CLEANUP OF OIL SPILLS ON COARSE SEDIMENTS

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Funding for this study was provided by the United States Minerals Management Service and Environmental Emergencies Technology Division of Environment Canada.

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EE-127 JANUARY 1991

ABSTRACT

A literature review was conducted to assess if rational oil spill cleanup decisions could be based on the existing data. The review focused on techniques for cleaning spills of crude oil and Bunker fuel on coarse sediments. Over 60 references are reviewed and ranked on the basis of environmental, oiling, and cleanup descriptions. A brief discussion with tables summarizing the rankings is presented in the main text, and individual assessments of the references are available in the Appendices. It was found that there is a lack of quantitative documentation concerning the biological impact of cleanup techniques.

RÉSUMÉ

La documentation a été examinée pour déterminer si le données actuelles permettent de prendre des décisions rationnelles en matière de nettoyage en cas de déversement. L'examen est axé surtout sur les techniques de nettoyage en cas de déversement de pétrole brut et de fuel de soute sur des sédiments à gros grains. Plus de soixante titres ont été évalués et classés en fonction de leurs descriptions portant sur l'environnement, le mazoutage et le nettoyage. Dans le corps du texte principal, un bref résumé et des tableaux justifient le classement, et une évaluation de chaque ouvrage figure en annexe. L'examen a mis en évidence une lacune au niveau de la documentation quantitative sur les effets biologiques des techniques de nettoyage.

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1.0 LITERATURE ASSESSMENT

1.1 Procedure

An extensive literature survey of oil spill cleanup techniques was conducted using bibliographies and on-line-databases for spills of crude oil and Bunker fuel on coarse sediments. The literature was assessed for the quality of information describing each technique. Four categories of information were examined:

environmental baseline description
oiling data
cleanup technique description
monitoring of the environment

Almost fifty references for cleanup methods and thirteen references of natural recovery have been assessed. Several particularly valid British and Swedish sources were uncovered during the on-line database search.

To assess the completeness of the literature, a ranking form was created. The reports are ranked "Good" or "Poor" against each heading, according to the quality of information presented. A "Good" ranking was given if a decision to use a particular cleanup method could be made from the information presented.

If cleanup methods were tested in a laboratory situation, oil permeability, location, and fate were assigned a "Poor" ranking. A report may have clearly documented the position and fate of the oil, but, in an artificial situation with small sediment samples or lack of waves and tides. The results are difficult to apply in a real spill setting.

Where components of an oil spill study were in separate papers, the papers were grouped together and ranked as one.

Reports discussing only natural cleaning and fate and effects have been ranked separately, using a slightly different form.

The completed forms are available in Appendix A for cleanup methods and in Appendix B for natural cleaning. A matrix of results was compiled from the evaluations.

1.2 Results

Table 1 is a matrix showing the completeness of the cleanup literature assessed. The matrix for natural cleaning is given in Table 2. A "•" in the Tables indicates a "Good" ranking.

Reports by Exxon Company, USA (1990), Foget et al. (1979), Logan (1975), and Owens (1977a and 1977b) are oil spill response manuals. Under headings where they are ranked "Good" a decision to use a method described could be made from the information available. The drawback is that very few methods for pebble/cobble beaches are presented in the manuals. The few methods described involve manual cleanup or removal of beach material with heavy equipment.

1.3 Discussion

There is no single test or spill which contains information in all of the required headings. In general, there is a serious lack of biological assessment data related to cleanup techniques. Both the pre-spill biological activity and post-spill biological recovery headings have few entries.

Several reports of shoreline trials and spills present information which is particularly relevant to the West Coast. Page et al., Gillfillan et al. (1986) report on the results of dispersant trials in Maine. Unfortunately, the dispersant was premixed into the oil before it was released. Levine, Lindstedt-Siva et al., Miller (1987) report the results of a beach agitation technique used on a gravel beach during the cleanup of the *Arco Anchorage* spill, but this work suffers from a lack of pre-spill conditions and oiling information. Graves (1975) also presents agitation results, but with the same incompleteness.

Mattson et al. (1981) performed an extensive biological assessment of three cleanup methods. The drawback to their study was the very small plot sizes (2 by 3 m) and the poorly described sediment composition. The small plot size precludes conclusions about realistic oil removal rates (because of the edge effects) and even questions the biological recovery information presented. Probably the most complete trials in terms of oil fate and persistence are the BIOS (Baffin Island Oil Spill) tests reported by Owens et al. (1987). The only tests conducted on a purely pebble beach are those by Morris (1987) in which various heavy equipment was tested as well as dispersants and a beach washing plant. Biological impacts were not studied.

If one was able to combine the "Good" rankings from different spills of opportunity and tests, overall conclusions could be drawn. This is not possible due to differences in oiling, beach type, wave energy, and other parameters; the resulting knowledge gaps prevent a complete understanding of the relative effects and effectiveness of different shoreline cleanup techniques.

Table 1 Literature Assessment Matrix: Cleanup Methods

Author	Shoreline	Wave energy/tides	Biological activity	Oil properties	Area oiled	Volume of oil	Permeability/location of oil	Environmental impact	Equipment	Removal rate	Cost/manpower	Logistics/disposal	Duration	Oil fate	Biological recovery
Advanced Technology Inc., 1989															
Bayliss and Spoltman, 1981				•							•	•			
Bellier and Massart, Bocard et al., Hann, Hayes, 1979	•			•	•	•	•					•		•	
Broman et al. 1983			•	•	•	•	•	•						•	•
Brown and Denham, 1980						•			•			•		•	
Canadian Coast Guard, 1989					•				•			•			
Crawford, 1989; Crawford, 1990													•		
Der and Ghormley, 1975				•	•	•	•		•	•			•		
Environement Canada, 1978							•								
Exxon Company, USA, 1990 (Man.)									•						
Federal On Scene Coordinator, 1989	•					•		•	•			•			
Foget, et al., 1977								•	•		•	•			
Foget et al., 1979 (Manual)	•	•	•	•			•	•	•	•	•	•	•	•	
Page et al., Gilfillan et al., 1983			•	•	•	•		•						•	•
Graves, 1985	•								•				•		•
Gundlach et al., 1977a, 1977b	•	•					•								
Gundlach et al., 1981	•														
Hardy Associates (1978) Ltd., 1981	•			•	•	•				•				•	
Huet et al, 1989	•			•					•	•	•	•	•	•	
Klokk, 1985									•	•	•				
Levine, Lindstedt-Siva et al., Miller, 1987	•			•		•		•	•	•	•	•		•	
Logan, 1975 (Manual)	•	•							•	•		•			
Mattson et al., 1981		•	•	•	•	•	•	•		•			•		•
Ministry of Transport, 1973	•								•		•	•	•		
Morris, 1987	•				•	•	•		•	•	•	•	•	•	
Morris et al., 1983									•	•	•	•	•		
Nauman, 1990									•		•				
Owens, 1972	•					•									
Owens, 1977a (Manual)	•	•		•	•		•		•					•	
Owens, 1977b (Manual)	•	•		•			•		•					•	
Owens and Trudel, 1985	•	•	•	•										•	
Owens et al., Sergy and Blackall, 1987	•		•	•	•	•	•		•	•				•	

Note: "•" denotes a "Good" ranking

Table 1 Literature Assessment Matrix: Cleanup Methods

Author	Shoreline	Wave energy/tides	Biological activity	Oil properties	Area oiled	Volume of oil	Permeability/location of oil	Environmental impact	Equipment	Removal rate	Cost/manpower	Logistics/disposal	Duration	Oil fate	Biological recovery
Pertile, 1986	•			•						•	•		•		
S.L. Ross Environ. Res. Ltd., 1984a	•			•					•	•	•	•			
S.L. Ross Environ. Res. Ltd., 1984b	•								•		•	•			
Stewart, 1975				•	•					•					
Tramier et al., 1981; van Oudenhoven et al., 1980							•		•			•			
Twardus, 1980	•			•			•		•						
Vandermeulen et al., 1985	•			•											

