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Chapter 3

Waste Disposal Activities and Pollutant

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Waste Disposal Activities and Pollutant Inputs

INTRODUCTION

To fully understand the potential for wastes to affect marine resources and ecosystems and to evaluate management options for reducing adverse impacts, it is important to have an understanding of the amounts of different pollutants entering marine waters from different sources. Marine waters currently receive a variety of wastes, including municipal and industrial effluents, sewage sludge, dredged material, and some industrial wastes. These wastes vary considerably in physical nature and in biological and chemical composition. In addition, many of the same pollutants can be carried directly into marine waters by nonpoint sources such as agricultural and urban runoff, and both disposal activities and nonpoint pollution can occur upstream in rivers that later flow into marine waters.

This chapter first discusses the quality of information available about pollutant inputs into U.S. marine waters, including the issue of unregulated but potentially significant pollutants. The chapter then reviews the extent and variability of waste disposal activities and nonpoint runoff, including a comparison of the relative contributions of pollutants from different sources, and describes the major sources of pollutants to marine waters.

AVAILABILITY AND QUALITY OF DATA

Ability To Make National Comparisons

Considerable information is available describing waste disposal and nonpoint sources and pollutant inputs from these sources. The quality of this information varies considerably, however, which creates some uncertainty in estimates of pollutant inputs on a national scale and places some constraints on our ability to make comparisons among different sources of pollutants. This section briefly describes the quality of available information and how well it can be used in making estimates and conducting comparisons.

For this report, data on dumping activities were obtained primarily from Environmental Protection Agency (EPA) reports and from the Corps of Engineers. Data on pipeline discharges and nonpoint source pollution were obtained primarily from analyses of various EPA computer databases such as the Industrial Facilities Data Base (139,503), and from databases provided by the National Oceanic and Atmospheric Administration (NOAA) and Resources for the Future (RFF).[1]

Information on the magnitude of major pipeline discharges and dumping operations that occur into or directly adjacent to marine waters is relatively complete and reliable. For example, the quantities of wastes dumped and the number of major industrial and municipal pipelines discharging into marine waters are relatively well-documented. This is because they occur in a limited area and involve a relatively small number of discrete events or continuous activities.[2] Such data can readily be used to compare the relative importance of these particular sources in different marine waters.

In contrast, the information that would be needed for an accurate national assessment of relative inputs of particular pollutants from all sources (discharges, dumping, nonpoint sources, and upstream activities) is often less complete and reliable, or is gathered and analyzed using differing methodologies and assumptions. Any comparison of information about different pollutant sources that

[1] NOAA's Ocean Assessments Division provided data from its National Coastal Pollutant Discharge Inventory, which will eventually contain estimates for all coastal regions. RFF provided data from its Environmental Data Inventory, which contains estimates for both coastal and inland areas. These inventories are referred to as the NOAA and RFF databases, respectively.

[2] Even then, however, extracting information about different types of discharges from existing databases can sometimes be difficult (139).

relies on different databases is constrained by the following:

- available databases rarely consider *all* significant sources using internally consistent methodologies;
- definitions of key parameters (e. g., the geographic boundary delineating an "upstream" source) can differ considerably among studies;
- information on the quantity and composition of different wastes (and variability in these parameters) often is not available, or is expressed in units that are difficult or impossible to compare;
- different studies often rely on different assumptions or models which are supported by varying degrees of field validation;
- available data for various sources may have been collected at different times, and may be out-of-date or unrepresentative of current circumstances; or
- aggregation of data in some studies can mask highly significant short-term fluctuations (e.g., even one day of low dissolved oxygen levels can cause a massive fish kill).

Nevertheless, some individual databases can be used to evaluate pollutant inputs from most (but not all) sources nationally. The NOAA and RFF databases used by OTA in preparing this report, for example, estimate pollutant inputs from discharges and runoff into all U.S. coastal waters. It will be essential to continue developing and refining national databases to provide a sound basis for assessing trends and evaluating policy and technical decisions regarding waste disposal in marine environments. However, several factors currently limit the usefulness of these databases (477,600). In particular, neither database includes readily comparable information on pollutant inputs from dumping activities. In addition, the NOAA database will not be completed until 1987 (D. Farrow, NOAA, pers. comm., Sept. 9, 1986).

Lack of Information on Unregulated Pollutants of Concern

The information now available about pollutant inputs to marine waters is largely restricted to the substances that are specifically regulated under the Clean Water Act (CWA) or Marine Protection, Research, and Sanctuaries Act (MPRSA) because information programs and resources are generally focused on regulated pollutants.[3] Thousands of additional pollutants are present in the wastes disposed of in marine waters, however, and hundreds of these may have the potential to affect marine environments and human health. Most of these unregulated and potentially significant pollutants are either pathogens or organic chemicals. Little information is available about their presence in waste materials or marine environments.

These unregulated pollutants can be important. Hundreds of types of microorganisms—viruses, parasites, bacteria, fungi, and protozoa—can be present in waste discharges, sludge, or runoff, and many of these are capable of causing diseases. They can contaminate water and fish, and thus cause economic and recreational losses and direct risks to human health. Only one class of microorganisms—fecal coliform bacteria—is regulated as a CWA pollutant.[4] While not generally pathogenic, it is used to indicate the presence of sewage-derived material (and indirectly, pathogens). Recent studies have concluded, however, that the presence of fecal coliform bacteria is not a good indicator of the presence of these pathogens in marine waters (205).

Several hundred organic chemicals that are not on the CWA list of 126 toxic ''priority' pollutants can also be present in waste material and sometimes in runoff. In one survey, EPA identified 385 organic chemicals (with hundreds of others unidentified for various technical reasons) in municipal and industrial wastestreams (644). The chemicals included xylenes, dibenzofurans, and trichlorophenols. In addition, the environmental degradation of chemicals can yield products that sometimes are as toxic or more toxic than the parent compounds. Since tens of thousands of organic chemicals are currently in commercial use and hundreds of new ones are produced annually (386), it is likely that many other chemicals are also present in waste

‘**Regulated pollutants** are defined in box A of chapter 1. Information is not always available, however, even for regulated pollutants, For example, waste dischargers only report the quantities of those pollutants in their discharge for which some limitation has been specified in the discharge permit. Most discharge permits, however, include limitations on only a small fraction of listed toxic pollutants.

‘EPA recently has developed a marine water quality-based standard for *Enterococcus* bacteria; however, it is restricted to recreational waters.

discharges and runoff (e. g., from pesticide application). An unknown portion of these may be potentially harmful and warrant regulation.

As coastal populations and developments increase, and as the land-based disposal of certain hazardous wastes is increasingly restricted, it is highly likely that the amounts of pollutants—both regulated and unregulated—entering marine environments will increase. This trend raises concerns over whether current regulations cover all of the ‘‘ important’ pollutants —those pathogens, metals, and organic chemicals that are most likely to cause impacts.

In marine environments, there is little disagreement that the conventional and nonconventional pollutants currently regulated under C WA should indeed be regulated. [5] This consensus is based on a long history of experience, research, and monitoring.

Substantial disagreement exists, however, about the need to regulate additional pathogens, organic chemicals, and metals. From an economic perspective, resources are not available to individually regulate the dozens of metals and hundreds of microorganisms and organic chemicals that have been detected in waste material. Moreover, our technical capabilities and scientific understanding are not sufficient to determine which of these substances are present in concentrate ions sufficient to cause Impacts.

One way to evaluate and regulate the large number of potentially significant pollutants would be to develop better pollutant *screening* approaches to identify the unregulated pollutants that are of primary concern in marine environments. EPA has taken some initial steps to develop screening processes that, while broadly designed, could identify additional pollutants important in marine environments. In one effort, for example, EPA analyzed various industrial wastestreams and identified hundreds of unregulated organic chemicals (644). EPA identified six chemicals that were present in significant amounts, were not currently treatable, and which exhibited toxicity to humans or aquatic organisms: dibenzofuran, two trichlorophenols, carbazole, trichlorobenzene, and a form of dioxane. No standards have yet been developed for these six compounds, however. In a second effort, EPA is developing technical regulations for sewage sludge disposal options (including ocean dumping and various land-based options); the regulations will identify and focus on those pollutants that pose the greatest risks to humans and various environments.

These screening efforts have focused primarily on organic chemicals for several reasons. Many of these chemicals tend to persist in the environment for long periods and are acutely toxic to organisms. In addition, many are soluble in the fatty tissues of organisms and, once ingested from water or sediment, can bioaccumulate (i. e., concentrate) in these tissues. Some of these chemicals can also biomagnify (i. e., increase in concentration in higher levels of food chains) when the contaminated organisms are consumed by predators. Significant acute and long-term chronic impacts attributable to many organic chemicals have been documented in the laboratory and in the field. They are perhaps best exemplified by our experiences with DDT, the use of which has been banned since the early 1970s (54).

