AN ECONOMIC ANALYSIS OF OCEAN DUMPING

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1. Introduction

Historically, the Atlantic, Pacific and Arctic oceans have played a critical role in Canada's economic, social and cultural development. Canada has the longest coastline in the world at 243,797 km and an exclusive economic zone of 4.7 million km^2 (Wells and Côté, 1988). In addition to providing a habitat for a vast number of marine species, the oceans sustain major fisheries, industries such as offshore oil and gas, energy and non-renewable mineral resources, transportation, shipping, ship-building as well as oceans-related manufacturing and services (Government of Canada, 1991c). Furthermore, the oceans support tourism, recreational activities as well as the traditional lifestyles of maritime and native communities.

It is estimated that in 1988 alone, approximately 165,000 jobs and over $6 billion of Canada's national income could be attributed to oceans-related industries, of which fisheries accounted for 48% of the national income and almost 75% of the jobs (Government of Canada, 1991c). More specifically, Table 1 shows the estimated income from, and employment in various industries undertaking oceans-related activities. The total estimated income represents approximately 1.1% of Canada's 1988 Gross Domestic Product and the total estimated jobs represent approximately 1.6% of the average employment level of the same year.[1] In addition to these income and employment aspects which are relatively easy to estimate, one must also consider the value of the social, cultural and ecological components which are not easily estimated, but which certainly contribute greatly to the value of the oceans.

Table 1
Estimated Income From, and Employment in,
Selected Oceans-Related Industries

Industry	Year	Income ($billions)	Employment[a] (000's)[b]
Fisheries	1988	3.2	123.0
Oil and Gas	1988	0.3	1.6
Marine Shipping	1988	2.3	23.8
Shipbuilding and Ship Repair	1988	0.5	10.5
Oceans-related Manufacturing and Services	1986	0.3	6.2
Total		6.6	165.1

[a] Represents jobs and not necessarily person-years of employment.
[b] Data are for 1987.

Source: Department of Fisheries and Oceans, 1987, cited in Government of Canada, 1991c, 4-5.

As with many other natural resources, the oceans have been perceived as common property. As pointed out by Coase (1960), a common property resource, which by definition is not owned by anyone, will not be efficiently used and consequently, the oceans have been exploited by many nations. However, the responsibility for the health of the oceans in terms of an acceptable level of marine quality, has neither been allocated to, nor taken by, any nation. The oceans are often perceived as inexhaustible, able to provide an unlimited amount of resources and able to absorb an infinite amount of pollutants. In reality, the negative pressures we are exerting on our oceans through various forms of pollution are increasingly degrading the marine environment. They are threatening the delicate global balance upon which the survival of all species depends, as well as the benefits that can be derived from the oceans.

Marine pollution is generally categorized into three groups - land-based, vessel source and ocean dumping. The latter is considered to be different from the other forms of marine pollution because it involves the transportation of wastes on a vessel followed by the intentional discharge of wastes into the ocean. Ocean dumping is legally defined as:

- Any deliberate disposal at sea of wastes or other matter from vessels, aircraft, platforms or other man-made structures at sea.
- Any deliberate disposal at sea of vessels, aircraft, platforms or other man-made structures at sea.[2]

As ocean dumping is deliberate, it is arguably amenable to a considerable degree of administrative, legal and technological control (Hughes, 1988). The reason is that since agents in principle must obtain a permit before dumping a material, the types of materials can be controlled before they are dumped. Furthermore, if we are aware of the potential for serious environmental harm, we may be able to deal with issues less expensively now, rather than later, when harm to the environment has already occurred.

The purpose of this paper is to examine ocean dumping from a theoretical and practical perspective in order to assess the ways in which the negative impacts on the marine environment can be most effectively controlled. Economic theory is used to analyze the various categories of substances that are dumped, with specific reference to three industry cases. The effectiveness of several policy instruments is discussed based on the theoretical analysis.

2. Background

2.1 Types and Volume of Ocean Dumping

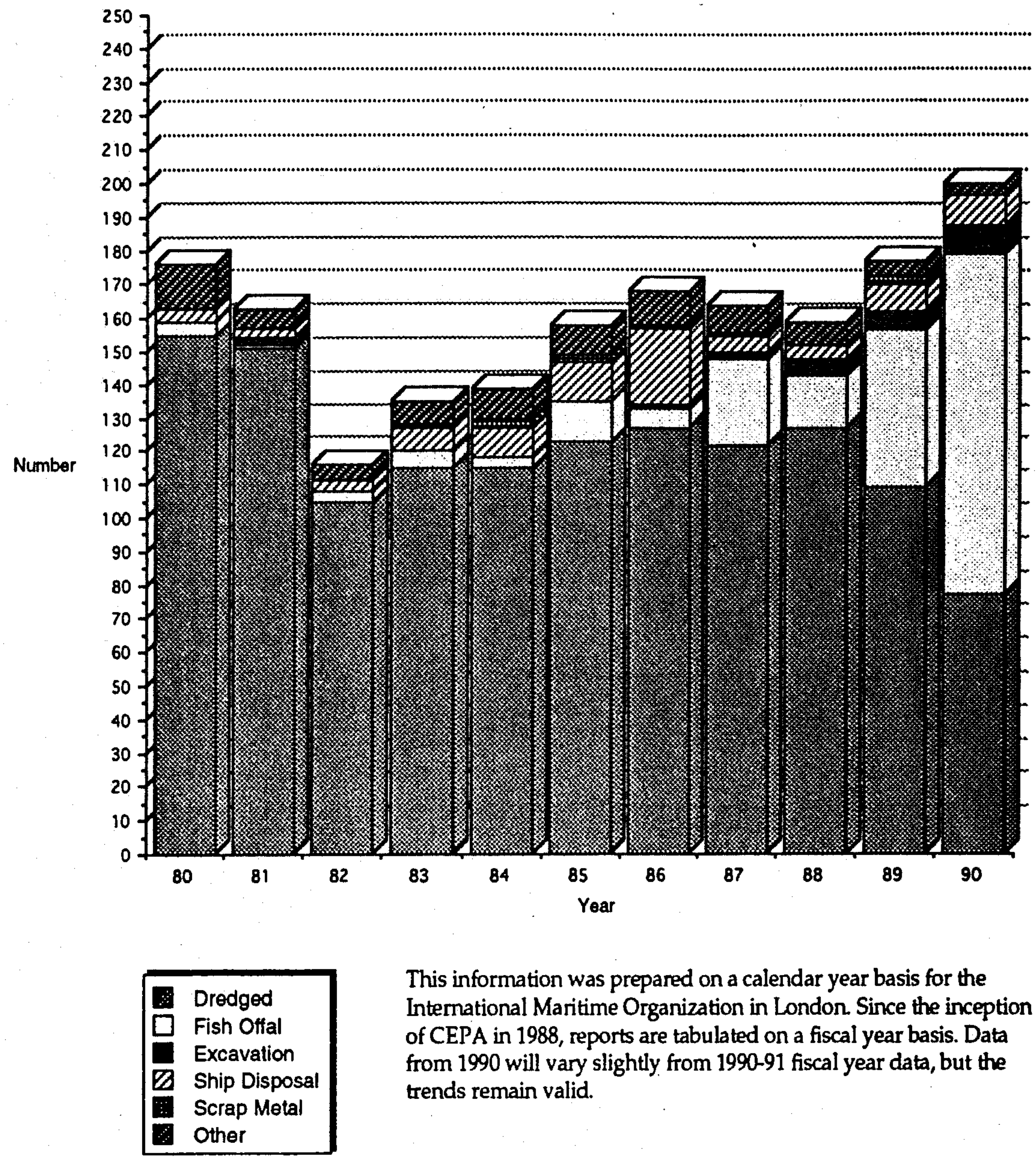
The use of the oceans as a receptacle for waste was virtually unregulated before 1972. The types of substances that were dumped included:

> radioactive wastes, nerve gas, arsenic, construction and demolition debris, sewage sludge, garbage and trash, dredge spoil, acids, pesticides, explosives, biological and chemical warfare agents, heavy metals, polychlorinated biphenyls (PCB's), pharmaceuticals, various hydrocarbons, vessels, herbicides, benzene, organic wastes, poisons, fish offal, detergents and various solid objects.[3]

Since then, there have been numerous conventions and international agreements to place limits on the use of the oceans as a disposal alternative. In Canada, the substances that are presently dumped consist primarily of dredged material, fish offal, excavation material, construction rubble, vessels and scrap metal (Government of Canada, 1992a).

Ocean dumping is federally regulated, whereby a permit is required to dispose of any substance in Canada's waters. Due to informational problems, data on the number of permits issued must be relied upon as a quantitative indicator of how much is dumped.[4] Table 2 shows the number of permits that were issued for ocean dumping between 1980 and 1990, and Table 3 shows the permits issued in 1990 - 1991 as indicated by the 1990 - 1991 report of the Canadian Environmental Protection Act (CEPA) (Government of Canada, 1992a). In addition, Tables 5, 6, 7, 8, and 9 of the appendix indicate the quantities measured in tonnes, of dredged material, fish offal, excavation and construction material, ships and scrap metal, for the permits issued between 1980 and 1990 (Government of Canada, 1992a).

Table 2
Number of Permits Issued in Canada Between 1980 and 1990



This information was prepared on a calendar year basis for the International Maritime Organization in London. Since the inception of CEPA in 1988, reports are tabulated on a fiscal year basis. Data from 1990 will vary slightly from 1990-91 fiscal year data, but the trends remain valid.

