

The Fate of Stranded Pelagic Tar on a Bermuda Beach

THOMAS M. ILIFFE and ANTHONY H. KNAP

Bermuda Biological Station for Research, St. George's West, 1-15, Bermuda

The major process involved in the removal of stranded petroleum residues or 'tar lumps' from sandy high energy beaches is the adsorption of sand and shell particles to the residues effecting a density change. This results in transport off the beach, sinking, and sometimes burial of the tar in sublittoral sediments.

The occurrence of petroleum residues on the beaches of Bermuda has been well documented (Butler *et al.*, 1973; Morris & Butler, 1973). The surface current patterns of the North Atlantic, which concentrate floating *Sargassum* weed into the central ocean gyre known as the Sargasso Sea, also accumulate and retain floating petroleum residues or 'tar lumps'. Since Bermuda is the only land mass in the Sargasso Sea, considerable quantities of the tar from this part of the North Atlantic may be eventually stranded on Bermuda's beaches. Although the fate of these petroleum residues at sea has been discussed (Butler, 1976), along with that of their weathering once on the beaches (Blumer *et al.*, 1973; Zsolnay, 1978), there is little information available on the fate of beach deposited material, nor have there been any detailed experiments on the mechanical processes affecting beach tar distributions. Recently, the mechanics of the removal of stranded oil from a beach has been related to the energy conditions present (Owens, 1978). This present report discusses the physical processes occurring on a beach which receives considerable amounts of stranded pelagic tar.

Observations

The site chosen for this study was Whalebone Bay; a shallow bay on the northeastern coast of Bermuda. The semi-enclosed bay, rimmed with aeolian carbonate sandstone, measures about 150 m by 200 m. It has a bare sandy substrate in the middle, with beds of the sea grasses *Thalassia* and *Cymodocea* fringing the edges. On the eastern side is a small sandy beach about 75 m long where much of the pelagic tar is stranded. During winter, the prevailing northerly winds blow directly into the bay. Under these conditions, Whalebone Bay receives the highest amounts of stranded pelagic tar found for any beach in Bermuda. The geometric mean of tar stranded at Whalebone Bay during January-June 1978 was $610 \text{ g m}^{-1}/6 \text{ days}$, while four other Bermuda beaches had geometric means ranging from 22-95 $\text{g m}^{-1}/6 \text{ days}$. The large quantities of tar at Whalebone Bay make it an excellent site for the study of the distribution and fate of stranded tar.

In order to examine factors influencing the distribution of tar on a beach, we utilized a 1 m wide transect extending from the upper edge of the storm tide line, across the beach, to 32 m past the low tide line (Fig. 1a). The transect strip was located near the centre of the beach to minimize the influence of the adjacent rocky shore line. All tar that was visible was collected within sections of the transect at low tide. Tar lumps from each section were placed in a vessel containing seawater and the weights of tar that floated and sank deter-

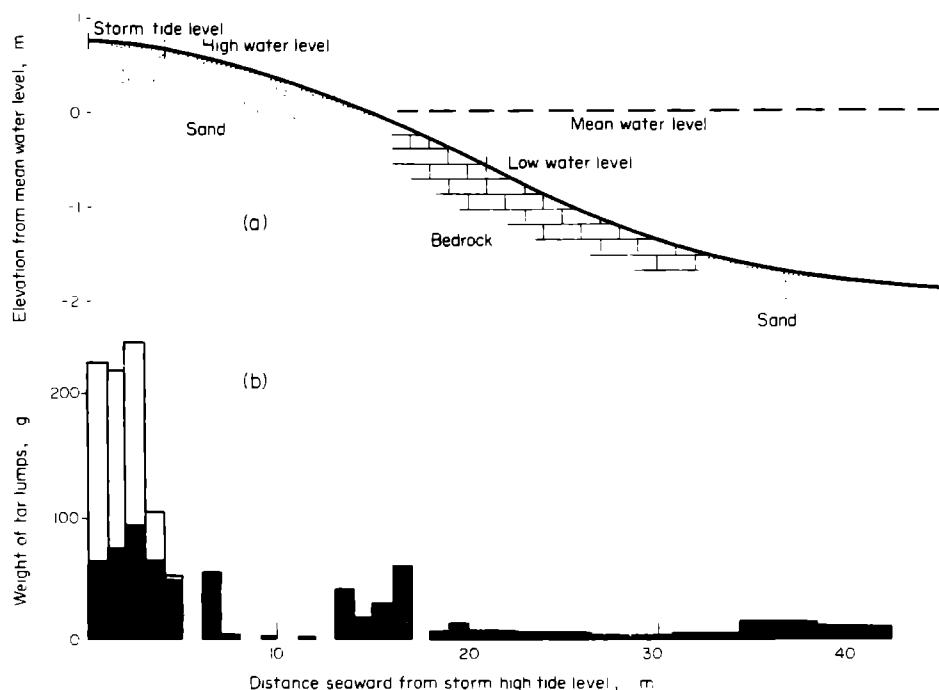


Fig. 1 Whalebone Bay 1 m wide beach transect. (a) Description and elevation of beach along transect. (b) Total weight of tar lumps per metre of transect; shaded bars represent total weight of tar lumps that sink; unshaded bars represent weight of tar lumps that float.

