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REGULATORY IMPACT ASSESSMENT FOR PROPOSED HAZARDOUS WASTE COMBUSTION MACT STANDARDS

DRAFT

APPENDICES

Prepared for:

Office of Solid Waste
U.S. Environmental Protection Agency
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November 13, 1995

Appendix C

WASTE MINIMIZATION REPORT

MEMORANDUM

TO: Lisa Harris, EPA/OSW; Bob Black; IEc

FROM: Jerome Strauss and Peter Von Szilassy, Versar, Incorporated

DATE: March 30, 1995

SUBJECT: Preliminary Assessment of Waste Minimization Potential for Combusted Wastes

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PURPOSE

The EPA Office of Solid Waste is developing new combustion standards for hazardous waste combustion facilities. The new standards will most likely result in increased combustion costs. One of the potential responses of hazardous waste generators, both large and small, to increased waste combustion costs may be to apply technologies and opportunities to reduce or eliminate the wastestream currently being combusted. Of particular interest to EPA is the potential for smaller quantity generators to reduce waste generation rather than absorb additional disposal coats. The purpose of this investigation is to evaluate the potential pollution prevention and waste minimization opportunities/technologies that hazardous waste generators may pursue. Opportunities that are especially appropriate for smaller quantity generators are emphasized.

METHODOLOGY

The wastestreams considered for waste minimization are grouped by source code and industry as the potential minimization or prevention technologies will be similar or identical within each source code/SIC group. Any differences in application will be noted in the discussion or listing of technologies and/or opportunities. Cost estimates and/or savings for implementation of the technology or opportunity cannot be provided except in the most general of terms, if at all, as the implementation/applicability of a specific technology requires detailed knowledge of the specific industrial processes involved and the specific composition, flow, and concentrations of the wastestreams under consideration.

The data used for the analysis are a subset of the Biennial Report Survey (BRS) database for combusted wastes. The data are limited to source code/SIC code combinations of more than 500 tons and with more than 5 generators. The data were retabulated as shown in Table A. The cost of combustion per generator per SIC code were based on a composite combustion cost

Table A: Waste Minimization Assessment

SOURCE CODE	SOURCE CODE DESCRIPTION	SIC CODE	SIC CODE DESCRIPTION	WASTE QUANTITY (TONS)	SOLID / LIQUID FRACTION %	COMPOSITE DISPOSAL COST/TON	DISPOSAL COST	NUMBER OF GENERATORS	TONS PER GENERATOR	DISPOSAL COST PER GENERATOR
S01	Cleaning, Rinsing, and Degreasing	2869	Industrial Organic Chemicals	908	10/90	$389	$353,303	17	53	$20,622
		3674	Semiconductors	2,318	5/95	$337	$780,123	11	211	$71,012
		3721	Aircraft Manufacturing	679	8/92	$368	$249,926	10	68	$25,029
		2824	Organic Fibers	2,172	15/85	$442	$959,264	8	271	$119,687
		3861	Photo Equipment	1,046	5/95	$337	$352,031	7	149	$50,146
		4953	Refuse Disposal	1,657	20/80	$494	$818,889	7	227	$112,183
			Total	8,780			$3,513,537	60		
S02	Painting and Coating	2511	Furniture - wood	711	30/70	$599	$426,102	29	25	$14,982
S05	Solvent & Product Recovery/Distillation	2869	Industrial Organic Chemicals	410,337	70/30	$1,020	$418,420,639	71	5,779	$5,892,846
		2821	Plastic Materials	18,372	80/20	$1,125	$20,664,826	16	1,148	$1,291,270
		2865	Organics / Dyes	44,378	80/20	$1,125	$49,916,374	15	2,959	$3,328,283
		2879	Pesticides	7,396	90/10	$1,230	$9,096,340	7	1,057	$1,300,004
		7389	Business Services	7,629	90/10	$1,230	$9,382,907	6	1,272	$1,564,433
			Total	488,112			$507,481,086	115		
S06	Product Processing	2869	Industrial Organic Chemicals	175,479	30/70	$599	$105,164,565	65	2,700	$1,618,110
		2821	Plastic Materials	14,146	40/60	$704	$9,964,442	32	442	$311,345
		2833	Medicinal Chemistry	77,721	20/80	$494	$38,409,718	17	4,572	$2,259,482
		2879	Pesticides	56,991	30/70	$599	$34,154,706	16	3,562	$2,134,707
		2834	Pharmaceutical	17,179	30/70	$599	$10,295,375	13	1,321	$791,675
		2899	Miscellaneous Chemicals	584	30/70	$599	$349,991	10	58	$34,759
		3861	Photo Equipment	13,331	40/60	$704	$9,390,356	9	1,481	$1,043,216
		2865	Organics / Dyes	10,546	30/70	$599	$6,320,218	8	1,318	$789,877
			Total	365,977			$214,049,372	170		
S07	Process Waste Removal and Cleaning	2869	Industrial Organic Chemicals	129,487	40/60	$704	$91,210,643	67	1,933	$1,361,605
		2821	Plastic Materials	68,913	50/50	$810	$55,785,074	33	2,088	$1,690,236
		2851	Paints and Varnishes	2,493	50/50	$810	$2,018,084	22	113	$91,474
		2879	Pesticides	210,701	40/60	$704	$148,417,784	18	11,706	$8,245,706
		2834	Pharmaceutical	92,662	40/60	$704	$65,271,113	17	5,451	$3,839,684
		2911	Petroleum Refining	805	50/50	$810	$651,648	15	54	$43,713
		2899	Miscellaneous Chemicals	6,003	40/60	$704	$4,228,513	14	429	$302,188
		3861	Photo Equipment	1,950	60/40	$915	$1,783,470	14	139	$127,129
		2819	Inorganic Chemicals	18,501	50/50	$810	$14,976,560	11	1,682	$1,361,579
		2833	Medicinal Chemistry	7,348	40/60	$704	$5,175,931	11	668	$470,539
		2865	Organics / Dyes	1,878	50/50	$810	$1,520,241	8	235	$190,233

