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An Economic Analysis of Controls on the Discharge of Oil at Sea

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THIS PAPER has three objectives. The first is simply to provide some basic information about the pollution of the sea by the deliberate discharge of oil from tankers. The second objective is to develop an economic framework which can be used to examine the 1973 International Convention for the Prevention of Pollution from Ships. And the third objective is to assess the 1973 Convention in light of our knowledge of economic concepts and the costs of alternative approaches to preventing deliberate pollution by tankers.

The paper has developed from our concern that the negotiating framework within which international conventions are conducted may not be conducive to economically efficient decisions. Further, the political sensitivity of pollution issues in many countries may have led to the least controversial and most tangible approaches being given priority to the detriment of more efficient solutions. Unfortunately, most of the research reported on oil pollution control is concerned with technical or environmental and scientific inputs. While these studies are certainly essential it is also important that more attention be given to the economic benefits and costs of pollution control.

The probable expansion of tanker trades on both the Canadian east and west coasts, and possibly in the Arctic, will make it increasingly important for Canadians to become more conversant with the multiple facets of oil pollution control. The conclusion of the 1973 Convention does not assure seas free from oil pollution nor does it provide us with much indication of the cost to countries, ports, and ships of the pollution control measures agreed to.

This paper is in six parts. The first part describes the significance of the disposal at sea of oil from ballast and tank cleanings. The second part summarizes the major international agreements reached on ship pollution prior to 1973. The economic nature of the problem of controlling oil pollution by ships is examined next. The alternate means of controlling the discharge of oil at sea are described in part four and the costs of the alternatives estimated. The fifth part of the paper summarizes the regulations agreed to in the 1973 Convention. The paper concludes by examining the cost implications of implementing the regulations set down in the Convention.

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I. The Sources and Magnitude of Oil Pollution in the Oceans

Ship generated pollution tends to attract considerable public attention. Marine casualties (collisions and groundings) when they occur often result in large spills. Further, the deliberate discharge of oil in small quantities during normal ship operations may seem to the public to be an unwarranted contamination of our ocean heritage by unscrupulous ship owners. Consequently, it is believed too often that oil pollution from ships can be eliminated by ship owners. Like many simple views, this view would be quite unreasonable and stems from a lack of appreciation of the oil pollution problem.

About half of the oil pollution of the oceans is derived from land and not marine sources. While this does not minimize the importance of controlling oil pollution by ships it demonstrates the necessity of keeping the relative size of the ship problem in mind. Public attention should not become so riveted on the ship aspects of the pollution problem that land based discharges are ignored.

One estimate of the sources of oil pollution in 1970 is provided in Table 1. Oil pollution from tankers counted for less than 1/3 of the total oil finding its way to the seas. The amount of oil lost through routine tanker operations (tank cleaning, ballasting, and terminal operations) was much greater than the amount lost through the more highly publicized vessel casualties (collisions and groundings). "Normal" procedures accounted for over 80% of the tanker derived pollution. Therefore, control of this source of pollution is important.

The particular aspects of tanker operation of concern in this paper are tank cleaning and ballasting.

Tank cleaning: When an oil tanker discharges its cargo about .4% of the cargo is left in the ship. The amount may range from 0.1% to 1.2%. This residue is accounted for by the clingage of oil to tank surfaces[1] and puddles of oil around suction lines and in the lines and pumps. The amount of residue va-

SOURCES OF OIL POLLUTION

Source		Percent of Total		Millions of Long Tons
Land Sources				
—Highway Vehicles	29		1.4	
—Industrial Machinery	15		0.8	
—Refineries and Petro-Chemical Plants	6	51	0.3	2.5
Off-Shore Production		2		0.1
Vessels other than tankers		19		0.9
Tankers				
—LOT tank clearing and ballasting	5		0.3	
—other tank clearing and ballasting	14		0.7	
—other discharges	2		0.1	
—Tanker Terminals	1		0.07	
—Accidents	5		0.25	
		28		1.4
		100		4.9

Source: Porricelli, J. D., Keith, V. F., and Stopch, R. I., "Tankers and the Ecology," S.N.A.M.E. Transactions, 1971, p. 172.

TABLE 1

ries with the viscosity of the oil; for lighter free flowing crudes the figure would be about 0.3%; for heavy crudes with waxy deposits the total residue might be 1.0% to 1.2%. The quantities are also generally higher after voyages in rough seas.

It is not necessary that all tanks be cleaned after all voyages. However, if different oil products are to be carried washing may be essential and frequent washing is desirable to prevent the build-up of scale and sludge. The tanks are generally cleaned with pressure sprays of sea water while the vessel is sailing in ballast.[2] It is during the washing process that the danger of the explosion of flammable gas is greatest.[3] Cleaning half of the tanks of a 200,000 dwt tanker could be expected to yield from 300 to 1,000 tons of oil, mixed initially with sea water.

