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The History of Petroleum Pollution in Malaysia; Urgent Need for Integrated Prevention Approach

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Abstract

Petroleum pollution is known as point and non-point source of contaminations in the environment. A major class of petroleum contaminant is groups of compounds consist of two or more fused benzene rings called polycyclic aromatic hydrocarbons (PAHs) that are carcinogenic, mutagenic and toxic. Source identification of petroleum pollution is necessary to prevent pollution entry into the environment. Eight sedimentary cores were obtained from developed and developing areas around Peninsular Malaysia to investigate the historical profile of PAHs, their characteristics and its possible origins. The results showed that the PAHs concentrations varied from very minimum to 2400 ng/g d. w. in average quarter century intervals. Most of the studied locations showed high contribution of PAHs from combusted fuel, coal, biomasses and wood materials except for the southern part of Peninsular Malaysia in which revealed dominance of petroleum products. The findings indicate that PAHs are delivered from different intermediate materials such as asphalt, street dust, vehicular emission and crankcase oil. However, there has been a decline of PAHs input into the marine environment in recent years; petroleum is shown to be a significant cause of marine pollution since the second quarter of 20th century. An overview on sourced materials of petroleum pollution indicates multi-approach necessity toward pollution control, regardless of concentration and possible degradation processes. Various sectors both governmental and non-governmental are needed for prevention and control of petroleum pollution where different sources apparently contribute to the pollution generation process.

Keywords: petroleum pollution; source identification; PAHs; integrated management; Malaysia

1. Introduction

Since the 1970s, there has been increasing interest on pollution studies in historical aspects. Many studies were initiated to use depositional environment to understand the chronology of the pollution. Until now, the first and foremost reason in these series of studies is focused on managerial issues where revealed data provide the trend of pollution input. Among many chronological researches on environmental pollution, petroleum pollution showed the most interest. This is after more than a century that oil is being used worldwide for energy purposes. Hence, their changes over time are of interest to many research institutions. Petroleum chemicals are divided into many categories and compounds including polycyclic aromatic hydrocarbons (PAHs), aliphatic hydrocarbons and biomarkers (Neff *et al.,* 1979; Wang and Stout, 2007). Petroleum hydrocarbons come into the environment through accidents, spills or leaks, urban input, industrial releases and commercial or domestic uses (Ou *et al.,* 2004). Therefore their fingerprints can be found in the exposed environment of the petroleum pollution. Petroleum hydrocarbon as a source of pollution are generated from crude oil and oil derivatives, and dispersed to the environment via atmospheric transportation, urban runoff, oil spills, tanker accidents and other possible ways. Furthermore, the wide usage of petroleum products in various sectors release related pollution to the environment from many different sources including factories, power plants, residential areas, transportation and oil fields.

Malaysia, which is located in Southeast Asia, has a unique tropical environment and climate. It is

Figure 1. Map of the sampling station in Peninsular Malaysia

surrounded by the Straits of Malacca and the South China Sea in the western and eastern shores, respectively (Fig. 1). On the other hand, the strategic location of this country has made it as one of the busiest shipping route in the world due to the huge petroleum demand from the Middle East to the Far East.

While Malaysia is experiencing extraordinary economic and population growth, it is also developing fast in areas of industrialization, urbanization and motorization in the last few decades. As a result of this development, the environment of this country is receiving more threats and hazards especially from the main source of energy which is petroleum. In Malaysia, the concentration and sources of hydrocarbon pollution reported vary according to the locations. For instance, in west coast of P. Malaysia the concentration reported was medium to high with city source materials, industrial points, workshops and run off (Zakaria *et al.,* 2002; Zakaria and Mahat, 2006; Sakari *et al.,* 2008a). In the east coast of P. Malaysia, the scenario is slightly different where no heavy industrialization and residential areas exist. The concentrations were observed significantly lower than the west coast with dominant of local boats and limited residential source contribution (Sakari *et al*., 2008b).

Hence, this study tries to investigate and suggest possible approaches towards prevention of petroleum pollution in Malaysia. Results and solutions would be used as managerial tools to assure the safe future of the marine environment of Peninsular Malaysia.

2. Materials and Methods

Eight sedimentary cores were taken from September 2005 to January 2007 from Klang Estuary, Malacca, Johor and Tebrau Straits, using stainless steel gravity corers (i.d. 3cm) equipped with compacted precleaned plastic tube inserts to prevent cross contamination prior to slicing. The information of sampling locations is presented in Table 1.

