IV. CHEMICAL RELEASE AND OTHER WASTE MANAGEMENT PROFILE

This section is designed to provide background information on the pollutant releases that are reported by this industry in correlation with other industries. The best source of comparative pollutant release and other waste management information is the Toxic Release Inventory (TRI). Pursuant to the Emergency Planning and Community Right-to-Know Act, TRI includes self-reported facility release and other waste management data for over 650 toxic chemicals and chemical categories. Facilities within SIC Codes 10 (except 1011, 1081, and 1094), 12 (except 1241), 20-39, 4911 (limited to facilities that combust coal and/or oil for the purpose of generating electricity for distribution in commerce), 4931 (limited to facilities that combust coal and/or oil for the purpose of generating electricity for distribution in commerce), 4939 (limited to facilities that combust coal and/or oil for the purpose of generating electricity for distribution in commerce), 4953 (limited to facilities regulated under the RCRA Subtitle C, 42 U.S.C. section 6921 *et seq*.), 5169, 5171, and 7389 (limited to facilities primarily engaged in solvents recovery services on a contract or fee basis) have more than 10 employees, and that manufactures, processes or otherwise uses listed chemical in quantities greater than the established threshold in the course of a calendar year are required to report to TRI annually release and other waste management quantities (on- and off-site). The information presented within the sector notebooks is derived from the most recently available (2000) TRI reporting year (which includes over 650 chemicals and chemical categories), and focuses primarily on the on-site releases reported by each sector. Because TRI requires consistent reporting regardless of sector, it is an excellent tool for drawing comparisons across industries. TRI data provide the type, amount and media receptor of each chemical released or otherwise managed as waste.

Although this sector notebook does not present historical information regarding TRI chemical releases over time, please note that in general, toxic chemical releases have been declining. In fact, according to the 2000 Toxic Release Inventory Public Data Release, reported on-site and off-site releases of toxic chemicals to the environment from original TRI reporting industries (SIC codes 20-39) decreased by more than 8 percent (644 million pounds) between 1999 and 2000 (not including chemicals added and removed from the TRI chemical list during this period). Reported on-site releases dropped by almost 57 percent between 1988 and 2000. Reported transfers of TRI chemicals to off-site locations for disposal increased by almost 7 percent (28 million pounds) between 1988 and 2000. More detailed information can be obtained from EPA's annual Toxics Release Inventory Public Data Release Report (which is available through the EPCRA Call Center at 800-424-9346), or directly from the Internet at www.epa.gov/tri.

Wherever possible, the sector notebooks present TRI data as the primary indicator of chemical release within each industrial category. TRI data provide the type, amount and media receptor of each chemical released or otherwise managed as waste. When other sources of pollutant release data have been obtained, these data have been included to augment the TRI information.

TRI Data Limitations

Certain limitations exist regarding TRI data. Within some sectors, (e.g., printing and transportation equipment cleaning) the majority of facilities are not subject to TRI reporting either because they do not fall under covered SIC codes, or because they are below the TRI reporting threshold amounts. However, EPA lowered threshold amounts for persistent bioaccumulative toxic (PBT) chemicals starting reporting year 2000. For these sectors, release information from other sources has been included. In addition, many facilities report to TRI under more than one SIC code, reflecting the multiple operations carried out onsite whether or not the operations are the facilities' primary area of business as reported to the U.S. Census Bureau. Reported chemicals are limited to the approximately 650 TRI chemicals and chemical categories. A portion of the emissions from organic chemicals facilities, therefore, are not captured by TRI. Also, reported releases and other waste management quantities may or may not all be associated with the industrial operations described in this notebook.

The reader should also be aware that TRI "pounds released" data presented within the notebooks is not equivalent to a "risk" ranking for each industry. Weighting each pound of release equally does not factor in the relative toxicity of each chemical that is released. The Agency is in the process of developing an approach to assign toxicological weightings and population exposure levels to each chemical released so that one can differentiate between pollutants with significant differences in toxicity. This project, the Risk Screening Environmental Indicators Model, can be found at *http://www.epa.gov/opptintr/rsei/*.

As a preliminary indication of the environmental impact of the industry's most commonly released chemicals, this notebook briefly summarizes the toxicological properties of the top five chemicals (by weight) reported by the organic chemical industry.

Definitions Associated with Section IV Data Tables

General Definitions

SIC Code -- is the Standard Industrial Classification (SIC) is a statistical classification standard used for all establishment-based Federal economic statistics. The SIC codes facilitate comparisons between facility and industry data.

TRI Facilities -- are facilities that are within specified SIC codes that have 10 or more full-time employees and are above established threshold amounts for manufacture or process or otherwise use activities in the course of a calendar year. These facilities are in standard industrial classification codes 10 (except 1011, 1081, and 1094), 12 (except 1241), 20-39, 4911 (limited to facilities that combust coal and/or oil for the purpose of generating electricity for distribution in commerce), 4931 (limited to facilities that combust coal and/or oil for the purpose of generating electricity for distribution in commerce), 4939 (limited to facilities that combust coal and/or oil for the purpose of generating electricity for distribution in commerce), 4953 (limited to facilities regulated under the RCRA Subtitle C, 42 U.S.C. section 6921 *et seq*.), 5169, 5171, and 7389 (limited to facilities primarily engaged in solvents recovery services on a contract or fee basis), and federal facilities. Facilities must submit release and other waste management estimates for all chemicals that are on the EPA's defined list and are above manufacturing or processing or otherwise use thresholds.

Data Table Column Heading Definitions

The following definitions are based upon standard definitions developed by EPA's Toxic Release Inventory Program. The categories below represent the possible pollutant destinations that can be reported.

ON-SITE RELEASES -- are an on-site discharge of a toxic chemical to the environment. This includes emissions to the air, discharges to bodies of water, releases at the facility to land, as well as contained disposal into underground injection wells.

Releases to Air (Point and Fugitive Air Emissions) -- Include all air emissions from industry activity. Point emissions occur through confined air streams as found in stacks, ducts, or pipes. Fugitive emissions include losses from equipment leaks, or evaporative losses from impoundments, spills, or leaks.

Releases to Water (Surface Water Discharges) -- encompass any releases going directly to streams, rivers, lakes, oceans, or other bodies of water. Any estimates for storm water runoff and non-point losses must also be included.

Releases to Land -- includes disposal of toxic chemicals in waste to on-site landfills, land treated or incorporation into soil, surface impoundments, spills, leaks, or waste piles. These activities must occur within the facility's boundaries for inclusion in this category.

Underground Injection -- is a contained release of a fluid into a subsurface well for the purpose of waste disposal.

TRANSFERS -- is a transfer of toxic chemicals in wastes to a facility that is geographically or physically separate from the facility reporting under TRI. The quantities reported represent a movement of the chemical away from the reporting facility. Except for off-site transfers for disposal, these quantities do not necessarily represent entry of the chemical into the environment.

Transfers to POTWs -- are waste waters transferred through pipes or sewers to a publicly owned treatments works (POTW). Treatment and chemical removal depend on the chemical's nature and treatment methods used. Chemicals not treated or destroyed by the POTW are generally released to surface waters or land filled within the sludge. Metals and metal compounds transferred to POTWs are considered as released to surface water.

Transfers to Recycling -- are sent off-site for the purposes of regenerating or recovering still valuable materials. Once these chemicals have been recycled, they may be returned to the originating facility or sold commercially.

Transfers to Energy Recovery -- are wastes combusted off-site in industrial furnaces for energy recovery. Treatment of a chemical by incineration is not considered to be energy recovery.

Transfers to Treatment -- are wastes moved off-site for either neutralization, incineration, biological destruction, or physical separation. In some cases, the chemicals are not destroyed but prepared for further waste management.

Transfers to Disposal -- are wastes taken to another facility for disposal generally as a release to land or as an injection underground.

IV.A. EPA Toxic Release Inventory for the Organic Chemicals Industry

According to the Toxics Release Inventory (TRI) data, 467 organic chemical facilities released (to the air, water or land) and transferred (shipped off-site or discharged to sewers) a total of 594 million pounds of toxic chemicals during calendar year 2000. That represents approximately 5.5 percent of the releases and transfers for all facilities reporting to TRI that year.

Because the chemical industry (SIC 28) has historically released more TRI chemicals than any other manufacturing industry, the EPA has worked to improve environmental performance within this sector. This has been done through a combination of enforcement actions, regulatory requirements, pollution prevention projects, and voluntary programs. In addition, the chemical industry has focused on reducing pollutant releases. For example, the American Chemistry Council's Responsible Care® initiative is intended to reduce or eliminate chemical manufacturers' wastes. All members of the Council, firms that account for the majority of U.S. chemical industry sales and earnings, are required to participate in the program as a condition of Council membership. Participation involves demonstrating a commitment to the program's mandate of continuous improvement of the environment, health, and safety. State-level toxics use reduction requirements, public disclosure of release and transfer information contained in TRI, and voluntary programs such as EPA's 33/50 Program during the 1990's have also been given as reasons for release reductions.

Table 10 presents the number and volumes of chemicals released by organic chemical facilities. The quantity of the basic feedstocks released reflects their volume of usage. The top inorganic chemicals released (ammonia, chlorine, nitric acid, and hydrochloric acid) are also large volume reaction feedstocks. Forty three percent of releases occurred via on-site underground injection. Air releases accounted for another 38 percent (83 million pounds), 18 percent (39 million pounds) was released to water, and the remaining one percent (2.1 million pounds) was disposed of on land.

Table 11 presents the number and volumes of chemicals transferred off-site by organic chemical facilities. Off-site transfers account for the largest amount, 63 percent, of the organic chemical industry's total releases and transfers as reported in TRI. One chemical, methanol, accounted for 24 percent of the 374 million pounds transferred by facilities in the industry. Approximately 14 percent of transfers are sent to recycling facilities.

The frequency with which chemicals are reported by facilities within a sector is one indication of the diversity of operations and processes. Many chemicals are released or transferred by a small number of facilities, which indicates a wide diversity of production processes, particularly for specialty organic chemicals. Almost two-thirds of the 302 chemicals reported are released by fewer than 10 facilities. Overall, the organic chemicals industry reports the use of about half of the roughly 600 TRI reportable chemicals.

Table 10: 2000 TRI Releases for Organic Chemical Facilities (SIC 286), by Number of Facilities Reporting (Releases Reported in pounds/year)*

Chemical Name	# Reporting Chemical	Fugitive Air	Point Air	Water Discharges	Underground Injection	Land Disposal	Total Releases	Avg. Releases Per Facility
Methanol	278	3,912,475	13,933,787	167,959	7,868,577	132,361	26,015,152	93,580
Toluene	179	2,657,687	1,328,947	4,488	154,733	3,423	4,149,278	23,180
Ammonia	169	2,380,590	6,631,275	865,496	17,043,040	144,995	27,065,392	160,150
Xylene (Mixed Isomers)	128	623,681	189,952	13,940	32,055	8,000	867,628	6,778
Benzene	103	521,616	981,150	1,940	105,954	3,212	1,613,872	15,669
Chlorine	92	84,788	341,885	37,100			463,773	5,041
Formaldehyde	90	171,456	590,489	45,016	3,817,671	6,655	4,631,287	51,459
Ethylene Glycol	90	703,306	263,220	93,569	455,430	5,833	1,521,358	16,904
N-butyl Alcohol	89	202,970	437,658	3,296	1,890,507	656	2,535,087	28,484
Nitrate Compounds	88	517	4,846	36,970,944	10,326,216	67,602	47,370,128	538,297
Hydrochloric Acid (1995 and after "Acid Aerosols"	87	320,566	2,436,134	255			2,756,955	31,689
Ethylbenzene	75	308,199	248,117	2,625	530,250	2,071	1,091,262	14,550
Ethylene	75	6,016,036	5,229,560				11,245,596	149,941
Styrene	74	318,753	414,241	112	260,000	7,461	1,000,567	13,521
N-hexane	72	1,596,421	1,469,279	1,024	107,705	1,014	3,175,443	44,103
Phenol	71	252,980	177,624	3,283	1,875,339	53,932	2,363,158	33,284
Naphthalene	69	106,289	319,392	442	179,721	1,347	607,191	8,800
Certain Glycol Ethers	69	143,832	68,906	43,385	43,140	16,059	315,322	4,570
Propylene	63	2,728,645	2,231,243	2,607		5	4,962,500	78,770
Zinc Compounds	59	4,226	8,663	35,256	454	437,102	485,701	8,232
Acetaldehyde	51	302,805	501,401	4,687	324,571	219	1,133,683	22,229
Cyclohexane	50	349,609	232,819	15,166	81,879	12	679,485	13,590
Maleic Anhydride	48	29,022	94,141		6	280	123,449	2,572
Methyl Ethyl Ketone	47	295,954	153,075	3,768	139,500	405	592,702	12,611
Methyl Isobutyl Ketone	43	636,118	240,543	15,182	2,900	689	895,432	20,824
Copper Compounds	42	325	2,297	14,943	64,026	61,133	142,724	3,398
Dichloromethane	42	270,914	1,593,846	4,160	3	74	1,868,997	44,500
1,2,4-trimethylbenzene	40	71,232	22,567	687		1,955	96,441	2,411
Acrylic Acid	39	96,543	53,143	5,565	516,946	342	672,539	17,245
Propylene Oxide	39	61,004	99,296	233	2,100		162,633	4,170
1,3-butadiene	39	416,282	556,472	108		2	972,864	24,945
Ethylene Oxide	38	104,457	151,142	1,001	226		256,826	6,759
Nitric Acid	38	17,428	35,802		11,518,220	7,641	11,579,091	304,713
Biphenyl	38	87,173	6,268	1,214		81	94,736	2,493
Aniline	37	60,746	110,058	9,093	696,924	297	877,118	23,706
Chloromethane	35	192,552	481,349	668	34,177	3	708,749	20,250
Formic Acid	34	97,353	111,538	113,545	2,740,685	2,059	3,065,180	90,152
Polycyclic Aromatic Compounds[PBT]	32	21,378	14,199	2,020		507	38,104	1,191
Cumene	30	181,133	347,323	97	550	11,000	540,103	18,003
Sulfuric Acid (1994 and after "Acid Aerosols" Only	30	33,255	587,041	1,000			621,296	20,710
Barium Compounds	30	2,124	3,542	28,228	43	368,655	402,592	13,420
N,n-dimethylformamide	29	34,570	13,035	1,197			48,802	1,683
Nickel Compounds	29	116	5,429	16,489	27,745	19,187	68,966	2,378
Sodium Nitrite	28	174	1,019	150,413	2,028,206	85	2,179,897	77,853
Chlorodifluoromethane	27	1,036,287	853,487	2,891			1,892,665	70,099
Chloroethane	27	117,292	130,617	680			248,589	9,207
Chlorobenzene	27	75,227	301,303	79	80,008	1,206	457,823	16,956
Phthalic Anhydride	27	42,872	86,375				129,247	4,787
Acetonitrile	27	121,362	99,411	10,480	7,594,103	584	7,825,940	289,850
Dimethylamine	27	38,044	38,467	2,410	950	3,435	83,306	3,085
Tert-butyl Alcohol	26	537,999	105,206	1,963	766,176	477	1,411,821	54,301
Acrylonitrile	26	83,992	181,243	216	3,280,408	1	3,545,860	136,379
Dicyclopentadiene	25	88,752	15,601	2,433		29	106,815	4,273

