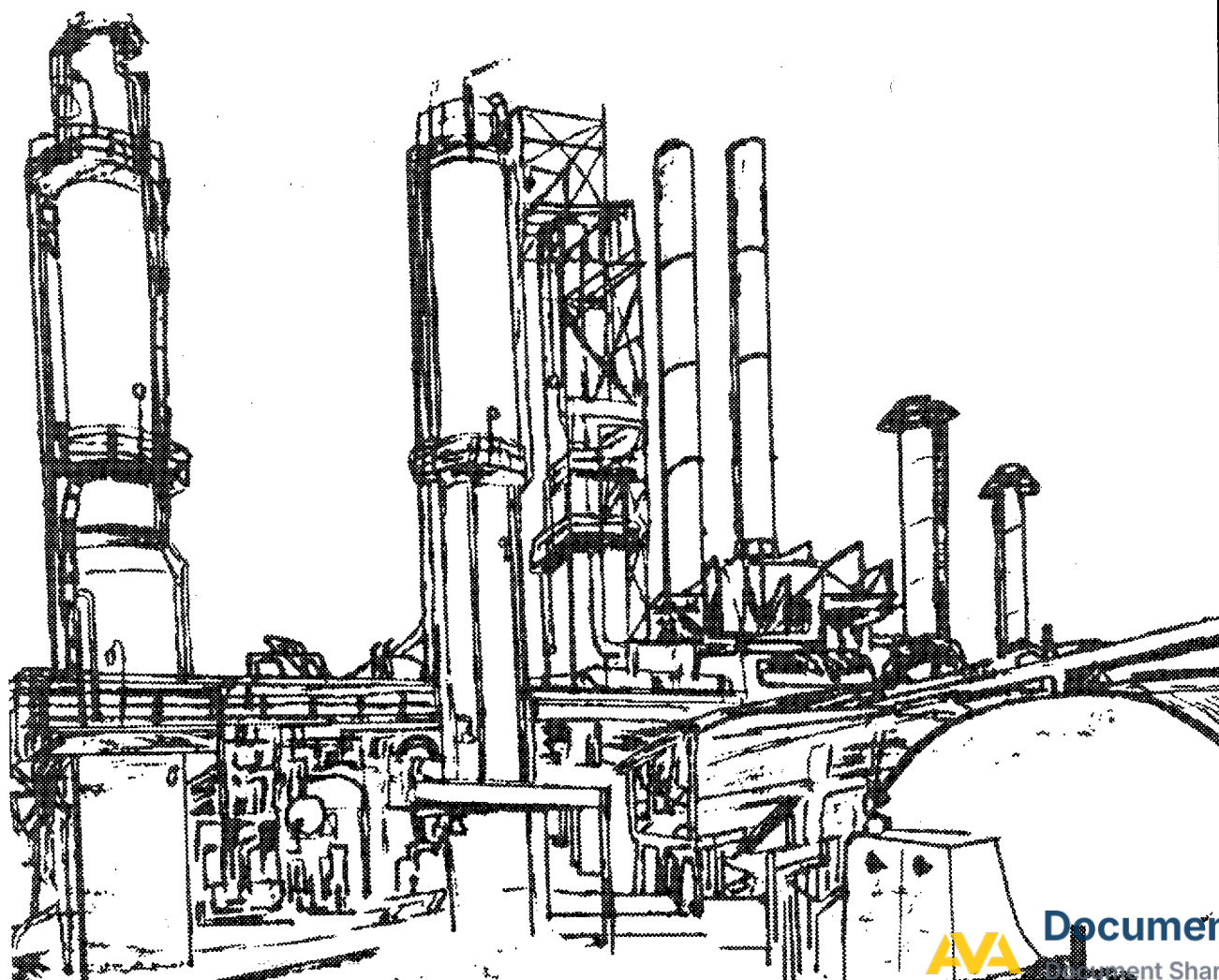


Management of Residual Materials: 1994

Petroleum Refining Performance

Health and Environmental Affairs Department
Publication Number 336
September 1996





One of the most significant long-term trends affecting the future vitality of the petroleum industry is the public's concerns about the environment. Recognizing this trend, API member companies have developed a positive, forward-looking strategy called STEP: Strategies for Today's Environmental Partnership. This program aims to address public concerns by improving our industry's environmental, health and safety performance; documenting performance improvements; and communicating them to the public. The foundation of STEP is the API Environmental Mission and Guiding Environmental Principles.

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The members of the American Petroleum Institute are dedicated to continuous efforts to improve the compatibility of our operations with the environment while economically developing energy resources and supplying high quality products and services to consumers. The members recognize the importance of efficiently meeting society's needs and our responsibility to work with the public, the government, and others to develop and to use natural resources in an environmentally sound manner while protecting the health and safety of our employees and the public. To meet these responsibilities, API members pledge to manage our businesses according to these principles:

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- ❖ To operate our plants and facilities, and to handle our raw materials and products in a manner that protects the environment, and the safety and health of our employees and the public.
- ❖ To make safety, health and environmental considerations a priority in our planning, and our development of new products and processes.
- ❖ To advise promptly, appropriate officials, employees, customers and the public of information on significant industry-related safety, health and environmental hazards, and to recommend protective measures.
- ❖ To counsel customers, transporters and others in the safe use, transportation and disposal of our raw materials, products and waste materials.
- ❖ To economically develop and produce natural resources and to conserve those resources by using energy efficiently.
- ❖ To extend knowledge by conducting or supporting research on the safety, health and environmental effects of our raw materials, products, processes and waste materials.
- ❖ To commit to reduce overall emission and waste generation.
- ❖ To work with others to resolve problems created by handling and disposal of hazardous substances from our operations.
- To participate with government and others in creating responsible laws, regulations and standards to safeguard the community, workplace and environment.
- ❖ To promote these principles and practices by sharing experiences and offering assistance to others who produce, handle, use, transport or dispose of similar raw materials, petroleum products and wastes.

Management of Residual Materials: 1994

Petroleum Refining Performance

Health and Environmental Affairs Department

API PUBLICATION NUMBER 336

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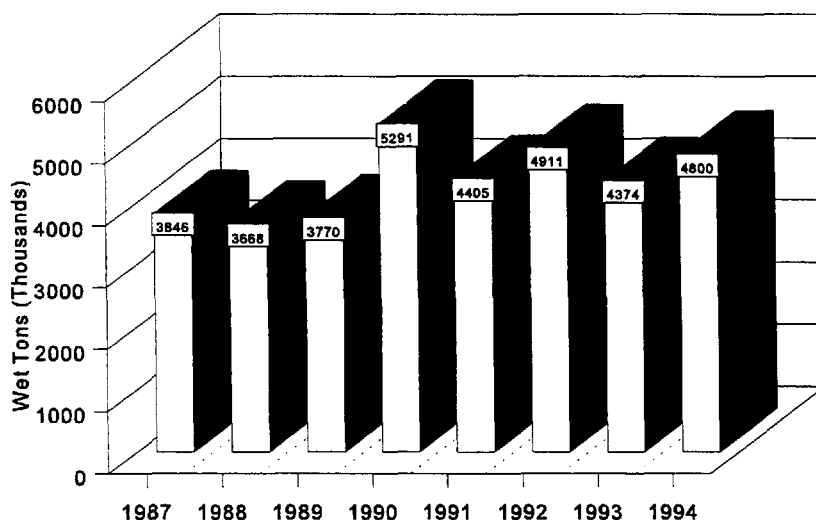
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EXECUTIVE SUMMARY

The petroleum refining industry managed 4.8 million wet tons of 15 key residual materials in 1994. This was comparable to the quantity for these streams reported in 1992, and is somewhat less than the high observed in 1990. A peak in the Primary Sludge residual stream (associated with the regulatory deadlines to close or retrofit surface impoundments) and an increase in Hydroprocessing Catalysts overwhelmed the reductions observed for Pond Sediments and Contaminated Soils, and contribute to making this last cycle the third largest documented by the American Petroleum Institute's (API) annual refining survey.