Source: Photocopied from Government of Canada, 1992a, 32.

Table 3
Ocean Dumping Permits Issued in 1990-1991

Material	Quantity	Percentage of Total Quantity	Number of Permits	Percentage of Total Permits
Dredged Material	4,404,200 m^3 or 5,725, 460 t	69.2	77	39.9
Fish Offal	157,824 t *	1.9	95	49.2
Excavation Material	2,374,750 t	28.7	9	4.7
Vessels	2,937 t	less than 1	9	4.7
Gypsum (wallboard)	10,000 t	less than 1	1	0.5
Test Burn	n/a **	--	1	0.5
Cement Pier	222 t	less than 1	1	0.5
Total	8,271,193 t	100	193	100

* This does not include 10 "load only" permits issued for loading herring waste, but does include shellfish waste.

** Permit issued to a barge-mounted incinerator to test compliance with federal air emission guidelines.

Source: Government of Canada, 1992a, 29.

In total, 193 permits were issued in 1990 - 1991 and the total estimated amount of material was 8.3 million metric tonnes (t) (Government of Canada, 1992a, 30). Of the total number of permits issued, approximately 40% were for dredged material, which includes rocks, gravel, sand, silt, clay and wood wastes. Furthermore, 49% of the permits were issued for fish offal which includes shells, herring waste and fish processing waste water. 4.7% were issued for excavation material and the remaining permits were issued for vessels, a cement pier and gypsum wallboard (Government of Canada, 1992a, 30).

However, the percentage of the total volume is not reflected by the number of permits issued in each category. Dredged material totalled 5.7 million t, or 69.2% of the total volume. The total volume of fish offal was 0.2 million t or 1.9% of the total quantity, excavation material constituted 2.4 million t or 28.7% of the total quantity, and other permits made up less than 1% of the total quantity of materials for which dumping permits were issued (Government of Canada, 1992a, 30). As dredged material, fish offal and excavation material account for 99.8% of the total quantity dumped and 93.8% of the total permits issued in 1990 - 1991, the analysis of this paper concentrates on these three categories.

The tables also indicate an increase in the number of permits issued for materials other than dredge spoil. This increase is attributed to the rise in the amount of permits that have been issued for fish processing waste (Government of Canada, 1991c, and Government of Canada, 1992a). Both the State of the Environment Report issued by Environment Canada in 1991 and the CEPA Report for 1990 - 1991, do not attribute this increase to a rise in the amount of dumping activity, but rather, to an improved awareness within the fish-processing industry of the need for a permit. This realization serves to further emphasize the problematic nature of data in this area, highlighting the fact that the figures on the number of permits issued, are not necessarily an accurate reflection of the actual amounts, nor the types of substances that are being dumped into the oceans.

2.2 Effects of Ocean Dumping

The great number of substances involved in marine pollution, as well as the complexity of biological processes in the ocean, make it difficult to determine precisely what the effects of ocean dumping are on marine life and the ecosystems in general. Nevertheless, negative effects have been observed as both a quantitative and qualitative reduction of marine resources, including reduced community size or diversity, reduced growth or reproductive capability and increased health-related deformities (OceanChemGroup, 1989). Generally, the effects can be categorized as physical, chemical and biological (Government of Canada, 1989).

With respect to the physical effects, ocean dumping may result in the destruction of marine habitat through the smothering of a specific area (Government of Canada, 1989). This type of environmental damage occurs when solid wastes such as wood residues, cover the sea floor, thereby smothering aquatic life underneath. Another potential physical change involves the disruption of the bottom currents or the dispersion of contaminants associated with sediment (Government of Canada, 1991c). However, there are cases in which the physical effects may be positive. For example, dumping concrete blocks or other large objects may create an artificial reef, thereby establishing a new habitat for marine life.[5]

The chemical changes to the ocean may include an increase of particular elements, some of which may be of a different form than those which occur naturally. There may be a depletion of oxygen as a result of the natural biodegradation of wastes (Government of Canada, 1989) or as a result of algae blooms that may occur if there are nutrients contained in the dumped substances (Munro, 1992).[6] It is also possible that "blooms of toxic phytoplankton species can be taken up by commercially viable shellfish, making then temporarily unfit for human consumption" (Government of Canada, 1991c, 4-5).

There are also potential biological effects associated with ocean dumping such as the bioconcentration or bioaccumulation of certain substances in organic materials as toxins accumulate in the tissues of animals. Furthermore, biomagnification, which refers to an increase in the concentration of the contaminant through the food chain, may also occur (Government of Canada, 1989). These biological considerations as well as the potential chemical effects as discussed above, may have enormous negative consequences.

In Canada, dredged material accounted for almost 70% of the substances dumped into the ocean in 1990 - 1991 (Government of Canada, 1992a). Theoretically, dredged material should consist of clean silt and sand, and thus the effects associated with dumping should primarily be physical, and limited to the area upon which the material is dumped. However, most dredging activity is done near municipalities and industries, where there are numerous sources of pollution. These sources include industrial facilities, sewage treatment plants, urban runoff, rivers, pipelines, coastal facilities, as well as atmospheric sources, and their effluents may contain among other substances, heavy metals, synthetic organic compounds and petroleum hydrocarbons (Gringalunas and Opaluch, 1989, 318).

The concerns with the adverse effects of ocean dumping involve environmental, health-related, as well as economic considerations. In addition to the contamination of many species of wildlife, there are potentially harmful effects on humans through direct contact with the contaminants, or consumption of contaminated seafood. Furthermore, there may be a reduction of property values in coastal areas and contamination may affect recreational and commercial fisheries as a result of a "direct lethal effect on adult fish and shellfish, juveniles, eggs and larvae" (Gringalunas and Opaluch, 1989, 318). Ultimately, ocean dumping may result in the closure of fisheries, entailing negative effects on local economies in terms of employment, prosperity and the survival of traditional lifestyles. This is of particular concern in regions such as the maritimes where the economy depends heavily on marine resources and marine-related industries.

Despite the serious negative consequences of ocean dumping, domestic and global pressures to continue using the ocean as a disposal option are increasing. A rising global population, rapid industrial expansion and a lack of adequate disposal facilities on land, are increasing the demand for the ocean as a disposal alternative. In addition, the cost of land-based disposal is rising as a result of more stringent environmental regulations (Hughes, 1988). Finally, ocean dumping is attractive because the pressure from local residents is less than that of residents opposing a disposal facility in their immediate area. Thus, politically, ocean dumping is more easily accepted than alternative disposal options. Therefore, despite the consequences of dumping substances into Canada's oceans, the oceans are often perceived to be an appealing disposal alternative.

2.3 An Overview of the Problem: Ocean Dumping in Canada

Although the dangers of oils in the marine environment were specifically acknowledged by the 1950's, ocean dumping was only recognized in the 1958 Geneva Convention on the High Seas in terms of the dumping of radioactive wastes (Kunig, 1980). It was not until the 1960's, following a number of serious events including "the 1970's U.S. Open Chase nerve gas dumping in 1969 and the Dutch proposal to dump chemical wastes in the North Sea in 1970" (Hughes, 1988, 160) as well as the concern of Nordic countries over the publicised plans of several European countries to dump industrial effluents (Boelens, 1988), that there emerged an increased awareness of the seriousness of waste disposal in the ocean.

By 1972, the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (the London Dumping Convention or LDC) was established. When it finally came into force in 1975, it represented the first global agreement that specifically dealt with issues related to the dumping of wastes into the oceans (Boelens, 1988). The LDC categorizes substances in terms of their level of toxicity. Particular substances are prohibited and others are strictly limited. In addition, factors that must be taken into account when assessing the level of toxicity to the environment are outlined (OceanChemGroup, 1989). The LDC applies to all marine waters except internal waters of states, although flag, port and coastal states have some authority over what is dumped in waters under their jurisdiction (Hughes 1988). The LDC is intended to encourage judicious decision-making with respect to the marine environment and has served as a legal framework for signatory countries to develop and implement their own ocean dumping programs and criteria.

In 1975, the principles of the LDC were implemented in Canada through the Ocean Dumping Control Act (ODCA), which prohibited the disposal of toxic substances in the ocean, unless there was evidence that they could be "rapidly rendered harmless in the marine environment" (Tay, 1989, 595). Furthermore, Regional Ocean Dumping Advisory Committees, with representatives of Environment Canada and the Department of Fisheries and Oceans, were established in each of Canada's five regions to review ocean dumping applications (Waldichuck, 1988). On June 30, 1988 the ODCA was replaced by Part VI of the Canadian Environmental Protection Act (CEPA). The full title of CEPA is "An Act respecting the protection of the environment and of human life and health," and with this objective as its focus, the government has determined various environmental quality guidelines as well as codes of practice for the handling of toxic chemicals. Some of the key issues of CEPA that pertain the most to the ocean dumping issue are:

-provisions to control all aspects of the life cycle of toxic substances from their development, manufacture or importation... and their ultimate disposal as waste

-provisions to regulate federal works, undertakings and federal lands and waters, where existing legislation administered by the responsible federal department or agency does not provide for the making of regulations to protect the environment

-provisions to create guidelines and codes for environmentally sound practices as well as objectives setting desirable levels of environmental quality

> -provisions to issue permits to control dumping at sea from ships, barges, aircraft and man-made structures...

