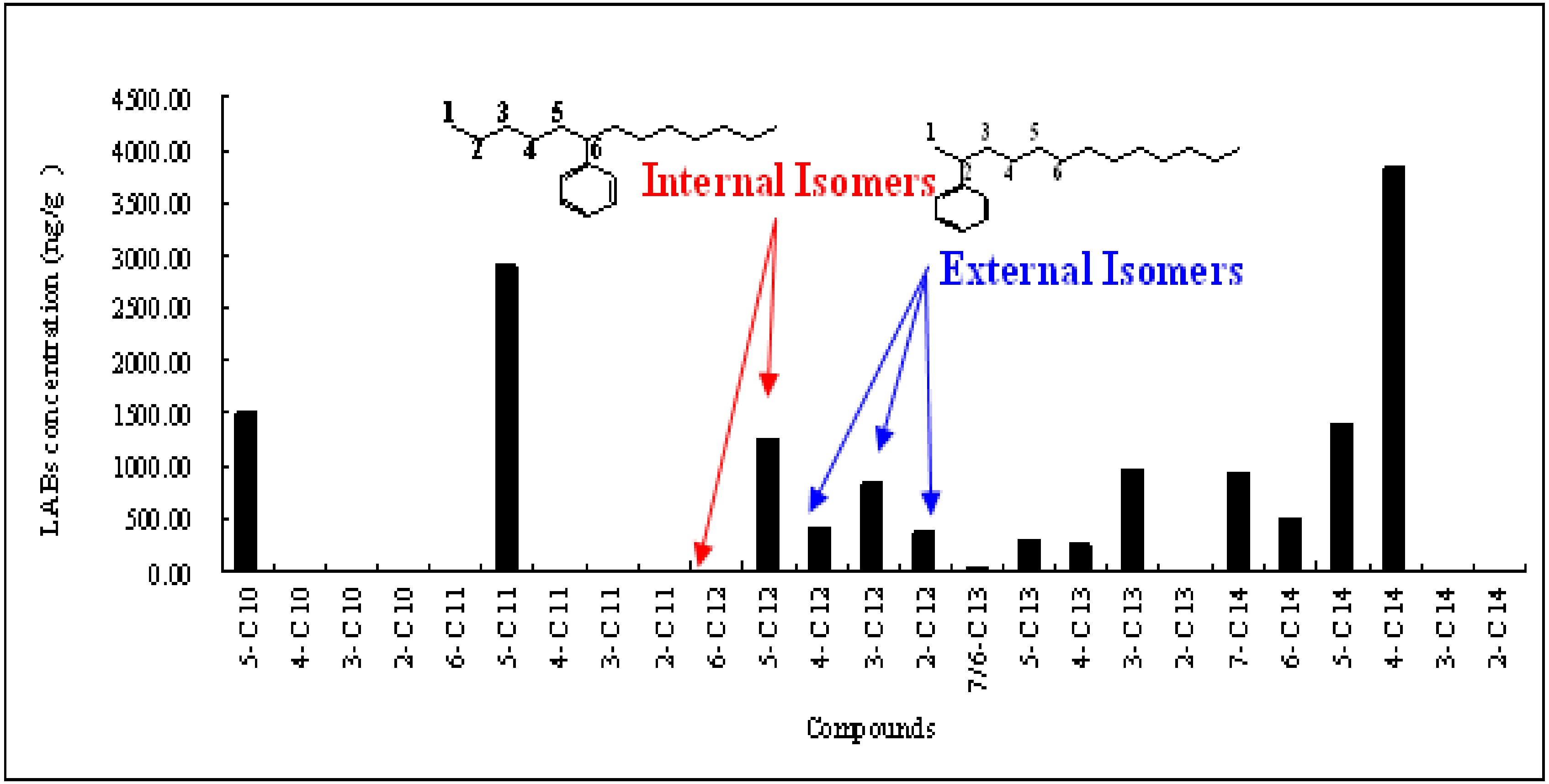


Figure B-3 LABs concentration for the entire compound shows the internal and external isomers for calculating *I/E* ratio.