Table A: Waste Minimization Assessment

SOURCE CODE	SOURCE CODE DESCRIPTION	SIC CODE	SIC CODE DESCRIPTION	WASTE QUANTITY (TONS)	SOLID / LIQUID FRACTION %	COMPOSITE DISPOSAL COST/TON	DISPOSAL COST	NUMBER OF GENERATORS	TONS PER GENERATOR	DISPOSAL COST PER GENERATOR
		3089	Plastic Production	575	70/30	$1,020	$586,328	7	82	$83,615
		4911	Electrical Power	1,771	50/50	$810	$1,433,625	7	253	$204,804
		2891	Adhesives / Sealants	2,105	60/40	$915	$1,925,233	6	351	$321,025
		8731	Physical / Biological Research	1,118	80/20	$1,125	$1,257,526	6	186	$209,213
			Total	546,310			$396,241,771	256	--	..
S08	Waste and Spent Material Removal	4911	Electrical Power	4,998	50/50	$810	$4,045,881	38	132	$106,854
		2869	Industrial Organic Chemicals	6,208	40/60	$704	$4,372,915	31	200	$140,880
		5171	Petroleum Bulk Stations	997	40/60	$704	$702,287	18	55	$38,742
		2821	Plastic Materials	514	50/50	$810	$416,083	17	30	$24,285
		2911	Petroleum Refining	3,570	40/60	$704	$2,514,708	14	255	$179,622
		2819	Inorganic Chemicals	979	50/50	$810	$792,501	7	140	$113,330
		4953	Refuse Disposal	14,690	80/20	$1,125	$16,523,312	6	2.448	$2,753,510
			Total	31,956			$29,367,687	131		
S09	Laboratory Operations	8731	Physical / Biological Research	1,337	80/20	$1,125	$1,503,858	19	70	$78,736
		4953	Refuse Disposal	670	80/20	$1,125	$753,616	15	45	$50,616
			Total	2,007			$2,257,474	34		
S10	Discarding and Decommissioning	2869	Industrial Organic Chemicals	3,637	30/70	$599	$2,179,654	53	69	$41,352
		2899	Miscellaneous Chemicals	670	30/70	$599	$401,531	26	26	$15,582
		2821	Plastic Materials	1,431	50/50	$810	$1,158,395	23	62	$50,189
		2879	Pesticides	2,434	40/60	$704	$1,714,510	21	116	$81,710
		2851	Paints and Varnishes	699	40/60	$704	$492,376	15	47	$33,107
		3861	Photo Equipment	824	50/50	$810	$667,028	15	55	$44,523
		4225	Warehouse	591	40/60	$704	$416,300	11	54	$38,038
			Total	10,286			$7,029,793	164		
S11	Routine Spill & Leak Collection	2869	Industrial Organic Chemicals	2,124	50/50	$810	$1,719,378	45	47	$38,047
		2834	Pharmaceutical	7,027	50/50	$810	$5,688,357	10	703	$569,079
		4911	Electrical Power	5,465	80/20	$1,125	$6,147,032	9	607	$682,754
		4953	Refuse Disposal	3,654	90/10	$1,230	$4,494,055	7	522	$642,008
			Total	18,270			$18,048,821	71		
S12	Remediation and Closure	2869	Industrial Organic Chemicals	7,726	90/10	$1,230	$9,502,207	12	644	$792,056
		9999	Unclassified	12,509	90/10	$1,230	$15,384,819	11	1,137	$1,398,396

Table A: Waste Minimization Assessment

SOURCE CODE	SOURCE CODE DESCRIPTION	SIC CODE	SIC CODE DESCRIPTION	WASTE QUANTITY (TONS)	SOLID / LIQUID FRACTION %	COMPOSITE DISPOSAL COST/TON	DISPOSAL COST	NUMBER OF GENERATORS	TONS PER GENERATOR	DISPOSAL COST PER GENERATOR
		5541	Gas Station	3,167	90/10	$1,230	$3,895,093	9	352	$432,925
		4953	Refuse Disposal	3,272	100/0	$1,335	$4,368,120	6	545	$727,575
			Total	26,674			$33,150,240	38		
S13	Pollution Control & Wastewater Treatment	2911	Petroleum Refining	179,285	60/40	$915	$163,974,061	42	4,239	$3,904,427
		4953	Refuse Disposal	12,345	90/10	$1,230	$15,183,116	28	441	$542,386
		2869	Industrial Organic Chemicals	80,860	70/30	$1,020	$82,452,942	18	4 492	$4,580,492
		9511	Environmental Administration	1,785	90/10	$1,230	$2,195,372	11	162	$199,244
		9999	Unclassified	1,066	100/0	$1,335	$1,423,110	11	97	$129,495
		2821	Plastic Materials	3,833	90/10	$1,230	$4,714,207	8	479	$589,122
		2879	Pesticides	1,862	70/30	$1,020	$1,898,681	7	266	$271,240
		2899	Miscellaneous Chemicals	19,271	70/30	$1,020	$19,650,639	7	2,753	$2,807,234
		9711	National Security	2,560	90/10	$1,230	$3,148,544	7	366	$450,143
			Total	302,867			$294,640,671	139		
S14	Unknown	4922	Natural Gas Production	730	not determinable			34	21	
		9999	Unclassified	23,751				21	1,131	
		4953	Refuse Disposal	16,872				20	844	
		2869	Industrial Organic Chemicals	16,965				18	942	
		2821	Plastic Materials	10,781				17	634	
		2879	Pesticides	3,380				11	307	
		8999	Administration	13,707				11	1,246	
		2819	Inorganic Chemicals	18,139				8	2,267	
		2851	Paints and Varnishes	1,766				8	221	
		2899	Miscellaneous Chemicals	1,001				7	143	
			Total	107,092				155		
Total all Industries and Source codes except S14				1,801,950			$1,506,206,553			
Total smaller quantity generators (<50 tons/year)				5,388			$4,209,086			

for solids and liquids. Wastestreams that are not amenable to pollution prevention or waste minimization either due to the nature of the waste (e.g. remediation and closure) or due to lack of waste description (e.g. unknown) were eliminated from consideration. Remediation and closure wastes are, inherently, one-time wastes whose waste reduction must be addressed through the selection of the remediation technology.