Table 10: 2000 TRI Releases for Organic Chemical Facilities (SIC 286), by Number of Facilities Reporting (Releases Reported in pounds/year)*

Chemical Name	# Reporting Chemical	Fugitive Air	Point Air	Water Discharges	Underground Injection	Land Disposal	Total Releases	Avg. Releases Per Facility
Diethanolamine	24	24,166	2,147	4,801		51,006	82,120	3,422
Vinyl Acetate	24	519,283	1,174,490	473	223,177	4,549	1,921,972	80,082
Chromium Compounds	24	39	1,233	2,821	202	17,645	21,940	914
Methyl Methacrylate	22	183,621	362,406	2,908			548,935	24,952
O-xylene	22	123,135	170,981	2,378		56	296,550	13,480
Manganese Compounds	21	1,059	8,323	91,508		201,094	301,984	14,380
1,2-dichloroethane	20	74,676	94,852	35	14		169,577	8,479
Dioxin and Dioxin-Like Compounds[PBT]	20	5	121	88		440	654	33
Anthracene	20	8,333	7,653	111		1	16,098	805
Hydrogen Fluoride	19	50,221	176,558	250		23	227,052	11,950
Phenanthrene	18	15,747	11,125	115		172	27,159	1,509
N-methyl-2-pyrrolidone	18	19,542	2,616	959	566,036	19	589,172	32,732
Triethylamine	18	22,434	63,340	10,995	15,180	13,682	125,631	6,979
Butyl Acrylate	18	26,597	54,651	14,460	271		95,979	5,332
Chloroform	18	14,398	52,751	281			67,430	3,746
Pyridine	18	38,335	19,240		835,760		893,335	49,630
Butyraldehyde	17	70,899	129,169	15			200,083	11,770
Epichlorohydrin	17	15,125	5,067	383		123	20,698	1,218
Cresol (Mixed Isomers)	16	9,857	9,397	814	611,641	3,059	634,768	39,673
Methyl Acrylate	16	127,929	19,488	289	13,670		161,376	10,086
Hydroquinone	16	568	120	3,160	171,200		175,048	10,941
Diisocyanates	16	42,507	394			800	43,701	2,731
Methyl Tert-butyl Ether	16	56,181	76,392	9,529	70	7,352	149,524	9,345
Hydrogen Cyanide	16	24,208	268,828	212	688,362	55	981,665	61,354
Bromine	16	16,317	3,916				20,233	1,265
Nickel	15	306	573	3,466	11,553	35,249	51,147	3,410
Benzyl Chloride	15	8,446	2,176	83			10,705	714
Cobalt Compounds	15	454	12,146	31,180	3,525	16,550	63,855	4,257
Lead Compounds[PBT]	15	2,127	573	487		76	3,263	218
Acrylamide	15	955	974	17	5,339,361	4	5,341,311	356,087
Allyl Alcohol	15	340,164	25,601	5,452	283,712		654,929	43,662
Trichloroethylene	15	25,033	6,375	1			31,409	2,094
Carbon Disulfide	14	34,375	29,537	1,520	17,326	372	83,130	5,938
Tetrachloroethylene	14	50,236	22,549	77		1	72,863	5,204
Sec-butyl Alcohol	14	26,859	13,405	941			41,205	2,943
Cyanide Compounds	14	118	4,789	6,202	2,269,181	912	2,281,202	162,943
Ethyl Acrylate	14	12,239	14,301	9	403	2	26,954	1,925
Acrolein	14	4,765	11,736	113	200,550		217,164	15,512
Carbon Tetrachloride	13	21,228	133,443	45			154,716	11,901
Antimony Compounds	13	861	637	279	2,777	85,358	89,912	6,916
Mercury Compounds[PBT]	13		222	5		17	244	19
Nitrobenzene	13	16,780	13,414	120	297,084	18	327,416	25,186
Propionaldehyde	13	18,768	64,296	3,576	3,100	2,259	91,999	7,077
Allyl Chloride	13	4,875	125,390				130,265	10,020
Benzo(g,h,i)perylene[PBT]	13	943	4,215	12			5,170	398
O-toluidine	12	3,243	7,326	25	7,040		17,634	1,469
Mercury[PBT]	12		136		3	1	140	12
P-xylene	12	99,796	395,276	40		106	495,218	41,268
Cyclohexanol	12	74,583	64,772	4,978	2,652,916		2,797,249	233,104
Isobutyraldehyde	12	110,668	17,328	129			128,125	10,677
1,4-dioxane	12	20,879	15,697	30,890		2,700	70,166	5,847
2-methoxyethanol	11	64,019	4,538	3,286			71,843	6,531
1,2-dichlorobenzene	11	15,699	45,506	585	1,600	778	64,168	5,833
Hexachlorobenzene[PBT]	11	43	5	37			85	8

Table 10: 2000 TRI Releases for Organic Chemical Facilities (SIC 286), by Number of Facilities Reporting (Releases Reported in pounds/year)*

Chemical Name	# Reporting Chemical	Fugitive Air	Point Air	Water Discharges	Underground Injection	Land Disposal	Total Releases	Avg. Releases Per Facility
4,4'-isopropylidenediphenol	11	8,087	9,577	2,107		1,657	21,428	1,948
Vinyl Chloride	10	53,870	15,903				69,773	6,977
Quinoline	10	2,452	4,480	15	31,413	6	38,366	3,837
Creosote	10	9,910	26,443	5			36,358	3,636
Diphenylamine	10	9,558	13,990	32	3,200		26,780	2,678
Hydrazine	10	2,555	127	10			2,692	269
Benzoyl Chloride	10	6,166	1,169				7,335	733
Dichlorodifluoromethane	10	158,393	28,984	5			187,382	18,738
Phosgene	9	348	1,294				1,642	182
P-cresol	9	6,179	7,604	28	319,553		333,364	37,040
Acetophenone	9	24,202	16,014	22	580,000	16	620,254	68,917
1,1-dichloro-1-fluoroethane	9	179,758	261,532	168			441,458	49,051
Polychlorinated Biphenyls[PBT]	9		18	23		15	56	6
Cumene Hydroperoxide	9	29,846	782	94	130,000		160,722	17,858
M-xylene	9	153,987	59,901			28	213,916	23,768
M-cresol	9	6,433	3,678	37	542,970		553,118	61,458
Copper	8	9	259	373	596	15,524	16,761	2,095
4,4'-methylenedianiline	8	11,009	346	296	30,000	8	41,659	5,207
Vanadium Compounds	8	151	52	78,872	20,105	10,044	109,224	13,653
Dibenzofuran	8	9,442	14,374	16			23,832	2,979
Molybdenum Trioxide	8	15	1,374	94	71,800	5,409	78,692	9,836
2-chloro-1,1,1,2-tetrafluoroethane	7	58,227	13,936	5			72,168	10,310
Trichlorofluoromethane	7	117,585	3,242	885			121,712	17,387
Boron Trifluoride	7	1,463	523				1,986	284
Freon 113	7	175,354	51,250	1,272			227,876	32,554
O-cresol	7	1,867	1,756	9	501,865	13	505,510	72,216
Dimethyl Sulfate	7	596	34	22		40	692	99
1-chloro-1,1-difluoroethane	7	104,544	183,655	34			288,233	41,176
Chloroacetic Acid	7	1,395	820			300	2,515	359
1,2,4-trichlorobenzene	6	3,541	51,947	19			55,507	9,251
Methyl Iodide	6	20,589	38,522	22	8	1,002	60,143	10,024
Bromomethane	6	594	327,699				328,293	54,716
2-ethoxyethanol	6	6,132	56,640	129			62,901	10,483
Dibutyl Phthalate	6	687	455	2	150,000		151,144	25,191
Diaminotoluene (Mixed Isomers)	6	4,827	3,355	1,809	23,000		32,991	5,498
3,3'-dichlorobenzidine Dihydrochloride	6		16	5			21	4
N,n-dimethylaniline	6	2,108	13,538	48			15,694	2,616
Toluene Diisocyanate (Mixed Isomers)	6	1,674	158			1	1,833	305
1,2-butylene Oxide	5	2,388	1,436				3,824	765
Vinylidene Chloride	5	16,247	5,949	1,623		36	23,855	4,771
Propargyl Alcohol	5	1,944	1,344		1,031,538		1,034,826	206,965
4,6-dinitro-o-cresol	5	5	118				123	25
Crotonaldehyde	5	3,235	2,842	33,038		10	39,125	7,825
Acetamide	5	42			2,195,410		2,195,452	439,090
Di(2-ethylhexyl) Phthalate	5	3,660	237				3,897	779
Dimethyl Phthalate	5	33	1,441	808	1,900	3	4,185	837
1,3-phenylenediamine	5	192	1,716	179		36,910	38,997	7,799
1,1,2-trichloroethane	4	2,870	124				2,994	748
Phosphorus (Yellow or White)	4	5	253				258	65
Diethyl Sulfate	4	2,830	19				2,849	712
Cadmium Compounds	4	8	24	5			37	9
Monochloropentafluoroethane	4	54,509	5,240	5			59,754	14,939
Aluminum (Fume or Dust)	4	60	24,632	176			24,868	6,217
Dinitrotoluene (Mixed Isomers)	4	3,438	5,104	4	3,300		11,846	2,961
2-methylpyridine	4	6,251	12,486	22	11,000		29,759	7,440

Table 10: 2000 TRI Releases for Organic Chemical Facilities (SIC 286), by Number of Facilities Reporting (Releases Reported in pounds/year)*

Chemical Name	# Reporting Chemical	Fugitive Air	Point Air	Water Discharges	Underground Injection	Land Disposal	Total Releases	Avg. Releases Per Facility
Methacrylonitrile	4	989			54,549		55,538	13,885
1,3-dichlorobenzene	4	2,819	2,250	6			5,075	1,269
Silver	4		121	79			200	50
2,4-dimethylphenol	4	411	360	5	201,020		201,796	50,449
1,1,1-trichloroethane	4	16,770	7,108	53			23,931	5,983
Chloroprene	4	40	137				177	44
Pentachlorobenzene[PBT]	3		2				2	1
Toluene-2,4-diisocyanate	3	3	1				4	1
Barium	3		671	1		67,000	67,672	22,557
1,2-dichloroethylene	3	93	783				876	292
1,2-phenylenediamine	3	19	137	118		3,497	3,771	1,257
Acifluorfen, Sodium Salt	3	27	305	5,811			6,143	2,048
Vanadium (Except When Contained in an Alloy)	3		145		8,121	12,777	21,043	7,014
1,2-dibromoethane	3	1,801	1,000	5	65		2,871	957
Zinc (Fume or Dust)	3	5	195				200	67
Titanium Tetrachloride	3	2,391	26			41	2,458	819
Dichlorotetrafluoroethane (Cfc-114)	3	77,516	21,078	5			98,599	32,866
Benzoyl Peroxide	3		2,014				2,014	671
Asbestos (Friable)	3							
2-methyllactonitrile	3	1,777	1,002		139,007		141,786	47,262
Tetrabromobisphenol A[PBT]	3	5	468				473	158
1,1,2,2-tetrachloroethane	3	128	22				150	50
Methyl Chlorocarbonate	3	2,239	4				2,243	748
Peracetic Acid	3	1,109	2,146				3,255	1,085
4-nitrophenol	3	323	65	16			404	135
1,4-dichlorobenzene	3	23,570	33,109	25		174	56,878	18,959
1,1,1,2-tetrachloroethane	3	202	327				529	176
2,4-dinitrotoluene	2	2	1	24			27	14
3-chloro-2-methyl-1-propene	2	285	167				452	226
Methylene Bromide	2	15	1,527				1,542	771
Isopropyl Alcohol (Manufacturing, Strong-acid Proc	2	1,985	1,827				3,812	1,906
P-chloroaniline	2	406	20	60			486	243
Benzal Chloride	2	236	9				245	122
P-phenylenediamine	2	15	34	7		954	1,010	505
N-methylolacrylamide	2	456	50				506	253
Decabromodiphenyl Oxide	2		912			3,285	4,197	2,098
Quinone	2	4					4	2
2,4-dinitrophenol	2	1	1	23,287			23,289	11,645
P-nitroaniline	2	1,911	2,020				3,931	1,965
Benomyl	2	5	1				6	3
Benzoic Trichloride	2	493	45				538	269
Safrole	2	251	9				260	130
Dihydrosafrole	2	251	9				260	130
O-anisidine	2	705	19				724	362
1,2-dichloro-1,1-difluoroethane	2	5,520	3,705	45			9,270	4,635
Bis(2-chloroethyl) Ether	2	133	8				141	71
Dicamba	2	5	5				10	5
Dinitrobutyl Phenol	2		39				39	20
2-nitrophenol	2	5	12				17	8
2-chloro-1,1,1-trifluoroethane	2	8,350	69,400				77,750	38,875
2-mercaptobenzothiazole	2	5	246	35,268			35,519	17,760
Dichlorofluoromethane	2	13,304	106,405				119,709	59,855
P-cresidine	2	1,029	703	224			1,956	978

