OCCURRENCE OF TAR POLLUTION

ALONG SOME SHORES IN INDONESIA

by

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PREFACE

The Indonesian - French Joint Cooperative Research on Oceanology agreement was signed on October 13, 1980, by the State Ministry for Research and Technology, Indonesia and Centre National pour l'Exploitation des Oceans (CNEXO), France, each representing the respective government, and followed by the Indonesian French Joint Commision Meeting on May 12 - 14, 1982, a joint programme on Marine Environment Study has been set up.

One of the programmes is to study the occurrence of tar pollution along shores in Indonesia with long term objective to assess the level of tar pollution and try to identify the type and possible origin.

LEMIGAS Research and Development Centre of Oil and Gas Technology and Centre Oceanologique de Bretagne execute this study in 1982 and 1984. In this article assessment of the level of the tar pollution is discussed.

On behalf of the French - Indonesian Team an expression of gratitude is due to Prof. Wahjudi Wisaksono of LEMIGAS, Dr. Laubier of CNEXO for their confidence to the team.

ABSTRACT

Four typical Indonesian coasts : Jakarta Bay, Malacca and Makassar Straits, as well as South coast of Yogyakarta, Central Java, were surveyed in August 1982 and May 1984 with the purpose of assessing, quantifying and identifying tar stranded thereon. The estimation of tar pollution was determined using a typical statistical methodology based on a stratified random sampling. Quantitative beach sampling conducted in August 1982 during the East monsoon season yielded average stranded beach tar concentrations ranging from less than 1 g/m to about 2.800 g/m (values in gross weight) of shoreline. The values obtained in May 1984 after the West monsoon ranged between 2,8 and 9.500 g/m.

In the two surveys, the most polluted area was located in the Kepulauan Seribu area (Jakarta Bay). Average tar weight of over 2 kg/m beach are comparable to that of other coast along major tanker routes as Kuwait or Bermuda. Observed tar pollution in Pulau Kapal Besar, Labon Kecil, Nirup, Pelampong and Takong Kecil (in the Straits of Malacca) and Langga Beach (on the Straits of Makassar) was lower during these surveys. The reason why inspite of such dense marine traffic is not clear, until one examines the internal current circulation between the islands, the local geographical features of the site and preferential wind directions.

I. INTRODUCTION

Oil enters the marine environment from various sources, e.g. from the accidental and intentional release of petroleum wastes during the production, transportation, refining and the use of fossil fuel, advection through land run-off and domectic/industrial oily waste discharge. Oil contamination in the marine environment are among others in the form of stranded tarball on beaches and floating tar residues, which has had weathering sequences of physical, chemical and biological processes. Accumulation of oil contaminants are strongly dependent on the geographical, hydrographical and topographical features of the coastal waters.

Indonesia is situated between 95° and 141° longitude and between 6° North and 11° South latitude. It composes of 13,677 islands and has a total coastline length of approximately 81,000 km (Soegiarto, 1983).

Being located on the equator, Indonesia has a tropical climate with temperate and stable temperature in the range of 20° to 32° C. The climate is completely controlled by monsoon, where seasonal wind blows in turns every half year. The monsoon wind blows during the month April to October from the Southwest and during the remaining of the year from the Northeast.

Wind are important for the oil slicks and floating tar drift direction, however water surface currents play a bigger role. The most authoritative work on surface

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currents was done by Wirtky (1961) and has been condensed as seen in figure 1 and 2.

The distribution of stranded tarball on beaches has already been identified as a regional problem in the Southeast Asian countries by various international and regional meetings. Since more than 90% of the crude oil supply for the Pacific Countries, particularly Japan and the United States, is shipped from the Middle East through the Indonesian and Southeast Asian Water. Nasu et.al. (1975) have indicated that oil lumps and pelagic tar have been covering a large area of the Pacific and Indian Ocean following the general pattern of tanker routes and the surface currents, as indicated in figure 3.

Numerous loading and unloading ports and refineries are located on the East Coast of Sumatra, West Coast of the peninsular Malaysia as well as the West Coast of Sabah and on the islands belonging to Singapore and also productive offshore fields which are located in this water.

Oil in Indonesia produced by Pertamina and its 79 contractors has reached a total amount of 488 million barrels or a daily average of 1.3 million barrels per day in 1982, which include the offshore production of 44%. Oil is exported mainly to the Far Eastern Countries (0.55 million barrels per day) and to the West Pacific Countries (0.22 million barrels per day), (Department of Mining and Energy, 1982). The oil transportation pattern, location of important productive offshore fields and refineries is indicated in figure 4.

Stranded tarball on beaches has been reported in some islands and beaches of Indonesia. Toro et.al. (1982) from the National Oceanology Institute observes this phenomena in Kepulauan Seribu since 1978, while Suryowinoto (1982) from the Gajah Mada University has reported that stranded tarball has been occasionally occured in the South Coast of Jogjakarta but systematic observation has not been conducted.

Oil in sediment has been observed by Baker et.al. (1980) in Kepulauan Riau.

