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Use of Peat Moss in Controlled Combustion Technique

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USE OF PEAT MOSS

IN CONTROLLED COMBUSTION

TECHNIQUE

REPORT PRESENTED BY
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TO
Department of the Environment
Environment Protection Service
Environmental Emergency Branch

TERMS OF REFERENCE

This Contract was commissioned by the Environmental Emergency Branch, Environmental Protection Service, Environment Canada.

The terms of reference were as follows:

a) A literature review of the recent works and publications on the uses of peat moss in combating oil pollution;

b) An inventory on the availability of peat moss in Canada;

c) A description of the testing equipment and test procedures;

d) Summary of test data and its compilation in the report;

e) Editing and preparation of final report;

f) Testing parameters to include but not limited to Bunker C and crude oils, natural and heat-treated peat moss, oil thickness, oil weathering and peat moss-light fuel oil mixtures.

Items a) and b) are presented together in Chapter one. The second Chapter includes data on the capacity of absorption of peat moss and finally the experiments conducted on combustion are presented in Chapter III.

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CHAPTER I

Inventory of peat moss in Canada and literature review

It has been estimated that peat bogs cover in excess of 37,000 square miles of Canada, with a large proportion of that area in Central Canada. The tonnage of peat moss produced in Canada has multiplied fifteen times in the past twenty years. The availability of peat moss in Canada is continually surveyed in all the provinces and Table I - 1 gives the actual area of peatland for all the provinces.

Table I - 1 (1)

Distribution of peatland in Canada

Province	Peatland		
	surveyed area	area which could be exploited	exploited area
	ACRES	ACRES	ACRES
British Columbia	2,385,000	47,000	2,000
Alberta	2,000,000	-	400
Saskatchewan	10,000,000	-	2,000
Manitoba	92,500	4,900	1,000
Ontario	-	-	500
Quebec	255,000	59,000	7,000
New Brunswick	-	-	6,000
Nova Scotia	9,000	5,000	400
Prince Edward Island	6,400	1,000	100
New Foundland	28,500	5,000	5

The finding of new uses for peat has re-awakened industry and resource evaluation agencies of governments to a new realization of the potential economic value of peatlands. As far as the use of peat in combating oil pollution is concerned, the distribution of bogs and the large quantities available everywhere in Canada are two important factors.

The use of peat moss in combating oil pollution has been reported from various places. Here are some of the case histories (2):

Case 1:

Date of Spill :	December 15, 1969
Location :	West of Emasalo, Finland
Cause and Extent of Spill:	50,000 dwt Russian tanker, "Raphael", went aground spilling more than 60 tons of crude oil which formed a slick 10 km. long and several meters wide.
Environmental Conditions :	Snowing
Cleanup procedures :	BOOMS: Used unsuccessfully BURNING: Peat, fuel oil, and petrol used as fire promoters and burning agents to remove 90% of spilled oil.

Case 2:

Date of Spill :	February 4, 1970
Location :	Chedabucto Bay, Nova Scotia
Cause and Extent of Spill:	The Liberian-registered tanker "Arrow", carrying 16,000 tons of Venezuelan Bunker C fuel oil, went aground and broke up, spilling most of the oil into the bay.

	Several slicks formed and 190 miles of coastline were polluted.
Environmental Conditions:	Water temperature 0-1°C; air temperature much lower. Storm winds 40-50 mph. Severe wave conditions. Water depth about 100 feet.
Cleanup Procedures:	BOOMS: Floating booms were unsucessful. Home-made booms of wire mesh covered with spruce boughs were more successful than commercial semi-flexible, non-porous booms. SKIMMERS: "Slick-lickers" were used sucessfully in sheltered waters. DISPERSANTS: Corexit 8666 was sprayed on the slick, but could not penetrate thick layers of oil which formed as a result of low temperatures and weathering. BP1100B was effective in removing oil on rocks. ABSORBENTS: Peat moss proved to be a good absorbent; straw was used on some beaches. BURNING: Wicking agent, SeaBeads, was used successfully on beaches and on isolated slicks in 1-2°C water. Part of the spill was burned by spilling two drums of fresh oil on it, and igniting with Kontax. Onshore oil deposits at Arichat were ignited with napalm and a flame thrower and burned well.

Case 3:

Date of Spill	: April 1970
Location	: Glace Bay, N.S.
Cause and Extent of Spill	: Sinking of "Patrick Morris" 100,000 gallons of Bunker C was spilled
Cleanup Procedures	: Peat moss was used to absorb oil on beaches with a 90% recovery.

Case 4:

Date of Spill	:	September 1970
Location	:	Gulf of St-Lawrence near Prince Edward Island.
Cause and Extent of Spill	:	Sinking of oil barge "Irving Whale" 4,000 tons of Bunker C was spilled.
Environmental Conditions	:	Water temperature: 12^{o}C.
Cleanup Procedures	:	Peat moss was used as an absorbent with excellent recovery both on sea and shoreline.

