Environmental Performance Indicators:

METHODS FOR MEASURING POLLUTION PREVENTION

STEP
Strategies for Today's Environmental Partnership

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.

API ENVIRONMENTAL MISSION AND GUIDING ENVIRONMENTAL PRINCIPLES

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:

- To recognize and to respond to community concerns about our raw materials, products and operations.
- 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.

Environmental Performance Indicators:

Methods for Measuring Pollution Prevention

Health and Environmental Affairs Department

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TABLE OF CONTENTS

LIST OF TABLES

FIGURES

EXECUTIVE SUMMARY

This report identifies a variety of methods for demonstrating performance and progress towards pollution prevention in each sector of the petroleum industry. The tools discussed here are based on pollution prevention techniques that are already in use at companies or facilities, or that have been used in other industrial sectors in similar situations.

API invites its membership to review these measures as an aid for developing internal pollution prevention programs, or to measure the effects of programs already in place. Application of these measures may include the following benefits:

- *Support for internal planning or tracking of pollution prevention efforts.* Where companies have put programs in place, these measurement techniques may help produce uniform data on program effectiveness.

- *Support for management performance goals.* Where companies have adopted pollution prevention goals as performance targets for managers, these tools may be applied to evaluate management performance.

- *Public discussions.* Because pollution prevention is a topic of strong public interest, companies may use the methods in this document to measure pollution reductions in new ways to increase the public's understanding of complex issues. Where pollution prevention programs are already in place, companies may find the data generated by these tools to be valuable for outreach on environmental issues.

The various measurement parameters that were identified in this study were organized into five categories, ranging in nature from least quantitative to most quantitative, and are described below.

Program-oriented Measurements. A simple indicator of pollution prevention activity is the presence of pollution prevention or waste minimization programs to reduce waste. While these programs may contain specific elements that actually *quantify* wastes reduced, the presence of the program itself is the element described in this category.

Activity-based Measurements. Activity-based measures are semi-quantitative measures of pollution prevention efforts that are related to equipment or procedures already in use. The activities use specific processes or operating practices that may be part of an overall program to reduce a particular waste stream or chemical release. In order to use an activity-based measurement, it is necessary to have specific information on the benefits of particular processes or equipment. The use of solvent-free paint stripping processes and the use of mixers in storage tanks to prevent the depositing of settleable solids are examples of processes and equipment that can be used to develop activity-based measurements.

Mass-based Measurements. Mass-based measurements attempt to provide quantitative information on the amount or mass of waste or residual materials produced or managed. Mass-based measurements can be exact measures achieved by weighing individual loads of material or they can be estimates supported by professional judgements and/or mathematical assumptions. Because estimation accuracy can vary widely, mass-based measurements must be used with care when comparing a single facility year-to-year or when comparing two different facilities. When collected periodically and consistent methods are used, however, mass-based measurements can provide an indication of the performance of a facility. The chemical quantities reported as estimated releases in the Toxics Release Inventory and the quantities of residual streams reported as generated and managed in API's Refining Survey are examples of mass-based measurements.

Normalized Efficiency Measurements. Normalization provides a method of relating one variable to another item. By doing this, facilities of different sizes can be compared to each other on a "per unit" basis to determine the efficiency of their respective practices. Normalization also minimizes some of the problems that can occur when reviewing operations at one facility over time. Because one parameter is indexed against another variable (e.g., an activity, production) for a similar period of time, the performance or efficiency of the activity can be determined, independent of changes in operating rates.

Measures of the efficiency of pollution prevention activities can be normalized or indexed against a variety of related measures. Three methods of normalizing are discussed in this report:

- By activity/operation
- By production
- By residual generation

Concentration-based Measurements. In chemistry, concentration refers to the amount of one substance contained in another substance. Concentration measures are typically expressed as units of weight or mass by volume or capacity (e.g., mg/kg, mg/l, mg/cm^3). Those typically used in the petroleum industry include the concentrations of petroleum hydrocarbons in drilling muds destined for disposal, concentrations of phenols in the effluent process water in the refinery, and concentrations of chromium-based compounds in cooling tower blowdown.