Summary of Residual Generation: 1987 - 1994 (represents 15 residual streams¹)



Regarding the management of these streams, treatment continues to account for slightly more than 30 percent of the residuals. Since 1992, however, more material has been recycled than treated. Use of land treatment has diminished substantially and disposal, which peaked between 1990 and 1991, has stabilized at a low level comparable to that observed in 1989.

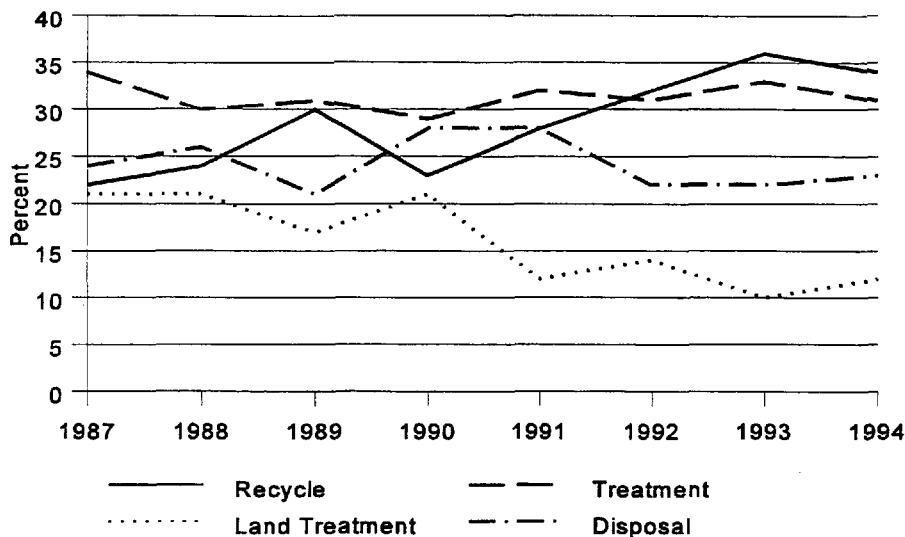
These findings were based on the data from 15 residual streams that were included in API's refining survey. API substantially reduced the number of streams included in its 1994 survey in order to curtail the burden associated with participating in the study. The streams selected for continued study include the most closely regulated residuals and other high volume streams that are generated by the majority of refineries. The 15 streams represent approximately 80 percent of all residuals generated and are the most costly streams to manage. Refiners responded positively to these changes, reporting that the new, abbreviated forms were much easier to complete. This was reflected in the response rate for the study, which continued to represent more than 60 percent of the domestic refining capacity.

Other modifications of the survey questionnaire were undertaken to improve the utility of the data. For example, the spent caustic stream was broken out to differentiate the three types of caustics: sulfidic,

¹ API's Petroleum Industry Environmental Performance (PIEP) report (API, 1996) lists 13 residuals. The numbers are comparable, however, since the PIEP report treated three caustic streams as one stream. These streams represent approximately 80% of all residuals generated.

naphthenic and cresylic. This enabled a better comparison between Environmental Protection Agency's (EPA) and API's findings on the management of these materials. As noted in the report, both groups found that a substantial portion of the spent caustics are reclaimed, used as commercial feedstock, or reused as secondary materials in other manufacturing processes.

Trends in Management Practices



Other revisions included new questions on wastewater treatment systems and discharges and the inclusion of questions on the management costs for several of the streams. This information should expand the utility of the survey findings, enabling multi-media tracking of industry progress and practical experience with cost accounting strategies. A series of scatter plot charts summarizing the cost data are included following the discussions of API separator sludge, hydroprocessing catalysts, and spent sulfidic caustic.

INTRODUCTION

For 1994, the American Petroleum Institute (API) substantially revised its annual refining survey. The scope of the survey was expanded from the single media (waste/residual) approach by the inclusion of new questions on wastewater treatment systems and discharges. A series of questions on the management costs for select residual streams was added to the basic survey items on generation quantities and handling practices. To reduce the burden associated with completing the survey, API limited the number of residual streams included in the survey. Using criteria that included regulatory status, quantity generated, and the magnitude of management costs, the number of streams included in the 1994 survey was reduced from 30 to 15. Data reported in the Executive Summary represents only the 15 streams surveyed for years 1987-1994.

These changes reflect API's ongoing critical review of the survey effort and its commitment to implement modifications that will improve the quality and utility of data collected. The reductions in the scope of the survey were born of necessity. Given the overarching economic considerations directing the streamlining of American industries in the 1990s, refiners view voluntary efforts critically. An important factor in their decision to participate in such efforts is the "value added" to their operations from participation in an external effort.

The *additions* to the 1994 survey are API's attempt to increase the value of the survey. The inclusion of information on capital improvements to the wastewater system and on management costs will be used to create benchmarks that refiners can use to evaluate their performance and the efficiency of their operations. The inclusion of these questions also reflects API's desire to keep abreast of current environmental performance monitoring trends: multi-media tracking systems and mechanisms to support total cost accounting.

The changes in the scope of the survey also have ramifications on the public reporting of the industry-wide *estimates*. Whereas the survey previously summarized *all* residuals generated by the industry, the 1994 effort provides a profile of *some* of the residuals. Accordingly, the format used in this report focuses on specific streams, in a section-by-section basis. The waste management hierarchy--which recognizes that prevention of waste by source reduction activities and recycling is preferred to treatment and disposal of wastes--has been retained, but is used now to structure the reporting on each of the residual streams.

Despite these changes, the procedures used to collect and analyze the data have remained consistent over time. The next chapter of this report will describe these methods.

METHODOLOGY

The listing of refineries published by the Department of Energy as *The Petroleum Supply Annual for 1994* was used to identify the census of 159 operating refineries. The revised questionnaires were mailed out in April, 1994 with instructions to return the completed forms within six weeks. This submission deadline was extended 10 additional weeks to maximize the response rate. As in all previous surveys, contact was maintained with all refineries during the field administration, with follow-up calls placed to refineries to encourage participation and through a "HELP-line" staffed by a refining expert.

The sections that follow describe the revisions to the data collection forms and the estimation procedures used in the study.

Data Collection Forms

The two-section format was retained for the survey questionnaire. The first section was comprised of 12 short-answer questions that obtained information on refinery characteristics such as age, size, complexity of processing, sulfur content in the crude slate, sewer and wastewater treatment system configurations, and effluent characteristics.

The major revisions to the questionnaire focused on its second section, wherein data are collected on specific residual streams. As noted previously, the number of residual streams was reduced from 30 to the 15 streams listed below¹:

API Separator Sludge
DAF Float
Slop Oil Emulsion Solids
Primary Sludge (F037)
Primary Sludge (F038)
Tank Bottoms
Pond Sediments
Contaminated Soils
Biomass
FCCU Catalyst or Equivalent
Hydroprocessing Catalysts
Other Spent Catalysts
Spent Sulfidic Caustic
Spent Naphthenic Caustic
Spent Cresylic Caustic

These streams actually correspond to 14 of the residuals used in previous surveys, because Tank Bottoms includes both Unleaded and Leaded Tank Bottoms, while the three Spent Caustic streams had previously been amalgamated into one Spent Caustic category.

To further minimize the effort required to complete the forms, the data sheets were streamlined. In the past, empirical data were collected on the amount of residual *generated* and the total amount that was *managed* in a given year. Because the industry had substantially reduced its use of additives to facilitate subsequent handling, and movement of residual material in and out of storage was extremely small, it was decided to drop the questions on generated quantities and the adjustments made for treatment additives and storage. This eliminated four items from the data sheet.

