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PELAGIC TAR AND PLASTIC IN THE GULF OF ALASKA AND BERING SEA: 1975

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ABSTRACT

Seventy-one tows of 740 m^2 each were made in search of pelagic tar and plastics in the Gulf of Alaska and Bering Sea during the period October 1974 to October 1975. Tar was observed on nine occasions while plastics were found six times. The arithmetic mean value of tar abundance, 3.3×10^{-3} mg/m^2, is considerably lower than most other oceanic areas for which values have been reported. Gas chromatographic analysis of this tar indicates that it is more extensively weathered than tar from the north Atlantic. An estimate of the abundance of tar lumps too small to be sampled by net tows is made based on the assumption that there are equal weights of particles in logarithmetically equal size intervals. The abundance of pelagic plastics is also low.

INTRODUCTION

The occurrence of pelagic tar in various parts of the world ocean is a well-documented fact that has been the subject of recent reviews (National Academy of Sciences, 1975; Butler et al., 1973). In the light of the number of reports of pelagic tar, it is perhaps surprising that its existence was first reported in the scientific literature as recently as 1970 (Horn et al., 1970). Evidence that the tar's origin is associated with petroleum transport includes the findings that its spatial distribution corresponds to major tanker routes and the chemical similarity of the tar to material in tank washings of oil tankers (Butler et al., 1973). Further evidence of this association is the elevated iron content of pelagic tar which indicates contact with steel structures (Attaway, unpublished, cited in National Academy of Sciences, 1975, p. 49).

Pelagic plastic has also recently been found to be widely distributed (Carpenter and Smith, 1972; Wong et al., 1974; Morris and Hamilton, 1974) on the surface of the ocean as well as other parts of the marine environment (Cundell, 1973; Hays and Cormons, 1974). The sources of these materials appear to be both discarded plastic products and wastes from plastics manufacturing processes.

Most measurements of pelagic tar and plastic have been made in areas where high concentrations of these materials are to be expected such as the north Atlantic and the Mediterranean Sea. Measurements made in more remote areas such as the southwest Pacific show significantly lower concentrations (Wong unpublished, cited in

National Academy of Sciences, 1975, p. 53). The tar and plastic measurements reported here are from a region, the Gulf of Alaska and the Bering Sea, which might a priori be expected to be relatively free of these materials. Some coastal oil seeps are known in the Gulf of Alaska and crude oil moves through the area from fields in Cook Inlet to Japan and the west coast of the United States. But these crude oil inputs seem to be minor compared to global levels. There is no history of tar being washed up on Gulf of Alaska beaches as there is for instance in some parts of southern California. The total production of oil fields in the Cook Inlet area was about 62 million barrels ($9.9 \times 10^6 m^3$) in 1974 (*International Petroleum Encyclopedia*, 1975). Only part of this was shipped by sea. Likewise there would appear to be few sources of plastics to these waters. Neither the Gulf of Alaska nor the Bering Sea is an area of heavy shipping. There is little plastics manufacturing in Alaska and the small population would suggest a small amount of plastic trash. Thus these areas provide an example of an oceanic region presently having low inputs of pelagic tar and plastics. This makes the present data of interest for comparison with other areas. Added significance is given to these data by the fact that petroleum transport in the Gulf of Alaska will soon increase with the completion of the trans Alaska pipeline and may further increase if presently contemplated petroleum exploration in the Gulf of Alaska and Bering Sea results in production.

METHODS

Sampling was accomplished during eight cruises of five research vessels as detailed in Table 1. Collections of tar and plastics were made using a surface sampler constructed to the design of Sameoto and Jaroszynski (1969) using 363 μm nets. The sampler was rigged so that it rode outside the ship's bow wake. Each tow was for one nautical mile (1.85 km), most commonly obtained by towing at four knots for 15 min. In this way the 0.4 m wide mouth of the sampler swept through 740 m^2 of sea surface. A sample was washed into a glass bottle, frozen, and returned to the laboratory for