Note: "•" denotes a "Good" ranking

Table 2 Literature Assessment Matrix: Natural Recovery

Author	Shoreline	Wave energy/tides	Biological activity	Oil properties	Area oiled	Volume of oil	Permeability/location of oil	Oil fate	Biological recovery
Baker et al., 1990									•
Cretney et al., 1978				•	•			•	•
Drapeau, 1972		•		•					
Finkelstein and Gundlach, 1981				•	•		•	•	
Gundlach and Reed, 1986	•	•						•	
Hann, 1975 and 1977	•			•	•		•	•	•
McLaren, 1985	•	•		•	•		•	•	
Owens, 1978			•			•			
Owens, 1984	•			•	•	•	•		
Owens et al., 1987a	•	•	•	•	•	•	•	•	•
Owens et al., 1987b and 1988				•				•	

Note: "•" denotes a "Good" ranking

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APPENDIX A

Assessments of Cleanup Literature

Advanced Technology Inc. November 1989. *Exxon Valdez* Oil Spill Winter Studies: Draft Notes - Cleanup Technology Workshop. for NOAA, Office of Oceanography and Marine Assessment, Seattle.

Summary

Discusses excavation and removal of sediments, land farming, flushing and washing, water injection, use of dispersants in conjunction with previous methods, oleophilic fertilizers, slow release fertilizers, solutions and inoculations. Discussions are very general and of qualitative nature only. Concludes that available chemicals are ineffective for subsurface treatment.

Completeness of Description

Environmental baseline	
Shoreline	Poor
Wave Energy/Tides	Poor
Biological activity	Poor
Oiling	
Oil properties	Poor
Area oiled	Poor
Volume of oil or oiling rate	Poor
Permeability/location of oil	Poor
Cleanup methods	
Environmental impact	Poor
Equipment	Poor
Removal rate	Poor
Cost/manpower	Poor
Logistics/disposal	Poor
Duration	Poor
Monitoring	
Oil fate	Poor
Biological recovery	Poor

Comments

Bayliss, R. and R. Spoltman. 1981. The Wreck of the *Lee Wang Zin*. Proceedings, 1981 Oil Spill Conference, Atlanta, Georgia, pp. 221-226

Summary

Between 2,381-7,143 barrels of heavy Bunker and diesel oil came ashore in Southern Alaska, near the B.C. border. Cleanup was on a beach-by-beach basis. Because of the isolated shoreline affected, it was not known if all the oiled beaches were identified. At one cleanup location a test of on-situ burning of oily debris in drums was conducted.

Completeness of Description

Environmental baseline	
Shoreline	Poor
Wave Energy/Tides	Poor
Biological activity	Poor
Oiling	
Oil properties	Good
Area oiled	Poor
Volume of oil or oiling rate	Poor
Permeability/location of oil	Poor
Cleanup methods	
Environmental impact	Poor
Equipment	Poor
Removal rate	Poor
Cost/manpower	Good - cost of manual cleanup
Logistics/disposal	Good
Duration	Poor
Monitoring	
Oil fate	Poor
Biological recovery	Poor

Comments - Cost of manual cleanup only.

Bellier, P. and G. Massart. 1979. The *Amoco Cadiz* Oil Spill Cleanup Operations—An Overview of the Organization, Control, and Evaluation of the Cleanup Techniques Employed. Proceedings, 1979 Oil Spill Conference, Los Angeles, California, p. 141.

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Summary

223,00 tons of light crude oil were spilled. Approximately one third of the oil reached the shoreline, oiling 400 km of coast. Polluted shingle beaches were treated by beach relocation to the low tide area. Hayes and Gundlach profiled 19 beaches several days after the spill and resurveyed the beaches one month later. At least one gravel beach was included in the initial survey. Bocard et al. discusses the use of sorbents, plaster, paper strips, and woven sorbents to soak up emulsions on the shorelines. Diluted dispersants were sprayed on one shingle beach. Hann found that the oil had a wide range of emulsification.

Completeness of Description

Environmental baseline	
Shoreline	Good
Wave Energy/Tides	Poor
Biological activity	Poor
Oiling	
Oil properties	Good
Area oiled	Good
Volume of oil or oiling rate	Good
Permeability/location of oil	Good
Cleanup methods	
Environmental impact	Poor
Equipment	Poor
Removal rate	Poor
Cost/manpower	Poor
Logistics/disposal	Good
Duration	Poor
Monitoring	
Oil fate	Good
Biological recovery	Poor

Comments - No correlation is reported between oil volumes remaining on the beaches and the level of cleaning that took place.
- Manpower and costs were not broken down by beach type.

Broman, D. B. Ganning, and C. Linbald. 1983. Effect of High Pressure, Hot Water Shore Cleaning after Oil Spills on Shore Ecosystems in the Northern Baltic Proper. Marine Environmental Research 10, pp. 173-187.

Summary

The cleanup methods were inefficient on stony, gravelly shores. The method drastically reduced shore vegetation and macrofauna. The test plots were observed for one year. High pressure, hot water cleaning is to be avoided on stony, gravelly shores.

Completeness of Description

Environmental baseline	
Shoreline	Poor
Wave Energy/Tides	Poor
Biological activity	Good
Oiling	
Oil properties	Good
Area oiled	Good
Volume of oil or oiling rate	Good
Permeability/location of oil	Good
Cleanup methods	
Environmental impact	Good
Equipment	Poor
Removal rate	Poor
Cost/manpower	Poor
Logistics/disposal	Poor
Duration	Poor
Monitoring	
Oil fate	Good
Biological recovery	Good

Comments
- Only the top 5 cm of sediment was sampled.
- Stony, gravelly beaches are not always comparable to pebble/cobble beaches.

Brown, W.J. and F.R. Denham. 1980. An Economic Evaluations of a Mobile Rotary Kiln Designed for the Cleanup of Oil Contaminated Beaches. Stevenson & Kellogg Ltd. for Environmental Protection Service, Environment Canada, Report No. EE-10.

Summary

The kiln is designed to burn oil out of sand. High concentrations of oil (6-10%) are required. The cleaning rate is 30 tonnes/hr of sand. The kiln is road transportable and is designed for beaches with good access. The kiln must sit on a hard bearing surface such as a parking lot or road. Material must be brought and returned. It is intended for small spills

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Completeness of Description

Environmental baseline	NA
Shoreline	
Wave Energy/Tides	
Biological activity	
Oiling	
Oil properties	Poor
Area oiled	Poor
Volume of oil or oiling rate	Good
Permeability/location of oil	Poor
Cleanup methods	
Environmental impact	Poor
Equipment	Good
Removal rate	Poor
Cost/manpower	Poor
Logistics/disposal	Good
Duration	Poor
Monitoring	
Oil fate	Good
Biological recovery	Poor

Comments - No discussion of logistics to remove and replace sand.
- Kiln was developed to process sand.

Canadian Coast Guard, Western Region. June 1989. Nestucca Oil Spill Report. Transport Canada

Summary

On December 23, 1983 a leaking barge spilled 875 m^3 of Number 6 fuel oil. Most of the oil came ashore along the west coast of Vancouver Island. Most of the cleanup was manual. Petromesh and oil snares were used to scrape oil from boulders and cobbles. Wood fires were set on gravel and cobble beaches to remove oil from the stones. Napalm was used to burn oil contaminated rocks, but was ineffective. Use of Tiger torches was found to mobilize the oil and was discontinued. A reciprocating kiln was ineffective at burning oiled cobble and gravel because of the low oil concentrations. The kiln could also not handle the volume of gravel requiring cleaning.