Case 5:

Date of Spill	:	Summer 1970
Location	:	Point Barrow, Alaska
Cause and Extent of Spill	:	The U.S. Coast Guard was conducting tests to study behavior of oil in the Arctic and possible cleanup procedures. Approximately 55 gallons of North Slope crude was spilled in each of several tests.
Environmental Conditions	:	Ice Temperature: 0.3^{o}C; water temperature: 1-2^{o}C, air temperature: 1-4.8^{o}C.
Cleanup Procedures	:	BURNING: Fresh and 6-day old crudes ignited and burned well both in water and on ice. No difference in ignition and burning was noted when a glass bead or fumed silica burning agent was used. ABSORBENTS: Peat moss and straw were effective absorbents with peat moss showing greater absorption both in water and on ice. However, straw proved to be much easier to handle.

DISPERSANTS: Chemical dispersants tested were judged impratical because conditions made it difficult to supply adequate mixing energy.

From private communication following the "Arrow" incident, there are other cases where peat moss has been used. It is simply impossible to have all of them in file.

CHAPTER II

Removal of oil spills by absorption

INTRODUCTION

Physical removal of an oil slick is the most positive way of dealing with oil pollution. Absorbents offer such a means of removal. Laboratory tests have shown that peat moss is a very good absorbent, and because of its large availability, can be used on a large scale. The following tables give results from different sources.

Table II - 1 (3,4,5)

OIL SORPTION CAPACITY GRAMS OIL/100 GRAMS SORBENT

Absorbing Agent	Diesel Oil	Light Fuel Oil	Prudhoe Bay Crude	Bunker "C"	Heavy Crude (Venz.)	Light Crude (La.)	No. 2 Fuel
Redwood Fiber, ground				1470	1180	650	640
Peanut Hulls, ground				580	430	220	220
Wood Cellulose Fiber				1860	1730	1140	900
Corn Cob, ground				570	560	470	380
Volcanic Ash				2120	1810	720	500
Wheat Straw				580	640	240	180
Straw on water			345				
Straw on ice			698				
Vermiculite				430	380	330	360
Wood Flour	270	280					
Perlite	310	310		460	400	330	300
Sawdust				300	370	360	280
Peat	330	320					
Peat Moss on water			1568				
Peat Moss on ice			698				
Urea Formaldehyde Foam				7270	5240	5030	4780
Polyethylene Fibers							
A. Wool type				3700	2780	1970	1610
B. Sheet, matted				1860	1760	1190	1060
C. Continuous element, non-woven				4600	3670	4540	3620
Polypropylene Fiber, non-woven				2170	1810	690	480
Polyurethane Foams							
A. Shredded				7270	7480	6000	4870
B. Reticulated				3030	2450	3060	2750
C. 1/2 in. cubes				7270	7170	6610	6490
Polystyrene Powder				2340	2170	2040	580
Polyester Shavings				880	740	660	470
PTFE Shavings				500	600	140	100
Foamed Plastic	1960	1830					

Table II - 2 (4)

PEAT REQUIRED TO REMOVE 100 GRAMS OF OIL SLICK (1/16" thick)

Absorbing Agent	Moisture Content, %	Absorbing Capacity, gm
Milled peat*	0	19.0
Milled peat*	38	28.4
Milled peat*	46	27.4
Peat Moss	33	23.0
Briquette press feed	11	41.0

*Different sources

Table II - 3 (4)

OIL SORPTION CAPACITY OF PEAT AND PERLITE: LITERS OIL ABSORBED/LITER SORBENT

				Quantities of oil and water absorbed from an oil layer resting on the water surface	
Absorbing Agent	Moisture content % of dry weight	Density gm/liter	Oil-absorbing capacity, liter of oil/liter of peat	liter of oil/liter of peat	liter of water/ liter of peat
Peat,* artificially dried flour	7.0	82	0.68	0.62	0.18
" " " "	6.4	85	0.65	0.54	0.12
" " " "	6.4	95	0.62	0.54	0.12
" " " "	2.8	74	0.63	0.48	0.12
Peat, art. dried crushed matter	2.8	81	0.46	0.40	0.06
Peat, air-dry flour	24.0	77	0.57	0.44	0.30
Air-dry milled peat	60.8	178	0.50	0.26	0.30
Perlite	(0.8)	(70)	(0.46)	(0.46)	(0.06)

*Mellial Heporahka peat

Many competent authorities agree that peat has a definite place among oil absorbants. The Irish (4) and Finnish (7) Peat Boards, reporting the results of their own tests, agree that peat possesses the hydrophobic and oleophilic properties which qualify a sorbent for use against oil slicks. Tests conducted at the Université de Sherbrooke support these findings. Peat is presently being used as an absorptive agent in Scandinavian harbors (6).