¹ The streams on which data were not collected in 1994 were: Waste Oils/Spent Solvents; Other Oily Sludges & Organic Wastes NOS; Heat Exchanger Bundle Cleaning Sludge; Waste Coke/Carbon/Charcoal; Waste Sulfur; Other Contaminated Soils; Oil Contaminated Waters (Not Wastewater); High pH/Low pH Waters; Spent Sulfite Solution; Spent Stretford Solution; Other Aqueous Wastes; TSD Leachate (F039); Spent Acids; Waste Amines; Other Inorganic Wastes; and Other Wastes. These residual streams were reported by fewer respondents and in smaller quantities than those streams retained for investigation in the 1994 survey. The 15 streams included in the survey represent about 80% of all residuals generated.

The data sheets were also precoded to further reduce the respondent burden. The responses to the 1992 and 1993 questionnaires were reviewed to identify the most common recycle, treatment and disposal methods used for each residual stream. These methods were then used to customize and precode the data sheet for each stream, obviating the need to look up management techniques and transcribe the associated numeric codes. Spaces were provided for respondents to designate "other" handling techniques, in addition to those preprinted on the forms.

The question on pollution prevention activities previously included on each data sheet was moved to the first section of the questionnaire with the other short answer questions. This placement of the question gave recognition to the importance of the *descriptive* information obtained on innovative pollution prevention activities.

These changes to the data sheet enabled a substantial reformatting of the form to further increase the ease of completion.

As noted previously, new items were developed to obtain information on the costs associated with handling residual materials. In an effort to limit the burden of these new questions, while gaining experience with the cost data elements, the questions were placed on only three data sheets: API Separator Sludge, Hydroprocessing Catalysts and Spent Sulfidic Caustics. Two cost questions were asked. The first was directed at on-site management costs. Respondents were asked to indicate the total expenditures as well as the factors included in the estimates (e.g., capitalization of costs, operating expenses or contractual costs). The second question focused on off-site management costs, requesting a break-out that included recycling, treatment, disposal, analytical, transportation, and tax costs. Here respondents were asked to designate the basis of their response, either actual costs/receipts, estimates or rough estimates.

A copy of the questionnaire illustrating these revisions is presented in Appendix A.

Data Analysis

For the 1994 survey cycle, all data handling and analysis procedures were performed on a PC platform. This necessitated rewriting the statistical programs (which had previously been performed on a mainframe computer using the SAS programs), but even with this reprogramming, the overall data management costs were reduced by the reliance on PCs.

As in the past, the data verification and estimation procedures included automated consistency checks for the variables on each data sheet, as well as final range checks across respondents and comparisons with the data previously submitted by the respective refinery. In all cases, any questionable data were verified by direct contact with the facilities to ensure their accuracy.

A detailed description of the estimation procedures is presented in Appendix B. As discussed, preliminary analyses were performed with data sets from previous survey cycles to ascertain if the reduction in the number of residual streams and collection of data on the "managed" quantities (as opposed to "generated" quantities) would affect the use of regression analysis to create industry-wide estimates. Because very little change was noticed in the overall pattern of the abbreviated data set as compared to the scattergram containing all residuals, it was concluded that the 1994 survey would not require a new regression model.

The general linear regression model used relates the square root of the residual quantity, R , for an individual refinery directly to throughput capacity, C , as shown in the following equation:

$$\sqrt{R} = b_o + b_1 C$$

where b_o is the intercept and b_1 is the slope of the regression line.

The specific regression equation developed for the 1994 data is:

$$\sqrt{R} = 46.284 + 8.9652 \times 10^{-4} C$$

with a coefficient of determination (COD), r^2 , of 0.59. This COD is similar to values obtained in previous surveys. (It should be understood that this equation is used to develop an estimate for the *group* of refineries that did not participate in the survey. It is not intended for use with an individual refinery.)

As described in Appendix B, procedures similar to those used previously were developed to create a bias correction factor for the estimate and to calculate its variance and the percent error. The percent error for the 1994 estimate, 5.44 percent, was similar to that for previous survey cycles.

RESULTS

Response Rate

Of the 159 operating refineries in 1994, 84 (53 percent) completed and returned the survey forms. These refineries represented 64 percent of the domestic crude oil refining capacity.

Participation of refineries in the largest capacity classes was quite high, with more than half of all operating refineries greater than 10,000 barrel per stream day (bsd) responding. Also, as noted in the discussion of the estimation procedures, the six largest refineries all participated in the survey.

Respondent Characteristics

The location of the participating refineries is illustrated in Figure 2. The largest concentration of participating refineries was in the U.S. Department of Energy's Petroleum Administration for Defense (PAD) III, the Texas/Louisiana region. With 33 refineries, this was one more facility than responded in the last survey cycle. The number of refineries participating in PADs I, II, and IV were similar to those previously reported (11, 18 and 8, respectively). In contrast, the 14 refineries responding from PAD V represent a substantial drop in participation from the California region.

Figure 1. Number of Respondents by Capacity Group

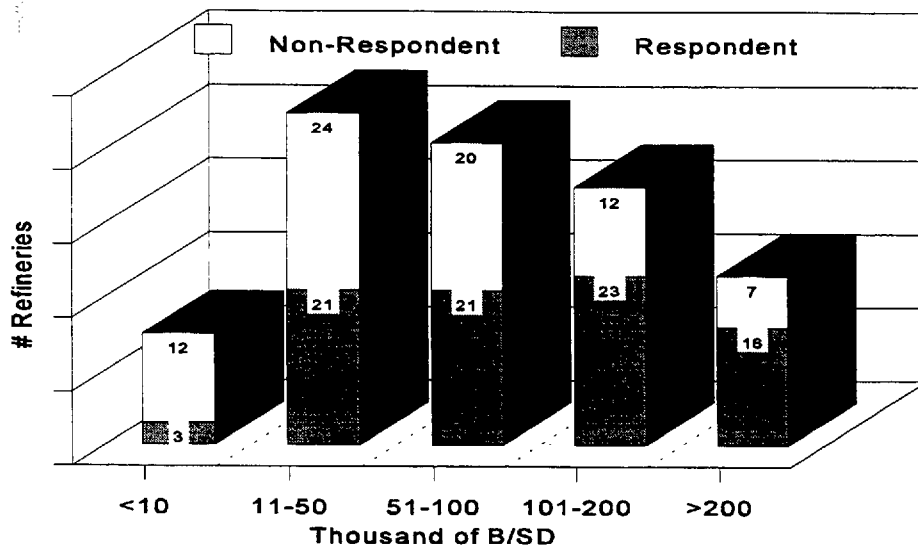
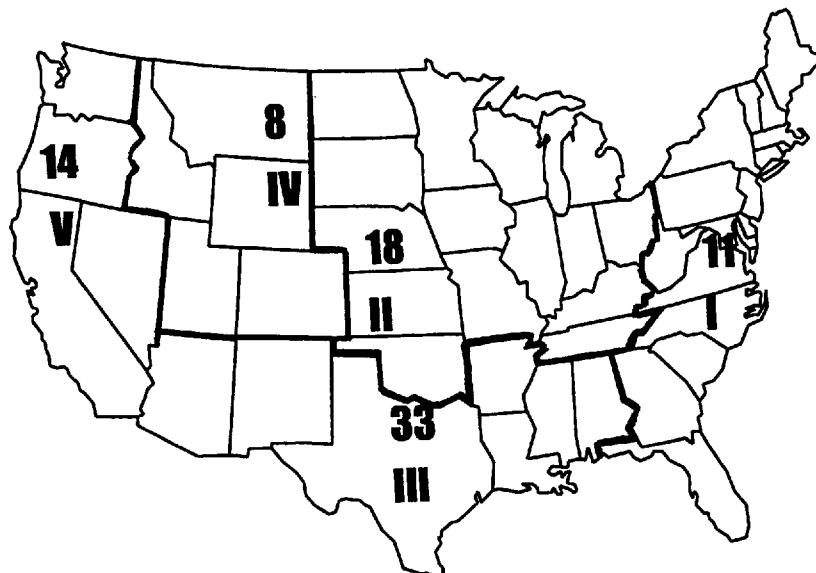
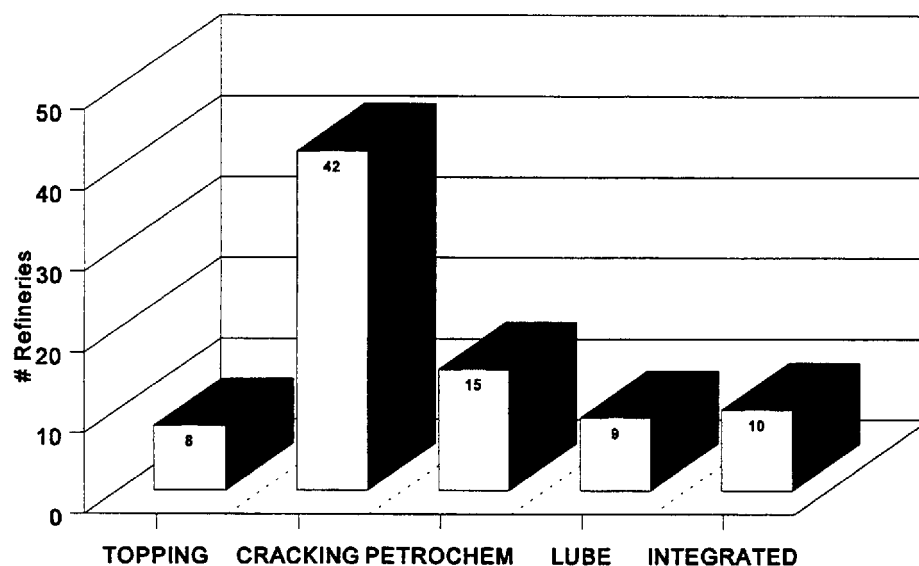


