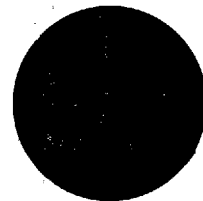


# GENERATION AND MANAGEMENT OF WASTES AND SECONDARY MATERIALS



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**Petroleum Refining  
Performance**



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# **Generation and Management of Wastes and Secondary Materials**

***Petroleum Refining Performance  
1989 Survey***

AMERICAN PETROLEUM INSTITUTE

HEALTH AND ENVIRONMENTAL AFFAIRS DEPARTMENT

JUNE 1992

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## Executive Summary 1989 Survey

Each year, U.S. petroleum refineries process 650 million tons of crude oil as they create fuels and other petroleum products vital to the U.S. economy and way of life. Not much waste results -- less than 1 percent of those 650 million tons. Still, that amount of waste is a big number in its own right.

This is the third annual survey of wastes generated by U.S. petroleum refineries -- and how they handle those wastes. Conducted by the American Petroleum Institute, it is the only ongoing industry-wide effort of its kind. It is also the first to track "source reduction" in refineries -- preventing pollution by avoiding the creation of waste.

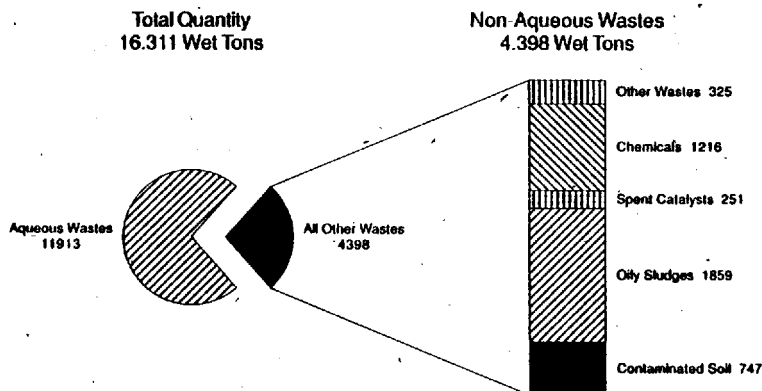
For this survey, *Generation and Management of Wastes and Secondary Materials: Petroleum Refining Performance*, API mailed questionnaires to 183 operating U. S. refineries. The 117 refineries that responded represent 74 percent of domestic refining capacity. This high response rate enabled API to develop industry-wide estimates with a high degree of confidence and statistical accuracy.

### Wastes Generated

U.S. refineries generated roughly 16.3 million wet tons of wastes and secondary materials in 1989 -- about the same as in 1987 and 1988. The total includes non-hazardous and hazardous wastes (as classified under RCRA, the federal Resource Conservation and Recovery Act), byproducts, and other secondary materials.

The survey obtained information on 28 waste streams, grouped in six categories. As shown below, aqueous wastes constitute about two-thirds of the total. Four facilities (treated as outliers in the statistical analysis) generate nearly all of these wastes and dispose of them by injecting them into underground wells. In diminishing order of volume, the remaining wastes are oily sludges, chemicals, contaminated soils, "other," and spent catalysts.

### Types of Wastes Generated (millions of wet tons)



With the exception of contaminated soil, the amount of each type of waste has remained about the same since 1987. It appears that the amount of contaminated soil is on the rise -- most likely, a result of new construction at refineries and stepped-up efforts to clean up and remediate contamination from past releases.

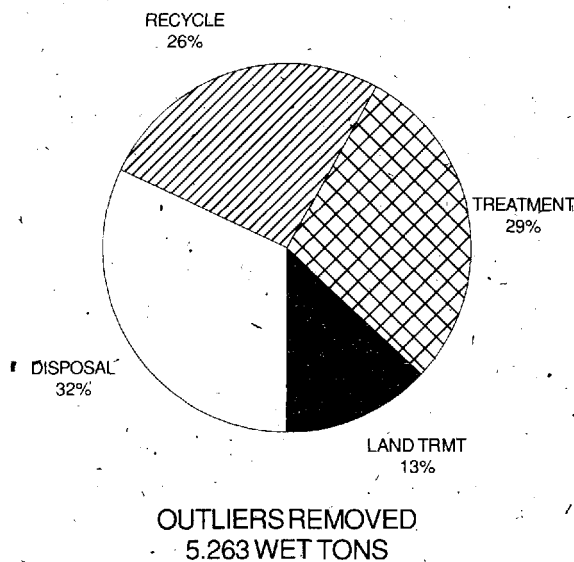
### **Waste Management**

The U.S. Environmental Protection Agency has created a waste management hierarchy that reflects the growing emphasis on reducing the amount of waste generated rather than treating and disposing of it. The ranking (in general order of preference) is source reduction, recycling, treatment, and disposal.

Trends in handling petroleum refining wastes reflect the shift in emphasis in the waste management community at large. Of the 117 refineries that participated in the 1989 survey, 55 reported progress in source reduction. Their activities included technical and procedural modifications, in-process recycling, and improved housekeeping practices. Economic incentives such as lower treatment and disposal costs were the main reasons they undertook such source reduction activities.

Recycling of refinery wastes is also on the rise. Twenty-six percent of refineries' wastes were recycled in 1989, compared to 21 percent in 1987. In contrast, land farming has declined dramatically. It was used to dispose of 66 percent of refinery wastes in 1981 and 17 percent in 1987, but just 13 percent in 1989. As the illustration below shows, refineries use other waste management methods as well. In 1989, they eliminated 29 percent of their wastes through treatment and 32 percent through disposal -- about the same proportions as in 1987 and 1988.

### **Methods of Managing Wastes** (millions of wet tons)



ii

### ***Implications***

API's waste management survey is a tool that quantifies the wastes petroleum refineries generate. It helps individual refineries assess their performance and monitor progress, while providing an overview of the industry's performance as a whole.

Now that three successive years of data are available, it is also possible to compare the performance of individual refineries and the industry as a whole over time. Here, "within facility" variations in amounts of wastes generated suggest that the industry-wide aggregated data give a false sense of stability.

Annual variations in generation quantities for specific waste streams at individual refineries are up to seven times greater than those of the industry as a whole. If additional observations validate this trend, it could lend support to the view that site-specific factors merit consideration -- especially, in regulatory decisions.

## Introduction

Four years ago, API began chronicling the generation and management of wastes and secondary materials in the petroleum refining industry. Recognizing that one-time data collection would provide a snapshot that could not be used to reliably assess progress, API committed to analyzing at least four consecutive years of data.

In February 1991, the first two years of data were compiled and published in *The Generation and Management of Wastes and Secondary Materials in the Petroleum Refining Industry 1987-1988* (API publication number 849-30000). This report on 1989 data continues the series. Data for 1990 are now being collected and will be published separately.

The scope of the survey is broader than the Resource Conservation and Recovery Act (RCRA) regulatory definition of solid waste. API has collected data on a variety of materials, including hazardous and non-hazardous wastes and secondary materials sometimes considered byproducts or recyclable materials. The rationale for including both wastes and secondary materials in the survey is to characterize -- and quantify -- the non-fuel materials the refining industry generates and manages. Previous data collection efforts -- by regulatory agencies and the industry itself -- focused only on certain wastes; the resulting lack of comprehensive information impaired advocacy efforts and slowed the planning of pollution prevention initiatives.

The primary goal of the survey is to track the management of wastes and secondary materials from the point of generation. API has incorporated an integrated waste management hierarchy in the data collection forms -- classifying waste handling practices as source reduction, recycling, treatment or disposal. This conceptual framework acknowledges that a range of practices is needed to handle wastes, and that some practices are more desirable than others. It may also help the industry and individual refineries assess progress over time both in reducing the amount of waste generated and in handling those that remain in an environmentally sound manner.