The continued development and use of screening procedures may help resolve existing uncertainties about which pollutants are of primary concern in marine environments (254). For example, a relatively simple test of the volubility of an organic chemical in certain organic solvents can serve as a measure of its potential to bioaccumulate in the tissues of marine animals (195). Similarly, the susceptibility of an organic chemical to degrade (e. g., by light energy or by organisms) or volatize can be used as a measure of its potential to be available to marine organisms or to cause impacts in marine environments.

For metals, additional factors such as the precise chemical form can be essential in determining bioavailability or toxicity. For example, organic mercury shows much higher toxicity and bioaccumulation potential than does inorganic mercury. Under conditions that generally prevail in marine environments, most metals bind strongly to particulate material, thus altering their environmental fates and impacts. Thus, screening efforts could focus on identifying those forms of metals that are

[5] Some concerns have been raised over [ht. appropriateness of using st an dards for fecal co] i form bacteria to control the level of m icrobiological pollutants in marine waters, as discussed previously

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actually toxic in marine environments, and those settings where toxic forms are likely to be present in levels sufficient to cause impacts to humans or marine organisms.

The presence in sewage sludge and other waste material of microorganisms that can cause diseases in humans often limits the availability of disposal options for these wastes. Monitoring for their presence is difficult because microorganisms are exceedingly difficult to detect in the field or characterize in the laboratory. Better culturing methods and indicators need to be developed before more extensive pathogen screening efforts can be undertaken. In addition, because many microorganisms are more likely to survive in sediments or in marine organisms than in the water column, monitoring programs must be designed to sample sediments and organisms.

Even for chemicals identified as being of potential significance through screening efforts, however, other factors must be evaluated in determining the need for, or the form of, regulation. For example, in some areas an important source of polycyclic aromatic hydrocarbons (PAHs) to marine environments is the natural seepage of oil from the ocean floor (19). Similarly, certain known human pathogens are natural members of the bacterial communities in nearshore marine environments (ch. 6).

The screening approaches discussed here focus on identifying individual compounds that have the potential to cause significant impacts. Because numerous pollutants can be present in wastestreams and in marine waters, approaches that first consider the overall toxicity of a wastestream or the cumulative impacts of all pollutants in a waterbody could also be helpful. For example, as a first step biomonitoring procedures (including whole-effluent toxicity tests) (49 FR 9016-9019, Mar. 9, 1984; ref. 64) and environmental indices (414) could be used to identify an effluent or water quality condition that has the potential to cause or is actually causing impacts. Then more extensive screening, using the approaches discussed for individual pollutants, could be used to pinpoint particular pollutants.

THE EXTENT OF POLLUTANT INPUTS INTO U.S. MARINE WATERS

Waste disposal activities in marine environments are diverse and highly variable in type, frequency, volume, location, and potential to cause adverse effects. Despite this diversity, much of the debate about marine waste disposal has centered on two main issues: 1) the direct dumping of sewage sludge, industrial waste, and radioactive materials; and 2) the incineration of hazardous wastes at sea. Much less attention has been devoted to comparing the relative contributions of pollutants from other disposal activities or sources such as pipeline discharges and runoff.

While the available data about these two main sources exhibit serious deficiencies, some generalizations can be made about pollutant inputs in different marine environments. In addition, the data can be used to illustrate the complexity and site specificity of disposal activities and pollutant inputs in marine waters.

Pollutants From Pipeline Discharges and Dumping

Marine waste disposal activities (i.e., pipeline discharges and dumping operations) are overwhelmingly concentrated in estuaries and coastal waters (see tables 2 and 3). For example, over 1,300 major industrial and almost 600 municipal facilities discharge directly into estuaries and coastal waters, and at most a few discharge into the open ocean. The open ocean is used for the dumping of some dredged material, sewage sludge, and industrial wastes, but four-fifths of the marine-disposed dredged material and virtually all marine-disposed sewage sludge are dumped in estuaries and coastal waters.[6]

[6]The New York Bight is included among coastal waters. However, the dumping of sewage sludge that now takes place in the New York Bight will soon be shifted to a site in the open ocean 106 miles from shore (see below and ch. 9). Current waste disposal sites are discussed below; both active and inactive sites are illustrated in (612).

Furthermore, most pipeline discharges and many dumping activities occur specifically in estuaries rather than in coastal waters. Almost 99 percent of industrial pipelines and 89 percent of municipal pipelines discharge directly into estuaries (table 2), and over half of all marine dumping of dredged material occurs there as well. The extent of these activities varies greatly around the country (tables 2 through 4). For example, over half of the major industrial and municipal pipelines are located in the Northern Atlantic region[7] and the western Gulf of Mexico; three-fourths of all municipal effluent is discharged from the Northern Atlantic States and California. The marine dumping of industrial wastes and sewage sludge is restricted to a few sites in the coastal and open ocean waters of the Northern Atlantic region.

[7]To facilitate discussion, OTA has grouped coastal States into various " regions —northern Atlantic, southern Atlantic, Gulf of Mexico, California and Hawaii, and northern Pacific (see fig. 21 in ch. 5).

Table 2.—Number of Municipal and Major Industrial Facilities Discharging Directly Into Marine Waters

Coastal States	Number of dischargers: Municipal		Major industrial		Total	
Northern ***Atlantic region:***						
Maine	***38***	***(3)b***	***35***		***73***	***(3)***
New Hampshire	***2***		***4***		***6***	
Massachusetts	20	(1)	20		40	(1)
Rhode Island	8	(2)	24		32	(2)
Connecticut	22		75		97	
New York	47	(1)	29		76	(1)
New Jersey	48	(12)	129	(2)	177	(14)
Pennsylvania	9		33		42	
Delaware	4		30		34	
Maryland	34	(1)	120		154	(1)
Virginia	11	(4)	76		***87***	***(4)***
District of Columbia	1		1		***2***	
Total	244	(24)	576	(2)	820	(26)
Southern Atlantic region:						
North Carolina	10	(1)	41		51	(1)
South Carolina	11		22		33	
Georgia	4		26		30	
Florida (Atlantic)	34	(Io)	24	(1)	58	(11)
Total	59	(11)	113	(1)	172	(12)
Gulf of Mexico region:						
Florida (Gulf)	22	(5)	17	(1)	39	(6)
Alabama	6		29		35	
Mississippi	6		30		36	
Louisiana	27	(1)	79		106	(1)
Texas	52		192	(1)	244	(1)
Total	113	(6)	347	(2)	460	(8)
California and Hawaii:						
California,	50	(18)	112	(5)	162	(23)
Hawaii	13	(4)	'?		13	(4)
Total	63	(22)	112	(5)	175	(27)
Northern Pacific region:						
Oregon	17	(1)	40	(5)	57	(6)
Washington	51		144		195	
Alaska	31	(5)	7		31	(5)
Total	99	(6)	184	(5)	283	(11)
Total/United States	***578***	***(69)***	1,332	(15)	1,910	(84)

[a]Municipal category includes all municipal facilities Industrial category includes those industrial facilities (excluding steam electric Plants) discharging more than 10.000 gallons per day The most recent available data pertain to dischargers as of 1982 or earlier
[b]Numbers in parentheses indicate discharges directly into coastal waters All remaining discharges are into estuarine waters.

SOURCES Office of Technology Assessment 1987; after EG&G Washington Analytical Services Center, *Industrial Waste Disposal in Marine Environments*, contract prepared for U.S Congress Office of Technology Assessment (Waltham, MA: 1966), Science Applications International Corp., *Overview of Sewage Sludge and Effluent Management*, contract prepared for US Congress, Office of Technology Assessment (McLean, VA 1986)

Table 3.—Quantities of Dredged Material Disposed of Annually in Marine Waters (mmt/yr)

	Average quantities disposed of annually			
Coastal region	Estuaries	O to 3 miles offshore[b]	Over 3 miles offshore[b]	Total
Northern Pacific	5.4	10.0	0.3	15.7 (9)
Southern Pacific.	8.4	4.3	2.4	15.1 (8)
Gulf of Mexico	91.3	16.4	10.9	118.6 (66)
Southern Atlantic	6.1	1.5	10.6	18.2 (lo)
Northern Atlantic	4.0	2.2	6.3	12.5 (7)
Total	115.2 (64)	34.4 (19)	30.5 (17)	180.1 (100)

[a]Data were obtained from each U.S. Army Corps of Engineers District Office in the form of an annual average; data were not obtained fOr individual years The period over which the data are averaged varies from one district to the next, but generally includes most of the 1970s and early 1980s. Units are millions of metric tons per year (mmt/yr); numbers in parentheses are the percent of the total.

[b]The distinction between "0 t. 3 miles offshore" and "over 3 miles offshore" was used by the Corps to classify its data, based on the statutory definition Of the territorial sea. This division does not, however, correspond exactly to the division between coastal and open ocean waters used by OTA: some open ocean waters may be Included in the "O to 3 miles offshore" category, and some coastal waters may be included in the "over 3 miles offshore" category (see box A in ch. 1).