CONCLUSIONS

While no one measurement can be considered to accurately reflect pollution prevention performance, it does not necessarily follow that the appropriate course is to mount a multi-dimensional measurement project. It generally holds that several measures are better, but companies must choose a complement of measures that make sense--both economically and environmentally--to them.

Ultimately, the determination of the most appropriate parameters for measuring pollution prevention progress must be made at the company or facility level, based on knowledge of site-specific operations and conditions, with consideration given to available resources and to merits and limitations of the measurement technique itself.

INTRODUCTION

Why Pollution Prevention??

Pollution prevention has become the preferred option for dealing with residual materials and wastes. Under a pollution prevention scenario, if a waste is reduced or eliminated at the source or recycled, it requires no further management and will not pose a threat to human health or the environment. In addition, future liability for potential cleanup from waste treatment and disposal is eliminated. Despite its broad use, pollution prevention is a term with no uniformly accepted definition. It is usually defined in terms of the environmental management hierarchy (sometimes known as the waste management hierarchy) -- source reduction, recycling, treatment, and disposal -- but there is disagreement over which elements of the hierarchy it spans. Some see pollution prevention exclusively as source reduction or more strictly, product substitution or toxics use reduction, whereas others are willing to include some types of recycling. Few are willing to include treatment.

Pollution prevention should be viewed as a dynamic process that includes the idea of continuous improvement, such as movement up the environmental management hierarchy. EPA Administrator Carol Browner endorsed this hierarchical approach to reducing risk in her Pollution Prevention Policy Statement of June 15, 1993:

> [P]ollution prevention is not the only strategy for reducing risk but it is the preferred one. Environmentally sound recycling shares many of the advantages of prevention--it can reduce the need for treatment and disposal, and conserve energy and natural resources. Where prevention or recycling are not feasible, treatment followed by safe disposal as a last resort will play an important role in achieving environmental goals.

API's definition also recognizes the need for a complementary set of strategies, referencing the principles of waste minimization (from the Hazardous and Solid Waste Amendments of 1984), and explicitly addresses the concern that pollutants have been transferred from one medium to another under the single-media statutes:

> Pollution prevention is a multi-media concept that reduces or eliminates pollutant discharges to air, water, or land and includes the development of more environmentally acceptable products, changes in processes and practices, source reduction, beneficial use and environmentally sound recycling.

Although pollution prevention is usually thought of as applying to manufacturing, it is relevant to all industries, including agriculture, energy, and transportation. Successful implementation of pollution prevention, however, requires a broad based cultural change: those who generate residual materials[1]

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[1] API uses the term "residual materials or residuals" to refer to what many call "wastes." This terminology reflects petroleum industry practices--the use of many of these materials as feedstocks or for recycling, reuse, and reclamation. This change helps to reconcile the utilization of these materials in the petroleum industry with the regulatory usage of the term "waste."

and waste--even consumers--must anticipate and internalize the costs of this pollution, and devote energy to determining cost-effective means to reduce residual materials and waste at the source.

State and local governments moved quickly to enact pollution prevention legislation that is still under debate within the federal sector. By June 1993, 30 states had enacted some type of pollution prevention legislation; 20 states included facility planning provisions. As a result of these initiatives, many facilities are now required to develop plans for reducing waste and periodic reports on the progress made toward implementing such plans.

The petroleum industry itself is moving towards a self-assessment process that will aid companies in monitoring their environmental progress. In 1990, the American Petroleum Institute (API) added a set of Guiding Environmental Principles to its bylaws. In the following year, API endorsed in principle a process to demonstrate adherence to the Guiding Environmental Principles that include management practices, company self-assessment to monitor progress in implementing the management practices, and resource materials that companies may find helpful in implementing the management practices.