The survey is an ambitious undertaking. In the area of waste -- where conventional wisdom holds that smaller is better -- a large industry essentially asked, "How much?" Petroleum refineries process some 15.7 million barrels of crude oil per per day -- 5.7 billion barrels or 650 million tons per year. Even if the waste from each barrel is small, the sheer volume results in a large number.

By amassing several years of data in an effort to create a reliable baseline, the industry risks being asked a second question, "How much less?" Here, the variability inherent in refineries' operating practices works against early detection of incremental progress in reducing wastes. One-time events such as turnarounds or shutting down surface impoundments create peaks in waste volumes that can mask the progress better management practices and source reduction activities achieve.

Simply by conducting the survey, API invites a third question, "What does it mean?" While many quantitative observations can be explained -- particularly where there are strong trends -- the reasons why other numbers increase or decrease are more elusive. Though some may never be entirely clear, additional measures over an extended period of time may identify more factors that influence generation rates and the magnitude of their effects.

Individual refineries have already reported that they find the survey a useful accounting tool for classifying and quantifying wastes. Having characterized their wastes, they may go on to compare themselves to the industry as a whole and target areas where change is needed. The aggregated survey data also provide a context for evaluating the impact of new regulations and reporting requirements. Though it takes two to three years to amass the data, API's information is more current and comprehensive than any other waste management database. Thus, the survey can also provide more reliable estimates of the impact of proposed regulatory changes.

## Methodology

Since the 1989 survey largely replicates the 1987-1988 survey, the following discussion focuses on changes made to improve the quality of the data. For detailed information on general survey procedures, see *The Generation and Management of Wastes and Secondary Materials in the Petroleum Refining Industry: 1987-1988* (API publication number 849-30000).

### Survey Design

This survey, like its predecessors, took a census approach. Using the Department of Energy's 1989 *Petroleum Supply Annual* and API's *Entry and Exit in U.S. Petroleum Refining, 1948-1989*, the Institute updated its list of 176 operational refineries. The resulting population of 183 refineries used for the 1989 survey reflect the opening (under new ownership) of some refineries and the closing of others. Ninety-five companies owned the refineries; roughly a third were API members.

### Data Collection

The survey questionnaire had two parts: 12 short-answer questions about the age, size and complexity of the refinery, the types of source reduction activities performed, and "data sheets" that captured quantitative information on generation of 28 types of wastes and secondary materials, and methods of managing them (see Appendix A).

The 1989 survey used the same list of 28 waste streams used in the 1987-1988 survey. As Table 1 on the next page shows, these waste streams are divided into six broad categories that reflect the typical grouping of wastes and secondary materials in a refinery (see Appendix A for the subcategories of each waste stream).

As a quality control measure, the data sheets balanced waste "inputs" and "outputs." As the illustration below shows, the inputs are quantity generated, treatment additives, and net from storage (the total amount of waste removed from storage minus the amount placed into storage). The outputs are quantity recycled, quantity treated, and quantity disposed.

$$\text{Quantity Generated} + \text{Treatment Additives} + \text{Net From Storage} = \text{Total Quantity Managed}$$

$$\text{Total Quantity Managed} = \text{Quantity Recycled} + \text{Quantity Treated} + \text{Quantity Disposed}$$

To improve the consistency of the data collected, API made several changes in the data sheets. Respondents were asked to indicate whether wastes were generated on a routine or one-time basis and whether they had been dewatered. In addition, each data sheet included a simplified source reduction question that served largely as a consistency check with the source reduction questions in the short-answer section.

**Table 1**  
**Refining Waste Streams**

| Category                          | Constituents                                                                                                                                                                                                                                    |
|-----------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Aqueous wastes                    | Biomass<br>High pH/low pH waters<br>Oil contaminated waters (not wastewaters)*<br>Spent Stretford solution<br>Spent sulfide solution<br>Other aqueous wastes NOS**                                                                              |
| Chemicals/inorganic wastes        | Spent acids<br>Spent caustics<br>Waste amines<br>Other inorganic wastes NOS**                                                                                                                                                                   |
| Contaminated soils/solids         | Contaminated soils/solids<br>Heat exchanger bundle cleaning sludge***<br>Waste coke/carbon/charcoal<br>Waste sulfur<br>Other contaminated solids NOS**                                                                                          |
| Oily sludges/other organic wastes | API separator sludge***<br>DAF float***<br>Leaded tank bottoms***<br>Nonleaded tank bottoms<br>Other separator sludges<br>Pond sediments<br>Slop oil emulsion solids***<br>Waste oils/spent solvents<br>Other oily sludges/organic wastes NOS** |
| Spent catalysts                   | Fluid cracking catalyst<br>Hydroprocessing catalyst<br>Other spent catalysts NOS**                                                                                                                                                              |
| Other wastes                      | Other wastes NOS**                                                                                                                                                                                                                              |

\* Does not include NPDES or POTW wastewaters.

\*\* Not otherwise specified.

\*\*\* RCRA-listed hazardous wastes for petroleum refining.

## **Waste Minimization**

Congress mandated a waste minimization policy in 1984 amendments to RCRA, applying the term "waste minimization" to a variety of activities that reduce the amount of waste requiring disposal. The waste management hierarchy -- source reduction, recycling, treatment, and disposal -- illustrates how different activities at different points in the continuum work in concert to achieve this goal.

In the 1987-1988 survey, waste minimization questions focused on source reduction activities -- changes in practices that prevent generating wastes in the first place. Quality control edits of the data received, coupled with follow-up calls to respondents, indicated a need to clarify the meaning of "source reduction" and ways of calculating reductions in the quantities of waste managed (see Appendix D, summary of questionnaire development issues, 1987-1988 survey).

Some of the confusion regarding source reduction stems from the difficulty of measuring an unknown -- successfully preventing waste means that what is being measured no longer exists. Early instructional materials clouded the concept by suggesting that year-to-year reductions in wastes can be construed as source reduction. This is not necessarily the case: the reduction may simply be a normal fluctuation. For example, a refinery could have a major turnaround that creates peak quantities of waste. When wastes decline in subsequent years, the reason is not source reduction, but a return to usual operating conditions.

Another reason source reduction can be hard to measure is that refineries sometimes undertake activities that reduce wastes for reasons other than waste management -- to improve products or increase efficiency. Such practices include modifying equipment, technology or procedures, recycling within a process, and streamlining housekeeping practices. Although the main goal is to make a product more efficiently, a secondary benefit may be that wastes are also reduced.

In light of these considerations, the source reduction questions on the 1989 survey had implicit goals beyond the obvious objective of developing a quantitative profile of progress. Specifically, those goals were to:

- Promote understanding of the source reduction concept -- in particular, how activities other than feedstock substitution can reduce waste.
- Give respondents latitude in measuring progress so as not to arbitrarily influence their responses, yet enable quality control measures to ensure the comparability of data from year-to-year.
- Facilitate technology transfer and innovation by collecting descriptive information on the steps that resulted in waste reduction.

- Create a linkage with federal efforts to identify incentives for source reduction and eliminate barriers to innovation.

API met these goals by including a fairly long introductory passage; by asking respondents to use a six-point classification framework for source reduction activities and provide a narrative description of innovations made and methods used to measure the reduction; and by including questions drafted by EPA on incentives for -- and barriers to -- source reduction activities (see Appendix A, questions 9-12).

### ***Automated Questionnaire***

The automated version of the questionnaire was redesigned for the 1989 survey. To make the program faster and simpler to use, it was rewritten in Clipper™, a commercially available compiler for dBase™. The revised version had five menu-driven parts with quality control checks and "help" screens. API sent survey participants diskettes with their 1987 and 1988 data, and instructions on retrieving them for analysis; this allowed survey participants to create their own databases for site-specific analysis.