SOURCE: Office of Technology Assessment, 1987; compiled from data obtained through a 1985-88 survey of District Offices of the U.S. Army Corps of Engineers.

Table 4.—Relative Contribution of Pollutants (in percent) by Major Sources in Coastal Hydrologic Units,[a] Circa 1977"81

Region and source	BOD	TSS	TKN	TP	CD	CR	CU	PB	AS	FE	HG	ZN	OIL	CHL HCS	FEC COL
Northern Pacific:															
Industrial[b]	34	<1	11	4	98	7	35	46	96	3	86	40	29	99	0
Municipal	27	<1	27	23	<1	1	1	2	2	2	0	4	16	<1	
Nonpoint	40	99	62	73	2	92	63	53	2	95	14	57	55	<1	9:
Southern Pacific:															
Industrial	3	<1	3	<1	81	2	<1	6	99	6	88	16	10	90	0
Municipal	55	1	31	21	3	8	7	7	<1		9	6	58	9	34
Nonpoint	43	99	67	78	16	90	91	87	<1	9:	3	78	33	<1	66
Gulf of Mexico:															
Industrial	34	<1	31	32	95	39	45	45	100	18	93	47	53	97	0
Municipal	26	<1	32	34	<1	4	6	2	<1	<1	3	5	9	3	16
Nonpoint	40	99	37	34	4	57	49	53	<1	82	3	49	39	<1	84
Southern Atlantic:															
Industrial	28	<1	10	14	73	58	27	12	100	7	89	25	8	98	<1
Municipal	35	<1	54	73	1	8	9	3	0	1	6	7	13	1	10
Nonpoint	37	99	36	13	26	34	64	85	<1	92	6	68	79	<1	90
Northern Atlantic:															
Industrial	6	<1	8	7	84	15	18	16	100	21	92	25	5	93	<1
Municipal	73	3	74	76	2	32	23	13	<1	10	5	19	46	7	12
Nonpoint	21	97	17	18	13	52	60	72	<1	69	3	56	49	<1	88
Total U.S. coastal:															
Industrial	**11**	<1	9	5	89	15	18	20	100	13	91	25	11	94	<1
Municipal	**56**	1	46	36	1	13	11	8	<1	5	5	9	41	6	16
Nonpoint	34	99	45	59	10	72	71	73	<1	82	3	66	47	<1	84

KEY: BOD—Biochemical oxygen demand; TSS—Total suspended solids; TKN—Total Kjeldahl nitrogen; TP—Total phosphorus; CD—Cadmium; CR—Chromium; CU—Copper; PB—Lead; AS—Arsenic; FE—iron; HG—Mercury; ZN—Zinc; OIL—Oil and grease; CHL HCS—Chlorinated hydrocarbons; FEC COL—Fecal coliform bacteria

[a]Information regarding contribution of pollutants is aggregated for all maritime hydrologic units in each region. Hydrologic units are designated by the U.S. Geological Survey and represent natural and human-made drainage areas. Only pollutants that first enter surface waters in maritime hydrologic units (i.e., directly adjacent to marine waters) are included. Pollutants originating in upstream hydrologic units and flowing into the maritime units considered here are excluded, although in some instances the upstream units contribute a sizable portion or even a majority of the pollutants entering coastal waters. Regions are graphically illustrated in ch. 5 (see fig. 21). Here, the Northern Pacific excludes Alaska; the Southern Pacific includes California only and excludes Hawaii; the Southern Atlantic excludes Puerto Rico,

[b]The "industrial" category includes pOWerplantS.

SOURCE: Office of Technology Assessment, 1987; based on Resources for the Future, Pollutant *Discharges to Surface Waters in Coastal Regions,* contract prepared for U.S. Congress, Office of Technology Assessment (Washington, DC: February 1988), The largest quantities of waste material are introduced into marine waters by industrial and municipal pipeline discharges and from the dumping of dredged material. Pipeline discharges are generally expected to increase in association with increasing industrial development and the growth of coastal populations. Dumping of dredged material in coastal and open ocean waters has fluctuated widely (figure 2A), depending on the nature and timing of harbor development and maintenance activities. Only relatively small quantities of industrial wastes and sewage sludge are currently dumped in marine waters. [e] During the last 10 years, dumping of industrial wastes declined dramatically, while dumping of sludge increased (figure 2B).

Pollutants From Waste Disposal and Nonpoint Sources

Pollutants that enter marine environments from waste disposal activities and nonpoint sources are classified into three categories in the Clean Water Act. [8] Conventional *pollutants* include suspended solids, oxygen-demanding substances, pH, oil and grease, and fecal coliform bacteria. *Nonconventional polutants* is a catch-all category that includes nutrients such as nitrogen and phosphorus. *Toxic or priority pollutants* include 126 metals and organic chemicals. Each of these categories of regulated pollutants has been linked with observed impacts on marine resources and humans.

Inputs of these pollutants from disposal activities are significantly greater in estuaries and coastal waters than in the open ocean because of the greater intensity of these activities in waters close to shore. This skewed distribution is even further accentuated because many of the same pollutants are introduced into estuaries and coastal waters by rivers and by nonpoint sources (i. e., agricultural and urban runoff).

On a national scale, available data allow a rough comparison of pollutant inputs from point source pipeline discharges and nonpoint runoff that directly enter marine waters. In this limited compar-

Figure 2A.-Amount of Dredged Material Dumped in Coastal and Open Ocean Waters Only, 1973.84
(excluding dumping **in estuaries)**

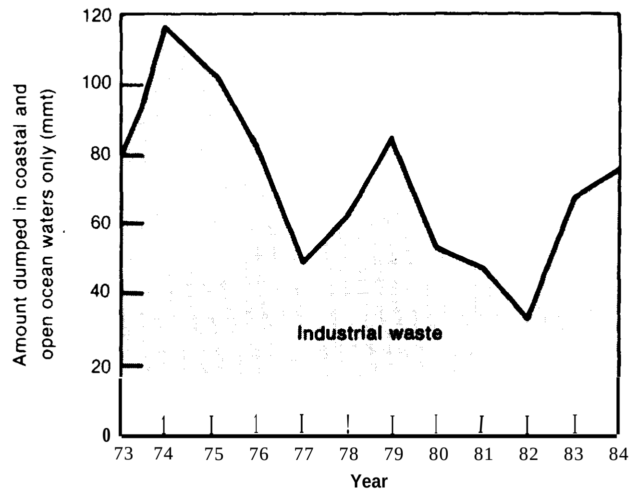
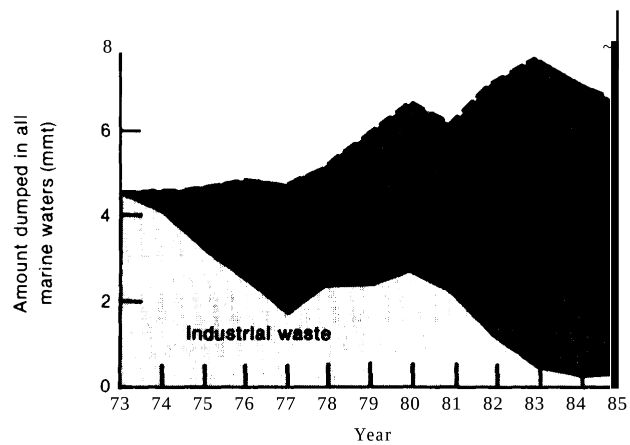


Figure 2B.– Amounts of Industrial Waste and Municipal Sewage Sludge Dumped in Ail Marine Waters, 1973-85



Amounts **in million metric tons (mmt). All dumping of industrial wastes and municipal sewage sludge occurs in coastal and open ocean waters. Two-thirds of all dumping of dredged material occurs in estuaries, but data are not available on a yearly basis for such dumping; therefore, only the amounts of dredged material dumped in coastal and open ocean waters are shown in figure 2A. Note that the scale for dredged material is about 10 times greater than the scale for industrial wastes and sewage sludge.**

SOURCES U.S Army Corps of Engineers, *1980 Report to Congress on Administration of Ocean Dumping Activities*, Pamphlet 82-PI (Fort Belvoir, VA: Water Resources Support Center, May 1982), U S Army Corps of Engineers, *Ocean Dumping Report for Calendar Year 1981*, Summary Report 82-S02 (Fort Belvoir, VA" Water Resources Support Center, June 1982); U S Army Corps of Engineers, Ocean *Dumping Report for Calendar Year 1982,* Summary Report 83-SRI (Fort Belvoir, VA: Water Resources Support Center, October 1983); U S Environmental Protect Ion Agency, *Report to Congress,* January 1987 *-December* 1983, On *Administration of the* Marine *Protection, Research, and Sanctuaries Act of 1972, As Amended (Public Law 92-532) and Implementing the International London Dumping Convention* (Washington, DC: Off Ice of Water Regulations and Standards, June 1984): J Wilson, U S Army Corps of Engineers, personal communication. 1986; R DeCesare, Off Ice of Water, U.S. Environmental Protectlon Agency, personal communication, January 1987

'The total amount of dredged material dumped is about 10 times greater than the amount of sewage sludge and about 25 times greater than industrial wastes. In the New York Bight, however, the amounts of dredged material and sewage sludge are roughly comparable.

