IN SITU QUANTIFICATION OF OIL ENTERING AN ESTUARY UNDER PROTECTIVE BOOMS

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Abstract

After an exploratory oil well (IXTOC I) blew out in the Gulf of Mexico in June 1979, three million gallons of oil were estimated to impact the Texas coast, primarily along Padre Island. Booms, either complete or staggered, were placed across the inlets to prevent oil from entering the environmentally sensitive estuaries, including the Laguna Madre. These estuaries are important nesting areas for birds and nursery areas for fish and other marine life. There was concern that subsurface oil of substantial quantities was entering the estuaries under the booms during flood tides.

Diving investigations at the booms to observe and quantify the amount of subsurface oil entering the estuaries indicated that between zero and 100 kg of weathered oil was entering the Laguna Madre per day. Except for some small deposits on the shores of the inlet and flats in the estuary, the oil had no obvious impact.

Introduction

An exploratory oil well, IXTOC I, being drilled 80 km off Campechi, Mexico in 50 meters of water blew out on the third of June 1979. This blowout resulted in one of the world's largest oil spills, with oil flow estimates ranging from 8,000 to 30,000 barrels of oil per day,[1,2] eventually covering approximately one-tenth of the entire Gulf of Mexico.[3] By early August roughly three million gallons of oil began to come ashore on the south Texas beaches (Fig. 1).

The lighter petroleum hydrocarbons, upon reaching the surface, spread rapidly and produced a very large but extremely thin (in the order of micrometers) slick or "sheen". The heavier hydrocarbons spread much more slowly than the lighter fractions and became thickened into "pancakes" of oil, one to ten meters in diameter. Oil in emulsions, containing up to 60% water, were created during periods of rough weather and were called mousse after the chocolate dessert they resembled. As the oil weathered, it became more dense and less buoyant. The neutrally buoyant oil became distributed through the upper water column due to the attachment of heavier debris or through wind action and subsequent Langmuir circulation. Tar balls and flakes of tar began to break away from the larger pancakes and mousse patches and were observed as deep as 12 meters in the water column. After travelling between 600 and 800 km the oil was well weathered and largely in the form of tar balls, pancakes, mousse and conglomerates of tar and organic debris.

Padre Island, a sand barrier beach, runs north from the Brazo Santiago Pass about 200 km and separates the environmentally sensitive Laguna Madre from the Gulf of Mexico. At the northern end of Padre Island, a similar barrier beach, Mustang Island, continues for 30 km and terminates at Aransas Pass.

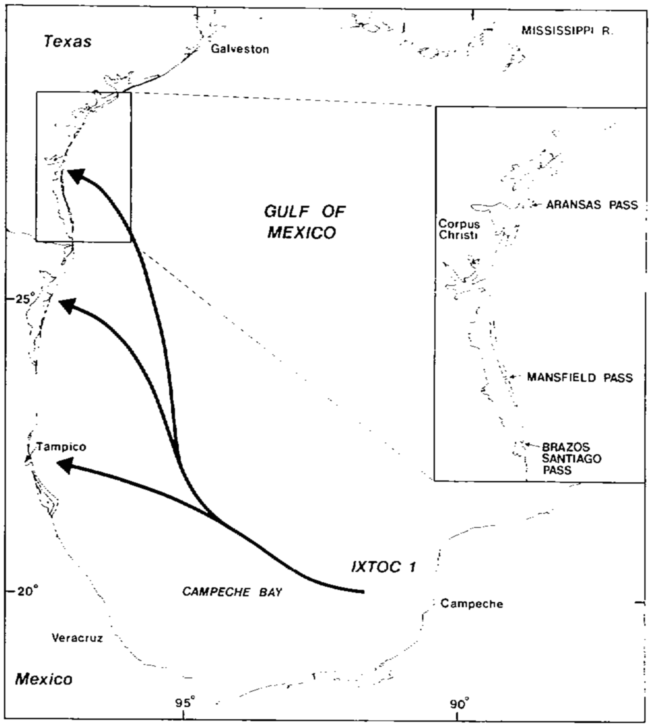

Fig. 1. Trajectory of oil from the IXTOC I blowout and associated passes.