TABLE 1

CRUISES FOR COLLECTION OF PELAGIC TAR AND PLASTICS

Dates	*Ship*	*No. of tows*	*Cruise area*
October 74	R/V Acona	2	Eastern Gulf of Alaska
January 75	R/V Acona	1	Resurrection Bay
February 75	R/V Acona	5	Eastern Gulf of Alaska
May 75	FR/V Townsend Cromwell	12	Eastern Gulf of Alaska and Prince William Sound
September 75	USNS Silas Bent	11	Eastern Gulf of Alaska
September 75	USNOSS Discoverer	21	Bering Sea
October 75	R/V Acona	2	Mouth of Copper River
October 75	USNOSS Discoverer	18	Western Gulf of Alaska

visual inspection. Tar lumps were dried in a dessicator for at least 48 h before weighing.

Hexane extracts of selected tar lumps were subjected to gas chromatography on a Varian model 1520 instrument using a 12 ft. by 1/8 in. stainless steel column of 3% OV-101 on 100–120 mesh Chromosorb W (AW-DMCS). Chromatograms were temperature programmed from 60 to 290 °C at 8 °C min^{-1}.

RESULTS AND DISCUSSION

Results of tows in the Gulf of Alaska and Bering Sea are given in Tables 2 and 3, respectively. Tar was found in only 9 of 71 tows made. The greatest weight from a single tow was 127 mg. Never were nets visibly fouled as has been reported in the north Atlantic and Mediterranean. The grand arithmetic mean value for the abundance of tar is 3.3×10^{-3} mg/m^2. This is lower than any mean value reported by the National Academy of Sciences (1975). The only comparable value is < 0.01 mg/m^2 for the southwest Pacific. Mean values for various parts of the North Atlantic, the Mediterranean, and the Kuroshio Current system in the Pacific fall in the range 0.1 to 10 mg/m^2. Wong et al. (1974) have reported tar concentrations in the north Pacific. These workers found 3.8 mg/m^2 in the west, 0.4 mg/m^2 in the east along 35 °N and a complete absence of tar along 125 °W.

Gas chromatograms of three tar lumps are reproduced in Fig. 1. Chromatogram A has the appearance of a relatively fresh crude or fuel oil. It was collected in the southeastern Bering Sea (56 °09′N, 162 °56′W) and was a sticky semi-solid material which flowed on standing in a vial. Identified n-alkane peaks extend from heptadecane to dotriacontane. The value of $N_{1/2}$ for this tar is 18.5. $N_{1/2}$, the equivalent normal paraffin carbon number having a retention index equal to that at which the unresolved envelope reaches half its maximum height, is an indication of the extent of weathering of a tar lump (Butler and Harris, 1975 and references therein). Tar lumps from the north Atlantic analysed by Butler and Harris showed $N_{1/2}$ values in the range 15–20. Tars represented by chromatograms B and C each have an $N_{1/2}$ of 24 which is indicative of more highly weathered oils. The tar of chromatogram B was collected at a near shore station off Icy Bay (58 °44.1′N, 141 °27.9′W), an area where several onshore coastal oil seeps have been observed. The tar of chromatogram C came from a station at the edge of the continental shelf in the Gulf of Alaska (59 °27.5′N, 145 °11.5′W). These two lumps were quite different from that shown in chromatogram A, being more solid and less sticky. The remainder of the lumps collected were physically similar to B and C.

The bimodal distribution of chromatogram B is typical material discharged by oil tankers in their tank washing procedures, but would be highly unusual in a crude oil. Thus, although this tar was collected adjacent to a natural oil seep area, it probably did not come from a seep. Chromatogram C shows a highly weathered material as evidenced by its $N_{1/2}$ value and by the almost complete lack of normal alkanes.

