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Pelagic Tar in the Mediterranean Sea

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Floating tar samples were collected, using neuston nets, in 101 stations in the Mediterranean Sea in August–September, 1987, by research vessels of Cyprus, Germany, Israel, and Turkey. The distribution of the tar content indicates that the most tar contaminated sea is in the northeast between Cyprus and Turkey and in the Gulf of Sirte off the coast of Libya, where the mean tar content was 1847 and 6859 μg m^{-2}, respectively. The least polluted areas were the western Mediterranean, 236 μg m^{-2}, and the northern Ionian Sea as far east as halfway between Crete and Cyprus with mean tar concentration of 150 μg m^{-2}. Strongly heterogeneous but overall intermediate mean values of 1347 and 876 μg m^{-2} were found in the Levantine Basin west and south of Cyprus, respectively.

A comparison between pelagic tar data collected in 1969, in 1974 and our data shows a sharp decline in tar concentration with time, from 37,000 μg m^{-2} in 1969 to 9700 μg m^{-2} in 1974 and to 1175 μg m^{-2} in 1987.

The geographical distribution of tar may be explained by the severe reduction in the activity of oil terminals in Israel, Lebanon and Syria which causes a reduction in tar content in the southeastern Mediterranean. The increased activity of the oil terminal in Iskenderun Bay, Turkey, and the activity of oil loading at the terminals in Libya still leave a high level of tar pollution in the Mediterranean water off these coasts. However, recent technologies in the oil shipping industry, international conventions on oil pollution of the Mediterranean, and harsher steps to administer the anti pollution laws by various countries in the Mediterranean have caused a general decline of this problem.

The Mediterranean Sea is considered to be one of the most oil polluted seas in the world (U.S. National Academy of Science, 1975). This is not surprising, considering that on this sea, which covers only 0.8% of the world ocean area, more than 20% of the world oil transport takes place. As tar is a derivative of oil, this sea is plagued with this pollution as well.

Systematic investigations of tar distribution in the Mediterranean Sea started in 1969 when Horn *et al.* (1970) collected floating tar lumps using a neuston net during a cruise of the R/V *Atlantis II* from Rhodes to the Azores. Subsequent measurements of pelagic tar were reported by Polikarpov & Benzhitsky (1974), Morris *et al.* (1975), Ros & Faraco (1979), De Armas (1985) and Zsolnay (1987). All these studies were conducted mainly in the western Mediterranean. In the eastern Mediterranean, Oren (1970) carried out observations on the relative abundance of pelagic tar, El Hehyawi (1979), Aboul-Dahab & Ḥalim (1981a,b) and Wahby & El Deeb (1981) reported on floating tar in the coastal water of Egypt and Saydam *et al.* (1985) on the tar off Turkey.

Recently, there have been reports indicating that tar pollution is undergoing reduction on Mediterranean beaches as well as outside the Mediterranean (Golik & Rosenberg, 1987; Knap *et al.*, 1980; Robertson Smith & Knap, 1985). This raised renewed interest in the pelagic tar quantities in the Mediterranean. An opportunity to collect floating tar samples from extensive areas in the eastern Mediterranean arose when a multi-national expedition was carried out in the summer of 1987 to study the physical oceanography of the East Mediterranean ('POEM'). Four participants in this expedition, the R/V *Bilim* of Turkey, R/V *Meteor* of Germany, R/V *Shikmona* of Israel and R/V *Triton* of Cyprus, agreed to collect pelagic tar samples between the stations occupied for physical oceanography measurements. In this way 101 samples were collected in August–September 1987, most of them in the eastern Mediterranean.

The purposes of this paper are to report on the new information gathered about tar distribution in the Mediterranean Sea and to determine the factors which control this distribution in terms of space and time.

Methods

Sampling was done by towing a neuston net, which samples the surface water, behind the ship for a distance of approximately 1 nautical mile. The material which was collected at the cup of the net was transferred into a bottle which was frozen until it was transferred to the laboratory. Table 1 provides the specific dimensions and characteristics of the equipment of each of the participants.

In the laboratory, the samples were thawed, the tar lumps were manually separated from the rest of the material in the sample, allowed to dry in free air and weighed (except the *Meteor* samples in which tar lumps were already separated on board and later dried in a desiccator with P_2O_5 before weighing). The area which was sampled was calculated by multiplying the width of the net opening by the length of the tow. The tar concentration was then normalized to m^2 and is reported here in terms of $\mu g\ m^{-2}$.