The Laguna Madre, a shallow high salinity estuary, is an important nesting area for birds and nursery area for fish, shrimp and other marine life. When the slick hit the sand of Padre Island the tar balls, mousse and pancakes combined to produce lengths of tarred beach. Although the oiled barrier beaches were certainly unattractive and hurt the regions' tourist industry, they functioned extremely well in their capacity as barriers by preventing the oil from entering the estuaries. Figure 1 shows three of the four passes or cuts through Padre and Mustang Islands which allow ship and boat traffic between the mainland cities and the Gulf of Mexico.

The Aransas and Brazo Santiago Passes could not be boomed completely due to the large volume of ship traffic using these deepwater accesses to the Gulf so staggered booms were installed. These booms were secured to the shore at one end and the other was anchored in the pass at an angle so that the currents would effectively concentrate the oil in the apex between boom and shore. Skimmers and tanker trucks were then used to remove the oil.

Mansfield Cut and Fish Cut which connect the Gulf with the Laguna Madre and Corpus Christi Bay respectively, are relatively narrow and shallow, being used primarily for smaller fishing and pleasure boats. Both cuts were boomed completely from shore-to-shore with a regular oil boom followed by two booms containing an oil absorbant.

Due to the observation by University of Texas divers of tar particles in the water column offshore (personal communication), there was concern that oil may enter the inlets under the booms and move into the estuaries. The Scientific Support Coordinator requested the assistance of a team of scientist/divers from the National Oceanic and Atmospheric Administration (NOAA) to investigate and quantify the problem. We made the decision to concentrate our investigation in Mansfield Cut as it connected with the middle of the Laguna Madre, the beaches north and south of the inlet were substantially oiled and the physical and hydrographic features of the cut could be adequately and quickly described.

Site Description

A sampling station was established at the westerly end of the cut near dayshape 14, approximately 2 km from the Gulf. This station, designated station 14, was about 50 m east of where the cut opens into the Laguna Madre, therefore any oil moving past this station was considered to have reached the estuary. A NOAA survey unit estimated the maximum depth at station 14 to be 5 m and the cross sectional area to be 360 m^2 with maximum tidal velocities approaching 102 cm/sec (2.0 kts). The surface tidal velocities during maximum flood were usually about 82 cm/sec (1.6 kts) causing appriximately 100 m^3 of water per second to enter the estuary.

The hydrography of the cut is complicated by the Laguna Madre being more saline than the Gulf of Mexico. This higher salinity is the result of limited fresh water input and high evaporation rates. A salt wedge is therefore produced along the bottom of the cut in reverse of most estuaries and, in this case, forced the less saline, oil bearing Gulf water to the surface and the absorbant booms. One high and one low astronomic tide was found to occur each day and could be predicted; however local meteorological conditions caused the actual tides to occur two to six hours later. We added a mean of four hours to the predicted astronomic tide in order to sample at or about maximum flood tide.

Methods

SCUBA was used to make all observations as the oil appeared to be in relatively low concentrations at the boom and station 14 dive sites and no toxic hazards to the divers were anticipated. Light coveralls were sometimes worn to prevent the oil that was present from reaching the diver's skin.

To maintain station during the maximum flood tide, the divers swam a lightweight Danforth anchor and chain to mid-channel and set the anchor. From the chain there was about seven meters of light nylon line to which a buoy (approximately 1/3 m^3 in volume) was secured. This buoy was used to support the divers and had attached a four meter safety line and life ring.

Preliminary sampling at depth with a fine mesh tropical fish net and slurp gun allowed the divers to calibrate their eye to what was and was not oil particles. The oil particles, almost exclusively in the form of tar flakes, would be obviously tarlike when smeared between the fingers or in the net. Non-tar particles would either remain in their original configuration or would disappear entirely during the smear test. With the visibility in the cut averaging about 20 cm, the diver, if the current velocity was 82 cm/sec (1.6 kts), would have about one quarter of a second to determine if the particle he was observing was indeed oil.