Table 1. Sampling site information description

Core sample	Water depth (m)	Core length (cm)	geographical coordination (N)	geographical coordination (E)	Date of sampling	Sampling location
Klang River	4	21	03° 00' 52"	101° 22' 43"	27 Jan. 2007	Klang River
Offshore Klang	5	42	02° 55' 06"	101° 16' 58"	27 Jan. 2007	Klang Coast
Tebrau 1	8	64	01° 21' 31"	104° 04' 46"	15 June 2006	Tebrau Straits
Tebrau 2	8	56	01° 25' 50"	104° 01' 04"	15 June 2006	Tebrau Straits
Johor City	3	33	01° 26' 50"	103° 45' 37"	27 September 2005	Johor Bharu
Johor Straits	5	36	01° 21' 38"	103° 38' 32"	27 September 2005	Straits of Johor
Malacca coast	8	42	02° 11' 09"	102° 14' 33"	28 September 2005	Coastal area of Malacca city
Malacca Offshore	8	54	02° 07' 39"	102° 12' 20"	28 September 2005	Coastal area of Malacca city

The cores were taken so as to avoid collecting the samples where dredging activities had been conducted. The cores lengths were from 21 and 64 cm. The sedimentary cores in the pre-cleaned compacted plastic container was placed vertically and transferred immediately to the shore for slicing. The core was sliced in 3 and 4 cm intervals from the top using pre-cleaned stainless steel sheets. Each sediment interval was transferred to a pre-cleaned stainless steel container and transported to the laboratory and stored at -18°C prior to further analysis.

2.1. Chemical analysis

PAHs authentic standards were purchased from Sigma Chemical Company (St. Louis, MO, The United States). All organic solvents used in the analysis were distilled in glass. Sediment samples were defrosted under the Al Foil cover at room temperature and homogenized using a pre-cleaned spatula. Five grams of the samples (dry weight basis) were dried with baked anhydrous sodium sulphate and placed in pre-cleaned cellulose thimbles and Soxhlet extracted for 11 hours by distilled dichloromethane. The extracts were subjected to activated copper and left overnight to remove the elemental sulfur which may interfere in the analysis. Precisely, 200 µl of the surrogate internal standards mixture containing (10 ppm each component), naphthalene-*d8*, anthracene-*d10*, benzo[a] anthracene-*d12,* and chrysene-*d12*) were spiked into the extracts. The solution was purified and fractionated by method previously described by Sakari *et al*., (2008 a,b). Briefly, the solution was transferred onto the top of silica gel column (i.d. 0.9 cm, length 9 cm) which was deactivated with 5% distilled H_2O to remove polar components. PAHs ranging from and 2-7 rings were eluted with 20 ml of 3:1 hexane/dichloromethane (v/v). Then, the solution was fractionated using fully activated silica column (*i.d.* 0.47 cm, length 18 cm) to obtain PAHs fractions using 4 ml hexane and 14 ml 3:1 hexane/dichloromethane (v/v), respectively. PAHs fraction was individually evaporated to approximately 1 ml, transferred to 2 ml amber vial, and evaporated to dryness under a gentle stream of nitrogen. The fraction was re-dissolved into an appropriate volume (200 µl) of isooctane containing p-terphynyl-*d14* was used as an internal injection standard (IIS). PAHs was analyzed using a Hewlett Packard 5972A quadrupole mass spectrometer integrated with a HP5890 gas chromatograph equipped with a J&W Scientific Durabond HP-5MS, 30 m fused silica capillary column, 0.25mm i.d. and 0.25m film thickness, using helium as the carrier gas on a constant pressure at 60 kg/cm^2. GC-MS operating conditions were 70 eV ionization potential with the source at 200°C and electron multiplier voltage at ~1200 eV. The injection port was maintained at 300°C and the sample was injected with split mode followed by purge 1 min after the injection. The column temperature was held at 70°C for 2 min, then programmed at 30°C/min to 150°C, 4°C /min to 310°C and held for 10 minutes. A selected ion monitoring (SIM) method was employed after a delay of 4 min. Individual PAHs were quantified by comparing the integrated peak area of the selected ion with the peak area of the IIS. Acenaphthene-d_8 and chrysene-d_{12} were used as IIS for the quantification of PAHs ranging from phenanthrene to 1-methylphenanthrene and for PAHs from fluoranthene to Dibenzo (a,h) antharacene, respectively. PAHs concentrations were recovery-corrected using the spiked surrogates and this procedure typically yields recoveries of PAHs in the range of 77% to 108%. The total PAHs were calculated as cumulative value of all identified individual PAH in this research.

2.2. Chronology experiments for determination of the age of the sediment core

For age determination experiments, the method that applied was comprehensively described by Mohamed *et al.,* (2006); but in brief, an aliquot of 2 g of each sediment intervals from the core samples was dried in an oven in 50°C overnight, sieved in less than 250 µm mesh size and kept dry for analysis. Approximately 0.3 g of this sample was placed in 50 ml beaker and 1 ml (25 ppm) $PbSO_4$ was added as carrier. Then, 20 ml of HCl (8 M) was added to the sample, left for 2 h in hot plate at 60°C for digestion. Digested material was filtered to separate non-usable solids using glass filter paper (*i.d.,* 47 mm). Digested filtered was left in hot plate till dryness and yellow-brown colored paste remained. Thirty ml of $HClO_4$ was added to the paste and warmed-up for ion-exchange resin column chromatography in which 200 ml of HCl (1 M) was gradually added to dilute the samples in the column. Pb was extracted in the column and collected in clean beaker, dried for a day on a hot plate till dryness or until precipitate was formed as a white paste. Fifty ml of HNO_3 (1 M) was added to the paste and left in hotplate for 1-2 minutes, cooled to room temperature then a few drops of H_2SO_4 was added to precipitate the Pb. The precipitated Pb ($PbSO_4$) was left for 3 days in cool condition and filtered using glass paper filter (25 mm) and subsequently subjected to α, β-spectrometry for emission measurements and age determination. The following equation is used to achieve the sedimentation rate and the age of each layer.