To determine whether a waste minimization opportunity will be adopted, we rely on "payback period" method. From professional experience, pollution prevention and/or waste minimization technologies that have a potential payback period of three years or less are readily implemented by industry. Technologies that have a payback of less than 10 years but more than 3 years usually have a 50 percent implementation rate, and technologies that have a payback of greater than 10 years are normally not be implemented. Implementation of this method relies on several additional assumptions:

- Paybacks are based on capital investment costs divided by savings in combustion costs.
- The cost of combustion is a composite cost for solids combustion ($1,335 per ton) and liquid combustion ($284 per ton) expressed as a solids to liquid ratio in Table A.
- The technologies discussed may be implemented across SIC codes with the degree of sophistication (and cost) varying between SIC codes. The applicability of a technological initiative is expressed as a percentage in Table B through Table I.
- Recovered process water or product is reused in-plant or facility.
- The industry cost savings shown in Tables B through I are based on combustion cost avoidance and do not include the initial capital investment cost for the waste minimization measure.
- The capital investment cost for the waste minimization measure is on a per generator basis and indicates the approximate cost for the technology relative to the quantity of waste generated at the facility (i.e., the size of the waste generator).

In general, the waste minimization opportunities identified here are applicable to both large quantity generators and smaller quantity generators. However, implementation of a technology and/or opportunity by smaller quantity generators will be more heavily dependent on the cost of the technology/opportunity relative to the existing and future cost of waste combustion. For this discussion, a smaller quantity generator is considered to be one that generates 50 tons or less of waste annually. Waste minimization opportunities most applicable to small quantity generators are highlighted in the discussion.

Caveats

Due to the limited information available on the wastestreams, a number of assumptions must be made in order to determine the potentially viable waste minimization technologies. These assumption include inferences of the general wastestream composition, combustion costs, the current state of industry's implementation of waste minimization and pollution prevention, modernization of the industry. Because of the simplifications and assumptions made, this analysis should only be viewed as an approximate assessment of the waste minimization potential that exists for routinely combusted wastes.

WASTE MINIMIZATION OPPORTUNITIES

Source Code S01 - Cleaning, Rinsing, and Degreasing.

Opportunities

The assumption is made that the cleaning, rinsing, and degreasing operations are a combination of solvent/caustic cleaning, including paint stripping; aqueous rinsing; and solvent degreasing, including vapor degreasing. There are numerous waste minimization and pollution prevention opportunities available. These include:

a. Paint stripping

- Alternative non-hazardous chemical paint strippers
- Alternative plastic and agricultural media blasting (i.e. walnut shells)
- Carbon dioxide pellet blasting
- Laser stripping
- Cyrogenic blasting
- Sodium Bicarbonate media blasting
- Paint stripper waste compression and drying
- Chemical paint stripper extraction (vacuum, compression) and reuse
- High pressure water blasting
- Fluidized bed paint stripping

b. Cleaning - Acid, Caustic, Solvent, Aqueous

- Conversion to aqueous detergents
- Carbon dioxide pellet cleaning
- Supercritical carbon dioxide cleaning (semiconductors and optics)
- Cabinet type cleaning systems with aqueous detergents
- Conversion to high pressure, high temperature steam cleaning
- Solvent reclamation
- Cleaning liquor life extension through in-situ filtration and separation of contaminants
- Reclamation/recovery of aqueous detergent process water

c. Rinsing

- Process modification - use of countercurrent rinsing and/or still rinsing
- Use of deionized water
- Reclamation/recovery of rinse waters through filtration/separation/membrane techniques
- Increase drip time to reduce draggout
- Instrumentation to determine rinse water life
- Store and reuse rinse waters for less demanding in-house applications
- Reuse rinse waters as production process water

d. Degreasing

- Conversion to aqueous detergents
- Carbon dioxide pellet degreasing
- Cabinet type degreasing systems with aqueous detergents
- Conversion to high pressure, high temperature steam cleaning/degreasing
- Solvent reclamation
- Degreasing liquor life extension through in-situ filtration and separation of contaminants
- Reclamation/recovery of aqueous detergent process water

Discussion

Non-hazardous paint strippers are approximately twice to three times the cost of hazardous paint strippers and are usually not as aggressive, resulting in lowered production throughput. The non-hazardous paint strippers may be particularly suited for smaller quantity generators who perform hand assisted stripping. The less aggressive characteristics of non-hazardous paint strippers may be compensated for by more frequent application or longer vat residence time followed by more vigorous hand scraping or scoring. If hazardous paints are being removed, then investment in a separation technology to remove paint particles from the stripper, and then to reuse the stripper, and compress/dry the paint sludge may be a cost effective alternative. Separation, compression, and drying technology will vary in cost from $25,000 to $150,000 depending on capacity and specific technology used. In most cases, paybacks will be less than 3 years. The data shown in Table A does not allow determination of the quantity of paint stripper waste nor is it evident from the industry description.

Alternative blast media or fluidized bed paint stripping will vary in cost based on capacity and degree of automation required. The alternative media will normally allow relatively easy separation of paint chips from the media resulting in paint waste reductions of up to 90 percent. Investment costs may be as little as $15,000 for a hand operated carbon dioxide pellet blast system to greater than $500,000 for a fluidized bed system or automated laser system.