Results

Figure 1 shows the results of the tar content in the stations occupied by the present study. It has already been noted by Morris *et al.* (1975) that the distribution of pelagic tar follows rather closely that of a log normal distribution. Figure 2 shows that this is indeed the case in our study as well. The significance of this distribution is that statistical analyses of this material must be done with tests which are adequate to non parametric data. The Mann-Whitney Rank Sum Test (Pratt & Gibbons, 1981) was used in this study to test if significant differences exist between populations which were selected to examine various hypotheses.

The analysis of the spatial distribution of the tar is rather difficult because of the heterogeneity of the tar quantities. This heterogeneity prevents drawing contour lines of equal tar weight which would provide the pattern of the tar distribution. We have therefore divided the Mediterranean Sea into six geographical areas on the basis of subjective evaluation of the tar pollution level. These areas are shown in Fig. 1 and their tar statistics is given in Table 2. It shows that Areas I and V in the NE Mediterranean between Cyprus and Turkey, and in the Gulf of Sirte off Libya, are the most polluted areas, Areas II and III in the Levantine Basin south and west of Cyprus suffer from heterogeneous but overall intermediate pollution, and the least polluted areas are IV and VI which are the northern Ionian sea and the southern part of the western Mediterranean. A rank sum test was conducted on each pair of areas and the results are provided in Table 3. They show that there is no significant difference between the most polluted Areas I and V but that these two are significantly different from the other sea areas. There are no statistical differences among the

TABLE 1

Technical specifics of sampling equipment and procedures of participating vessels

	Bilim	Meteor	Shikmona	Triton
Sampling period	September 1987	19 Aug 1987–19 Sep 1987	23 Aug 1987–11 Sep 1987	15 Sep 1987–29 Sep 1987
Number of samples	30	51	15	5
Width of net opening	61 cm	88 cm	80 cm	40 cm
Length of tow	~2000 m	1726±235 m	~1 nautical mile	~1 nautical mile
Reference to neuston sludge	MARMAP, in Carpenter, 1976	Hempel and Weikert, 1972	Ben-Yami et al., 1970	Sameoto and Jaroszynski, 1969