'MPR SA prohibits the disposal of substances that "unreasonably degrade' the marine environment. Unlike CWA A, however, it does not explicitly classify substances, although it docs include the lists of prohibited or regulated substances developed by the London Dumping Convention, ison, the source contributing the majority of a particular pollutant varies with the pollutant (table 4).[10] It is also apparent that more than one source can be an important contributor of some pollutants (e. g., phosphorus). As can be seen from table 4, *some* generalizations at a national level are possible, however:

- Industrial discharges are, not surprisingly, the dominant sources of many organic chemicals and some metals, accounting for about 90 percent or more of the inputs of cadmium, mercury, and chlorinated hydrocarbons. Inputs of some other metals (e. g., chromium and lead) are dominated by nonindustrial sources in some areas of the country.
- Municipal point sources are major contributors of certain conventional pollutants, accounting for about half of biochemical oxygen demand, total nitrogen, and oil and grease. Surprisingly, however, municipal discharges contribute only one-sixth of the input of fecal coliform bacteria.[11] Municipal discharges are particularly dominant sources of biochemical oxygen demand and nitrogen in the northern Atlantic and in California.
- Nonpoint runoff dominates as a source of suspended solids, and also contributes half or more of total phosphorus, chromium, copper, lead, iron, and zinc. It is also the overwhelming contributor of fecal coliform bacteria in all areas of the country. Nonpoint runoff is a particularly significant contributor of a range of pollutants along the Pacific coast.

In addition, sufficient information is available to conclude that upstream sources of pollutants—whether originating from waste disposal or nonpoint pollution—are the largest sources in the Gulf of Mexico and appear to be important in the northern Atlantic region. However, the absolute *quantity* of pollutants is only a partial measure of their subsequent *impact;* for example, many riverborne pollutants are considerably more diluted or degraded by the time they reach marine waters than they would be if they had been released directly into those waters. Thus, the magnitude of marine impacts due to upstream sources is not necessarily commensurate with the magnitude of their pollutant inputs.

It is difficult to compare pollutant inputs from pipeline discharges and runoff to those resulting from marine dumping of dredged material or sewage sludge because of the extreme variability in composition of dumped wastes and the intermittent and localized nature of dumping operations. Dumping—and resulting pollutant inputs—appears to be relatively minor in *most* estuaries and coastal waters; however, in those areas where dumping does occur, it can be a significant contributor of many pollutants. Table 5 compares inputs from various sources to the waters of the New York Bight based on estimates for the mid-1970s; more recent comprehensive data are not available. This example represents an extreme case, however, because the significance of dumping as a source of pollutants is probably greater in the New York Bight than in other estuarine or coastal regions of the United States.

On a local or regional scale, the relative importance of any source can vary from the above generalizations, depending on factors such as: the type of industrial development, the nature of industrial discharges to municipal sewage treatment systems, the relative amounts of urban and agricultural runoff, the extent of combined sewer overflow, the relative contamination of sediments by discharges and runoff, and the extent of port maintenance. The majority of total phosphorus, for example, is contributed by municipal pipelines along the east coast and by nonpoint sources along the west coast; in the Gulf of Mexico, roughly equal amounts are contributed by industrial discharges, municipal discharges, and nonpoint sources (table 4).

The amounts of specific pollutants in discharges or runoff can change over time. For example, regulations governing the production, use, or disposal of certain substances can affect the amounts of pol-

[10]The estimated amounts of pollutant inputs (478) are not included in table 4 because the purpose here is to examine the relative contributions by different sources and to illustrate the variability that is an important feature of pollutant inputs. The assumptions and uncertainties in the database are discussed in detail by RFF (477,478); information from other databases (particularly NOAA's) corroborate the general relationships portrayed in table 4 and support the importance of variability.

[11]This is *not* to imply that fecal coliforms are necessarily contributed primarily by natural sources. Sources such as combined sewer overflows, leakage from septic tanks, and other discharges of untreated sewage may well contribute to the high contribution of fecal coliforms by nonpoint sources,

Photo credit National Oceanic and Atmospheric Administration

Many pollutants are carried into the Gulf of Mexico by rivers, especially the Mississippi River, from areas far from the coast. This satellite photo shows river water laden with sediment and other matter appearing as whispy white plumes.

Table 5.— Relative Contribution of Various Pollutants by Major Sources in the New York Bight, Circa Mid-1970s

		Percent contribution by source			
	Total mass input	Dumping[a]	Atmospheric input	Pipeline discharges[b]	Runoff
Cadmium	880 mt/yr	82	2	6	10
Chromium	1,810 mt/yr	50	1	23	26
Copper	5,060 mt/yr	51	3	20	26
Lead	4,600 mt/yr	43	9	22	25
Mercury	110 mt/yr	9	—	73	18
Zinc	12,000 mt/yr	29	18	10	43
PCBS	7.4-8.6 mt/yr	55-64	—	3-13	39[c]
TSS	8,800 x 10° mt/yr	63	5	4	28
TOC	950 X 10^9 mt/yr	25	12	30	33
Nitrogen	190 x 10’ mt/yr	16	13	42	29
Phosphorus	50 x $1O^U$ mt/yr	50	0.7	36	13

ABBREVIATIONS PCBs = polychlorinated biphenyls; TSS = total suspended solids, TOC = total organic carbon; mt/yr = metric tons per year
[a] Includes dumping of both sewage sludge and dredged material
[b] Includes both municipal and Industrial discharges
[c] Estimate is for upstream sources, which include both Point and non point sources

SOURCES Off Ice of Technology Assessment, 1987, based on J.A Mueller, et al , “Contaminants in the New York Bight, ” *Journal of Water Pollution Control Federation 48(10) 2309-2326, 1976* (for metals, TSS, TOC, nitrogen, phosphorus), J.M O’Connor, et al , “Sources, Sinks, and Distribution of Organic Contaminants in the New York Bight Ecosystem, ” in *Ecological Stress and the New York Bight: Science and Management,* G F Mayer (ed) (Columbia, SC: Estuarine Research Federation, 1982) (for PCBs); A J Mearns, et al , “Effects of Nutrients and Carbon Loadings on Communities and Ecosystems, ” in *Ecological Stress and the New York Bight: Science and Management,* G.F Mayer (ed) (Columbia. SC Estuarine Research Federation, 1962) (for TSS, TOC, nitrogen, phosphorus] lutants, such as when restrictions on DDT and PCBs significantly reduced the levels of these substances in pipeline discharges. Regulations have resulted in some reductions in the amounts of oxygen-demanding pollutants and nutrients in industrial and municipal discharges.

Climatic factors also differentially affect the contribution of pollutants from various sources and their subsequent impacts. For example, municipal point sources may be more important contributors ef nutrients during summer months, when rainfall and river flow (and thus nonpoint runoff are generally lower; conditions conducive to eutrophication are also most prevalent in the summer.

MAJOR SOURCES OF POLLUTANTS TO U.S. MARINE WATERS

Two major source categories contribute pollutants to U.S. marine waters: waste disposal and nonpoint pollution. (In addition to this information, box H discusses the management of low-level radioactive waste, and box I summarizes information about the quantities of wastes dumped in the ocean by other countries.)

Waste Disposal

Waste disposal means the intentional release of wastes to marine waters, either through direct dumping or through pipeline discharges. Nonpoint pollution, in contrast, is more diffuse and includes, for example, runoff from rural and urban land surfaces.

Dumping Activities

Wastes dumped in marine environments include dredged material, municipal sewage sludge, and industrial wastes.

Dredged Material.—Very large amounts of dredged material—about 180 million wet metric tons (mt)—are disposed of each year in U.S. marine waters (table 3), accounting for some 80 to 90 percent of the volume of all material dumped in these waters. Approximately two-thirds of all dredged material is dumped in the Gulf of Mexico.

Almost two-thirds of marine dumping of dredged material occurs in estuaries (including intertidal areas), The remainder is divided more or less evenly between waters within the 3-mile territorial boundary and waters beyond this boundary. [2] The types of marine waters used most frequently for disposal vary considerably around the country. In the Gulf of Mexico and in California, for example, most material is dumped in estuaries; in the southern Atlantic region, in contrast, most material is dumped more than 3 miles from shore.

Over the last 10 to 15 years, the annual amount of dredged material disposed of in coastal and open ocean waters only has varied considerably (data are not readily available for the amounts of material dumped each year in estuaries). The total amount of material dumped in these waters showed a general decline from 120 million wet mt in 1974 to about 35 million wet mt in 1982 (figure 2A). It is difficult to predict how much material will be dredged in the future, but it could increase substantially if several harbor deepening projects that are now being considered by the Corps of Engineers and Congress are undertaken (see ch. 10).