Source: Government of Canada, 1988b, 13-14.

CEPA applies to Canada's territorial sea (12 miles), internal Canadian waters, except fresh waters, fishing zones, any exclusive economic zone that may be created by Canada, Arctic waters, any area of the sea under foreign jurisdiction except internal waters, and any area of the sea, other than internal waters, not mentioned above (Government of Canada, 1988a).

The "polluter-pay" principle is intended to underline CEPA's approach such that polluters must compensate for the environmental damage they cause. To this end, CEPA combines elements of both 'ex ante' regulation and legal liability.[7] With respect to the regulatory approach, the disposal of wastes in the oceans is regulated by a system of permits as previously discussed, whose terms and conditions vary according to the material in question (Government of Canada, 1989).[8] Table 10 of the appendix outlines the categories of substances related to ocean dumping included under Part VI of CEPA. In addition, when considering an application for a permit, Environment Canada is supposed to take into account the:

> toxicity to marine organisms, contamination of sediments or other materials, bioaccumulation, habitat smothering, potential for odour, foaming, and release of debris, and possible disruption of economic activities such as fishing and navigation (Government of Canada, 1991c, 4-11).

Anyone requesting a dumping permit must undertake an investigation to characterize the wastes and justify the use of the sea for disposal purposes. The polluter-pay principle seems to be applied directly as a fee for these ocean dumping permits and indirectly through the costs of complying with the regulations and conditions.

Furthermore, there is an 'ex post' application of the polluter-pay principle in the sense that permittees are strictly liable for any damage to the environment that results from dumping. Consequently, if they are found to have caused the damages, then a fine is imposed by the court. Theoretically the fines should equal the magnitude of the environmental damage. However, an examination of the fines that have actually been levied (Table 4), indicates that the courts do not seem to be relying heavily on legal liability as a deterrent to dumping. The following sections will focus on a theoretical analysis of the ocean dumping problem followed by a discussion of how CEPA is intended to control ocean dumping as well as the limitations of the theoretical approach.[9]

Table 4
Ocean Dumping Cases Under the Canadian Environmental Protection Act

Company Name	Status	Offence Date and Location	Date Charged	Court Date	Result	Penalty	Notes
Daley Brothers Fish Plant and Ralph Dobbin, Nfld.	Concl.*		92/04/30	92/05/25	Guilty Plea	$500 Fine.	
Bay Bulls Sea Product, Nfld.	Concl.	89/07/05 Bay Bulls, Nfld.	89/11/17	91/03/20	Guilty Plea	$3,000 Fine.	Crown recommended a $5,000 fine but Judge considered that the material was not oil, just fish waste.
Beaver Marine Construction Group, N.S.	Concl.	Newcastle, N.B.	90/04/26	90/04/04	Guilty Plea	$2,000 Fine.	
Cheticamp Packers, N.S.	Concl.	Cheticamp, N.S.	88/08/04	89/04/28	Guilty Plea	$1,500 Fine. $750 per charge.	
Harry Lowell Newman, N.S.	Concl.	88/09/19, Yarmouth	88/12/02	89/04/12	Conviction	$500 Fine.	
Richard Thibodeau, N.S.	Concl.		88/11/03	89/02/13	Acquitted		
Wilfred S. Deveau, N.S.	Concl.	Cheticamp, N.S.	88/08/04	88/12/13	Guilty Plea	$500 Fine.	
Gervais Dubé Inc., Quebec	For Trial	90/10/00-90/12/00 Carleton, Quebec	92/02/00	Trial date to be set.			

Raymond Murray and the Dept. of Public Works	Concl.	90/06/01 - 90/08/31 Havre-aux-maisons, Ile de la Madeleine	91/04/25	92/04/15	Guilty Plea.	A fine of $1.00 without costs. Public Works was ordered to bury and eliminate garbage on Ile-de-le-Madeleine for no less than $100,000. The work must be completed by June 4, 1993 and will be evaluated by Environment Quebec.	The amount of $100,000 is the largest penalty since the beginning of CEPA. The charge against Raymond Murray was withdrawn.
Aqua Clean Ships Ltd., Pacific Incinerators Ltd. and Alan G. Price, B.C.	Before the Court	90/07/5-7 North foot of Nanaimo St. Vancouver 49 18'N, 123 03'W	90/10/02	Started 91/06/17	For Trial	N/A	There have also been court dates in Aug. 91, Sept.91, Oct. 91, Nov. 91, Dec. 91, Apr. 92, May 92 and June 92. At the end of 1991, there were 31 days of trial which makes this case the longest environmental trial under criminal proceedings in B.C. history. Mr. Price has appealed, unsuccessfully, an earlier court ruling on constitutional, jurisdictional, Charter and legislative grounds. Mr. Price has alleged abuse of process.
Valley Towing Limited, B.C.	Before the Court	91/02/25	92/02/05	92/10/00			Trial date has been held over.
Crown Zellerbach Canada Ltd., B.C.	Concl.	80/08/16-17 Beaver Cove, Johnstone Strait, B.C. 50 32'N 126 51'W	80/02/20	90/10/15	Conviction	$8,000 Fine. $4,000 per charge.	Went through the courts to the Supreme Court of Canada. Federal powers apply to Provincial territorial waters.
MacMillan Bloedel - Alberni Division, B.C.	Concl.	89/07/1-3, Polly Point, Alberni Inlet, B.C.	Unknown	90/01/26	Conviction	$1,000 Fine. Plus $14,000 court order to improve habitat.	First conviction under CEPA court order was to improve spawning habitat but not in the area where the offence occurred.

* Concluded

Source: Government of Canada, 1992c.

3. Theoretical Discussion

The oceans have historically been perceived as an inexhaustible resource, with an unlimited capacity to absorb toxic materials. However, there are many competing oceans-related activities, each one affecting the use of the oceans by the others. Ocean dumping involves an 'externality' which results in the private market setting inappropriate prices. This market failure arises because the private costs to those who are using the oceans as a disposal option, account for neither the injury to marine life nor the eventual effects on human health and well-being. As Coase (1960) among others has pointed out, the market allocations of activities that result in negative externalities are characterized by levels of output and pollution that exceed the socially acceptable amounts, theoretically determined where the social marginal costs (SMC) are equal to the social marginal benefits (SMB). Consequently, prices for the polluting products are too low. Furthermore, in the absence of government intervention, the private market does not encourage the development and implementation of processes to reduce pollution, nor does it encourage the reuse and recycling of the polluting substances (Tietenberg, 1988).

Policies to protect the marine environment should be designed to restrict the level of pollution to the socially acceptable level. However, as the aggregation of demand functions (or "marginal benefits") across industries is not possible, and as the clean-up costs of the various externalities associated with ocean dumping differ,[10] the ocean dumping problem must be considered at least on an industry-by-industry basis, if not on a firm-by-firm basis. As the three most significant categories of substances for which permits were issued in 1990 - 1991 were fish offal, excavation and dredged material (Government of Canada, 1992a), the following discussion concentrates on these three categories. In addition, three industry cases are developed to analyze the ocean dumping problem. The types of regulatory instruments that would be most effective in each case, as well as which case is most applicable to each category of materials are then discussed.

3.1 Economic Model of Ocean Dumping

In the following discussion, Spulber's (1985) model of effluent regulation is used to identify the ocean dumping problem. [11] Spulber assumes identical firms purchase inputs x_j at given input prices r_j, $j = 1,\ldots,m$, which are used to produce output q, with a production function of $q = f(x_1,\ldots,x_m)$ where f is twice differentiable, increasing and concave. For each vector of inputs, an externality $e = h(x_1,\ldots,x_m)$ is defined, where h is convex and differentiable. The external costs of the pollution are defined by a social damages function D(E) where $E = ne$ represents the total effluent generated by n firms. Spulber found that in a competitive market with small firms, the policy mechanisms that achieve long-run optimality are effluent taxes and tradeable permits. However, "direct intervention through output taxes or output control, entry tariffs, or restrictions or effluent constraints will create further distortions in the allocation of resources" (Spulber, 1985, 117-118).

Although Spulber's approach is typical of the theoretical work on effluent regulation,[12] it has limited applicability to ocean dumping. Although commonly made, the assumption of identical firms producing identical products is inappropriate in this case. Therefore, this paper modifies Spulber's model to reflect the ocean dumping problem more closely. As is evident from Table 3, the materials which are dumped in Canada's oceans arise from rather different activities. Consequently, an externality function must be defined for each category of material to reflect the particular characteristics of the different industries. Since these may be quite different, the externality functions for each category cannot, in general, be combined. The model assumes that contamination only applies to dredged material since fish offal and excavation material can be screened on land prior to being dumped, whereas dredged material originates in the ocean. Also, in order to concentrate on the ocean dumping problem, other sources of marine pollution are not included.

3.1.1 Fish Offal

Assume that the fish processing industry uses inputs $x_1,\ldots,x_m$ to produce output q_f represented by the production function $q_f = f(x_1,\ldots,x_m)$, where f is twice differentiable, increasing and concave. There is an externality associated with this activity represented by e_f, where $e_f = h(x_1,\ldots,x_m)$. The function h is convex and differentiable. Assume also that $q_f = g(e_f)$ and this function can be inverted such that $e_f = h(q_f)$.