Figure 2. Location of Participating Refineries



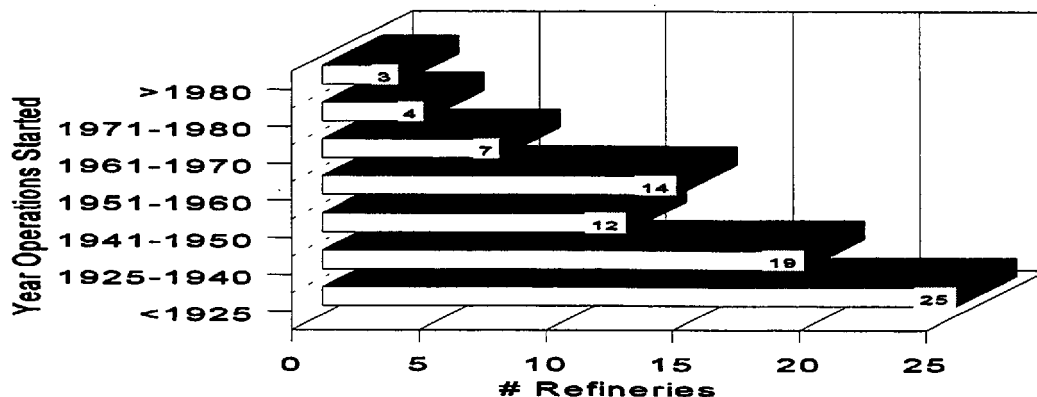
API uses the National Pollution Discharge Elimination System (NPDES) permit classifications to categorize the complexity of refineries (See Question 4 in Appendix A). The simplest form of crude processing is performed at facilities that exclusively rely on "Topping" operations, while the most complex processing configuration is an "Integrated" system that includes operations to catalytically crack hydrocarbons and to produce chemical and lubricating products. As shown in Figure 3, the "cracking" refineries were the most predominant group, with 42 refineries or approximately half of the respondent population. As depicted, there were slightly more petrochemical plants than topping, lube or integrated facilities.

Figure 3. Distribution of Respondents by NPDES Complexity Classification



As the distribution of refineries by age shows, half of the refineries began operations before 1940, and another third came on line between 1941 and 1960. Only eight of the participating refineries began operations in the last 25 years.

Figure 4. Distribution of Respondents by Refinery Age



As previously noted, the 84 responding refineries represented 64 percent of the domestic refining capacity. They reported processing 3.34 million barrels of crude during 1994. Thirty-four (34) refineries charged crude every day during the year and another 12 were down for less than a week. All other refineries reported operating on 304 days or more. Regarding the crude run, 43 reported stock with less than 1 weight percent of sulfur, while 29 reported a slate between 1 and 2 weight percent sulfur. The remaining 12 refineries reported crudes with more than 2 weight percent of sulfur.

Eighty facilities answered the new question (Question 7) on the configuration of their wastewater system. None of these refineries indicated that they did not have wastewater treatment components. As indicated in the following table, 80 refineries reported having primary oil/water separation equipment, 60 had secondary oil/water separation components, 64 used secondary biological treatment, and 34 reported tertiary/polishing treatment. Most refineries reported having only one type of each stage of treatment, but 8 indicated that they had more than one type of secondary biological treatment and 5 had more than one type of tertiary/polishing treatment.

Table 1. Frequency of Reporting Wastewater System Components

WASTEWATER TREATMENT COMPONENT	# REFINERIES
PRIMARY OIL/WATER SEPARATION (n = 80)	
Oil/Water Separator (e.g., API separator; corrugated plate, etc.)	76
Other	3
SECONDARY OIL/WATER SEPARATION (n = 60)	
Gas Flotation (Dissolved or Induced Gas)	52
Filtration	2
Other	6
SECONDARY BIOLOGICAL TREATMENT (n = 64)	
Aerated Lagoon	11
Trickling Filter	4
Activated Sludge	52
Rotating Biological Contactor	4
Other	1
Anaerobic Filters or Contactors	0
Other	3
TERTIARY/POLISHING TREATMENT (n = 34)	
Filtration	17
Carbon Adsorbers	6
Biological Denitrification	3
Metals Removal Processes	3
Other	11

As would be expected by the reporting patterns, the most commonly reported combination of wastewater treatment components include primary oil water separation, dissolved/induced air flotation and activated sludge. As shown in Table 2, reporting such a combination of primary and secondary wastewater treatment components predominated in each capacity class. Note that 40 percent of the refineries with capacities greater than 100 BSD have upgraded their systems to include tertiary treatment.

Table 2. Comparison of Wastewater Treatment Components by Capacity Class

TREATMENT TYPE/ CAPACITY CLASS	<10 BSD	10-50 BSD	51-100 BSD	101-200 BSD	>200 BSD
Primary Separation Only		2		3	
Primary & Secondary	3	16	13	11	9
Primary, Secondary & Tertiary		2	3	10	7

In response to the new Question 8, 35 refineries indicated that they exclusively use tanks to manage storm water and wastewater downstream of their primary oil/waste separation units, while 6 reported that they use only surface impoundments. The 32 other facilities that answered Question 8 use a combination of tanks and impoundments. Sixteen facilities reported having obtained Resource Conservation and Recovery Act (RCRA) permits for their impoundments (or the impoundments had interim status). These impoundments ranged in size from 1 to 44 acres. Combined, there were 249 acres of permitted impoundments. There was a total of 1178 acres of impoundments reported as not regulated under RCRA. The 31 facilities reporting these impoundments indicated that their size ranged from less than 1 acre up to 350 acres.