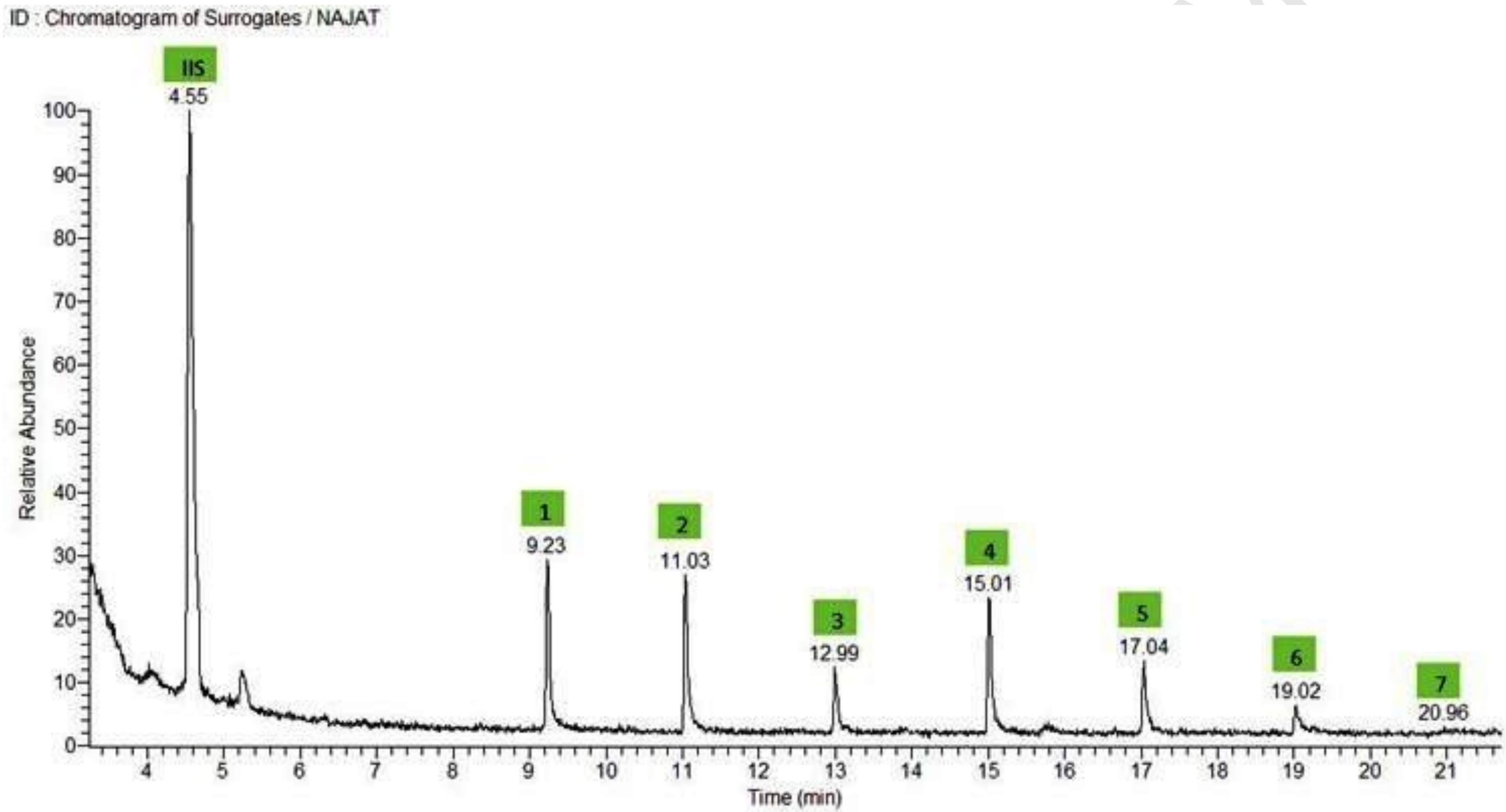
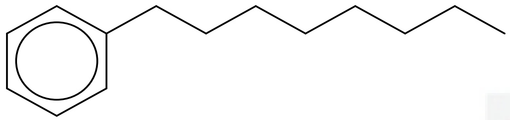
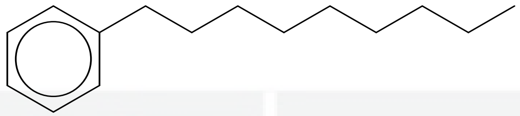


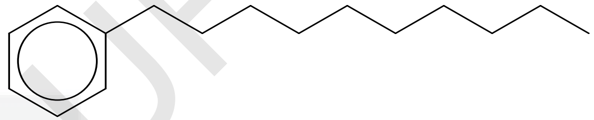
Figure B-4 Chromatogram of Surrogates (SIS, Surrogate 1-Cn, n= 8-14), and Internal Injection Standard (IIS).