Ballasting: The second reason that oil and water are mixed is the need for tankers to take on water ballast to sail safely and economically from a discharge to a loading port. The amount of water ballast required depends on expected sea conditions. It ranges from 20% of deadweight capacity for good sea conditions to about 50% for rough seas. Characteristically, tankers have had segregated clean ballast tanks for about 10% of their deadweight capacity. Generally, more clean ballast tanks than this would increase the size and weight of tankers for a given oil carrying capacity. Therefore, additional ballast water is taken into cargo tanks in the discharge ports and before the tanks have been cleaned. While at sea other tanks are cleaned to receive clean ballast water and the old ballast water must be disposed of.

The cheapest way for ship owners to get rid of both the oil and water mixture from tank cleaning and ballasting has been to dump it far out at sea. However, various post-war trends have made this practice increasingly unacceptable. These trends include the tremendous increase which has occurred in the world oil trade. In the period 1950 to 1970 world seaborne oil trade has increased more than sixfold.[4] The trade has also changed from the movement of products, many of them light non-persistent oils, to the movement of crude oil with heavier persistent residues.

Consequently, an increasing percentage of the tanker fleet has been built to dispose of the oil-water mixture through the load on top system (LOT). Under the LOT system dirty ballast water and cleaning water is pumped into a holding or slop tank. Here the mixture is allowed to settle and the water is drawn off from the bottom. As the water level of the mixture is lowered the percentage of oil increases so that it is necessary to use separators and/or control systems to prevent the dumping of undue quantities of oil into the sea.

Under the LOT system a new cargo of crude is loaded into the ship, including the slop tank containing oil residue. However, for this practice to be followed the ship owner must be willing to accept a smaller tonnage of cargo than would otherwise be possible. (The residue in the slop tank may be from 0.4% to over 1% of the ship's oil carrying capacity.) Also the discharge port must be willing to accept some oil with salt water content.

Alternatively it is possible for facilities at the loading port to receive the oily waste so that a full cargo of uncontaminated oil can be loaded. The problem of treating and disposing of the oil and water mixture is then transferred to the loading port.

II. Major International Agreements prior to 1973

The disposal of oil from tankers (and other ships) has been a matter of international concern for many years. However, the first international conference was held only twenty years ago. It was the International Convention for the Prevention of Pollution of the Sea by Oil, 1954, called together by the Government of the United Kingdom. Resolution 1 of the 1954 Conference sought the complete avoidance, as soon as practicable, of the discharge of persistent oil into the sea. However, the Articles of the Convention were concerned with the discharge of oil or oily mixtures in which the oil content was 100 parts or more per 1,000,000 parts of the mixture (100 ppm). Oil was defined as persistent oil, that is, crude oil, fuel oil, heavy diesel oil and lubricating oil.

The Intergovernmental Maritime Consultative Organization (IMCO) was set up as a United Nations Agency in 1959. It convened a conference in 1962 to strengthen the 1954 recommendations. The main points of the 1954 Convention, as amended in 1962, are as follows: (1) the Convention applied to tankers of more than 150 gross tons and other ships of more than 500 gross tons, (2) such ships registered in participating countries were prohibited from dumping oil or oily mixtures within 50 or 100 miles of various coast lines and in specified prohibited zones such as the North Sea, the Baltic Sea and parts of the North Atlantic. (3) Ships exceeding 20,000 gross registered tons ordered after the 1962 amendments came into force were to recognize total prohibition of the discharge of oil except in special cases such as saving of life or preventing damage to the ship. (This has not been possible to implement for technical reasons.) (4) Sediment (dug out of tanks after washing) must no longer be dumped over board in prohibited areas. (5) Governments were required to take all appropriate steps to promote the provision of facilities for receiving oily mixture residues.

The original 1954 Convention had come into effect on July 26, 1958 and the 1962 amendments became effective on May 18, 1967.

Adherence to the IMCO resolutions was extremely difficult because of the limited development of both port reception facilities and on board pollution control devices. However, during the 1960's significant advances in the LOT system were realized and were reflected in the amendments to the Convention reached at the IMCO Assembly in 1969. The amendments recognized that some discharge of oil would take place under the LOT system and established standards within which this would be permitted. Oil could be discharged as long as the following conditions are all satisfied: (1) the tanker is preceding on route, (2) the instantaneous rate of discharge of oil content does not exceed 60 litres per mile, (3) the total quantity of oil discharged on a ballast voyage does not exceed 1/15,000th of the total cargo-carrying capacity of the ship, (4) the tanker is more than 50 miles from the nearest land. The 1969 amendments were intended to make the flow of oil sufficiently small that water turbulences caused by the ship would dilute the oil and further support natural biodegradation.[5] However, in November, 1973 it was reported that only twenty countries had signed the 1969 amendments which require thirty two signatures before they are effective twelve months later. Several countries had not signed the 1969 amendments because they wanted to achieve complete avoidance of the discharge of oil into the sea. Before examining the alternate means of preventing any discharge of waste oil into the sea it is appropriate to examine the general economic nature of the problem. Is the goal of "the complete avoidance of discharge of persistent oil into the sea" economically sound?