Another new question (Question 10) developed for the 1994 survey pertained to the quantity of water discharged daily from the refineries. The 72 facilities that answered the question reported values from 0 to 34 million gallons per day (MGD) for a total of 268 MGD. This resulted in an average of 3.3 MGD per refinery. The median value was 1.73 MGD.

The second part of the question on water discharges required the refiner to indicate the sources that contributed to the water discharged (e.g., the percentage that was process wastewater, non-contact once through cooling tower water, treated storm water, etc.) The table below summarizes these responses.

Table 3. Sources of Water Discharged by Refineries

SOURCE	# REPORTING	RANGE(MGD)	MEDIAN(MGD)
Process Wastewater	71	<0.01 - 14	1.2
Non-contact once through cooling water	47	<0.01 - 4.5	0.01
Treated storm water	42	<0.01 - 4.0	0.19
Untreated storm water	26	<0.01 - 2.6	0.14
Treated groundwater	23	<0.01 - 0.85	0.04
Other	20	<0.01- 2.9	0.12

As these values indicate, almost all refineries report that process wastewaters contribute to the water discharged under their NPDES permit. In fact, 18 refineries indicated that process wastewaters represent more than 90 percent of the water they discharge. More than half of the respondents indicated that non-contact cooling tower waters and treated storm water contribute to their effluent, while approximately one third reported discharging untreated storm water or treated groundwater.

Another new question (Question 11) requested information on the annual water quality discharge parameters. To standardize the responses, the pounds of each parameter reported as discharged annually was divided by the wastewater flow reported in Question 10. The values for the five parameters that were most widely reported are presented below.

Table 4. Water Quality Discharge Parameters

PARAMETERS	# REFINERIES	RANGE	MEDIAN
Total Suspended Solids (TSS)	67	10 - 2143 lbs/MG	113 lbs/MG
Biochemical Oxygen Demand (BOD)	63	7 - 3730 lbs/MG	54 lbs/MG
Chemical Oxygen Demand (COD)	56	10 - 8338 lbs/MG	583 lbs/MG
Ammonia	59	10 - 1521 lbs/MG	31 lbs/MG
Oil & Grease	61	5 - 2023 lbs/MG	22 lbs/MG

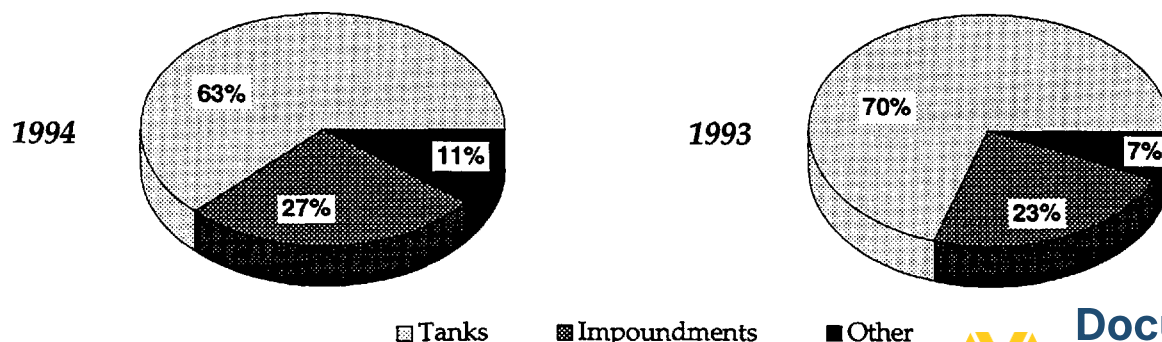
As the table entries indicate, the values vary substantially within a given parameter. Because of this, the median is used as a measure of central tendency since it provides a better understanding of the distribution of responses. Specifically, use of this middle most value as a benchmark highlights that the majority of responses are well below the high end of the range reported.

The survey also collected information on the amount of wastewater that failed the Toxicity Characteristic (TC). In 1994, a total of 143 million wet tons were reported by 46 facilities. Of this quantity, 77 percent was managed solely in tanks exempt from RCRA permitting prior to discharge. Eighteen percent was managed in RCRA permitted surface impoundments and 4 percent was managed in other ways.

To monitor the industry's progress on managing TC wastewater, API compares the quantities reported by refineries that participate in successive survey cycles. This procedure controls for the turnover in survey respondents or changes in the response rate that influence the reported quantity of TC wastewater. The total quantity reported in 1993 by the 29 refineries that reported TC wastewaters in both years was 116.0 million wet tons; for 1994, this dropped to 92.8 million wet tons.

Comparison of the management methods used by these refineries to handle TC wastewaters is graphically depicted in Figure 5. As indicated, the management practices remained fairly constant. More than 60 percent of TC wastewater was treated in tanks that are exempt from RCRA permitting requirements. Only one quarter of the TC wastewater was managed as a RCRA hazardous waste in surface impoundments and the remainder was reported as "Other" management techniques.

Figure 5. Management of TC Wastewater 9 (Totals may not equal 100% due to independent rounding.)



As noted in the section on the instrument revision, the pollution prevention questions were moved to the first section of the questionnaire. The question format was similar to that previously used, with the exception that quantitative data were not requested. The responses are summarized in Table 5.

As indicated, the residuals with the highest number of responses were the API Separator Sludge stream and the Primary Sludges with 39 and 35 responses, respectively. This listing of pollution prevention activities highlights the industry's reliance on in-process recycling to minimize the generation of oily waste and its use of reclamation and regeneration to handle spent catalysts and chemicals. Refiners also continue to report housekeeping improvements and staff training programs to promote more efficient management practices.

Few source reduction activities were reported this year. This is not surprising given the subset of streams included in the 1994 survey. These streams were selected because they are more closely regulated and their management costs are higher. Consequently, these are the streams on which pollution prevention activities have focused in the past. Processes have already been modified, materials substituted wherever possible and external sources for residual reuse have already been identified. Thus, the "low hanging fruit," those pollution prevention activities most easily accomplished, have already been picked. Successive achievements for these streams will be driven by additional analyses and R&D efforts, both of which require time and funding to succeed.

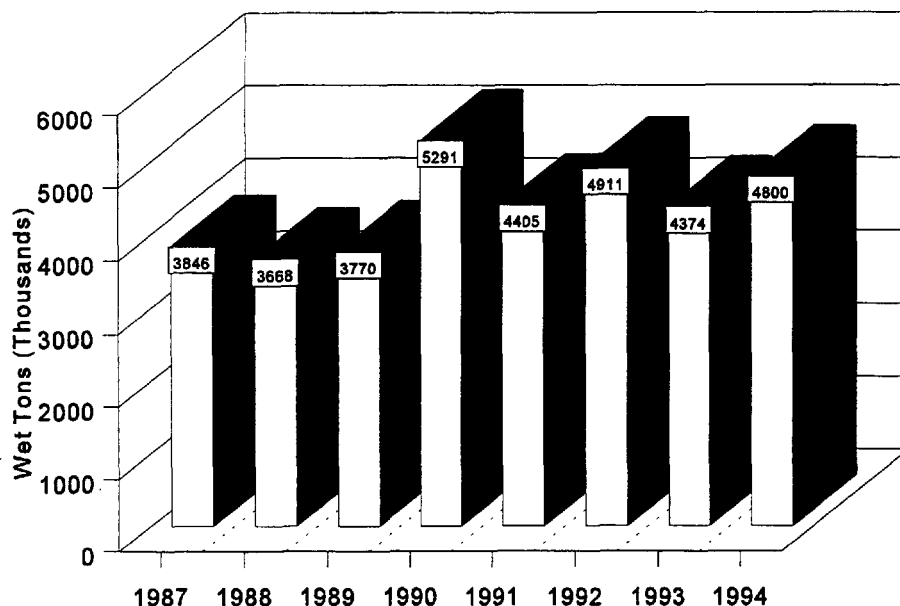
Table 5. Responses to Pollution Prevention Question