To determine which pollution prevention practices are most appropriate, API encourages the use of facility-specific assessments followed by the development of plans that include goals for attainment over time. This strategy allows for maximum flexibility and consideration of site-specific conditions to be factored into the planning process.

Measuring Performance and Progress: The Driving Forces

Pollution prevention can be achieved through a variety of practices. Regardless of the specific techniques employed, a key aspect of pollution prevention is how to measure it to determine how successfully implementation is being achieved. Quantification of pollution is central to this activity.

Quality management theory identifies three generic forms of metrics:

- **stakeholder metrics** taken at the "end" or "side" of a process at the interface with the external environment and/or marketplace (e.g., analytic measures used in risk assessments; public opinion polls)

- **results metrics** that quantify the results desired by stakeholders; and

- **process metrics** that are necessary to assure that the process in under control.

These three metrics form a logical hierarchy: if the process is under control, preferred results will be attained; if the preferred results are attained, stakeholder needs will be met.

Metrics are useful tools. They can provide information on progress and business objectives and, for those factors that are within one's sphere of influence, they track the quality of business decisions and the need to allocate additional resources to improve practices. It is crucial to note that some metrics are useful for explaining results, but these parameters may not be anything that one has much influence over. Other metrics may also measure improvement, but are of outcomes that are subject to our rational control.

The Toxics Release Inventory (TRI), compiled under section 313 of the Emergency Planning and Community Right To Know Act (EPCRA), also known as Title III of the Superfund Amendments and Reauthorization Act (SARA), is frequently cited as a tool for assessing progress towards pollution prevention. Although it was not developed specifically for this purpose, it is the only database that is multi-media in its scope and organization. The TRI documents the annual releases of some 300 chemicals and chemical categories as reported by the manufacturing sector. Beginning in 1992, facilities that report under the TRI are required to report on an expanded set of elements that include the quantities of chemicals entering residual streams prior to any recycling, treatment, or disposal.

The Pollution Prevention Task Force of the American Petroleum Institute initiated this project with the primary purpose of identifying other methods of measuring progress towards pollution prevention. This was born out of recognition that when new measurements like the TRI are established, considerable care must be exerted to assure that the appropriate aspects of an operation are subjected to scrutiny. Are the *right* things being measured? Are *all* the right things being considered? Is there an appropriate target performance level?

In light of these concerns, the objectives of this project were defined as follows:

- to determine what measurable parameters could be used or need to be developed to demonstrate progress towards pollution prevention in the petroleum industry and

- to determine what methods could be used to measure the parameters.

The project execution strategy included: (1) the identification of the most relevant available information sources used by EPA and industry in defining pollution prevention and the measurement of progress towards that end; (2) the development of a list of measurable parameters that could be used to demonstrate progress towards pollution prevention; (3) the determination of measurement methods that can be applied to the parameters; and (4) the organization of the information acquired in steps (1) through (3) into a format that would be most useful to petroleum industry facilities.

This report identifies a variety of methods for demonstrating performance and progress towards pollution prevention in each sector of the petroleum industry. The tools discussed here are based on pollution prevention techniques that are already in use at companies or facilities, or that have been used in other industrial sectors in similar situations.

API invites its membership to review these measures as an aid for developing internal pollution prevention programs, or to measure the effects of programs already in place. Application of these measures may include the following benefits:

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MEASUREMENT PARAMETERS

There are many ways to approach the measurement of pollution prevention progress. The lists of methods presented in this document contain numerous examples, but are not exhaustive. Most are based on approaches already in use at oil companies or are in use in other industrial sectors with similar processes. Some are original ideas suggested through the review of the literature on pollution prevention. In determining which approaches are appropriate, the following questions should be considered:

- *What is to be measured?* The ideal in environmental risk management is to measure end-points, such as actual human exposure to carcinogens. This is not always possible or practical. Frequently there are intermediate end-points that, through modelling and other estimation techniques, may be used to arrive at the desired end-point.