There are a multitude of aqueous detergent cleaning systems. Some of these systems are suited for precision cleaning required for optics and semiconductors and entail sophisticated drying systems. Cleaning systems for conventional, non-precision parts cleaning are available from $15,000 to $80,000 depending on capacity and drying requirements. Precision aqueous detergent cleaning systems are two or three times the cost of conventional systems. If hazardous compounds do not contaminate the cleaning liquor, then in most cases, the spent cleaning solution may be discharged to the sanitary sewer. An alternative to discharge, or if the spent cleaning liquor exhibits hazardous properties due to contaminants, is to reclaim the spent liquor and recycle the process water. Reclamation units, using gravity separation, filtration, and/or membrane technology are available from $20,000 to $80,000 and may achieve process water recovery as high as 90 percent. Calculation results presented in Table B show conversion to aqueous cleaning systems may potentially reduce hazardous waste quantities by 4,620 tons for an industry savings of almost $2 million. The conversion to aqueous cleaning systems should be attractive to smaller quantity generators due to their relatively low cost.

For precision cleaning requirements such as optics and semiconductors, carbon dioxide blasting or supercritical carbon dioxide cleaning technologies are available. The systems are usually highly automated and may cost from $25,000 to over $500,000. As shown in Table B, conversion to supercritical carbon dioxide by the semiconductor and photo equipment industries may potentially reduce waste generations by 789 tons for an industry savings of $265,437.

Cleaning liquor baths (acid, caustic, aqueous) may be extended by in-process filtration/recycling systems at relatively minor cost. The cost of in-situ systems will vary from $3,000 or less for simple filter cartridge/gravity separation systems to $40,000 for systems that incorporate membrane technology.

The process modifications to implement countercurrent rinsing can normally be performed with minor plumbing changes and may reduce waste disposal by up to 20 percent. Rinse waters can be reclaimed using the same technology mentioned above for aqueous detergent systems at comparable cost.

The opportunities, the cost to implement the opportunities, and the potential savings for degreasing operations is nearly identical to that for alternative cleaning systems.

The total cost saving potential (Table B) for implementing aqueous detergent cleaning systems and supercritical carbon dioxide precision cleaning systems is approximately $2.2 million by avoiding the generation of 5,400 tons of wastes requiring combustion.

Source Code S02 - Painting and Coatings - Wood Furniture

Opportunities

- Use of non-hazardous paints and coatings
- Conversion to water-base paints and coatings
- Use of high volume, low pressure (HVLP) spray equipment
- Use of airless spray equipment
- Use of dry filter spray booths
- Use of wipe coatings in place of spray coatings
- Use of solventless (carbon dioxide, nitrogen) paint delivery systems
- Recovery/recycle of wet curtain paint booth liquors
- Compression and drying of paint sludge

Table B: Source Code S01 - Cleaning, Rinsing, and Degreasing

Aqueous detergent cleaning systems - non-hazardous wastestream

Industry	Disposal Cost Per Generator	Capital Cost	Years Payback	% Industry Implementation	% Industry Applicability	Industry-wide Wastes (tons)	Waste Reduction (tons)	Composite Disposal Cost/ton	Industry Cost Savings
Industrial Organic Chemicals	$20,622	$15,000	0.73	100	50	908	454	$389	$176,651
Semiconductors	$71,012	$120,000	1.69	100	30	2,318	695	$337	$234,037
Aircraft Manufacturing	$25,029	$45,000	1.80	100	70	679	475	$368	$174,948
Organic Fibers	$119,687	$40,000	0.33	100	50	2,172	1,086	$442	$479,632
Photo Equipment	$50,146	$120,000	2.39	100	40	1,046	418	$337	$140,813
Refuse Disposal*	$112,183	$75,000	0.67	100	90	1,657	1,491	$494	$737,000
Subtotal						8,780	4,620		$1,943,082

* includes $25,000 for process water reclamation

Precision cleaning systems - supercritical carbon dioxide

Semiconductors	$71,012	$300,000	4.22	50	50	2,318	580	$337	$195,031
Photo Equipment	$50,146	$175,000	3.49	50	40	1,046	209	$337	$70,406
Subtotal							789		$265,437
Total						**8,780**	**5,409**		**$2,208,519**

- Purchase paints on an as-needed basis in small quantities to reduce off-spec disposals
- Use of recycling paint gun cleaners
- Improved paint can management (lids tight, stock rotated)

Discussion

The generators in this group are all smaller quantity generators. The opportunities inherent in alternative non-hazardous or water-based paints and coatings as well as more efficient application equipment are particularly suited for smaller quantity generators due to the low investment costs.

The use of non-hazardous paints and coatings as well as water-base paints do not require, in most cases, an initial investment in capital equipment. The non-hazardous and water base paints are competitively priced with their hazardous counterparts. The use of non-hazardous or water-base coating formulations will totally eliminate the wastestream. If 25 percent of the furniture manufactures (Table C) convert to non-hazardous paints or coatings, a reduction of approximately 178 tons of waste with a cost savings of about $100,000 can be achieved.

The cost of high volume, low pressure or airless paint spray equipment is only slightly more expensive than conventional spray equipment. A handheld HVLP spray gun costs approximately $350 versus $200 for a conventional gun. Both the HVLP and airless spray equipment provide significantly improved paint transfer efficiencies (70 percent versus 40 percent) resulting in less overspray and subsequently less generation of paint waste. The cost of converting automated spray equipment is also relatively minor and consists of changing spray heads with some plumbing changes depending on the capacity of the existing plumbing system. The use of HVLP or airless spray equipment will, at a minimum, reduce paint waste by approximately 25 percent, producing an annual industry savings of about $80,000. Payback periods will be less than one year regardless of the specific equipment required.