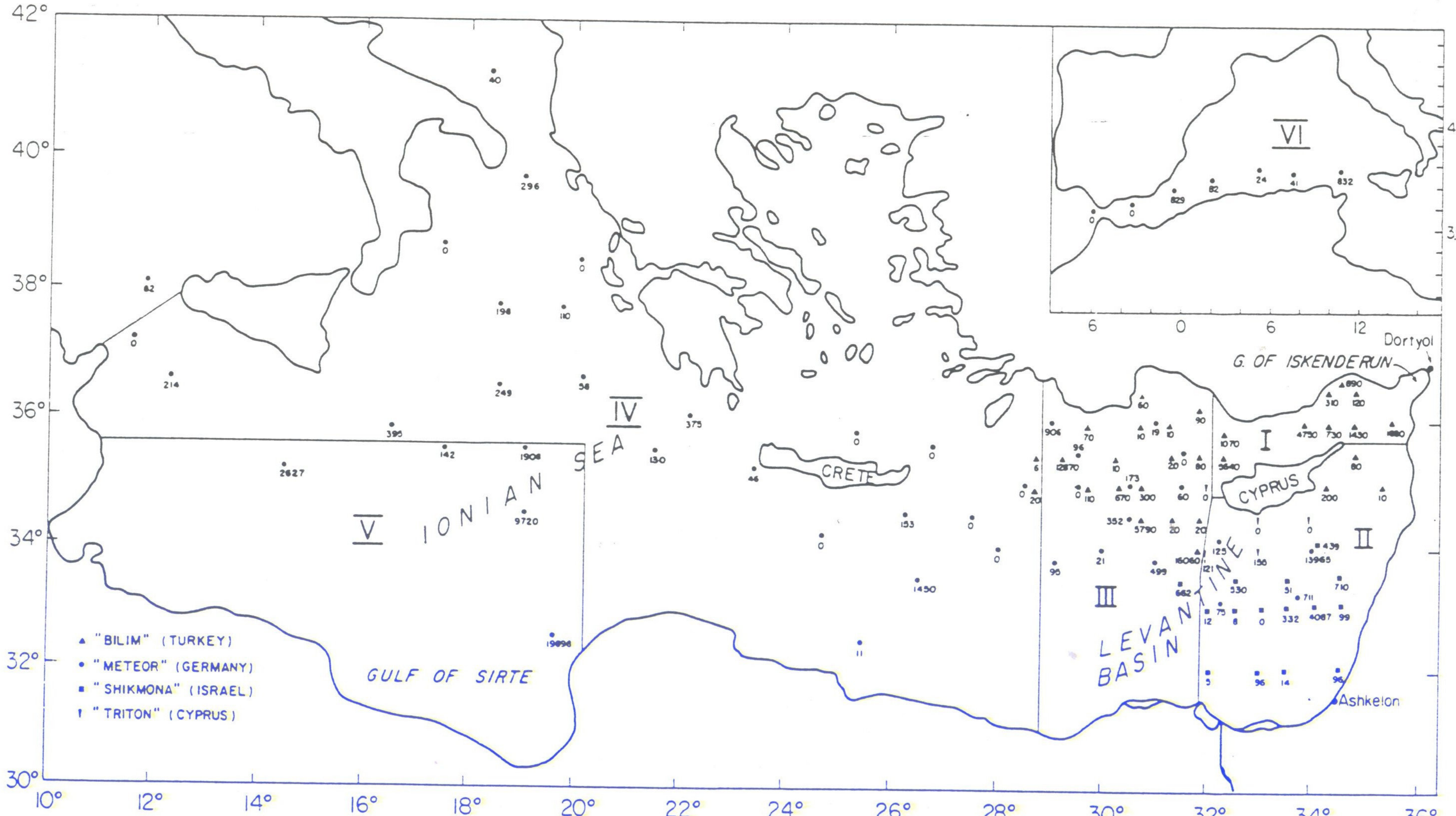

Fig. 1 Pelagic tar quantities, in $\mu g\ m^{-2}$, in the Mediterranean Sea in summer 1987.

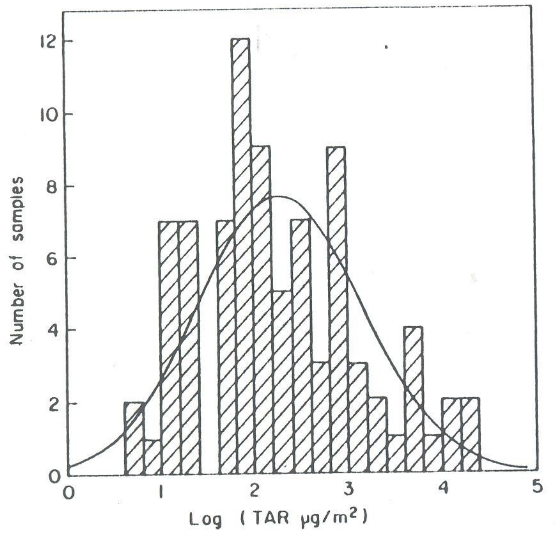

Fig. 2 Weight distribution of sampled pelagic tar quantities. The horizontal scale is logarithmic and the curve is that of a normal distribution curve with the same mean and standard deviation as the log of the sample quantities. Samples with zero tar content are not included.

TABLE 2

Pelagic tar statistics in each of the six areas in the Mediterranean Sea in $\mu g\ m^{-2}$

	Number of stations	Mean	Range	Standard deviation
Area I	9	1847	120–5640	1972
Area II	25	876	0–13965	2844
Area III	29	1347	0–16060	3811
Area IV	25	150	0–1450	298
Area V	5	6859	142–19898	8151
Area VI	8	236	0–832	368
All Mediterranean	101	1175	0–19898	3320

TABLE 3

p values which resulted from rank sum tests in which comparisons of results between the various areas were conducted.

Area	I	II	III	IV	V
VI	0.004*	0.58	0.18	0.52	0.008*
V	0.16	0.007*	0.008*	0.002*	
IV	0.0002*	0.11	0.085		
III	0.002*	0.94			
II	0.0013*				

*Significant difference.

other areas, except maybe Areas III and IV where p is rather low and therefore might be a difference between these two.

Another test was carried out to find if there has been a change in tar pollution with time in the Mediterranean. To do that, the data collected for this study must be compared with data that were collected sometime in the past. Unfortunately, the only study which was conducted in the eastern Mediterranean in the past was that of Oren (1970) who reported his results in relative rather than absolute terms. From the other studies on tar in the Mediterranean only that of Morris *et al.* (1975) provides the raw data which could be compared statistically to those of the present study. Morris *et al.* (1975) collected tar samples in 1974–75 at 48 stations in the Ionian Sea and the western Mediterranean. A rank sum test that was conducted on the data of Morris *et al.* (1975) and the present data yielded $p<0.01$, indicating a sharp difference between the two populations.