Under the framework of the Franco-Indonesia Joint Research Programme on Oceanology, LEMIGAS and CNEXO have executed a Joint Study on Tarball Occurrence i Indonesian Shores with the objective to quantify the dynamic of oil pollution on different coastline and trv to identify by qualitative analysis the possible origin of the oil pollution through the stranded tarball. Based on the consideration of the existing tarball reports, prevailing currents oil activities location and shipping routes, four test sites namely the Kepulauan Seribu, Kepulauan Riau, the Southern West Coast of Sulawesi/Langga Beach and the South Coast of Jogjakarta has been observed and surveyed from 13th of August to 3rd of September in 1982 and from 3rd to 17th of May in 1984. There is a different monsoon between these two sampling periods. The periods of May - October is usually called as East monsoon and on the other hand West monsoon is in the period of December - April. So the joint survey is very beneficial because the obtained data are successively collected in a part of each monsoon.

II. IMPLEMENTATION OF THE SURVEY

II.1. Kepulauan Seribu

Kepulauan Seribu or Thousand Islands Archipelago is located in the Java Sea at about 40 km Northwestward from Jakarta (Fig. 6). This archipelago is mainly composed of six islands : P. Pari (which is the biggest), P. Tengah, P. Kongsi, P. Tikus, P. Tidung and P. Burung surrounded by a coral reef delimiting an internal lagoon. The main shipping line to and from Jakarta harbour goes Northwards the vicinity of Pulau Pari while the Northwestern part of the archipelago is occupied by offshore oil activities. According to these features and the importance of P. Pari as a scientific research station in oceanology, P. Pari had been the main focus in our tar ball study.

II.2. Kepulauan Riau

Kepulauan Riau is an archipelago of more than 100 islands situated South of Singapore island in the Malacca Straits Main international lanes connecting both the Indian and Pacific Oceans lie between these islands and Singapore. Some of these islands (P. Pemping, P. Kasu, Kepala Jernih) were polluted by the Showa Maru oil spill in 1975 (Baker et.al., 1980). The sampling was done on sandy areas of five islands located in the vicinity of the straits (figure 7).

Pulau Takong Kecil Pulau Pelampong	in the principal strait
Pulau Nirup Pulau Labon Kecil Pulau Kapal Besar	on the Southeastern part of the strait

Usually these islands are mainly occupied by mangrove essentialy composed of sonneratia and rhizophora and the sandy beaches are of small extent. They are also dominantly influenced by strong tidal currents.

II.3. Southwestern Coast of Sulawesi (Langga)

Langga beach located about 180 km Northward from Ujung Pandang is the only test site surveyed in this area. This sandy beach is a representative area of chronic turball pollution resulting from oil transportation in Makassar straits.

II.4. South Coast of Java

The studied area is located in the Southern Coast of Java near Yogyakarta. It is mainly composed of the beaches of Kukup and Krakal. These beaches are well exposed to the open ocean swell. They are composed of a sandy flat limited in their eastern and western part by rocky cliffs.

III. QUANTITATIVE ASSESSMENT OF TAR POLLUTION

III.1. Sampling Methodology

The aim of the developed methodology is to obtain an estimation as precise as possible of the quantity of stranded tar over a determined test site in taking into account that the tar loading are not homogeneous (very high density variation may appear on the same beach). The stratified random sampling adopted in this study has the advantage of giving a good precision of the estimated mean and of notably minimizing the variance of the mean.

Briefly, this methodology could be divided into two steps :

* The first step consists of making a rapid reconnaissance of the test area in order to divide it into strata representative of a type of accumulation (i.e. very high, medium, low, very low) each of which is internally homogeneous.

* The second step consists in selecting, in each stratum, a random sampling composed of **n** samples of the total gross weight of tar collected in a transect of known width (generally 1 m) perpendicular to the water line from the lower part of the investigated zone up to the upper part of the beach. The values are expressed in gross weight of tar balls (oil, sand or other litter). By a further extraction in laboratory, it is possible to pass from the gross weight to net weight of hydrocarbons.

III.2. Analytical Aspect of the Method

Tar pollution on beaches are determined by the estimation of sample mean and confidence limits. The symbols in the formulas used are defined as following.

- The suffix **h** denotes the name of stratum.
- The suffix **i** denotes the unit of sampling in the stratum.
- N_h = length of the stratum **h** (unit = meter).
- n_h = total number of sampling units taken in stratum **h**.
- y_{hi} = value of the i th sampling unit in stratum **h**.
- Stratum Weight : $W_h = \frac{N_h}{N}$
- Sampling fraction in the stratum : $f_h = \frac{n_h}{N_h}$
- Sample mean : $\overline{Y}_h = \sum_{i=1}^{n_h} \frac{Y_{hi}}{n_h}$
- Total length of test site (L strata) :
  $N = N_1 + N_2 + N_3 + \ldots\ldots\ldots\ldots + N_L$
  (Equal to the sum of the length of all strata).
- Estimation of standard deviation (S_h) in stratum **h** :

$$s_h = \sqrt{\frac{n_h}{n_h - 1} \cdot \frac{1}{n_h} \sum_{i=1}^{n_h} (Y_{hi} - \overline{Y}_h)^2} \quad \text{of}$$

$$s_h = \sqrt{\frac{1}{n(n-1)} \cdot n \sum Y^2 - (\sum Y)^2}$$

- Estimation of the whole population :

$$Y_{st} = \sum_{h=1}^{L} N_h \cdot \bar{Y}_h$$

- Estimation of mean per unit over the whole population : $\bar{Y}_{st} = \sum_{h=1}^{L} \frac{N_h \bar{Y}_h}{N}$.
- Total estimation of population : $Y_{st} = N.\bar{Y}_{st}$
- Estimation of variance of $\bar{Y}_{st}$:

$$V(\bar{Y}_{st}) = s^2(\bar{Y}_{st}) = \sum_{h=1}^{L} W_h^2 \frac{s_h^2}{n_h} . (1 - f_h)$$

- Estimation of variance of the whole population : $V(Y_{st}) = N^2 . V(\bar{Y}_{st})$.
- Approximation of number of the degrees of freedom of $s(\bar{Y}_{st})$:

$$n_e = \frac{\left(\sum_{h=1}^{L} g_h . s_h^2\right)^2}{\sum_{h=1}^{L} \frac{g_h^2 . s_h^4}{n_h - 1}} \quad \text{where } g_h = N_h \frac{(N_h - n_h)}{n_h}$$

- Confidence limits of Estimated mean = $\bar{Y}_{st} \pm t_p \times s(\bar{Y}_{st})$.

t_p obtained from Student's tables for probability p and the number of degrees of freedom n_e.