Residual Stream	# Responses	Pollution Prevention Techniques Reported
API Separator Sludge	39	Coking Filtering/dewatering/drying Housekeeping (sweeping, paving, covered API separator)
DAF Float	22	Coking Filtering/dewatering/drying Treated & recycled through wastewater treatment plant
Slop Oil Emulsion Solids	14	Coking Filtering/dewatering
Primary Sludges	38	Coker Filtering/dewatering Housekeeping (dust control, paving, replaced ponds w/ tanks, covered sewers, install silt fences in tank farm areas)
Tank Bottoms	28	Coker Crude unit Filtering/dewatering/centrifuge
Contaminated Soils	19	Thermal desorption Housekeeping/training (paving, spill/leakage control awareness, segregate wastes) Other reuse (use as road base, capping material at municipal landfill, stabilization agent for non-haz tank bottoms)
Pond Sediments	8	Recycle to LTU Replace ponds with tanks Thermal desorption for oil recovery Housekeeping (dust suppression, cleaned basins & segregated WW)
Biomass	9	Coker Filtering/centrifuging Recycle to LTU
FCCU Catalysts	24	Recycle to cement kilns Modified procedures to reduce catalyst loss Reuse as catalyst
Hydroprocessing Catalyst	30	Reclamation
Other Catalysts	21	Regeneration/Reclamation Cement kiln feed
Spent Caustics	28	Sold as feedstock/product (Merichem, paper mill) Reuse (corrosion inhibitor in crude oil charge, pH control in WWTS) Regeneration

Residual Stream Profiles

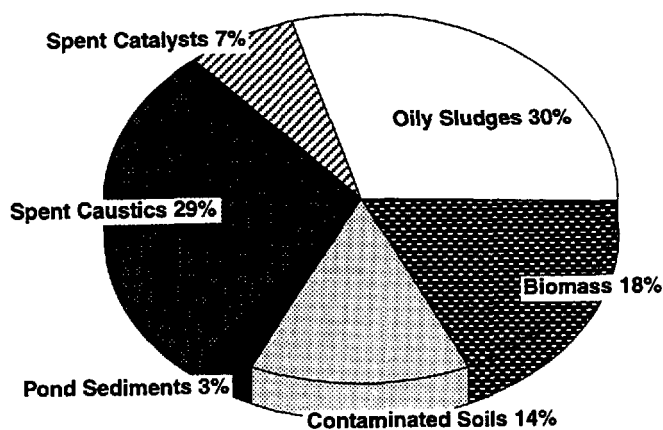
For 1994, the total industry estimate of residuals managed was 4.8 million wet tons. As graphically portrayed in Figure 6, this was intermediate in the range of quantities reported since 1990.

Figure 6. Summary of Residual Generation: 1987 - 1994 (represents 15 residual streams)



As shown in the pie chart, Oily Sludges (a broad group of residual streams that includes the RCRA listed K and F wastes) accounted for 30 percent of the total quantity managed. This was comparable to the 29 percent that was Spent Caustics (Sulfidic, Naphthenic and Cresylic). Biomass represented 18 percent of the total, while Contaminated Soils were 14 percent. Spent Catalysts were 7 percent of the total quantity of residuals, and Pond Sediments were just 3 percent.

Figure 7. Residuals Managed in 1994 (Totals may not equal 100% due to independent rounding.)



The remainder of this chapter will present information on the management of each of the residual streams. *It should be understood that the residual stream labels used in this survey are NOT used in a*

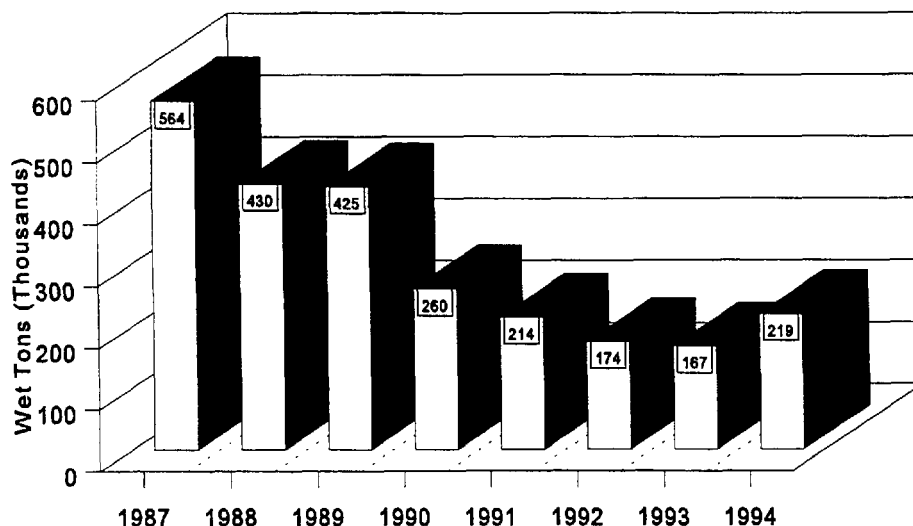
regulatory sense. Whereas the Environmental Protection Agency (EPA) regulations implementing RCRA have given these terms special meaning, our usage here is in a broader, more generic sense. API's intent is to have survey participants report the management of all residual type materials (e.g., materials that are byproducts or residuals of petroleum refining operations). This includes residuals that are beneficially recycled or reclaimed, as well as materials that are discarded.

Note that the computer print-outs, from which all the statistics presented in the text are derived, can be found in Appendix C.

API Separator Sludge²

The estimated quantity of API Separator Sludge residual stream for the entire refining industry was 219 thousand wet tons. As illustrated in Figure 8, this was somewhat higher than in 1991 and 1992, but substantially below the large quantities reported in the late 1980s.

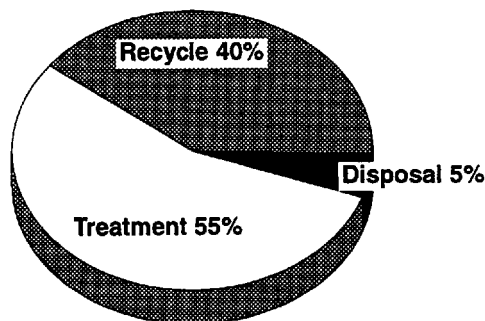
Figure 8. Managed Quantities of the API Separator Sludge Residual Stream: Industry Estimates for 1987 - 1994



² As noted in the introduction of this section, API's use of the term "API Separator Sludge" is not in a regulatory sense. The API Separator Sludge residual stream includes materials--such as water and oil--which when recovered by dewatering and deoiling do not fall under the purview of RCRA.

Figure 9 summarizes how the refiners handled the API Separator Sludge residual stream in 1994, highlighting the fact that the industry relies on recycling—primarily via cokers and crude units—to manage this material.

Figure 9. Management of the API Separator Sludge Residual Stream



Review of the data in Table 6 shows how the specific management practices have changed over time. Note that the amount of material recycled in cokers has fluctuated: in 1994 it was twice the quantity for 1993, but still less than that reported in 1988. Recycling of the API Separator Sludge residual stream as Cement Kiln Fuel and as Other Industrial Fuel both peaked in 1994, while its use as feed for cement kilns dropped substantially.