Chapter III

Removal of oil slicks by combustion with peat

INTRODUCTION

The objective of this research is to investigate the possibilities of destroying oil slicks by burning with peat impregnated with a promoter (light paraffin oil). Such a technique has been used elsewhere (7) and the results appear to be very positive. The main problem is associated with

1 - the fact that rapid heat transfer to the cold sea water lowers the oil temperature below the flash point

2 - as the oil burns, its temperature rises and its viscosity decreases. While the rise in temperature may accelerate burning temporarily, the less viscous oil tends to spread into a thinner film which will not burn as readily

3 - wave action may cause spilled oil to form emulsions which do not burn easily

Since Bunker C and crude oil are the two main types of oil most likely to be spilled, it was decided to carry out experiments with both of them. This report describes the results obtained from combustion experiments with artificial oil slicks spread on snow or water in a steel vat. The following parameters were studied in this research project:

1 - the effects of weathering (duration for which oil on snow or water is left in open air) on combustion.

2 - the effect of different types of promoters

3 - the exact proportions of peat and promoter needed to achieve good combustion.

DESCRIPTION OF EQUIPMENT

All experiments were conducted in a steel vat (8' wide X 8' long X 8" deep) built specially for the project and located on the campus, just outside the Engineering Building. This location had been chosen in agreement with the Department of Security of the Université de Sherbrooke. The Bunker C oil was provided by the university power house where it is used in water-tube boilers. The crude oil was a Venezuelan cut, coming from the Golden Eagle refinery at St. Romuald, Quebec. Commercial sphagnum peat moss (blonde peat) was bought from Lambert peat moss, Rivière Ouelle, Quebec. It had been stored in the basement of the Engineering Building for approximately 2 years, and this explained its low moisture content. Viscosities, temperatures, etc. were measured with standard equipment.

DESCRIPTION OF PROCEDURE

The vat was first filled with either ice or water, depending on weather conditions to varying depths (usually around 5") and nine (9) U.S. gallons of oil were spread on top. This quantity of oil resulted in a layer thickness of approximately a quarter of an inch (¼").

The oil was left in the open air for varying length of time, as shown in Table III-1. On the day of the burning experiment, a weighed quantity of peat was steeped in a measured volume of promoter and spread over the oil. The quantity of peat was determined according to the capacity of peat to absorb oil as given in chapter II. The moisture content of peat was measured by the ASTM standard method test # D 2974-71. The oil was then ignited. Ignition was conveniently accomplished with a piece of cloth which had been saturated with gasoline, then dropped onto the treated surface and ignited. Combustion generally continued for 15-20 minutes before the fire died out. The quantity of oil burned was then determined as follows:

After the combustion, lumps of unburned peat, ash and oil were present. They were collected and analysed for their oil content. The technique used was the so-called Skinkle method used to measure the quantity of oil in wool, and is described in Appendix A.

Appendix C gives the method of calculation used to evaluate the efficiency of the combustion technique.

EXPERIMENTS WITH BUNKER C OIL

The list of the main experiments carried out with Bunker C oil is presented in Table III-1, and each experiment is further described in Appendix B. Of the two types of promoters used in these experiments, gasoline and diesel oil, the latter was found to be more effective. A proportion of two (2) liters of diesel oil and 4-5 lbs of peat for 9 U.S. gallons of Bunker C oil was found to be good for proper combustion. Larger amounts of diesel oil did not improve combustion and the ratio of 2 liters of promoter to 9 gallons of Bunker C oil is recommended as the right proportion.

Table III - 1

CONDITIONS AND RESULTS OF BURNING EXPERIMENTS

WITH BUNKER C OIL

Dates of tests: March and April 1972

Viscosity : 4800 cp at 72°F

Exp. No	Weathering (day)	Volume of Bunker C oil (U.S. gallons)	Quantity of peat used (lb.)	Moisture content of peat* %	Promoter**	Volume of Promoter (Liters)	Temperature of Bunker C and water before ignition (°F)	Depth of snow or ice below oil (inches)	% burnt
1	1	9	5	31	gasoline	3	28	1 (snow)	> 80
2	3	9	5	31	gasoline	2½	28	3 (ice + water)	70
3	2	9	5	30	diesel oil	3	32	5 (ice + water)	80
4	11	9	5	31	diesel oil	2	34	6 (ice + water)	70
5	7	9	4	31	diesel oil	2	40	5 (water)	80