$$A = A_0 e^{-\lambda\,(z/s)}$$

Where,

A is the activity of ^{210}Pb of the sediment in the laboratory (dpm/g)

A_0 is the activity of ^{210}Pb of the sediment in the date of sampling (dpm/g)

λ is the half life of ^{210}Pb, $(e/t_{1/2})$; $0.693/ t_{1/2}\,^{210}Pb_{\,(22.3\,y)}$ >>>>λ= 0.031

z is the depth of sediment

s is the sedimentation rate

e is Neparian Number

$$A = A_0 e^{-\lambda\,(z/s)}$$

$\ln(A / A_0) = \ln (e^{-\lambda\,(z/s)})$

$\ln(A) - \ln(A_0) = -\lambda\,(z/s)$

$$Z = -\frac{s}{\lambda}[\ln(A) - (\ln(t\circ)]$$

=> y = mx (The equation of trendline from ^{210}Pb activity points through out the core) ;

$$(where,\ m = -\frac{s}{\lambda}) \Rightarrow S_{y/cm} = -m\lambda$$

=> Age calculation:

Interval Deposition Time (y) =

$$\frac{\text{Thickness of core internal (cm)}}{\text{Sedimentation rate (cm/y)}}$$

Age Calculation at Surface Laye =

$$\frac{\text{Interval deposition time}}{\text{Zero (sampling year)}}$$

Age at layer $_{(x)}$ y =

Interval Deposition Time of layer $_{(x)}$ y - Age of layer $_{(X-1)}$ y

3. Results and Discussion

The results from the analytical experiments in this research are shown in Table 2. As it is shown in the table, quarter century intervals data indicate increasing trend of average total PAHs in some locations during specific era. The core that was collected from the Malacca Coast showed the highest average concentration of PAHs during forth and third quarter century with 2396 and 2183 ng/g d. w., respectively. The results of quarter century periods are demonstrated in Fig. 2. These high values are followed by average total concentration of 1700 ng/g d. w. in Klang City core during 1976 to 1999.

Meanwhile, Johor region demonstrated the medium average data where the highest values of total PAHs were observed from 1925 to 1950. During this period, P. Malaysia was busy with World War II and the country was occupied. There are several minimum PAHs input in many other stations. Usually, in Tebrau Strait core samples and most offshore locations these observations were dominant. Except for the recent years input of PAHs in Tebrau Strait 1 core that showed more than 300 ng/g d.w., the rest of the concentrations did not exceed 57 ng/g d.w. However, the recent input is still at the minimum and does not take into considerations the critical pollution where most of ancient samples show the same level but with non polluted origins. There are apparent differences between core samples in their PAHs concentration and the locations where they were taken. Samples which were taken near the city hinterland usually show higher PAHs concentrations than offshore samples. This is an indicative of transport pathways where PAHs in near shore samples are derived to the study areas via lateral transport using run-off and water ways throughout daily rainfall (Boonyatumanond *et al.*, 2006). On the other hand, daily rain washes off the PAHs associated materials to the sedimentary record compartments. Heavy rainfall and flood is a significant phenomenon in pollution contribution in the sedimentary environ ment (Ikaneka *et al.*, 2005). While this phenomenon highly contributed to the PAHs deposition, offshore locations demonstrate significant lower values up to less than 1 percent. This was described elsewhere with research done by other scientists (Farrington *et al.*, 1983; Prahl and Carpenter, 1983). The PAHs characteristics were high in oil contaminated sites which significantly contribute to the pollution of the studied areas. The results from compound analysis showed that offshore locations receive mostly PAHs with burning signatures while near shore stations influenced with both burnt materials and oil products. Old samples which are delivered from the deep sedimentary taken cores do not reveal oil signature but some PAHs compounds exist. Results from the statistical analyses of PAHs compounds agreed that old sedimentary environment had been increasing natural PAHs input. PAHs in oil derived samples are highly abundant in some specific compounds such as Phenantherene and its methylated derivatives. Therefore in crude oil, petrogenic and pyrogenic products parent and methylted compounds are highly correlated. This correlation in old sedimentary samples showed minimum, no and negative values. These individual signatures of samples are suggested to be derived from natural input with no oil signatures (Krauss *et al.,* 2005; Wilcke *et al.,* 2003).