Completeness of Description

Environmental baseline	
Shoreline	Poor
Wave Energy/Tides	Poor
Biological activity	Poor
Oiling	
Oil properties	Poor.
Area oiled	Good
Volume of oil or oiling rate	Poor
Permeability/location of oil	Poor
Cleanup methods	
Environmental impact	Poor
Equipment	Good
Removal rate	Poor
Cost/manpower	Poor
Logistics/disposal	Good
Duration	Poor
Monitoring	
Oil fate	Poor
Biological recovery	Poor

Comments

Crawford, M. 1989. Exxon Bets on Bugs in Alaska Cleanup. Science, Vol. 245, August 18, 1989, p. 704.

Crawford, M. 1990. Bacteria Effective in Alaska Cleanup. Science, Vol. 247, March 30, 1990, p. 1537.

Summary

Summary of use of nitrogen and phosphorous-bearing fertilizers to boost bioaugmentation. One of the fertilizers is Inipol EAP 22

Completeness of Description

Environmental baseline	
Shoreline	Poor
Wave Energy/Tides	Poor
Biological activity	Poor
Oiling	
Oil properties	Poor
Area oiled	Poor
Volume of oil or oiling rate	Poor
Permeability/location of oil	Poor
Cleanup methods	
Environmental impact	Poor
Equipment	Poor
Removal rate	Poor
Cost/manpower	Poor
Logistics/disposal	Poor
Duration	Good
Monitoring	
Oil fate	Poor
Biological recovery	Poor

Comments: - No conclusions with reference to beach type.
- Contacts are Hap Pritchard, microbiologist, EPA Office of Research and Development; and Russell R. Chianelli, Exxon Research and Engineering Company.

Der, J.J. and E.L. Ghormley. 1975. Oil Contaminated Beach Cleanup. Proceedings, 1975 Conference on Prevention and Control of Oil Pollution, San Francisco, California, p. 431.

Summary

A review of representative oil spill incidents combined with interviews was made to evaluate methods suitable for future operations. The recommended method for treating grave/cobble beaches is removal of the oiled sediment by heavy equipment. Recommends draglines and soft tired bulldozers. Based on past experiences, an estimate of oiled shoreline lengths based on oil spill volume is presented .

Completeness of Description

Environmental baseline	
Shoreline	Poor
Wave Energy/Tides	Poor
Biological activity	Poor
Oiling	
Oil properties	Good
Area oiled	Good
Volume of oil or oiling rate	Good
Permeability/location of oil	Good
Cleanup methods	
Environmental impact	Poor
Equipment	Good
Removal rate	Good
Cost/manpower	Poor
Logistics/disposal	Poor
Duration	Good
Monitoring	
Oil fate	Poor
Biological recovery	Poor

Comments - Very little reference is made to cleanup of gravel, pebble, or cobble beaches.

Environment Canada. 1978. The Impact and Cleanup of Oil Spills on Canadian Shorelines: A Summary. Environmental Emergencies Branch, Environmental Protection Service, Environment Canada, Report No. EPS 6-EC-78-1.

Summary

The structure of Canadian shorelines is described in terms of ten basic types. Cleanup methods for each beach type are briefly summarized. The report is an overview of previous Environmental Protection Service reports.

Completeness of Description

Environmental baseline	
Shoreline	Poor
Wave Energy/Tides	Poor
Biological activity	Poor
Oiling	
Oil properties	Poor
Area oiled	Poor
Volume of oil or oiling rate	NA
Permeability/location of oil	Good
Cleanup methods	
Environmental impact	Poor
Equipment	Poor
Removal rate	Poor
Cost/manpower	Poor
Logistics/disposal	Poor
Duration	Poor
Monitoring	
Oil fate	Poor
Biological recovery	Poor

Comments - Too much of an overview to be useful.

Exxon Company, USA, Alaskan Operations. March 1990. 1990 Planning Document. Anchorage, Alaska.

Summary

This manual provides summary of the 1989 *Exxon Valdez* cleanup efforts (primarily manpower and equipment usage), winter program monitoring studies and results, and plans for 1990 shoreline treatments. Primary treatments considered for the 1990 season were bioremediation and manual pick-up. Also considered were hot water flushing, spot steam cleaning and beach relocation.

Completeness of Description

Environmental baseline	
Shoreline	Poor
Wave Energy/Tides	Poor
Biological activity	Poor
Oiling	
Oil properties	Poor
Area oiled	Poor
Volume of oil or oiling rate	Poor
Permeability/location of oil	Poor
Cleanup methods	
Environmental impact	Poor
Equipment	Good
Removal rate	Poor
Cost/manpower	Poor
Logistics/disposal	Poor
Duration	Poor
Monitoring	
Oil fate	Good
Biological recovery	Poor

Comments
- Generally some descriptions of oil properties, and shoreline lengths oiled are provided, but details are not given.
- General overview only of cleanup with no details of cost, logistics, rates, or duration.

Federal On Scene Coordinator. 1989. Exxon Valdez Oil Spill - Field Shoreline Treatment Manual. United States Coast Guard. Valdez, Alaska.

Summary

Recommends washing, low pressure flushing, high pressure flushing, and manual cleanup for cobble beaches. The report presents cleanup methods in terms of shoreline types, shoreline oiling, biological constraints, and environmental effects.

Completeness of Description

Environmental baseline	
Shoreline	Good
Wave Energy/Tides	Poor
Biological activity	Poor
Oiling	
Oil properties	Poor
Area oiled	Poor
Volume of oil or oiling rate	Good
Permeability/location of oil	Poor
Cleanup methods	
Environmental impact	Good
Equipment	Good
Removal rate	Poor
Cost/manpower	Poor
Logistics/disposal	Good
Duration	Poor
Monitoring	
Oil fate	Poor
Biological recovery	Poor

Comments - Basis for environmental impact descriptions is not presented.

Foget, C.R., S. Thornton, R. Castle. 1977. Evaluations of Selected Surface Treatment Agents for the Protection of Shorelines from Oil Spills. Proceedings of the 1977 Oil Spill Conference, New Orleans, Louisiana, p. 237.

Summary

Summarizes various test of surface treatment agents (including Stewart, 1975). The treatment agents when sprayed on rocks and sand form a flim which prevents the oil from wetting. All of the results presented are from laboratory tests.

Completeness of Description

Environmental baseline	
Shoreline	Poor
Wave Energy/Tides	Poor
Biological activity	Poor
Oiling	
Oil properties	Poor
Area oiled	Poor
Volume of oil or oiling rate	Poor
Permeability/location of oil	Poor
Cleanup methods	
Environmental impact	Good
Equipment	Good
Removal rate	Poor
Cost/manpower	Good
Logistics/disposal	Good
Duration	Poor
Monitoring	
Oil fate	Poor
Biological recovery	Poor

Comments

Foget et al. 1979. Manual of Practice for Protection and Cleanup of Shorelines, Volume I and II. for the Environmental Protection Agency, NTIS No. PB80-108848.

Summary

A manual for the on-scene field commander. The manual provides a decision-making guide based on oil characteristics, fate of oil, shoreline types, protection and cleanup priorities, and impact of cleanup operations. It is intended as a general use manual and is not restricted to specific shoreline types. The manual recommends rubber tired bulldozers, front end loader, or draglines for removing material from pebble/cobble beaches.

Completeness of Description

Environmental baseline	
Shoreline	Good
Wave Energy/Tides	Good
Biological activity	Good
Oiling	
Oil properties	Good
Area oiled	NA
Volume of oil or oiling rate	NA
Permeability/location of oil	Good
Cleanup methods	
Environmental impact	Good
Equipment	Good
Removal rate	Good
Cost/manpower	Good
Logistics/disposal	Good
Duration	Good
Monitoring	
Oil fate	Poor
Biological recovery	Good

Comments
- Cleanup methods presented are not useful for inaccessible beaches.
- Biological recovery is qualitative for cleanup techniques discussed. Recovery times are not given.

Graves, N.A. 1985. A Northern Idaho Gasoline Spill and Cleanup Using Stream Bed Agitation. Proceedings, 1985 Oil Spill Conference, pp. 189-191.