III. The Economic Nature of Controlling Tanker Pollution

In this section we examine some basic economic principles which underline the optimal regulation of pollution by tankers. Two principles of the problem are pointed out. First, the economically-optimal solution depends on a comparison of pollution costs with the costs of preventing pollution. The solution will depend on a number of variables and circumstances. No one global solution can be expected which will apply to all ships on all routes. Second, given any specific equipment or procedures adopted, it is not necessarily economically-optimal to equip all ships to the same extent. The total economic costs to the world community may be less if only a portion of the world's fleet are required to adopt the pollution-control equipment. These two principles overlap but it is convenient to discuss them independently.

(i) The Optimal Level of Pollution:

"Total Pollution Costs" can be related to the volume of oil trade (for some hypothetical route and ship type). Without any controls the amount of pollution would vary in direct proportion to the volume of oil traded. The popular concensus is that the sea can assimilate a certain level of pollutants and render them harmless but at some point the costs of pollution, however we would measure them, begin to rise. The popular view is probably that the pollution costs rise at an accelerating rate (i.e., first and second derivatives are positive). This is illustrated in Figure 1 by the Total Pollution Costs curve (TPC).

Alternatives to the Total Pollution Costs exist; we can prevent pollution. Consider the possibility of an all or nothing solution: suppose we can equip all ships with a device which would eliminate all pollution. For convenience, we assume the costs of pollution control per ship are the same regardless of oil trade volume (i.e., we assume no economies of scale in the manufacture of pollution prevention equipment). Therefore, the total cost of control or prevention rises at constant rate with volume of oil trade. This is labelled Total Control Costs (TCC) in Figure 1.

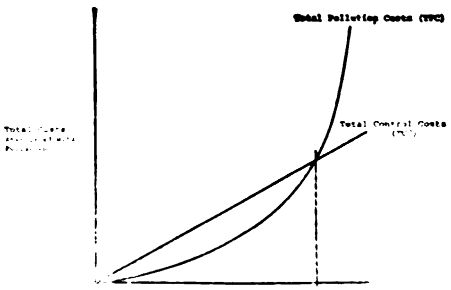
Figure 1 illustrates clearly that whether or not a ban on pollution is desirable depends on the volume of trade and pollution. Below trade volume V_1 the costs of pollution are less than the costs which would be imposed on the fleet in order to eliminate pollution.

Figure 1 refers to an "all or nothing" situation, which is unrealistic. An important modification must be made. The total costs of pollution may be viewed as the sum of pollution costs plus the costs of controlling or preventing pollution. The total social costs of pollution probably are minimized by a combination of some pollution costs and some expenditures on pollution prevention. This combination can appear in two forms: (1) by varying the proportion of ships equipped with pollution control equipment; and/or (2) purchasing cheaper but less effective pollution control equipment. These two approaches can overlap but we will discuss them separately.

Economists are suspicious of complete bans or blanket regulations of pollution because this does not recognize that some pollution may be the optimal policy. The economist's objective would be to minimize the total social costs associated with pollution whether these are the costs of pollution itself or the costs of preventing pollution. Figure 2 (Figure 1 redrawn) illustrates the "optimal" amount of pollution where there is only one type of control technology available. Total costs to society are minimized if we allow pollution to rise until the marginal costs of further pollution exceed the marginal costs of instituting pollution controls. Pollution is allowed to rise unchecked until volume V_2 but beyond that point ships must be equipped with pollution control devices because the cost of extra pollution exceeds the cost of added control devices. That is, the marginal cost of polluting exceeds the marginal cost of control (the slope of TPC equals the slope of TCC at volume V_2).

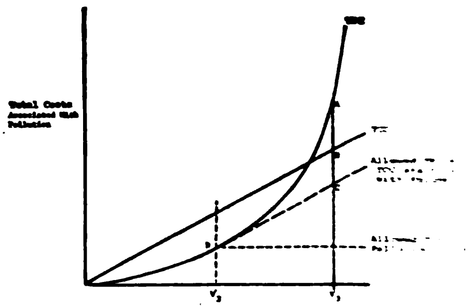
If the volume of trade is not yet greater than V_2 then installing equipment only on new ships would be optimal in the short run. In the long run an optimal solution would require some pollution to continue. If the trade is greater than V_2 it is necessary to devise some method of deciding which ships are to be equipped for pollution control, e.g., some method of issuing "licenses to pollute."

Consider volume V_3. Pollution costs are greater than control costs (Point A is above Point B). But the optimal policy is not to suddenly institute blanket controls (Point B). Instead, it is to determine the optimal amount of pollution and limit it to that level (Point D).



Costs of Pollution versus Costs of Pollution Prevention Related to the Volume of Oil Trade on a Hypothetical Route

FIGURE 1



Costs of Pollution, Costs of Pollution Prevention and Costs of Allowing Some Pollution.

FIGURE 2

Total costs are indicated by Point C, allowed TPC plus TCC starting from volume V_2. The required investment in pollution control is still volume dependent. The proportion of the world fleet to be equipped with controls rises as the volume of oil trade rises.