* Determined according to ASTM TEST D 2974-71

** Viscosity of diesel oil is 9 cp at 72°F
Viscosity of gasoline is 5 cp at 72°F

It was observed in the first two experiments, using gasoline as promoter, that it was not possible to set fire to Bunker C oil according to the procedure described previously because the peat burned too quickly. Also, the gasoline was too volatile, evaporating so quickly that it was impossible to initiate and sustain the combustion. In both experiments 1 and 2, additional quantities of gasoline had to be added to the vat. On the other hand, with peat steeped in Diesel oil, combustion could easily be maintained. The process of setting fire, with gasoline as promoter, may not be practicable at sea with large oil spills and more over it would be more economical to use Diesel oil. In all experiments most of the Bunker C oil was floating on the water as a separate layer. However in the last two experiments, with longer weathering periods, some oil was found to float under the water surface. This phenomenon had been observed in Chedabucto Bay in February 1970 (8) and the formation of an emulsion of oil in water decreases the efficiency of burning. The difficulty experienced in burning oil slicks is associated with the rapid loss by evaporation of the more volatile components of the oil with time while on the water. Long weathering time degrades the oil and it becomes a solidlike material. Experiment # 4 indicates the difficulty in burning weathered oil.

A possible explanation for the combustion is as follows: after ignition, the wicking action of the peat causes the flame front to travel very gradually from the burning cloth to the entire treated area of the slick. The peat also draws up oil by capillary action, increasing the rate of vaporization. The increase in temperature that occurs after ignition lowers the viscosity of oil and facilitates further wicking. Another positive effect of peat is to sustain combustion through its caloric capacity of approximately 8,000 BTU/pound. This effect is necessary in order to balance the heat loss to the underlying water mass which tends to lower the oil temperature below the flash point.

ESTIMATED QUANTITIES FOR LARGER OPERATION

From the results obtained with Bunker C oil, it seems that a ratio of 4/9 pound of peat/gallon of Bunker is sufficient to give a good combustion. On this basis, we can establish the quantities needed for the following hypothetical case. Suppose there is an oil spill of 300 tons of Bunker C oil. Quantities of promoter and peat required for good combustion will be as follows:

Bunker C oil:

$$300 \text{ tons} \times 2{,}000 \frac{\text{lbs}}{\text{tons}} \times \frac{1 \text{ ft}^3}{62.4 \times 0.97 \text{ lbs}} \times 7.5 \frac{\text{gal}}{\text{ft}^3} \doteq 74{,}000 \text{ gal}$$

Quantity of peat needed:

$$74{,}000 \text{ gal} \times \frac{4 \text{ lb}}{9 \text{ gal}} \doteq 37{,}200 \text{ lbs}$$

Number of bales:

$$37{,}200 \text{ lbs} \times \frac{1 \text{ bale}}{80 \text{ lbs}} \doteq 330 \text{ bales}$$

Quantity of Diesel oil:

$$\frac{2 \text{ liters}}{9 \text{ gal}} \times 74{,}000 \text{ gal} \times 0.26 \frac{\text{gal}}{\text{liter}} \doteq 4{,}320 \text{ gal}$$

It is interesting here to compare these results with those obtained in an actual spill in Finland where a similar technique was used (9). In September 1968, 300 tons of oil were spilled at sea, resulting from the accident of a Russian tanker.

The following quantities of peat and promoter were used:

300 bales of peat moss

10,400 gallons of promoters

The quantity of peat used in Finland is almost equal to what we used. There is however a large discrepancy in the quantity of promoter which was used. This can be explained by the fact that in Finland, the peat was mixed with a larger quantity of promoter in order to facilitate the spreading by pneumatic equipment.

EXPERIMENTS CONDUCTED WITH CRUDE OIL

The results of experiments conducted with crude oil are presented in Table III - 2 and each experiment is further described in Appendix B. The procedure was not changed and the results obtained with Bunker C oil were used as starting point. It was observed that peat moss absorbed crude oil much faster than Bunker C oil. This is in agreement with absorption tests carried out previously. As the absorption proceeded, the peat sank into the crude oil and consequently did not float on the surface. Fire, in this case, did not propagate quickly if the same quantities of peat moss and promoter used with the Bunker C oil were used. It may be that as burning progresses and the oil viscosity decreases, the peat and absorbed oil sink below the oil into the water layer and the burning ceases. In order to act as a wick, the peat should float on the surface or remain in the oil layer throughout burning.

Adding more peat seemed to be one way of improving the technique. Fire propagated very rapidly and lasted over thirty minutes. The larger quantity of peat in the case of crude oil is explained by the larger absorption capacity of peat for crude oil.