3.1.2 Excavation Material

The excavation externality can be represented in a way similar to that of fish offal. The output q_x represents excavation activities such that $q_x = f(x_1,\ldots,x_m)$. The associated externality is represented by e_x where $e_x = h(x_1,\ldots,x_m)$. Furthermore, $q_x = g(e_x)$ and again it is assumed that this function can be inverted such that $e_x = h(q_x)$.

3.1.3 Dredged Material

Dredged material constitutes the category for which most permits are issued and is therefore of primary concern. However, dredged material is very different from the other categories because the sediments that are dumped originate in the ocean rather than on land. The need for dredging arises each spring as sand accumulates in docks and harbours during the winter storms (Picard, 1992). Dredging activity is represented by q_d. If not contaminated, the effects of dumping dredged material are said to be only physical as previously discussed and are represented by e_d. However, dredged material is often contaminated by land-based effluents entering the marine environment. C_m represents the contamination of sediments and is a function of various land-based activities. The contamination of sediments is therefore defined as C_m = h(land-based sources of pollution: agricultural run-off, sewage, oil, industrial effluents, urban run-off, rivers, pipelines, coastal facilities, atmospheric sources). Thus, the total externality associated with dredging activities is $e_{td} = e_d + C_m$. Since the physical effects of dumping are relatively limited, whereas the contaminants from various land-based sources involve highly toxic materials, the following discussion will concentrate on the contamination component of this dredging example.[13]

3.2 Diagrammatic Discussion

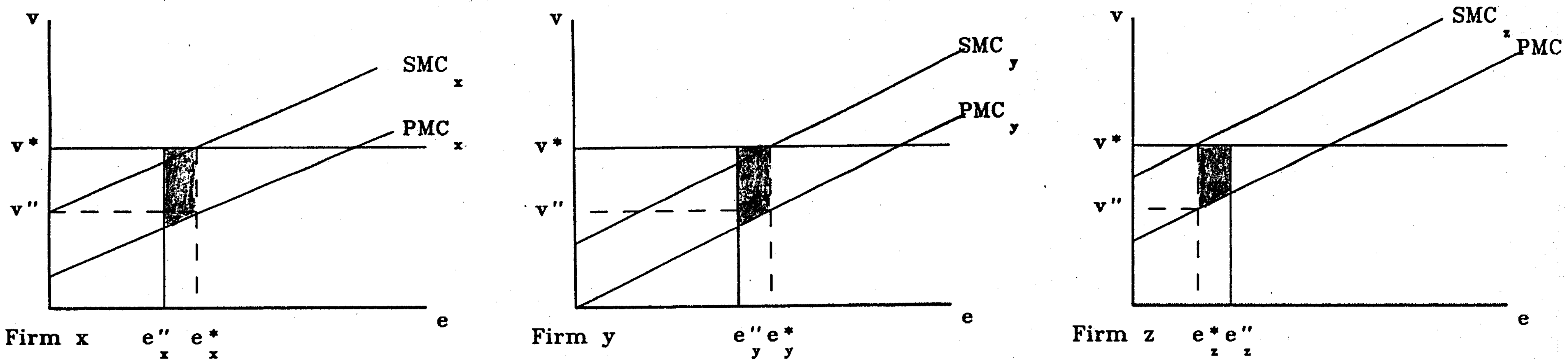
The following discussion outlines three different cases that can be used to analyze the ocean dumping problem. The effectiveness of various policy instruments and the applicability of each case to the three categories of materials, are then discussed.

3.2.1 Homogeneous Product & Identical Clean-up Costs

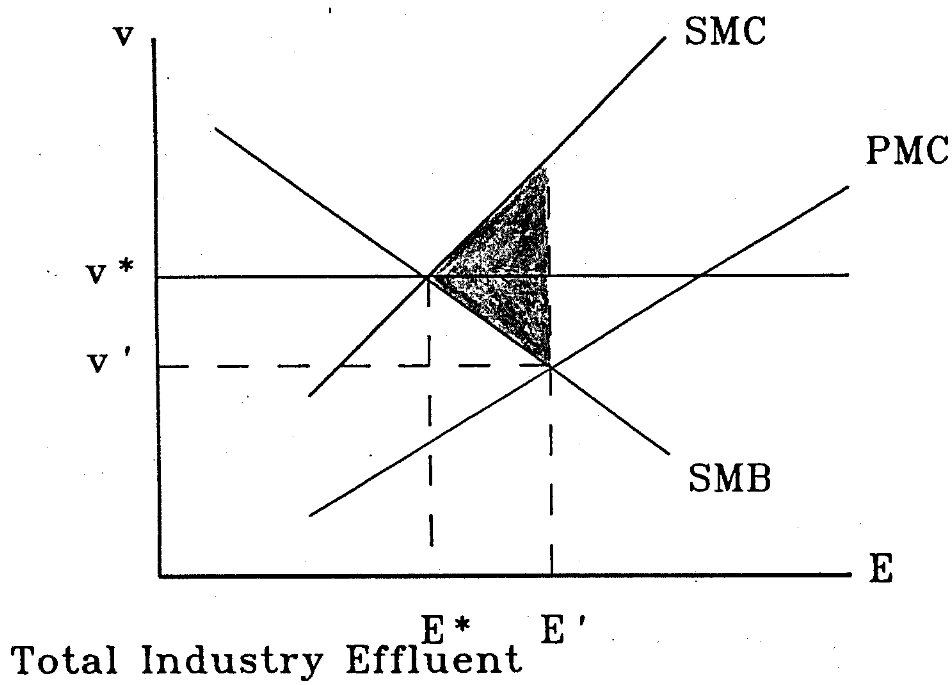
If a homogeneous product is produced in an industry, then individual firms' demand or marginal benefits functions can be aggregated. Thus the socially optimal amount of the pollutant can be calculated. For example, in figure 1a, it is assumed that firms x, y and z are producing a homogeneous product q, and generate an externality e, such that $e = f(q)$, $f'(q) > 0$, $f''(q) = 0$. It is also assumed that the production function can be inverted and expressed as $e = g(q)$. Since the objective of ocean dumping policy is to monitor the quantity of effluent that is dumped into the ocean, the amount of effluent rather than the quantity of output was chosen as the target variable. Furthermore, in this case, it is assumed that the clean-up costs of the externality, where clean-up costs reflect the social cost of the externality, are identical. This is shown in the diagram by the difference between the private marginal cost (PMC) and social marginal cost (SMC) functions, which is the same for each firm in the industry (figure 1a). Note, however, that the PMC functions may differ across firms.

The industry PMC and SMC curves in figure 1b are theoretically obtained by aggregating the PMC and SMC curves for each firm in the industry. The private market determined "value" per unit of effluent as measured on the vertical axis, is v', where the industry PMC and social marginal benefit (SMB) curves intersect.[14] The total amount of effluent E for the industry, associated with the price v', is E'. However, this level of effluent does not take into account the externality associated with the productive activities and is therefore too high. The total social cost to society of this inefficiency is the deadweight loss represented by the difference between the SMC and the SMB functions, as demonstrated in figure 1b by the shaded area.

The level of total effluent which is efficient from a societal point of view is E*, where the industry SMC and SMB curves intersect. At the level E*, which is associated with some socially optimal total level of output Q*, all costs to the environment are accounted for and the level of effluent is optimal. The value per unit of effluent associated with this optimal level of effluent E*, which includes the cost to the environment, is v*. At this value, the optimal levels of effluent for the individual firms are e_x*, e_y* and e_z* as shown by figure 1a. Notice that an optimal distribution of e



1a.



1b.

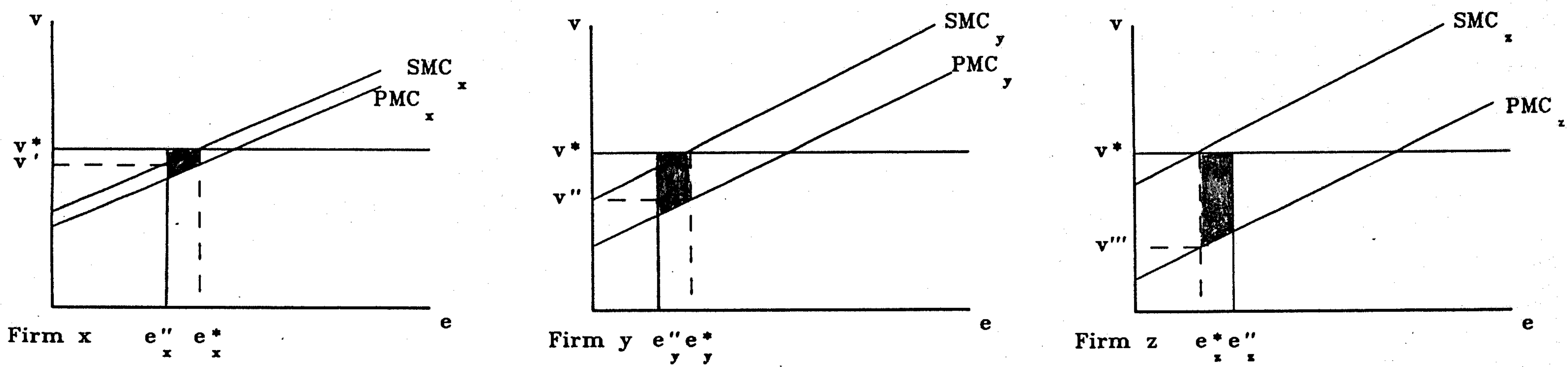
Figure 1
Homogeneous Product & Identical Clean-up Costs Case
(Asymmetric Private Costs)

implies that v* is identical across firms. In this case where clean-up costs are identical across firms, the per unit value of the effluent to each firm at e_i* (where i = x,y,z) is the same across firms, as shown by v'' in figure 1a. This outcome affects the policy instruments that can be used to achieve the socially desirable allocation, which will be addressed in section 3.3.