Table 2. Quarter Century Data on Petroleum Pollution in Peninsular Malaysia Since 1876; a) Average Total PAHs (ng/g d.w.), b) dominant Identified Sources, c) Dominant Origins and d) Major Pollution Transport Possible Routes

	Historical Periods					
	1876-1899	1900-1925	1926-1950	1951-1975	1976-1999	2000-2007
Klang City	a) na b) na c) na d) na	a) na b) na c) na d) na	a) 499 b) petrogenic, pyrogenic c) oil d) run off	a) 200 b) pyrogenic c) oil d) run off	a) 1700 b) pyrogenic c) oil d) run off	a) 33 b) pyrogenic and petrogenic c) oil d) run off
Offshore Klang	a) na b) na c) na d) na	a) 30 b) burning, petroleum c) coal and oil d) in site	a) 20 b) pyrogenic c) oil d) atmospheric	a) 15 b) pyrogenic c) oil d) atmospheric	a) 14 b) pyrogenic c) oil d) atmospheric	a) 11 b) pyrogenic c) oil d) atmospheric
Near Shore Malacca	a) 380 b) burning c) coal d) in site and run off	a) 454 b) burning, petroleum c) coal, oil d) run off	a) 714 b) burning, petroleum c) coal, oil d) run off	a) 2183 b) burning, petroleum c) coal, oil d) run off	a) 2396 b) burning, petroleum c) coal, oil d) run off	a) 452 b) burning, petroleum c) coal, oil d) run off
Offshore Malacca	a) 25 b) natural and burn c) coal and bacteria d) in site and atmospheric	a) 98 b) burning, petroleum c) coal, oil d) atmospheric	a) 45 b) burning, petroleum c) coal, oil d) atmospheric	a) 226 b) burning, petroleum c) coal, oil d) atmospheric	a) 72 b) burning, petroleum c) coal, oil d) atmospheric	a) 98 b) burning, petroleum c) coal, oil d) atmospheric
Johor City	a) 790 b) burning, petroleum c) oil, coal d) run off	a) 563 b) burning, petroleum c) oil, coal d) run off	a) 930 b) burning, petroleum c) oil, coal d) run off	a) 411 b) burning, petroleum c) oil, coal d) run off	a) 102 b) burning, petroleum c) oil, coal d) run off	a) 170 b) burning, petroleum c) oil, coal d) run off

Johor Strait	a) 312 b) burning, petroleum c) oil, coal d) atmospheric and run off	a) 80 b) burning, petroleum c) oil, coal d) atmospheric and run off	a) 432 b) burning, petroleum c) oil, coal d) atmospheric and run off	a) 250 b) burning, petroleum c) oil, coal d) atmospheric and run off	a)173 b) burning, petroleum c) oil, coal d) atmospheric and run off	a) 99 b) burning, petroleum c) oil, coal d) atmospheric and run off
Tebrau Strait 1	a) 15 b) natural c) micro organisms, bacteria d) in site	a) 23 b) pyrogenic c) oil d) atmospheric and run off	a) 23 b) pyrogenic c) oil d) atmospheric and run off	a) 57 b) pyrogenic c) oil d) atmospheric and run off	a) 57 b) pyrogenic c) oil d) atmospheric and run off	a) 310 b) pyrogenic c) oil d) atmospheric and run off
Tebrau Strait 2	a) 13 b) natural c) bacteria, micro organisms d) in site	a) 23 b) pyrogenic c) oil d) atmospheric and run off	a) 13 b) pyrogenic c) oil d) atmospheric and run off	a) 12 b) pyrogenic c) oil d) atmospheric and run off	a) 12 b) pyrogenic c) oil d) atmospheric and run off	a) 38 b) pyrogenic c) oil d) atmospheric and run off
Major Historical Events and Development	Oil discovery in the eastern Malaysia	Oil production and starting point of urban development in some major locations such as Kuala Lumpur and Malacca	General development, rural expansion, World War II and occupation of Malaysia	Independent of Malaysia from the British in 1957, start development of urban and rural areas	Rapid development, accelerated industrialization, urbanization, economic growth and motorization of the country	Several economic recession, steady economic movement, slowed down development

