Clean-Up after Territorial Oil Spills in the Arctic

The Trans-Alaska oil pipeline is being constructed from Prudhoe Bay to Valdez, and may be followed in the nineteen eighties by an oil pipeline from the Mackenzie Delta and Beaufort Sea to Alberta, Canada. Although pipelines are the safest known method of transporting oil, accidental oil leaks will occur. The Trans-Alaska pipeline will have a maximum leakage potential, after block valve closure, of about 50,000 barrels (8,000 m^3) of oil, although for over half of its length the leakage potential will be less than 15,000 barrels[1]. It is probable that a Mackenzie Valley pipeline would be the subject of a number of catastrophic leaks due to major ruptures in which volumes of oil in the amounts of some tens of thousands of barrels would be discharged[2]. There might also be a larger number of small ruptures causing leaks whose volume would depend on the time taken for detection and repair. Experiments are currently under way to determine the physical and biological effects of such oil spills; however, little attention has been devoted to the development of a technology for clean-up after such spills. It is clearly desirable that this technology be developed, tested and available prior to the construction of a pipeline.

The nature of a spill will depend on the local weather conditions, including the presence or absence of snow, the absorptive capacity of the ground (which is influenced by the prevailing ground-water level), and local topography. It is impossible to predict the shape or area of a spill in advance; however, it is likely that areas of some tens or even hundreds of thousands of square metres would be affected. The oil may flow both on the surface and under the surface by permeating the moss or detritus layer. The purpose of the present note is to show that the nature of the problems of containment and clean-up in arctic and sub-arctic regions is substantially different from that in the temperate south. Indeed, there is a risk that the application in the Arctic of clean-up techniques appropriate to temperate areas would result in substantially greater environmental damage than would occur if no clean-up were attempted.

In clean-up operations after oil spills, the first requirement is to contain the spill in as small an area as possible, and to prevent it from reaching water courses and thus contaminating their environments. Devices and techniques can then be employed to remove oil from the contaminated region and convey it to temporary storage. Thirdly, the area can be treated to remove residual oil and promote its early restoration through the use of chemical and biological techniques. It is probable that a fire or explosion hazard will exist during and immediately after a spill, and so explosimeters should be used continuously where personnel are likely to be exposed to hydrocarbon vapours.

In temperate regions, terrestrial spills are most readily contained by artificial dykes or dams constructed by means of earth-moving equipment, and it is also possible to dig trenches and ditches into which oil will flow and be retained. In areas of permafrost, however, suitable damming material may not be readily available, or may be obtained only if considerable areas of permafrost are exposed — that is, at the cost of additional environmental damage. The use of heavy vehicles, even if they are available, will compact the insulating active layer of permafrost and thereby cause eventual melting of the permafrost. Containment should involve a minimum of disturbance of the area, with no removal or compaction of the active layer and exposure of permafrost.

A method of containment which may be feasible is to use damming material that can be quickly transported to the site and installed without the aid of machinery. For example, corrugated metal sheeting in sections about three feet high by ten feet long (1 m x 3 m approximately), with vertical corrugations, could be driven through the active layer down to the water table or frost level or thawed clay soil, all of which provide a basement to vertical oil penetration, and retained in position by T-bar stakes driven into the ground. This assembly could form a water-tight dam since the sections could be bolted or clamped together and, if necessary, a polyethylene sheet draped overall to provide a seal. It would be necessary to cut a narrow trench for the metal sections through roots, rocks and high permafrost areas with the aid of hand tools such as axes or spades, or with light, tracked trench-excavating vehicles such as are normally used to lay underground telephone cables. It might not be necessary to provide a perfect seal, since the region at the bottom would normally be water-logged so that oil would be unable to flow under the barrier provided. If the depth of the layer increased, the sections could be driven further into the ground. Heat conduction down the metal would probably result in local melting and provide improved sealing if the sections were hammered down in a regular manner. The presence of permafrost ironically brings the substantial benefit of there being little of the infiltration of oil into porous soils, with subsequent ground-water contamination, which constitutes such a severe problem in temperate regions; that is, clean-up operations can be facilitated by the presence of permafrost.

Another approach to containment, which was tested briefly during the summer of 1974 on wet tundra on Richards Island in the Mackenzie Delta, is to cut a trench, 30 cm wide, to permafrost level across the path of the flowing oil. The trench successfully intercepts the flow of oil, both on and below the surface, and drains it to a low-level point from where it can be pumped to storage or for disposal. A trench thus has the advantages that it contains the oil, requires no materials for construction apart from trenching equipment, and makes the oil accessible for recovery. It has the disadvantage that, if left open, it could lead to thermokarst conditions. Possibly the optimal arrangement is first to cut a trench, then when the oil flow slows, to insert a barrier and fill the trench.