Discussion

Relationship between tar pollution, oil terminals and tanker lanes

Tar lumps in the marine environment are formed from oil or oily compounds which are released into the marine environment. The light fraction of the oil evaporates, leaving its viscous, heavy fraction, called tar lumps or tar balls, floating on the water. The release of oil into the water may result from natural seepage of oil from the sea bottom, accidental release from oil tankers or other oil installations, or intentional discharges by the release of oily ballast water from oil tankers. Tankers release their ballast to make room for the oil which they are about to load. Therefore, the tanker lanes leading to an oil terminal and at some distance from it are likely to be contaminated with oil and tar balls, especially if no reception facilities for ballast waters in the oil terminal are available. Although such facilities have been installed in many oil ports, it seems that there are still not enough of these and that some tankers still release their ballast water to the sea.

Examination of the data presented in this study supports this hypothesis. During the last decade, significant changes in the activities of oil terminals in the eastern coastline of the Mediterranean took place. The political change in Iran brought about the cessation of oil shipment from the Red Sea to the Ashkelon oil terminal on the Mediterranean coast of Israel. The wars in Lebanon during this decade stopped the activity of the oil terminals of that country. Disputes between Iraq and Syria reduced the oil flow from Iraq to Syrian oil terminals in the Mediterranean. On the other hand two oil pipelines became very active in the region: a pipeline from Iraq to Dortyol, in Iskenderun Gulf, Turkey, and the Sumed pipeline leading oil from the Gulf of Suez on the Red Sea to the vicinity of Alexandria, Egypt, on the Mediterranean Sea. The Iraq–Turkey pipeline was completed in 1977 with a capacity of 14 Mt yr^{-1} and steadily increased to 75 Mt yr^{-1} in 1987 (Anon., 1987). The Sumed pipeline increased its capacity from 11 Mt yr^{-1} in 1975 to 121 Mt yr^{-1} in 1985 (Maritime Transport, 1976–1986).

These changes in the activity of oil terminals in the eastern coast of the Mediterranean are reflected in our findings. Area I, which includes the Gulf of Iskenderun and the tanker lanes leading to the Dortyol oil terminal, is significantly more polluted than Area II, which includes the oil terminals of Syria, Lebanon and Israel, in which operation has greatly decreased. However, there is still spotwise tar pollution along the shipping lanes south and southwest of Cyprus, indicating activities in this area. We do not have quantitative data on the pelagic tar at the times that the afore-mentioned terminals were in full operation, but according to Oren (1970), out of 9 samples which he collected in 1970 between Cyprus and the east Mediterranean coastline (our Area II), five were ranked between 4 and 6 on a scale of relative pollution ranging from 1 (no tar) to 7 (polluted with tar). In addition, in 1975–76, Golik (1982) found an average of 3.6 kg of tar per frontal metre of beach along the Israeli coastline.

Another example of the relationship between oil terminal and tar quantity is the Gulf of Sirte (Area V). This is the most polluted area in our study, a pollution which probably reflects the intense activity of the oil terminals on the Libyan coast of the Mediterranean. In this connection, it must be noted that at least until 1980, in 4 out of 5 oil terminals in Libya, no reception facilities for oil residues from tankers existed (UNEP, 1986; Table 3). If that, or a similar situation continued to exist through the last few years, it may explain the high tar pollution that we find in Area V. There too, high coastal tar pollution exists. El Ghirani (1981) found an average of 1.2 kg of tar per frontal metre of beach. He estimated that along the Libyan cost 2000 tons of tar are stranded on the beach.

In our study, stations were not occupied in the area north of Alexandria, Egypt, where the Sumed oil terminal exists, and it is therefore impossible to state if such relationship between oil terminal and tar pollution is found there too.

Decline in tar pollution in the Mediterranean Sea

Figure 3 shows the volume of oil traffic on the Mediterranean Sea between 1975 and 1985. In spite of the oil crisis that took place during that period and the reduction in oil consumption that followed, oil transportation on the Mediterranean has increased at that period by approximately 150%. This should have caused an increase in tar pollution in the Mediterranean, but instead, a sharp decrease is observed. A comparison of our findings with tar data collected in 1969 and 1974 by Horn *et al.* (1970) and Morris *et al.* (1975) shows:

year	1969	1974	1987
mean tar concentration ($\mu g\ m^{-2}$)	37 000	9700	1175

As mentioned above, 1974 and 1987 are statistically different and there is no doubt that the difference between 1969 and 1987 is real too.