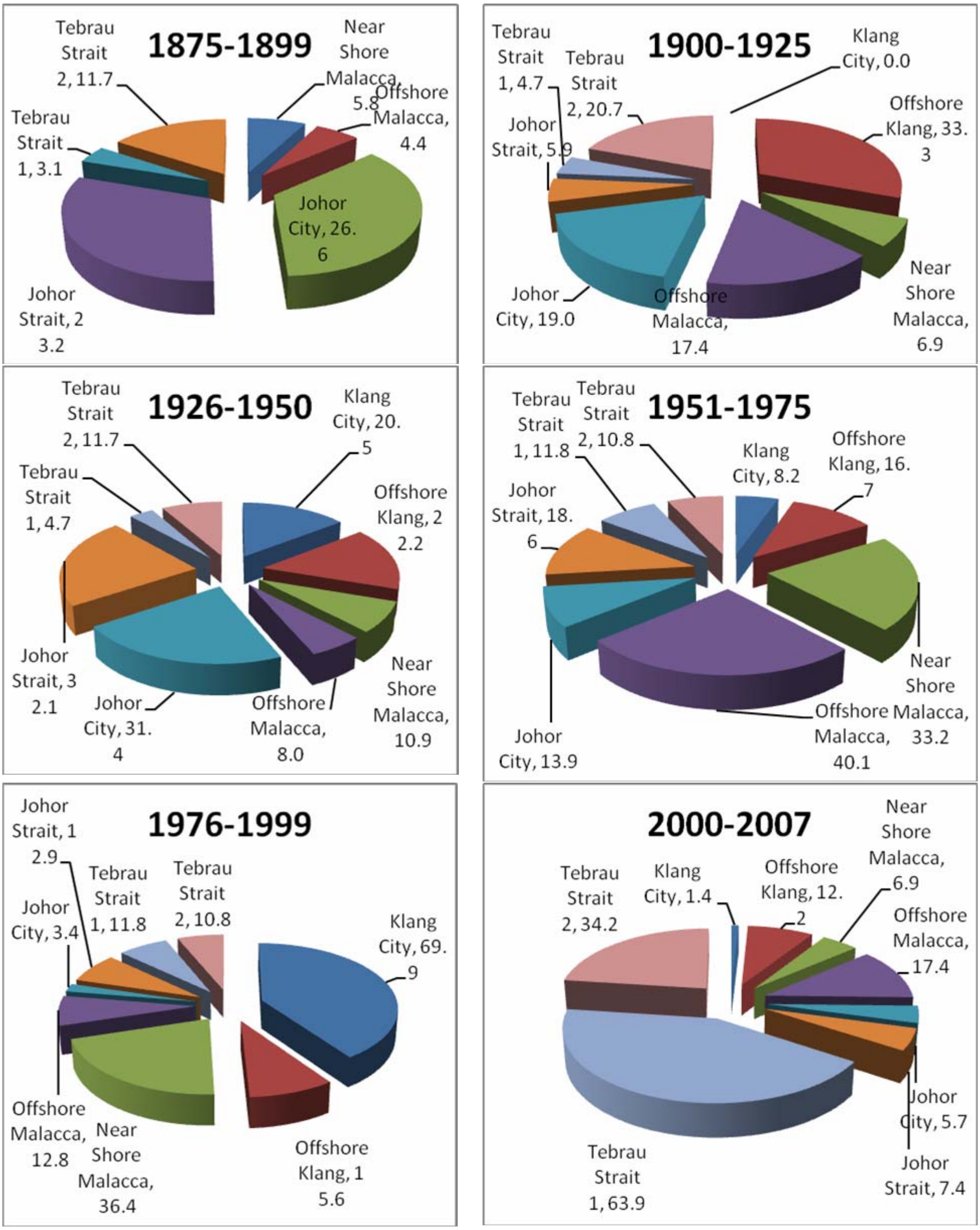

Figure 2. Quarter-Century Historical contributions of total PAHs among selected locations

3.1. Effects of Major Events on Petroleum Pollution

Malaysia experienced several historical events in which recent century development played an important role in its current socio-economic, political and environmental situations. In the late 19th century, Malaysia was of interest to many foreign countries, multinational companies and individual researchers. This interest was for specific purposes such as spice trade which began since early 15th century. Natural resources were one of the areas that held a fascinating demand for research and business, but among the many types of natural resources, oil was the most important. Special interests were shown in oil fields in Sarawak during the late 19th century and in the East Coast in Terengganue during the early 20th century. This is the time when Malaysia emerged a country with dominant sources of energy. Although Malaysia's energy sources are still partially imported (e.g. Coal from Australia and China) due to economic reasons, she is independent in term of oil production. The sources, as observed from the analysis in this study, revealed that until the beginning of the 20th century, there was abundance and dominance of non-oil sourced PAHs. In this era, the highest values are observed in the Malacca coast and Johor region where coal was used as the local energy source for different purposes. The beginning the 20th century showed a slight increase in PAHs concentration and contribution of oil into the sedimentary environment. This signature is provided by specific compound statistical correlation calculations. The historical trend of PAHs accumulation is shown in Fig. 3. This cumulative bar chart of PAHs concentrations simulates the depository environment of the studied locations. The graph demonstrates stations in X axis that is plotted against cumulative concentrations of PAHs in Y axis.

However, the first quarter of 20th century showed a slight increase of average total PAHs; the second quarter again revealed higher increase of concentration in total PAHs. This era was in conjunction with many important events nationally and worldwide. First of all, development began in many areas in Malaysia. Marine transportation to remote destination was shown to be rapidly increasing and Malacca Straits was recognized as a vital water way. Along the shore, urban and rural development took place and like many other nations demand for energy were increased via industrializations and motorizations. The trend no longer existed during World War II and the subsequent occupation of Malaysia. Therefore, several changes affected the environmental history of the region. The results in this study showed that the core in which corresponding Kuala Lumpur region, Klang City core, started with around 500 ng/g d.w. of petrogenic and pyrogenic signatures. Likewise, Malacca Coast samples revealed the same trend and it is exceeded over 700 ng/g d.w. A rapid increase is also observed in Johor cores. In Johor, values are increased rapidly and observed over 900 and 400 in Johor City and Johor Straits, respectively.