A dam or trench of the type just described, which would necessarily have to be located on the downslope side of the area of spillage, would interfere with natural drainage, and so it would be necessary to control drainage from the area while oil and water were being separated. The present authors suggest that this control could be effected by the installation of an API (American Petroleum Institute) type of oil-water separator which can be constructed easily from prefabricated metal sheeting, usually about 5 feet deep by 10 feet wide by 30 feet long (1.5 m x 3 m x 9 m approximately). These separators would ensure retention for sufficient time for most of the oil to float to the surface, the horizontal velocity in the separator being controlled to a value sufficiently low to avoid the creation of turbulence such as would hinder oil flotation. The oil-water mixture could be fed by gravity from behind the dam to the separator. If possible, pumping should not be used unless local terrain makes it necessary, because emulsification of the oil might result. The oil skimmed from the water surface could be led to storage tanks of the bladder or pillow type. The water could then be treated for removal of residual oil by passage through a suitable absorbent material in a second separator before discharge into a creek.

Another possibility would be the use of a compact plate-type oil-water separator. This device, which can be used as a self-contained above-ground unit, is reasonably compact — approximately 12 feet x 11 feet x 4 feet (3.7 m. x 3.4 m x 1.2 m) — and can, therefore, be transported to a site of spillage and put into operation very quickly. It is claimed that it ensures a good quality effluent, even with influents of high oil content, and is more effective in removing volatile hydrocarbons than are separators of the conventional API design.

A significant further advantage of the general technique just explained is the possibility of controlling, and even accelerating, the flow of oil from the area of spillage. In summer, water can be pumped to a location uphill of the area to float out the oil. By a continuous pumping of the water at a rate sufficient to keep the oil-water separator functioning properly, much of the oil can be leached from the area of spillage without anybody actually having to enter it. The effluent from the oil-water separator can be returned to the area of spillage for reuse in the process of removing the oil. If properly diluted in a river, the effluent is unlikely to cause problems of toxicity. Small-scale laboratory tests have demonstrated that significant proportions of the absorbed oil can be floated out of detritus by gravity alone and without agitation.

It is likely that, due to its slow rate of evaporation, the sub-surface oil would maintain a viscosity sufficiently low for it to be floated out by water. It is generally recognized, also, that the toxic constituents of oil are the most volatile and water-soluble. Thus, it is likely that the oil would exhibit toxicity only during the first few months after spillage, and then be permanently absorbed in the vegetation and soil and become immobilized. The oil would pose no threat of subsequent spreading, and would be destroyed ultimately, although slowly, by natural biodegradation.

The most significant advantage of the technique just described is that there is minimum disruption of the terrain during containment and removal of oil. The strategy must be to preserve as far as possible the structural integrity of the active layer in the hope that its insulating properties do not become seriously impaired. Wein and Bliss[3] have suggested that oiled vegetation absorbs more radiation as a result of the decrease in albedo, but that the extra energy is dissipated in causing water to evaporate and by a direct transfer of heat to the air, resulting in drier, dead vegetation with a low thermal conductivity. The frequently-practised alternatives of burning the oil *in situ*, or excavating the contaminated material and burning it in an incinerator, are likely to result in substantially greater environmental damage.

The same general technique can be adopted in dealing with a winter spillage. Surface oil and oily snow should be removed where possible and disposed of by burning. It has been shown that oily snow burns readily, and so it may be desirable to design melter-burners of specific type[2]. As the area of spillage thaws, the oil will be mobilized by the run-off of water, and it will be necessary to have ready-deployed a system of containment and separation similar to those described above.

As a final stage of restoration of an affected area, it may prove beneficial to fertilize it and promote the growth of oil-degrading micro-organisms[4,5]. Since the albedo of the area will be reduced, and so there will be greater absorption of radiation and increased depth of active layer, it may be desirable to increase the albedo artificially by sprinkling the area with reflective material. It would also seem logical to fence in the area to prevent compaction of the dead vegetation by humans, animals or vehicles.

In conclusion, the present authors contend that new techniques must be developed for the clean-up of terrestrial spills in the Arctic, since methods used in temperate regions are inappropriate. Perhaps this note will serve to encourage innovation in this area of study. The history of the so-called development of the Arctic is replete with unfortunate examples of technology from temperate regions being applied there, with an inadequate understanding of the effects on, and response of, the northern environment. Fortunately, there is still sufficient time to develop appropriate oil-spill clean-up technologies for the Arctic. Whether these will, in fact, be developed in good time or only as a result of a first emergency remains to be seen.

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