Summary

One month after a spill of unleaded gasoline, an agitation technique was used to release trapped gasoline from a pebble/gravel stream bed. Three inches of stream bed were turned over by dragging a bulldozer blade over the bed. Released gasoline was collected with sorbent material. Two miles of stream were cleaned in two days

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Completeness of Description

Environmental baseline	
Shoreline	Good
Wave Energy/Tides	NA
Biological activity	Poor
Oiling	
Oil properties	Poor
Area oiled	Poor
Volume of oil or oiling rate	Poor
Permeability/location of oil	Poor
Cleanup methods	
Environmental impact	Poor
Equipment	Good
Removal rate	Poor
Cost/manpower	Poor
Logistics/disposal	Poor
Duration	Good
Monitoring	
Oil fate	Poor
Biological recovery	Good

Comments

Gilfillan, E.S., S.A. Hanson, D. Vallas, R. Gerber, D.S. Page, J.Foster, J. Hotham, and S.D. Pratt. 1983. Effect of Spills of Dispersed and Non-Dispersed Oil on Intertidal Infaunal Community Structure. Proceedings, 1983 Oil Spill Conference, San Antonio, Texas, pp. 457-463.

Page, D.S., J.C. Foster, J.R. Hotham, E. Pendergast, S. Herbert, L. Gonzalez, E.S. Gilfillan, S.A. Hanson, R.P. Gerber, and D. Vallas. 1983. Long-term Fate of Dispersed and Undispersed Crude Oil in Two Nearshore Test Spills. Proceedings, 1983 Oil Spill Conference, San Antonio, Texas, pp. 465-471.

Summary

Effect of two nearshore discharges of Murban crude oil on community in the intertidal zone was studied. One discharge was premixed with dispersant Significant amounts of oil were found in the test plot exposed to untreated oil. In contrast to the untreated oil, there was no evidence of adverse effects on the infaunal community from exposure to dispersed oil.

Completeness of Description

Environmental baseline	
Shoreline	Poor
Wave Energy/Tides	Poor
Biological activity	Good
Oiling	
Oil properties	Good
Area oiled	Good
Volume of oil or oiling rate	Good
Permeability/location of oil	Poor
Cleanup methods	
Environmental impact	Good
Equipment	Poor
Removal rate	Poor
Cost/manpower	Poor
Logistics/disposal	Poor
Duration	Poor

Gundlach, E.R., S. Berné, L. D'Ozouville, J.A. Topinka. 1981. Shoreline Oil TwoYears after Amoco Cadiz: New Complications from Tanio. Proceedings, 1981 Oil Spill Conference, Atlanta, Georgia, pp.525-534

Summary

Discusses the shoreline distribution of *Amoco Cadiz* oil. High pressure spraying with mechanical re-working of sediment into the surf zone proved to be the most effective method.

Completeness of Description

Environmental baseline	
Shoreline	Good
Wave Energy/Tides	Poor
Biological activity	Poor
Oiling	
Oil properties	Poor
Area oiled	Poor
Volume of oil or oiling rate	Poor
Permeability/location of oil	Poor
Cleanup methods	
Environmental impact	Poor
Equipment	Poor
Removal rate	Poor
Cost/manpower	Poor
Logistics/disposal	Poor
Duration	Poor
Monitoring	
Oil fate	Poor
Biological recovery	Poor

Comments

Gundlach, E.R., C.H. Ruby, M.O. Hayes, and A.E. Blount. 1978. The *Urquiola* Oil Spill, La Coruna, Spain: Impact and Reaction on Beaches and Rocky Coasts. Environmental Geology, Vol. 2, No. 3, pp. 131-143.

Gundlach, E.R., and M.O. Hayes. 1977. The *Urquiola* Oil Spill, La Coruna, Spain: Case History and Discussion of Methods of Control and Clean-up. Marine Pollution Bulletin, Vol. 8, No. 6, pp. 132-136.

Summary

Monitoring of oil distribution of beaches. Only one gravel beach was affected. Thickness of the oiled gravel was 65 cm.

Completeness of Description

Environmental baseline	
Shoreline	Good
Wave Energy/Tides	Good
Biological activity	Poor
Oiling	
Oil properties	Poor
Area oiled	Poor
Volume of oil or oiling rate	Poor
Permeability/location of oil	Good
Cleanup methods	
Environmental impact	Poor
Equipment	Poor (for gravel beach)
Removal rate	Poor
Cost/manpower	Poor
Logistics/disposal	Poor
Duration	Poor
Monitoring	
Oil fate	Poor
Biological recovery	Poor

Comments

Hardy Associates (1978) Ltd. 1981. Preliminary Assessment of Certain Beach Cleanup Techniques. Environmental Protection Service, Environment Canada, Report No. EPS 4-EC 81-1.

Summary

Tests of in-situ burning, a coating agent, and a burning promoter were conducted on fine gravel, sand, and mud flat sediments. Both high-to-medium and medium-to-heavy oils failed to burn on gravel unless the water table was high and film thickness were at least 4 mm for light-to-medium and 6 mm for medium-to-heavy oil. Tests were conducted in boxes 30 cm deep and 120 cm square.

Completeness of Description

Environmental baseline	
Shoreline	Good
Wave Energy/Tides	NA
Biological activity	NA
Oiling	
Oil properties	Good
Area oiled	Good
Volume of oil or oiling rate	Good
Permeability/location of oil	Poor
Cleanup methods	
Environmental impact	Poor
Equipment	Poor
Removal rate	Good
Cost/manpower	Poor
Logistics/disposal	Poor
Duration	Poor
Monitoring	
Oil fate	Poor
Biological recovery	Poor

Comments - the tests documented the area oiled and the removal rates, but the conditions were very artificial. The effect of tides and waves on the cleanup technique can not be determined

Huet, J., Y. Naour, J. Belluteau, C. Bocard, C. Such, and D. Valliant. 1989. Operational Use of a Mobile Sand-Washing Plan for Cleaning Pebbles: the *Amazzone* Oil Spill. Proceeding, 1989 Oil Spill Conference, San Antonio, Texas,p. 149.

Summary

Spill of medium fuel in Brittany, France. The spill reached pebble beaches. A mobile plant was used to clean the pebbles. Throughput of 20-25 m^3 of pebbles was achieved. The authors tested washing with hot water only, and washing with hot water and an oil solvent.

Completeness of Description

Environmental baseline	
Shoreline	Good
Wave Energy/Tides	Good
Biological activity	Poor
Oiling	
Oil properties	Good
Area oiled	Poor
Volume of oil or oiling rate	Poor
Permeability/location of oil	Poor
Cleanup methods	
Environmental impact	Poor
Equipment	Good
Removal rate	Good
Cost/manpower	Good
Logistics/disposal	Good
Duration	Good
Monitoring	
Oil fate	Good
Biological recovery	Poor

Comments

Klokk, T. 1985. Costs and Cleanup Strategies of the Offshore Region of the Norwegian Coast. Proceedings of the Eighth Arctic Marine Oil Spill Program Technical Seminar, Edmonton, Alberta.

Summary

Using existing data from Norwegian oil spills, the costs of cleanup based on a given oiling rate and degree of cleanliness desired are given for several shoreline types including gravel. Rates are based on a cleanup consisting of manual cleanup with sorbents in combination with chemical dispersion and water flushing. To be used as a guide only.

Completeness of Description

Environmental baseline	
Shoreline	Poor
Wave Energy/Tides	Poor
Biological activity	Poor
Oiling	
Oil properties	Poor
Area oiled	Poor
Volume of oil or oiling rate	Poor
Permeability/location of oil	Poor
Cleanup methods	
Environmental impact	Poor
Equipment	Good
Removal rate	Good
Cost/manpower	Good
Logistics/disposal	Poor
Duration	Poor
Monitoring	
Oil fate	Poor
Biological recovery	Poor

Comments - Costs given in Norwegian currency.

Levine, R.A. 1987. Operational Aspects of the Response to the *Arco Anchorage* Oil Spill, Port Angeles, Washington. Proceedings, 1987 Oil Spill Conference.