We now examine the second component in optimal pollution control, viz., the trade-offs between cheaper, but less effective, prevention systems. Figure 1 postulated a very limited technology, either 100 per cent effective control aboard ship or none at all. Generally, there is some choice between the level of costs and the effectiveness of alternate pollution controls. This can be illustrated by using a variation of Figure 1 and then developing a new diagram (Figure 4) to illustrate the problem in a more general way.

Figure 3 modifies Figure 1 by introducing an alternative to the 100 per cent versus zero per cent control of pollution. TPC_1 and TCC_1 are the same as in Figure 1. TCC_2 is the cost of incomplete pollution control devices which allow some pollution to occur (indicated by TPC_2). The pollution prevention control costs of this alternative are less (per ship) but they do not eliminate pollution entirely. These two new cost curves must be summed ($TCC_2 + TPC_2$) to compare with either of the cost curves in Figure 1.[6] For oil trade less than volume v_1 the optimal policy is to bear the pollution costs. Beyond v_1 but less than v_2, the moderate-pollution and moderate-cost pollution controls entail the lowest total costs. For high volumes, i.e., greater than v_2, the more costly complete-control system becomes the lowest cost solution.

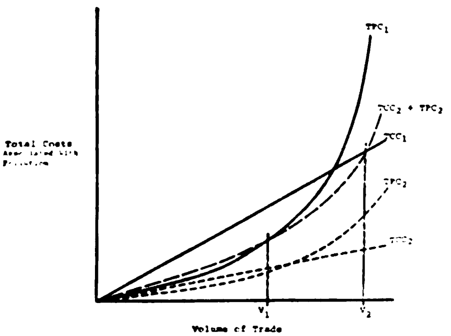
In sum, the conclusion illustrated by Figure 1 still applies. The best (lowest total cost) solution depends on the volume of trade (and therefore pollution). The greater the volume of trade, the greater the degree of pollution control which is optimal.

(ii) The Optimal Choice of Pollution-Control Technology:

In this section we address in more detail the issue of selecting from alternate pollution-control technologies. We continue to deal with a hypothetical trade route and ship type. The question of concern is what considerations would guide us to the optimal choice of pollution-control technology?

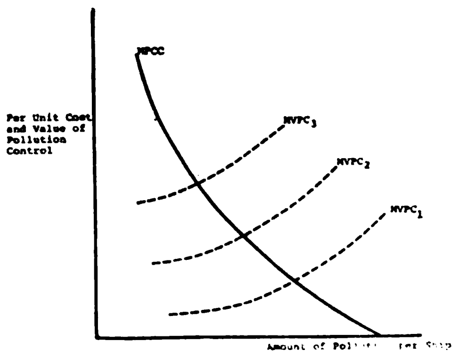
The marginal pollution control cost, Figure 4, portrays the trade-off between the costs expended per ship and the amount of pollution.[7] The shape of the curve reflects the assumption that modest control costs lead to substantial reductions in pollution from an initial point of no controls, but the control costs rise quite sharply as pollution standards become more strict. Each point on the marginal pollution-control cost (MPCC) curve of Figure 4 corresponds to the slope of one Total Control Cost (TCC) curve as in Figures 1 and 3. There is a family of TCC curves whose slopes are less positive (less cost per ship) as the techniques of pollution control are less effective. Therefore, the MPCC curve indicates the cost per ship of providing pollution-control devices of different degrees of effectiveness.

The MPCC curve in Figure 4 illustrates the range of choice of pollution control technology but it does not, by itself, indicate the most efficient choice. For that we must compare the marginal pollution-control cost (MPCC) with the marginal value or benefit of reducing pollution. The marginal value of decreased pollution is derived from the total costs of pollution which were illus-



Costs of Pollution, Costs of Complete Pollution Prevention, and Costs of Partial Prevention of Pollution

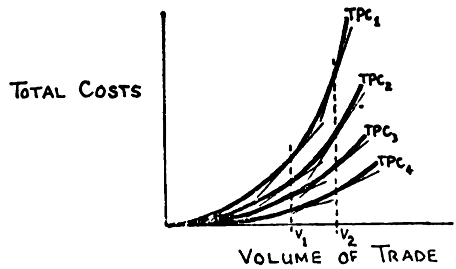
FIGURE 3



Optimal Choice of Pollution Prevention Technology

FIGURE 4

trated by the Total Pollution Cost curves in Figures 1 through 3. The marginal value of pollution control could be interpreted as indicating our willingness to pay to avoid extra pollution. This marginal value of pollution control (MVPC) will depend upon how serious the problem is, i.e., it will depend upon the volume of trade on a route, (as well as on several other route, ship, and market characteristics which affect the shape of TPC). Therefore, there is an MVPC curve for each volume of trade. The greater the volume, the greater the marginal value of pollution control. The MVPC for 3 volumes is illustrated in Figure 4. For a given volume, the slope of MVPC is positive. The greater the pollution per ship (resulting from less effective controls) the greater the marginal costs of pollution.[8]



The MPCC curve did not shift with volume because we assumed there were no economies of scale in pollution control equipment, i.e., the Total Control cost curves were linear with respect to the volume of trade and pollution level. Therefore the slope of each TCC curve is constant with increasing volume. The shift in the slope of the linear TCC curves as control effectiveness changes is non-linear as indicated by the shape of MPCC.