The potential industry cost savings and waste reductions for implementing both technologies is $180,000 and 300 tons, respectively.

<u>Source Code S05 - Solvent and Product Recovery/Distillation</u>

Opportunities

The waste minimization opportunities are limited for this group of wastestreams as the process in itself is a waste minimization initiative. The primary opportunities that may be implemented include conversion to more efficient recovery/distillation systems and improved process control such as:

- Conversion to vacuum distillation versus pot/atmospheric distillation
- Multi-stage distillation versus single stage
- Conversion to ion specific filtration/exchange media for improved recovery
- Conversion to high efficiency, multi-stage membrane recovery technology

Table C: Source Code S02 - Painting and Coatings

Industry	Disposal Cost Per Generator	Capital Cost	Years Payback	% Industry Implementation	% Industry Applicability	Industry-wide Wastes (tons)	Waste Reduction (tons)	Composite Disposal Cost/ton	Industry Cost Savings
	Non-hazardous paint and coating systems - non-hazardous wastestream								
Wood Furniture	$14,982	$0	0	25	100	711	178	$599	$106,472
	High volume low pressure or airless painting equipment - 25% waste reduction								
Wood Furniture	$14,982	$1,400	0.37	100	100	711	133	$599	$79,817
Total						**711**	**311**		**$186,289**

- Compression, separation, and drying of waste concentrate

Discussion

The industries in the Solvent and Product Recovery/Distillation group are all large quantity generators, with the largest industry being the organic chemical industry. This group has traditionally practiced product recovery/distillation for many years, and, as such, may use equipment that is less efficient than modern state-of-the-art technology. The potential additional costs for combustion disposal may provide an incentive to invest in modern equipment.

The conversion to vacuum distillation from atmospheric distillation normally provides increased efficiency and allows a 15 percent to 25 percent increase in distillate with an attendant decrease in still bottoms. A typical vacuum still costs approximately 50 percent to 100 percent more than an atmospheric still ($25,000 versus $15,000 for a small still). A multi-stage still essentially is a series of stills where the bottoms from one still is the feed to the next stage. The technology is well proven and is cost effective for large solvent users. A multi-stage still varies in cost from $60,000 to $180,000 depending on capacity and degree of automation. The technology can reduce the total still bottoms by 75 percent as compared to a single stage distillation unit. The conversion to vacuum distillation from atmospheric distillation and the conversion to multi-stage distillation may potentially save the industry (Table D) approximately $238 million while reducing waste disposal requirements by 230,000 tons.

The applicability of an alternative recovery technology will vary based on the specific solvent and the composition of contaminants. Filtration and ion exchange-based technology as well as membrane technology have been used by some organic chemical and dye manufacturers successfully.

<u>Source Code S06 - Product Processing</u>

Opportunities

Product processing wastes are generated from product rinsing, filtering, extraction, and forming. They usually consist of virgin product material mixed with a solvent or water as well as product solids. The primary pollution prevention and waste minimization efforts entail recovering product for reuse as well as reusing the rinsewaters to the maximum extent possible. Potential pollution prevention and waste minimization opportunities include:

- Product/rinse water/solids recovery through separation technologies (membrane, centrifuge, compression, filtration) and reuse
- Use of countercurrent and other rinsing technologies
- Storage and reuse of rinsewaters based on product compatibility
- Reuse of product rinsewaters as virgin process water
- Compression and drying of non-recoverable solids
- Use of agricultural sourced raw materials versus petrochemical sourced raw materials

Table D: Source Code S05 - Solvent and Product Recovery/Distillation

Industry	Disposal Cost Per Generator	Capital Cost	Years Payback	% Industry Implementation	% Industry Applicability	Industry-wide Wastes (tons)	Waste Reduction (tons)	Composite Disposal Cost/ton	Industry Cost Savings
Conversion to vacuum distillation - 20% waste reduction									
Industrial Organic Chemicals	$5,892,846	$200,000	0.17	100	20	410.337	16 413	$1,020	$16.736,826
Plastic Materials	$1,291,270	$100,000	0.39	100	25	18,372	919	$1,125	$1,033,241
Organics / Dyes	$3,328,283	$150,000	0.23	100	40	44,378	3,550	$1,125	$3,993,310
Pesticides	$1,300,004	$100,000	0.38	100	30	7,396	444	$1,230	$545,780
Business Services	$1,564,433	$125,000	0.40	100	50	7,629	763	$1,230	$938,291
Subtotal						488,112	22,089		$23,247,448
Conversion to multi-stage distillation - 75% waste reduction									
Industrial Organic Chemicals	$5,892,846	$540,000	0.12	100	60	410,337	184,652	$1,020	$188,289,288
Plastic Materials	$1,291,270	$180,000	0.19	100	50	18,372	6,890	$1,125	$7,749,310
Organics / Dyes	$3,328,283	$360,000	0.14	100	40	44,378	13,313	$1,125	$14,974,912
Pesticides	$1,300,004	$180,000	0.18	100	30	7,396	1,664	$1,230	$2,046,677
Business Services	$1,564,433	$180,000	0.15	100	30	7,629	1,717	$1,230	$2,111,154
Subtotal							208,235		$215,171,340
Total						**488,112**	**230,324**		**$238,418,788**

Discussion

The industries in the Product Processing group are all large quantity generators (greater than 50 tons per year of waste) as defined in this study.

The product recovery technologies are similar to the aqueous detergent recovery systems mentioned above but usually are more costly depending on the product being recovered. Typically a system entailing a combination of gravity settling, various stages of filtration, and membrane technology will cost from $80,000 to $300,000 depending on capacity and degree of automation. Normally, a recovery system will achieve 75 percent or higher product recovery.[1] As shown in Table E, significant combustion waste reductions and cost savings can be potentially achieved by implementing product recovery technologies. The industry wide potential savings and waste reductions may be greater than $110 million while reducing combustible waste disposal amounts by over 187,000 tons.