- Optimal Allocation.

In order to minimize the variance of $\bar{Y}_{st}$, a total number of sample units n, n_h must be :

$$n_h = n . \frac{N_h . s_h}{\sum_{h=1}^{L} N_h . s_h}$$

- Comparison of Results.

For $\bar{Y}_{1st}$ and $\bar{Y}_{2st}$, two means obtained from two different sites or from the same site at two different time (dates), the confidence limits of the difference is calculated as follows :

$$(\bar{Y}_{1st} - \bar{Y}_{2st}) \pm t_p . \sqrt{s^2(\bar{Y}_{1st}) + s^2(\bar{Y}_{2st})}$$

t_p obtained from Student's table for the probability p and number of degrees of freedom $V = n_{e1} + n_{e2}$.

III.3. Results and Discussion

The general estimation of stranded tar pollution on the test sites surveyed in August 1982 and in May 1984 is indicated on table 2.

Table 2

COMPARISON OF TAR POLLUTION ON INDONESIAN BEACHES in August 1982 and May 1984 (data expressed in g/m)

Geographical location	1982 survey mean in gross weight	1982 survey mean in net weight	1984 survey mean in gross weight	1984 survey mean in net weight
Pulau Pari South	102 ± 45	25,9 ± 11,4	542 ± 394	112,3 ± 85,8
Pulau Pari North	2867 ± 840	189 ± 55	9554 ± 5979	1880 ± 1224
Pulau Tikus	61,1 ± 49,4	18,1 ± 10,8	86 ± 37,8	19,8 ± 9,8
General estimation at Kepulauan Seribu	812,7 ± 219	67 ± 15,3	2460 ± 1349	494 ± 270
Pulau Takong	29,8 ± 18,2	8,14 ± 7	53,6 ± 77,6	13,7 ± 19,8
Pulau Pelampong	15,2 ± 16,5	7,6 ± 8,2	6,57	0,95
Pulau Nirup	11,3 ± 13,1	8,5 ± 9,9	5,21 ± 9,64	1,68 ± 3,10
Pulau Labon Kecil	9,6 ± 13,7	5,5 ± 7,9	2,85 ± 1,88	1,02 ± 0,67
Pulau Kapal Besar	24,1 ± 20,7	11,3 ± 10,1	41,2 ± 37,8	18,3 ± 16,8
General estimation at Kepulauan Riau	15,4 ± 5,4	7,8 ± 3,4	16,03 ± 12,4	4,80 ± 2,95
Makassar Straits (Langga)	56,8 ± 36,5	30,7 ± 21,1	22,6 ± 9,3	9,08 ± 3,32
Central Java coast (Kukup)	< 1		7,5 ± 2,7	3,13 ± 2,53

The data (mean and confidence limits) are expressed in gram per unit beach length (g/m) of collected tar residues before (values in gross weight) and after removal of non-petroleum compounds in the tar samples (values in net weight). The variability of coastal pollution is depending on many factors as time of observation, geographical location, currents systems, meteorology, monsoon, oil and shipping activities.

III.3.1. Comparison of data expressed in gross and net weight

The presence of non-petroleum inclusions in the tar samples (shell, sand, water, seaweeds...) inflated the weight of stranded tar so that the actual petroleum compounds may represent sometimes a low percent of the reported weights. During our field surveys we collected about fifty tar sample randomly distributed on each station of the studied test sites. Oil content in tar samples was determined by chemical analysis (soxhlet extraction) in order to express the pollution level in net weight. The ratio mean in net weight/mean in gross weight is ranged from 0.06 to 0.75. So the data expressed in net weight represents respectively about 40% (average value 41.4 $\pm$ 20.8%) and 30% (average value 28.7 $\pm$ 10.1%) of the values in gross weight reported in 1982 and 1984.

Looking only on the data expressed in gross weight may lead to incorrect evaluation and comparison between the pollution level on two sites when the values are very close. In this study the results expressed in gross or net weight do not change the order in the pollution level of the studied sites. In the order points of the discussion, only the values expressed in gross weight will be used. However it is interesting to indicate the average net oil content in the gross weight which is in the amount of 29.7%.

III.3.2. Comparison of Pollution level in studied sites

In 1982 and 1984 surveys, Kepulauan Seribu in Jakarta Bay appeared to be the most polluted area, in comparison with the other surveyed areas. With the values expressed in gross weight we observed a fluctuation of tar pollution during the two seasonal surveys in Kepulauan Seribu.