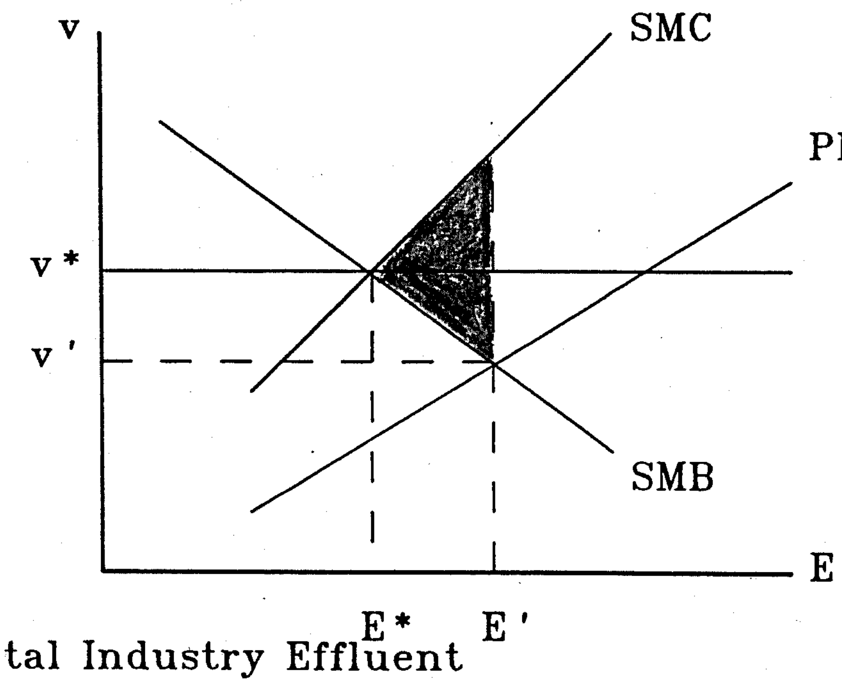
3.2.2 Homogeneous Product & Asymmetric Clean-up Costs

For an industry characterized by a homogeneous product and asymmetric clean-up costs, whereby the toxicity levels of the effluents may vary, the analysis is similar to that of the model with identical costs, although the policy implications differ. For example, in figure 2a, the externality generated by the production process of each firm involves different clean-up costs for each, as shown in the diagram by the difference between the PMC and SMC functions. The industry analysis of the previous model also applies to this model with asymmetric clean-up costs, and thus the socially optimal level of total effluent E, can be determined for the industry and its allocation across individual firms should be e_i* (where i = x,y,z) as shown in figure 2a.

However, in this model where clean-up costs are asymmetric, the per unit value of the effluent to each firm at e_i*, is not the same across firms, as shown by v', v'' and v''' in figure 2a. This difference in the per unit value of the effluent affects the ways in which the government can induce firms to achieve the socially optimal allocation, as will be discussed in section 3.3.



2a.



2b.

Figure 2
Homogeneous Product & Asymmetric Clean-up Costs Case

3.2.3 Non-Homogeneous Product

In the case where firms produce non-homogeneous products, their demand curves cannot be aggregated. For example, as discussed earlier, contamination of marine sediments is the major problem associated with the dumping of dredged material. However, this contamination results from a number of different sources, all of which belong to different industries. Figure 3 illustrates a situation in which the contamination of dredged material could be attributed to two different industrial facilities, firm r (say an oil refinery), firm p (say a pulp and paper plant) and one sewage treatment facility (s). It is assumed that the sewage facility faces a local demand curve whereas firm r and firm p are price-takers. The private production decisions of the firms would result in a level of effluent of e_i' (where i = r, p, s), whereas the socially optimal level of effluent would be e_i^*. Because the productive activities contaminating the sediments do not belong to the same industry, their demand functions cannot be aggregated. Thus, it is not possible to determine an optimal aggregate amount of effluent to be allocated to the various productive activities. An industry approach to controlling the effluents is not possible in this case and regulatory policies must be applied on a firm-by-firm or source-by-source basis, to ensure that the optimal levels of e_i^* are achieved.

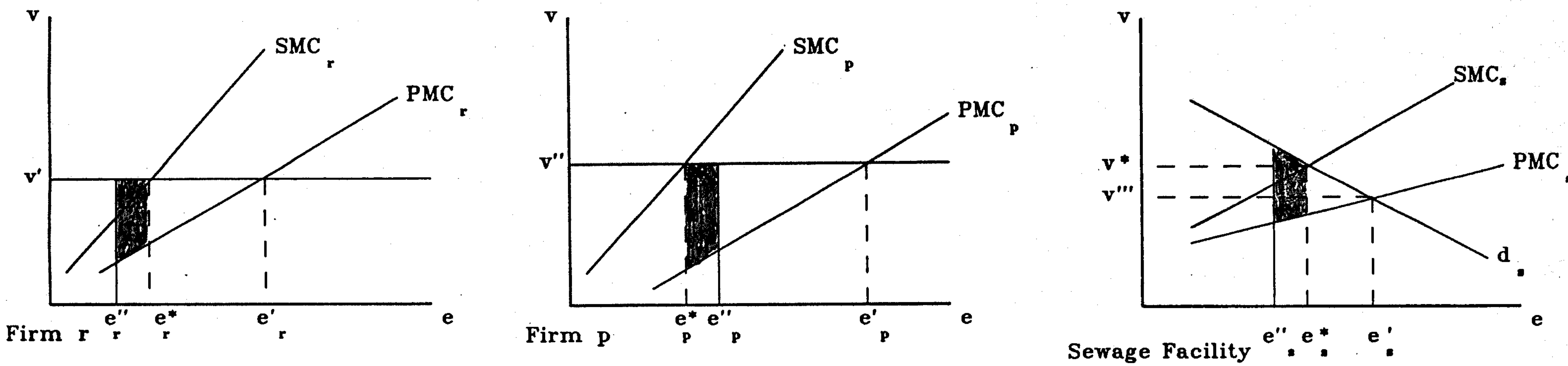


Figure 3
Non-Homogeneous Product Case

3.3 Policy Instruments for Achieving the Socially Desirable Outcome

The policy instruments available to the government to induce the socially optimal level of effluent e_i* include legal liability and regulations such as standards, fees, as well as non-tradeable and tradeable permits (defined over quantity dumped). Using figure 1 as an example, standards would involve legal limits on the quantity of material that can be dumped such that the optimal levels e_i* would be maintained. Liability rules would involve some legal or monetary penalty associated with dumping, such that the private marginal costs of the firm increase to coincide with its social marginal costs of production. A fee of v* levied on each unit of material that is dumped, would induce firms to reduce their level of effluent to the point at which the fee was equal to the marginal benefit. In addition, the government could issue permits of e_i* to each firm and thereby, firms would not be permitted to produce a quantity resulting in effluent levels greater than the socially determined optimum. These permits may be tradeable or not, depending on industry conditions.

3.3.1 Homogeneous Product & Identical Clean-up Costs

In the first model in which there is a homogeneous product and the clean-up costs are identical, all of the above policy instruments would be effective. This model could be applied to the fish processing industry, as it is likely that the fish offal from each firm involves the same environmental cost. If excavation material from different sources involves the same environmental cost, this case would also be applicable. With perfect information, standards, legal liability, fees and non-tradeable permits would induce firms to produce the level of output that is consistent with the socially optimal level of effluents, at which the costs to the environment are accounted for.

In addition, with perfect information, tradeable permits would also result in the socially efficient outcome. If permits can initially be traded, the social planner, which in this case would be the government, does not have to allocate the permits efficiently. Firms have the incentive to trade permits only until e_i* has been reached. The following example illustrates this point. If firm z in figure 1a wanted to increase its production to a level that would increase its level of effluent to e_z'', it would be willing to offer up to the value of the shaded area, which represents its producers' surplus, (e_z'' - e_z*) to purchase the permits enabling it to produce at the level associated with e_z''. However for firm x and y to reduce their level of effluent by the same amount in order to sell their permits to firm z, they must be offered an amount at least equal to the shaded area in each firm's diagram. These two areas, representing the amount for which firms x and y would be willing to sell their permits to firm z, are larger than the shaded area in firm z's diagram. Thus the amount that firm z is willing to offer to buy permits allowing it to produce e_z'', is not enough to induce either firm x or firm y to sell their permits. The reason is that at the optimal level of effluent, with identical clean-up costs, the per unit value of the effluent to the firm at the margin, is the same across firms. In the diagram this value is represented by v''. As each firm's valuation of the effluent is the same, there is no incentive to increase production and go beyond the efficient allocation of e_i*. Thus with perfect information, tradeable permits would also result in the socially optimal level of effluent for each firm.