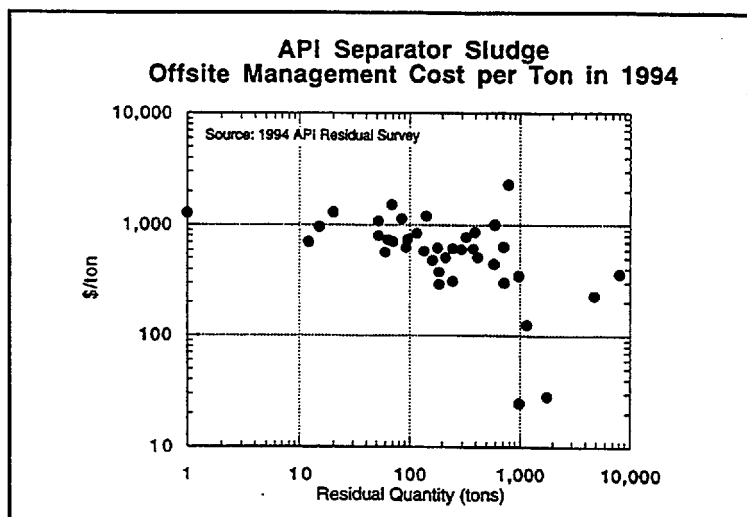
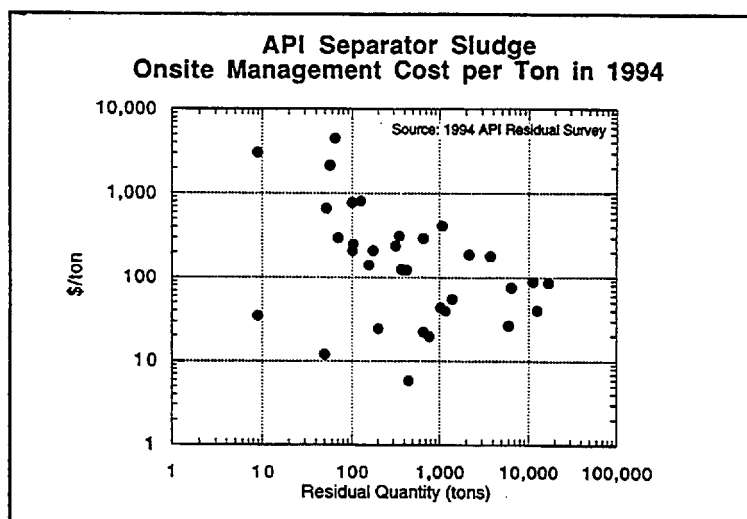
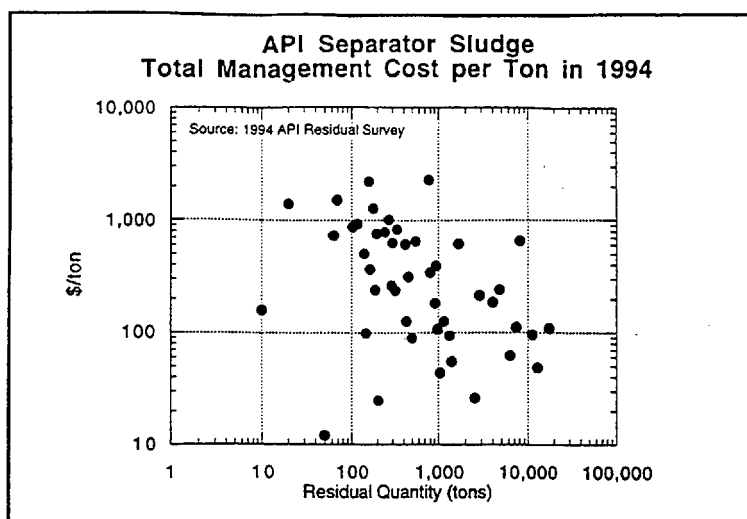
For treatment, Table 6 shows that the industry continues to use wastewater treatment to handle the separated aqueous portion of the residual material. This practice accounted for 84 percent of the residual that was treated. The fluctuations observed between years in the entries for incineration, heat and physical treatments are quite substantial, without any ready explanations.

A series of scatter plot charts summarizing the cost data for API separator sludge are included following Table 6.

Concerning disposal patterns, the 1994 responses reflect that several refineries successfully pretreated their API Separator Sludge which enabled them to landfill the material.

Table 6. Management Techniques Used for the API Separator Sludge Residual Stream (Industry Estimates)

	1994	1993	1992	1991	1990	1989	1988	1987
QUANTITY MANAGED	218,517	167,296	174,147	214,031	259,600	424,499	430,045	563,774
MANAGEMENT TECHNIQUES								
RECYCLE								
In-Process								
Coker	44,340	22,759	23,905	31,201	8,373	54,582	72,901	14,485
Crude Unit	16,794	11,265	10,542	10,992	10,015	23,821	13,236	17,963
Catalytic Cracker	82	200	1,790	148				
Other In-Process Recycle	10	1,120	796					
Sour Water Stripper						9	14	92
Out-of-Process								
Cement Kiln Fuel	15,969	14,086	8,208	15,681				
Other Industrial Fuel	3,392	492	127					
Reclamation	1,676	3,212	1,894	219	3,942	859	3,666	6,418
Cement Kiln Feedstock	295	1,829	79	3,400				
Regeneration		76						
Sold					1,426			
Industrial Furnace					864	502	39	411
Other Out-Of-Process Recycle		127	159					
Other Recycle	4,701	2	1		4,682	3,827	1,599	712
TOTAL	87,259	55,168	47,501	61,641	29,302	83,600	91,455	40,081
TREATMENT								
Wastewater Treatment	100,327	74,073	68,185	112,760	55,690	149,190	136,219	146,011
Incineration	8,615	11,965	25,687	29,098	4,639	7,417	5,290	4,131
Heat	5,672	662	7,531	3,695	2,336			
Physical	233	19,138	20,110	1,515	12,618	33,848	9,770	1,754
Chemical				24		1,299		
Stabilization					5,075	143		
Impoundment						3,280	1,968	10,597
Other Treatment	4,396							
TOTAL	119,244	105,838	121,513	147,092	80,358	195,177	153,247	162,493
LAND TREATMENT	1,442	1,320	363		65,496	60,562	85,395	210,829
DISPOSAL								
Landfill	10,298	4,741	4,550	5,297	79,342	76,598	51,210	53,886
Other Disposal	274	229	220		901	4,004		36,687
Impoundment				1	249	4	22,382	48,308
Landsread					3,952	4,554	26,356	11,490
TOTAL	10,572	4,970	4,770	5,298	84,444	85,160	99,948	150,371

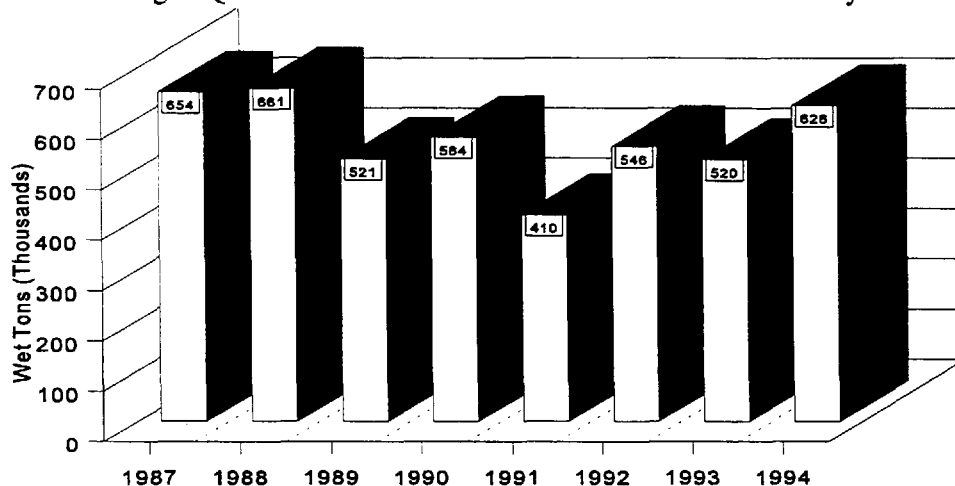


API Separator Sludge Cost Data

DAF Float⁴

The industry-wide estimate for the DAF Float residual stream was 628 thousand wet tons. This quantity was comparable to that observed in 1987 and 1988.