### ***Survey Administration***

API assured survey participants that the data for individual refineries would remain confidential, mailing survey materials to the headquarters of the refining branch of each company, which then distributed them to the refineries themselves. All materials were mailed by mid-October; eight weeks were allowed for response. About a month after the mailing of the materials, API made follow-up calls to refineries that had not previously participated in the survey. The purpose of these calls was to confirm receipt of the survey materials and to ascertain whether the refineries intended to complete them.

API retained the consulting services of an expert in refining practices, who staffed a "helpline" for survey-related questions. Survey participants were advised to contact the consultant to clarify technical issues. In addition, the consultant reviewed questionnaire items that automated edit checks identified as potentially out-of-range or inconsistent. The consultant resolved such problems with the contact person at the refinery in question.

### **Data Analysis**

The 1989 survey used essentially the same data verification, non-respondent estimation, and extrapolation procedures as the 1987-1988 survey (see Appendix B). A summary of the main differences between the 1989 survey and the earlier survey follows.

With regard to data verification, the most substantive change was reducing the number of questionable data elements. The improved quality of the data was probably due to increased reliance on the automated questionnaire -- with its internal consistency checks -- and the "learning" effect generally associated with a second administration. In addition:

- Special efforts were made to verify generation quantities for four facilities identified as statistical "outliers" in the 1987 and 1988 surveys. Though three of these facilities were unable to participate in the 1989 survey, API telephoned them and verified that they were still following practices that resulted in the generation of comparable quantities of **aqueous wastes NOS**. Accordingly, the 1988 data for these refineries were used for the 1989 survey.
- Problems detected through edit checks -- for example, patterns of inconsistent responses to questions about hazardous wastes and source reduction -- identified several questions that needed structural revision.
- Edit checks of the consistency in generation quantities between survey years were made both across and within facilities. They helped identify reasons for annual fluctuations in generation rates for various waste streams.

API used statistical models to estimate generation quantities for refineries that did not participate in the survey. The models developed for the 1987-1988 data were tested to determine their reliability, including a separate linear regression model for estimating waste generation as a function of capacity for refineries with less than 200,000 barrels per stream day (B/SD). A non-linear relationship between waste generation and capacity held true for refineries with more than 200,000 B/SD.

Although there were some differences between the 1987-1988 and 1989 surveys -- notably, 183 active refineries and 117 participants in 1989 versus 176 refineries and 115 participants in 1987-1988 -- the modeling procedures retained their validity. The  $R^2$  for smaller refineries indicated that the model accounted for 43 percent of the variability in generation quantities, while the model for larger refineries accounted for 60 percent of the variability. An approximate 2 percent margin of error was estimated for the total waste generation quantity and an approximate 15 percent margin of error was estimated for the individual waste streams.

The extrapolation procedures used to calculate the amount of waste generated by the entire population of refineries was the same as that used in the 1987-1988 survey. API added estimates for the 66 non-responding facilities to the responses of the 117 participating facilities, performing successive calculations to create generation estimates for each waste stream and for each waste handling method. Unless otherwise specified, all data reported for the 1989 survey are estimates of wastes for all 183 refineries.

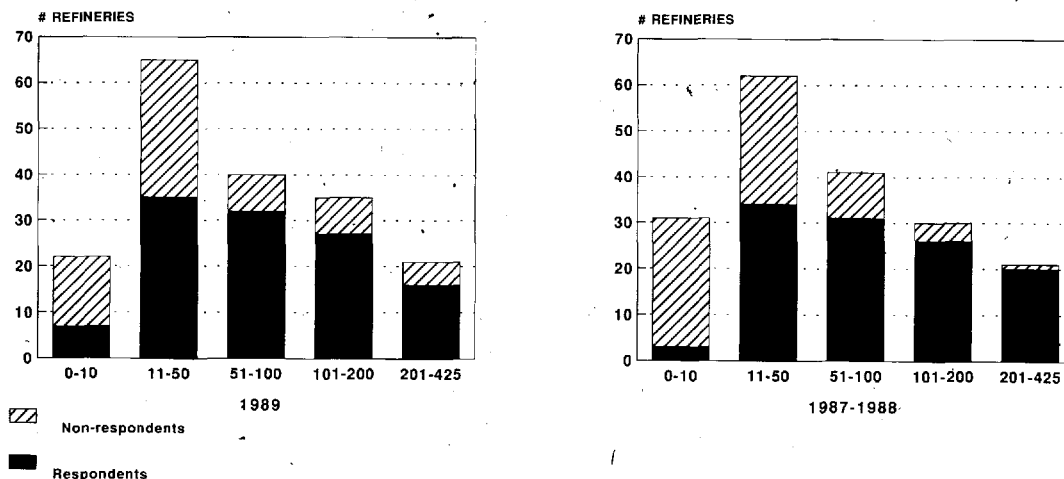
## Results

### Response Rate

The 1989 survey response rate was comparable to the 1987-1988 survey: 117 refineries. They reported operating capacity of 12,659,939 barrels per day. In 1989, they processed 3.9 billion barrels of oil. These refineries represent 64 percent of the population of 183 active refineries, and 74 percent of domestic crude refining capacity. This is somewhat less than the 80 percent of capacity represented by 1987-1988 survey participants.

There was some turnover in participants: 19 refineries that participated in 1989 had not done so previously and 18 refineries that participated in the 1987-1988 survey did not do so in 1989. This did not change the overall profile of participants (see Figure A below). In 1989, representation of 101,000 to 200,000 B/SD refineries remained constant, several refineries of less than 100,000 B/SD joined the survey, and three of the largest refineries dropped out of the survey.

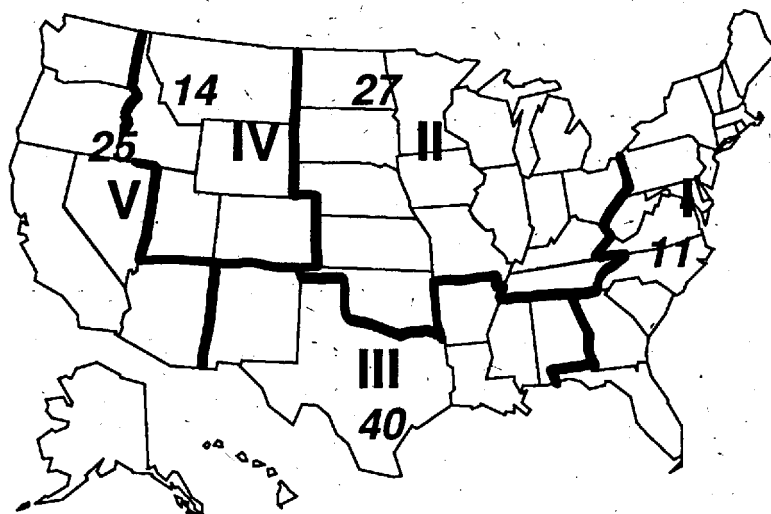
**Figure A**  
**Number of Respondents by Capacity Group**  
(thousand barrels per stream per day)