At the sampling times, the two islands, Pulau Pari and Pulau Tikus, surveyed in this area were characterized by a great difference in stranded tar ball accumulation. The reason why more tar was deposited on Pulau Pari than on Pulau Tikus was not clear until one examines possible internal current circulation inside the lagoon, local geographical features of the site and preferential wind direction. The northern coast of Pulau Pari is situated near the main shipping lines to and from Jakarta and is directly exposed to the tar pollution coming from the oil wastes and ship spillage discharged at sea. On this area pollution appears in the form of large agglomerated oily patches several cm deep continuously distributed at the upper tidal zone. The southern coast of Pulau Pari showed an aspect of tar pollution which is different from the one on the northern coast. Accumulations of tar on the beach are very often dispersed at random. Usually oily residues were composed of small tar balls and oil patches were often lying on the sea bottom at low tidal zone. Some samples were relatively soft whereas others were as hard as bituminous coal.

On this side, we observed also a lot of plastic and rubber wastes probably coming from industrial discharges in Jakarta Bay. Oil pollution in this area seemed to be related more likely to local shipping activities (fishing and local transportation) and petroleum discharges (industrial and oil terminal activities) in Jakarta Bay.

In the case of the "Malacca Straits", it could be very surprising to find that pollution in front of Singapore Harbour and in region of such dense a marine traffic is less than that at the other surveyed sites. The reason for this could be explained by the presence of strong tide currents. In fact, it seems that the small visited islands observed in the region do not act, as Pulau Pari does, as a trap for hydrocarbons. This was observed in Pulau Takong in the Middle of the Straits. Fresh tars were coming with the flood-tide and going back with ebb-tide and the strong drift associated to it. In fact the same portion of the island shore showed a complete redistribution of tars in 24 h although the level of pollution in weight had not changed.

The general pollution in the Straits could be elsewhere and located south ward along the coasts of Sumatra and Bangka, northward along the Sumatra and Malaysia coasts and maybe in some other beaches of the other island in the Kepulauan Riau.

In the case of South Java the pollution is too light to be considered. It seems that it is because of the very strong action of the Indian ocean swell, the pollution cannot stay on the beaches. On the other hand, this region is certainly not subjected to chronic pollution but to occasional one.

To summarize this discussion, Pulau Pari acting as a trap could be considered as a good test site for further investigation. The chronic pollution on the Southern coast may be due to the general traffic in the region.
The pollution of the Northern coast seems to be linked to a particular incident also linked to the traffic. It could be interesting to test the gradient of pollution from South (bay of Jakarta) to North (Northern islands) in the Seribu archipelago.

III.3.3. Evaluation of coastal pollution between 1982 and 1984

We observed an increase of the tar pollution level in Kepulauan Seribu area by a factor of about three times between August 1982 and May 1984. On the other sites no characteristic fluctuations in tar loading were noted when compared to the two surveys. To summarize this part of the discussion, Pulau Pari in Kepulauan Seribu area, acting as a trap of all wastes discharged at sea, could be considered as a good test site for further investigations. The increase of deposition in May could be due to changes in coastal circulation patterns and wind direction during the northwestern monsoon.

It is possible with the approach of monsoon conditions, that the oil wastes and ship spillage floating at sea for sometimes are washing ashore in a great deal during this time. The pollution on Pulau Pari seems to be linked to the general traffic in the region of a shipping lane to the harbour of Jakarta.

In particular on the northern coast, the oil depositions were found in soft or melted conditions due to heat and get mixed with sand to form large lumps continuously distributed along the beach. So it could be interesting to test the gradient of pollution from South (Bay of Jakarta) to North (Northern islands) in Kepulauan Seribu.

III.3.4. Comparison of pollution level on Indonesian coasts with some reference data

Table 3 summarizes the results obtained during our two surveys in Indonesia and permits to make a comparison with results obtained from the literature. The general estimation of tar pollution on Kepulauan Seribu in 1982 survey is comparable to that of other coasts along major tanker routes as Kuwait or Bermuda while the values determined during our 1984 survey are among the most polluted sites as Mediterranean coast of Israel. Pollution levels observed along Malacca and Makassar Straits are comparable with the less polluted areas such as Trinidad and Tobago coasts.

Table 3
Estimation of Stranded Tar Ball Pollution on some Geographical Areas

Location	date	mean weight (g/m^2)	max. weight (g/m^2)	mean weight (g/m)	max. weight (g/m)	References
Cape Cod (USA)	1958				45	(4) Dennis J.V. 1959
Malacca Straits (Indonesia)	1984	1,9		16		(1) CNEXO-LEMIGAS report (preliminary)
Trinidad and Tobago	1980			54	3000	(5) Georges et.al. 1983
Gujarat (India)	1974	500	2375			(5) Georges et.al. 1983
Makassar Straits (Indonesia)	1984	1,7		23		CNEXO-LEMIGAS report (preliminary)

(continued)

Table 3 (continuation)

North Brittany (France)	1982			190	5800	(6) CNEXO report 1983
West Brittany (France)	1984	7,1		260	540	(6) CNEXO report 1983
Bermuda	1973			700		(7) Butler et.al. 1973
Kepulauan Seribu (Indonesia)	1982			812	29000	(1) CNEXO-LEMIGAS report
South California	1978				4700	(8) Straughan 1979
Kuwait	1977	200	6290	1280		(9) Oostdam et.al.1978
Kepulauan Seribu (Indonesia)	1984	363		2460		CNEXO-LEMIGAS report (preliminary)
Mediterranean coast (Israel)	1977			3625		(10) Wahby 1978
Gulf of Guinea	1980			9100	40000	