Comparison of tar and plastic abundance values is complicated by the fact that nets of various mesh sizes have been used for collections. A common response to this complication, both here and in other papers on this subject, has been to note the

TABLE 2

TAR AND PLASTICS COLLECTED IN THE GULF OF ALASKA

Position		*Date*	*Tar*	*Plastic*
N. Lat.	*W. Long.*		*(mg)*	
59° 50.2′	149° 30.5′	5/6/75	0.5	
59° 50.2′	149° 30.5′	9/14/75	—	
59° 07.2′	148° 47.5′	9/12/75	—	
58° 49.7′	148° 30.0′	9/9/75	—	
58° 13.0′	141° 55.0′	5/10/75	—	
58° 54.3′	141° 00.5′	9/2/75	—	
59° 10.8′	140° 38.9′	5/10/75	7.4	
59° 32.6′	140° 06.0′	9/1/75	—	
59° 44.1′	141° 27.9′	2/27/75	—	
58° 44.1′	141° 27.9′	5/11/75	5.9	
59° 16.2′	142° 59.2′	2/20/75	—	
59° 16.2′	142° 59.2′	5/12/75	—	
59° 16.2′	142° 59.2′	9/5/75	—	
59° 35.7′	142° 49.5′	9/5/75	—	
59° 45.4′	142° 44.5′	2/28/75	3.2	
59° 55.1′	142° 39.5′	9/4/75	—	
59° 55.1′	143° 51.2′	5/9/75	—	
59° 17.5′	145° 13.0′	9/7/75	—	
59° 27.5′	145° 11.5′	10/10/74	—	
59° 27.5′	145° 11.5′	2/24/75	127.1	
60° 07.6′	145° 06.5′	9/8/75	—	
60° 23.0′	146° 54.0′	5/8/75	—	
60° 23.0′	146° 54.0′	9/8/75	—	packaging
60° 27.0′	146° 54.0′	2/26/75	—	
59° 45.6′	146° 31.0′	10/9/74	8.7	clear sheet 6 mm
59° 49.6′	147° 41.3′	5/15/75	—	
59° 00.0′	151° 45.1′	10/15/75	—	
57° 06.9′	156° 00.0′	10/14/75	—	
56° 55.0′	155° 44.1′	10/13/75	—	green thread
56° 43.2′	155° 27.9′	10/13/75	9.1	
56° 31.3′	155° 12.0′	10/13/75	—	styrofoam
56° 07.1′	154° 39.4′	10/13/75	9.2	
55° 46.3′	158° 51.0′	10/12/75	—	
55° 33.4′	158° 38.3′	10/12/75	—	
55° 20.3′	158° 25.1′	10/12/75	—	
54° 54.3′	157° 59.0′	10/12/75	—	
55° 00.9′	161° 20.5′	10/11/75	—	
54° 49.4′	161° 12.5′	10/11/75	—	
54° 36.2′	161° 00.7′	10/11/75	—	
54° 23.5′	160° 49.1′	10/11/75	—	
54° 29.2′	165° 11.3′	10/10/75	—	
54° 04.5′	164° 46.2′	10/10/75	—	polyline 3 1/2 in.
53° 51.9′	164° 34.0′	10/10/75	—	
53° 43.3′	164° 25.6′	10/10/75	—	
60° 42.0′	147° 00.0′	5/8/75	—	
61° 00.3′	146° 45.9′	5/18/75	—	
61° 00.3′	146° 45.9′	5/18/75	—	
61° 00.3′	146° 45.9′	5/18/75	—	
60° 03.5′	149° 22.4′	1/21/75	—	
60° 11.0′	145° 10.0′	10/8/75	—	
60° 14.9′	145° 34.0′	10/8/75	—	

TABLE 3

TAR AND PLASTICS COLLECTED IN THE BERING SEA

Position		*Date*	*Tar*	*Plastic*
N. Lat.	*W. Long.*		*(mg)*	
58° 17′	159° 32′	9/19/75	—	
56° 09′	162° 56′	9/22/75	6.7	
55° 29′	165° 50′	9/28/75	—	
56° 40′	163° 57′	9/23/75	—	
58° 46′	162° 29′	9/18/75	—	
57° 10′	165° 04′	9/24/75	—	
56° 13′	168° 20′	9/14/75	—	
57° 06′	167° 01′	9/26/75	—	
57° 40′	166° 06′	9/24/75	—	styrofoam
58° 08′	165° 16′	9/17/75	—	
58° 47′	164° 15′	9/17/75	—	
58° 42′	166° 17′	9/17/75	—	
57° 35′	168° 04′	9/25/75	—	
56° 19′	169° 42′	9/14/75	—	
55° 49′	170° 47′	9/14/75	—	
56° 56′	170° 56′	9/15/75	—	
58° 06′	169° 05′	9/15/75	—	
59° 12′	167° 18′	9/16/75	—	
57° 25′	172° 05′	9/15/75	—	
56° 45′	173° 12′	9/15/75	—	