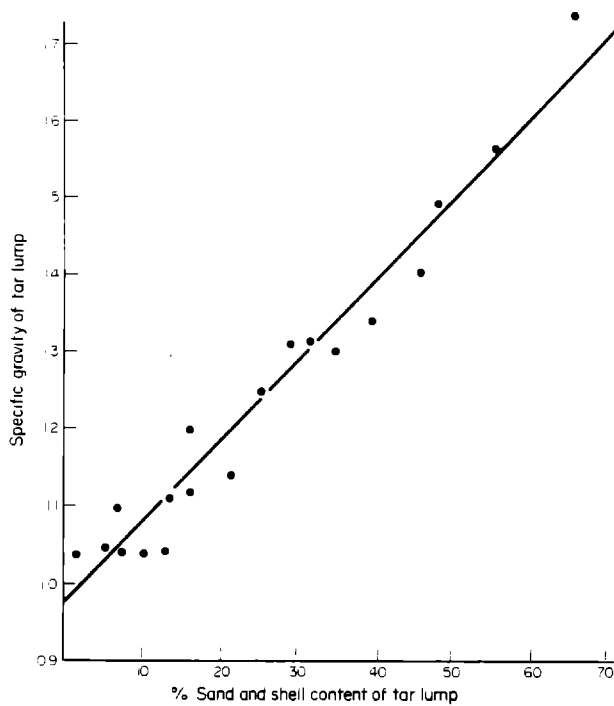


Fig. 2 Relationship between sand and shell content and specific gravity of 20 sunken tar lumps.

mined (Fig. 1b). The large amounts of tar found high on the beach are progressive accumulations deposited during storm tides. Farther down the beach, bands of tar are often found that have been left by the last receding tide. The percentage of sinking tar lumps increased seaward with no floating lumps found stranded below the high tide line.

Upon close examination of the individual tar lumps, differences were noted in both their shape and consistency. Pelagic tar, collected offshore in neuston tows, and freshly stranded beach tar, are both roughly spherical in shape as implied by their popular designation as 'tar balls'. Once on the beach, however, the lumps, upon exposure to strong sunlight, decrease in viscosity and begin to take on a flattened, irregular appearance. At the same time, the tar lumps, facilitated by their decreased viscosity and also by wave action on high energy beaches, accumulate sand and shells in an outer crust. This results in an increase in the specific gravity of the tar, causing lumps which had floated onto the beach, to now sink.

Specific gravities of tar lumps were obtained by first weighing the lump in air and then in distilled water. The specific gravity was calculated by dividing the weight in air by the weight in air minus the weight in water. The sand and shell content of the tar was found by dissolving the lumps in chloroform, washing the residue with distilled water, drying at 70°C and weighing the remaining material. When the specific gravity of 20 sublittoral tar lumps was plotted against their sand and shell content (Fig. 2), a correlation of 0.978 was obtained. This indicates that specific gravity of sunken sublittoral tar is directly related to the sand and shell content. Other factors known to cause sinking of pelagic tar, such as weathering (Butler, 1976; Morris *et al.*, 1976; Butler, 1975; Blumer *et al.*, 1973) or colonization by attaching organisms (Kajihara *et al.*, 1975; Horn *et al.*, 1970) do not appear to play a major role in the sinking of tar lumps in high energy beach environments.