Table 10: 2000 TRI Releases for Organic Chemical Facilities (SIC 286), by Number of Facilities Reporting (Releases Reported in pounds/year)*

Chemical Name	# Reporting Chemical	Fugitive Air	Point Air	Water Discharges	Underground Injection	Land Disposal	Total Releases	Avg. Releases Per Facility
Antimony	2		46	3,296		38	3,380	1,690
2,2-dichloro-1,1,1-trifluoroethane	2	15,413	5,518	5			20,936	10,468
Chromium	2		30	43	346		419	209
Cobalt	2	1	265	996		300	1,562	781
Catechol	2		250	200			450	225
Ethylidene Dichloride	2	99	227				326	163
Ethyl Chloroformate	2	1,565	15				1,580	790
Silver Compounds	2	24	86				110	55
Picloram	1		8	500			508	508
Nitrapyrin	1							
Molinate	1	944	52	105			1,101	1,101
Propargite	1	36	215				251	251
C.i. Disperse Yellow 3	1		31	25			56	56
Malononitrile	1				255,157		255,157	255,157
Thiourea	1	736		74			810	810
Prometryn	1	411	105				516	516
Sodium Dimethyldithiocarbamate	1	1	1				2	2
Lead[PBT]	1					31,340	31,340	31,340
Manganese	1					74,735	74,735	74,735
Urethane	1	21		29,580		33	29,634	29,634
Piperonyl Butoxide	1			144			144	144
Cupferron	1			343			343	343
Trans-1,4-dichloro-2-butene	1	4	1				5	5
Arsenic	1					42,189	42,189	42,189
P-dinitrobenzene	1		12	81			93	93
M-dinitrobenzene	1	10	345	466		134	955	955
Ethyleneimine	1		3				3	3
5-nitro-o-anisidine	1	5	5	5			15	15
Styrene Oxide	1		8				8	8
2,4,5-trichlorophenol	1	56	271	51			378	378
Diazinon	1		1	3			4	4
1,1,2,2-tetrachloro-1-fluoroethane	1	20	5				25	25
1,2-dichloro-1,1,2-trifluoroethane	1	73,027	35,486	5			108,518	108,518
Carbonyl Sulfide	1		466,000				466,000	466,000
O-dinitrobenzene	1	1	44	60			105	105
2,4-diaminotoluene	1	211	92				303	303
Bis(2-chloroethoxy)methane	1	1,320	10		9,302		10,632	10,632
Allylamine	1	250	750				1,000	1,000
2,4-d Butyl Ester	1		4	1			5	5
2,4-d	1	8	1,030	248		33	1,319	1,319
3,3'-dichlorobenzidine	1	5	5				10	10
Perchloromethyl Mercaptan	1	5	85				90	90
Ozone	1	14	2				16	16
Fenbutatin Oxide	1	664			1,260		1,924	1,924
Iron Pentacarbonyl	1	1,280	3				1,283	1,283
2,6-dinitrotoluene	1			27			27	27
Oryzalin	1		24				24	24
3,3'-dimethoxybenzidine Dihydrochloride	1	12	4	36			52	52
2-phenylphenol	1			10			10	10
Dichlorobenzene (Mixed Isomers)	1							
Chloromethyl Methyl Ether	1	1,350					1,350	1,350
Methyl Isocyanate	1		13				13	13
Norflurazon	1							
Octachlorostyrene[PBT]	1							
Pendimethalin[PBT]	1			302		332	634	634

Table 10: 2000 TRI Releases for Organic Chemical Facilities (SIC 286), by Number of Facilities Reporting (Releases Reported in pounds/year)*

Chemical Name	# Reporting Chemical	Fugitive Air	Point Air	Water Discharges	Underground Injection	Land Disposal	Total Releases	Avg. Releases Per Facility
Hexazinone	1	2		1,874			1,876	1,876
Permethrin	1	288		7			295	295
3-iodo-2-propynyl Butylcarbamate	1							
Picric Acid	1			274	21,093		21,367	21,367
3,3'-dichlorobenzidine Sulfate	1							
Fomesafen	1	577	221	1,176			1,974	1,974
Propanil	1	250	250	250			750	750
Arsenic Compounds	1							
Ethyl Dipropylthiocarbamate	1	815	88	92			995	995
1,4-dichloro-2-butene	1	89					89	89
Chlorophenols	1	3		39		1	43	43
Ametryn	1	403	157				560	560
2,4-dichlorophenol	1	266	149	25			440	440
2,4,6-trichlorophenol	1	92	12	29		1	134	134
Tetrachlorvinphos	1	99					99	99
N-nitrosodiphenylamine	1							
Saccharin (Manufacturing, No Supplier Notification	1	70	10				80	80
2-nitropropane	1	9,588	7,017	224			16,829	16,829
Dimethylcarbamyl Chloride	1	3	99				102	102
1,2-dichloropropane	1	2	3				5	5
Paraldehyde	1	14	19				33	33
Hexachlorocyclopentadiene	1	332	364				696	696
Pentachloroethane	1	9	1				10	10
Chlorotrifluoromethane	1	1,420	14,580	5			16,005	16,005
Atrazine	1	161	169	1			331	331
Propyleneimine	1	17	53				70	70
	467**	32,553,643	50,360,923	39,171,452	95,144,436	2,124,451	219,354,897	469,710

[PBT] Persistent, Bioaccumulative, and Toxic
* Refer to Section III for a discussion of the TRI data and its limitations, methodology used to obtain this data, definitions of the column headings, and the definition of persistant, bioaccumulative, and toxic chemicals.
**Total number of facilities (not chemical reports) reporting to TRI in this industry sector.

Table 11: 2000 TRI Transfers for Organic Chemical Facilities (SIC 286), by Number of Facilities Reporting (Transfers Reported in pounds/year)*

Chemical Name	# Reporting Chemical	POTW Transfers	Disposal Transfers	Recycling Transfers	Treatment Transfers	Energy Recovery	Total Transfers	Avg Transfers Per Facility
Methanol	278	20,036,448	649,306	7,311,495	20,357,616	39,862,432	88,217,297	317,328
Toluene	179	62,687	354,644	2,767,314	7,781,329	16,786,000	27,751,974	155,039
Ammonia	169	2,184,927	1,451,355	117,039	706,756	111,698	4,571,775	27,052
Xylene (Mixed Isomers)	128	12,480	100,443	1,244,063	2,647,063	7,696,733	11,700,782	91,412
Benzene	103	5,091	20,504	1,212,323	1,236,731	591,636	3,066,285	29,770
Chlorine	92	3,624			454,054		457,678	4,975
Formaldehyde	90	660,534	113,088	530	684,406	285,217	1,743,775	19,375
Ethylene Glycol	90	10,349,832	959,225	287,020	1,629,396	9,265,735	22,491,208	249,902
N-butyl Alcohol	89	1,442,267	83,406	1,362	658,121	3,740,885	5,926,041	66,585
Nitrate Compounds	88	20,333,408	4,816,868	2,247	6,368,480		31,521,003	358,193
Hydrochloric Acid (1995 and after "Acid Aerosols"	87	20	7,930		64,315	3,916	76,181	876
Ethylbenzene	75	1,368	16,912	593,873	421,897	1,467,573	2,501,623	33,355
Ethylene	75	243			9		252	3
Styrene	74	36,907	1,529	2,500,339	297,338	1,062,455	3,898,568	52,683
N-hexane	72	552	693	287,599	3,500,079	1,702,555	5,491,478	76,271
Phenol	71	644,708	28,338		949,527	3,374,972	4,997,545	70,388
Naphthalene	69	2,446	177,185	6,303,351	211,928	576,470	7,271,380	105,382
Certain Glycol Ethers	69	955,735	91,488	1,808	314,744	1,272,662	2,636,437	38,209
Propylene	63				117,735	52	117,787	1,870
Zinc Compounds	59	9,270	2,326,777	222,427			2,558,474	43,364
Acetaldehyde	51	1,188,158	87	62	208,154	300,309	1,696,770	33,270
Cyclohexane	50	108	2,006	738,733	817,156	136,306	1,694,309	33,886
Maleic Anhydride	48	447	2,956		777,222	47,270	827,895	17,248
Methyl Ethyl Ketone	47	487,694	29,778	5,437	108,173	2,991,541	3,622,623	77,077
Methyl Isobutyl Ketone	43	69,780	9,834	798,627	920,839	1,426,985	3,226,065	75,025
Copper Compounds	42	27,400	472,058	2,154,659			2,654,117	63,193
Dichloromethane	42	274	9,754	452,955	1,529,442	528,907	2,521,332	60,032
1,2,4-trimethylbenzene	40	5,541	18,786	1,436	63,184	419,117	508,064	12,702
Acrylic Acid	39	1,128,221	106,333		806,062	4,584,524	6,625,140	169,875
Propylene Oxide	39	151,147	4,860		2,138	28,521	186,666	4,786
1,3-butadiene	39	250	153,787	23,001	10,191	1,578	188,807	4,841
Ethylene Oxide	38	63,436	34		78	1	63,549	1,672
Nitric Acid	38	33,987	6,154,652	60,424	36,624		6,285,687	165,413
Biphenyl	38	111,285	12,294	870,770	252,195	118,799	1,365,343	35,930
Aniline	37	922,560	219,532	23,600	5,666,448	1,797,480	8,629,620	233,233
Chloromethane	35	281	7		117,663	57,286	175,237	5,007
Formic Acid	34	79,714	34,552	10	691,998	1,533,934	2,340,208	68,830
Polycyclic Aromatic Compounds[PBT]	32	8	367,218	64,287	82,195	95,803	609,511	19,047
Cumene	30	5,625	88,228	74,000	29,023	211,730	408,606	13,620
Sulfuric Acid (1994 and after "Acid Aerosols" Only	30		635	1,869,080	14,414	1,544	1,885,673	62,856
Barium Compounds	30	176,202	203,370	561,342			940,914	31,364
N,n-dimethylformamide	29	472,318	428	24,480	345,967	258,238	1,101,431	37,980
Nickel Compounds	29	8,106	706,377	976,507			1,690,990	58,310
Sodium Nitrite	28	202,287	1,294	20,872	227,037	2,719	454,209	16,222
Chlorodifluoromethane	27		84,770	231,455	278,097		594,322	22,012
Chloroethane	27	354	130	165,800	374,786	131,884	672,954	24,924
Chlorobenzene	27	2,690	217	171	935,980	552,101	1,491,159	55,228
Phthalic Anhydride	27	110,259	2,539,677		297,427	682,326	3,629,689	134,433
Acetonitrile	27	8	39,378	57	1,504,742	530,637	2,074,822	76,845
Dimethylamine	27	262,166	1,801	294	327,605	3,123	594,989	22,037
Tert-butyl Alcohol	26	574,667	71,835	2,023	499,998	6,480,152	7,628,675	293,411
Acrylonitrile	26	61,194	4,585		78,725	229,595	374,099	14,388
Dicyclopentadiene	25		844	270,003	16,056	332,551	619,454	24,778
Diethanolamine	24	36,432	153,116		31,076	546	221,170	9,215
Vinyl Acetate	24	30,297	7,432		745,976	6,539,457	7,323,162	305,132
Chromium Compounds	24	1,273	206,649	549,321			757,243	31,552
Methyl Methacrylate	22	297	102,287		75,551	410,427	588,562	26,753
O-xylene	22	61,148	19,586	31	767,008	408,987	1,256,760	57,125
Manganese Compounds	21	16,125	943,334	321,814			1,281,273	61,013
1,2-dichloroethane	20	273	1,744	6,255,710	175,429	216,088	6,649,244	332,462
Dioxin and Dioxin-Like Compounds[PBT]	20	24	253		6,798	1	7,076	354

Table 11: 2000 TRI Transfers for Organic Chemical Facilities (SIC 286), by Number of Facilities Reporting (Transfers Reported in pounds/year)*