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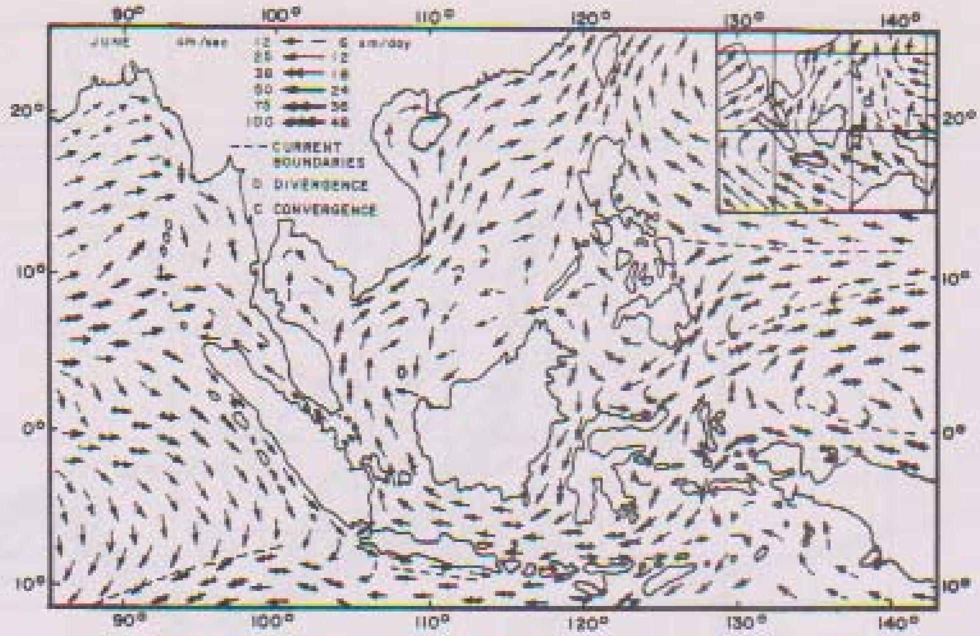


Figure 1 Surface Currents and wind in June
Source : K. Wirtky, 1961

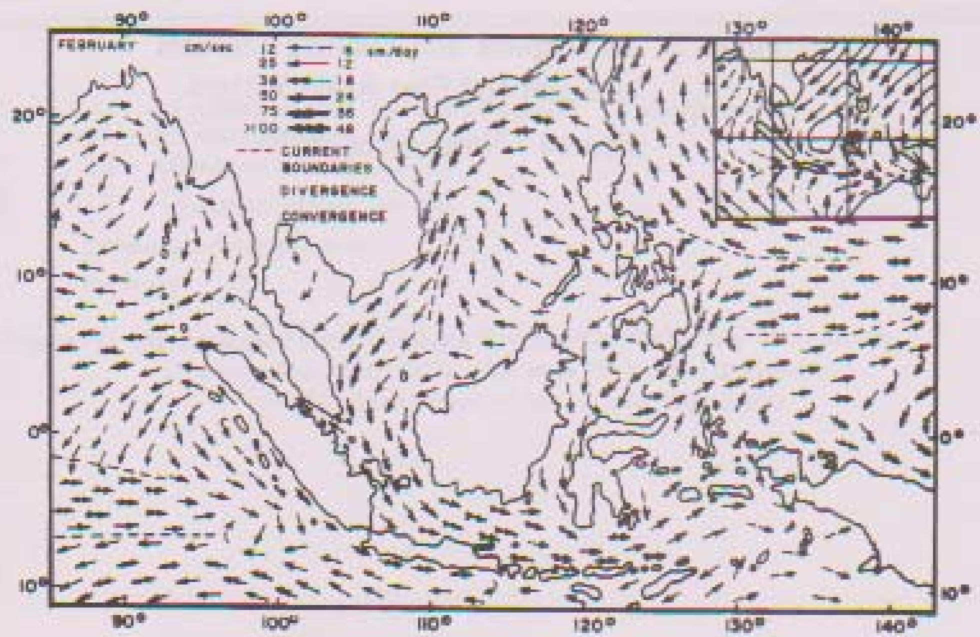
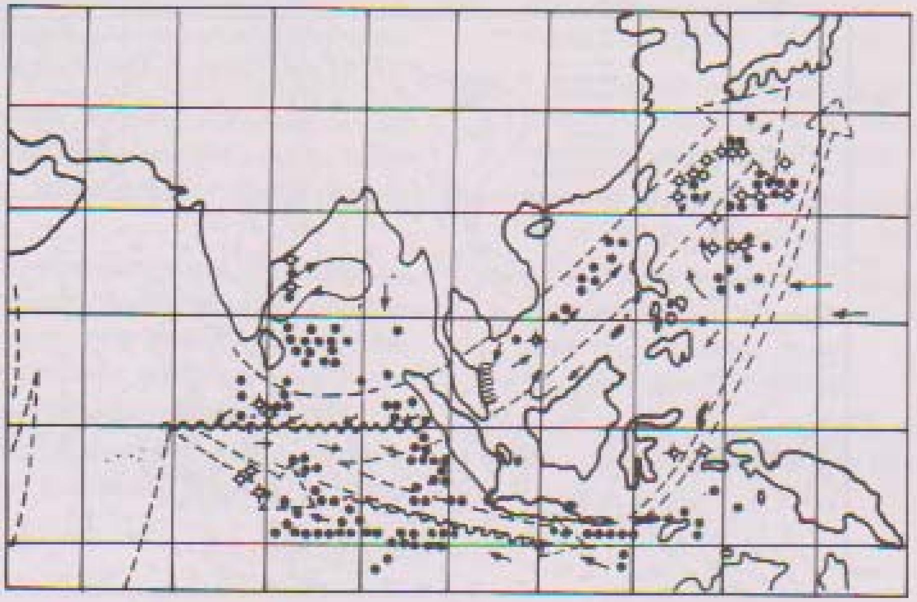