### Respondent Characteristics

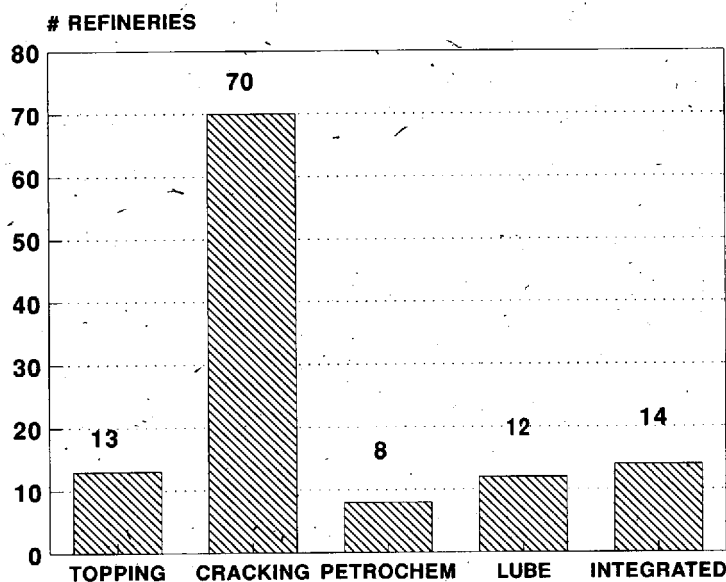
The survey elicited information about the refinery's *location, complexity, age, type of sewer system* and *RCRA permitting status*. As Figure B (following page) shows, the U.S. Department of Energy's Petroleum Administration for Defense (PAD) III, the Texas/Louisiana region, had 40 respondents (of 64 refineries). PAD II had 27 respondents (of 39 refineries), PAD V had 25 respondents (of 45 refineries), PAD IV had 14 respondents (of 17 refineries), and PAD I had 11 respondents (of 19 refineries).

**Figure B**  
**Distribution of Respondents by Location**



The second descriptive variable -- complexity -- used NPDES permit classifications (see Appendix A, question 2). The overwhelming majority of participants were "cracking" class refineries (see Figure C below). Though the actual distribution of complexity among refineries is unknown, the observed distribution is probably representative. Given that complexity tends to increase with size -- and that larger refineries are well represented in the survey -- it follows that most non-responding refineries would be smaller, less complex facilities of the "cracking" class.

**Figure C**  
**Distribution of Respondents by Complexity**



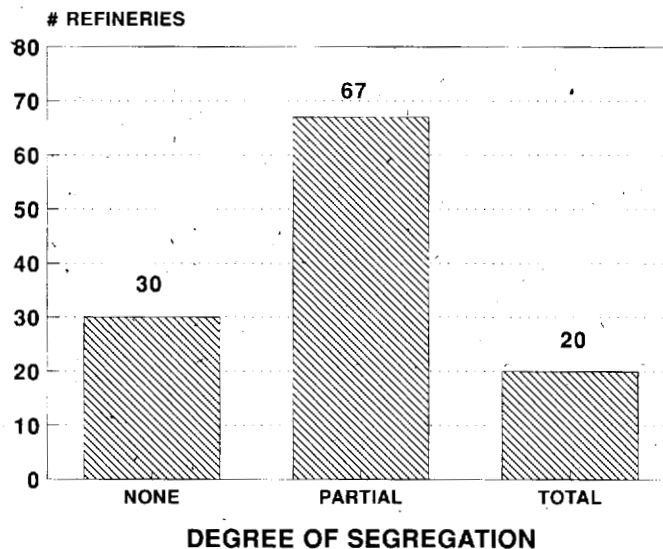
The age distribution of respondents was similar to that in the 1987-1988 survey. More than half the refineries were built before 1940, making them at least 50 years old (see Figure D below). The number of participants in the 30-40 age group (began operating between 1951 and 1960) rose slightly, as did the number in the youngest age group.

**Figure D**  
**Distribution of Respondents by Age**  
(year operations began)



The survey also gathered information about the degree of segregation of storm and process water sewer systems in refineries (see Figure E below). Sixty-seven refineries --57 percent of the respondents -- had partially segregated sewers.

**Figure E**  
**Distribution of Respondents by Sewer Type**



The last descriptive variable was RCRA permitting status. Forty-five refineries -- 39 percent of the respondents -- did not require permits because they are "generators" (as defined by RCRA) who neither treat, store nor dispose of hazardous wastes on-site. Of the remaining 72 refineries, 37 facilities -- 32 percent -- are involved in the permitting process (have filed Part A) and 35 facilities -- 30 percent -- have already obtained a permit.

RCRA permitting status seems to correlate loosely with size. Twenty-five of the 45 refineries that were only generators process less than 50,000 B/SD, while 21 of the 35 refineries that have permits process more than 100,000 B/SD. Refineries that process 50,000 to 100,000 B/SD were evenly distributed: 11 generators, 11 with interim status, and 10 with permits. Thirteen of the larger and 13 of the smaller refineries had filed for permits (Part A).

### **Total Waste Management Quantity**

The term "total waste management quantity" (illustrated below) is defined as generation quantities plus initial waste handling practices that contribute to the amount of waste subsequently managed during the survey year.

$$\text{Total Quantity Managed} = \text{Quantity Generated} + \text{Treatment Additives} + \text{Net From Storage}$$

### **Waste Generation**

As in the 1987-1988 survey, the instruction manual did not explicitly define "wastes" and "secondary materials." The manual said:

*Although denominated as a "solid waste" survey, it should be understood that neither this title nor the references herein (e.g., "wastes" and "residuals") are used in a statutory or regulatory sense. Whereas EPA regulations implementing RCRA have given these terms special meaning, our usage here is in a broader, more generic sense. API wants survey participants to 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 material that is discarded. This will allow reporting of industry data, wherever appropriate, according to the waste management hierarchy of source reduction, recycling, treatment, and disposal.*

The aim was to encourage reporting of actual practices and to avoid the potential bias of experimental or survey effects -- for example, arbitrary definitions of the point of generation. As a quality control measure, the data sheets distinguished between wastes generated on an ongoing, routine basis; wastes relating to a one-time event; and materials that had received some dewatering prior to classification as wastes. This allowed respondents to use their own operational definitions and quality control checks on data comparability.

Using the extrapolation procedures already described, API estimated that the 183 operating U.S. petroleum refineries generated 16.3 million wet tons of waste in 1989 -- slightly more than the 16.1 million wet tons refineries reported in 1987 and the 16.0 million wet tons reported in 1988. But when the waste generation rate is standardized by the 1989 crude throughput (657 million wet tons<sup>1</sup>), the ratio of waste to throughput is 0.0248 -- less than the 0.0256 observed in 1987 and virtually the same as the 0.0247 observed in 1988.

**Aqueous wastes NOS** remained the highest volume stream, representing close to 70 percent of all waste generated. As already noted, four facilities whose practices differ from the industry norm -- statistical outliers -- reported nearly all this waste. When waste to crude throughput is calculated without the outliers, the ratio is 0.0076.

During the survey years, increases and decreases in individual waste streams were fairly evenly distributed: quantities fell in 8 streams and rose in 10 streams. In the remaining 10 streams, the 1989 quantity fell somewhere between the 1987 and 1988 quantities.

The 1989 survey showed substantial percentage reductions in the quantities of **biomass, DAF float, high pH/low pH waters, spent acids and spent sulfite solution**. While the latter two dropped more than 80 percent, they accounted for relatively small quantities and thus had little impact on the aggregate. Overall, the rise in the quantity of waste generated in 1989 resulted from increases in **contaminated soils/solids, other inorganic wastes NOS, and waste coke/carbon/charcoal**.

As previously noted, one-time generation quantities were identified for the first time in 1989. Reasons included unit closure, new construction, soil remediation activities, and change-outs without a planned cycle. These data helped clarify the changes. For example, **contaminated soils/solids** had the most one-time generators (21 refineries), who accounted for a quarter of the total quantity (see Table 2, following page).

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<sup>1</sup>U.S. Department of Energy *Petroleum Supply Annual* figures on total crude input were converted from barrels to wet tons by dividing by 5.94.