The optimal degree of pollution control is where the marginal value of pollution control (MVPC) intersects MPCC. This will vary between routes because routes have different trade volumes, and, therefore, different levels of "pollution problems."

(iii) Summary:

In summary, this section of the paper has developed an elementary framework for considering the problem of controlling the pollution of the sea by routine operations of ships. The conjectural pollution cost and control or pollution-avoidance cost curves indicated an optimal solution for a hypothetical route with homogeneous ships. Even in this simple framework we see that the optimal solution is not a unique answer but will depend on the volume of trade (and its accompanying pollution). The economically-optimal solution is not blanket regulation for all. For a single type of pollution-control technology the optimal policy would be to equip only a portion of the tanker fleet. This was illustrated in Figure 2. If there is a range of alternate control technologies of differing costs and effectivness, the optimal choice of technology is not unique but will vary with trade volume. This was illustrated in Figures 3 and 4.

The analyses of Figures 1 through 4 are for a hypothetical route and ship type. But TPC will vary for different routes and TCC will vary by ship type and market condition. Thus, in a world of heterogeneous routes and ships the optimal solution will differ from place to place. Simple, all-encompassing regulations are not likely to be the optimal policy.

Given that different countries own different types of ships operating on different routes and markets, it follows that the various countries will have particular interests which must be reconciled before agreements can be reached. Blanket regulatory control schemes would run afoul of these particular country interests. Even for "economically-optimal" solutions, the issue of who will bear the global costs entailed by controls is an important point for debate. It is one that must be resolved before a voluntary multilateral agreement to avoid polluting the seas can result. Simple and strong anti-pollution measures have a very limited chance of being adopted and enforced in this decision-making environment.

IV. Alternate Means of Eliminating the Discharge of Waste Oil into the Sea

The MVPC curve is the more speculative curve in Figure 4, as the valuation which society places on pollution prevention is unknown. The MPCC curve is a more promising target to pursue. By focusing on the costs of control technologies we can give some indication of what the value of pollution prevention must be to justify expenditures on control. Estimating a precise equation for MPCC is not possible but the MPCC curve does provide a useful focal point for discussion. In this section we summarize briefly the costs (and effectiveness) of the major alternative methods of alleviating oil pollution from routine tanker operations.

The problem of dumping waste oil at sea must be tackled within a systems framework. It cannot be addressed solely as a ship design problem but must be considered in a framework to include refineries, ports and ships. Design features which are recommended for ships must consider accidental spill hazards as well as oil pollution from normal operations.

The most obvious way to reduce oil discharge into the sea is to reduce the need for oil and water to be mixed together. This could be achieved by the use of segregated ballast tanks (tanks reserved solely for taking ballast water) and by diminishing the frequency of oil tank cleaning. Progress in the latter direction has been achieved, for example, by the use of new coatings for tank surfaces to reduce oil clingage and seals development. When oil and water mixtures are created during ship operations it is necessary to mitigate pollution effects by effective ship procedures and adequate port reception and processing capabilities.

Under the auspices of MCO, technical reports on the costs and effectiveness of the major alternatives for oil pollution prevention and abatement were prepared for the 1973 Conference. The studies were carried out by separate working groups comprising "lead" and associated countries and organizations in consultive status with IMCO. The five schemes examined are:[9] (1) retention of oil on board (primarily the "Load on Top" or LOT system); (2) segregated ballast tankers; (3) dual purpose tanks with means to isolate oil from water; (4) cleaning ballast tanks prior to vessel sailing; (5) retaining dirty ballast on board for in-port disposal at the loading port. Not all of these schemes individually would result in the complete elimination of dumping at sea. The major conclusions of these studies are summarized briefly.[10]

(1) Retention of oil on board: The study found that use of the lot system can keep the rate of oil discharge and the total amount discharged well within the 1969 amendment limits. The greatest weakness is that the system as now practiced relies too much on the human element. For example, crew judgment is often used to estimate when the oil content of discharged water is too high. Further, the use of the LOT system is restricted by the limited number of ports able to receive contaminated oil and the limited number of refineries willing to process it.

The study concludes that significant improvements could be achieved at an estimated 1971 cost of about $390,000,000 for the 1971 world fleet, by the universal adoption of recirculatory tank washing and the installation of adequate oily water separators with monitors and/or controls on overboard discharges. Amortized over several years, this expenditure would entail an insignificant increase in the required freight rates of tank ships. The cheapest and quickest way to reduce oil pollution would be through a more extensive and rigorous adoption of the LOT system.

(2) Segregated ballast tankers: This study examined the capital and operating cost of a new family of tankers constructed with different levels of segregated ballast capability. Such tankers would not have dirty ballast water to dispose of, but would still be faced with the problem of tank cleaning water. The provision of segregated ballast capability would increase the capital and operating cost of tankers. The amount of this increase would depend on the size of the tanker and the amount of ballast capability provided. The cost expressed as a percentage of the required freight rate (RFR) was estimated to vary between 3 and 25 per cent for the designs tested.