Figure 2 Surface Currents and wind in February
Source : K. Wirtky, 1961



Few oil lumps

Many oil lumps

Movement of oil; width indicates amount

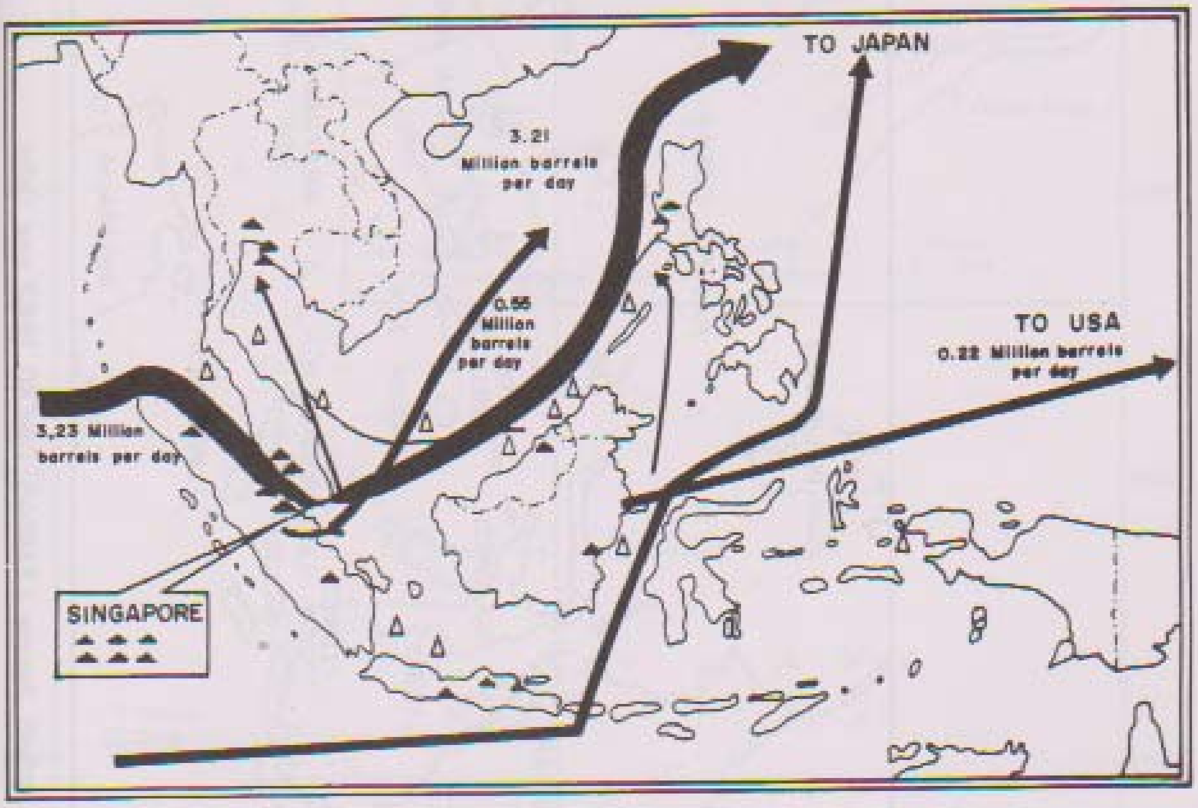
Average surface currents

Area of most intense pollution by oil lumps

Border between currents

Figure 3. Oil Droplets and Surface Currents in South and East Asian Waters.
Source : Nasu et. al. 1975

Locations of the test sites is indicated in figure 5.



< - 0.1 million barrels per day (7 barrels   1 metric ton)
0.1 - 0.2 million barrels per day
0.2 - 1.0 million barrels per day
> 3 million barrels per day
Offshore production site
Refinery

Figure 4. Oil Transportation, Offshore Production Field and Refineries
Source: after FAO, 1976; Finn et.al. 1979; Bilal & Kuehnhold 1980; Department of Mining and Energy, 1982