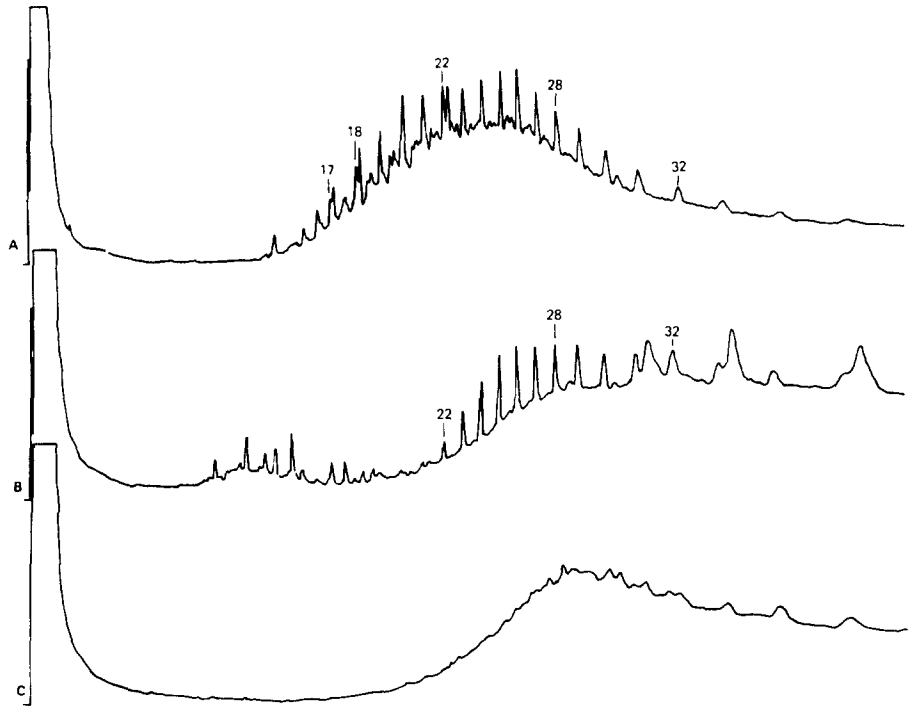

Fig. 1. Gas chromatograms of hexane extracts of tar lumps.

variety and then to proceed to ignore it. This is probably justified in view of the difficulty of observing objects less than 1 mm during the visual inspection and of sampling problems caused by the extreme patchiness of tar and plastic. However, there is an interesting related question about the lower bound, if any, on the size spectra of these materials. Since the tar fragmentation process is a mechanical one, the sizes of particles produced should be randomly distributed and in particular should include sizes too small to be retained by the nets commonly used.

In an examination of particles in the size range 1 to 100 μm which occur naturally in the ocean Sheldon et al. (1972) found that there are roughly similar weights of particles in logarithmically equal size intervals. Gordon (1970) has presented particle size-frequency distribution data which shows the same relationship for naturally occurring organic particles. In a study of oil in water emulsions prepared in the laboratory Lien and Phillips (1974) found a roughly logarithmic size distribution for particles in the range 0.75 to 12.5 μm. It has been shown in the laboratory that mechanical energy breaks larger tar lumps into smaller ones (Wade and Quinn, 1975). Butler (1975) has presented arguments indicating tar lumps at sea undergo extensive fragmentation. Thus it seems appropriate to use the assumption of similar weights of particles in logarithmically equal size intervals as a basis for crudely estimating the abundance of tar particles too small to have been sampled. All of the tar lumps obtained in this study were in the size range 1–10 mm (greatest dimension). It appears reasonable to extrapolate over the range 1 μm–1 mm. Below 1 μm the colloidal size range is entered, surface effects become dominant and particle sizes may no longer be distributed randomly. Performing the extrapolation leads to the estimate that about 10^{-2} mg/m^2 of tar lumps in the size range 1 μm–1 cm were floating on the surface of the study area in 1975. However, much more important than the four-fold increase in mass indicated by the extrapolation are its implications about surface area. If total weight is constant, reducing particle size by a factor of 10 increases surface area by a factor of 10. Thus particles in the size range 1 μm–10 μm have about a thousand times as much surface area as particles in the 1 mm–10 mm range. An increase in surface area would promote diffusive loss of water soluble components from the lump and would provide more substrate for bacteria that have been observed on the surface of larger lumps (Horn et al., 1970). At least in these two respects the impact of tar lumps on marine environments is probably dominated by lumps much smaller than those commonly collected.