(3) Dual-purpose tanks with means to isolate oil from water: This study examines the feasibility of using impermeable membranes within tanks to isolate oil from seawater ballast. While the scheme was found to have economic potential, technical difficulties were identified which made it inappropriate to consider implementing it at this time.

(4) Clean tanks for ballast prior to vessel sailing: The study examines alternate procedures whereby a tanker would sail from the discharging port only with clean ballast. This would require cleaning certain tanks while the vessel is in port and discharging the oily water to a shore-side reception facility.[11] The cost of this system would add about one percent to required freight rates.

(5) Retaining dirty ballast on board for in-port disposal: This scheme envisages the provision of facilities for receiving dirty ballast by loading ports. The system could also be applied to the reception of tank cleanings. The estimated cost of providing the necessary port and ship facilities resulted in an increase in the required freight rate of a little less than one percent.

Some of the studies expressed the cost of a scheme per ton of pollution saved assuming that the tanker fleet was operating on the LOT system. For example, the annual cost of preventing one more ton of oil pollution, by taking on clean ballast in discharging ports, would be about $2,200.

Each of the studies is detailed but only provides cost estimates for a specific proposal. The studies were to provide a data base from which an overall assessment could be made before and during the 1973 Conference. The results of those deliberations were the regulations and resolutions passed at the International Conference on Marine Pollution, 1973.

V. International Convention for the Prevention of Pollution from Ships, 1973

The 1973 Convention is a substantial advance over previous agreements. When it comes into effect it will replace the 1954 Convention and amendments. The definition of "oil" is extended to include light products as well as crude and heavy products. The regulations include measures to reduce the generation of shipboard oily mixtures, to improve the effectiveness of the LOT system, to speed up the provision of port reception facilities for oil-water mixtures, and to introduce more effective means of gaining compliance by ship owners. The Convention will come into effect 12 months after it has been signed by not less than 15 states; whose combined merchant fleets constitute not less than fifty percent of the gross tonnage of the world's merchant fleet. The main regulations for the prevention of pollution by oil include:

(1) All tankers of over 150 gross tons will be required to undergo an initial survey and then periodic surveys at least every five years to obtain and maintain an International Oil Pollution Prevention Certificate.

(2) An oil tanker will be prohibited from discharging oil or oily mixtures into the sea except when either: (a) the tanker is proceeding en route; (b) the tanker is more than 50 miles from land; (c) the instantaneous rate of discharge of oil content does not exceed 60 litres per nautical mile; (d) the total quantity of oil discharged does not exceed 1/15,000 for existing and 1/30,000 for new tankers of the cargo of which the residue is a part; (e) the tanker has in operation approved discharge control systems; (f) the tanker is not within a special area; or: the tanker is discharging waste oil from machinery space bilges only. In this case a tanker proceeding en route, not in a special area, more than 12 miles from land may discharge providing it has approved discharge control systems and the oil content of effluent is less than 100 ppm.

(3) Within special areas (Mediterranean, Baltic, Black and Red Seas and "Persian Gulf area") no discharge of any oil or oily mixture will be permitted, subject to the provision of adequate reception facilities for dirty ballast and tank washing water at the ports of parties to the Convention with coastline on the special areas. In the absence of special facilities the open sea regulations apply ((2) above). For the Mediterranean, Black and Baltic Seas signatories would undertake to ensure the availability of facilities by January 1, 1977. In the Red Sea and Persian Gulf the undertaking would be to provide facilities "as soon as possible."

(4) Governments would be required to ensure the provision of facilities for the reception of residues and oily mixtures.

(5) Every new tanker[12] of 70,000 tons deadweight and over shall be provided with segregated ballast tanks of sufficient capacity to provide adequate operating draught without the need to carry ballast in cargo tanks.

(6) All tankers of 150 gross tons and over will be provided with oil discharge monitoring and control systems and slop tank arrangements. In the case of existing tanker these shall be provided within three years of the coming into force of the Convention. The capacity of the slop tank (at least two tanks for new tankers over 70,000 dwt) shall be not less than 3 percent of the oil carrying capacity of the ship (or 2 percent for segregated ballast tankers).

(7) Oil-water separators, discharge monitoring and control systems are to meet approved standards recommended by IMCO in 1971 (Resolution A.233 (VII)).

(8) All tankers of 150 gross tons and over must maintain an Oil Record Book.

VI. Issues raised by the Regulations for the Prevention of Pollution by Oil, 1973

(a) What goal should be appropriate for IMCO pollution control measures?

Resolution 1 of the International Conference on Prevention of Pollution of the Sea by Oil, 1954 called for "The complete avoidance as soon as practicable of discharge of persistent oil into the sea." This was reaffirmed by the 1962 Conference. The main objective adopted by Resolution A237(VII), 1971, for the International Conference on Marine Pollution, 1973, was ". . . the achievement, by 1975 if possible but certainly by the end of the decade, of the complete elimination of the wilful and intentional pollution of the seas by oil and noxious substances other than oil, and the minimization of accidental spills." This objective was reaffirmed by the 1973 Conference, Resolution 1.