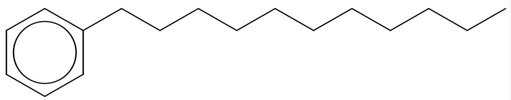
1) Benzene, Octyl ($C_{14}H_{22}$)



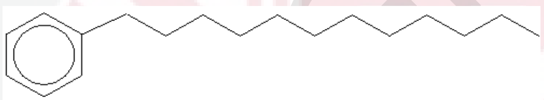
2) Benzene, Nonyl ($C_{15}H_{24}$)



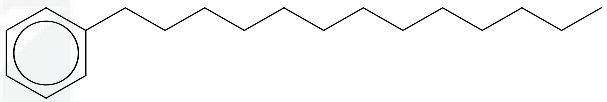
3) Benzene, Decyl ($C_{16}H_{26}$)



4) Benzene, Undecyl ($C_{17}H_{28}$)



5) Benzene, Dodecyl ($C_{18}H_{30}$)



6) Benzene, Tridecyl ($C_{19}H_{32}$)

Figure B-5 Surrogate Compound (Peak 1-6 shown as in the the previous page)

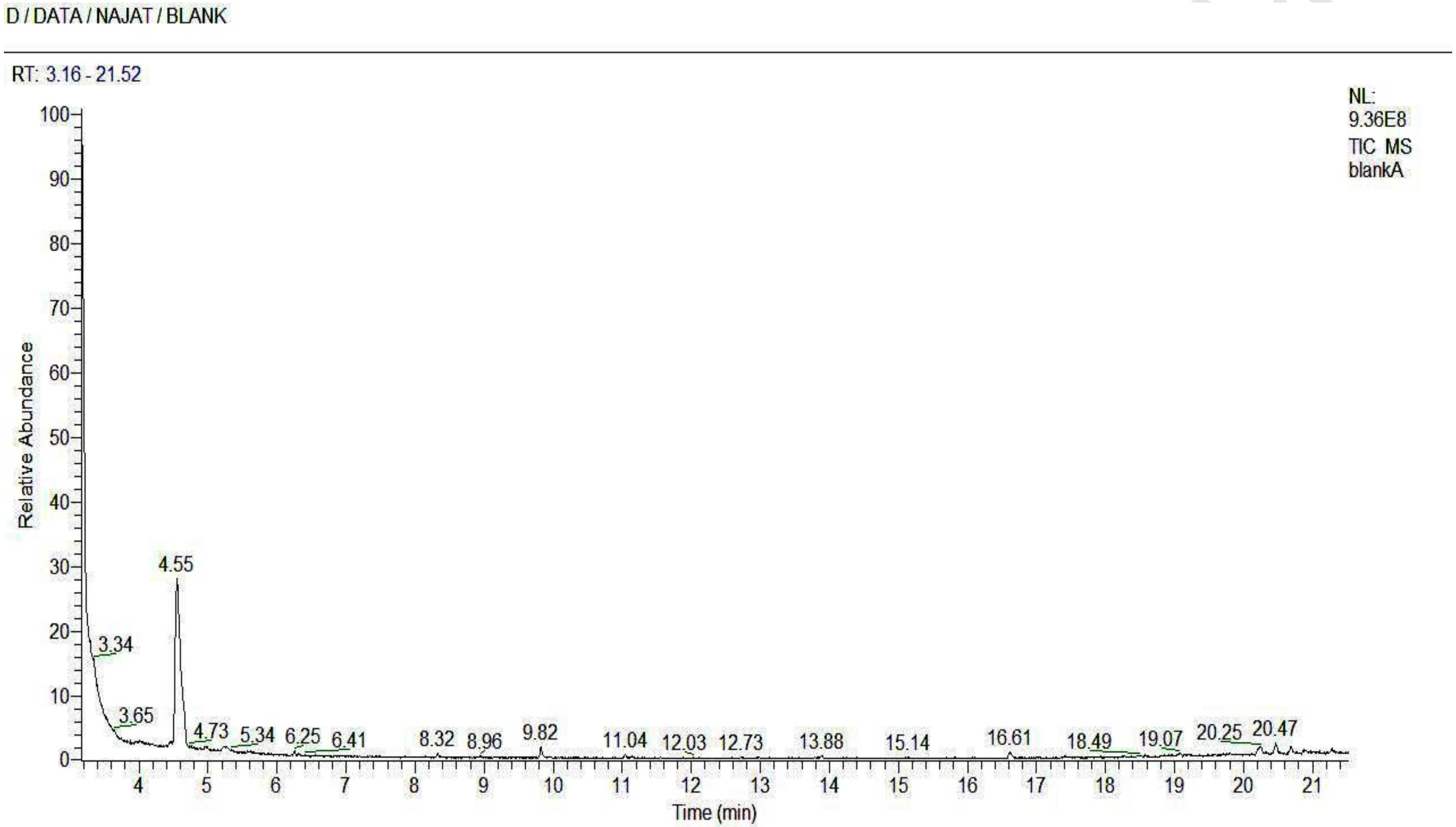
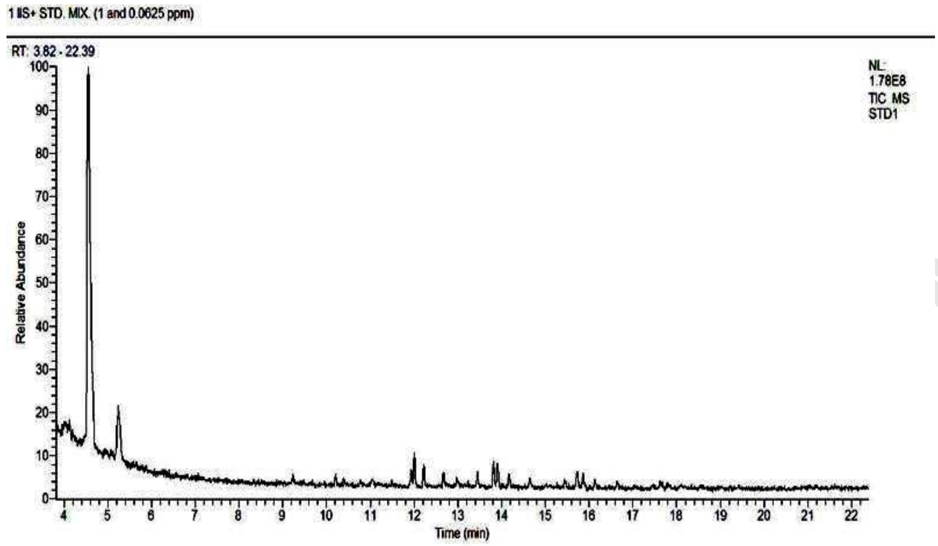
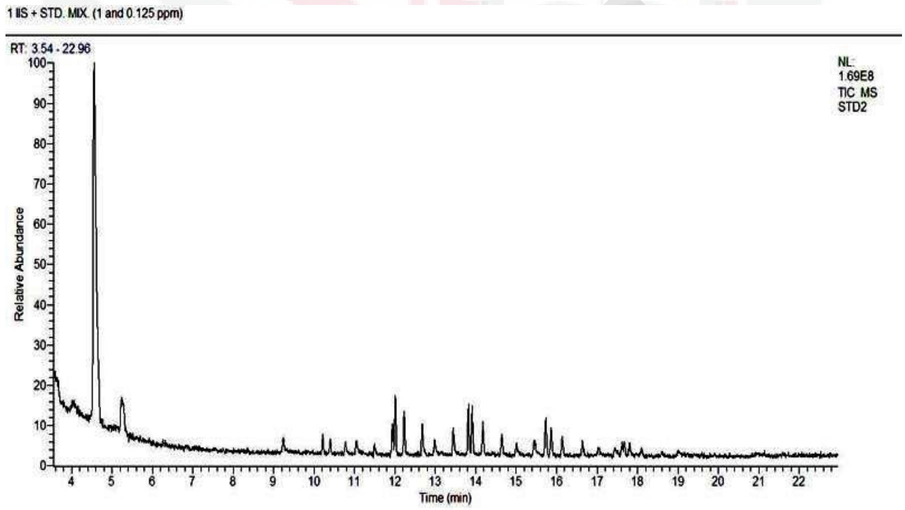