Chemical Name	# Reporting Chemical	POTW Transfers	Disposal Transfers	Recycling Transfers	Treatment Transfers	Energy Recovery	Total Transfers	Avg Transfers Per Facility
Anthracene	20	86	48,914		103,836	103,091	255,927	12,796
Hydrogen Fluoride	19		1,571		189,168	5,099	195,838	10,307
Phenanthrene	18	3	11,932	496,127	139,744	127,276	775,082	43,060
N-methyl-2-pyrrolidone	18	52,677	7,010	1,092	16,036	4,503,153	4,579,968	254,443
Triethylamine	18	5	18,026		140,970	104,396	263,397	14,633
Butyl Acrylate	18	118,677	7,563		11,016	77,253	214,509	11,917
Chloroform	18	281	739	16,900	396,230	45,681	459,831	25,546
Pyridine	18	57,935	34,083	111,499	279,459	57,329	540,305	30,017
Butyraldehyde	17	36,233	12,203	1,200	27,967	529,462	607,065	35,710
Epichlorohydrin	17	9,364	983		23,863	14,556	48,766	2,869
Cresol (Mixed Isomers)	16	4,541	3,644		130,496	26,218	164,899	10,306
Methyl Acrylate	16	255	11,000		10,623	491,097	512,975	32,061
Hydroquinone	16	39,814	23		7,842	6,787	54,466	3,404
Diisocyanates	16		32,129		93,704	152,194	278,027	17,377
Methyl Tert-butyl Ether	16	1,001	560		14,361	207,617	223,539	13,971
Hydrogen Cyanide	16	858	682		11,779		13,319	832
Bromine	16	128,250	686	1,696,776	202,220		2,027,932	126,746
Nickel	15	500	42,139	335,179			377,818	25,188
Benzyl Chloride	15	1,204	2,640		2,242	521,926	528,012	35,201
Cobalt Compounds	15	66	154,276	641,093			795,435	53,029
Lead Compounds[PBT]	15	15	104,134	752,822			856,971	57,131
Acrylamide	15	137,481	1,178		7,270	16,111	162,040	10,803
Allyl Alcohol	15	597	2		477,729	483,995	962,323	64,155
Trichloroethylene	15	10		44,640	172,103	117,720	334,473	22,298
Carbon Disulfide	14	1,348	918	180	5,552	31,241	39,239	2,803
Tetrachloroethylene	14	10	21	845,291	15,850	70,544	931,716	66,551
Sec-butyl Alcohol	14	68,930	270		1,213	631,395	701,808	50,129
Cyanide Compounds	14	4,739	5,890		10,868	10,540	32,037	2,288
Ethyl Acrylate	14	429,881	7,727		141,955	1,241,214	1,820,777	130,055
Acrolein	14		410		62	169,678	170,150	12,154
Carbon Tetrachloride	13	117		2,184	266,856	21,600	290,757	22,366
Antimony Compounds	13	2	63,040	224,152			287,194	22,092
Mercury Compounds[PBT]	13		59	83			142	11
Nitrobenzene	13	107	6,354		2,165,679	823,282	2,995,422	230,417
Propionaldehyde	13	4,713	283		182	380	5,558	428
Allyl Chloride	13		3,375	82,000	122,052	229,123	436,550	33,581
Benzo(g,h,i)perylene[PBT]	13	43	44,923	3,392	1,144	2,325	51,827	3,987
O-toluidine	12	2,056	219		128,758	206,023	337,056	28,088
Mercury[PBT]	12		161	59			220	18
P-xylene	12		43		43,309	3,872	47,224	3,935
Cyclohexanol	12	5,593	4,357		10,976	18,073	38,999	3,250
Isobutyraldehyde	12	9,087	149,650	1,200	50,178	526,289	736,404	61,367
1,4-dioxane	12	20,120	2,185	1		169,125	191,431	15,953
2-methoxyethanol	11	37,330	750			293,197	331,277	30,116
1,2-dichlorobenzene	11	5	9,025	960	233,199	445,879	689,068	62,643
Hexachlorobenzene[PBT]	11	3	608	1,383	5,952		7,946	722
4,4'-isopropylidenediphenol	11	1	1,581	680	6,374	6,871	15,507	1,410
Vinyl Chloride	10	54	7	58,400	2,515	96	61,072	6,107
Quinoline	10	250	2,445		17,476	3,649	23,820	2,382
Creosote	10		20,644		19,315	286	40,245	4,024
Diphenylamine	10	3,039	23,864	40,158	56,460	23,465	146,986	14,699
Hydrazine	10	85			46		131	13
Benzoyl Chloride	10	251			303,839		304,090	30,409
Dichlorodifluoromethane	10			7,500			7,500	750
Phosgene	9				4,565		4,565	507
P-cresol	9	1,086	32,371	818,151	4,464	83,257	939,329	104,370
Acetophenone	9	32,546	2,843		22,737	10,833,075	10,891,201	1,210,133
1,1-dichloro-1-fluoroethane	9	7		70,661	981,077	509,863	1,561,608	173,512
Polychlorinated Biphenyls[PBT]	9		290	320	24,222		24,832	2,759
Cumene Hydroperoxide	9	353,094	250		4,407	804	358,555	39,839
M-xylene	9	12,335	311	341,011	700	239,485	593,842	65,982
M-cresol	9	963	330	1,660,747	7,346	500	1,669,886	185,543
Copper	8	12,002	139,544	3,579			155,125	19,391

Table 11: 2000 TRI Transfers for Organic Chemical Facilities (SIC 286), by Number of Facilities Reporting (Transfers Reported in pounds/year)*

Chemical Name	# Reporting Chemical	POTW Transfers	Disposal Transfers	Recycling Transfers	Treatment Transfers	Energy Recovery	Total Transfers	Avg Transfers Per Facility
4,4'-methylenedianiline	8	2,017	6,550		28,028	249	36,844	4,605
Vanadium Compounds	8		186,514	49,040			235,554	29,444
Dibenzofuran	8	250	10,306	288	52,547	23,827	87,218	10,902
Molybdenum Trioxide	8		57,930	40,294	17,385	20,744	136,353	17,044
2-chloro-1,1,1,2-tetrafluoroethane	7							
Trichlorofluoromethane	7	1		13,200	16,990		30,191	4,313
Boron Trifluoride	7				11,314		11,314	1,616
Freon 113	7			128,504	117,635		246,139	35,163
O-cresol	7		1,556		4,048	73,853	79,457	11,351
Dimethyl Sulfate	7	1		62,518	212,000		274,519	39,217
1-chloro-1,1-difluoroethane	7				161,940	101,208	263,148	37,593
Chloroacetic Acid	7	389					389	56
1,2,4-trichlorobenzene	6	255	3,700	570	187,863	16,700	209,088	34,848
Methyl Iodide	6	21,282	64		395		21,741	3,623
Bromomethane	6							
2-ethoxyethanol	6	225,765	591		162	14,400	240,918	40,153
Dibutyl Phthalate	6	10			23,802	3,863	27,675	4,612
Diaminotoluene (Mixed Isomers)	6	365	9,026		28,245	455,801	493,437	82,240
3,3'-dichlorobenzidine Dihydrochloride	6	5	2,300		37,800	17,000	57,105	9,517
N,n-dimethylaniline	6	19,098	60			104,111	123,269	20,545
Toluene Diisocyanate (Mixed Isomers)	6		4,296		79,221	7,670	91,187	15,198
1,2-butylene Oxide	5				477	277,281	277,758	55,552
Vinylidene Chloride	5	259	7		11,817	44,400	56,483	11,297
Propargyl Alcohol	5	29,347	26,096		11,533	86	67,062	13,412
4,6-dinitro-o-cresol	5		114,579		69,966	58,658	243,203	48,641
Crotonaldehyde	5				11	1,620	1,631	326
Acetamide	5				2,442		2,442	488
Di(2-ethylhexyl) Phthalate	5	1,383	73		3,309	1,030	5,795	1,159
Dimethyl Phthalate	5	250	7,270		21,446	36	29,002	5,800
1,3-phenylenediamine	5	2,305			1,276,247	1,671	1,280,223	256,045
1,1,2-trichloroethane	4		7	2,558,590	11,605		2,570,202	642,550
Phosphorus (Yellow or White)	4				720		720	180
Diethyl Sulfate	4	2,008	621		662	5,843,600	5,846,891	1,461,723
Cadmium Compounds	4	24	6,117				6,141	1,535
Monochloropentafluoroethane	4			2,348			2,348	587
Aluminum (Fume or Dust)	4	5			13,764		13,769	3,442
Dinitrotoluene (Mixed Isomers)	4		22,093		841,268		863,361	215,840
2-methylpyridine	4				2,647	4,200	6,847	1,712
Methacrylonitrile	4							
1,3-dichlorobenzene	4			940	44,830		45,770	11,443
Silver	4		665	224,796			225,461	56,365
2,4-dimethylphenol	4				7,998		7,998	1,999
1,1,1-trichloroethane	4				115,020	598,000	713,020	178,255
Chloroprene	4			148,400	630		149,030	37,258
Pentachlorobenzene[PBT]	3			1	84		85	28
Toluene-2,4-diisocyanate	3					240	240	80
Barium	3		32,146				32,146	10,715
1,2-dichloroethylene	3		7	2,310	1,178		3,495	1,165
1,2-phenylenediamine	3	10			46,778		46,788	15,596
Acifluorfen, Sodium Salt	3		225,664		2,079		227,743	75,914
Vanadium (Except When Contained in an Alloy)	3	202	4,654	353			5,209	1,736
1,2-dibromoethane	3	5			2,838	8	2,851	950
Zinc (Fume or Dust)	3		80				80	27
Titanium Tetrachloride	3		92		16	142	250	83
Dichlorotetrafluoroethane (Cfc-114)	3				93,520		93,520	31,173
Benzoyl Peroxide	3	35,917			7,192		43,109	14,370
Asbestos (Friable)	3		120,435				120,435	40,145
2-methyllactonitrile	3							
Tetrabromobisphenol A[PBT]	3		553		581		1,134	378
1,1,2,2-tetrachloroethane	3		7	1	445		453	151
Methyl Chlorocarbonate	3							
Peracetic Acid	3							

Table 11: 2000 TRI Transfers for Organic Chemical Facilities (SIC 286), by Number of Facilities Reporting (Transfers Reported in pounds/year)*

Chemical Name	# Reporting Chemical	POTW Transfers	Disposal Transfers	Recycling Transfers	Treatment Transfers	Energy Recovery	Total Transfers	Avg Transfers Per Facility
4-nitrophenol	3	59,511					59,511	19,837
1,4-dichlorobenzene	3				209,742		209,742	69,914
1,1,1,2-tetrachloroethane	3				50,317	837	51,154	17,051
2,4-dinitrotoluene	2				24		24	12
3-chloro-2-methyl-1-propene	2				7,213		7,213	3,606
Methylene Bromide	2							
Isopropyl Alcohol (Manufacturing, Strong-acid Proc	2					402,304	402,304	201,152
P-chloroaniline	2				10,947	850	11,797	5,898
Benzal Chloride	2				92	1,100,000	1,100,092	550,046
P-phenylenediamine	2				17,981		17,981	8,990
N-methylolacrylamide	2							
Decabromodiphenyl Oxide	2							
Quinone	2		130		164,935	124,080	289,145	144,572
2,4-dinitrophenol	2		51		183,793	58,458	242,302	121,151
P-nitroaniline	2	8,042			1,369		9,411	4,705
Benomyl	2				7,560	42,029	49,589	24,795
Benzoic Trichloride	2				1		1	1
Safrole	2	5					5	2
Dihydrosafrole	2	5					5	2
O-anisidine	2	1,983					1,983	991
1,2-dichloro-1,1-difluoroethane	2				94,254		94,254	47,127
Bis(2-chloroethyl) Ether	2				130,118		130,118	65,059
Dicamba	2	500			380		880	440
Dinitrobutyl Phenol	2		8,850				8,850	4,425
2-nitrophenol	2	2,509			15,525		18,034	9,017
2-chloro-1,1,1-trifluoroethane	2				3,600		3,600	1,800
2-mercaptobenzothiazole	2		192,242		6,028	1,958	200,228	100,114
Dichlorofluoromethane	2		10,570		60		10,630	5,315
P-cresidine	2	13,700	12,249				25,949	12,975
Antimony	2		15,811				15,811	7,905
2,2-dichloro-1,1,1-trifluoroethane	2				1,246	5,217	6,463	3,231
Chromium	2		3,222	3,000			6,222	3,111
Cobalt	2	2,822	2,356				5,178	2,589
Catechol	2					1,260	1,260	630
Ethylidene Dichloride	2		7		32	347	386	193
Ethyl Chloroformate	2							
Silver Compounds	2		340	119,358			119,698	59,849
Picloram	1							
Nitrapyrin	1				250		250	250
Molinate	1		1,080		76,999		78,079	78,079
Propargite	1	250	1,101	3,240	8,330		12,921	12,921
C.i. Disperse Yellow 3	1		450				450	450
Malononitrile	1							
Thiourea	1							
Prometryn	1							
Sodium Dimethyldithiocarbamate	1	12					12	12
Lead[PBT]	1		3,076	866			3,942	3,942
Manganese	1		7,336	2,066			9,402	9,402
Urethane	1							
Piperonyl Butoxide	1				8,994		8,994	8,994
Cupferron	1							
Trans-1,4-dichloro-2-butene	1							
Arsenic	1		4,141	1,166			5,307	5,307
P-dinitrobenzene	1				17		17	17
M-dinitrobenzene	1				473		473	473
Ethyleneimine	1							
5-nitro-o-anisidine	1	5					5	5
Styrene Oxide	1							
2,4,5-trichlorophenol	1							
Diazinon	1							
1,1,2,2-tetrachloro-1-fluoroethane	1				7,306	30,589	37,895	37,895
1,2-dichloro-1,1,2-trifluoroethane	1							

Table 11: 2000 TRI Transfers for Organic Chemical Facilities (SIC 286), by Number of Facilities Reporting (Transfers Reported in pounds/year)*