The difference between the 1954 and 1971 resolutions is important. The later Resolution allows some oil to be discharged into the sea. This is consistent with the economic framework explained in this paper. It recognizes, firstly, that absolute prohibition may be appropriate in some areas but not on a global basis. Secondly, under existing technological and economic conditions water from oily water mixtures must be disposed of at sea and it is not realistic to expect "complete avoidance" of some droplets of oil being placed in the sea.

Therefore, the issue which exists now is what is "pollution" and what economic value should be placed on alternate levels of pollution control. Resolutions 6 and 12 passed at the 1973 Conference recommend that IMCO participate in further studies on the problem created by oils discharged into the sea. In particular, Resolution 12 recommends that IMCO working with other groups (notably the Joint Group of Experts on the Scientific Aspects of Marine Pollution) examine the method and procedure necessary to establish water quality criteria for the protection of the marine environment. Since the means of protecting the marine environment will cost money, it is important that organizations and countries also give consideration to the economic cost and value of different levels of environmental quality.

The current orientation of IMCO objectives appear to allow some flexibility in standards. This is consistent with the economic framework developed in this paper and the realities of international shipping operations and international agreements.

(b) What is the cost of the regulations passed at the 1973 Conference?

We are unaware of cost estimate for the standards set in the 1973 Convention for the Prevention of Pollution by Oil. The studies carried out prior to the Conference were on specific and separate aspects of ship design and operation and on specific facilities for ports. The cost implications of the individual studies were summarized in section IV. However, no estimate has been made public of the possible cost of the specific combination of regulations contained in the 1973 Convention. It would be difficult and time consuming to make such an estimate. But it seems important for this research to be done both on a regional and global basis. Without such an assessment it will be difficult to appraise the economic and environmental consequences of adoption. The speed with which individual countries become parties to the Convention will be influenced, no doubt, by their perception of economic costs as well as the environmental effects of the regulations. Knowledge of the costs imposed by the 1973 regulations will have an important influence on future decisions.

(c) How are the costs and benefits of the regulations distributed?

Since the costs of the regulations are not known it is not surprising that the distribution of costs among shipowners, port operators and different nations is not clear. The application of different standards to heterogeneous sets of vessels, e.g., between existing and new ships, is bound to have differential effects on the economics of individual vessels, corporations, and national shipping interests. To determine these effects the costs of operating different sized vessels, on different trade routes with and without the features required by the IMCO Regulations needs to be examined. It would be particularly useful if the incremental costs of pollution control measures could be determined. Our theory tells us that the incremental costs and benefits will vary by route. What effect this will have in practice on the willingness of particular countries to sign the Convention is not known. It could also result that the pollution of seas adjacent to some countries would impose such high cost that those countries might be interested in raising control standards higher than those recommended by IMCO. The political, economic and, not least, the legal implications of such intentions are most uncertain. (The legal issues of international control are one of the substantial areas to be discussed at the Law of the Sea Conference in Caracas later this year.)

(d) When might the 1973 Convention be in effect?

Unfortunately to attempt an answer to that question would be idle speculation! However, it is known that hundreds of millions of dollars need to be spent both on ships and in ports. Since the discharge of oil comes from ships, there is a danger that the public will not give sufficient attention the provision of adequate port facilities. Table 2 shows the substantial need which exists for improved facilities in many ports of the world. It is particularly noticeable that the oil exporting countries have lagged behind most in the provision of reception facilities. And it is at these ports that facilities to receive oily water would be most useful from the shipowner's viewpoint.

Future economic conditions will no doubt affect the rate at which countries sign the Convention. For example, higher oil prices will encourage conservation and make the discharge of oil at sea less desirable financially. On the other hand, a depressed condition in the shipping industry, which is now forecast for tankers, will make owners far more reluctant to install expensive capital equipment and to adopt costly operating procedures.

FACILITIES IN PORTS FOR THE RECEPTION OF OIL RESIDUES

Country	Storage Capacity of Reception Facilities[a] metric tons	Storage Capacity as Percentage of Oil Trade Tonnage[b]
Algeria	92,500	N.A.
Australia	103,370	0.16
Belgium	99,950	0.37
Brazil	21,600	N.A.
Canada	108,800	0.31
Denmark	15,150	0.14
W. Germany	36,500	0.03
Finland	41,500	0.46
France	167,000	0.15
Greece	38,900	0.8
Ireland	172,300	5.5[d]
Israel	98,550	0.11
Japan	310,140[c]	0.14
Netherlands	391,300	0.52
New Zealand	19,000	0.62
Norway	23,100	N.A.
Spain	50,200	0.14
Sweden	52,300	0.43
U.S.S.R.	192,800	N.A.
U.K.	497,400	0.44
U.S.A.	1,073,900	1.65

a. Totalled from "Facilities in Ports for the Reception of Oil Residue" IMCO, London, 1973. The survey was carried out in 1972.
b. Figures for total sea-borne international oil trade were obtained from, "World Trade Annual: 1971," vol. 2, Statistical Office of the United Nations, New York, 1973.
c. Many of the ports in Japan can only accommodate vessels of less than 30,000 dwt. Storage capacity in these ports is 138,000 metric tons compared with 172,000 m.t. in larger ports.
d. The high percentage for Ireland is accounted for by the large reception facility of Gulf Oil at Bantry Bay, a transhipment port.