3.3.2 Homogeneous Product & Asymmetric Clean-up Costs

In the second model in which there is a homogeneous product but clean-up costs are asymmetric, appropriately set standards, taxes, legal liability and non-tradeable permits would again, result in the optimal outcome if there is perfect information. This case could apply to excavated material if the clean-up costs depend upon the material that is excavated. However, with asymmetric clean-up costs, tradeable permits would not result in a socially optimal outcome. For example, if firm z (figure 2a), which has the most toxic effluent as demonstrated by the larger difference between the PMC and the SMC functions, wanted to increase its level of production to a level that would result in e_z'', it would be willing to offer up to the value of the shaded area to purchase the necessary permits. The shaded areas in the diagrams for firm x and y, represent the amounts that firm x and firm y would be willing to accept to sell the number of permits desired by firm z. A comparison of the shaded areas shows that the amount that firm z is willing to offer to firm x and y to purchase additional permits, is larger than the amount that firms x and y are willing to accept and thus, they are both willing to sell their permits to firm z.

Asymmetric clean-up costs, where clean-up costs reflect the social cost of the externality, imply that the per unit value of the effluent to the firm differs across firms.

In the diagrams these values are represented by v', v'', v''' for firms x, y and z respectively, and are determined at the point where e* = PMC for each firm. For firm z, the clean-up cost is relatively high and because its PMC is much lower that its SMC, firm z has an incentive to increase production beyond the optimal allocation of e_z*. Therefore, with different clean-up costs, firms x and y would be willing to sell these permits to firm z for less than the maximum amount that firm z is willing to pay. However, because the toxicity of firm z's effluent is higher, an increase in the level of e_z implies that the cost to the environment would be higher, rendering the outcome with tradeable permits socially undesirable.

3.3.3 Non-Homogeneous Product

In the third case where the effluents are generated by productive activities of different industries, policies must be applied on a firm-by-firm or source-by-source basis. This case is most applicable to dredged material, as the contaminants result from many different productive activities.[15] Standards, legal liability, fees and non-tradeable permits allocated to each firm would, theoretically, with perfect information, result in the socially optimal allocation of effluent. However, asymmetric clean-up costs imply that tradeable permits are not socially desirable. In figure 3, the amount that firm p would be willing to pay for an additional number of permits enabling it to emit e_p'', is greater than what firm r and the sewage facility are willing to accept. As before, because firm p's effluent is relatively more toxic, an increase in its production would result in a cost to the environment that would be higher than the socially determined outcome. Thus tradeable permits would not result in a socially desirable outcome in the non-homogeneous product case.

The previous analysis has shown that with perfect information, appropriate standards, legal liability, fees and non-tradeable permits are effective in all three cases and tradeable permits are only effective in the homogeneous product and identical clean-up costs case. However, in reality the assumption of perfect information is not realistic and therefore the social planner does not know the costs of the firms. Thus, appropriate standards, fines and fees cannot be accurately set. The second best solution may therefore be to issue tradeable permits, because although they may be less efficient in a situation of perfect information, the trade of permits may allow the authorities to obtain the necessary information.

4. Application of the Theoretical Approach

4.1 The Relationship Between CEPA and Economic Theory

From a theoretical point of view, CEPA's provisions should encourage those who use the ocean as a disposal option to internalize the externality associated with dumping. The regulatory aspect of CEPA, consisting of standards and permits, could do so by directly limiting the amount of toxic substances that are dumped. The strict liability system could internalize the externality indirectly through the disincentive effect of the possible legal actions that may be taken if damage is done to the environment. Firms would be induced to internalize the cost of the externality, as they would be liable for the full cost of any environmental damages such that the private marginal costs of the firm increase to coincide with its social marginal costs of production. The following examines the choice between a direct regulatory approach including permits, and an indirect liability approach.

4.2 The Choice Between Regulation and Liability

There exist basically four criteria that determine whether an activity is best dealt with indirectly through a liability system, or directly using regulations such as standards or permits. These are: the asymmetry of information, the ability of private parties to pay for damages, the likelihood of agents undertaking polluting activities not being sued for damages, and finally, the administrative costs involved with either system (Shavell, 1984).

In the case of asymmetric information, if the regulator has less information than the polluter, regulations may result in an inefficient standard. For ocean dumping, as those who dump generally possess more information regarding their activities than the authorities, a liability approach would theoretically be more effective than regulations because firms would be induced to consider the expected costs of the damages.

Another consideration involves the ability to pay for damages. If a polluter cannot cover the full costs of the damages incurred, the liability system will not provide sufficient incentive to account for damages, as liability would be bounded by the assets available to the agent. With regulations, the polluter's assets and its ability to pay for harm done, are not of concern as expenditures on safety measures are generally incurred before the activity is undertaken. The problem of insufficient assets varies in applicability to ocean dumping, as those who pollute vary quite significantly with respect to their productive activities and size of assets.

The effects of the inability to bring suit for damages are similar to the inability to pay as discussed above, in that with the liability system there is a disincentive to account for the damages. The lack of understanding of the basic functioning of the ocean ecosystems and the effects of effluents on marine life as well as the lack of information preventing accurate and confident assessments, may make it difficult to determine when the dumping occurred as well as the extent of the damage. In addition, the time factor is important since damages may not be discovered until long after the dumping has occurred, and thus it may be extremely difficult to ascertain who is actually responsible for the damage. These informational problems may however, also affect the regulatory system in the same way that insufficient knowledge impedes the effective functioning of the liability system. Clearly, a great deal of information is required in order to determine appropriate regulations.

The final factor determining the choice between liability or regulation rules deals with administrative costs. For the liability system the costs include time and legal expenses whereas for the regulatory system, the costs include instituting and supporting a relevant regulatory organization as well as the costs to the companies of complying with the regulations. In general, using legal liability results in lower administrative costs because the costs are not incurred unless damage occurs. In a situation in which the system was completely effective and provided the correct incentive to take the required level of care, there would be no cost apart from the cost of establishing the system. However, in the case where a polluter is willing to go to court and take the chance of being fined an amount less than the social cost of their pollution, the legal system would be a costly option. Under a system of regulations, administrative costs do not depend on whether or not there is damage. Given the informational circumstances of ocean dumping as previously discussed, a regulatory system would also require continual expenditures to determine the correct level at which to set the regulations given that there is not full information regarding the marine environment and the effects of waste materials in the oceans. Thus, neither the regulatory nor the liability system as implemented under CEPA, can encompass all the characteristics of the ocean dumping problem.

4.3 Limitations of the Theoretical Approach

In general, there are a number of practical reasons why the theoretical analysis cannot be readily applied to the real world. The following sections discuss some of these problems.

4.3.1 Informational Limitations

Successful implementation of economic theory to control ocean dumping is complex and depends on "the existence of complete databases on the uses of the ecosystem, on physical, chemical and biological processes within it and the toxicological effect of specific contaminants" (Hirvonen and Coté, 1986, 20). Incomplete or inaccurate information will certainly limit the extent to which these policies can be reliably and comprehensively developed and applied. For example, the black/grey lists as established by the London Dumping Convention, are supposed to categorize toxic substances such that certain environmental quality objectives are maintained. However, some have argued that this strategy is questionable as "such classification lacks a firm scientific base" and "few substances are always harmful in a biological sense although there are many whose presence is undesirable" (Boelens, 1988, 39). Thus, in addition to the lack of scientific support for these lists, determining to what extent substances are harmful in terms of their direct effects on marine organisms or harmful in terms of their effects on other environmental factors, poses a problem. It is also unclear whether or not it is appropriate to control man-made substances and those which occur naturally in the marine environment equally. Consequently, the classification of toxic materials upon which the ocean dumping control mechanisms are based, are not necessarily accurate.

There are also methodological problems with certain features of 'information technologies'[16] that must be dealt with before complete implementation into the decision-making process can occur. The information can be used to assist decision-makers but "it is no substitute for making clear, accountable decisions in the use of the environment" and neither is it "an excuse for avoiding difficult and political implications associated with using the environment in one way rather than another" (Wigan 1987, cited in Moffat, 1990, 218). Thus, although feasible in theory, effective implementation of theoretical frameworks for managing ocean dumping is significantly impeded by a lack of accurate information as well as reliable information technology.

4.3.2 Measuring Social Costs and Benefits

Measuring the social costs and benefits of marine-related activities also poses a problem. Although private costs are quite easily determined and include such factors as the actual costs to the firm of dumping, the social costs and benefits are not as easily measured. The primary difficulty with measuring the provision or removal of a natural resource involves constructing a meaningful measure of welfare to determine the equivalent of a large price change, as market prices for measuring the economic value of environmental quality are not available. The four primary methodologies that have been used to estimate these values are the contingent valuation method, the travel cost approach, hedonic pricing and the avoided cost approach. There have been a great number of articles written on the strengths and weaknesses of these approaches (for example, Green and Tunstall, 1991, Hanley, 1992 and Grigalunas and Opaluch, 1989). In general, all of the above approaches to assessing the net social impact of an activity such as ocean dumping, are affected by imprecision and bias, and therefore, "important social decisions must necessarily be made within this uncertain environment since no amount of research can completely resolve the uncertainty faced by society" (Gringalunas and Opaluch, 1989, 323). Thus, accurate measurement of the social costs and benefits associated with the various uses of the ocean is not possible and in practice, the theoretical frameworks cannot be easily implemented.[17]

4.3.3 Choice of Control Mechanisms

Although section 3 outlined that with perfect information, standards, legal liability, fees and non-tradeable permits are equally effective in inducing the socially optimal level of pollution in all three cases, and tradeable permits are effective only in the case of homogeneous product and identical clean-up costs, the literature on this subject does not suggest a consensus in support of this argument. As outlined in section 4.2, the asymmetry of information, ability of private parties to pay for damages, the likelihood of agents undertaking polluting activities not facing the threat of suit for damages as well as the administrative costs of different systems, significantly affect the effectiveness of regulatory and liability approaches. Thus, depending on individual circumstances, the effectiveness of the approaches can vary.