**Table 2**  
**Estimated Wastes from the U.S. Refining Industry**  
(thousands of wet tons)

| Waste Stream                              | 1989          | 1988          | 1987          |
|-------------------------------------------|---------------|---------------|---------------|
| Aqueous wastes NOS                        | 11,100        | 11,076        | 11,296        |
| Spent caustics                            | 716           | 656           | 675           |
| Biomass                                   | 642           | 786           | 757           |
| DAF float                                 | 496           | 655           | 652           |
| Contaminated soils/solids                 | 512           | 240           | 165           |
| Other inorganic wastes NOS                | 440           | 213           | 325           |
| API separator sludge                      | 419           | 355           | 400           |
| Other wastes NOS                          | 325           | 412           | 203           |
| Pond sediments                            | 313           | 266           | 337           |
| Slop oil emulsion solids                  | 272           | 224           | 208           |
| FCC catalyst or equivalent                | 182           | 193           | 173           |
| Nonleaded tank bottoms                    | 161           | 129           | 216           |
| Waste coke/carbon/charcoal                | 129           | 67            | 43            |
| Other separator sludges                   | 114           | 104           | 79            |
| High pH/low pH waters                     | 91            | 138           | 144           |
| Other contaminated soils NOS              | 53            | 68            | 82            |
| Waste sulfur                              | 52            | 22            | 17            |
| Waste amines                              | 51            | 14            | 13            |
| Other oily sludges/organic wastes NOS     | 47            | 61            | 38            |
| Spent Stretford solution                  | 42            | 49            | 5             |
| Hydroprocessing catalysts                 | 36            | 36            | 40            |
| Other spent catalysts NOS                 | 33            | 37            | 33            |
| Waste oils/spent solvents                 | 31            | 7             | 4             |
| Oil contaminated waters (not wastewaters) | 29            | 36            | 28            |
| Spent acids                               | 8             | 149           | 126           |
| Spent sulfite solution                    | 8             | 40            | 42            |
| Leaded tank bottoms                       | 4             | 8             | 9             |
| Heat exchanger bundle cleaning sludge     | 2             | 5             | 3             |
| <b>Total</b>                              | <b>16,311</b> | <b>16,044</b> | <b>16,144</b> |

Another stream that rose significantly was **waste oils/spent solvents**, which went from 5,000 to 7,000 wet tons per year to more than 30,000 wet tons in 1989. This was mainly due to a single refinery with a large, one-time generation quantity. In contrast, **other inorganic wastes NOS** had few one-time generators, but a single routine generator reported 25 percent of the total: 111,000 wet tons. Similarly, a single refinery reported close to half the routinely generated quantity of waste coke/carbon/charcoal.

The number of refineries reporting each waste stream has remained fairly constant. The five most common waste streams have also remained constant, though the order has varied somewhat. For example, **API separator sludge** was the second most frequently cited stream in 1987, reported by 91 refineries; in 1988 and 1989, it was the most frequently cited stream (see Table 3, following page).

**Table 3**  
**Number of Refineries Reporting Wastes**

| Waste Stream                              | 1989 | 1988 | 1987 |
|-------------------------------------------|------|------|------|
| Other wastes NOS                          | 89   | 85   | 92   |
| API separator sludge                      | 93   | 94   | 91   |
| FCC catalyst or equivalent                | 84   | 86   | 85   |
| Spent caustics                            | 70   | 77   | 79   |
| Contaminated soils/solids                 | 88   | 77   | 77   |
| Other inorganic wastes NOS                | 73   | 73   | 77   |
| Nonleaded tank bottoms                    | 72   | 75   | 72   |
| Other contaminated soils NOS              | 61   | 71   | 70   |
| Other spent catalysts NOS                 | 60   | 60   | 62   |
| Hydroprocessing catalysts                 | 65   | 60   | 57   |
| DAF float                                 | 47   | 50   | 53   |
| Waste oils/spent solvents                 | 56   | 61   | 52   |
| Heat exchanger bundle cleaning sludge     | 49   | 48   | 49   |
| Other oily sludges/organic wastes NOS     | 49   | 47   | 49   |
| Waste coke/carbon/charcoal                | 51   | 47   | 48   |
| Biomass                                   | 44   | 45   | 47   |
| Slop oil emulsion solids                  | 38   | 43   | 47   |
| Waste sulfur                              | 42   | 47   | 41   |
| Leaded tank bottoms                       | 31   | 37   | 38   |
| Waste amines                              | 38   | 36   | 32   |
| Pond sediments                            | 31   | 29   | 26   |
| Spent acids                               | 18   | 23   | 20   |
| Other separator sludges                   | 22   | 20   | 15   |
| High pH/low pH waters                     | 11   | 12   | 14   |
| Oil contaminated waters (not wastewaters) | 14   | 10   | 14   |
| Other aqueous wastes NOS                  | 14   | 12   | 13   |
| Spent Stretford solution                  | 11   | 13   | 12   |
| Spent sulfite solution                    | 2    | 1    | 1    |

### Treatment Additives

Always low, use of treatment additives (chemicals that facilitate subsequent handling of wastes) declined from 55,000 and 72,000 wet tons in 1987 and 1988, to 35,000 wet tons in 1989 -- 0.2 percent of the total. Additives were used with 18 streams in 1989, 1 less than before. **Biomass, API separator sludge, DAF float, slop oil emulsion solids, other separator sludges** and **pond sediments** continued to require the most additives.

### Storage

Instead of using positive and negative values to distinguish between wastes "removed from storage" and wastes "placed into storage," the 1989 data sheets had separate spaces for them. According to survey participants, **FCC catalyst or equivalent** had the most wastes removed from storage, followed by **DAF float** and **waste coke/carbon/charcoal**. In other streams, the amount removed from storage was 1 percent or less of the total waste generated (see Table 4, following page).

**Table 4**  
**Top-five Waste Streams Removed from Storage**  
(thousands of wet tons)

| Waste Stream               | Total Managed | From Storage | Percent of Total |
|----------------------------|---------------|--------------|------------------|
| FCC catalyst or equivalent | 5             | 31           | 17               |
| DAF float                  | 521           | 19           | 4                |
| Waste coke/carbon/charcoal | 137           | 8            | 6                |
| Nonleaded tank bottoms     | 164           | 2            | 1                |
| Other inorganic wastes NOS | 441           | <1           | <1               |

During the survey years, there has been a complete turnover in the streams with high volumes of waste removed from storage. None of the high-volume streams in the 1987-1988 survey -- **API separator sludge, pond sediments, contaminated soils/solids, other contaminated soil NOS and other catalysts NOS** -- were among the top-five in 1989. Three streams -- **DAF float, FCC catalyst or equivalent and other inorganic wastes NOS** -- had high volumes put in storage in 1987-1988 that were removed for final disposition in 1989.

The five streams with the most wastes put in storage in 1989 were **pond sediments, contaminated soils/solids** (with the highest one-time generation rate), **slop oil emulsion solids and biomass** (where high volumes were also reported in the 1987-1988 survey), and **API separator sludge** (see Table 5 below).

**Table 5**  
**Top-five Waste Streams Placed into Storage**  
(thousands of wet tons)

| Waste Stream              | Total Managed | From Storage | Percent of Total |
|---------------------------|---------------|--------------|------------------|
| Pond sediments            | 273           | 41           | 15.0             |
| Contaminated soils/solids | 496           | 17           | 3.0              |
| Slop oil emulsion solids  | 262           | 12           | 5.0              |
| Biomass                   | 655           | 2            | <1.0             |
| API separator sludge      | 425           | 1            | <1               |

#### **Total Quantity of Waste Managed**

As noted above, the total quantity of waste managed (input) is the sum of the estimated quantity of waste generated, treatment additives used, and net waste from storage. Table 6 (following page) presents these data for 1989 and compares the totals for the survey years. The amount of waste put in storage was greater than the amount of additives used, so the total amount of waste managed in 1989 was less than the amount of waste generated. The data also illustrate some of the fluctuations within individual waste streams noted above.