Table III - 2

CONDITIONS AND RESULTS OF BURNING EXPERIMENTS

WITH CRUDE OIL

Dates of tests: April, May, June 1972

Viscosity : 63 cp at 20°C

Exp. No	Volume of crude oil (U.S. gallons)	Quantity of peat (lbs)	Moisture of peat (lbs)	Promoter	Volume of promoter (liters)	Temperature of crude oil and water before ignition (°F)	Level water below oil (inches)	Weathering (day)	% oil burnt
6	9	4	38	Diesel oil	2	46	5	2	70
7	9	6	32	Diesel oil	2	68	5	4	87
8	9	4	37	Kerosene	2	66	4½	2	70
9	9	4	37	Diesel oil	2	77	6	12	40
10	9	4	37	Diesel oil	2	68	6	2	75
11	9	8	36	Diesel oil	2	70	6	5	91
12	9	6	35	Diesel oil	2	76	6	3	95

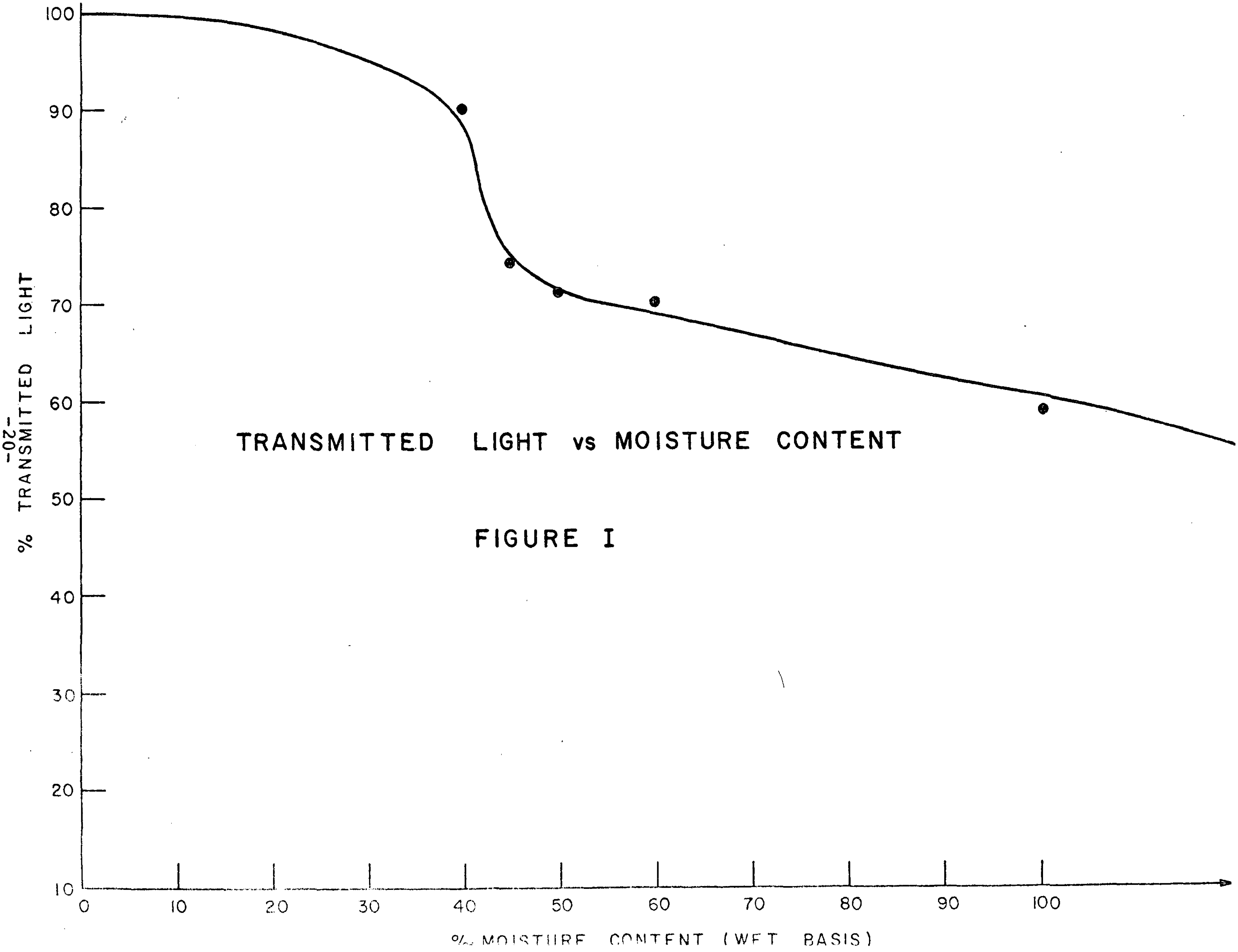
INFLUENCE OF OTHER PARAMETERS

The tests conducted so far took into account some of the parameters such as the type and quantity of promoter and the quantity of peat moss. It is however necessary to comment on other parameters.