Figure B-6 Example of GC-MS Chromatogram in Blank

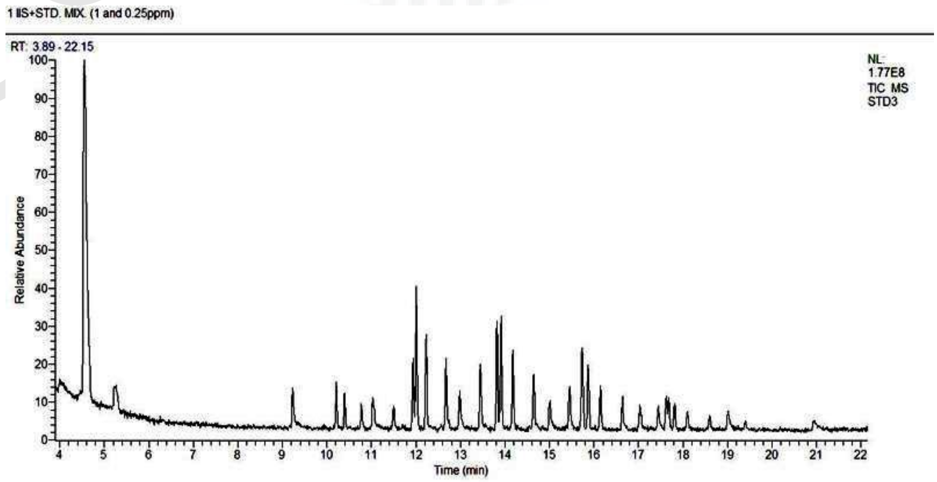
A)


1 IIS+ STD. MIX. (1 and 0.0625 ppm)
RT: 3.82 - 22.39
NL: 1.78E8 TIC MS STD1
Relative Abundance
Time (min)

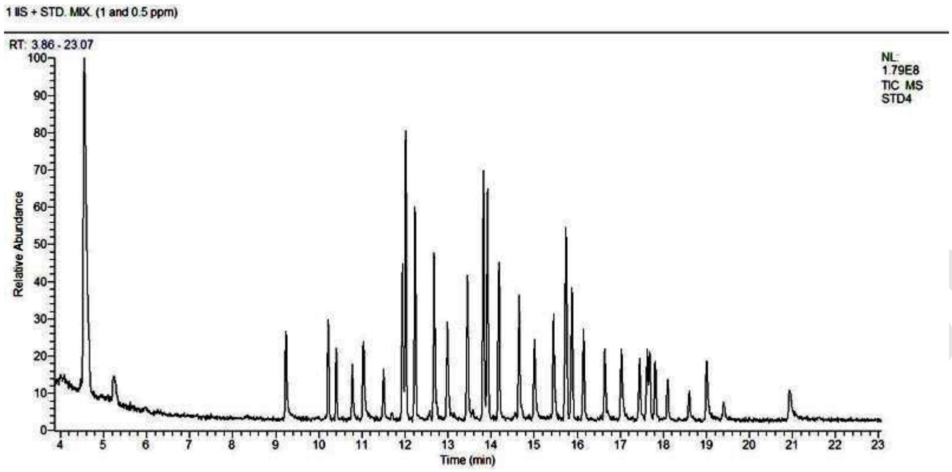
B)


1 IIS + STD. MIX. (1 and 0.125 ppm)
RT: 3.54 - 22.96
NL: 1.69E8 TIC MS STD2
Relative Abundance
Time (min)

C)


1 IIS+STD. MIX. (1 and 0.25ppm)
RT: 3.89 - 22.15
NL: 1.77E8 TIC MS STD3
Relative Abundance
Time (min)

D)



E)