**Table 6**  
**Estimated Waste Quantities**  
(wet tons)

| Waste Stream                              | 1989 Input        |                     |                 | Total Amount Managed |                   |                   |
|-------------------------------------------|-------------------|---------------------|-----------------|----------------------|-------------------|-------------------|
|                                           | Amount Generated  | Treatment Additives | From Storage    | 1989                 | 1988              | 1987              |
| Aqueous wastes NOS                        | 11,100,221        | 0                   | 0               | 11,100,221           | 11,076,251        | 11,296,230        |
| Spent caustics                            | 715,502           | 20                  | 18              | 715,540              | 655,528           | 674,522           |
| Biomass                                   | 642,466           | 14,146              | (1,615)         | 654,977              | 748,589           | 720,355           |
| DAF float                                 | 495,790           | 6,403               | 18,605          | 520,798              | 660,514           | 653,899           |
| Contaminated soils/solids                 | 511,666           | 657                 | (16,812)        | 495,511              | 242,074           | 185,819           |
| Inorganic wastes NOS                      | 440,442           | 21                  | 346             | 440,809              | 220,503           | 322,702           |
| API separator sludge                      | 419,176           | 6,679               | (1,354)         | 424,501              | 430,042           | 563,733           |
| Other wastes NOS                          | 325,227           | 0                   | (15)            | 325,212              | 412,380           | 202,645           |
| Pond sediments                            | 312,892           | 1,479               | (41,154)        | 273,217              | 311,268           | 359,996           |
| Slop oil emulsion solids                  | 272,164           | 2,322               | (12,137)        | 262,349              | 213,551           | 211,854           |
| FCC catalyst/equivalent                   | 182,220           | 12                  | 3,148           | 185,380              | 189,191           | 170,853           |
| Nonleaded tank bottoms                    | 161,095           | 375                 | 2,230           | 163,700              | 130,851           | 217,869           |
| Waste coke/carbon/charcoal                | 129,218           | 0                   | 7,885           | 137,103              | 66,549            | 42,712            |
| Other separator sludges                   | 114,948           | 2,091               | (94)            | 116,945              | 110,251           | 82,797            |
| High pH/low pH waters                     | 91,261            | 252                 | 0               | 91,513               | 138,269           | 144,015           |
| Contaminated soils NOS                    | 53,294            | 0                   | (28)            | 53,266               | 76,698            | 88,002            |
| Waste sulfur                              | 51,706            | 0                   | (1)             | 51,705               | 22,714            | 17,299            |
| Waste amines                              | 51,052            | 0                   | 1               | 51,053               | 13,798            | 13,107            |
| Oily sludges/organic wastes NOS           | 47,108            | 101                 | 10              | 47,219               | 61,336            | 40,024            |
| Spent Stretford solution                  | 42,449            | 0                   | 0               | 42,449               | 49,264            | 34,881            |
| Hydroprocessing catalysts                 | 35,532            | 0                   | 255             | 35,787               | 36,630            | 39,415            |
| Other spent catalysts                     | 33,032            | 522                 | (158)           | 33,396               | 37,904            | 38,238            |
| Waste oils/spent solvents                 | 30,858            | 18                  | 20              | 30,896               | 7,346             | 4,453             |
| Oil contaminated waters (not wastewaters) | 28,861            | 43                  | 3               | 28,907               | 35,867            | 28,156            |
| Spent acids                               | 8,424             | 0                   | 0               | 8,424                | 160,399           | 130,436           |
| Spent sulfite solution                    | 7,937             | 0                   | 0               | 7,937                | 40,274            | 42,262            |
| Leaded tank bottoms                       | 4,347             | 13                  | 111             | 4,471                | 9,615             | 9,264             |
| Heat exchanger bundle cleaning sludge     | 2,450             | 6                   | (1)             | 2,455                | 4,643             | 2,977             |
| <b>Total</b>                              | <b>16,311,318</b> | <b>35,160</b>       | <b>(40,737)</b> | <b>16,305,741</b>    | <b>16,162,299</b> | <b>16,338,555</b> |

## Source Reduction

The 1989 survey tested several new questions to elicit information on source reduction -- about activities specifically undertaken to prevent waste generation, methods of measuring progress, and factors influencing progress. Responses to the survey indicated that while not all facilities have implemented source reduction activities, the activities undertaken affect nearly all waste streams.

In 1989, 55 refineries initiated source reduction activities involving all but four streams: **waste coke/carbon/charcoal, hydroprocessing catalysts, spent acids and spent sulfite solution**. Table 7 (below) presents the quantitative data for the waste streams with the largest reductions (for detailed data on all 24 waste streams with source reduction activities, see Appendix C).

The single largest reduction -- 56,000 wet tons for **slop oil emulsion solids** -- included a reduction of 41,900 wet tons in one refinery. The three streams with the most responses were RCRA-listed hazardous wastes: **API separator sludge, DAF float and slop oil emulsion solids**. More refineries -- 25 -- indicated source reduction for **API separator sludge** than any other stream.

**Table 7**  
**Summary of Source Reduction Achievements**

| Waste Stream               | Tons Reduced (thousands) | Number of Refineries |
|----------------------------|--------------------------|----------------------|
| Slop oil emulsion solids   | 56                       | 11                   |
| Other inorganic wastes NOS | 26                       | 5                    |
| DAF float                  | 17                       | 11                   |
| API separator sludge       | 13                       | 25                   |
| Biomass                    | 15                       | 5                    |
| Nonleaded tank bottoms     | 11                       | 7                    |
| Other separator sludges    | 10                       | 7                    |
| All others                 | 21                       | NA                   |
| <b>Total</b>               | <b>169</b>               | <b>NA</b>            |

The statistical validity of these estimates is unclear. While there probably was some under-reporting of potential source reduction practices (for example, housekeeping improvements), the methods used to quantify reductions suggest variation in the precision of the estimates.

Descriptions of methods used to estimate reductions were divided into six categories (see Table 8, following page). The most common method was comparing successive years (36 percent), followed by engineering (23 percent), waste management records (16 percent), and mass balance and other data based methods (each 3 percent).

**Table 8**  
**Methods of Calculating Source Reduction Achievements**

| Estimation Method        | Number of Responses | Percent of Total |
|--------------------------|---------------------|------------------|
| Subtract 1989 from 1988  | 16                  | 36               |
| Engineering estimate     | 10                  | 23               |
| Waste management records | 7                   | 16               |
| Mass balance             | 3                   | 7                |
| Other data based method  | 3                   | 7                |
| Other                    | 5                   | 11               |

The pattern of targeting hazardous waste streams for source reduction is repeated in Table 9 (following page). The 25 facilities that reported reducing generation of **API separator sludge** used all 6 source reduction methods; some facilities used several of them. **DAF float**, cited by 13 facilities, ranked second and included all source reduction methods except product reformulation. Refineries also performed a variety of source reduction activities for oily sludges, a category that includes the first nine streams listed in Table 9, and for **other wastes NOS**.

Source reduction activities (described in detail in Appendix C) included *equipment and technology modifications* for 15 streams -- for example, installing more efficient dewatering equipment, improving containment methods to reduce sewer infiltration, and improving individual process units such as sulfur recovery units. *In-process recycling* also occurred in 15 streams -- most often, recovering hydrocarbons from centrifuge or filter presses and the use of oily materials as feedstreams for cokers.

Refineries reported *improved housekeeping, employee training or inventory control* for 12 streams. With the exception of **aqueous wastes NOS**, those streams were subject to other source reduction methods as well. The most frequently cited were controlling coke fines and debris that wash into sewers, and removing obsolete chemicals.