Lindstedt-Siva, J., D.W. Chamberlain, and E.R. Mancini. 1987. Environmental Aspects of the *Arco Anchorage* Oil Spill, Port Angeles, Washington. Proceedings, 1987 Oil Spill Conference.

Miller, J.A. 1987. Beach Agitation for Crude Oil Removal from Intertidal Sediments. Proceedings, 1987 Oil Spill Conference.

Summary

The three papers describe cleanup operations that took place on Ediz Hook—a coarse graines sand and cobble beach in Port Angeles Harbour. An unknown amount of crude oil penetrated into the beach sediments. The best cleanup method found was beach agitation by bulldozers equipped with rippers and spray nozzles, operating in 15-60 cm of water. 125 gpm was supplied to eight 1.5 in spray nozzles. Sorbent booms collected oil as it was swept into the surf line. Some areas of the beach required 40 passes. No significant changes in beach topography resulted. Recovery was estimated at nearly 67%. Bird monitoring and cleaning are discussed by Lindstedt-Siva et al. (1987)

Completeness of Description

Environmental baseline	
Shoreline	Good
Wave Energy/Tides	Poor
Biological activity	Poor
Oiling	
Oil properties	Good
Area oiled	Poor
Volume of oil or oiling rate	Good
Permeability/location of oil	Poor

Cleanup methods	
Environmental impact	Good
Equipment	Good
Removal rate	Good
Cost/manpower	Good
Logistics/disposal	Good
Duration	Poor
Monitoring	
Oil fate	Good
Biological recovery	Poor

Comments - Ediz Hook beaches consisted of a cobble armour over top of medium to coarse sand and fine to coarse gravel.

Logan, W.J., D.E. Thornton, and S.L. Ross. 1975. Oil Spill Countermeasures for the Southern Beaufort Sea, Environment Canada, Technology Development Report EPS3-EC-77-6.

Summary

Discusses cleanup plans for a well blowout in the Beaufort Sea. Concludes that the use of windrows to protect backshore areas is not feasible on shingle beaches. Also not feasible is placing peat moss and straw on the shore to gather oil as it strands.

Completeness of Description

Environmental baseline	
Shoreline	Good
Wave Energy/Tides	Good - tides
Biological activity	Poor
Oiling	
Oil properties	Poor
Area oiled	Poor
Volume of oil or oiling rate	Poor
Permeability/location of oil	Poor
Cleanup methods	
Environmental impact	Poor
Equipment	Good
Removal rate	Good
Cost/manpower	Poor
Logistics/disposal	Good
Duration	Poor
Monitoring	
Oil fate	Poor
Biological recovery	Poor

Comments

Mattson, J., C. Lethinen, and O. Linden. 1981. Biological Effects of Three Different Shoreline Cleanup Methods. Swedish Water and Air Pollution Research Laboratory, Report No. IVL-B-629, NTIS No. DE82750484.

Summary

Three cleanup methods were tested by treating four 2 by 3 m plots on a stone and gravel beach with weathered crude oil. The cleanup techniques tested were hot water flushing, solvent cleaning, and mechanical recovery (rakes and spades and removal of heavily oiled vegetation). A fourth plot was oiled and left to clean naturally. After 8 months the differences between the biological effects of the three methods, and the natural cleaning could not be concluded.

Completeness of Description

Environmental baseline	
Shoreline	Poor
Wave Energy/Tides	Good
Biological activity	Good
Oiling	
Oil properties	Good
Area oiled	Good
Volume of oil or oiling rate	Good
Permeability/location of oil	Good
Cleanup methods	
Environmental impact	Good
Equipment	Poor
Removal rate	Good
Cost/manpower	Poor
Logistics/disposal	Poor
Duration	Good
Monitoring	
Oil fate	Poor
Biological recovery	Good

Comments
- The oil was poured onto the beach rather than being allowed to strand naturally.
- The plot sizes were very small
- Only the top 7.5 cm of sediment were sampled for oil.

Ministry of Transport. 1973. Report to the Task Force - Operation Oil (Clean-up of the Arrow Oil Spill in Chedabucto Bay), Volume IV. Ottawa, Ontario.

Summary

Description of cleanup operations from July 1970 to May 1972 (spill was March 1970). Heavy equipment had difficulty maintaining traction on shingle beaches. Half Island Cove and Hadleyville #1 and #2 were the principal shingle beaches oiled. Shoreline cleanup was almost entirely manual. Trials of a grader on one of the finer beaches showed that it was most inefficient.

Completeness of Description

Environmental baseline	
Shoreline	Good
Wave Energy/Tides	Poor
Biological activity	Poor
Oiling	
Oil properties	Poor
Area oiled	Poor
Volume of oil or oiling rate	Poor
Permeability/location of oil	Poor
Cleanup methods	
Environmental impact	Poor
Equipment	Good
Removal rate	Poor
Cost/manpower	Good
Logistics/disposal	Good
Duration	Good
Monitoring	
Oil fate	Poor
Biological recovery	Poor

Comments

Morris, P.R. 1987. Oil Clean-up Trials on a Pebble Beach. Petroleum Review, September 1987, pp. 33-35.

Summary

Presents one week of beach trials on a pebble beach. Several cleanup techniques were tried: dispersants, beach material washing, and sweeping pebbles into a ridge for pick-up. Only material washing was successful. Only tracked equipment could climb the steep beach. Oil penetration was measured and reoiling after tides was observed.

Completeness of Description

Environmental baseline	
Shoreline	Good
Wave Energy/Tides	Poor
Biological activity	Poor
Oiling	
Oil properties	Poor
Area oiled	Good
Volume of oil or oiling rate	Good
Permeability/location of oil	Good
Cleanup methods	
Environmental impact	Poor
Equipment	Good
Removal rate	Good
Cost/manpower	Good
Logistics/disposal	Good
Duration	Good
Monitoring	
Oil fate	Good
Biological recovery	Poor

Comments
- Report did not describe pebble sizes or depth of pebble.
- Oil was applied to the beach rather than stranding naturally

Morris, P.R., D. Tookey, and T. Walsh. 1983. The Warren Spring Laboratory Beach Material Washing Plant for Shoreline Cleanup. Proceedings, 1983 Oil Spill Conference, San Antonio, Texas, pp. 283-290.

Summary

A continuous system for removal of weathered crude oil or residual fuel oil from sand and gravel involving agitation in sea water is described. The separated oil floats away from the cleaned material and then is recovered by separation. During testing 250 tons of material was cleaned at a rate of 10 tons/hr. Material contained 0.3-0.2% oil after washing.

Completeness of Description

Environmental baseline	
Shoreline	Poor
Wave Energy/Tides	Poor
Biological activity	Poor
Oiling	
Oil properties	Poor
Area oiled	Poor
Volume of oil or oiling rate	Poor
Permeability/location of oil	Poor
Cleanup methods	
Environmental impact	Poor
Equipment	Good
Removal rate	Good
Cost/manpower	Good
Logistics/disposal	Good
Duration	Good
Monitoring	
Oil fate	Poor
Biological recovery	Poor

Comments - Sediment sizes were less than 25 mm.
- Range of oiling acceptable was not discussed.

Nauman, S.A. 1990. Shoreline Cleanup Techniques: *Exxon Valdez* Operations. in Proceedings of the Thirteenth Arctic Marine Oil Spill Program Technical Seminar, Edmonton, Alberta, p. 431.

Summary

Reviews the key mechanical shoreline methods used during the summer of 1989. Details of methods are presented, but no reference is made to their usefulness as a function of oil properties, oil volumes, shoreline type, or biological sensitivity.