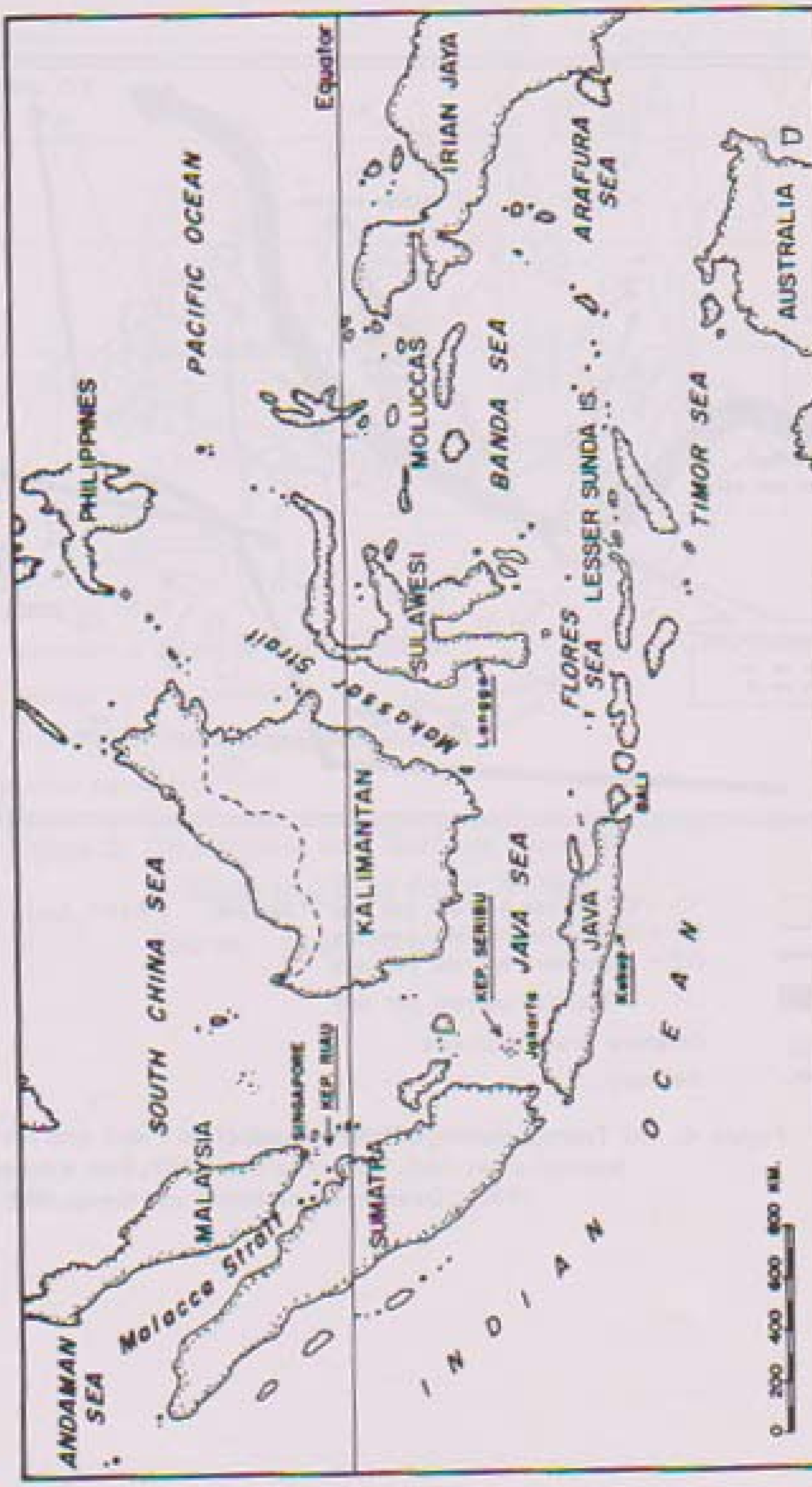


Figure 5 Test Sites Location Tarball Survey LEMIGAS-CNEXO 1982 and 1984

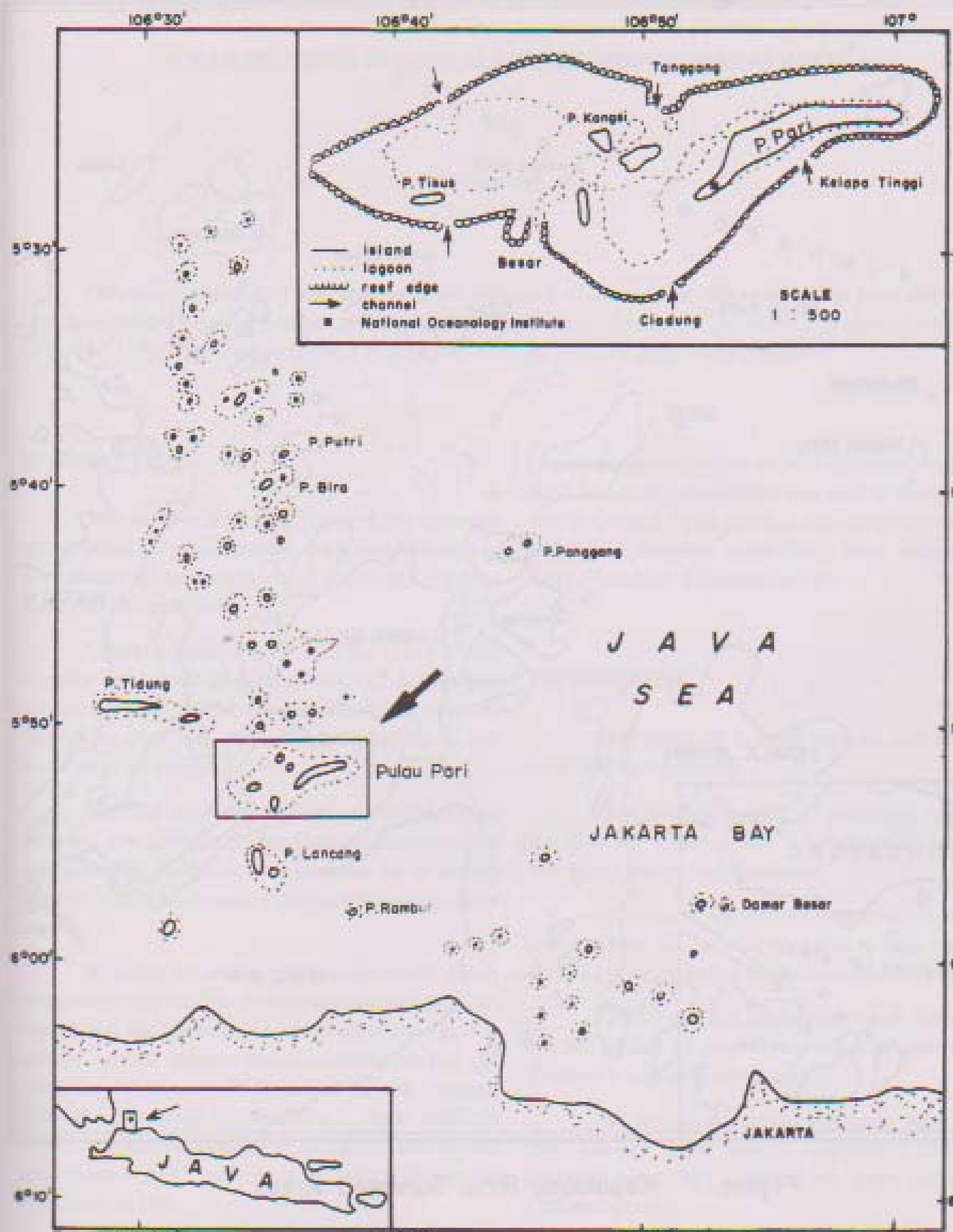