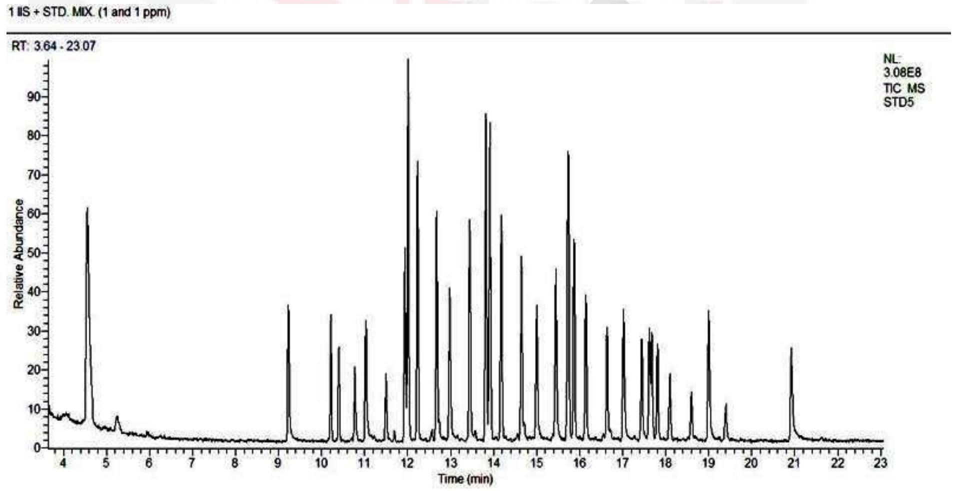


Figure B.7 Chromotograms of 26 LABs standard mixture with different concentrations, A-E (0.063, 0.125, 0.250, 0.500 and 1 mg/L) and constant concentration of internal injection standard–IIS (1 mg/L).

Area Percent Report

Data File:	SF01
Data Path:	C:\Xcalibur\Training\Najat
Sample ID:	1
Sample Type:	Unknown
Sample Name:	1PPM
Acquisition Date:	11/20/10 12:48:30 AM
Run Time(min):	50.63
Comments:	
Vial:	1
Injection Volume(µl):	10.00
Instrument Method:	C:\Xcalibur\Training\Najat\FS.meth
Processing Method:	
Instrument Software Version:	2.0.6.1008
Instrument Name:	TSQ
Instrument Model:	TSQ Quantum Access

RT	**Peak Height**	**Peak Area**	**Area %**	
3.12	280968987.28	1836322853.27	17.92	
3.30	9097557.60	25645482.63	0.25	
3.59	1356550.22	3236044.56	0.03	
3.92	11270854.89	132060126.88	1.29	
4.47	435654397.89	3064229317.79	29.90	**IIS**
4.88	9246637.46	52000527.69	0.51	
5.15	23798896.10	169363983.43	1.65	
5.47	1599123.82	10168012.80	0.10	
5.65	635813.98	2448841.95	0.02	
5.88	451682.64	2563279.48	0.03	
6.11	4567787.42	33976696.89	0.33	
6.33	842329.76	5966288.73	0.06	
6.58	2595190.34	10341583.89	0.10	
6.69	970081.35	3941477.78	0.04	
6.79	1239894.41	5986865.43	0.06	
6.89	397757.17	1147541.25	0.01	
7.07	426686.04	1735864.08	0.02	
7.20	419987.41	1392283.57	0.01	
7.28	455982.16	1760024.57	0.02	

7.66	496277.14	2054674.63	0.02	
7.94	2779263.76	12770572.86	0.12	
8.25	405771.31	3436385.03	0.03	
8.74	6840611.44	30361152.27	0.30	
8.88	1271492.90	11641919.87	0.11	
9.28	570202.93	43420532.59	0.03	**SIS**
9.46	4569000.58	29979374.29	0.29	
9.64	1570206.03	6229329.79	0.06	
9.81	612432.54	2061610.30	0.02	
10.00	600363.41	2613257.05	0.03	
10.17	589261.52	3497303.58	0.03	
10.29	383750.30	1275833.73	0.01	
10.49	2265182.95	9571573.00	0.09	
10.71	922808.70	6318531.78	0.06	3-C10
10.83	395794.20	1190081.94	0.01	
10.90	293883.75	1018732.16	0.01	
11.02	314273.89	9436599.44	0.01	**SIS**
11.10	459806.45	1972164.91	0.02	
11.38	314303.46	1879450.63	0.02	2-C10
11.64	575944.89	5235486.68	0.05	
11.79	476451.64	2842116.89	0.03	**6-C11**
12.00	311643.21	2620795.49	0.03	
12.46	5550504.50	25335803.75	0.25	4-C11
12.52	1231769.16	9653106.52	0.09	3-C11
12.98	375274.07	1938474.74	0.01	**SIS**
13.18	4337686.31	24045483.21	0.23	
13.37	1089396.95	6074087.97	0.06	
13.64	1087247.73	6662098.09	0.07	
13.83	395377.57	2699010.44	0.03	
13.94	449084.60	2022914.19	0.02	**6-C12**
RT	**Peak Height**	**Peak Area**	**Area %**	
14.08	317489.79	2144095.65	0.02	