Completeness of Description

Environmental baseline	
Shoreline	Poor
Wave Energy/Tides	Poor
Biological activity	Poor
Oiling	
Oil properties	Poor
Area oiled	Poor
Volume of oil or oiling rate	Poor
Permeability/location of oil	Poor
Cleanup methods	
Environmental impact	Poor
Equipment	Good
Removal rate	Poor
Cost/manpower	Good
Logistics/disposal	Poor
Duration	Poor
Monitoring	
Oil fate	Poor
Biological recovery	Poor

Comments

Owens, E.H. 1972. The Cleaning of Gravel Beaches Polluted by Oil. Proceedings of the Thirteenth Coastal Engineering Conference, July 10-14, 1972, Vancouver, B.C., p. 2549.

Summary

Description of cleaning of gravel beaches in Chedabucto Bay, following Arrow spill. Oil permeated below the surface layer and mechanical cleaning involved excavation to depths of 1 m or more—endangering the stability of the beach. Report suggests possible improvements might be made using beach relocation and remove-wash-replace methods.

Completeness of Description

Environmental baseline	
Shoreline	Good
Wave Energy/Tides	Poor
Biological activity	Poor
Oiling	
Oil properties	Poor
Area oiled	Poor
Volume of oil or oiling rate	Good
Permeability/location of oil	Poor
Cleanup methods	
Environmental impact	Poor
Equipment	Poor
Removal rate	Poor
Cost/manpower	Poor
Logistics/disposal	Poor
Duration	Poor
Monitoring	
Oil fate	Poor
Biological recovery	Poor

Comments

Owens, E.H. 1977a. Coastal Environments of Canada: The Impact and Cleanup of Oil Spills. Environmental Protection Service, Dept. of Fisheries and the Environment, Report No. EPS 3-EC-77-13.

Summary

A review of shoreline and process characteristics of Canada's coast. Front end loaders are the only effective equipment on pebble/cobble beaches. Report also recommends pushing material down the beach (beach relocation) and discourages removal of the material.

Completeness of Description

Environmental baseline	
Shoreline	Good
Wave Energy/Tides	Good
Biological activity	Poor
Oiling	
Oil properties	Good
Area oiled	Good
Volume of oil or oiling rate	Poor
Permeability/location of oil	Good
Cleanup methods	
Environmental impact	Poor
Equipment	Good
Removal rate	Poor
Cost/manpower	Poor
Logistics/disposal	Poor
Duration	Poor
Monitoring	
Oil fate	Good
Biological recovery	Poor

Comments - Report is very similar to EPS-3-ES-77-9 in terms of pebble/cobble beaches.

Owens, E.H. 1977b. Coastal Environments, Oil Spills and Cleanup Programs in the Bay of Fundy. Environmental Protection Service, Dept. of Fisheries and the Environment, Report No. EPS 3-EC-77-9.

Summary

Coastal environments and shoreline types have been identified. Information on coastal features and shoreline processes is applied to an assessment of the expected impact and persistence of oil on the shore. This report, written in 1977, states that available mechanical techniques for clean-up operations on pebble/cobble beaches are ineffective.

Completeness of Description

Environmental baseline	
Shoreline	Good
Wave Energy/Tides	Good
Biological activity	Poor
Oiling	
Oil properties	Good
Area oiled	Poor
Volume of oil or oiling rate	Poor
Permeability/location of oil	Good
Cleanup methods	
Environmental impact	Poor
Equipment	Good
Removal rate	Poor
Cost/manpower	Poor
Logistics/disposal	Poor
Duration	Poor
Monitoring	
Oil fate	Good
Biological recovery	Poor

Comments

Owens, E.H. and K. Trudel, 1985. Oil Spill Countermeasures for Low-Energy Shorelines - Research Recommendations. for EETD, Environment Canada, Edmonton, Alberta.

Summary

Low energy environments are considered in terms of 6 primary shoreline types. Low energy is defined as shorelines where oil is likely to persist after one year in sufficiently high concentrations or cover that it might require cleanup. For gravel/cobble beaches this would require a heavy oil. Discusses typical ecology of gravel/cobble beaches and concludes that the biological use of pebble/cobble beaches is low. Discusses flushing, dispersants, and mixing.

Completeness of Description

Environmental baseline	
Shoreline	Good
Wave Energy/Tides	Good
Biological activity	Good
Oiling	
Oil properties	Good
Area oiled	Poor
Volume of oil or oiling rate	Poor
Permeability/location of oil	Poor
Cleanup methods	
Environmental impact	Poor
Equipment	Poor
Removal rate	Poor
Cost/manpower	Poor
Logistics/disposal	Poor
Duration	Poor
Monitoring	
Oil fate	Good
Biological recovery	Poor

Comments

Owens, E.H., W. Robson, and C. Foget. 1987. A Field Evaluation of Selected Beach-Cleaning Techniques. Journal of the Arctic Institute of North America. Volume 40, Supplement 1, p. 244.

Sergy, G.A. and P.J. Blackall. 1987. Design and Conclusions of the Baffin Island Oil Spill Project. Journal of the Arctic Institute of North America. Volume 40, Supplement 1, pp. 1-9.

Summary

An isolated lagoons in the Canadian Arctic was used for tests of incendiary combustion, mechanical mixing, chemical dispersion, solidifiers, and low-pressure flushing. The test plots were 20-40 m^2 in the intertidal and backshore zones. The tests on the intertidal zone of a gravel beach were conducted in the second year of the four year program. The gravel beach was monitored for 3 years. Natural cleaning was comparable to cleanup methods. commercial fertilizers did not increase degradation on coarse sediments. Mechanical mixing reduced surface oil but increased subsurface oil.

Completeness of Description

Environmental baseline	
Shoreline	Good
Wave Energy/Tides	Good
Biological activity	Poor
Oiling	
Oil properties	Good
Area oiled	Good
Volume of oil or oiling rate	Good
Permeability/location of oil	Good
Cleanup methods	
Environmental impact	Poor
Equipment	Good
Removal rate	Good
Cost/manpower	Poor
Logistics/disposal	Poor
Duration	Poor

Monitoring	
Oil fate	Good
Biological recovery	Poor

Comments - The small test plots (2 m by 10 m) were easily affected by edge effects. As a result the removal rates were overestimated. Only the short term (8 days) results are useful.
- The oil was not allowed to strand naturally.

Monitoring	
Oil fate	Good
Biological recovery	Good

Comments - Dispersant was premixed into the oil—an option that is not available during accidental spills.

Pertile, L. 1986. In-Situ Combustion of Stranded Oil on Remote Shorelines. Proceedings of the Ninth Arctic Marine Oil Spill Program Technical Seminar, Edmonton, Alberta.

Summary

A feasibility study of the Bennett Beach Burner. It consists of an open bottomed combustion chamber, protected with skirts, that travels over the oiled beach. It was tested on a test beach 6 m by 0.5 m having sediments from fine sand to 2.5 cm gravel. Removal rates increased with reductions in particle size. The removal rate was 76% on a thinly coated beach.

Completeness of Description

Environmental baseline	
Shoreline	Good
Wave Energy/Tides	Poor
Biological activity	Poor
Oiling	
Oil properties	Good
Area oiled	Poor
Volume of oil or oiling rate	Poor
Permeability/location of oil	Poor
Cleanup methods	
Environmental impact	Poor
Equipment	Poor
Removal rate	Good
Cost/manpower	Good
Logistics/disposal	Poor
Duration	Good
Monitoring	
Oil fate	Poor
Biological recovery	Poor

Comments - Report does not describe how the beach burner is moved across beaches.

S.L. Ross Environmental Research Ltd. 1984a. An Engineering Study of Mechanical Shoreline Cleanup Systems for Oil Spills in Canada. for Canadian Offshore Oil Spill Research Association.

Summary

Seven commercially available beach cleaning systems were evaluated (including the Bennett Beach Burner). The target shorelines were inaccessible mixed sediment beaches, cobble beaches, or boulder beaches. A brainstorming session produced two concepts which were tested in the laboratory on bins of pebbles.

