CHAPTER 147

THE CLEANING OF GRAVEL BEACHES POLLUTED BY OIL

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Abstract

An attempt to clean beaches without the use of dispersants was undertaken in Chedabucto Bay, Nova Scotia, following a spill of Bunker C oil from the tanker "Arrow" in the spring of 1970. Sand beaches account for less than 2% of the coast of Chedabucto Bay and those which were polluted were cleaned manually using peat moss, rakes, and shovels. Most sand beaches can be cleaned with relative ease, as oil does not permeate the sediments, and the angle of sand beaches is generally low so that mechanical methods can be applied without large-scale removal of beach sediments. Oil deposited on gravel beaches permeates below the surface layer and cleaning by mechanical methods involves excavation of beach sediments to depths of one metre or more. This method endangers the stability of a beach, particularly if the sediment supply is limited. Also this method was found to be ineffective in removing all contaminated sediments.

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INTRODUCTION

The tanker "Arrow" ran aground on Cerberus Rock on February 4, 1970, and the resulting spill of Bunker C oil polluted more than 350 km of shoreline in Chedabucto Bay, Nova Scotia. The coast of Chedabucto Bay is made up of a variety of shoreline types ranging from rock or till cliffs to sandy beaches and sheltered lagoons. Attempts to clean sections of the polluted shoreline without the use of dispersants met with many difficulties. The effect of oil on the various shoreline types differs greatly so that no one cleaning technique could be applied to large sections of shoreline.

During the spring of 1970 a task force, established by the Canadian federal government to deal with the pollution problem, initiated a series of clean-up projects to restore contaminated beaches. Approximately 80 km of coast were selected for cleaning, based on their recreational value to the local residents and to tourists. Available dispersants were considered too toxic to marine life and the task force decided to clean the beaches by removing the contaminated sediments. The majority of beaches in Chedabucto Bay are made up of mixed sand-gravel sediments and in many locations oil had permeated up to 0.5 m or had been buried as much as 2 m below the surface, thus requiring the excavation of large volumes of beach sediment.

CLEAN-UP METHODS

Prior to the Chedabucto Bay spill, a great variety of techniques had been investigated for the containment and removal of oil from the surface of the sea, but relatively few studies had been concerned with shoreline clean-up technology. Even within the field of beach restoration, work had been concentrated on sand beaches with little attention to gravel and cobble beaches, tidal flats, or marshes. The problem of establishing criteria for the cleaning of shorelines is complicated by the different types of oil, each of which has different physical properties, and by the variety of coastal types in terms of different process environments and different erosional or depositional forms. The results of studies on oil contaminated sand beaches (e.g., F.W.P.C.A., 1970) could not be applied to gravel beaches, and adequate contingency plans for future spills must therefore take into account the nature of this particular coastal environment.

Various techniques have been discussed for the cleaning of oil-contaminated gravel beaches (Wardley Smith, 1968; 1969); these include burning, absorption, removal and dispersion of the oil with solvents. (i) Burning may be efficient but is costly and most types of oil are difficult to ignite and require constant application of heat. The warming of oil increases its mobility so that it permeates into the sediments. (ii) The use of absorbant materials is not always effective and requires mechanical or manual effort to apply and remove the absorbing material. (iii) Cleaning by the mechanical

removal of sediments poses many problems related to the natural beach equilibrium which may be disturbed and may result in more damage than that originally caused by pollution. (iv) The application of solvent-emulsifiers under controlled conditions appears to be the most effective way of removing oil without damage to the beach, but the dangers of toxicity to marine life have so far prohibited the large-scale use of this method. Eventually the best hope for efficient and practical removal of oil pollutants on coasts lies in the development of non-toxic chemical dispersants.

SEDIMENT REMOVAL

Sand beaches account for less than 2% of the coast of Chedabucto Bay (Owens, 1972) and those which were polluted were cleaned manually using peat moss, rakes, and shovels. On sand beaches oil rarely permeates below the surface and can be removed with relative ease. The only important geological concern in this part of the program was to minimize damage to backshore vegetation by vehicles gaining access to the beach.

On gravel beaches, oil was observed to have permeated up to 45 cm immediately following deposition in February and March, despite low air temperatures (Drapeau, 1970). Also, the normal processes of accretion on the beach led to burial of the oil-contaminated sediments in many localities. Subsequent periods of erosion frequently exposed layers of oiled sediments on the beach face slope. Attempts to clean these beaches involved excavation to depths in excess of one metre (Owens, 1971; Owens and Drapeau, 1972). This removal of sediment can lead to a serious disturbance of the existing beach equilibrium.