The composition of dredged material also varies from one area to the next. In some areas, sediments have been contaminated by metals and organic chemicals originating from industrial and municipal discharges and nonpoint pollution. When these sediments are dredged and then dumped, the pollutants are carried along to the dumping site, Only a fraction of all dredged material is considered by the Corps of Engineers to be contaminated, although the absence of specific numerical criteria to define contaminated material is a source of controversy.

Municipal Sewage Sludge and Industrial Wastes.—Most waste other than dredged material that is dumped in marine waters consists of sewage sludge from municipal treatment plants and acid or alkaline liquid industrial wastes. These wastes can contain a variety of different pollutants.

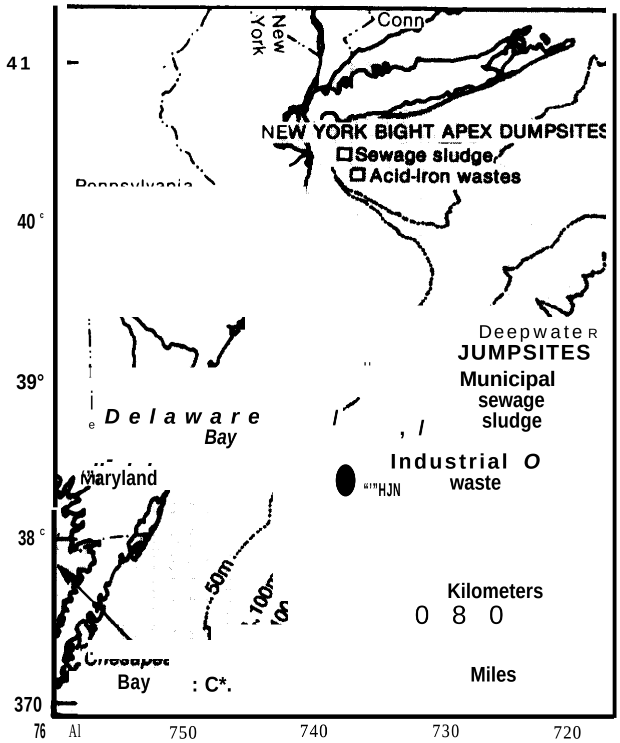
[2] Most of the waters beyond this boundar, can be classified as open ocean, but some- in particular, the New York Bight —are classified here as coastal waters.

For the last several decades, many marine dumpsites have been used for the disposal of sewage sludge and industrial wastes. However, most dumping of these materials has taken place in the coastal waters of the Northeastern United States. Currently, only a few sites are being used, all located either in the New York Bight or in open ocean waters about 100 miles east of the coast of Delaware.

The dumping of sewage sludge has steadily increased from 2.5 million wet mt in 1958 to 7.5 million wet mt in 1983; 6.6 million wet mt were dumped in 1985 (figure 2B), In 1980, EPA phased out dumping by over 100 municipalities (including one large city, Philadelphia); however, these municipalities together accounted for only 3 percent of all dumped sludge (292). The amount of sludge dumped continued to increase after 1980, partly because more secondary treatment plants, which produce more sludge, came into operation in the New York area. Most sewage sludge has been dumped either at the mid-Atlantic site off of Delaware Bay or at the 12-Mile Sewage Sludge Dump Site located in the New York Bight (figure 3). Sewage sludge currently dumped in marine waters originates from nine sewerage authorities in New York and New Jersey; most of it is currently dumped at the 12-Mile site, but over the next few years all remaining marine dumping will be moved to the Deepwater Municipal Sludge Site which lies just off the edge of the continental shelf (figure 3).13

Marine dumping of industrial wastes meanwhile has decreased dramatically over the last decade (figure 2 B) from a peak of 4,6 million wet metric tons in 1973 originating from over 300 industrial firms (6,1 15, 292), to the current level of about 200,000 wet metric tons dumped annually by 3 firms (ch. 11; refs. 139,648). Most of this is dumped at the Deepwater Industrial Waste Site, located about 10 nautical miles west of the Deepwater Municipal Sludge Site.[14] The vast majority of these industrial

Figure 3.— Location of Current Municipal Sewage Sludge and Industrial Waste Dumpsites in the Northern Atlantic Ocean



SOURCES 49 Federal Register 19005-19012, May 4, 1966, W D Muir, "History of Ocean Disposal in the Mid-Atlantic Bight," ch 14 in *Wastes in the Ocean*, VOl 1, I W Duedall, et al (eds) (New York John Wiley & Sons, 1983)

wastes has been dumped in the northern Atlantic, although pharmaceutical wastes were dumped at a site north of Puerto Rico for almost a decade until 1981.

Pipeline Discharges

OTA obtained two different types of estimates for the number and flow of pipelines whose discharges may affect marine waters. The first estimate includes all discharges located in coastal counties of the United States; this clearly represents an overestimate because only a fraction (albeit unknown) of wastewater and associated pollutants discharged in inland areas of coastal counties will reach marine waters. *The second estimate includes only those discharges directly into marine (estuarine or coastal) waters;* this number probably underestimates the total number and flow of pipelines affecting marine waters because it excludes that fraction

[13] The Deepwater Municipal Sludge Site occupies an area of approximately 100 square nautical miles. It is located approximately 120 nautical miles southeast of Ambrose Light, New York, and 115 nautical miles from Atlantic City, New Jersey, in water depths ranging from *2,250* to *2,750* meters (49 FR 19005-19012, May 4, 1984).

[14] The Deepwater Industrial Waste Site occupies an area of approximately 30 square nautical miles. It is located approximately 125 nautical miles southeast of Ambrose Light, New York, and 105 nautical miles from Atlantic City, New Jersey, in water depths ranging from 2,250 to 2,750 meters (49 FR 19005-19012, May 4, 1984).

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must still approve of any LLW dumping permit within 90 days of the initial application. As a result, the Navy has decided to bury the radioactive components on land, despite its conclusions about relative risks.

If dumping of LLW by the United States does occur again, current regulations would require greater containment than in the past.†† After dumping, for example, the waste would have to remain in a canister until it decayed to levels of radioactivity determined by EPA to be environmentally innocuous; in addition, a comprehensive monitoring plan would be required. EPA is updating and expanding these regulations (scheduled for completion in December 1987).

Some LLW has been discharged from pipelines into U.S. surface waters and carried downstream to marine waters. Prior to the mid-1960s, reactors at several defense sites had systems in which cooling water could be contaminated with radionuclides if a fuel leak occurred. Such incidents occurred at the Hanford site in Washington, for example, and the contaminated cooling water was discharged into nearby streams and carried into the Columbia River and the river estuary (456). Reactors with this design have been inoperative since the mid-1960s, yet estuaries downstream of them still contain residual radioactivity (e.g., of cobalt-60) (456). Reactors operating today are designed with a closed system, in which radioactive effluent is carried into cribs designed to trap radionuclides. Despite this, some radionuclides have migrated into nearby streams in concentrations higher than those acceptable under EPA drinking water standards (C. Welty, U.S. Department of Energy, pers. comm., September 1986); some of these radionuclides subsequently have migrated into estuaries.

Internationally, no LLW has been dumped since 1983, and an "indefinite" moratorium on such disposal was adopted in 1985 (see box I).

Issues Affecting Future Marine Disposal

Several issues affect the potential for future marine disposal of LLW: 1) environmental feasibility; 2) economical, political, and social acceptability; and 3) potential problems in siting land-based disposal facilities. Most analyses to date have focused on the environmental issue.

The environmental consequences of dumping at the most heavily used international marine site (in the northeastern Atlantic, see box I) have been investigated by a panel of experts appointed by the Organization for Economic Cooperation and Development's Nuclear Energy Agency. The panel concluded that: 1) maximum exposure of humans to radioactivity from marine dumping of LLW has been extremely low, substantially lower than exposure from land-based disposal; 2) no significant damage has occurred to marine organisms at or near the site; and 3) accelerated use of the site would not change these conclusions (312). However, the panel also noted that monitoring the site was difficult, that impacts could not be detected outside of a certain stated range, and that impacts in the deep sea could not be adequately assessed without improved biological and radioecological information (312). In addition, poor recordkeeping at many LLW dumping sites, including the early years of dumping at the northeastern Atlantic site, has made assessments of environmental impacts more difficult.