Compression technologies, such as pressure filters, and drying systems such as evaporators are effective means to reduce the volume of sludge being disposed. The filtrate may be reclaimed or directly reused depending on process requirements. The cost of compression and drying technologies vary significantly based on the type and composition of product.

Source Code S07 - Process Waste Removal and Cleaning

Opportunities

The wastes generated from process waste removal and cleaning usually are comprised of product and intermediates mixed with solid contaminants and water or solvent depending on the cleaning media. For multi-product process lines, the waste is generally virgin product that must be removed prior to product change-over. Pollution prevention and waste minimization opportunities include:

- Product/rinse water/solids recovery through separation technologies (membrane, centrifuge, compression, filtration, dialysis, ion exchange) and reuse
- Distillation or evaporation of solvent/water from waste product and reuse of product
- Improved process control through automation to reduce waste generation
- Improved product management or schedule to reduce change-over
- Reformulation of spent process materials into useful by-products

[1] Note that we implicitly assume that the wastestream managed by the recovery system is primarily product that can be reused, thereby allowing large (75 percent) reductions in waste quantity. In contrast, if the waste generated in product processing is primarily low concentration aqueous waste, product recovery may be high, but the tonnage reduction for the overall wastestream will be more limited. Because we have not factored in the form of the waste, it is likely that we overstate tonnage reductions.

Table E: Source Code S06 - Product Processing

Recovery systems - engineered for process - 75% waste reduction

Industry	Disposal Cost Per Generator	Capital Cost	Years Payback	% Industry Implementation	% Industry Applicability	Industry-wide Wastes (tons)	Waste Reduction (tons)	Composite Disposal Cost/ton	Industry Cost Savings
Industrial Organic Chemicals	$1,618,110	$550,000	0.45	100	80	175,479	105,287	$599	$63,098,739
Plastic Materials	$311,345	$250,000	1.07	100	60	14,146	6,366	$704	$4,483,999
Medicinal Chemistry	$2,259,482	$800,000	0.47	100	40	77,721	23,316	$494	$11,522,915
Pesticides	$2,134,707	$600,000	0.37	100	80	56,991	34,195	$599	$20,492,824
Pharmaceutical	$791,675	$750,000	1.26	100	40	17,179	5,154	$599	$3,088,612
Miscellaneous Chemicals	$34,759	$80,000	3.07	100	50	584	219	$599	$131,247
Photo Equipment	$1,043,216	$300,000	0.38	100	70	13,331	6,999	$704	$4,929,937
Organics / Dyes	$789,877	$350,000	0.59	100	80	10,546	6,328	$599	$3,792,131
Total						**365,977**	**187,863**		**$111,540,404**

Discussion

The industries in the Process Waste Removal and Cleaning group are all large quantity generators (greater than 50 tons per year of waste) as defined for this discussion.

The technologies and associated costs for pollution prevention and waste minimization are similar to that of the Product Processing Group (S06), however, product recovery is usually much less due to larger concentrations of contaminants. Recovery is typically 50 percent with the exception of process water. Process water recovery may be as high as 80 percent. Even using a conservative waste reduction estimate of 50 percent, the waste reduction and cost savings are still significant when considering the industries as a whole. In accordance with Table F, the cost savings is approximately $88 million with a waste reduction of approximately 122,000 tons.

Source Code S08 - Waste and Spent Material Removal

Opportunities

The wastes generated from this group include process and storage tank sludges, vat scrapings, and filter/screening solids. Pollution prevention and waste minimization initiatives are similar to group S07 and include:

- Product/solids recovery through separation technologies (membrane, centrifuge, compression, filtration, dialysis, ion exchange) and reuse
- Distillation or evaporation of solvent/water from waste product and reuse of product
- Improved process control through automation to reduce waste generation
- Improved mixing technologies to reduce in-tank deposition
- Reformulation of spent materials into useful by-products

Discussion

The discussion is essentially the same as for S07. The Plastic Materials industry is a smaller quantity generator as defined for this discussion with an average waste generation of 30 tons per year. Due to the large variety of plastics produced by any one manufacturer combined with the many types and high viscosity of the resins, catalysts, and other virgin products used in plastics manufacturing, the cost of recovering usable product from the wastes would be prohibitive for smaller quantity generators. As shown in Table G, the potential cost savings and waste reduction for the industries in Source Code S08 is less than $7 million and 7,000 tons, respectively.

Source Code S09 - Laboratory Operations

Due to the small quantities of wastes per sample and the potential human safety and health hazards involved with physical and biological research operations, pollution prevention and waste minimization opportunities can only be determined on a case-by-case basis and then

Table F: Source Code S07 - Process Waste Removal and Cleaning

Recovery systems - engineered for process - 50% waste reduction

Industry	Disposal Cost Per Generator	Capital Cost	Years Payback	% Industry Implementation	% Industry Applicability	Industry-wide Wastes (tons)	Waste Reduction (tons)	Composite Disposal Cost/ton	Industry Cost Savings
Industrial Organic Chemicals	$1,361,605	$450,000	0.66	100	60	129,487	38,846	$704	$27,363,193
Plastic Materials	$1,690,236	$300,000	0.35	100	50	68,913	17,228	$810	$13,946,268
Paints and Varnishes	$91,474	$120,000	2.62	100	60	2,493	748	$810	$605,425
Pesticides	$8,245,706	$750,000	0.18	100	40	210,701	42,140	$704	$29,683,557
Pharmaceutical	$3,839,684	$600,000	0.31	100	30	92,662	13,899	$704	$9,790,667
Petroleum Refining	$43,713	$160,000	7.32	50	80	805	161	$810	$130,330
Miscellaneous Chemicals	$302,188	$140,000	0.93	100	50	6,003	1,501	$704	$1,057,128
Photo Equipment	$127,129	$180,000	2.83	100	70	1,950	683	$915	$624,215
Inorganic Chemicals	$1,361,579	$400,000	0.59	100	50	18,501	4,625	$810	$3,744,140
Medicinal Chemistry	$470,539	$750,000	3.19	100	30	7,348	1,102	$704	$776,390
Organics / Dyes	$190,233	$120,000	1.26	100	70	1,878	657	$810	$532,084
Plastic Production	$83,615	$250,000	5.98	50	50	575	72	$1,020	$73,291
Electrical Power	$204,804	$180,000	1.76	100	30	1,771	266	$810	$215,044
Adhesives / Sealants	$321,025	$360,000	2.24	100	20	2,105	211	$915	$192,523
Physical / Biological Research	$209,213	$0	0.00	0	0	1,118	0	$1,125	$0
Total						**546,310**	**122,139**		**$88,734,254**