MOISTURE CONTENT OF PEAT MOSS

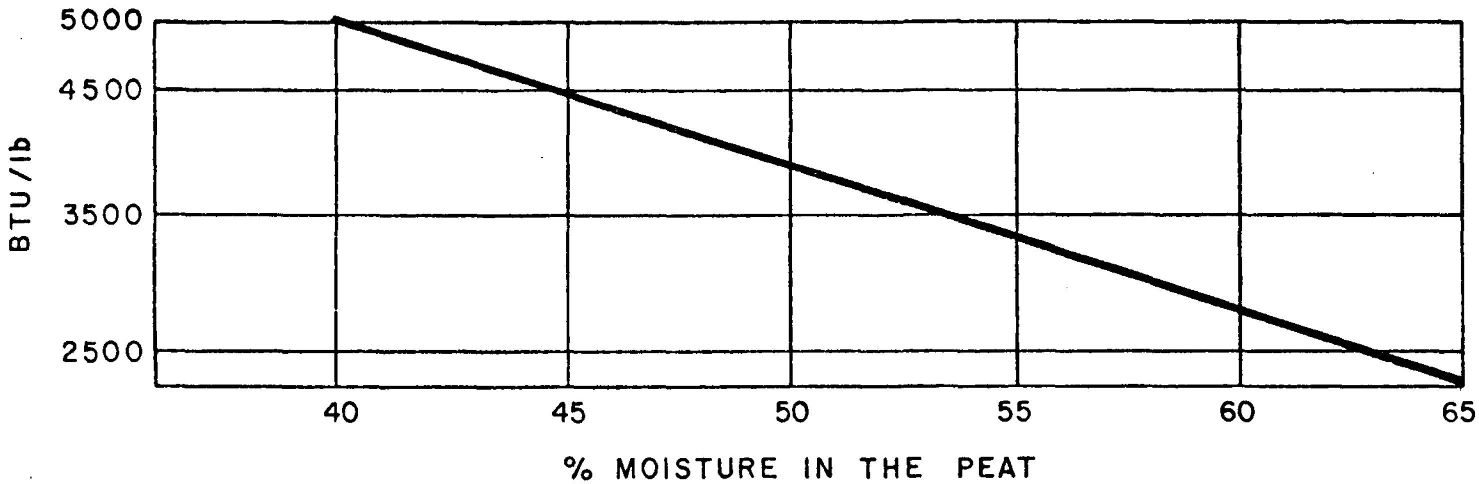
The capacity of peat to float is related to its moisture content. As the moisture content increases, the density also increases and the peat sinks rather rapidly. In order to evaluate the capacity of peat to float on water, tests were conducted in 4-liter beakers. Peat with different moisture contents (wet basis) was spread on the water in the beakers. The beakers were held in a vertical position in a vat filled with water and agitation was provided by a wave-making mechanism. The amount of peat in suspension (peat which had sunk) was measured by the percentage of light transmitted through the water in the beaker. This measurement is directly connected to the capacity of the material to float on water. Figure 1 gives the results as % of light transmitted versus the moisture content of peat. With peat having between 30% and 45% moisture content, there is a sharp decrease in the transmitted light. This means that the amount of peat which has sunk (below the water surface) has increased. Beyond a moisture content of 50%, the floating capacity of peat continuously decreases.

Since there will always be a certain period of time between the spreading operation and combustion, it is believed that peat with a moisture content greater than 40% would not be useful. Moreover the caloric value of peat is also related to its moisture content as shown in Figure 2. The heat released by combustion is lower and it is therefore more difficult to balance the heat losses.



TRANSMITTED LIGHT vs MOISTURE CONTENT

FIGURE I



CALORIC VALUE OF PEAT vs MOISTURE IN THE PEAT

FIGURE 2

THICKNESS OF THE OIL SLICK

It is obvious that any contingency plan should aim at eliminating an oil slick as soon as possible. The coefficient of spreading is related to temperature and volume of the oil and surface conditions. By keeping the same ratios as those found earlier, it has been possible to obtain similar results with slicks up to 1/16" thick. For oil slicks thinner than 1/16" thick, the heat losses become more and more important as compared to the heat released by combustion.

EFFECT OF SEA WATER

Absorption tests were conducted with oil on simulated sea water and no special effect has been observed.

CONCLUSION AND FURTHER WORK

We are well aware, of course, that the combustion of the oil produces a smoke column which itself is a form of pollution. It is felt however that the total damage to the environment by the quickly dissipated smoke is only a small fraction of that which is done by oil in the water. This combustion technique could be used in areas where the danger of propagation of fire to the vegetation on the shoreline is minimal. Owing to the positive results achieved by the use of peat in these tests and elsewhere, we feel that the project should be continued, with field tests. One way of doing this would be to select suitable places where an oil slick could be maintained in place either by fire resistant booms or by the shoreline. In case a sufficiently strong wind happens to be blowing towards the shore, not even booms are needed. Peat once impregnated with a promoter could be spread by means of a pneumatic spreading apparatus. The results of such tests could then be compared to the ones of this report. It is interesting to compare, at this point, the cost of cleaning up a hypothetical 300 tons oil spill via combustion with some clean up costs of well-known, actual spills. Table III-3 lists these figures.