In addition, a regulatory approach as implemented under CEPA, has been criticized for being characterized by "excessive bureaucratic centralization, rigidity, cost, litigation and delay" (Stewart, 1988, 153). In this case, economic incentives such as fees and tradeable permits, are perceived to be more effective for inducing optimal levels of pollution while avoiding the problems associated with regulation (Stewart, 1987). Furthermore, it has been shown that "water pollution control strategies allowing transfers between dischargers can be both cost effective and capable of maintaining any desired water quality standard" and that "a regulatory system which does not permit and encourage transfers is substantially and needlessly costly" (O'Neil, 1983, 354). However, there is also evidence that "most of the incentive systems for implementing environmental policies are not applicable if individual emissions or abatement efforts cannot be monitored" (Xepapadeus, 1989, 125). This certainly is the case for ocean dumping because the government cannot efficiently and effectively monitor all the sources of effluent entering the ocean, nor can it effectively monitor offsite and illegal dumping. Thus, the effectiveness of standards, legal liability, fees and permit policies varies with the conditions of each situation and it is not clear that any one approach would be more effective in the ocean dumping case.

5. Conclusion

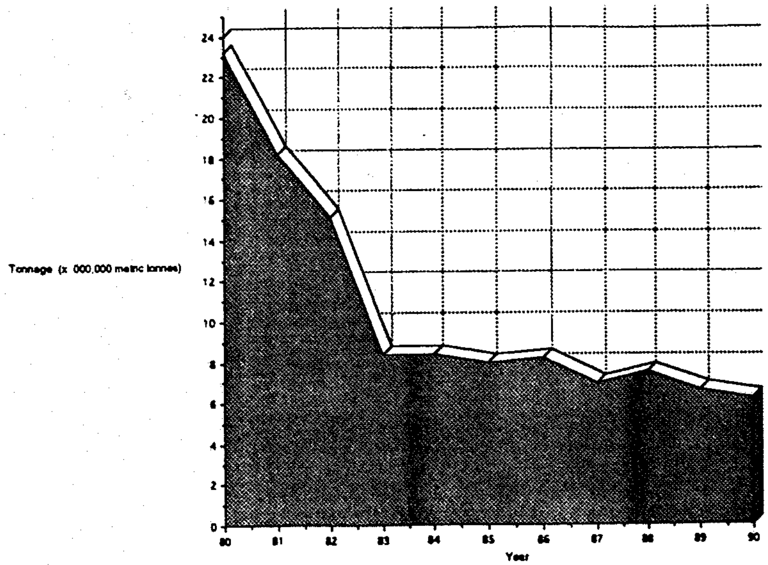
Although ocean dumping involves serious negative consequences, rapid population growth, industrial expansion, and a lack of adequate disposal facilities on land, are increasing the pressure to use the ocean as a disposal alternative. To limit the environmental damage, policies should be designed to restrict the level of dumping to the socially acceptable level, theoretically determined where the social marginal benefits and the social marginal costs are equal. However, as it is not possible to aggregate demand functions across industries and as the clean-up costs of the various externalities differ, the ocean dumping problem must be considered on an industry-by-industry or firm-by-firm basis.

This paper examined three industry cases categorized as homogeneous product and identical clean-up costs, homogeneous product and asymmetric clean-up costs and non-homogenous product. Fish offal and excavation material apply to the first two cases depending on whether or not the cost to the environment of the effluents is the same across firms in each industry. Dredged material applies to the third case because the contaminants in dredged material result from many different productive activities in different industries. From a policy perspective, it was found that in theory, if there is perfect information, standards, legal liability, fees and non-tradeable permits could be equally effective in inducing the socially optimal level of pollution in all three cases, but tradeable permits could be effective only in the case of homogeneous product and identical clean-up costs. However, there are many significant considerations that prevent the policies from operating effectively. Primarily, a situation of perfect information is unlikely and thus, although in theory tradeable permits are not efficient, they may be a good second-best alternative and may allow the authorities to obtain information on firms' costs.

In conclusion, although ocean dumping is currently controlled through a permit system which is applied equally to all substances, the analysis of this paper suggests that because ocean dumping involves many different substances, it does not easily fit into any one theoretical framework. A more effective approach would be to consider the substances on a case-by-case basis in order to assess which type of policy instrument would be best in each case, rather than an overall policy approach. Additional research is needed to ensure that policy instruments to control ocean dumping accurately reflect the costs to the environment. Furthermore, a more sustainable, long-term approach to waste management must be developed such that less pollution is generated, and more effective disposal options are made available.

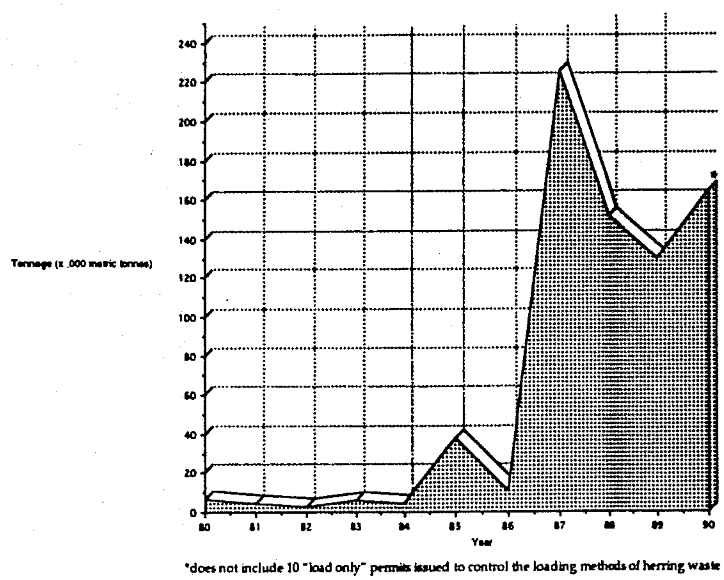
Appendix

Table 5
Quantity of Dredged Material for Permits Issued Between 1980 and 1990



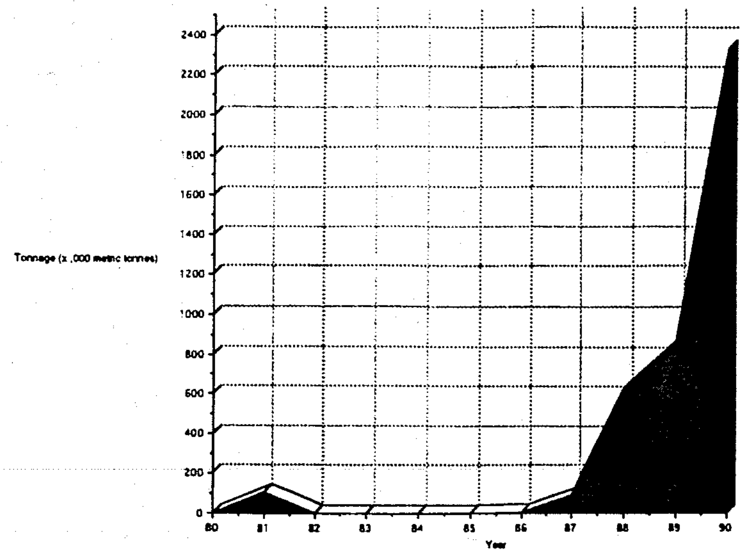
Source: Photocopied from Government of Canada, 1992a, 33.

Table 6
Quantity of Fish Offal for Permits Issued Between 1980 and 1990



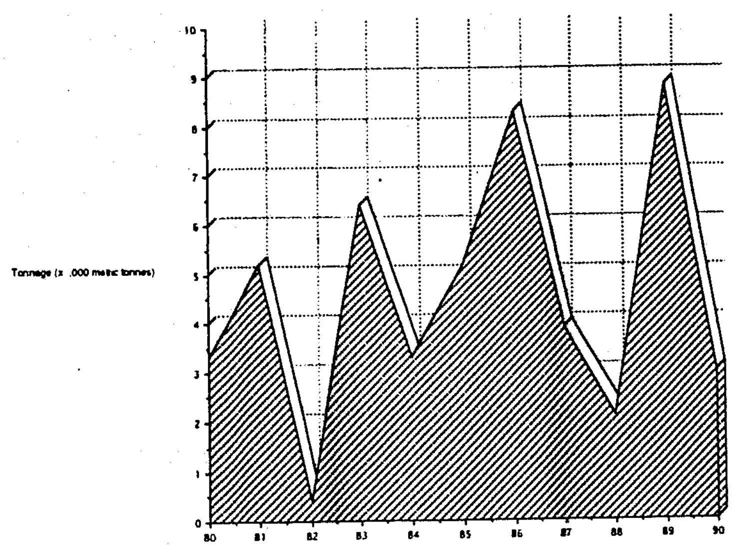
Source: Photocopied from Government of Canada, 1992a, 33.