Table G: Source Code S08 - Waste and Spent Material Removal

Recovery systems - engineered for process - 40% waste reduction

Industry	Disposal Cost Per Generator	Capital Cost	Years Payback	% Industry Implementation	% Industry Applicability	Industry-wide Wastes (tons)	Waste Reduction (tons)	Composite Disposal Cost/ton	Industry Cost Savings
Electrical Power	$106,854	$210,000	4.91	50	20	4,998	200	$810	$161,835
Industrial Organic Chemicals	$140,880	$180,000	3.19	50	80	6,208	993	$704	$699,666
Petroleum Bulk Stations	$38,742	$120,000	7.74	50	90	997	179	$704	$126,412
Plastic Materials	$24,285	$140,000	14.41	0	60	514	0	$810	$0
Petroleum Refining	$179,622	$160,000	2.23	100	90	3,570	1,285	$704	$905,295
Inorganic Chemicals	$113,330	$180,000	3.97	50	80	979	157	$810	$126,800
Refuse Disposal	$2,753,510	$600,000	0.54	100	70	14,690	4,113	$1,125	$4,626,527
Total						**31,956**	**6,928**		**$6,646,536**

only with extensive knowledge of the wastestream.

Source Code S10 - Discarding and Decommissioning

Opportunities

The wastes generated from discarding and decommissioning mainly includes off-spec materials, expired shelf-life products, and may include disposed equipment contaminated with hazardous products. The primary pollution prevention and waste minimization opportunities include:

- Improved process control through automation to prevent off-spec material production
- Improved process/procedural training to prevent off-spec material production
- Improved quality control
- Testing of expired shelf-life materials to determine life extension
- Reuse/recycling of off-spec and expired shelf-life material back to the process
- Reuse of off-spec and expired shelf-life material for less exacting requirements
- Improved inventory control to prevent shelf-life expiration
- Decontaminate equipment (thermal, aqueous, solvent decontamination)

Discussion

The opportunities available for this group can, in most cases, be implemented at no cost to minimal cost and as such are attractive to smaller quantity generators. Historically, improved quality control and training within the chemical, pesticide, and paint manufacturing industries will reduce the production of off-spec materials by approximately 30 percent and in some cases where automation is minimal, up to 50 percent. Manufactured chemicals and compounds that have a shelf-life are traditionally discarded as soon as the shelf-life expires. In many cases, the shelf-life is merely a manufacturer's estimate and is not inviolate. The compounds may be tested based on manufacturer's specifications for suitability and the shelf-life extended for a given period (followed by additional testing for suitability). If the compound has deteriorated, it may still be possible to use it for a lesser requirement. In general, through a combination of shelf-life extensions and lesser uses up to 40 percent of the discarded compounds could be reused in-house. Using a combined waste reduction potential of 50 percent for improved quality control/training, shelf-life extension, and reuse for lesser purposes or return to the manufacturing process, an industry wide potential savings and waste reduction (Table H) of approximately $2 million and 3,000 tons, respectively, may be achieved. The two smaller quantity generators (miscellaneous chemicals, and paints and varnishes industries), may potentially save a total of $270,000 while reducing combustion wastes by 413 tons.

Decontaminating equipment are available from $10,000 to $100,000 depending on technology and capacity. If aqueous or solvent decontamination procedures are used, the waste stream may be recovered using the technologies indicated in the S01 and S05 groups.

Table H: Source Code S10 - Discarding and Decommissioning

Improved quality control/training, shelf-life extension, and reuse - 50% combined reduction

Industry	Disposal Cost Per Generator	Capital Cost	Years Payback	% Industry Implementation	% Industry Applicability	Industry-wide Wastes (tons)	Waste Reduction (tons)	Composite Disposal Cost/ton	Industry Cost Savings
Industrial Organic Chemicals	$41,352	$0	0	100	70	3,637	1,273	$599	$762,879
Miscellaneous Chemicals	$15,582	$0	0	100	50	670	168	$599	$100,383
Plastic Materials	$50,189	$0	0	100	60	1,431	429	$810	$347,518
Pesticides	$81,710	$0	0	100	50	2,434	609	$704	$428,627
Paints and Varnishes	$33,107	$0	0	100	70	699	245	$704	$172,331
Photo Equipment	$44,523	$0	0	100	30	824	124	$810	$100,054
Warehouse	$38,038	$0	0	100	30	591	89	$704	$62,445
Total						**10,286**	**2,935**		**$1,974,238**

Source Code S11 - Routine Spill & Leak Collection

Opportunities

The waste generated from spill and leak collection most likely originates from leaking and/or broken storage tanks, process vats, piping, storage drums, and pipe connections. Usually the spilled or leaking product is contaminated with dirt and soil, and depending on the method of spill recovery may be contaminated with granular absorbent, water or other chemicals, and/or maybe absorbed in granular material or absorbent blankets. The primary pollution prevention and waste minimization opportunities include:

- Improved plant/operational maintenance to prevent leaks/spills
- Personnel training for spill prevention and control
- Automate plant/process control and leak/spill detection to detect and isolate leaks and spills
- Recover/reuse spilled/leaked material by separation technologies (membrane, centrifuge, compression, filtration, dialysis, ion exchange)

Discussion

Recovery technologies and costs for spills and leaks are similar to that of Product Processing group S06. The cost to automate a plant will vary greatly based on existing automation and software requirements and can only be determined on a plant specific basis. The Industrial Organic Chemicals classification is the only smaller quantity generator. Since the potential for spills and leaks is possibly the highest for this industry due to the storage tank and piping requirements, the fact that this industry indicates a relatively low spill and leakage rate could be attributed to a higher level of maintenance, process control, and automation than for the other industries in this group. Estimates of waste reduction and costs would only be possible on a plant/process specific basis.