Completeness of Description

Environmental baseline	
Shoreline	Good
Wave Energy/Tides	Poor
Biological activity	Poor
Oiling	
Oil properties	Good
Area oiled	Poor
Volume of oil or oiling rate	Poor
Permeability/location of oil	Poor
Cleanup methods	
Environmental impact	Poor
Equipment	Good
Removal rate	Good
Cost/manpower	Good
Logistics/disposal	Good
Duration	Poor
Monitoring	
Oil fate	Poor
Biological recovery	Poor

Comments

S.L. Ross Environmental Research Limited. 1984b. Hibernia Oil Spills and Their Control. for Mobil Oil Canada, Ltd., St. John's, Newfoundland.

Summary

Report discusses contingency plans and cleanup programs for the coast of Newfoundland. Various cleanup methods and their effects are summarized.

Completeness of Description

Environmental baseline	
Shoreline	Good
Wave Energy/Tides	Poor
Biological activity	Poor
Oiling	
Oil properties	Poor
Area oiled	Poor
Volume of oil or oiling rate	Poor
Permeability/location of oil	Poor
Cleanup methods	
Environmental impact	Poor
Equipment	Good
Removal rate	Poor
Cost/manpower	Good
Logistics/disposal	Good
Duration	Poor
Monitoring	
Oil fate	Poor
Biological recovery	Poor

Comments

Stewart, W.S. 1975. Microbiological and Natural Product Systems for the Protection of Coastal Shorelines from Oil Spills and Oil Contamination. Proceedings, 1975 Conference on Prevention and Control of Oil Pollution, San Francisco, California, p. 425.

Summary

Experimental evidence indicates that various microorganisms and natural plant secretions are effective in preventing the surfaces of dry rocks from being wet by crude oil. Experiments were conducted on stones 25-75 mm in trays 2.5 cm deep by 30 cm square placed upon a simulated beach. 15 cm waves were produced by a wave generator.

Completeness of Description

Environmental baseline	
Shoreline	Poor
Wave Energy/Tides	Poor
Biological activity	Poor
Oiling	
Oil properties	Good
Area oiled	Good
Volume of oil or oiling rate	Poor
Permeability/location of oil	Poor
Cleanup methods	
Environmental impact	Poor
Equipment	Poor
Removal rate	Good
Cost/manpower	Poor
Logistics/disposal	Poor
Duration	Poor
Monitoring	
Oil fate	Poor
Biological recovery	Poor

Comments - Tray depth was very shallow (2.5 cm) and probably only deep enough for one layer of pebbles.
- Monitoring of oil removal was visual.

Tramier, B., G.H.R. Aston, M. Durrieu, A. Lepain, J.A.C. M. van Oudenhoven, N. Robinson, K.W. Sedlacek, and P. Sibra. 1981. A Field Guide to Coastal Oil Spill Control and Cleanup Techniques. CONCAWE Report No. 9/81. Den Haag, Netherlands.

van Oudenhoven, J.A.C.M., M. Angles, A. De Roucher, R.P. Kelley, W.L. Louden, J.K. Rudd, and J.D. Levi. 1980. Disposal Techniques for Spilt Oil. CONCAWE, Den Haag, Netherlands.

Summary

A simple, easy-to-read manual. The various techniques which can be used to dispose of oil and oily debris are described in detail. Transportation and storage are also described.

Completeness of Description

Environmental baseline	
Shoreline	Poor
Wave Energy/Tides	Poor
Biological activity	Poor
Oiling	
Oil properties	Poor
Area oiled	Poor
Volume of oil or oiling rate	Good
Permeability/location of oil	Poor
Cleanup methods	
Environmental impact	Poor
Equipment	Good
Removal rate	Poor
Cost/manpower	Poor
Logistics/disposal	Good
Duration	Poor
Monitoring	
Oil fate	Poor
Biological recovery	Poor

Comments - The manual does not provide the impact of cleanup methods, the dependence of methods on oil properties, expected removal rates, or permeability of sediments.

Twardus, E. 1980. In-Situ Combustion: an Oil Spill Countermeasure for Arctic Shorelines. Proceedings of the Third Arctic Marine Oil Spill Program *Technical Seminar, Edmonton, Alberta.*

Summary

Tests were conducted in boxes 2.4 m square by 0.5 m deep, filled with sand. Beach slopes and water table heights were varied. Sand was ignited by Energetex igniters. Peat moss was tested as a burning promoter. The low viscosity oil could not be ignited on any beach slope. Emulsified oil, as well as addition of peat moss, made combustion possible.

Completeness of Description

Environmental baseline	
Shoreline	Good
Wave Energy/Tides	Poor
Biological activity	Poor
Oiling	
Oil properties	Good
Area oiled	Poor
Volume of oil or oiling rate	Poor
Permeability/location of oil	Good
Cleanup methods	
Environmental impact	Poor
Equipment	Good
Removal rate	Poor
Cost/manpower	Poor
Logistics/disposal	Poor
Duration	Poor
Monitoring	
Oil fate	Poor
Biological recovery	Poor

Comments

Vandermeulen, J.H. and D.E. Buckley, eds. 1985. The Kurdistan Oil Spill of March 16-17 1979. Activities and Observations of the Bedford Institute of Oceanography Response Team. Fisheries and Oceans, Canadian Technical Report of Hydrography and Ocean Sciences.

Summary

Oil was heaviest on gravel-cobble beaches near the high tide limit. The cleanup of the Bunker C fuel oil was manual.

Completeness of Description

Environmental baseline	
Shoreline	Good
Wave Energy/Tides	Poor
Biological activity	Poor
Oiling	
Oil properties	Good
Area oiled	Poor
Volume of oil or oiling rate	Poor
Permeability/location of oil	Poor
Cleanup methods	
Environmental impact	Poor
Equipment	Poor
Removal rate	Poor
Cost/manpower	Poor
Logistics/disposal	Poor
Duration	Poor
Monitoring	
Oil fate	Poor
Biological recovery	Poor

Comments

APPENDIX B

Assessments of Natural Cleaning Literature

Baker, J.M., R.B. Clarke, P.F. Kingston, and R.H. Jenkins. 1990. Natural Recovery of Cold Water Marine Environments after an Oil Spill. Presented at the Thirteenth Annual Arctic and Marine Oil Spill Program Technical Seminar, Edmonton, Alberta.

Summary

Defines clean and recovery. Concludes that long term impact of oil spills on biological resources is negligible. Found that on shingle and gravel beaches the oil sinks into the sediment and may penetrate to the water table. Report includes 27 pages of references.

Completeness of Description

Environmental Baseline	
Shoreline	Poor
Wave Energy/Tides	Poor
Biological activity	Poor
Oiling	
Oil Properties	Poor
Area oiled	Poor
Volume of oil or oiling rate	Poor
Permeability/location of oil	Poor
Monitoring	
Oil fate	Poor
Biological recovery	Good

Comments - The study was not directed towards recovery as a function of shoreline type

Cretney, W.J., C.S. Wong, D.R. Green, and C.A. Bawden. 1978. Long-term Fate of a Heavy Fuel Oil in a Spill-Contaminated B.C. Coastal Bay. Journal of the Fisheries Research Board of Canada, Volume 35, pp. 521-527.

Summary

A No. 5 fuel oil spill in which one bay was left uncleaned and observed for 4 years. The study area only had small amounts of pebble. The description of oiling and history of the oil fate is anecdotal. The report describes biological recovery in terms of limpets, periwinkles, and amphipods. One year after the spill oil pollution was no longer obvious.

Completeness of Description

Environmental Baseline	
Shoreline	Poor
Wave Energy/Tides	Poor
Biological activity	Poor
Oiling	
Oil Properties	Good
Area oiled	Good
Volume of oil or oiling rate	Poor
Permeability/location of oil	Poor
Monitoring	
Oil fate	Good
Biological recovery	Good

Comments - It is not clear if the conclusions would be applicable to pebble/cobble beach.

Drapeau, G. 1972. Natural Cleaning of Oil Polluted Seashores. Proceedings of the Thirteenth Coastal Engineering Conference, July 10-14, 1972, Vancouver, B.C., p. 2557.