Plastics were found less frequently than tar; in only 6 of 71 tows. However, the plastic fragments tended to be larger, the biggest being a 4.5-g square of packaging material. Most of the plastics were identifiable as pieces of finished materials (rather than production scraps): 2 pieces of styrofoam, 2 bits of line, packaging material. Only one small irregular piece of clear plastic was found. One of the plastic fragments was supporting a colony of barnacles *Lepas pectinata pacifica* which were estimated to be approximately six months old. No such growths were observed on tar lumps of the present study; however, L. *pectinata* has been reported on Mediterranean tar lumps (Horn et al., 1970).

The abundance of plastics found in this work, one object per 9000 m^2 can be

compared with other reported values. On the Sargasso Sea Carpenter and Smith (1972) found one piece per 280 m^2 on average. This higher value probably reflects both a higher input rate and the closed nature of surface circulation in the Sargasso. Wong et al. (1974) have reported abundance of plastics along 35°N in the Pacific. They found a maximum concentration, one piece per 29 m^2 at about 143° W and other local maxima at more westerly locations. Their interpretation is that both tar and plastics are associated with subtropical water masses but not with subarctic water. Venrick et al. (1973) have also reported the presence of plastic objects large enough to be visible from the bow of a ship in the central north Pacific about 600 miles northeast of Hawaii.

In considering the abundance of plastics in the ocean it is necessary to realize that not all plastics float in seawater and thus there must exist benthic plastics as well as pelagic plastics. Only the polyolefins and foamed plastics such as styrofoam and polyurethane foam float. Several other widely used plastics including teflon, nylon, acrylics, polyvinylchloride, polyesters, and cellulose acetate are dense enough to sink at sea. An estimate of plastic packaging found in municipal waste (Anonymous, 1972) puts the composition at 38% polyethylene, 31% polyvinylchloride, 21% polystyrene and 10% others. If, as seems reasonable, the composition of marine trash plastic is not greatly different from the municipal values, then one-third to one-half of the total may be benthic rather than pelagic. The fact that such benthic plastics have not been reported except in a heavily polluted estuary (Morris and Hamilton, 1974) probably reflects the areal limitations of benthic sampling; the abundance of pelagic plastic found in the work reported here is one piece per 9000 m^2. While sampling that area of sea surface is quite easy, sampling a comparable area of sea bed would be a formidable task.

CONCLUSIONS

(1) The abundance of pelagic tar and plastics in the Gulf and Bering Sea is substantially lower than in most other oceanic areas for which values have been reported. This is consistent with the tar and plastics measurements of Wong et al. (1974) which indicate that these materials are most abundant in the west central Pacific. Both the present measurements and Wong's are in keeping with the fact that the most heavily used tanker routes of the Pacific run southwest from Japan and that Japan is a major producer and consumer of plastics. The low standing stocks of both plastics and tar in the study area probably reflect both its distance from major sources of input and the open nature of the surface water circulation. This is in marked contrast to areas such as the Sargasso Sea which have closed surface circulation and are closer to major inputs of tar and plastic.

(2) Tar collected in this study area is generally more extensively weathered than is typical of north Atlantic tar as indicated by $N_{1/2}$ values.

(3) In terms of surface area and perhaps even weight tar particles too small to be sampled by a net tow may dominate the influence of these materials on the marine environment.

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