TABLE 2

VII. Summary and Directions for Further Research

This paper provides an introduction to the pollution problem associated with the deliberate discharge of oily wastes during routine tanker operations. This is the major source of oil in the sea from tankers although land-based sources are the major contributors to oil in the sea.

An economic framework is developed for analysing the control of pollution of the sea by ships. This elementary analysis shows that simple, all-encompassing bans on the dumping of oil are not economically efficient. The paper outlines the major methods for limiting the discharge of oil at sea and provides some information on the economic impact of adopting alternative technologies. The 1973 International Convention for the Prevention of Pollution from Ships is examined in the light of our economic framework. There are important differences between the 1973 Convention and the agreement which is currently in effect. However, it is apparent that very little is known about the economic impacts of the provisions contained in the 1973 Convention. The likelihood of the Convention's ratifications and the position taken by various countries will be influenced by the size and distribution of the costs and benefits. Investigations into these topics is an important and promising area for research.

Our own further research (a joint programme now underway between the University of British Columbia and The Institute for Shipping Research, Bergen) will be addressing several of the questions raised above. First of all, we wish to estimate the incremental cost effectiveness of the individual technological requirements of the Convention. For example, it is important to know the incremental cost-effectiveness of segregated ballast tankers assuming the LOT system is used effectively and adequate port reception facilities are available.

The second research topic is to estimate the distribution of the benefits and the costs of implementing the Convention. The costs will fall unevenly on shipowners, depending on the characteristics of their fleet, and on ports, depending on the facilities to be provided. The benefits too, will vary depending on the trade, shipping and environmental factors. It is most unlikely that the benefits and costs will be distributed in a similar manner. Knowledge of the distribution of benefits and costs may help us understand the position of different countries regarding the adoption of the Convention.

A third, and more general area of our research is a further analysis of the economic theory applicable to international pollution control. The simple analysis developed in this paper needs to be expanded to deal with a variety of complications regarding the distribution of the benefits and costs of pollution control measures. We also seek to clarify the role of economics in understanding the difficulties of reaching pollution control agreements through international negotiations among sovereign nations.

Research into the above questions will be of value in understanding the important international issues concerning pollution of the sea.

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The authors assume full responsibility for the end result.

FOOTNOTES

1 A typical 100,000 dwt tanker has about 25 acres of tank surface.

2 For a basic explanation of tank cleaning see G.A.B. King, Tanker Practice, (6th ed., London: Maritime Press, 1971) pp. 100-112.

3 "Tanker Explosion Inquiry," Seatrade, Vol. 3, No. 2 (February, 1973), p. 36.

4 Seaborne oil trade was 225 million metric tons in 1950 and 1410 million metric tons in 1970.

5 It should be noted that the 1969 amendments changed the definition of oily mixture from an oil content 100 ppm to "a mixture with any oil content." Oil was still defined as crude, fuel oil, heavy diesel oil and lubricating oil.

6 The point illustrated in Figure 2 (that it was optimal to equip only a portion of the fleet with pollution prevention equipment) is ignored in Figure 3. This is because the analysis of Figure 2 becomes less important now and may be no longer correct. Figure 2 was confined to the situation where there was no tradeoff among technologies with differing costs and effectiveness. If tradeoffs exist, total social costs generally will be less if all ships are equipped with cheaper less effective, control devices than if some ships are exempted from controls and the remaining fleet are equipped with more costly, more effective, equipment. (This is based on the assumed shape of the marginal pollution control costs curve developed in Figure 4).

7 Some of the expenditures would be for port facilities rather than aboard ship.

8 The MVPC is the slope of a family of total pollution cost curves (Figures 1 through 3) for a given volume. For an increased volume the slope of each TPC curve is greater, therefore, the MVPC shifts upward.

9 There are some other possible approaches. For example, there have been experiments of breeding microorganisms which will attack and break-down oil mixed with water. After the oil is consumed the organisms die and are consumed by other aquatic life. The feasibility of this approach is still quite uncertain and was not examined by IMCO.

10 A more detailed summary of the findings of these and other studies is contained in the IMCO (Intergovernmental Consultative Organization) document MP/CONF/INF.2, 7 May 1973 entitled "Summary of Reports on Nine Studies to the Problem of Marine Pollution Prevention and Abatement."

11 It should be noted that any scheme involving port facilities transfers the disposal problem from the ship to the port. While centralized port facilities can separate oil and water effectively the small quantities of oil remaining in the water may be disposed of close to land.

12 "New ship" means a ship: contracted after 31 December, 1975; or keel laid after 30 June, 1976; or delivered after 31 December, 1979; or which has undergone major conversion with the above dates applicable. These dates are not conditional on the date on which the 1973 Convention comes into effect.