A method to quantify the amount of subsurface oil entering the inlet was developed and consisted of counting the number of oil particles moving through a volume of water 10 cm high, 10 cm deep, and 20 cm wide in one minute. The bottom of this box was of white plastic to facilitate visibility; the sides and top were outlined in wire. For calculation purposes the box was considered a vertical plane of 200 cm^2. The horizontal dimension of depth provided time for counting the particles. Due to the limited visibility one diver with the counting box would descend along the line to the bottom and stay at the line. The second diver remained on the surface at the buoy and standard line signals as promulgated in the NOAA Diving Manual[4], were used for communication. The diver counting made duplicate one minute counts on the bottom, at mid-depth, and just under the surface (approximately 1/3 m). When the first diver finished counting the divers exchanged roles. The anchoring apparatus was then moved halfway between mid-channel and the shore (about 2.5 m of water) and the sampling regime was repeated.

Similar tar particle counts were made in Mansfield Cut during the flood tide 7 meters seaward of the boom, under the boom itself and approximately 20 m west of the boom.

The number of particles passing through the counting plane per minute were averaged for all depths at both the mid-channel and 2.5 m sites and multiplied by 18,000, the number of counting planes in the cuts cross section at station 14. Thus, the number of particles passing through station 14 per minute was estimated. I assumed the particles to have slight positive buoyancy and be near the density of fresh water. By converting the observed volume of the particles to weight using the density of fresh water as the conversion factor and integrating the influx of particles over an assumed nine hour flood tide the amount of oil, by weight, entering the estuary was calculated.

Sediment and sea grass samples from the bottom were taken and examined by the optic, olfactory and tactile human sensors for the presence of oil and tar.

Additional diving investigations were made 96 km north and 8 km south of Mansfield Cut from the Padre Island beach, offshore to just beyond the third and last set of breakers (approximately 300 m). The tar balls in a quarter square meter of bottom and bottom 8 cm of water were counted and put on a square meter basis. Counts were taken in the swash zone and in the two troughs between the bars.

Results

Oil particle counts averaged over all depths, seaward of the boom were almost twice that at station 14 (57.1 and 28.4 kg of oil per nine hour flood tide respectively) apparently indicating that the booms were effective in preventing at least part of the subsurface oil from reaching the estuaries. This is probably not the case, however, as the booms reach only about one meter below the surface and during strong tidal currents objects approaching the lower third of the booms were swept under it. I believe that the oil particles seaward of the boom passed into the cut but surfaced in the cut during periods of low tidal velocities and were blown by the persistent southeasterly winds onto the north shore of the cut. This hypothesis is supported by direct observations of tar and oil particles on the north shore of the cut.

In the swash zone 8 km south of the inlet we observed tar balls (conglomerates of sand and oil) ranging in diameter from 1 mm - 4 cm (with most around 1-2 cm) in concentrations of 20-32 per m^2. Ninety-six km north of the inlet, where the beach was more heavily oiled, the tar ball concentration in the swash zone approached 600/m^2 with a size range of 1-5 cm. At both sites no tar balls were located beyond the last set of breakers and the tar balls were being transported to the north in the littoral current.

There was no obvious effect by the oil on the animals of the estuary as crabs, fish, both large and small, and dolphins were observed swimming and feeding among subsurface oil conglomerates and tar balls.

Conclusions

1. The oil booms, while effective in preventing surface oil and oil conglomerates from entering the inlets, had no effect on the influx of subsurface oil particles.

2. The amount of oil entering the Laguna Madre ranged from zero to 100 kg per nine hour tidal cycle, was almost completely in the form of tar flakes and varied directly with the sporadic oiling of the barrier beach.

3. No oil was observed incorporated into the sediments of the cut or attached to submerged drifting sea grasses.

4. There was no observable effect on the marine and estuarine life indicating the amount of oil entering the estuary was probably insignificant.

5. The slick, after impacting the beaches of Padre and Mustang Islands, incorporated sand particles, causing it to be negatively buoyant once washed back to sea by storm or tidal actions. Heavy concentrations of these tar balls (600/m^2) were observed moving in the littoral current. It is hypothesized that these conglomerates reached rip currents and were transported back offshore probably creating the "asphalt" patches which have since been reported.

References

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