The third quarter started in 1950's where most of these events ended and Malaysia became independent in 1957. After this period, the country stepped forward to follow many other developed and developing countries. Industrialization, motorization, urbanization and urban-rural development were among the significant changes seen. The same trend was reported by Boonyatumanond *et al*., (2007) from Thailand where increasing of mobile and stationary sources of pollution in Bangkok revealed higher pollution loads. Furthermore, this trend was not limited to 1975 and almost continued until 1999, where more or less harmonic changes took place. The total value of PAHs increased in average up to 1700 ng/gd.w. in Klang City core with predominant input of burnt materials such as oil and petroleum products. The dominant of pyrogenic input reveals combusted petroleum input via automobiles and

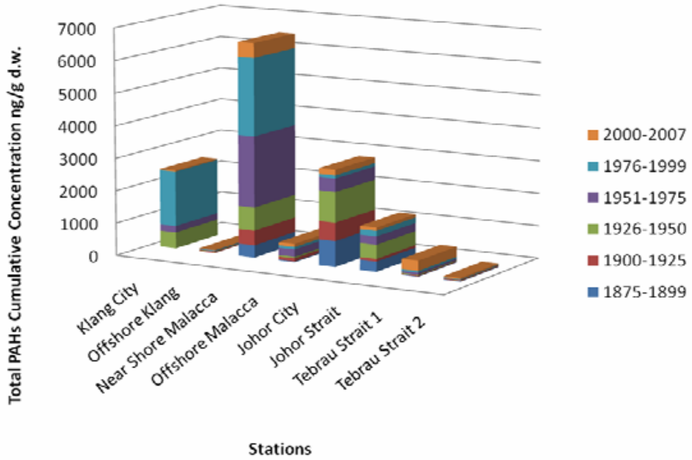

Figure 3. Cumulative total PAHs in sedimentary records of studied regions; coresû data simulated chart

industries. In Malacca again the numbers are observed up to 2400. While Malacca coast showed an exponential increasing rate, Malacca status in remote areas revealed an increase. As remote areas receive lower concentration of PAHs due to its transport pathways and atmospheric movements, the volume and concentration are depleted (Farrington *et al*., 1983). The higher values of Malacca sample with PAHs signatures throughout various compounds in comparison to many other locations suggest contribution of coal as a source of energy (Hartmann *et al*., 2005).

In Johor, this history was totally different. Johor cores showed interestingly decreasing trend of total PAHs. The PAHs concentrations were decreased dramatically to around 100 and 170 ng/g d.w. in Johor City and Strait, respectively. While the trend was changing, the transport pathways remained the same. The city run-off washed away materials from the city such as dust, sand and tire debris that were exposed to petrogenic and pyrogenic PAHs. As a reason to these changes it is noted that Singapore played an important role. A year after the independence of Malaysia, Singapore was formed and absorbed most of the economic activities. Therefore it is presumed that rapid and exponential inputs of PAHs are focused in a location out of sampling stations and were most probably out of the country.

The only location that showed rapid increase in PAHs only during the last decade was Tebrau Strait. In Tebrau 1, the exponential increases of total PAHs reached to over 300 ng/g d.w. from around 50 in past quarter century. Tebrau Strait became interesting to many Malaysian authorities in the last 2 decades. Therefore there were many development activities conducted such as new ports, construction of bridges and maritime related industries. Now, ocean-going ships enter into this water way from Far East and the South China Sea for uploading and downloading of goods.

3.2. Pollution Sources and authorized Bodies

In Malaysia, like many other countries, environmental management and monitoring of environmental factors are the duties of the Department of Environment (DOE). Although, many organizations such as universities, research and implementation institutions laterally contribute; DOE remains the main responsible body for such duties. Depending on the sources of pollution a specific authorized body would be responsible. For instance, monitoring of oil spills and accidents belong to the maritime department. City councils and municipalities mainly take care of whatever happens in workshops and urban areas. Therefore a wide range of legal bodies control the processes. DOE plays an umbrella role to all these organizations monitoring their activities and the cleanness of the environment in general.

Pollution in the environment come from complicated processes where controlling any individual types of pollution requiring contribution from others. For instance, an oil spill in the sea, resulting from a marine accident in a stormy weather condition needs prevention through a divers plan of action such as weather forecast, marine traffic, emergency response, prevention actions and oil collection facilities. All of them with individual management approach and would not be able to achieve optimal results unless an overall body controls the process. Therefore, when a body does not respond well, the others cannot fully function. The same things are proposed in urban management bodies where dust, workshops, land use, urban plans, wastewater systems, city run-off programs and inhabitants contribution to the environmental issues should be treated as a body where without either one of them the comprehensive environmental management fails (Table 3).

In this study, 3 different PAHs signatures are identified including petrogenic, pyrogenic and biogenic. Petrogenic inputs which are dominant in Malaysia even in recent years (Zakaria *et al*., 2002), comes from many different sources such as petroleum from oil spills, marine accidents, car workshops, industries, oil fields and city surface run-off. Even though all of these reasons are identified by specific authorized bodies, management of the entire system fails due to lack of resources, inappropriate involvement of organizations, careless procedures in management and beneficial issues. The coal which has some petrogenic signatures throughout the PAHs signs are derived from mining, processing and its transportations. The focus on coal related petrogenic like PAHs signatures are mostly deemed to be less important in both public and authorities' points of view. Coal has lower price in market as an energy source and is being increasingly used in Malaysia. An example to this is the biggest power plant in Malaysia that stands on coal fire processes in Kapar. It produces huge amount of tars, PAHs and hot water that enters into the marine environment adjacent to the power plant. Pyrogenic sources are vast where mobile and stationary input provide higher amount of PAHs input to the study area via lateral transportations in rivers and city run-off. Combustion of petroleum products and coals in industries together with biomass burning are very common and dominant in this region. Several forest fires such as during 1997 and 2005 in Indonesia contributed significantly in PAHs input of the region.