Refineries attributed reductions in wastes generated in 10 streams to *procedure modifications*. While many reported discontinuing the use of sand to cover sewers for hot work, other procedural changes seemed tailored to individual facilities -- for example, closing storm water ponds and performing equipment change-outs less frequently.

**Table 9**  
**Summary of Source Reduction Activities**

| Waste Stream                          | Number of Responses | Method of Source Reduction |   |   |   |   |   |
|---------------------------------------|---------------------|----------------------------|---|---|---|---|---|
|                                       |                     | 1                          | 2 | 3 | 4 | 5 | 6 |
| API separator sludge                  | 39                  | ✓                          | ✓ | ✓ | ✓ | ✓ | ✓ |
| DAF float                             | 13                  | ✓                          | ✓ |   | ✓ | ✓ | ✓ |
| Slop oil emulsion solids              | 11                  | ✓                          | ✓ |   |   | ✓ | ✓ |
| Leaded tank bottoms                   | 5                   |                            |   | ✓ | ✓ | ✓ |   |
| Other separator sludges               | 7                   |                            | ✓ |   |   | ✓ | ✓ |
| Pond sediments                        | 4                   | ✓                          | ✓ |   |   |   | ✓ |
| Nonleaded tank bottoms                | 8                   | ✓                          | ✓ |   |   | ✓ |   |
| Waste oils/spent solvents             | 6                   |                            | ✓ |   | ✓ | ✓ | ✓ |
| Other oily sludges/organic wastes     | 4                   |                            |   |   |   | ✓ |   |
| Heat exchanger bundle cleaning sludge | 2                   |                            |   |   |   | ✓ |   |
| Contaminated soils/solids             | 3                   | ✓                          |   |   |   |   | ✓ |
| Waste sulfur                          | 1                   |                            | ✓ |   |   |   |   |
| Other contaminated soils NOS          | 4                   | ✓                          |   |   | ✓ | ✓ |   |
| FCC catalyst or equivalent            | 3                   | ✓                          |   |   |   |   | ✓ |
| Other spent catalysts                 | 1                   |                            |   |   | ✓ |   |   |
| Biomass                               | 3                   | ✓                          |   |   |   | ✓ | ✓ |
| Oil contaminated waters               | 2                   | ✓                          |   |   |   | ✓ |   |
| High pH/low pH waters                 | 2                   | ✓                          | ✓ |   |   |   |   |
| Spent Stretford solution              | 1                   | ✓                          |   |   |   |   |   |
| Aqueous wastes NOS                    | 1                   |                            |   |   |   |   | ✓ |
| Spent caustics                        | 2                   | ✓                          |   |   |   | ✓ |   |
| Waste amines                          | 1                   |                            | ✓ |   |   |   |   |
| Other inorganic wastes NOS            | 3                   | ✓                          |   |   |   | ✓ | ✓ |
| Other wastes NOS                      | 6                   | ✓                          | ✓ |   | ✓ | ✓ | ✓ |

**Methods of Source Reduction**

- 1 = equipment or technology modifications
- 2 = procedure modifications
- 3 = reformulation or design of products
- 4 = substitution of raw materials
- 5 = recycling within a process
- 6 = improved housekeeping, employee training or inventory control

Seven refineries reported *substitution of raw materials* and two reported *reformulation or design of products*. Given the lack of feed substitutes for crude oil -- and the performance characteristics petroleum fuels must meet -- these low frequencies were not surprising.

The substitutions cited most often were using phosphate instead of chromium in cooling towers and using less toxic degreasing agents. The phase-out of leaded gasoline, which had affected the lead in **API separator sludge** and **leaded tank bottoms**, was characterized as product reformulation.

Refineries that reported source reduction activities were asked their reasons for undertaking them (see Table 10 below). The most common motive was reducing treatment and disposal costs (cited by 84 percent of survey participants), followed by self-initiated review (67 percent), and regulatory requirements (44 percent).

Source reduction does not seem to be a reactive tactic; few refineries undertook it as a result of pressure from the public or environmental groups. Rather, it appears to be a proactive stance to allay public concern (cited by 31 percent of survey participants), and to reduce occupational liabilities and process costs.

**Table 10**  
**Incentives for Source Reduction Activities**

| Reasons                                      | Number of Responses | Percent of Total |
|----------------------------------------------|---------------------|------------------|
| Reduction of treatment/disposal cost         | 46                  | 84               |
| Self-initiated review                        | 37                  | 67               |
| Regulatory requirement for waste             | 24                  | 44               |
| Occupational safety                          | 18                  | 33               |
| Concern over public reactions                | 17                  | 31               |
| Other process cost reduction                 | 25                  | 26               |
| Pressure from public or environmental groups | 5                   | 9                |
| Other                                        | 4                   | 7                |

### **Waste Management**

The term "waste management" applies to a range of practices that "eliminate" wastes, residuals and secondary materials after they have been treated with additives or moved into -- or out of -- storage. For purposes of this survey, these practices are classified as *recycling*, *treatment*, *land treatment*, and *disposal*.

### **Recycling**

When waste has been created, the preferential method to eliminate it is through recycling. Such reuse of materials obviates the need for further handling, treatment, and disposal. Petroleum refineries have long used their oil recovery systems to recycle oily materials. Much of this recycling occurs in-process before the materials

are considered wastes. For example, oil is routinely skimmed from the surface of water in wastewater treatment systems -- before the water is treated, discharged or considered a waste. As a result, many of these routine practices are not captured by this survey. Like the 1987-1988 survey, it documented a broader range of recycling activities -- in particular, the industry's extensive reuse of chemicals and spent catalysts.

In 1989, petroleum refineries recycled 1.4 million wet tons of waste -- about 9 percent of the total amount of waste managed. After adjustment to correct for the outliers, the proportion of recycled wastes is 26 percent -- slightly more than the 21 percent observed in 1987 and the 23 percent observed in 1988.

To some degree, petroleum refineries recycle all 28 waste streams (see Appendix D, Table D-1). The recycled quantity ranges from negligible for **aqueous wastes NOS** (the outlier category) to a high of nearly 600,000 wet tons -- 84 percent -- for **spent caustics**. In addition, survey participants reported recycling more than 78 percent of **spent sulfite solution, hydroprocessing catalysts, waste oils and spent solvents**, and **waste coke/carbon/charcoal**. In 14 streams, recycling eliminated 20 percent or more of the wastes managed.

Table 11 (below) summarizes the recycling practices used during the survey years. In 1989, refineries used cokers and crude units for slightly more than one-quarter of their recyclable materials. Over time, there has been a small -- but consistent -- increase in recycling via cokers and crude units. Though reclamation/regeneration was used for some 150,000 additional wet tons of waste in 1989, it accounted for 44 percent of total recycling activity -- a comparable level to prior years. Use of recycling devices in the "other" category -- desalters, sour water strippers and industrial furnaces -- seemed to dip slightly in 1989.

**Table 11**  
**Summary of Recycling Practices**  
(thousands of wet tons)

| Method of Recycling      | 1989         |            | 1988         |            | 1987         |            |
|--------------------------|--------------|------------|--------------|------------|--------------|------------|
|                          | Tons         | Percent    | Tons         | Percent    | Tons         | Percent    |
| Coker                    | 231          | 17         | 186          | 16         | 148          | 14         |
| Crude unit               | 125          | 9          | 85           | 7          | 68           | 6          |
| Reclamation/regeneration | 611          | 44         | 434          | 38         | 447          | 42         |
| Other                    | 408          | 30         | 474          | 41         | 410          | 38         |
| <b>Total</b>             | <b>1,376</b> | <b>100</b> | <b>1,179</b> | <b>100</b> | <b>1,073</b> | <b>100</b> |

Table 12 (page 24) shows the recycling methods reported for different waste streams (for detailed data, see Appendix D, Table D-2). *Cokers* and *crude units* received oily materials from several streams: **DAF float, API separator sludge, nonleaded tank bottoms and slop oil emulsion solids**. In 1989, cokers also received substantial

amounts of **biomass** and **nonleaded tank bottoms** that were not high volume recycling streams in earlier years. Similarly, crude units received **other separator sludges** not previously identified as significant sources of recyclable materials.