Figure 10. Managed Quantities of the DAF Float Residual Stream: Industry Estimates for 1987 - 1994



In 1994, slightly more than half of the DAF Float residual stream was recycled, while 48 percent was managed by treatment. Two thousand wet tons were land treated or disposed, but since this represents less than 1 percent of the total managed quantity, it is not graphically depicted on the following pie chart.

Figure 11. Management of the DAF Float Residual Stream

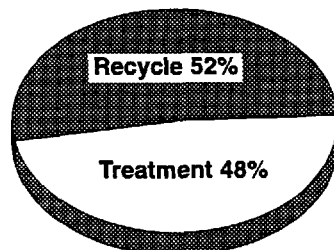


Table 7 displays the data on the management techniques used to handle the DAF Float residual stream. Review of the subtotals in the table indicates that the industry relied more on recycling in 1994 than ever before, while there was a reciprocal drop in the proportion of DAF Float that was treated.

Over half of the residual material that was recycled was handled by cokers, while another quarter went to crude units. For both recycling methods, the quantities reported in 1994 were substantially greater

⁴ Recall that API uses labels such as DAF Float in the broader context of a *residual stream* which includes materials that are not subject to RCRA regulation.

than ever reported before (i.e., the 170 wet tons that went to the coker were more than twice the previous high of 79 thousand wet tons reported in 1989, and the 85 thousand wet tons recycled in crude units were 10 thousand wet tons larger than the 75 thousand wet tons reported in 1992).

For out-of-process recycling, there was a marked drop in the quantity of material used as cement kiln fuel, while there was a sizeable quantity handled by "Other" methods.

Wastewater treatment, responsible for treatment of 91 percent of the DAF Float residual stream in 1994, continued to be the predominant treatment method. The 20 thousand wet tons sent to incinerators was the smallest quantity ever reported for this handling practice. For physical treatment there was a substantial increase over 1993, while there was a concomitant drop in the use of heat treatment.

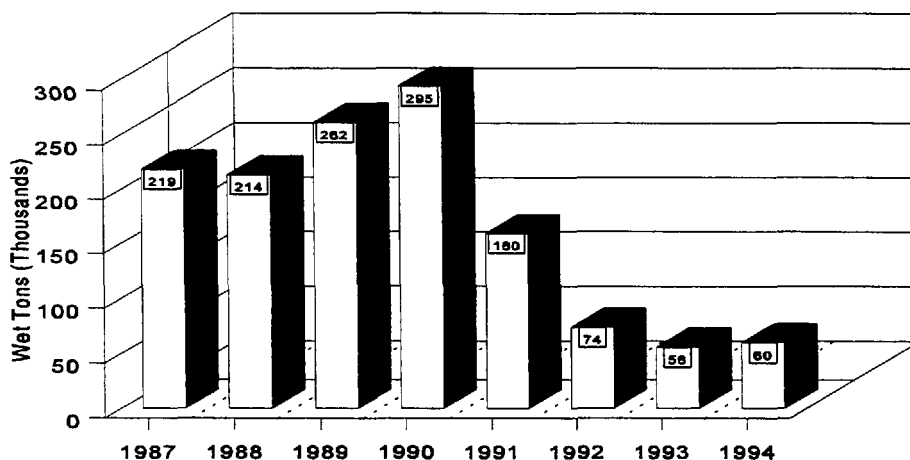
Table 7. Management Techniques Used for the DAF Float Residual Stream (Industry Estimates)

	1994	1993	1992	1991	1990	1989	1988	1987
QUANTITY MANAGED	627,773	520,118	546,136	409,551	564,300	520,797	660,515	653,899
MANAGEMENT TECHNIQUES								
RECYCLE								
In-Process Recycle								
Coker	170,199	47,367	48,664	55,516	74,597	78,982	45,400	81,981
Crude Unit	84,829	52,268	74,967	71,866	21,625	34,037	19,007	16,190
Catalytic Cracker	36,748		1,339					
Other In-Process Recycle	19	30,899	27,641	9			7,942	5,999
Out-of-Process Recycle								
Cement Kiln Fuel	4,358	14,062	18,884	11,666				
Other Industrial Fuel	1,523	1,098			492		137	74
Cement Kiln Feedstock	945	684	1,191	43				
Reclamation		777	11	1,243	1,505	533	12,031	10,573
Regeneration		121	3					
Other Recycle	28,377	349	413		39,829	18,595	11,290	7,362
TOTAL	326,998	147,625	173,113	140,343	138,048	132,147	95,807	122,179
TREATMENT								
Wastewater Treatment	272,596	338,268	308,004	208,287	305,645	247,735	236,052	262,535
Incineration	20,327	24,479	54,308	57,615	32,199	25,572	47,281	35,312
Physical	5,253	329	273	83	2,433	6,949		
Heat	210	6,145	6,466	1,302				
Chemical/Stabilization					3,810	2,309		
Impoundment							18,917	15,005
TOTAL	298,387	369,221	369,051	267,287	344,087	282,565	302,250	312,852
LAND TREATMENT	1,148	1,616	444	4	60,464	71,637	202,570	159,418
DISPOSAL								
Landfill	1,240	1,656	3,528	1,168	20,910	29,014	51,214	30,936
Impoundment							6,925	25,853
Landspread					575	4,228	1,749	1,831
Other Disposal				749	216	1,206		830
TOTAL	1,240	1,656	3,528	1,917	21,701	34,448	59,888	59,450

Slop Oil Emulsion Solids⁵

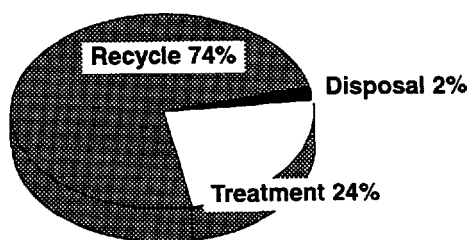
As the bar chart graphically depicts, the 60 thousand wet tons of the Slop Oil Emulsion Solids residual stream managed in 1994 was within the range reported in the two previous survey cycles. This was approximately 70 percent less than what was reported in 1987, and 80 percent below the peak quantity reported in 1990.

Figure 12. Managed Quantities of the Slop Oil Emulsion Solids Residual Stream: Industry Estimates for 1987 - 1994



Close to 75 percent of the Slop Oil Emulsion Solids stream was managed by recycling in 1995, while 23 percent was eliminated by treatment, as shown below.

Figure 13. Management of the Slop Oil Emulsion Solids Residual Stream



The specific handling practices used for the Slop Oil Emulsion Solids stream were similar to those reported for the API Separator Sludge and DAF Float streams: 60 percent of the recycled material was handled by cokers and crude units, while a smaller portion was sent off-site as cement kiln fuel. More material is eliminated by wastewater treatment than by any other treatment method. Overall, however, treatment of Slop Oil Emulsion Solids residuals has declined in the 1990s, as has Land Treatment and Disposal.

⁵ Recall that API uses labels such as Slop Oil Emulsion Solids in the broader context of a *residual stream* which includes materials that are not subject to RCRA regulation.