Summary

Twenty months of field observations at Chedabucto Bay after the *Arrow* oil spill. It was found that cobble and boulder beaches took one year to clean. Natural cleaning was a function of wave energy.

Completeness of Description

Environmental Baseline	
Shoreline	Poor
Wave Energy/Tides	Good
Biological activity	Poor
Oiling	
Oil Properties	Good
Area oiled	Poor
Volume of oil or oiling rate	Poor
Permeability/location of oil	Poor
Monitoring	
Oil fate	Poor
Biological recovery	Poor

Comments

Finkelstein, K. and E.R. Gundlach. 1981. Method for Estimating Spilled Oil Quantity on the Shoreline. Environmental Science & Technology, Volume 15, Number 5, May 1981, p. 545.

Summary

The paper presents a method for calculating the volume of oil spilt based on aerial photography, sediment sampling, measurement of oil depth, and width and length of oiled beaches. The method predicts the average volume of oil per kilometer. Surface oil and buried oil are calculated separately. Assumes 10% oil in the sediments. Oiling from the *Amoco Cadiz* spill is described.

Completeness of Description

Environmental Baseline	
Shoreline	Poor
Wave Energy/Tides	Poor
Biological activity	NA
Oiling	
Oil Properties	Good
Area oiled	Good
Volume of oil or oiling rate	Poor
Permeability/location of oil	Good
Monitoring	
Oil fate	Good
Biological recovery	Poor

Comments - Method assumes 10% oil in the sediments.

Gundlach, E.R. and M. Reed. 1986. Quantification of Oil Deposition and Removal Rates for a Shoreline/Oil Spill Interaction Model. Proceedings of the Arctic Marine Oil Spill Program Technical Seminar, June 1986, Edmonton, Alberta.

Summary

Natural removal coefficients are presented for each of seven shoreline types including gravel. For low energy (<1 m waves) the percent of oil removed after 5 days is 40-63%, high energy the percent removed is 86-92%. Rates are based on personal observations at several major spills.

Completeness of Description

Environmental Baseline	
Shoreline	Good
Wave Energy/Tides	Good
Biological activity	NA
Oiling	
Oil Properties	Poor
Area oiled	Poor
Volume of oil or oiling rate	Poor
Permeability/location of oil	Poor
Monitoring	
Oil fate	Good - for low oiling
Biological recovery	Poor

Comments - does not take into account an inital heavy oiling in which the oil may form a pavement.

Hann, R.W. 1975. Follow-up Field Survey of the Oil Pollution from the Tanker *Metula*. for the USCG Office of Research and Development, NTIS No. AD-A017 100/9SL.

—. 1977. Fate of Oil from the Supertanker *Metula*. Proceedings, 1977 Oil Spill Conference. Report to the U.S. Coast Guard Research and Development Program.

Summary

Reports on a survey, taken 5 months after the *Metula* spill, to view residual oil pollution. This was the second survey. The report summarizes the history of the spill, oil deposition, and impact. Periodic surveys of oil and biology were taken along the beaches. Punta Espora at Puerto Espora had cobbles in the intertidal zone.

Completeness of Description

Environmental Baseline	
Shoreline	Good
Wave Energy/Tides	Poor
Biological activity	Poor
Oiling	
Oil Properties	Good
Area oiled	Good
Volume of oil or oiling rate	Poor
Permeability/location of oil	Good
Monitoring	
Oil fate	Good
Biological recovery	Good

Comments - Very few of the beaches oiled were gravel.

McLaren, P. 1985. Behaviour of Diesel Fuel on a High Energy Beach. Marine Pollution Bulletin, Vol. 16, No. 5, p. 191.

Summary

The spilled diesel fuel moved through the beach sediments in response to the tidal cycle and the changing water table. During ebb tide, oil was released from the water table. The beach consisted of a cobble armour over gravel and sand.

Completeness of Description

Environmental Baseline	
Shoreline	Good
Wave Energy/Tides	Good
Biological activity	Poor
Oiling	
Oil Properties	Good
Area oiled	Good
Volume of oil or oiling rate	Poor
Permeability/location of oil	Good
Monitoring	
Oil fate	Good
Biological recovery	Poor

Comments
- Monitoring started two days after the spill.
- A cobble armoured beach.
- A good description of oil movement in sediment with tide.

Owens, E.H. 1978. Mechanical Dispersal of Oil Stranded in the Littoral Zone. Journal of the Fisheries Research Board of Canada, Volume 35, pp. 563-572.

Summary

Discusses the effect of wave energy, wind, and tides on dispersion of oil. Dispersion is related to beach material size, but quantitative formulas are not given. Less energy is available to cobble beaches as there is little backwash. Concludes that dispersal and persistence are independent of oil properties.

Completeness of Description

Environmental Baseline	
Shoreline	Poor
Wave Energy/Tides	Poor
Biological activity	NA
Oiling	
Oil Properties	Poor
Area oiled	Poor
Volume of oil or oiling rate	Good
Permeability/location of oil	Poor
Monitoring	
Oil fate	Poor
Biological recovery	Poor

Comments - No examples are given of typical dispersion times for shoreline type, wave energy, and volume of oil.

Owens, E.H. 1984. Variability in Estimates of Oil Contamination in the Intertidal Zone of a Gravel Beach. Marine Pollution Bulletin, Vol. 15, No. 11, p. 412.

Summary

Presents results from BIOS (Baffin Island Oil Spill Project). Estimates of oiling are affected by wet weather due to surface wetness. Ground surveys should be conducted on dry days.

Completeness of Description

Environmental Baseline	
Shoreline	Good
Wave Energy/Tides	Poor
Biological activity	NA
Oiling	
Oil Properties	Good
Area oiled	Good
Volume of oil or oiling rate	Good
Permeability/location of oil	Good
Monitoring	
Oil fate	NA
Biological recovery	NA

Comments - This is not very useful paper from a cleanup perspective.

Owens, E.H., J.R. Harper, W. Robson, and P.D. Boehm. 1987a. Fate and Persistence of Crude Oil Stranded on a Sheltered Beach. Journal of the Arctic Institute of North America. Volume 40, Supplement 1, p. 109.

Summary

An experimental spill of 15 m^3 of crude oil at BIOS. One third of the oil became stranded on the gravel beach. After 6 months of open water exposure, the oil was reduced by half. Nearshore macrobenthos, photoplankton, zooplankton, fishes, birds, and mammals were surveyed before and after the spill. The results provided no strong ecological reasons for the cleanup of oil stranded on these shoreline types.

Completeness of Description

Environmental Baseline	
Shoreline	Good
Wave Energy/Tides	Good
Biological activity	Good
Oiling	
Oil Properties	Good
Area oiled	Good
Volume of oil or oiling rate	Good
Permeability/location of oil	Good
Monitoring	
Oil fate	Good
Biological recovery	Good

Comments

Owens, E.H., W. Robson, and B. Humphrey. 1987b. *Observations and Initial* Results from a Site Visit the the *Metula* Spill 12.5 Years after the Incident. Proceedings of the Tenth Arctic Marine Oil Spill Program Technical Seminar, Edmonton, Alberta.

—, B. Humphrey, and W. Robson. 1988. Results of Beach Studies and Chemical Analysis from the BIOS Experimental Site and from the *Metula* Spill Site. Proceedings of the Eleventh Arctic Marine Oil Spill Program Technical Seminar, Vancouver, B.C.

Summary

Describes the *Metula* spill of 45,000 barrels in the Strait of Magellan. Discusses asphalt pavements found at the spill site. Many pavements had incorporated pebbles—making the asphalt harder. Oil was found mostly along the spring high tide line.

Completeness of Description

Environmental Baseline	
Shoreline	Poor
Wave Energy/Tides	Poor
Biological activity	Poor
Oiling	
Oil Properties	Good
Area oiled	Poor
Volume of oil or oiling rate	Poor
Permeability/location of oil	Poor
Monitoring	
Oil fate	Good
Biological recovery	Poor

Comments