Table 7
Quantity of Excavation Material and Construction Rubble for Permits Issued Between 1980 and 1990



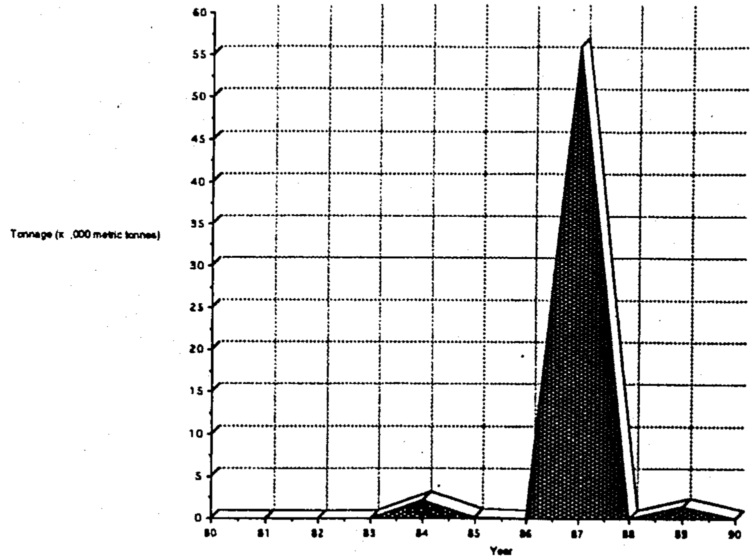
Source: Photocopied from Government of Canada, 1992a, 34.

Table 8
Quantity of Ship Disposal for Permits Issued Between 1980 and 1990



Source: Photocopied from Government of Canada, 1992a, 34.

Table 9
Quantity of Scrap Metal for Permits Issued Between 1980 and 1990



Source: Photocopied from Government of Canada, 1992a, 35.

Table 10
Categories of Substances Under Part VI of CEPA

Category:
Schedule III,
Part I (prohibited substances)

Coverage:
Substances that can seriously harm the marine environment. These cannot lawfully be dumped except in trace quantities and then only for good and compelling reasons, and when the risk to marine life and animal and human health in minimal, These substances include:

- mercury and mercury compounds
- cadmium and cadmium compounds
- crude oil and its wastes, refined petroleum products, petroleum distillate residues and any mixtures containing any of these substances
- organohalogen compounds, including PCB's
- high-level radioactive wastes or other high-level radioactive materials
- any substance produced for chemical or bacteriological warfare
- persistent plastics and other persistent synthetic materials

Category:
Schedule III,
Part II (restricted substances)

Coverage:
Substances that are potentially harmful, but can be dumped safely with extreme care, including:

- arsenic, lead, copper, zinc, beryllium, chromium, nickel, vanadium and their compounds
- cyanide and fluorides
- pesticides an their by-products not listed in Schedule III, Part I
- organosilicon compound, such as water repellents
- containers and scrap metal
- radioactive wastes or other radioactive matter not included in Schedule III, PartI
- substances that because of their bulkiness sink to the sea bottom, interfering with fishing and navigation

Category:
Schedule III,
Part II (all other substances)

Coverage:
All substances not listed in Schedules III, Part I and II. Factors that must be considered in granting all ocean dumping permits are also listed:

- the total amount and average composition of substances dumped
- toxicity
- other physical, chemical and biological characteristics
- location of dumpsite
- method of disposal
- effects of tides, winds, currents and other dispersal factors
- salinity, temperature and other water characteristics
- sea-bottom characteristics
- possible effects on marine life and fisheries
- possible effects on other uses of the sea
- accumulation and biotransformation in biological materials and sediments
- consideration of other waste management options

Source: Government of Canada, 1989, 11.

Endnotes

[1] Calculated by the author based on information in Statistics Canada, National Income and Expenditure Accounts, fourth quarter 1988, 1989, 3, and Statistics Canada, Employment, Earnings and Hours, January 1989 preliminary data, 1989, 155.

[2] (1972 Convention on the Prevention of Marine Pollution by the Dumping of Wastes and Other Matter (LDC) 26 U.S.T. 2403, Art. 3(1); T.I.A.S. 8165. In force, Aug. 1975, cited in Hughes, 1988, 156.)

[3] (Letalik, supra note 13, at 218: Kindt supra note 1, at 770, 1088-90; W. Marx, *the Frail Ocean* 75 (New York: Ballantine Books, 1967); L. Cuyvers, *Ocean Uses and Their Regulation*, Ch. 4 "Waste Disposal in the Sea," at 74 New York: John Wiley & Sons, 1984); E. Brown, "International Law and Marine Pollution: Radioactive Wastes and Other Hazardous Substances, " (1971) 11 Nat. Res. J. 221, 235; R. Soni, *Control of Marine Pollution in International Law* 215 (Johannesburg: Juta & Co., 1985); Environment Canada, "Ocean Dumping Control Act Annual Report, 1985-86," at 29; M. Hardy, "International Control of Marine Pollution," (1971) 11 Nat. Res. J. 296, 317, cited in Hughes, 1988, 157).

[4] The editorial of the May 8, 1992 edition of the Vancouver Sun concerning the Georgia Strait, points out that "waste material is scattered on the seafloor up to four kilometres away on a trail leading back to Vancouver's harbour, some of it on top of valuable shrimp fishing ground" (Vancouver Sun, May 8, 1992, A16). An informational problem exists because there is no guarantee that there has actually been a permit issued for all that has been dumped, nor that the material has been disposed of at the proper dumpsite. However, given that it is not possible to get data on offsite and illegal dumping, permit information must be relied upon as an indicator of how much is dumped.

[5] One of the justifications in support of an application to dump an old barge in Passamaquoddy Bay, was that it would result in an artificial reef which would provide a habitat for breeding fish and recreational benefits to qualified ship wreck divers (Honey, May 26, 1992).

[6] In September 1992, an algae bloom "killed an estimated 1/2 million salmon at fish farms on the west coast of Vancouver Island" (Munro, September 15, 1992, B8). Of particular interest to this paper is the fact that the kill was so massive that permits were issued to dump 250,000 kilograms of dead chinook at sea.

[7] Legal liability is intended to act as a disincentive to pollute through the possible legal actions that may be taken against polluters once damage to the environment has occurred, whereas regulations are intended to directly limit pollution to acceptable levels, thereby avoiding environmental damage. This will be addresses further in section 4.1.

[8] Terms and conditions include the timing, handling, storage, loading and placement at the disposal site (Government of Canada, 1989).

[9] There are currently proposed amendments to the ocean dumping regulations that involve, among other things, a waste audit to ensure that all other disposal alternatives have been considered as well as a revision of the substances currently regulated, the acceptable disposal concentrations and the testing protocols for substances (Government of Canada, 1992b).

[10] The clean-up costs associated with fish offal, excavation and dredged material differ. One tonne of fish offal which consists primarily of fish wastes, is less toxic than one tonne of dredged material that has been contaminated with highly toxic industrial effluents.

[11] Spulber examined the effectiveness of various effluent regulation instruments and since the focus of this paper is to examine the effectiveness of mechanisms to control ocean dumping, this model was chosen as a way of identifying the ocean dumping problem.

[12] In the papers by O'Neil, et. al. (1983) and Xepapadeus (1991), economic theory is used to discuss the effectiveness of various effluent control instruments. In addition, Kahn (1985, 246) uses "theoretical and ecological concepts from ecology and economics to derive a lower bound of the marginal damage function for reductions in the level of submerged aquatic vegetation in Chesapeake Bay".

[13] The other relatively significant categories of dumped substances can be described as follows:

Vessels/Large Objects:

In comparison to the case of fish offal in which the externality is directly related to a productive activity, there is no direct productive activity associated with the dumping of vessels/large objects and thus the effects on the marine ecosystems, such as smothering of the ocean floor, are represented by e_v. However, large objects may create an artificial reef which provides a habitat for marine life and is thereby a positive externality. Thus the vessels/large objects category is defined as $e_v - A$, where A represents the benefits of an artificial reef.

Mining:

q_m represents mining activities where $q_m = f(x_1,\ldots,x_m)$ and the associated externality is $e_m = h(x_1,\ldots,x_m)$.

Ocean Incineration:

q_i represents incineration activity where $q_i = f(x_1,\ldots,x_m)$ and the associated externality is $e_i = h(x_1,\ldots,x_m)$.

[14] Since $e = g(q)$, one can think of "v" as translating into the market price of the product in question.

[15] As pointed out by Hughes (1988, 165) aligning the regulation of materials "with the origins of the contamination rather than with the ultimate or end location of those substances is probably a more realistic approach to the control of ocean dumping activities...However, it is not clear that this approach is logical when applied to the dumping of re-use or clean dredge spoil." This point emphasizes the fact that the contamination of material should be of primary concern to regulators and should be regulated at the source rather than once it has contaminated marine sediments.

[16] Moffat (1990, 209) defines information technology as "the electronic storage, processing and subsequent retrieval of data to demonstrate the relationships between data sets."

[17] In theory, the effectiveness of the liability approach depends on the fines accurately reflecting the cost to the environment. From Table 4, it is evident that the fines for violations of CEPA, Part VI, have ranged from $1 to $8,000 with the majority under $4,000. It is conceivable that the direct costs to the environment in terms of the loss of marine life and reduced marine quality, as well as the indirect costs in terms of the effects on related industries and activities, are much higher than is indicated by the fines. It would be interesting to review the permit fees, the costs of complying with regulations, the fines and the estimated social costs, in order to examine the effectiveness of the policies currently used to control marine pollution. Effectiveness would be determined based on how closely the actual costs of compliance, the fees as well as the fines reflect the estimated costs to the environment.

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