Table 3 PAHs signature, possible sources, legal monitoring and managerial bodies, problems in management and proposed action

PAHs Signature	Origin	Sources	Legal Management Body	Managerial Problem	Proposed Body/Action
Petrogenic	Petroleum	Oil spill via marine accident	Dep. Of Maritime, DOE	Poor Responses	Using other resources
		Car workshops	Manucipalities, DOE	Lack of Management	Involving appropriate bodies
		Feul stations	Manucipalities, DOE	Lack of Management	Involving appropriate bodies
		Oil fields	Dep. Of Maritime, Oil companies, DOE	Careless Proceedures	New Techniques and equipm.
		City Run-Off	Manucipalities, DOE	Cost benefit problem	Enhancing treatment systems
	Coal	Mining	Industrial Authority, Energy, DOE	Less Importance	Research Contribution, Tech.
		Coal Proccessing	Industrial Sectors, DOE	Less Importance	New Technologies
		Coal Transportation	Private Sectors, DOE	Less Importance	Local bodies involvement
	Natural	Bacteria and Fungi	na	na	na
Pyrogenic	Petroleum	Mobile sources	DOE	Hard to manage	Green Technologies
		Industries	DOE	emloyment, Economy	Green Technologies
		Residential	DOE	Vital Daily Need	Green Technologies
	Coal	Industries	Industrial Authority, Energy, DOE	Cheap Energy Source	Clean Coal via Research
	Biomass	Forest and bush fire	Dep. Of Forestry, DOE, Rural Management	Remoteness	Expanding fire gaurds and involving more locals via edu.
		Green material burning	Dep. Of Natural Resources, DOE, Rural Management	Lack of awareness	
	Natural	bacteria, Fungi	na	na	
Biogenic	Natural	bacteria, Fungi	na	na	

However, departments of forestry and natural resources together with rural management authorities, the main responsible bodies, have been failing due to the remoteness of threaten areas and lack of public awareness. In industries, the factors like employment, economy and vital daily needs for products, prevent a sustainable approach toward environment management where not a single comprehensive goal is considered.

3.3. Toward an Integrated Environmental Management Approach

It is seen that management of environmental concerns are complicated throughout multi-disciplinary approaches. Organizations contribute to an environmental problem solving program, consider their own institutional benefits rather than the main environmental purpose. Therefore, they may play parallel roles and slightly modified goals would be targeted. This process usually is accompanied with inaccuracy and wasting of time. To overcome the problem and conduct accurate action, an organizational body needs to be created. This administration would provide appropriate collaboration atmosphere among various responsible organizations that deals with environmental issues. Any specific environmental issue such as oil spill need contributions from weather forecast department, maritime department, DOE, the Navy, Coastal Guards, emergency response, NGO's among others. Any of above mentioned organizations would take a part of entire duties in collaboration of other parties, considering whole benefits and concern. Likewise, the urban management to prevent oil derivatives entering into the coastal waters of adjacent cities also needs an integrated approach for management. Beside the duties of municipalities and DOE, various organizations should contribute such as wastewater treatment, run-off control and collection, NGOs, shopkeeper's council, city council, land use authority and the local government. However, many organizations would play applicable roles in prevention, control, monitoring and rehabilitation others provide administration and political support (Fig. 4).

In Malaysia, ever since 1957, several governmental and private bodies were established to consider environmental management, as there were indications that petroleum pollution was increasing. Furthermore, huge budgets had been allocated, new equipments were purchased and higher knowledge was gained. While exponential increases in every aspect exist, the enforcement factors against environmental pollution, petroleum pollution in particular failed.

In addition, a collaborative management body would be able to gather all the activities from various organizations and put them in an integrated action that targets the defined goals. Petroleum pollution in Malaysia, from the historical point of view, does not derive from a single source or reason; hence complicated processes are needed to provide comprehensive action in the future. The current trend of petroleum accumulation in the depository environment shows an increasing trend, although recent years (after 2000) data revealed promising. This study tried to provide evidence on petroleum pollution while different managerial bodies have been fulfilling their duties. On the other hand, current condition does not guarantee a better future for the environment in petroleum pollution aspects while many different organizations play their own roles. However, this study suggests that in some locations the levels are decreasing such as in the Johor