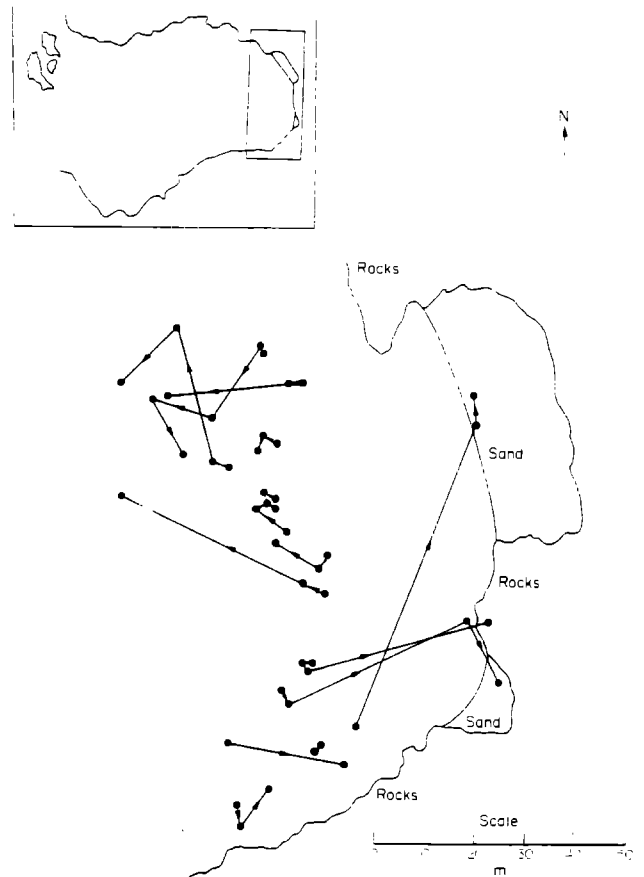


Fig. 3 Movement of numbered sunken sublittoral tar lumps in Whalebone Bay, Bermuda over a 24 day period, 28 March-20 April, 1978. Dots indicate the surveyed locations of the tar lumps. Lines connecting the dots show the inferred transport paths, while arrows indicate the direction of movement. The inset illustrates the location of the study area with respect to the entire bay.

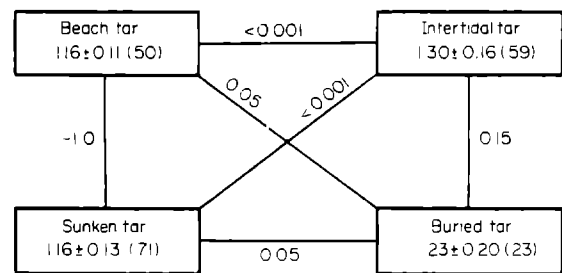


Fig. 4 Probabilities of the specific gravities of two populations of tar being identical. Each box represents a population of tar lumps collected at Whalebone Bay, Bermuda. The mean specific gravity \pm the standard deviation is given for each population. The number in parenthesis is the sample size. The number on the line connecting two boxes is the probability that the specific gravities of those two populations are identical as based on the two tailed t test. The beach tar population is defined as tar found above the high tide level that sinks in seawater. Intertidal tar also includes only those lumps that sink in seawater. Sunken and buried tar is found in 1-2 m of water directly off the beach. Buried tar is covered by as much as 50 cm of sandy sediments.

A tagging experiment was used to assess the mobility of sunken tar in the sublittoral environment. Sunken tar lumps were recovered from various locations in Whalebone Bay, and small numbered plastic tags attached. The lumps were then replaced at their original locations and these sites surveyed by means of distance and bearing measurements from shore stations. Subsequently, every 2-3 days the lumps

were relocated by divers and their new positions recorded (Fig. 3). The maximum movement of the lumps (40–50 m) occurs when the wind blows directly into the semi-enclosed bay. Tar lumps that have low specific gravities were found to have the greatest mobility. The direction of movement of the tar is related to the predominant circular current pattern within the bay. Some of the sunken tar is re-stranded on the beach indicating that considerable recycling of tar between beach and sublittoral environments occurs.

Buried tar was excavated from sublittoral sandy sediments with an airlift (Wilkes, 1971). Tar is found throughout the sediment column down to depths of 0.5 m. The highest buried tar concentrations are located at the base of the rocky beach slope in 1–2 m of water. The concentration of buried tar in the sediments decreases seaward.

Specific gravities of non-floating beach, intertidal, sunken subtidal and buried subtidal tar were compared (Fig. 4). Beach and sunken tar populations are found to be statistically identical with regard to their specific gravities. This is probably due both to the significant exchange of tar between beach and sublittoral environment, as demonstrated by the tagging experiment, and to the observation that tar lumps no longer accumulate sand once they leave the beach. Intertidal and buried tar populations are significantly different from beach and sunken tar, and differ from each other at the 85% confidence level.

Lower specific gravity beach tar and floating tar is deposited the farthest up the beach by storm tides. In the intertidal zone, the highest specific gravity tar lumps, which are pushed up the beach slope by high energy wave action on the rising tide, are stranded by the receding tide. Sunken subtidal tar is a representative sample of non-floating beach tar that was washed offshore without encountering further changes in specific gravity. Finally, in offshore sandy areas, higher density lumps are found buried in the sand.

Conclusion

These observations of tar lumps that sink, found both on and offshore and in the sediments, lead to a new understanding of the processes affecting beach stranded pelagic tar. When spherical pelagic 'tar balls' are stranded on a beach,

they often melt due to the heat of the sun and form a flattened mass. Considerable beach sand and shell material adheres to the melting tar. This process, combined with wave action at high tide moving the tar up and down the beach slope, produces a high density sand and shell crust on the tar lumps. Continued wave action may transport the lumps off the beach, where they sink due to their increased density. The sunken tar tends to accumulate in depressions on the bottom. During storms this sunken tar may be moved tens of metres and either be redeposited on the beach or transported farther offshore. Tar lumps may also be buried in the near-shore sediments during these storm periods. Thus, the eventual fate of a significant portion of the beach stranded pelagic tar may be in near-shore sediment burial.

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