In September 1985, a majority of Members of the London Dumping Convention (see box Q in ch. 7) passed a resolution that required additional studies [illegible] economic, and social aspects of dumping at sea; 2) costs and risks of land-based [illegible] disposal; 3) whether it can be proven that dumping will not harm human life or cause significant [illegible] damage; and 4) assessment by the International Atomic Energy Agency of [illegible]. A decision to terminate the moratorium on dumping was tabled (at the Tenth [illegible] of the Contracting Parties to the LDC, held in October 1986) pending the [illegible]

Problems in siting [illegible] also influence decisions about marine disposal of [illegible] Energy has been unable to find a disposal site on land that is acceptable to the public for Manhattan Project waste (mostly contaminated

††40 CFR 227.11, adopted after dumping practices ceased.

soil and building rubble containing very low concentrations of radionuclides) and is therefore considering the feasibility of dumping the waste at sea (E. Delaney, U.S. Department of Energy, pers. comm., September 1984). In addition, the governors of the three States (South Carolina, Nevada, and Washington) with land-based sites for LLW disposal have threatened to stop accepting commercial LLW from other States. To address this problem, Congress passed the Low-Level Radioactive Waste Policy Act of 1980, under which States are encouraged to form multi-State "compacts," with each compact having its own disposal site. No new sites had been selected by 1986, however, and Congress amended the act to further encourage States to take responsibility for their LLW. If new land-based disposal sites are not developed in the future, interest in marine disposal possibly could increase.

of upstream discharges that does reach marine waters. Table 6 presents a comparison of these two estimates for the number and flow of municipal and industrial pipelines.

Using the conservative data, almost 2,000 municipal and major industrial pipelines discharge effluent directly to estuaries and coastal waters. Almost all of these pipelines (about 96 percent) are located in estuaries, and over two-thirds are industrial (table 2).[15] The largest share (43 percent) of these discharges are concentrated in the northern Atlantic region. The Gulf of Mexico, in particular the western Gulf, also has a high concentration of pipelines.

There are, of course, substantial variations in the amounts of municipal and industrial discharges into individual waterbodies. In one analysis of four estuaries and coastal waterbodies, the number of major industrial dischargers was estimated to be three to five times higher than the number of municipal dischargers in three waterbodies (Puget Sound, San Francisco Bay, and Narragansett Bay). In contrast, in the Chesapeake Bay municipal dischargers were three times as numerous as major industrial dischargers (139).

[15] In addition to these discharges, a larger number of minor industrial and commercial facilities also discharge into these waters, but they account for only a small fraction of total pollutant inputs.

Table 6.-Comparison of All Discharges in Coastal Counties and Those Discharges Directly to Marine Waters

	Number of dischargers	Flow (bgy)	Database, source	Reference
Municipal dischargers:				
Coastal county[a]	2,207	3,620	NCPDI, from NOAA	1
Direct marine[b]	578	2,306	IFD and Needs Survey, from EPA	2
Industrial dischargers:				
Coastal county (major and minor)[c]	4,592	4,914	NCPDI, from NOAA	
Direct marine (major only)[d]	1,332	4,136	IFD, from EPA	

ABBREVIATIONS: bgy = billion gallons Per year
NCPDI = National Coastal Pollutant Discharge Inventory
IFD = Industrial Facilities Database
NOAA = National Oceanic and Atmospheric Administration
EPA = Environmental Protection Agency.

aDischargers located in coastal counties of the United States.
bDischargers actually discharging wastewater directly into marine (estuarine or coastal) waters of the United States.
cEstimates include both major and minor dischargers.
dEstimates include only major dischargers (defined by EG&G, 1986 (ref. 3 below), as those with wastewater flows greater than 0,01 million gallons per day).

REFERENCES:

1, Data from National Coastal Pollutant Discharge Inventory (NCPDI) received through personal communication, D.J. Basta, Chief, Strategic Assessments Branch, NOAA, Washington, DC, Nov. 14, 1988.

2, Adapted from Science Applications International Corp., Overview of Sewage *Sludge and Effluent Management,* contract prepared for US Congress, Office of Technology Assessment (McLean, VA: 1988); based on analysis of data from EPA's Industrial Facilities Database (IFD) and a 1982 EPA Needs Survey of municipal sewage treatment facilities (U.S. Environmental Protection Agency, Office of Municipal Pollution Control, *Assessment of Needed Publicly Owned Wastewater Treatment Facilities* in the *United States,* EPA 430/9-84-011 (Washington, DC: February 1985)).

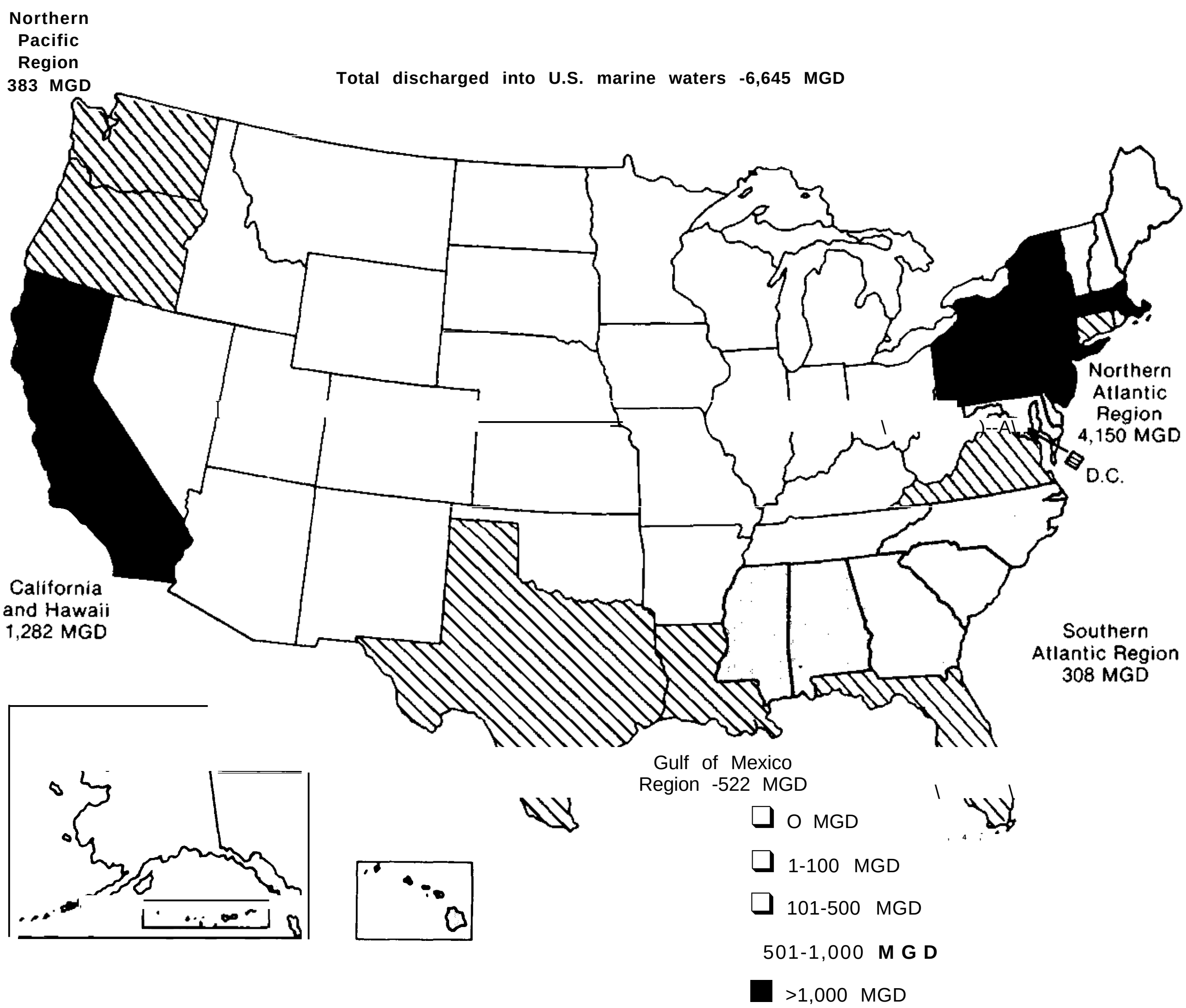
3. Adapted from EG&G Washington Analytical Services Center, Inc., Oceanographic Services, *Industrial Waste Disposal in Marine Environments*, contract prepared for U.S. *Congress,* Office of Technology Assessment (Waltham, MA: 1988); based on analysis of data from EPA's Industrial Facilities Database (IFD).

SOURCE: Office of Technology Assessment, 1987.

Municipal Discharges.—Of the approximately 15,500 publicly owned treatment works (POTWs) in the United States, only about 3.5 percent (i. e., a total of 578) discharge directly into estuaries and coastal waters (ref. 503). The POTWs that discharge into marine waters, however, account for one-fourth of the Nation municipal wastewater; moreover, almost 90 percent of them (509) discharge into estuaries (table 2). POTWs discharging into marine waters account for such a large portion of total wastewater because many of them are large and serve densely populated coastal areas. On an annual basis, they discharge a total of about 2.3 trillion gallons of effluent into marine waters—2 trillion gallons into estuaries and 0.3 trillion gallons into coastal waters (503).