Chemical Name	# Reporting Chemical	POTW Transfers	Disposal Transfers	Recycling Transfers	Treatment Transfers	Energy Recovery	Total Transfers	Avg Transfers Per Facility
Carbonyl Sulfide	1							
O-dinitrobenzene	1				61		61	61
2,4-diaminotoluene	1				250		250	250
Bis(2-chloroethoxy)methane	1		450		17		467	467
Allylamine	1							
2,4-d Butyl Ester	1							
2,4-d	1							
3,3'-dichlorobenzidine	1	24	24,000		19,180	150,000	193,204	193,204
Perchloromethyl Mercaptan	1	3					3	3
Ozone	1							
Fenbutatin Oxide	1							
Iron Pentacarbonyl	1							
2,6-dinitrotoluene	1				110		110	110
Oryzalin	1				11,033		11,033	11,033
3,3'-dimethoxybenzidine Dihydrochloride	1							
2-phenylphenol	1							
Dichlorobenzene (Mixed Isomers)	1				686		686	686
Chloromethyl Methyl Ether	1							
Methyl Isocyanate	1							
Norflurazon	1		14,462		448		14,910	14,910
Octachlorostyrene[PBT]	1				19		19	19
Pendimethalin[PBT]	1							
Hexazinone	1				157,038		157,038	157,038
Permethrin	1				4,900		4,900	4,900
3-iodo-2-propynyl Butylcarbamate	1				39,780		39,780	39,780
Picric Acid	1							
3,3'-dichlorobenzidine Sulfate	1				12,500		12,500	12,500
Fomesafen	1		6,240		1,522		7,762	7,762
Propanil	1				750		750	750
Arsenic Compounds	1	1	15				16	16
Ethyl Dipropylthiocarbamate	1		762		53,615		54,377	54,377
1,4-dichloro-2-butene	1				92,934		92,934	92,934
Chlorophenols	1							
Ametryn	1							
2,4-dichlorophenol	1							
2,4,6-trichlorophenol	1							
Tetrachlorvinphos	1				3,010	34,600	37,610	37,610
N-nitrosodiphenylamine	1				41,324		41,324	41,324
Saccharin (Manufacturing, No Supplier Notification	1	3	100				103	103
2-nitropropane	1				95		95	95
Dimethylcarbamyl Chloride	1							
1,2-dichloropropane	1							
Paraldehyde	1							
Hexachlorocyclopentadiene	1	530			31,661	502	32,693	32,693
Pentachloroethane	1							
Chlorotrifluoromethane	1							
Atrazine	1							
Propyleneimine	1							
	467**	65,055,291	26,150,154	50,991,020	79,389,964	152,670,979	374,257,408	801,407

[PBT] Persistent, Bioaccumulative, and Toxic

* Refer to Section III for a discussion of the TRI data and its limitations, methodology used to obtain this data, definitions of the column headings, and the definition of persistant, bioaccumulative, and toxic chemicals.

**Total number of facilities (not chemical reports) reporting to TRI in this industry sector.

The TRI database contains a detailed compilation of self-reported, facility-specific chemical releases. The top reporting facilities for this sector are listed below (Table 12).

Table 12: Ten Largest Volume TRI Releasing Facilities in the Organic Chemicals Industry*

Rank	Facility	Total TRI Releases in Pounds
1	BASF Corporation - Freeport, TX	24,266,032
2	BP Chemicals Incorporated - Port Lavaca, TX	16,870,944
3	Du Pont Victoria Plant - Victoria, TX	14,799,253
4	Solutia Chocolate Bayou - Alvin, TX	11,282,922
5	Sterling Chemicals Incorporated - Texas City, TX	10,648,084
6	E I Dupont De Nemours & Company - Beaumont, TX	10,306,093
7	Angus Chemical Company - Sterlington, LA	6,885,314
8	International Specialty Products Technologies Inc. - Texas City, TX	6,684,616
9	Rubicon Incorporated - Geismar, LA	5,846,299
10	Honeywell International Incorporated - Hopewell, VA	4,882,960

Source: 2000 Toxics Release Inventory Database

* Being included in this list does not mean that the release is associated with non-compliance with environmental laws.

IV.B. Summary of Selected Chemicals Released

The following is a synopsis of current scientific toxicity and fate information for the top chemicals (by weight) that facilities within this sector self-reported as released to the environment based upon 2000 TRI data. Because this section is based upon self-reported release data, it does not attempt to provide information on management practices employed by the sector to reduce the releases of these chemicals. Information regarding pollutant release reductions over time may be available from EPA's TRI program, or directly from the industrial trade associations that are listed in Section VIII of this document. Since these descriptions are cursory, please consult the sources referenced below for a more detailed description of both the chemicals described in this section, and the chemicals that appear on the full list of TRI chemicals appearing in Section IV.A.

The brief descriptions provided below were taken from the Hazardous Substances Data Bank (HSDB), accessed via TOXNET. TOXNET is a computer system run by the National Library of Medicine. It includes a number of toxicological databases managed by EPA, National Cancer

Institute, and the National Institute for Occupational Safety and Health.[1] HSDB contains chemical-specific information on manufacturing and use, chemical and physical properties, safety and handling, toxicity and biomedical effects, pharmacology, environmental fate and exposure potential, exposure standards and regulations, monitoring and analysis methods, and additional references. The information contained below is based upon exposure assumptions that have been conducted using standard scientific procedures. The effects listed below must be taken in context of these exposure assumptions that are more fully explained within the full chemical profiles in HSDB. For more information on TOXNET, contact the TOXNET help line at 800-231-3766 or see the website at http://toxnet.nlm.nih.gov/.

Nitrate compounds

Toxicity. Nitrate compounds that are soluble in water release nitrate ions which can cause both human health and environmental effects. Human infants exposed to aqueous solutions of nitrate ion can develop a condition in which the blood's ability to carry oxygen is reduced. This reduced supply of oxygen can lead to damaged organs and death. Because it is a source of nitrogen, an essential element for aquatic plant growth, nitrate ion may contribute to eutrophication of standing or slow-moving surface water, particularly in nitrogen-limited waters, such as the Chesapeake Bay.

Carcinogenicity. There is currently no evidence to suggest that nitrate compounds are carcinogenic.

Environmental Fate. Nitrogen in nitrate is the form of nitrogen most available to plants. In the environment, nitrate ion is taken up by plants and becomes part of the natural nitrogen cycle. Excess nitrate can stimulate primary production in plants and can produce changes in the dominant species of plants, leading to cultural eutrophication and ultimately to deterioration of water quality.

Methanol (CAS: 67-56-1)

Toxicity. Methanol is readily absorbed from the gastrointestinal tract and the respiratory tract, and is toxic to humans in moderate to high doses. In the body, methanol is converted into formaldehyde and formic acid. Methanol is excreted as formic acid. Observed toxic effects at high dose levels generally include central nervous system damage and blindness. Long-term

[1] Databases included in TOXNET are: CCRIS (Chemical Carcinogenesis Research Information System), DART (Developmental and Reproductive Toxicity Database), DBIR (Directory of Biotechnology Information Resources), EMICBACK (Environmental Mutagen Information Center Backfile), GENE-TOX (Genetic Toxicology), HSDB (Hazardous Substances Data Bank), IRIS (Integrated Risk Information System), RTECS (Registry of Toxic Effects of Chemical Substances), and TRI (Toxic Chemical Release Inventory).

exposure to high levels of methanol via inhalation cause liver and blood damage in animals.

Ecologically, methanol is expected to have low toxicity to aquatic organisms. Concentrations lethal to half the organisms of a test population are expected to exceed one mg methanol per liter water. Methanol is not likely to persist in water or to bioaccumulate in aquatic organisms.

Carcinogenicity. There is currently no evidence to suggest that this chemical is carcinogenic.

Environmental Fate. Liquid methanol is likely to evaporate when left exposed. Methanol reacts in air to produce formaldehyde which contributes to the formation of air pollutants. In the atmosphere it can react with other atmospheric chemicals or be washed out by rain. Methanol is readily degraded by microorganisms in soils and surface waters.

Physical Properties. Methanol is highly flammable.

Ammonia (CAS: 7664-41-7)

Toxicity. Anhydrous ammonia is irritating to the skin, eyes, nose, throat, and upper respiratory system.

Ecologically, ammonia is a source of nitrogen (an essential element for aquatic plant growth), and may therefore contribute to eutrophication of standing or slow-moving surface water, particularly in nitrogen-limited waters such as the Chesapeake Bay. In addition, aqueous ammonia is moderately toxic to aquatic organisms.

Carcinogenicity. There is currently no evidence to suggest that this chemical is carcinogenic.

Environmental Fate. Ammonia combines with sulfate ions in the atmosphere and is washed out by rainfall, resulting in rapid return of ammonia to the soil and surface waters.

Ammonia is a central compound in the environmental cycling of nitrogen. Ammonia in lakes, rivers, and streams is converted to nitrate.

Physical Properties. Ammonia is a corrosive and severely irritating gas with a pungent odor.

Nitric Acid (CAS: 7697-37-2)

Toxicity. The toxicity of nitric acid is related to its potent corrosivity as an acid, with ulceration of all membranes and tissues with which it comes in contact. Concentrated nitric acid causes immediate opacification and blindness of the cornea when it comes in contact with the eye. Inhalation of concentrated nitric acid causes severe, sometimes fatal, corrosion of the respiratory tract. Ingestion of nitric acid leads to gastric hemorrhaging, nausea, and vomiting. Circulatory shock is often the immediate cause of death due to nitric acid exposure. Damage to the respiratory system may be delayed for months, and even years. Populations at increased risk from nitric acid exposure include people with pre-existing skin, eye, or cardiopulmonary disorders.

Ecologically, gaseous nitric acid is a component of acid rain. Acid rain causes serious and cumulative damage to surface waters and aquatic and terrestrial organisms by decreasing water and soil pH levels. Nitric acid in rainwater acts as a topical source of nitrogen, preventing "hardening off" of evergreen foliage and increasing frost damage to perennial plants in temperate regions. Nitric acid also acts as an available nitrogen source in surface water, stimulating plankton and aquatic weed growth.

Carcinogenicity. There is currently no evidence to suggest that this chemical is carcinogenic.

Environmental Fate. Nitric acid is mainly transported in the atmosphere as nitric acid vapors and in water as dissociated nitrate and hydrogen ions. In soil, nitric acid reacts with minerals such as calcium and magnesium, becoming neutralized, and at the same time decreasing soil "buffering capacity" against changes in pH levels.

Nitric acid leaches readily to groundwater, where it decreases the pH of the affected groundwater. In the winter, gaseous nitric acid is incorporated into snow, causing surges of acid during spring snow melt. Forested areas are strong sinks for nitric acid, incorporating the nitrate ions into plant tissues.

Physical Properties. Nitric acid is a colorless or yellow fuming liquid with an acrid smell; it is caustic and corrosive.

Ethylene (74-85-1)

Toxicity. Ethylene has been used as an anaesthetic; the effects reported here are related to its properties as an anaesthetic. Asphyxia may occur from breathing ethylene in enclosed spaces and in cases where the atmospheric oxygen has been displaced to about 15 to 16 percent or less.

Carcinogenicity. According to the International Agency for Research on Cancer, there is inadequate evidence in humans and animals to suggest carcinogenicity in humans.

Environmental Fate. In the air, ozone, nitrate radicals, and hydroxyl radicals may degrade ethylene. In water and soil, ethylene may be oxidized to produce ethylene oxide, and the chemical may permeate soil and sediment. The major environmental fate process is volatilization. The most probable way humans are exposed is by inhaling ethylene from contaminated air.

Physical Properties. Ethylene is a colorless gas with a sweet smell and is non-corrosive.

IV.C. Other Data Sources

The toxic chemical release data obtained from TRI captures the vast majority of facilities in the organic chemicals industry. It also allows for a comparison across years and industry sectors. Reported chemicals are limited however to the approximately 650 required by TRI. Most of the hydrocarbon emissions from organic chemical facilities are not captured by TRI (EPA, 1992). The EPA Office of Air Quality Planning and Standards has compiled air pollutant emission factors for determining the total air emissions of priority pollutants (e.g., total hydrocarbons, SO_x, NO_x, CO, particulates, etc.) from many chemical manufacturing sources.

The EPA Office of Air's Aerometric Information Retrieval System (AIRS) contains a wide range of information related to stationary sources of air pollution, including the emissions of a number of air pollutants which may be of concern within a particular industry. With the exception of volatile organic compounds (VOCs), there is little overlap with the TRI chemicals reported above. Table 13 summarizes releases in 2001 of volatile organic compounds (VOCs), nitrogen oxides (NO_x), carbon monoxide (CO), sulfur dioxide (SO_2), and particulate matter of 10 microns or less (PM10).