In addition to the decrease in pelagic tar, a decrease in quantity of beach-stranded tar was reported from some Mediterranean coasts. In Israel, Golik & Rosenberg (1987), who used a successive series of air photographs from the beach between 1975 and 1985, showed a sharp decrease in tar on the beach over that period. Golik (1985) reported that an average tar quantity on the beaches of Haifa, Israel was 12 g m^{-1} in 1984, in comparison to 3600 g m^{-1}, the average for the Israeli coastline in 1975–76 (Golik, 1982). In 1976–78 the mean tar quantity on the beach of Paphos, Cyprus was 268 g m^{-2} (UNEP, 1980), whereas in 1983 Demetropoulos (1985) found in the same beach a mean of 67 g m^{-2}. The decrease of tar in the Mediterranean Sea is then real and needs explanation.

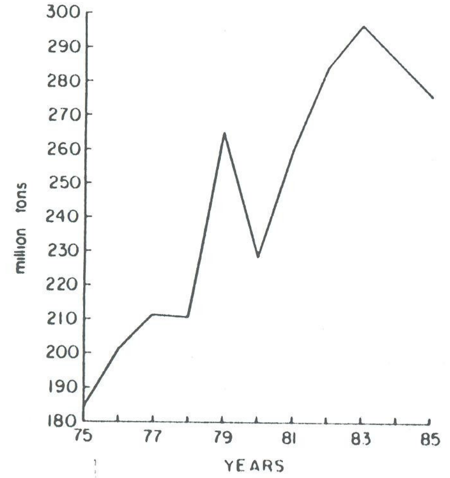

Fig. 3 Oil transport on the Mediterranean Sea between 1975 and 1985 (from Maritime Transport, 1976–1986).

Two events happened in 1978–79 that made this period a turning point in the history of oil pollution: in 1978 the 1969 amendment to the International Convention for Prevention of Pollution of the Sea by Oil 1954 (OILPOL) entered into force and in 1979 the oil crisis took place. These events caused a chain reaction that brought about the reduction in tar pollution.

The 1954 OILPOL convention prohibited discharge of oil or oily mixtures into the sea in water closer than 50 miles from land. In the Mediterranean this convention left two restricted areas, one east of Crete and the other west of it, in which deballasting of oily water was permitted. The 1969 amendment, which went into force in 1978, permitted in these areas discharge of oily residues only at certain rates or quantities. A second convention, the International Convention for the Prevention of Pollution from Ships, which was modified by a protocol in 1978 (MARPOL 73/78), considered the whole Mediterranean Sea as a special area in which any discharge into the sea of oil or oily mixture at concentrations above 15 ppm from any oil tanker or any ship of more than 400 grt is prohibited. MARPOL 73/78 entered into force in 1983. These conventions have increased the awareness of the impact of oil pollution on the marine environment. They caused a faster rate of installation of coastal reception facilities for oily residues in oil terminals, stricter policing and enforcing of regulations against oil spillages and immediate handling of any case of accidental oil spillage into the water.

The increase in oil prices which resulted from the 1979 oil crisis brought about a decrease in oil consumption and a search for ways to reduce oil waste. The oil shipping industry developed new techniques and procedures of oil handling, such as equipping all new tankers with segregated ballast, developing a clean ballast system in new tankers and developing a crude oil washing system which allows collection of the washed oil. All these measures help in saving oil and at the same time decrease its disposal into the sea, and thereby reduced tar pollution.

Conclusions

The adoption of the conventions against oil pollution, their enforcement and the new technologies which were developed to reduce intentional or accidental oil spillages to the sea have caused a significant reduction in tar pollution in the Mediterranean Sea during the last decade. Still, tar pollution exists in this sea and its geographical distribution is related to the activity of oil terminals.

The authors would like to thank POEM national coordinators of Cyprus, Germany, Israel and Turkey for allowing them to carry out the sampling for this study in conjunction with their study. The assistance of the captains and crews of the *Bilim*, *Meteor*, *Shikmona*, and *Triton* in collecting the tar samples and the personnel performing the laboratory procedures in the different institutes is greatly appreciated. Y. Cohen and Y. Mart critically read the manuscript and offered helpful comments.

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