Table III - 3

COST OF CLEAN-UP (2)

Incident	Amount Spilled (Tons)	Total Cost of Clean-up ($)	Unit Cost of Clean-up ($/Ton)	Remarks
Torrey Canyon	119,000	8,000,000	68	United Kingdom (Smith, 1968)
Ocean Eagle	12,065	1,200,000	100	Puerto Rico
		10,000,000	1,000	Puerto Rico claims only (Ludwigson, 1969)
"Arrow" Chedabucto Bay	16,200	3,250,000	200	Nova Scotia (only first year operation)
Deception Bay	1,830	25,000	14	Arctic, ice present
Sweden (Gulf of Finland)	250	2,000,000	8,000	1st spill 1969
	250	440,000	1,760	2nd spill 1970, Ice present
	200	312,500	1,560	3rd spill 1970, (Engdahl, personal communic.)
San Francisco Bay	10,000	4,000,000	400	United States
Hypothetical Spill *	300	9,000	30	

* The cost of clean-up is made up of the following items:

Peat	$1,000.
Promoter	$3,500.
Transportation and manpower	$4,500.

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APPENDIX A

Method used to analyse the oil content after combustion

Principle of the method:

After combustion, the residues were collected and analysed. The method used is the so-called Skinkle method, mainly used in the textile industry to determine the oil content in wool. It consists of mixing a given sample with a precise amount of solvent. The oil goes into solution and after evaporation, a gravimetric procedure gives the amount of oil originally present in the sample.

Description of Procedure:

Ten grams of the sample are placed in a beaker and 50 ml of solvent are added. A 100 ml cylinder with the opening covered with a 200 mesh stainless steel wire is placed upside down in the beaker. The solution gets through the wire mesh and 25 ml of solution are collected and placed in a crucible. Evaporation is then taking place and the amount of oil is determined by weighing.

As to the oil in water, it has been evaluated according to the method given in ASTM. In all cases, it was found negligible.

APPENDIX B

Experiment number 1

Date of experiment	:	3/16/72
Weather conditions	:	Temperature 28°F Level of snow below oil: 1" Duration for which oil and snow were left outside: 24 hrs
Moisture content of peat	:	31% (wet basis)
Quantity of Bunker C oil	:	9 U.S. gallons (¼" of oil)
Quantity of Peat Moss	:	5 lbs
Quantity of gasoline used	:	3 liters

Remarks

Following the procedure as described in the text, peat was spread and the setting of fire was delayed for 45 minutes due to late arrival of security people. When fire was set, peat did not catch fire easily and fire started at a few scattered spots only. This was probably due to rapid evaporation of gasoline. One more liter of gasoline was then poured over the peat and fire spread out. The burning went on for 30-35 minutes.

Experiment number 2

Date of experiment	:	3/23/72
Weather conditions	:	Temperature: 28^{o}F Level of ice and water below oil: 3" Duration for which oil and ice were left outside: 3 days
Moisture content of Peat	:	32% (wet basis)
Quantity of Bunker C oil	:	9 U.S. gallons
Quantity of Peat used	:	5 lbs
Quantity of gasoline used	:	2.5 liters

Remarks

On a layer of 1" snow, nine U.S. gallons of Bunker C oil were poured. During three days, it was left in the vat and heavy rains increased the quantity of water. Peat was spread and ignition made. It was found that only peat was burning and small flames started at a few places. After adding another liter of gasoline (1.5 liters were originally poured), fire broke out.

Experiment number 3

Date of experiment	:	3/29/72
Weather conditions	:	Temperature: 32°F Level of snow and water below oil: 5" Duration for which oil and water were left outside: 2 days
Moisture content of Peat	:	30%
Quantity of Bunker C oil	:	9 U.S. gallons
Quantity of Peat Moss	:	5 lbs
Quantity of Diesel oil	:	3 liters

Remarks

Fire brooke out very easily and continued for 20 minutes.

Experiment number 4

Date of experiment	:	4/10/72
Weather conditions	:	Temperature: 34°F Level of ice and water below oil: 6" Duration for which oil and ice were left outside: 11 days
Moisture content of Peat	:	31%
Quantity of Bunker C oil	:	9 U.S. gallons
Quantity of Peat Moss	:	5 lbs
Quantity of Diesel oil	:	2 liters

Remarks

Fire broke out easily but the amount burnt was less due to the weathering of 11 days.