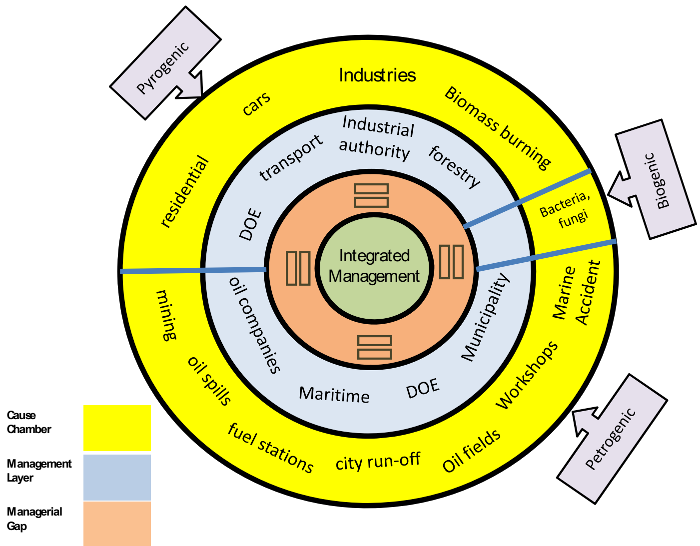

Figure 4. Pollution-Cause-Management; Integrated management approach toward managerial gap-filling sustainability

region due to alternative economics and geo-politic situations like the Singapore separation. The dramatic decrease of petroleum pollution in Klang region needs for further investigations whereby the last 25 years of the 20th century dropped by 98% in recent years. While DOE concerned about pollution control and rehabilitation, the environment seems unlikely to be supported by other stakeholder such as industries, urban management authorities and oil companies. This study suggests an urgent need for the establishment of an integrated managerial body to take care of the entire processes of environmental protection to fill up the managerial gap and protect the environment.

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References

Boonyatumanond R, Wattayakorn G, Amano A, Inouchi Y, Takada H. Reconstruction of pollution history of organic contaminants in the upper Gulf of Thailand by using sediment cores: First report from Tropical Asia Core (TACO) project. Marine pollution bulletin 2007; 54: 554-65.

Boonyatumanond R, Wattayakom G, Togo A, Takada H. Distribution and origins of Polycyclic Aromatic Hydrocarbons in estuarine, rivers and marine sediments in Thailand. Marine Pollution Bulletin 2006; 52: 942-56

Farrington JW, Goldberg ED, Risebrough RW, Martin JH, Bowen VT. "Mussel Watch" 1976-1978: An overview of the trace-metal, DDE, PCB, Hydrocarbons, and artificial radionuclide data. Environmental Science and Technology 1983; 17: 490-96.

Hartmann PC, Quinn JG, Carins RW, King JW. Depositional History of Organic Contaminants in Narragansett Bay, Rhode Island, USA. Marine Pollution Bulletin 2005; 50(4): 388-95.

Ikenaka Y, Eun H, Watanabe E, Kumon F, Miyabara Y. Estimation of sources and inflow of dioxin and polycyclic aromatic hydrocarbons from the sediment core of Lake Suwa, Japan. Environmental Pollution 2005; 138: 529-37.

Krauss M, Wilcke W, Martius C, Bandeira AG, Garcia MVB, Amelung W. Atmospheric versus biological sources of polycyclic aromatic hydrocarbons (PAHs) in a tropical rain forest environment. Environmental Pollution 2005; 135: 143-54.

Mohamed CAR, Theng TL, Ahmad Z. Inventory and flux of ^{210}Po and ^{210}Pb in the water column of Southern South China Sea and Malacca Straits. Coastal Marine Science 2006; 30(1): 379-86.

Neff JM. Polycyclic Aromatic Hydrocarbon in the Aquatic Environment: Sources, Fates and Biological Effects. Applied Science Publishers, London. 1979.

Ou SM, Zheng JH, Zheng JS, Richardson BJ, Lam PKS. Petroleum hydrocarbons and polycyclic aromatic hydrocarbons in the surficial sediments of Xiamen Harbour and Yuan Dan Lake, China, Chemosphere 2004, 56: 107-12.

Prahl FG, Carpenter R. Polycyclic aromatic hydrocarbon (PAH)-phase associations in Washington coastal sediment. Geochimica et Cosmochimica Acta 1983; 47(6): 1013-23.

Sakari M, Zakaria MP, JUNOS MB, ANNUAR NA, Yan YH, Sin HY, Zainuddin SMHS, Leong CK. Spatial Distribution of Petroleum Hydrocarbon in Sediments of Major Rivers from East Coast of Peninsular Malaysia. The Journal of Coastal Marine Science 2008a; 32: 1-10.

Sakari M, Zakaria MP, Lajis N, Mohamed CAR, Shahpoury P, Anita S, Chandru K. Characterization, distribution, sources and origins of aliphatic hydrocarbons from surface sediments of Prai Straits, Penang, Malaysia: A widespread anthropogenic input. Environment Asia 2008b; (2): 1-14.

Wang Z, Stout SA. Oil Spill Environmental Forensics. Elsevier San Diego. 2007.

Wilcke W, Amelung W, Krauss M, Martius C, Bandeira A, Garcia M. Polycyclic aromatic hydrocarbon (PAH) patterns in climatically different ecological zones of Brazil. Organic Geochemistry 2003, 34: 1405-17

Zakaria MP, Takada H, Kumata H, Nakada N, Ohno K, Mihoko Y. Distribution of Polycyclic Aromatic Hydrocarbons (PAHs) in rivers and estuaries in Malaysia: widespread Input of petrogenic hydrocarbons. Environmental Science and Technology 2002; 36:1907-18.

Zakaria MP, Mahat AA. Distribution of Polycyclic Aromatic Hydrocarbon (PAHs) in Sediments in the Langat Estuary. Coastal Marine Science Journal 2006; 30(1).

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