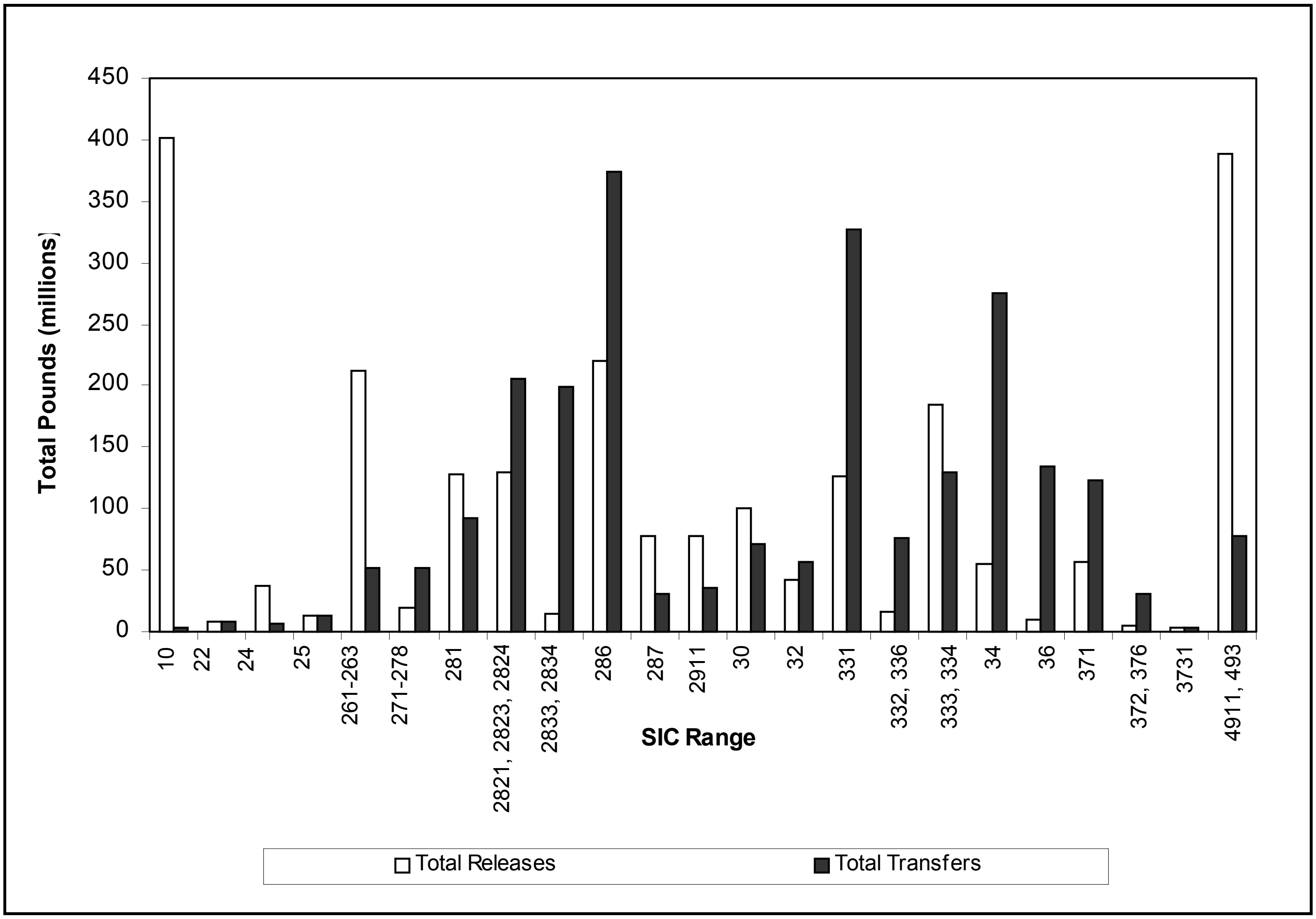
Table 13: Air Pollutant Releases by Industry Sector (tons/year)						
Industry Sector	CO	NO_2	PM10	PM25	SO_2	VOC
Metal Mining	8,039	45,341	61,358	32,534	10,926	2,109
Oil and Gas Extraction	151,763	366,793	4,607	4,379	226,208	94,549
Non-Fuel, Non-Metal Mineral Mining	27,001	15,747	48,760	20,956	16,874	3,806
Textiles	7,448	15,043	5,343	3,386	25,544	18,286
Lumber and Wood Products	142,955	37,313	57,009	38,337	9,189	100,761
Wood Furniture and Fixtures	7,046	3,008	6,905	5,260	2,779	62,457
Pulp and Paper	567,542	318,263	85,403	63,577	488,029	144,373
Printing	604	2,466	1,723	1,723	1,915	80,982
Inorganic Chemicals	176,697	94,938	19,549	12,586	201,994	43,563
Plastic Resins and Man-made Fibers	28,890	56,946	5,493	4,155	71,815	83,363
Pharmaceuticals	2,662	14,676	2,273	1,455	17,132	13,407
Organic Chemicals	**128,454**	**166,398**	**34,637**	**16,900**	**102,461**	**159,319**
Agricultural Chemicals	18,492	65,389	10,257	7,311	65,765	12,700
Petroleum Refining	438,375	298,602	33,620	26,870	478,998	161,207
Rubber and Plastic	2,515	9,565	5,209	3,217	20,368	87,258
Stone, Clay, Glass and Concrete	161,113	372,679	127,283	78,647	312,740	32,687
Iron and Steel	1,080,576	105,794	60,962	47,501	307,981	44,608
Metal Castings	104,350	6,298	22,393	15,654	4,770	17,285
Nonferrous Metals	418,647	30,882	24,019	17,433	244,413	8,663
Fabricated Metal Products	6,029	11,672	4,691	3,264	18,742	90,575
Electronics and Computers	22,105	6,428	3,184	2,349	6,882	27,453
Motor Vehicle Assembly	13,439	15,388	4,016	2,270	24,123	95,861
Aerospace	2,832	7,413	1,834	1,287	5,363	7,440
Shipbuilding and Repair	471	2,139	1,574	753	2,537	4,984
Ground Transportation	711,155	6,681,163	285,932	165,029	12,976,279	191,063
Water Transportation	83	153	2,162	733	66	6,787
Air Transportation	5,231	2,079	186	140	90	2,398
Fossil Fuel Electric Power	436,151	5,789,099	252,539	141,002	12,667,567	54,727
Dry Cleaning	217	438	190	117	220	3,163
Source: U.S. EPA Office of Air and Radiation, AIRS Database, 2001.						

IV.D. Comparison of Toxic Release Inventory Between Selected Industries

The following information is presented as a comparison of pollutant release and transfer data across industrial categories. It is provided to give a general sense as to the relative scale of releases and transfers within each sector profiled under this project. Please note that the following figure and table do not contain releases and transfers for industrial categories that are not included in this project, and thus cannot be used to draw conclusions regarding the total release and transfer amounts that are reported to TRI. Similar information is available within the annual TRI Public Data Release Book.

Figure 7 is a graphical representation of a summary of the 2000 TRI data for the organic chemical industry and the other sectors profiled in separate notebooks. The bar graph presents the total TRI releases and total transfers on the left axis and the triangle points show the average releases per facility on the right axis. Industry sectors are presented in the order of increasing total TRI releases. The graph is based on the data shown in Table 14 and is meant to facilitate comparisons between the relative amounts of releases, transfers, and releases per facility both within and between these sectors. The reader should note, however, that differences in the proportion of facilities captured by TRI exist between industry sectors. This can be a factor of poor SIC matching and relative differences in the number of facilities reporting to TRI from the various sectors. In the case of the organic chemical industry, the 1993 TRI data presented here covers 417 facilities. Only those facilities listing SIC Codes falling within SIC 286 were used.

Figure 7: 2000 Summary of TRI Releases and Transfers by Industry



Key to Standard Industrial Classification (SIC) Codes

SIC Range	Industry Sector	SIC Range	Industry Sector	SIC Range	Industry Sector
02	Agricultural Crops, Forestry	281	Inorganic Chemicals	333, 334	Nonferrous Metals
01, 08	Agricultural Livestock	2821, 2823, 2824	Plastic Resins and Man-made Fibers	34	Fabricated Metals
10	Metal Mining	2833, 2834	Pharmaceuticals	36	Electronics and Computers
13	Oil and Gas Extraction	286	Organic Chemicals	371	Motor Vehicle Assembly
14	Non-Fuel, Non-Metal Mining	287	Agricultural Chemicals	372, 376	Aerospace
22	Textiles	2911	Petroleum Refining	3731	Shipbuilding and Repair
24	Lumber and Wood Products	30	Rubber and Plastic	40, 42, 46, 4922-4925, 4932	Ground Transportation
25	Furniture and Fixtures	32	Stone, Clay, Glass and Concrete	44	Water Transportation
261-263	Pulp and Paper	331	Iron and Steel	45	Air Transportation
271-278	Printing	332, 336	Metal Casting	4911, 493	Fossil Fuel Electric Power Generation
				7216	Dry cleaning

Table 14: Toxics Release Inventory Data for Selected Industries

Industry Sector	SIC Range	# TRI Facilities	TRI Releases		TRI Transfers		Total Releases +Transfers (million lbs.)	Average Releases + Transfers per Facility (pounds)
			Total Releases (million lbs.)	Ave. Releases per Facility (pounds)	Total Transfers (million lbs.)	Ave. Transfers per Facility (pounds)		
Agricultural Crops, Forestry	2	Industry sector currently not subject to TRI reporting.						
Agricultural Livestock	01, 08	Industry sector currently not subject to TRI reporting.						
Metal Mining	10	58	402.1	690,837	2.8	4,894	404.9	695,731
Oil and Gas Extraction	13	Industry sector currently not subject to TRI reporting.						
Non-Fuel, Non-Metal Mining	14	Industry sector currently not subject to TRI reporting.						
Textiles	22	194	8.9	17,018	8.1	15,527	17.0	32,545
Lumber and Wood Products	24	410	36.6	28,305	7.1	5,497	43.7	33,802
Furniture and Fixtures	25	280	13.0	18,912	13.5	19,605	26.6	38,517
Pulp and Paper	261,262,263	268	211.6	90,180	51.5	21,971	263.1	112,151
Printing	271-278	163	19.0	50,148	51.5	21,971	70.5	72,119
Inorganic Chemicals	281	343	128.2	64,085	91.8	45,921	220.0	110,006
Plastic Resins and Man-made Fibers	2821, 2823, 2824	369	129.5	45,534	205.1	72,139	334.5	117,673
Pharmaceuticals	2833, 2834	151	15.1	19,275	199.0	254,766	214.0	274,041
Organic Chemicals	**286**	**467**	**219.4**	**47,377**	**374.3**	**80,833**	**593.6**	**128,210**
Agricultural Chemicals	287	172	78.1	78,927	30.1	30,417	108.3	109,344
Petroleum Refining	2911	162	78.5	25,948	36.2	11,973	114.7	37,921
Rubber and Plastic	30	1,154	100.2	28,358	71.0	20,099	171.2	48,457
Stone, Clay, Glass and Concrete	32	484	42.1	21,860	56.7	29,389	98.8	51,249
Iron and Steel	331	325	125.7	63,336	327.5	164,981	453.2	228,317
Metal Casting	332, 336	447	16.8	9,081	75.5	40,849	92.3	49,930
Nonferrous Metals	333, 334	181	185.3	184,340	128.9	128,258	314.2	312,598
Fabricated Metals	34	2,047	54.8	7,759	275.5	38,991	330.3	46,750
Electronics and Computers	36	419	9.0	5,968	133.7	88,279	142.7	94,247
Motor Vehicle Assembly	371	622	56.0	19,495	123.7	43,019	179.7	62,514
Aerospace	372, 376	184	5.3	8,277	30.1	46,674	35.4	54,951
Shipbuilding and Repair	3731	39	4.0	19,884	2.5	12,316	6.4	32,200
Ground Transportation	40, 42, 46, 4922- 4925, 4932	Industry sector currently not subject to TRI reporting.						
Water Transportation	44	Industry sector currently not subject to TRI reporting.						
Air Transportation	45	Industry sector currently not subject to TRI reporting.						
Fossil Fuel Electric Power Generation	4911, 493	613	388.7	73,037	78.0	14,647	466.7	87,684
Dry cleaning	7216	Industry sector currently not subject to TRI reporting.						
Sector Notebook Total	NA	9,552	2,327.8	1,617,941	2,374.1	1,213,016	4,701.9	2,830,957
2000 TRI Total	NA	23,484	6,575.7	280,007	4,139.7	176,277	10,715.4	456,285

Source: *US EPA Toxics Release Inventory Database, 2000.*

V. POLLUTION PREVENTION OPPORTUNITIES

The best way to reduce pollution is to prevent it in the first place. Some companies have creatively implemented pollution prevention techniques that improve efficiency and increase profits while at the same time minimizing environmental impacts. This can be done in many ways such as reducing material inputs, re-engineering processes to reuse by-products, improving management practices, and substituting benign chemicals for toxic ones. Some smaller facilities are able to actually get below regulatory thresholds just by reducing pollutant releases through aggressive pollution prevention policies.

In order to encourage these approaches, this section provides both general and company-specific descriptions of some pollution prevention advances that have been implemented within the organic chemical industry. While the list is not exhaustive, it does provide core information that can be used as the starting point for facilities interested in beginning their own pollution prevention projects. When possible, this section provides information from real activities that can, or are being implemented by this sector -- including a discussion of associated costs, time frames, and expected rates of return. This section provides summary information from activities that may be, or are being implemented by this sector. When possible, information is provided that gives the context in which the technique can be effectively used. Please note that the activities described in this section do not necessarily apply to all facilities that fall within this sector. Facility-specific conditions must be carefully considered when pollution prevention options are evaluated, and the full impacts of the change must examine how each option affects air, land and water pollutant releases.

The leaders in the organic chemical industry, similar to those in the chemical industry as a whole, have been promoting pollution prevention through various means. The most visible of these efforts is the Responsible Care® initiative of the American Chemistry Council. Responsible Care® is mandatory for Council members who must commit to act as stewards for products through use and ultimate reuse or disposal. One of the guiding principles of this initiative is the inclusion of waste and release prevention objectives in research and in design of new or modified facilities, processes and products. The Synthetic Organic Chemical Manufactures Association (SOCMA) also requires its members to implement the Responsible Care® Guiding Principles as a condition of membership. SOCMA is instituting the Responsible Care® management practice codes on a phased-in basis to assist its approximately 110 non-Council members, which are primarily small and batch chemical manufacturers, in successfully implementing their programs.

Using pollution prevention techniques which prevent the release or generation of pollution in the first place have several advantages over end-of-pipe waste treatment technologies. Table 15 below lists the direct and indirect benefits that could result.

Table 15: Pollution Prevention Activities Can Reduce Costs

Direct Benefits
• Reduced waste treatment costs
Reduced capital and operating costs for waste treatment facilities
Reduced off-site treatment and disposal costs
• Reduced manufacturing costs due to improved yields
• Income or savings from sale or reuse of wastes
• Reduced environmental compliance costs (e.g., fines, shutdowns)
• Reduced or eliminated inventories or spills
• Reduced secondary emissions from waste treatment facilities
• Retained sales (production threatened by poor environmental performance or sales)
Indirect Benefits
• Reduced likelihood of future costs from:
Remediation
Legal liabilities
Complying with future regulations
• Use of emission offsets (internal and external)
• Improved community relations
• Reduced societal costs
• Improved public health

Source: Chemical Manufacturers Association, 1993.