Experiment number 5

Date of experiment	:	4/27/72
Weather conditions	:	Temperature: 40° F Level of water below oil: 5" Duration for which oil and water were left outside: 7 days
Moisture content of Peat	:	30%
Quantity of Bunker C oil	:	9 U.S. gallons
Quantity of Peat Moss	:	4 lbs
Quantity of Diesel oil	:	2 liters

Remarks

Oil and water were not in an emulsion stage. Oil was mainly floating as a distinct layer. Fire was propagated by a strong wind and continued for 20 minutes.

Experiment number 6

Date of experiment	:	5/3/72
Weather conditions	:	Temperature: 46°F Level of water below oil: 5" Duration for which oil and water were left outside: 2 days
Moisture content of Peat	:	38%
Quantity of crude oil	:	9 U.S. gallons
Quantity of Peat Moss	:	4 lbs
Quantity of Diesel oil	:	2 liters

Remarks

Peat was found to absorb oil very quickly and there were lumps of peat and oil on the surface. Fire did not propagate quickly. Fire continued for 10 minutes and was extinguished quickly. Although a good quantity of oil was burnt and fire was all over the vat, a considerable quantity of peat with oil was left unburnt in the vat.

Experiment number 7

Date of experiment	:	5/4/72
Weather conditions	:	Temperature: $68^{o}F$ Level of water below oil: 5" Duration for which oil and water were left outside: 4 days
Moisture content	:	32%
Quantity of crude oil	:	9 U.S. gallons
Quantity of Peat Moss	:	6 lbs
Quantity of Diesel oil	:	2 liters

Remarks

Fire propagated with difficulty.

Experiment number 8

Date of experiment	:	5/11/72
Weather conditions	:	Temperature: 66°F Level of water below oil: 4½" Duration for which oil and water were left outside: 2 days
Moisture content	:	37%
Quantity of crude oil	:	9 U.S. gallons
Quantity of Peat Moss	:	4 lbs
Quantity of kerosene	:	2 liters

Experiment number 9

Date of experiment	:	5/31/72
Weather conditions	:	Temperature: $77^{o}F$ Level of water below oil: 6" Duration for which oil and water were left outside: 12 days
Moisture content of Peat	:	37%
Quantity of crude oil	:	9 U.S. gallons
Quantity of Peat Moss	:	4 lbs
Quantity of Diesel oil	:	2 liters

Remarks

Oil on water was ignited after peat steeped in diesel oil was spread. Fire propagated quickly and all over the vat. After the fire was extinguished, it was found that a considerable quantity of oil was left unburnt. Unlike previous experiments, there was not much peat lumps on the surface. Obviously, peat burnt quickly. One could explain the phenomenon by the long weathering period. During those days (many with temperature above $80^{o}F$), the more volatile components evaporated and the residu was worse than Bunker C oil.

Experiment number 10

Date of experiment	:	6/3/72
Weather conditions	:	Temperature: 68°F Level of water below oil: 6" Duration for which oil and water were left outside: 2 days
Moisture content of Peat	:	35%
Quantity of crude oil	:	9 U.S. gallons
Quantity of Peat Moss	:	4 lbs
Quantity of Diesel oil	:	2 liters

Remarks

Fire propagated and lasted for fifteen minutes. Due to a very strong wind, peat could not be properly spread all over the oil surface.

Experiment number 11

Date of experiment	:	6/8/72
Weather conditions	:	Temperature: 66°F Level of water below oil: 6" Duration for which oil and water were left outside: 5 days
Moisture content of Peat	:	35%
Quantity of crude oil	:	9 U.S. gallons
Quantity of Peat Moss	:	8 lbs
Quantity of diesel oil	:	2 liters

Remarks

There was no unburnt oil in the vat, but some unburnt fresh peat was left after the fire extinguished.

Experiment number 12

Date of experiment	:	6/12/72
Weather conditions	:	Temperature: 76^0F Level of water below oil: 6" Duration for which oil and water were left outside: 3 days
Moisture content of Peat	:	35%
Quantity of crude oil	:	9 U.S. gallons
Quantity of Peat Moss	:	8 lbs
Quantity of Diesel oil	:	2 liters

Remarks

No unburnt oil and peat left in the vat.

APPENDIX C

Method of calculation used to evaluate the efficiency of the combustion technique

The method is best illustrated with an example and experiment # 11 will be used.

Amount of water in the vat: $\frac{6}{12} \times 8 \times 8 \times 62.3 \doteq 1{,}994$ lbs

Amount of oil in the vat before combustion: $\frac{9 \times 3785 \times 0.9}{454} \doteq 68$ lbs

% of oil: $\frac{68}{1994} \times 100 \doteq 3.4$ %

% of oil in sample after combustion: 0.3 %

% of oil burnt: $\frac{3.4 - 0.3}{3.4} \times 100 \doteq 91$ %