Source Code S12 - Remediation and Closure

Remediation and closure wastes are not conducive to pollution prevention and waste minimization except in very specific cases. The appropriate manner to reduce remediation and closure wastes is through the selection of the remediation technology.

Source Code S13 - Pollution Control & Wastewater Treatment

Opportunities

In general, pollution prevention and waste minimization opportunities are limited for pollution control and wastewater treatment wastes. Normally, the best opportunities occur upstream of the control or treatment system or within the process generating the wastestream. However, limited opportunities may include:

- Extraction of valuable compounds/materials from treatment plant sludges
- For single process pollution control devices (rather than centralized treatment), recovery of waste material and reuse within the process (i.e. baghouse solids) or recovery prior to process change-over
- Recovery and reuse of petroleum refinery tank bottoms/oil separator petroleum through centrifuge and membrane technologies
- Implementing state-of-the-art control and treatment technologies that reduce waste generation
- Improved waste treatment process control through automation

Discussion

The large variety of wastestreams and different composition of the wastestreams preclude any estimation of costs and waste reductions with the exception of that indicated in Table I. Tank bottoms as well as oil-water separator petroleum products from the oil refinery industry may be successfully recovered using centrifuge and/or membrane technology. Approximately 90 percent of product may be recovered at a cost of $250,000 to $500,000 depending on capacity. The chemical industries and plastic material industries may have valuable compounds and materials that are cost effective to recover from treatment plant sludges/wastestreams. Based on Table I, a potential cost savings of approximately $69 million and a waste reduction of over 70,000 tons may be achieved. There are no smaller quantity generators in this source code group.

Source Code S14 - Unknown

Due to the lack of information on the general nature of unknown wastestreams, pollution prevention and/or waste minimization opportunities cannot be determined.

CONCLUSIONS

Implementing waste minimization techniques and technologies in lieu of disposal by combustion may significantly reduce the generation of wastes requiring combustion. For all industries in Source Codes S01 through S13 indicated in this analysis, the total waste combustion quantity is 1.8 million tons. By implementing the initiatives shown in Tables B through I, a total waste reduction of approximately 600,000 tons or 33 percent may be achieved. The smaller quantity generators (i.e. those disposing of less than 50 tons of combustion wastes per year) disposed of about 5,400 tons of combustible waste. The smaller quantity generators may potentially achieve a reduction of 720 tons or 13 percent.

This analysis is subject to several key caveats that will likely mitigate waste minimization potential.

Table I: Source Code S13 - Pollution Control and Wastewater Treatment

Recovery and reuse of waste products

Industry	Disposal Cost Per Generator	Capital Cost	Years Payback	% Industry Implementation	% Industry Applicability	Industry-wide Wastes (tons)	Waste Reduction (tons)	Composite Disposal Cost/ton	Industry Cost Savings
Petroleum Refining	$3,904 427	$350,000	0.09	100	30	179,285	53,786	$915	$49,192,218
Refuse Disposal	$542,386					12,345		$1,230	
Industrial Organic Chemicals	$4,580,492	$250,000	0.05	100	20	80,860	16,172	$1,020	$16,490,588
Environmental Administration	$199,244					1,785		$1,230	
Unclassified	$129,495					1,066		$1,335	
Plastic Materials	$589,122	$300,000	0.51	100	20	3,833	767	$1,230	$942,841
Pesticides	$271,240					1,862		$1,020	
Miscellaneous Chemicals	$2,807,234	$400,000	0.14	100	10	19,271	1,927	$1,020	$1,965,064
National Security	$450,143					2,560		$1,230	
Total						**302,867**	**72,651**		**$68,590,712**

- First, as with our investigation of waste management alternatives, a number of technologies appear to have costs low enough that one would expect them to already be implemented. We have not evaluated, however, the total costs associated with the waste minimization measures. For a waste minimization measure to truly be cost effective, the total per ton cost of reducing the waste must be less than the cost per ton of combustion. The payback method of identifying waste minimization options relies on simplified capital cost information that may understate the total costs by not incorporating operating costs associated with the option. Therefore, the method may overstate the degree of waste minimization potential that exists.

- Second, a variety of obstacles could impede the adoption of waste minimization, including lack of information and lack of capital for new investments (for smaller generators).

- Finally, we should reiterate that the analysis considers wastes characterized at a very general level -- BRS source code and industry. At a greater level of detail, there may be characteristics of any given wastestream that preclude use of the waste minimization measure identified in the analysis.

These caveats suggest that the specific figures for tonnage reduction presented here may be overstated. Nonetheless, this analysis still broadly demonstrates that a significant portion of combusted waste potentially could be subject to waste minimization. This is especially likely given that increased combustion costs caused by the MACT standards (and other regulatory changes) may lead to combustion price increases. This may give generators an increased incentive to pursue at least a portion of the waste minimization opportunities identified in this analysis.

NOTE TO ELECTRONIC FILE USERS:

APPENDIX CONTINUES ON SEPARATE FILES. SEE NOTE ON PAGE 1.