The amount of municipal effluent discharged to marine waters varies considerably among different regions of the country (figure 4). More than 60 per-

Figure 4.—Amount of Effluent Discharged From Major Municipal Sewage Treatment Plants Directly Into Marine Waters, By State, Circa 1982 **(amounts in million gallons per day, MGD)**



SOURCE" Off Ice of Technology Assessment, 1987; after Science Applications International Corp., "Overview of Sewage Sludge and Effluent Management, " contract prepared for U.S Congress, Office of Technology Assessment (McClean, VA: 1986) cent of all municipal discharges to marine waters occurs in the waters of the northern Atlantic region, especially from New York. Almost 20 percent is discharged from California. The magnitude of municipal discharges has increased roughly in parallel with population growth and as previously unsewered sources have been connected to municipal systems.

A few sewerage authorities in Los Angeles and Boston discharge sludge through POTW outfalls into marine waters (see ch. 9). Such discharges are scheduled to be terminated by 1987 for Los Angeles and the mid- 1990s for Boston.[16] In 1980, some 107,000 dry metric tons of sludge were discharged by POTWs in southern California (U.S. General Accounting Office, 1983, cited in ref. 503).

The quantities of different pollutants in municipal effluent and sludge depends primarily on the nature of any industrial discharges to POTWs and the degree of treatment used by POTWs. A significant portion of the wastewater entering POTWs consists of indirect industrial discharges. Nationally, some 160,000 indirect discharges account for about one-eighth of the wastewater flow through all POTWs (ref. 666). For those POTWs that discharge into marine waters, indirect industrial discharges account for a slightly larger portion, about one-seventh (0.33 trillion gallons per year, or tgy) of wastewater flow; most of this (about 0.31 tgy) enters estuaries rather than coastal waters (ref. 503). In addition, the concentration of pollutants in municipal discharges depends on the degree of treatment because higher levels of treatment remove (either intentionally or incidentally) greater amounts of pollutants. About two-fifths of the effluent discharged into marine waters receives less than secondary treatment (see ch. 9).

Industrial Discharges .—Over 1,300 major industrial facilities (excluding powerplants) discharge effluents directly into marine waters; about 98 percent of these discharge into estuaries (table 2). This estimate excludes minor dischargers, facilities located upstream whose discharges reach marine waters, and indirect industrial discharges into municipal sewers; lack of data on these additional industrial sources introduces considerable uncertainty into the estimation of these contributions.

As seen in table 2, the number of industrial dischargers varies significantly among different geographic regions, not surprisingly showing a strong correlation with the density of industrial development. The quantity and composition of industrial discharges also varies from one area to the next, depending on the degree and nature of industrial development. Because of the wide variations resulting from these factors, it is very difficult to assess the relative importance of pollutant inputs from industrial discharges in different regions of the country. Information about the amounts of metals and organic chemicals in industrial discharges is discussed in detail in chapter 8.

Nonpoint Pollution

Nonpoint pollution is an important contributor of pollutants to marine waters in all parts of the country. Sources of nonpoint pollution include:

- runoff from cities, industrial sites, and farmland, caused mostly by precipitation and subsequent drainage;
- precipitation itself;
- atmospheric deposition;
- underground transport through aquifers; and
- other releases of pollutants (e. g., leaching of pollutants such as tributyltin from ship hulls; see box J).

Nonpoint pollution also can originate from septic tank systems and from combined sewer overflows (CSOs) (figure 6). Sewage from septic tanks, for example, can drain either directly or through aquifers into marine waters or into rivers flowing into marine waters.

Generally, the only data available on the contribution of pollutants by different nonpoint sources are for runoff. Runoff tends to be an especially large source of fecal coliform bacteria, suspended solids, and, to a lesser extent, oxygen-demanding pollutants and nutrients (table 4). Urban runoff contributes large quantities of oil and grease, lead, and

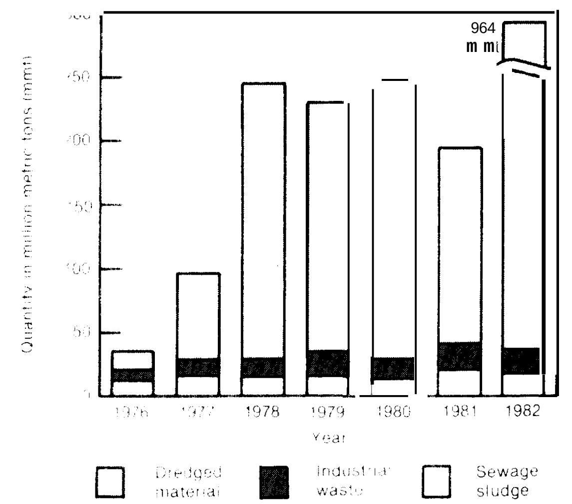
[16] In the Ocean Dumping Amendments Act of 1985, passed by the House of Representatives but not considered by the Senate, a provision was included which would have allowed Boston to dump its sewage sludge on an interim basis in the open ocean beyond the edge of the continental shelf (146,581). However, Boston has since announced its intention to develop land-based options and not pursue ocean dumping, either at the Deepwater Municipal Sludge Site or a new site (153).

Box I.—Quantities of Wastes Dumped in the Ocean by Other Countries

The United States is not the only country that dumps wastes into marine waters. According to the most recent data available from records maintained by the London Dumping Convention (LDC), an annual average of 300 to 400 million tons of waste was dumped into marine waters between 1976 and 1982 by Nations that are members of the LDC (including the United States) (figure 5). * About 90 percent of this is dredged material generated by the deepening or maintenance of ports, harbors, and shipping channels. Of the remaining 10 percent, about half is industrial waste and half is sewage sludge. This material was disposed of under some 400 to 600 individual annual permits.

No data are available on numbers and amounts of pipeline discharges of industrial and municipal effluents worldwide, and virtually no data exists on the practices of Nations that are not parties to the LDC. Information on the incineration of hazardous wastes at sea is reviewed in reference 586.

Figure 5.-Annual Worldwide Quantities of Waste Disposed of in the Ocean, 1976-82



SOURCE: I.W. Duedall, et al. (eds.), "Chapter 1: Global Inputs, Characteristics, and Fates of Ocean-Dumped Industrial and Sewage Wastes, " *Wastes in the Ocean*, vol. 1 (New York, NY" John Wiley & Sons, 1983).

Dredged Material

About 1.3 billion metric tons of sediment are dredged each year worldwide. The United States accounts for about 35 percent of this material. Of the total amount of material dredged worldwide, a large portion— about 1.1 billion tons—is disposed of in or near marine waters. * * Some 23 percent is disposed of in open ocean waters, 36 percent in nearshore and intertidal sites (and behind bulkheads), 27 percent in wetlands or in open-water areas in estuaries, and the remainder in upland areas and other environments. About three-fourths of this total was from new projects and one-fourth from maintenance dredging (442).

Industrial Wastes

The types of industrial wastes disposed of in the ocean vary greatly among different countries. The most toxic industrial wastes are banned from ocean disposal by all of the international conventions (see box Q in ch. 7), and some countries are phasing out all ocean dumping of industrial wastes. Little if any hazardous waste (as they would be defined by the U.S. Resource Conservation and Recovery Act) is disposed of in the ocean, other than certain corrosive wastes (acid or alkaline liquids) which are neutralized by the natural buffering capacity of seawater.

Many nations, however, still dump some "nonhazardous' industrial wastes in the ocean. Between 1977 and 1982, an annual average of about 17 million metric tons of industrial waste was dumped in the ocean. The largest amount was dumped by the United States, followed by France, the United Kingdom, Hong Kong, Germany (FRG), h-eland, the Netherlands, Belgium, Italy, Spain, New Zealand, Canada, Australia, and Denmark (132).

Sewage Sludge

Between 1977 and 1982, an average of 17 million wet metric tons of sewage sludge was dumped in the ocean each year. The United States and the United Kingdom contribute roughly equal shares, and together account for more than 95 percent of this total. In many countries, both treated and untreated

*The LDC is an international agreement that governs the deliberate dumping of wastes into the world's oceans (see box Q in ch. 7). Member Nations are required to report annually to the LDC the number of permits granted for ocean dumping and the types and tonnages of wastes disposed of in this manner. It is not possible to discern whether dumping of waste into *all* marine waters (estuaries, coastal waters, and the open ocean) is included in the LDC estimates. This accounts for any discrepancies between these figures and others cited here.

**These figures are based on a survey of 108 ports in 38 countries conducted in 1980 by the International Association of Ports and Harbors.

sewage is discharged into marine waters through pipelines or into rivers that directly enter marine waters.