These incentives may encourage organic chemical manufacturers to undertake pollution prevention activities voluntarily, but a number of barriers still exist in achieving widespread adoption of pollution prevention. The U.S. Office of Technology Assessment has identified and characterized a number of these barriers in its report titled *Industry, Technology, and the Environment*.

Pollution prevention can be carried out at any stage during the development of a process. In general, changes made at the research and development stage will have the greatest impact; however, changes in the process design and operating practices can also yield significant results.

In the research and development stage, all possible reaction pathways for producing the desired product can be examined. These can then be evaluated in light of yield, undesirable by-products, and their health and environmental impacts. The area of "green synthesis" is the focus of considerable research funded jointly by the Agency and by the National Science Foundation. Several alternative syntheses have already been developed that could reduce wastes. For example, Joseph M. Desimone of the University of North

Carolina, Chapel Hill, has used supercritical carbon dioxide as a medium for carrying out dispersion polymerizations. He uses a specially engineered free-radical initiator to start the reaction and a polymeric stabilizer to affect the polymerization of methyl methacrylate. Because the carbon dioxide can easily be separated from the reaction mixture, this reaction offers the possibility of reduced hazardous waste generation, particularly of aqueous streams contaminated with residual monomer and initiator.

Because of the large investment in current technology and the lifetime of capital equipment, pollution prevention at the earliest stages is unlikely unless a company undertakes the design of a new production line or facility. Also, producers of specialty chemicals in particular must work within the specifications of customers and maintain the flexibility required to manufacture many chemicals at a single facility. Despite these limitations, there are numerous pollution prevention opportunities that can be realized by modifying current processes and equipment. Table 16 presents examples for several areas of the chemical manufacturing process.

Table 16: Process/Product Modifications Create Pollution Prevention Opportunities

Area	Potential Problem	Possible Approach
By-products Co-products		
Quantity and Quality	■ Process inefficiencies result in the generation of undesired by-products and co-products. Inefficiencies will require larger volumes of raw materials and result in additional secondary products. Inefficiencies can also increase fugitive emissions and wastes generated through material handling.	■ Increase product yield to reduce by-product and co-product generation and raw material requirements.
Uses and Outlets	■ By-products and co-products are not fully utilized, generating material or waste that must be managed.	■ Identify uses and develop a sales outlet. Collect information necessary to firm up a purchase commitment such as minimum quality criteria, maximum impurity levels that can be tolerated, and performance criteria.
Catalysts		
Composition	■ The presence of heavy metals in catalysts can result in contaminated process wastewater from catalyst handling and separation. These wastes may require special treatment and disposal procedures or facilities. Heavy metals can be inhibitory or toxic to biological wastewater treatment units. Sludge from wastewater treatment units may be classified as hazardous due to heavy metals content. Heavy metals generally exhibit low toxicity thresholds in aquatic environments and may bioaccumulate.	■ Catalysts comprised of noble metals, because of their cost, are generally recycled by both onsite and offsite reclaimers.
Preparation and Handling	■ Emissions or effluents are generated with catalyst activation or regeneration. ■ Catalyst attrition and carryover into product requires de-ashing facilities, which are a likely source of wastewater and solid waste.	■ Obtain catalyst in the active form. ■ Provide insitu activation with appropriate processing/activation facilities. ■ Develop a more robust catalyst or support.

Table 16: Process/Product Modifications Create Pollution Prevention Opportunities (Continued)

Area	Potential Problem	Possible Approach
Catalysts (cont.)		
Preparation and Handling (cont.)	■ Catalyst is spent and needs to be replaced.	■ In situ regeneration eliminates unloading/loading emissions and effluents versus offsite regeneration or disposal.
	■ Pyrophoric catalyst needs to be kept wet, resulting in liquid contaminated with metals.	■ Use a nonpryrophoric catalyst. Minimize amount of water required to handle and store safely.
	■ Short catalyst life.	■ Study and identify catalyst deactivitation mechanisms. Avoid conditions which promote thermal or chemical deactivation. By extending catalyst life, emissions and effluents associated with catalyst handling and regeneration can be reduced.
Effectiveness	■ Catalyzed reaction has by-product formation, incomplete conversion and less-than-perfect yield.	■ Reduce catalyst consumption with a more active form. A higher concentration of active ingredient or increased surface area can reduce catalyst loadings. ■ Use a more selective catalyst which will reduce the yield of undesired by-products. ■ Improve reactor mixing/contacting to increase catalyst effectiveness.
	■ Catalyzed reaction has by-product formation, incomplete conversion and less-than perfect yield.	■ Develop a thorough understanding of reaction to allow optimization of reactor design. Include in the optimization, catalyst consumption and by-product yield.
Intermediate Products		
Quantity and Quality	■ Intermediate reaction products or chemical species, including trace levels of toxic constituents, may contribute to process waste under both normal and upset conditions.	■ Modify reaction sequence to reduce amount or change composition of intermediates.
	■ Intermediates may contain toxic constituents or have characteristics that are harmful to the environment.	■ Modify reaction sequence to change intermediate properties. ■ Use equipment design and process control to reduce releases.

Table 16: Process/Product Modifications Create Pollution Prevention Opportunities (Continued)

Area	Potential Problem	Possible Approach
Process Conditions/ Configuration		
Temperature	▪ High heat exchange tube temperatures cause thermal cracking/decomposition of many chemicals. These lower molecular weight by-products are a source of "light ends" and fugitive emissions. High localized temperature gives rise to polymerization of reactive monomers, resulting in "heavies" or "tars." Such materials can foul heat exchange equipment or plug fixed-bed reactors, thereby requiring costly equipment cleaning and production outage.	▪ Select operating temperatures at or near ambient temperature whenever possible. ▪ Use lower pressure steam to lower temperatures. ▪ Use intermediate exchangers to avoid contact with furnace tubes and walls. ▪ Use staged heating to minimize product degradation and unwanted side reactions. ▪ Use superheat of high-pressure steam in place of furnace. ▪ Monitor exchanger fouling to correlate process conditions which increase fouling, avoid conditions which rapidly foul exchangers. ▪ Use online tube cleaning technologies to keep tube surfaces clean to increase heat transfer. ▪ Use scraped wall exchangers in viscous service. ▪ Use falling film reboiler, pumped recirculation reboiler or high-flux tubes.
	▪ Higher operating temperatures imply "heat input" usually via combustion which generates emissions.	▪ Explore heat integration opportunities (e.g., use waste heat to preheat materials and reduce the amount of combustion required.)
	▪ Heat sources such as furnaces and boilers are a source of combustion emissions.	▪ Use thermocompressor to upgrade low-pressure steam to avoid the need for additional boilers and furnaces.
	▪ Vapor pressure increases with increasing temperature. Loading/ unloading, tankage and fugitive emissions generally increase with increasing vapor pressure.	▪ If possible, cool materials before sending to storage. ▪ Use hot process streams to reheat feeds.

Table 16: Process/Product Modifications Create Pollution Prevention Opportunities (Continued)

Area	Potential Problem	Possible Approach
Process Conditions/ Configuration (cont.) *Temperature (cont.)*		■ Add vent condensers to recover vapors in storage tanks or process. ■ Add closed dome loading with vapor recovery condensers.
	■ Water solubility of most chemicals increases with increasing temperature.	■ Use lower temperature (vacuum processing).
Pressure	■ Fugitive emissions from equipment.	■ Equipment operating in vacuum service is not a source of fugitives; however, leaks into the process require control when system is degassed.
	■ Seal leakage potential due to pressure differential.	■ Minimize operating pressure.
	■ Gas solubility increases with higher pressures.	■ Determine whether gases can be recovered, compressed, and reused or require controls.
Corrosive Environment	■ Material contamination occurs from corrosion products. Equipment failures result in spills, leaks and increased maintenance costs.	■ Improve metallurgy or provide coating or lining. ■ Neutralize corrosivity of materials contacting equipment. ■ Use corrosion inhibitors.
	■ Increased waste generation due to addition of corrosion inhibitors or neutralization.	■ Improve metallurgy or provide coating or lining or operate in a less corrosive environment.
Batch vs. Continuous Operations	■ Vent gas lost during batch fill.	■Equalize reactor and storage tank vent lines. ■Recover vapors through condenser, adsorber, etc.
	■ Waste generated by cleaning/purging of process equipment between production batches.	■ Use materials with low viscosity. Minimize equipment roughness.

Table 16: Process/Product Modifications Create Pollution Prevention Opportunities (Continued)

Area	Potential Problem	Possible Approach
Process Conditions/ Configuration (cont.) *Batch vs. Continuous Operations (cont.)*		■ Optimize product manufacturing sequence to minimize washing operations and cross-contamination of subsequent batches.
	■ Process inefficiencies lower yield and increase emissions.	■ Sequence addition of reactants and reagents to optimize yields and lower emissions.
	■ Continuous process fugitive emissions and waste increase over time due to equipment failure through a lack of maintenance between turnarounds.	■Design facility to readily allow maintenance so as to avoid unexpected equipment failure and resultant release.
Process Operation/Design	■ Numerous processing steps create wastes and opportunities for errors.	■ Keep it simple. Make sure all operations are necessary. More operations and complexity only tend to increase potential emission and waste sources.
	■ Nonreactant materials (solvents, absorbants, etc.) create wastes. Each chemical (including water) employed within the process introduces additional potential waste sources; the composition of generated wastes also tends to become more complex.	■ Evaluate unit operation or technologies (e.g., separation) that do not require the addition of solvents or other nonreactant chemicals.
	■ High conversion with low yield results in wastes.	■ Recycle operations generally improve overall use of raw materials and chemicals, thereby both increasing the yield of desired products while at the same time reducing the generation of wastes. A case-in-point is to operate at a lower conversion per reaction cycle by reducing catalyst consumption, temperature, or residence time. Many times, this can result in a higher selectivity to desired products. The net effect upon recycle of unreacted reagents is an increase in product yield, while at the same time reducing the quantities of spent catalyst and less desirable by-products.

Table 16: Process/Product Modifications Create Pollution Prevention Opportunities (Continued)

Area	Potential Problem	Possible Approach
Process Conditions/ Configuration (cont.)		
Process Operation/Design	▪ Non-regenerative treatment systems result in increased waste versus regenerative systems.	▪ Regenerative fixed bed treating or desiccant operation (e.g., aluminum oxide, silica, activated carbon, molecular sieves, etc.) will generate less quantities of solid or liquid waste than nonregenerative units (e.g., calcium chloride or activated clay). With regenerative units though, emissions during bed activation and regeneration can be significant. Further, side reactions during activation/regeneration can give rise to problematic pollutants.
Product		
Process Chemistry	▪ Insufficient R&D into alternative reaction pathways may miss pollution opportunities such as waste reduction or eliminating a hazardous constituent.	▪ R&D during process conception and laboratory studies should thoroughly investigate alternatives in process chemistry that affect pollution prevention.
Product Formulation	▪ Product based on end-use performance may have undesirable environmental impacts or use raw materials or components that generate excessive or hazardous wastes.	▪ Reformulate products by substituting different material or using a mixture of individual chemicals that meet end-use performance specifications.
Raw Materials		
Purity	▪ Impurities may produce unwanted by-products and waste. Toxic impurities, even in trace amounts, can make a waste hazardous and therefore subject to strict and costly regulation.	▪ Use higher purity materials. ▪ Purify materials before use and reuse if practical. ▪ Use inhibitors to prevent side reactions.
	▪ Excessive impurities may require more processing and equipment to meet product specifications, increasing costs and potential for fugitive emissions, leaks, and spills.	▪ Achieve balance between feed purity, processing steps, product quality and waste generation.
	▪ Specifying a purity greater than needed by the process increases costs and can result in more waste generation by the supplier.	▪ Specify a purity no greater than what the process needs.

Table 16: Process/Product Modifications Create Pollution Prevention Opportunities (Continued)

Area	Potential Problem	Possible Approach
Raw Materials (cont.)		
Purity (cont.)	■ Impurities in clean air can increase inert purges.	■Use pure oxygen.
	■ Impurities may poison catalyst prematurely resulting in increased wastes due to yield loss and more frequent catalyst replacement.	■Install guard beds to protect catalysts.
Vapor Pressure	■ Higher vapor pressures increase fugitive emissions in material handling and storage.	■ Use material with lower vapor pressure.
	■ High vapor pressure with low odor threshold materials can cause nuisance odors.	■ Use materials with lower vapor pressure and higher odor threshold.
Water Solubility	■ Toxic or nonbiodegradable materials that are water soluble may affect wastewater treatment operation, efficiency, and cost.	■ Use less toxic or more biodegradable materials.
	■ Higher solubility may increase potential for surface and groundwater contamination and may require more careful spill prevention, containment, and cleanup (SPCC) plans.	■ Use less soluble materials.
	■ Higher solubility may increase potential for storm water contamination in open areas.	■ Use less soluble materials. ■ Prevent direct contact with storm water by diking or covering areas.
	■ Process wastewater associated with water washing or hydrocarbon/water phase separation will be impacted by containment solubility in water. Appropriate wastewater treatment will be impacted.	■ Minimize water usage. ■ Reuse wash water. ■ Determine optimum process conditions for phase separation. ■ Evaluate alternative separation technologies (coalescers, membranes, distillation, etc.)