- *How accurate does the measurement have to be?* Accuracy requirements should be a function of the intended use of the data. Because of the implications for reporting burden and measurement costs, the necessary accuracy of the measurement should be carefully considered. Does the measurement need to be accurate only as to the direction of trends, within an order of magnitude, within a few percent, or within a few tenths of a percent? Can the parameter be estimated through models or must it be measured directly? How many sampling points are needed for the desired accuracy?

- *Do measurement techniques exist?* Once a statistic is defined, is there more than one acceptable way to estimate or measure the parameter?

The various measurement parameters that were identified in this study were organized into five categories, ranging in nature from least quantitative to most quantitative:

1) Program-oriented Measurements
2) Activity-based Measurements
3) Mass-based measurements
4) Concentration-based Measurements
5) Normalized Efficiency Measures
    a) By Activity/Operation
    b) By Production
    c) By Waste Generation

Activity measurements, such as documenting the consistent use of Class II well injection (an indicator of reliable reinjection), are sometimes more useful than quantitative calculations, especially where waste generation rates are determined by external factors like well depth, crude oil quality, or unique reservoir characteristics. Where quantitative statistics are calculated, it can be more useful to define the parameters by which a statistic is normalized (e.g., by product, barrel throughput, or time interval).

It is important to note that across categories listed above, there is an inverse relationship between the ease with which data can be acquired and the amount of information provided by the parameter. For example, program indicators (e.g., the existence of a pollution prevention or recycling program), are perhaps one of the easiest statistics to acquire. However, knowledge of the number of programs that exist within a company or facility provides only a limited amount of information on performance and does not provide any indication of the types of activities pursued by the facility or the quantities of waste being reduced by implementation of any program.

Mass-based measurements, such as those gathered under the TRI or in the API Refining Survey, require more sophisticated data collection efforts, but can also provide quantitative information about chemical releases or waste stream generation. Mass-based measurements do not, however, account for production fluctuations that may influence generation and release quantities. Mass-based measurements must be normalized by some type of facility operations parameter (e.g., activity, production, throughput, or waste generation) to indicate the efficiency of pollution prevention operations. Collection of this type of statistic is likely to be more resource intensive.

It is also important to recognize that pollution prevention progress, regardless of the type of parameter, inherently calls for periodic measurements. Comparisons are made from one point in time to another, typically annual cycles. Depending on the type of parameter considered, progress can be represented by either increases or decreases. For example, when using qualitative parameters such as program or activity measures, increases in the number or types of programs or activities would be considered improvements. Reductions constitute progress for most mass-based measurements, such as annual comparisons of the emissions or releases to the environment.

The following sections of this report provide a more detailed description for each of the five categories of measurements, highlighting the benefits and limitations of each, and presents specific examples.

Category 1. Program-oriented Measurements

Description. A simple indicator of pollution prevention activity is the presence of pollution prevention or waste minimization programs to reduce waste. While these programs may contain specific elements that actually *quantify* wastes reduced, the presence of the program itself is the element described in this category.

Many companies have instituted programs aimed at preventing pollution and all generators of over 1000 kilograms per month of hazardous waste are required to have a waste minimization program in place[2]. As EPA recognized in its Interim Final Guidance to Hazardous Waste Generators on the Elements of a Waste Minimization Program (Fed. Reg. 31114 - 31117; May 23, 1993) facilities require flexibility in designing and implementing programs[3]. Some are formal corporate-wide programs, while others are more informal, facility-specific programs. Programs may target a variety of releases and phase in other elements over time. For example, a program may be initiated to reduce hazardous wastes and then expand to cover non-hazardous wastes. Releases may also be targeted by medium (i.e., air, water, or land) and prioritized to place initial efforts on those posing the greatest risk. Programs may also target very specific wastes such as used motor oil or office paper.

Advantages. Program-oriented measures can be used anywhere in a company or facility. The information necessary is relatively easy to collect and can be obtained quickly at relatively low cost.

Limitations. Program measurements are considered indicators of pollution prevention progress in that they provide only limited information on the type of activities being pursued, but they alone do not quantify the amount of waste reduced or the performance of the programs involved.