Figure 6 Kepulauan Seribu in Jakarta Bay (geographical location)

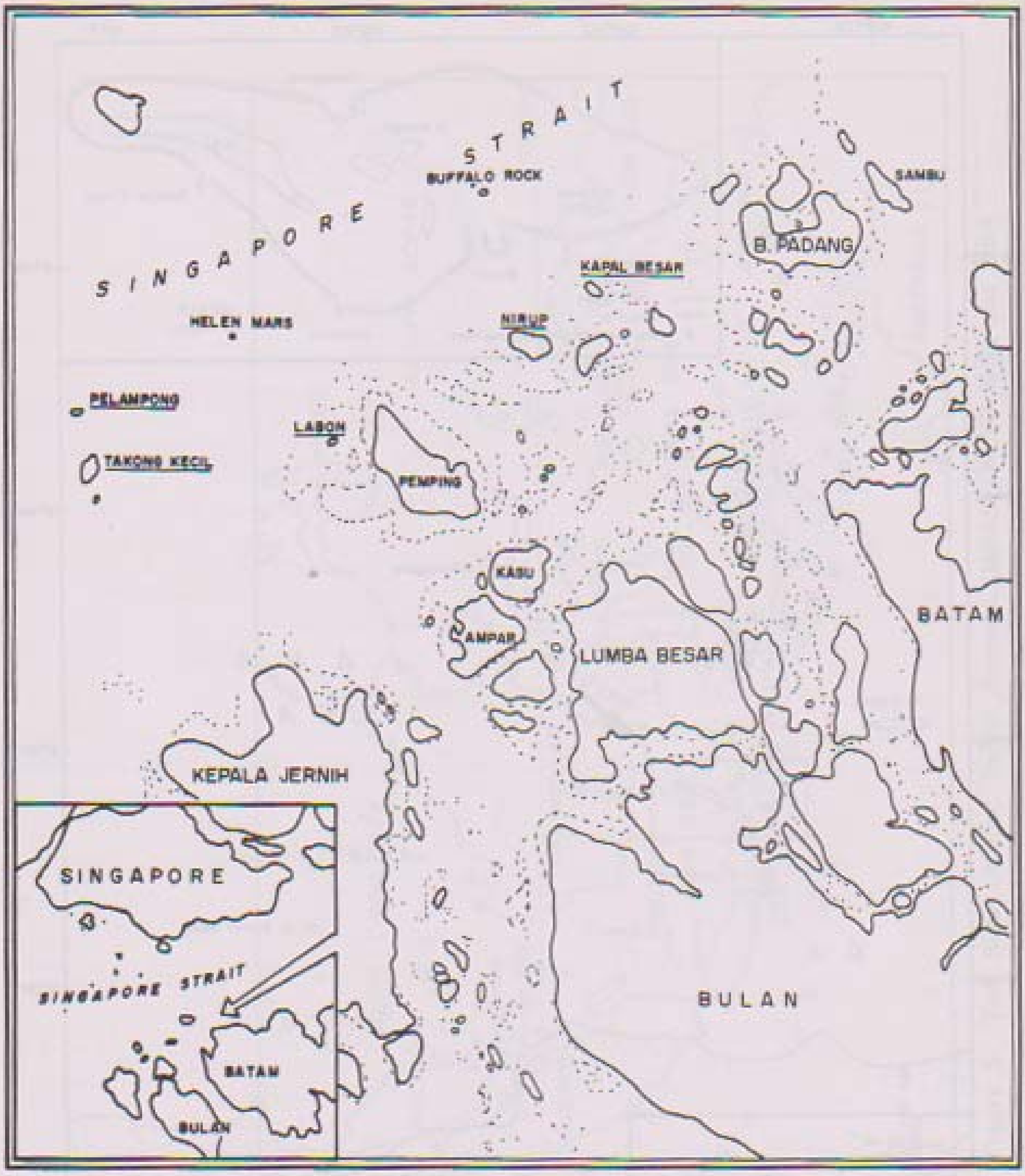


Figure 7 Kepulauan Riau Surveyed Areas