Table 16: Process/Product Modifications Create Pollution Prevention Opportunities (Continued)

Area	Potential Problem	Possible Approach
Raw Materials (cont.)		
Toxicity	■ Community and worker safety and health concerns result from routine and nonroutine emissions. Emissions sources include vents, equipment leaks, wastewater emissions, emergency pressure relief, etc.	■ Use less toxic materials. ■ Reduce exposure through equipment design and process control. Use systems which are passive for emergency containment of toxic releases.
	■ Surges or higher than normal continuous levels of toxic materials can shock or miss wastewater biological treatment systems resulting in possible fines and possible toxicity in the receiving water.	■ Use less toxic material. ■ Reduce spills, leaks, and upset conditions through equipment and process control. ■ Consider effect of chemicals on biological treatment; provide unit pretreatment or diversion capacity to remove toxicity. ■ Install surge capacity for flow and concentration equalization.
Regulatory	■ Hazardous or toxic materials are stringently regulated. They may require enhanced control and monitoring; increased compliance issues and paperwork for permits and record keeping; stricter control for handling, shipping, and disposal; higher sampling and analytical costs; and increased health and safety costs.	■ Use materials which are less toxic or hazardous. ■ Use better equipment and process design to minimize or control releases; in some cases, meeting certain regulatory criteria will exempt a system from permitting or other regulatory requirements.
Form of Supply	■ Small containers increase shipping frequency which increases chances of material releases and waste residues from shipping containers (including wash waters).	■ Use bulk supply, ship by pipeline, or use "jumbo" drums or sacks. ■ In some cases, product may be shipped out in the same containers the material supply was shipped in without washing.
	■ Nonreturnable containers may increase waste.	■ Use returnable shipping containers or drums.
Handling and Storage	■ Physical state (solid, liquid, gaseous) may raise unique environmental, safety, and health issues with unloading operations and transfer to process equipment.	■ Use equipment and controls appropriate to the type of materials to control releases.

Table 16: Process/Product Modifications Create Pollution Prevention Opportunities (Continued)

Area	Potential Problem	Possible Approach
Raw Materials (cont.) *Handling and Storage (cont.)*	■ Large inventories can lead to spills, inherent safety issues and material expiration.	■ Minimize inventory by utilizing just-in-time delivery.
Waste Streams		
Quantity and Quality	■ Characteristics and sources of waste streams are unknown.	■ Document sources and quantities of waste streams prior to pollution prevention assessment.
	■ Wastes are generated as part of the process.	■ Determine what changes in process conditions would lower waste generation of toxicity.
		■ Determine if wastes can be recycled back into the process.
Composition	■ Hazardous or toxic constituents are found in waste streams. Examples are: sulfides, heavy metals, halogenated hydrocarbons, and polynuclear aromatics.	■ Evaluate whether different process conditions, routes, or reagent chemicals (e.g., solvent catalysts) can be substituted or changed to reduce or eliminate hazardous or toxic compounds.
Properties	■ Environmental fate and waste properties are not known or understood.	■ Evaluate waste characteristics using the following type properties: corrosivity, ignitability, reactivity, BTU content (energy recovery), biodegradability, aquatic toxicity, and bioaccumulation potential of the waste and of its degradable products, and whether it is a solid, liquid, or gas.
Disposal	■ Ability to treat and manage hazardous and toxic waste unknown or limited.	■ Consider and evaluate all onsite and offsite recycle, reuse, treatment, and disposal options available. Determine availability of facilities to treat or manage wastes generated.

Source: Chemical Manufacturers Association, 1993.

Table 17: Modifications to Equipment Can Also Prevent Pollution

Equipment	Potential Environment Problem	Possible Approach: Design Related	Possible Approach: Operational Related
Compressors, blowers, fans	■ Shaft seal leaks, piston rod seal leaks, and vent streams	■ Seal-less designs (diaphragmatic, hermetic or magnetic) ■ Design for low emissions (internal balancing, double inlet, gland eductors) ■ Shaft seal designs (carbon rings, double mechanical seals, buffered seals) ■ Double seal with barrier fluid vented to control device	■ Preventive maintenance program
Concrete pads, floors, sumps	■ Leaks to groundwater	■ Water stops ■ Embedded metal plates ■ Epoxy sealing ■ Other impervious sealing	■ Reduce unnecessary purges, transfers, and sampling ■ Use drip pans where necessary
Controls	■ Shutdowns and start-ups generate waste and releases	■ Improve on-line controls ■ On-line instrumentation ■ Automatic start-up and shutdown ■ On-line vibration analysis ■ Use "consensus" systems (e.g., shutdown trip requires 2 out of 3 affirmative responses)	■ Continuous versus batch ■ Optimize on-line run time ■ Optimize shutdown interlock inspection frequency ■ Identify safety and environment critical instruments and equipment
Distillation	■ Impurities remain in process streams	■ Increase reflux ratio ■ Add section to column ■ Column intervals ■ Change feed tray	■ Change column operating conditions - reflux ratio - feed tray - temperature - pressure - etc.

Table 17: Modifications to Equipment Can Also Prevent Pollution (Continued)

Equipment	Potential Environment Problem	Possible Approach: Design Related	Possible Approach: Operational Related
Distillation (cont.)	■ Impurities remain in process streams (cont.)	■ Insulate to prevent heat loss ■ Preheat column feed ■ Increase vapor line size to lower pressure drop	■ Clean column to reduce fouling
	■ Large amounts of contaminated water condensate from stream stripping	■ Use reboilers or inert gas stripping agents	■ Use higher temperature steam
General manufacturing equipment areas	■ Contaminated rainwater	■ Provide roof over process facilities ■ Segregate process sewer from storm sewer (diking) ■ Hard-pipe process streams to process sewer	■ Return samples to process ■ Monitor stormwater discharge
	■ Contaminated sprinkler and fire water	■ Seal floors ■ Drain to sump ■ Route to waste treatment	
	■ Leaks and emissions during cleaning	■ Design for cleaning ■ Design for minimum rinsing ■ Design for minimum sludge ■ Provide vapor enclosure ■ Drain to process	■ Use drip pans for maintenance activities ■ Rinse to sump ■ Reuse cleaning solutions
Heat exchangers	■ Increased waste due to high localized temperatures	■ Use intermediate exchangers to avoid contact with furnace tubes and walls ■ Use staged heating to minimize product degradation and unwanted side reactions. (waste heat >>low pressure steam >>high pressure steam)	■ Select operating temperatures at or near ambient temperature when-ever possible. These are generally most desirable from a pollution prevention standpoint ■ Use lower pressure steam to lower temperatures

Table 17: Modifications to Equipment Can Also Prevent Pollution (Continued)

Equipment	Potential Environment Problem	Possible Approach: Design Related	Possible Approach: Operational Related
Heat exchangers (cont.)	■ Increased waste due to high localized temperatures (cont.)	■ Use scraped wall exchangers in viscous service ■ Using falling film reboiler, piped recirculation reboiler or high-flux tubes ■ Use lowest pressure steam possible	■ Monitor exchanger fouling to correlate process conditions which increase fouling, avoid conditions which rapidly foul exchangers ■ Use on-line tube cleaning techniques to keep tube surfaces clean
	■ Contaminated materials due to tubes leaking at tube sheets	■ Use welded tubes or double tube sheets with inert purge. Mount vertically	■ Monitor for leaks
	■ Furnace emissions	■ Use superheat of high-pressure steam in place of a furnace	
Piping	■ Leaks to groundwater; fugitive emissions	■ Design equipment layout so as to minimize pipe run length ■ Eliminate underground piping or design for cathodic protection if necessary to install piping underground ■ Welded fittings ■ Reduce number of flanges and valves ■ All welded pipe ■ Secondary containment ■ Spiral-wound gaskets ■ Use plugs and double valves for open end lines ■ Change metallurgy ■ Use lined pipe	■ Monitor for corrosion and erosion ■ Paint to prevent external corrosion

Table 17: Modifications to Equipment Can Also Prevent Pollution (Continued)

Equipment	Potential Environment Problem	Possible Approach: Design Related	Possible Approach: Operational Related
Piping (cont.)	■ Releases when cleaning or purging lines	■ Use "pigs" for cleaning ■ Slope to low point drain ■ Use heat tracing and insulation to prevent freezing ■ Install equalizer lines	■ Flush to product storage tank
Pumps	■ Fugitive emissions from shaft seal leaks	■ Mechanical seal in lieu of packing ■ Double mechanical seal with inert barrier fluid ■ Double machined seal with barrier fluid vented to control device ■ Seal-less pump (canned motor magnetic drive) ■ Vertical pump	■ Seal installation practices ■ Monitor for leaks
	■ Fugitive emissions from shaft seal leaks	■ Use pressure transfer to eliminate pump	
	■ Residual "heel" of liquid during pump maintenance	■ Low point drain on pump casing	■ Flush casing to process sewer for treatment ■ Increase the mean time between pump failures by: - selecting proper seal material; - good alignment; - reduce pipe-induced stress - Maintaining seal lubrication
	■ Injection of seal flush fluid into process stream	■ Use double mechanical seal with inert barrier fluid where practical	
Reactors	■ Poor conversion or performance due to inadequate mixing	■ Static mixing ■ Add baffles ■ Change impellers	■ Add ingredients with optimum sequence

Table 17: Modifications to Equipment Can Also Prevent Pollution (Continued)

		Possible Approach	
Equipment	Potential Environment Problem	Design Related	Operational Related
Reactors (cont.)	■ Poor conversion (cont.)	■ Add horsepower ■ Add distributor	■ Allow proper head space in reactor to enhance vortex effect
	■ Waste by-product formation	■ Provide separate reactor for converting recycle streams to usable products	■ Optimize reaction conditions (temperature, pressure, etc.)
Relief Valve	■ Leaks	■ Provide upstream rupture disc	
	■ Fugitive emissions	■ Vent to control or recovery device	■ Monitor for leaks and for control efficiency
	■ Discharge to environment from over pressure	■ Pump discharges to suction of pump ■ Thermal relief to tanks ■ Avoid discharge to roof areas to prevent contamination of rainwater	■ Monitor for leaks
	■ Frequent relief	■ Use pilot operated relief valve ■ Increase margin between design and operating pressure	■ Reduce operating pressure ■ Review system performance
Sampling	■ Waste generation due to sampling (disposal, containers, leaks, fugitives, etc.)	■ In-line insitu analyzers ■ System for return to process ■ Closed loop ■ Drain to sump	■ Reduce number and size of samples required ■ Sample at the lowest possible temperature ■ Cool before sampling
Tanks	■ Tank breathing and working losses	■ Cool materials before storage ■ Insulate tanks ■ Vent to control device (flare, condenser, etc.) ■ Vapor balancing ■ Floating roof	■ Optimize storage conditions to reduce losses

Table 17: Modifications to Equipment Can Also Prevent Pollution (Continued)

Equipment	Potential Environment Problem	Possible Approach	
		Design Related	Operational Related
Tanks (cont.)	■ Tank breathing and working losses (cont.)	■ Floating roof ■ Higher design pressure	
	■ Leak to groundwater	■ All aboveground (situated so bottom can routinely be checked for leaks) ■ Secondary containment ■ Improve corrosion resistance	■ Monitor for leaks and corrosion
	■ Large waste heel	■ Design for 100% de-inventory	■ Recycle to process if practical
Vacuum Systems	■ Waste discharge from jets	■ Substitute mechanical vacuum pump ■ Evaluate using process fluid for powering jet	■ Monitor for air leaks ■ Recycle condensate to process
Valves	■ Fugitive emissions from leaks	■ Bellow seals ■ Reduce number where practical ■ Special packing sets	■ Stringent adherence to packing procedures
Vents	■ Release to environment	■ Route to control or recovery device	■ Monitor performance

Source: Chemical Manufacturers Association, 1993.

It is critical to emphasize that pollution prevention in the chemical industry is process specific and oftentimes constrained by site-specific considerations. As such, it is difficult to generalize about the relative merits of different pollution prevention strategies. The age, size, and purpose of the plant will influence the choice of the most effective pollution prevention strategy. Commodity chemical manufacturers redesign their processes infrequently so that redesign of the reaction process or equipment is unlikely in the short term. Here operational changes are the most feasible response. Specialty chemical manufacturers are making a greater variety of chemicals and have more process and design flexibility. Incorporating changes at the earlier research and development phases may be possible for them.

Changes in operational practices may yield the most immediate gains with the least investment. For example, the majority of the waste generated by the chemical processing industry is contaminated water: Borden Chemical Company has collected and isolated its waste water in a trench coming from the phenol rail car unloading area and reused the water in resin batches. This eliminated the entire waste stream with a capital investment of $3,000 and annual savings of $1,500 a year in treatment costs. Rhone-Poulenc, in New Brunswick, New Jersey, is now sending all quality control and raw material samples back to be reused in the production process saving $20,000 per year and reducing waste volume by 3,000 pounds.

Another area that can yield significant benefits is improved process control so that less off-specification product is produced (that must be discarded) and the process is run more optimally (fewer by-products). Exxon Chemical Americas of Linden, New Jersey, used continuous process optimization to reduce the generation of acid coke, a process residue, thus saving $340,000 annually in treatment costs. New in-line process controls are under development (a fertile area of research being pursued by the Center for Process Analytic Chemistry at the University of Washington) that may allow better process optimization through tighter process control.

Chemical substitution, particularly of water for non-aqueous solvents, can also prevent pollution. For example, Du Pont at the Chamber Works in New Jersey is using a high-pressure water-jet system to clean polymer reaction vessels. This replaces organic solvent cleaning that annually produced 40,000 pounds of solvent waste. Installing the new cleaning system cost $125,000 but it will save $270,000 annually.

Improved separations design also offers a pollution prevention opportunity since separations account for about 20 percent of energy use in the chemical process industry. In one case, a solvent was replaced by an excess of a reaction component, thus eliminating the need to separate the solvent from the waste stream while reducing separation costs.