14.20	323041.42	1162523.64	0.01	4-C12
14.57	376849.69	1744765.22	0.02	3-C12
15.11	250986.45	2110818.32	0.02	2-C12
15.13	501288.41	58534001.52	0.01	**SIS**
15.45	1432616.53	7179216.00	0.07	5-C13
16.00	3449075.84	14231513.52	0.14	
16.27	792313.32	4296609.27	0.04	4-C13
16.84	1555953.30	8644990.33	0.08	3-C13
17.11	2564066.06	15849549.85	0.15	**SIS**
17.27	907280.04	4430713.03	0.04	
17.45	598000.18	3344913.72	0.03	
17.63	723845.85	5608947.88	0.05	4-C14
17.85	481684.39	2213065.15	0.02	
18.17	1121714.30	4921604.05	0.05	
18.60	351042.67	1524477.29	0.01	3-C14
18.77	319786.35	2488672.22	0.02	
19.02	396728.18	1545126.48	0.02	**SIS**
19.13	310937.17	1526156.33	0.01	2-C14
19.30	288269.87	859087.82	0.01	
19.66	276053.38	2115712.81	0.02	
20.09	1878675.16	9984180.37	0.10	
20.22	845502.23	6581118.99	0.06	
20.92	1380201.39	60437931.78	0.08	**SIS**
21.29	589824.91	3311888.90	0.03	

BIODATA OF STUDENT

Najat Abdullah Ebrahim Masood was born in Makkah, Saudi Arabia on first January 1979. On 1997, she started her graduate study at Faculty of Marine Science/University of Hodiedah and graduated with a B.Sc in Marine Chemistry on 2001 and at the same year, she became a lecturer at Faculty of Marine Science/University of Hodiedah/ Yemen. In the year 2008, she enrolled for the Master Degree at Faculty of Environmental Studies, Universiti Putra Malaysia under the supervision of Associate Professor Mohamad Pauzi Zakaria, PhD.

LIST OF PUBLICATIONS

1. Publication in Journal Article

Sami Muhsen Magam, Mohamad Pauzi Zakaria, Normala Halimoon, **Najat Masood**, Murad Ali Alsalahi, 2012. Distribution of Linear Alkylbenzenes (LABs) in Sediments of Sarawak and Sembulan Rivers, Malaysia. **(***Accepted by EnvironmentAsia* 5(1) (2012) 48-55).

2. Publication in Book Chapter

Najat Masood, Mohamad Pauzi Zakaria, Normala Halimoon, Sami Muhsen Magam, Adila Izyan A.Rahman, Norliza Ismail. 2011. Linear Alkylbenzenes (LABs) in Surface Sediments of South China Sea, Molecular Marker for Sewage Pollution: A Pilot Study. in: Zakaria MP, Mohamed MI, Kasmin S (Eds.), Contemporary Environmental Quality Management in Malaysia and Selected Countries. Universiti Putra Malaysia Press, Serdang, pp. 25-33.

3. Submitting to Journal Article

Najat Masood, Mohamad Pauzi Zakaria, Normala Halimoon, Sami Muhsen Magam, Norazida Manan, Norliza Ismail. 2011. Linear Alkylbenzenes (LABs) as Molecular Marker for Sewage Pollution in Surface Sediments of South China Sea. . (Submitted to Journal of *Environmental Monitoring and Assessment)*

Norazida Manan, Mohamad Pauzi Zakaria, Hafizan Juahir, Abdul Halim Abdullah,Che Abdul Rahim, Lee Chiow Yee, Norliza Ismail, **Najat Masood**, 2011. Chemometrical Pattern Recognition and Source Apportionment of Polycyclic Aromatic Hydrocarbons in Surface Sediments Collected from southwest corner of South China Sea. *(Submitted to Journal of Environmental Sciences)*

4. Exhibition

Mohamad Pauzi Zakaria**, Najat Abdullah** and Adila Izyn A. Rahman. 2009. Assessment of Sewage Contaminants Using Linear Alkylbenzenes (LABs) in Sediments Collected from South China Sea. *Pameran Reka Cipta, Penyelidikan dan Inovasi UPM 2009*. (Silver).

Najat Masood, *Mohamad Pauzi Zakaria, Normala Halimoon, Sami Magam*. 2010. Linear Alkylbenzenes (LABs) in Sediments of South China Sea, Molecular Marker for Sewage pollution. *Pameran Reka Cipta, Penyelidikan dan Inovasi UPM 2010*. (Gold)**.**