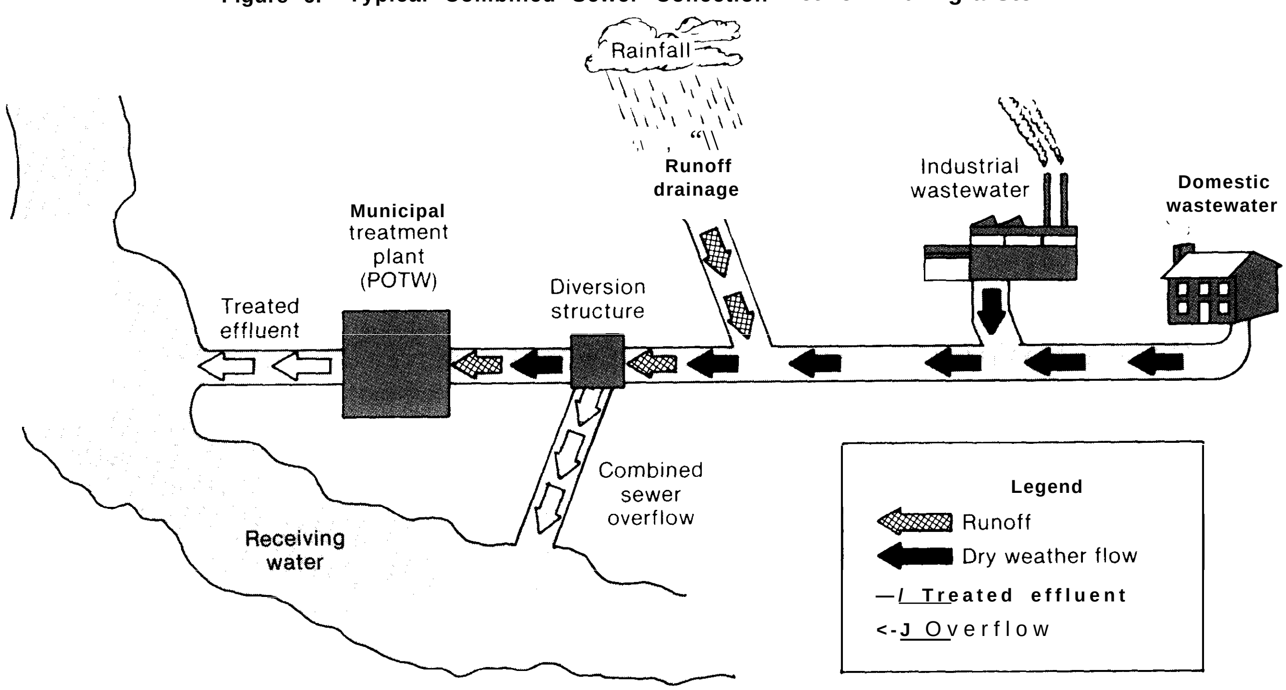
Radioactive Wastes

No nation has yet used marine *waters* for the intentional disposaI of high-levei radioactive waste. The concept of intentionally disposing of such waste within deep-sea sediments, however, has been cooperatively investigated by the Subseabed Working Group, a group of countries within the Nuclear Energy Agency (NEA) of the Organization for Economic Cooperation and Development (585).

In contrast, intentional dumping of low-level radioactive waste has occurred in marine waters. Since 1950, European countries have dumped almost 1 million curies of low-level radioactive waste at a site approved by NEA, northwest of Spain in the northeastern Atlantic ocean (378). The dumping of low-level radioactive waste in marine waters has been curtailed since 1983 by all European countries (as well as by the United States), pending the completion of several studies identified by the London Dumping Convention (see box H). Several European countries (e.g., France, Switzerland, and the United Kingdom) and Japan have expressed interest in resuming such disposal should it be allowed (refs. 378,559; J.P. Olivier, Division of Radiation Protection and Waste Management, NEA, pers. cornm., May 1986).***

*** Effluent containing low-level radioactive waste from two fuel reprocessing plants in Europe (Sellafield in the United Kingdom and La Hague in France) continues to be discharged into marine waters. The effluent from Sellafield has been discharged into the Irish Sea since 1957; between 1957 and 1980, it contained 2.3 million curies of radioactivity, considerably more than the total amount of curies clumped at the northeastern Atlantic site.

Figure 6.—Typical Combined Sewer Collection Network During a Storm



The capacity of municipal sewage treatment plants is usually not adequate to handle the large volumes of combined wastewaters (domestic wastewater, industrial wastewater, and storm water runoff) that may result during storms. In such situations, the wastewater that cannot be handled by the plant is not treated and is diverted to the receiving waters. This diversion is known as a combined sewer overflow.

SOURCE After U S Environmental Protection Agency, Of free of Water, *Combined Sewer Overflow Toxic Pollutanf Study,* EPA 440/1 -84/304 (Washington, DC April 1984) chromium; *agricultural runoff* contributes large quantities of pesticides and herbicides, including various chlorinated hydrocarbons (478,608). Runoff is highly variable in different areas and at different times, although this fact can be obscured in average annual statistics.

Some information has been collected to address the importance of nonpoint sources in general. According to an analysis of State and EPA data for 10 States, nonpoint sources were considered the most important contributor of damaging pollutants in 48 percent of the cases where estuaries failed to support key uses (e. g., fishing, swimming, and the propagation of marine life) (658). Furthermore, in all regions but the Northeast, nonpoint sources were considered more important than point sources; 78 percent of the States considered the magnitude of water problems associated with nonpoint sources to be greater than that relating to point sources (658). Even in the Northeast, there are numerous instances where nonpoint sources are the most important sources of specific pollutants and major contributors to serious problems. In the Chesapeake Bay, for example, roughly 60 to 80 percent of the nitrogen (which contributes to eutrophication) in the Bay originates from nonpoint sources (624).

Additional evidence from State reports issued in 1986 provides ample support for the conclusion that nonpoint sources are very significant. In Florida, for example, nonpoint sources were the primary factor in 43 percent of the estuaries which failed to support their designated uses (220). These State reports also indicate that septic systems can be important contributors of certain pollutants (in particular, fecal coliform bacteria) in coastal areas with a high portion of unsewered households—e. g., the Gulf of Mexico and the southern Atlantic coast. In addition, CSOs tend to be more frequent in the older cities of the Northeast that rely to a greater extent on combined sewer systems (63 1), but are also major problems in areas such as Puget Sound (463) and coastal Florida (220).

Pollutants such as metals and organic chemicals can also be carried from some hazardous waste sites into marine waters through contaminated runoff or transport through aquifers (61 O). At least 75 hazardous waste sites in coastal counties are considered to present some threat to marine resources and human health.

Photo credit: S. Dollar, University of Hawaii

After treatment, sewage effluent is often discharged from underwater pipes. No major effects to the surrounding coral reef communities have been observed at this discharge site in Hawaii.

[Page Omitted]

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While most observers agree that recycling and the development of biodegradable plastics would help reduce the problem, opinions differ about the availability of technologies to carry out these processes, the degree to which they would help, whether biodegradable plastics will break down into nonharmful substances, and which institutional methods (e.g., taxation) would provide effective incentives. Environmental groups (e.g., Environmental Defense Fund, The Oceanic Society) and the plastics industry (e.g., Society of the Plastics Industry), along with the U.S. Coast Guard and several other governmental agencies, support the adoption of Annex 5 of MARPOL (580). Legislation was introduced in Congress in 1986 to begin addressing the issue.

Leaching of Tributyltin From Ship Hulls

Another source of pollution to marine waters is the leaching of constituents of antifouling paint from ship hulls. One of these constituents, tributyltin (TBT), is a highly effective antifouling agent used on thousands of recreational and commercial vehicles. By preventing the attachment of barnacles and tubeworms to hulls, for example, TBT can save vessel operators hundreds of millions of dollars annually; in addition, it is used in many consumer products, such as household cleaners.

TBT also is one of the most toxic antifouling agents used. Although it has been used for decades, its potentially deleterious impacts have only recently received attention (190,332). It can damage nontarget marine organisms, some of which have commercial value or are important in estuarine food webs. In Europe, for example, TBT has been considered responsible for malformations and deaths of oysters in the coastal waters of Britain and France. There is also concern over worker exposure to TBT in shipyards; some studies indicate that it may cause health problems ranging from skin disorders to some forms of cancer.

As a result of these and other findings, some countries now regulate the use of TBT. For example, the United Kingdom regulates the composition of antifouling paint, while France prohibits its use on ships below a certain size (190,474).

In the United States, most attention to date regarding the control of TBT has occurred at the State level (D. Bailey, Environmental Defense Fund (EDF), Richmond, VA, pers. comm., January 1987). North Carolina has adopted a strict water quality standard (2 parts per trillion) for the presence of TBT in saltwater. Concern that TBT may harm shellfish in Chesapeake Bay has led to calls for controls on the use of TBT (D. Bailey, EDF, pers. comm., January 1987; Reid, 1986; EDF 1986). In Virginia, for example, EDF petitioned the State Water Control Board to adopt a water quality standard for TBT; the Board may consider such an action after EPA's water quality criteria document for TBT is issued (tentatively scheduled for draft release in spring 1987). The State has considered banning the use of TBT on recreational vessels less than 25 meters in length and restricting its use on larger vessels; Maryland may consider similar legislation. As a result of these types of concerns, Congress held hearings in 1986 on the use and effects of TBT and EPA has conducted risk-benefit analyses of its use.

Photo credit: Tim McCabe/Soil Conservation Service

Runoff from agricultural lands can carry soil particles, pesticides, bacteria, and other pollutants directly into estuaries and coastal waters or into rivers that later flow into these waters.