Mechanical equipment was used in Chedabucto Bay to clean 50 km of mixed sand-gravel beaches by removal of contaminated material. Data is available for some locations (Mackay, 1970) and it indicates that approximately 3 to 6 cubic metres were removed for each linear metre of beach. Most of this material was removed from the beach in the zone near or above high water level. Removal of sediment from this zone is particularly undesirable because natural replacement of material is slow, as areas above normal high water are only affected by littoral processes during periods of storm wave activity (Fig. 1a). At Indian Cove on the south shore of Chedabucto Bay the removal of sediments enabled waves to wash over the crest of the beach and this resulted in a retreat of the beach crest by 20 metres over a one year period (Fig. 1b).

The beach sediments in Chedabucto Bay are largely derived from the erosion and reworking of till deposits over the last 10,000 years during a period of rising sea level. Present-day processes do not provide sufficient

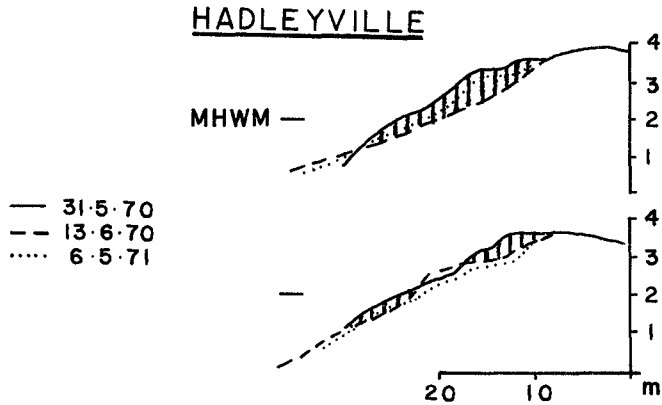

Figure 1a. Beach profiles at Hadleyville. Shaded area indicates sediment removed by beach cleaning. Most of the contaminated sediments on this beach on the west shore of Chedabucto Bay were removed from the zone above Mean High Water Mark.

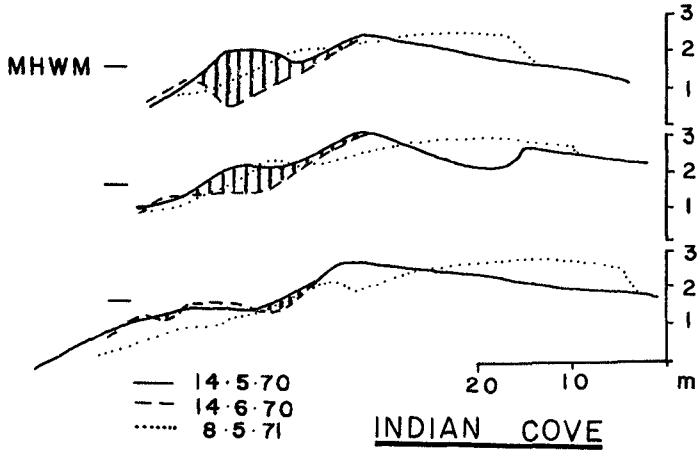

Figure 1b. Beach profiles at Indian Cove, a pocket beach on the south shore of Chedabucto Bay. Shaded area indicates sediment removed by beach cleaning. In certain sections sediments were removed to depths in excess of one metre. Within twelve months the beach crest retreated more than 20 metres.

sediment to the beach zone to replace large-scale losses. A similar situation is reported by Robinson (1961) who traces rates of shoreline retreat following sediment removal at Hallsands on the south coast of England. In both cases present-day sediment supply is limited and is unable to replace material lost by natural or human activity. Gravel is transported more slowly than sand and even if material is available for redistribution, serious damage to the beach equilibrium may be incurred before natural healing can take place.

NATURAL CLEANING

Many of the heavily polluted sand and gravel beaches in Chedabucto Bay were cleaned by normal wave action within a period of several months following contamination. This natural physical breakdown and removal of the oil was particularly evident on the beaches exposed to the full effect of waves from the Atlantic. Much of the oil had been deposited during a period of storm waves, and therefore contaminated material concentrated in the zone beyond the limit of normal wave action. This oil would only be removed by biodegradation or during subsequent periods of storms. However, the effectiveness of natural processes to clean beaches is important provided there is no urgent requirement for restoration of the beach.