**Spent caustics, waste coke/carbon/charcoal, hydroprocessing catalysts and FCC catalyst or equivalent** remained high volume streams for *reclamation/regeneration*. **Waste oils/spent solvents** was a new high volume stream for this recycling method in 1989. (By contrast, spent acids, slop oil emulsion solids and DAF float were high volume streams for this method in 1987-1988, but not in 1989.)

Use of *other* recycling methods increased in several streams in 1989. In descending order, they were **spent caustics, slop oil emulsion solids, and waste coke/carbon/charcoal** (used in industrial furnaces).

These aggregate statistics do not take into account that the proportion of waste recycled by a particular method is a potentially biased measure -- for example, large refineries create more waste and may manage it differently. In other words, the proportion of waste handled in a certain way may not reflect how frequently the industry as a whole uses that method.

Thus, a second analysis of the frequency of responses was undertaken in 1989. These frequency counts (see Appendix D, Table D-3) are the actual number of refineries using each method; no attempt was made to extrapolate them for the entire population. Thus, they differ substantially from the extrapolations used to estimate the amount of wastes generated and how they are managed industry-wide.

The number of practices cited less than 10 times suggests considerable variation in recycling methods among refineries. There were just 8 streams where the recycling practices appear somewhat standardized, including reclamation of **hydroprocessing catalysts** (54 responses), **spent caustics** (23 responses), **other spent catalysts** (22 responses), and **FCC catalysts** (15 responses). Twenty-seven refineries reported reclamation of **waste oils/spent solvents**, but the remaining refineries reported quite diverse recycling practices: 10 returned them to crude units, 4 used them in industrial furnaces, 5 undertook regeneration, and 3 employed other methods.

**Table 12**  
**Estimated Quantities of Recycled Wastes**  
(thousands of wet tons)

| Recycling Method/<br>Waste Stream | 1989         | 1988         | 1987         |
|-----------------------------------|--------------|--------------|--------------|
| <b>Coker</b>                      |              |              |              |
| DAF float                         | 79           | 45           | 82           |
| Biomass                           | 59           | 27           | 25           |
| API separator sludge              | 55           | 73           | 14           |
| Nonleaded tank bottoms            | 23           | 7            | -            |
| Slop oil emulsion solids          | 9            | 23           | 19           |
| All others                        | 6            | 11           | 8            |
| <b>Total</b>                      | <b>231</b>   | <b>186</b>   | <b>148</b>   |
| <b>Crude unit</b>                 |              |              |              |
| DAF float                         | 34           | 19           | 16           |
| Other separator sludges           | 26           | 13           | 8            |
| API separator sludge              | 24           | 13           | 18           |
| Nonleaded tank bottoms            | 18           | 13           | 11           |
| Slop oil emulsion solids          | 17           | 27           | 12           |
| All others                        | 6            | -            | 3            |
| <b>Total</b>                      | <b>125</b>   | <b>85</b>    | <b>68</b>    |
| <b>Reclamation/regeneration</b>   |              |              |              |
| Spent caustics                    | 459          | 243          | 262          |
| Waste coke/carbon/charcoal        | 40           | 43           | 27           |
| Hydroprocessing catalysts         | 32           | 21           | 26           |
| FCC catalyst or equivalent        | 27           | 7            | 11           |
| Waste oils/spent solvents         | 18           | -            | -            |
| All others                        | 35           | 120          | 212          |
| <b>Total</b>                      | <b>611</b>   | <b>434</b>   | <b>447</b>   |
| <b>Other*</b>                     |              |              |              |
| Spent caustics                    | 138          | 254          | 232          |
| Slop oil emulsion solids          | 63           | -            | -            |
| Waste coke/carbon/charcoal        | 67           | -            | -            |
| All others                        | 141          | 220          | 178          |
| <b>Total</b>                      | <b>409</b>   | <b>474</b>   | <b>410</b>   |
| <b>Grand total</b>                | <b>1,376</b> | <b>1,179</b> | <b>1,073</b> |

\* Includes materials sent to desalters, industrial furnaces, sour water strippers, and unspecified practices.

**API separator sludge and DAF float** -- two streams with constellations of responses for cokers and crude units -- show the difficulty of interpreting the relationship between frequency and quantity. For **API separator sludge**, 15 refineries reported recycling via cokers and 22 reported recycling via crude units. A comparison of actual quantities of waste recycled (see Appendix D) shows that cokers accounted for 55,000 tons (about 65 percent) and crude units 24,000 tons. Conversely, 17 refineries sent 79,000 tons of **DAF float** to cokers while 9 refineries sent 34,000 tons to crude units.

The final recycling variable was *location*. Table 13 (below) shows the distribution of on-site and off-site activities for streams where recycling eliminated more than 10,000 wet tons of waste. **Spent caustics** -- the highest volume stream -- was the only stream in which roughly equivalent amounts were handled on-site and off-site. Seven streams containing usable hydrocarbons -- **DAF float, slop oil emulsion solids, API separator sludge, nonleaded tank bottoms, other separator sludges, contaminated soils/solids and other oily sludges/organic wastes NOS** -- were recycled on-site almost exclusively, as was **biomass**. Five streams -- consisting of spent chemicals, chemical mixtures, and catalysts -- were mostly recycled off-site.

**Table 13**  
**Location of Recycling Activities**  
(thousands of wet tons)

| Waste Stream                          | Quantity | Percent On-Site | Percent Off-site |
|---------------------------------------|----------|-----------------|------------------|
| Spent caustics                        | 598      | 55%             | 45%              |
| DAF float                             | 132      | 100             | 0                |
| Waste coke/carbon/charcoal            | 107      | 0               | 100              |
| Slop oil emulsion solids              | 93       | 95              | 5                |
| API separator sludge                  | 84       | 99              | 1                |
| Biomass                               | 61       | 100             | 0                |
| FCC catalyst or equivalent            | 51       | 6               | 94               |
| Nonleaded tank bottoms                | 43       | 100             | 0                |
| Hydroprocessing catalysts             | 32       | 0               | 100              |
| Waste sulfur                          | 30       | 0               | 100              |
| Other separator sludges               | 27       | 100             | 0                |
| Waste oils/spent solvents             | 24       | 11              | 89               |
| Contaminated soils/solids             | 23       | 95              | 5                |
| Other oily sludges/organic wastes NOS | 11       | 100             | 0                |

### Treatment

In the waste management hierarchy, treatment is a tertiary choice for the handling of wastes. The treatment methods refineries use include separation procedures -- to concentrate dilute wastes and other chemicals -- and physical, thermal, and stabilization techniques. (Incineration is classified as a treatment method; the ash that remains is designated a residue for disposal.) Though land treatment was classified as a treatment method during the data collection phase of the survey, findings on it are presented separately in a later section of this report -- reflecting its unique status as a means of both treatment and disposal.

In 1989, petroleum refineries reported treatment of 1.51 million tons of waste (for a breakdown by waste stream, see Appendix D, Table D-4). This was more than the 1.45 million tons reported in 1988 and less than the 1.58 million tons treated in 1987. After adjusting for the outliers who generated large amounts of **aqueous wastes NOS**, the proportion of waste eliminated by treatment was 28 percent of the 1989 total -- the same share as in 1988 and a slightly smaller share than the 31 percent in 1987.