Thomas monitored several intertidal locations of differing exposure over a one year period following the spill and reports (1971) that all locations showed significant reductions in oil coverage except for one site, a sheltered heavily-oiled lagoon. "Reductions in oil coverage were most noticeable at exposed locations. For instance at the Crichton Island study location the maximum percentage oiling of the intertidal zone (in April, 1970) was 10% in the upper portion while none of the remainder showed over 5% oiling. At maximum oil coverage, in June 1970, coverage ranged from 100% in the upper portion to 90-20% on the lower portion of the shore" (Thomas, 1971).

The northern coast of Chedabucto Bay is a lowland area which has been drowned to produce a complex series of islands, inlets, and bays. Most of this shoreline is not exposed to wave action from the open sea and in the sheltered low-energy environments oil was removed only very slowly by littoral processes. In such environments beach cleaning is valuable as physical processes are operating on a greatly reduced level. Contamination in sheltered localities is often more extensive and may be sufficient to prevent the normal movement of beach sediments. The immobilized beaches can be partly restored by the use of heavy equipment to break the surface layers which have been bound by the oil. In some cases this may be sufficient to permit wave processes to clean the sediments but in many areas further action may be necessary.

The beaches of low-energy wave environments are similar to many polar beaches and some measure of the probable effects of a spill in the Canadian arctic archipelago can be gained from the Chedabucto Bay area. In areas where

wave action is limited biodegradation is the only process that will break down the oil naturally and rates of biodegradation are greatly reduced in higher latitudes. The rate of natural cleaning in a low-energy wave environment in the arctic would be extremely slow.

CLEAN-UP OPERATIONS

Except in those areas where natural processes cannot clean beaches, due to low wave energy conditions or to excessive accumulations of oil, it is recommended that beach cleaning should only be undertaken at locations where contamination presents serious social or economic difficulties. Clearly, pollution of beaches frequently visited by tourists requires action but even in this case a spill occurring during the off-season could be left. Eventual cleaning before the tourist season would probably be necessary but this would be on a greatly reduced scale due to the effects of natural cleaning.

Whenever it is necessary to clean gravel or mixed sand-gravel beaches for social or economic reasons this should be accomplished without sediment removal. However, no techniques are available at present which can clean gravel beaches for recreational use without the application of dispersants, but two possibilities are suggested. One method which may be effective involves the use of a bulldozer to push contaminated material into the surf zone at low tide to allow normal wave processes to clean and redistribute the material. A second possibility involves the adaption of a technique developed in Bermuda for the cleaning of sand beaches repeatedly contaminated by oil (I.W. Hughes, pers. comm.). This process involves cleaning the sediment by washing with a dissolvant and then returning the material to the beach. Equipment could be designed to handle large volumes of gravel so that contaminated sediments could be excavated, fed into a tumbler system to dissolve or remove the oil, and then discharged for return to the beach. In this way oil could be removed rapidly without loss of beach sediment.

CRITERIA FOR CLEAN-UP OPERATIONS

Reaction to an oil spill which leads to pollution of the shoreline should be based on consideration of the socio-economic, geological, and wild-life factors within the area.

(1) The immediate response should be to protect those areas which would be most seriously affected by contamination, such as marshes and estuaries.
(2) Recreational or economic use will determine if any of the beach areas require cleaning. It may not be necessary to restore areas of shoreline which are little used and will, in time, clean themselves.

(3) If restoration is necessary then operations should only commence when there is no danger of recontamination.
(4) If natural cleaning would not be a feasible approach the available techniques must be evaluated to determine whether they can achieve the desired objective. There is little point in attempting to clean gravel or mixed sand-gravel recreational beaches with existing manual or mechanical methods as it is not yet possible to remove all contaminated material without the use of dispersants.
(5) A decision to adopt clean-up techniques which involve sediment removal must take into consideration the possible effects of lowering beach storm ridges, or of the destruction of backshore vegetation as this may lead to permanent damage, more serious than that caused by the original pollution.

CONCLUSIONS

The cleaning of shorelines contaminated by oil presents many problems, particularly on gravel beaches or in sheltered areas. As yet, there is no simple, efficient clean-up method and in some cases it may be necessary to suffer the inconvenience of a polluted coast rather than disturb the natural stability of a beach by large-scale sediment removal, resulting in more damage than that caused by the original pollution.

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