Examples. Used oil from motor vehicle fleets is typically a waste stream generated by all sectors of the petroleum industry. Recycling of waste oil and recovery of oil from used oil are practices that are both beneficial to the environment as well as energy efficient. The goal of such a program would be to ensure that virtually all used oil is properly handled. Determining the percent of vehicles covered by recycling programs is an alternative way to measure the presence of a used oil program.

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[2] To comply with requirements of sections 3002(b) and 3005(h) of the Solid Waste Disposal Act as amended by the Resource Conservation and Recovery Act and the Hazardous and Solid Waste Amendments of 1984, "large quantity" generators of hazardous waste must certify that they have a *program in place* "to reduce the volume and toxicity of hazardous waste generated to the extent economically practicable."

[3] In its guidance document, EPA specifies that waste minimization programs should have each of the following six elements: 1) top management support; 2) characterization of waste generation and management costs; 3) periodic waste minimization assessments; 4) appropriate cost allocation; 5) encouragement of technology transfer; and 6) program implementation and evaluation. Generators, however, are allowed flexibility in determining the number and types of activities to implement in each of the six program areas. The Guidance document provides many examples of waste minimization activities.

Table 1 below lists other examples of program-oriented measurements.

Table 1. Examples of Program-Oriented Measurements

Program	Description of Measurement	Sector	Data Requirements	Comments
Hazardous waste monitoring	# facilities with program/ Total # facilities generating hazardous waste	Refining, Marketing	Minimal	Company records on hazardous wastes already exist
Non-hazardous waste monitoring	# facilities with program/ Total # facilities generating non-hazardous waste	All	Minimal	Records on non-hazardous wastes may already exist to comply with State or local requirements
Used motor oil recycling	# facilities with program/ Total # facilities generating or processing used motor oil	All, especially Marketing	Minimal	Companies have already initiated used oil recycling programs at service station outlets
Office paper recycling	# offices with program/ Total # offices in company	All	Minimal	Office workers can be contacted at different facilities for a quick confirmation of program status
TRI releases	# facilities with program/ Total # facilities reporting TRI releases	Refining, possibly Marketing	Minimal	May refer to sectors other than refining if TRI SIC code list is expanded. Because of EPA definition of "facility," some refineries already report releases from adjacent marketing facilities

Category 2. Activity-based Measurements

Description. Activity-based measures are semi-quantitative measures of pollution prevention efforts that are related to equipment or procedures already in use. The activities use specific processes or operating practices that may be part of an overall program to reduce a particular waste stream or chemical release. In order to use an activity-based measurement, it is necessary to have specific information on the benefits of particular processes or equipment. The use of solvent-free paint stripping processes and the use of mixers in storage tanks to prevent the depositing of settleable solids are examples of processes and equipment that can be used to develop activity-based measurements.

Advantages. Activity-based measurements are similar to program-based measurements, but provide slightly more information. With activity-based measures, and the knowledge of an approximate amount of waste reduced by each activity, companies can move towards developing more quantitative measures of residual reduction. Since activity-based measures relate to equipment or procedures actually installed and in use, there is a greater presumption of concrete reduction in waste measured by this tool.

Limitations. Most of these measurements, while simple technically, may require new data collection.

Examples. The phaseout of chromium-based corrosion inhibitors in refinery cooling towers is an example of an activity-based measure. The measure involves the choice of which specific chemical that will ultimately be in a waste stream. A tally of the number of cooling towers within a company that have had chromium-based inhibitors replaced with less toxic substances provides an indication of progress on preventing pollution by a particular compound. In addition, if the approximate amount of chromium typically used in a cooling tower is known, it is possible to estimate the total amount of chromium reduced through initiation of the substitution.

An example of an activity-based measure in the E&P sector of the industry is the use of a multi-compartment, managed reserve pit system. A managed pit system enables a facility to segregate wastes generated in drilling operations. The system involves segregating different drilling residuals, such as drilling fluids contaminated by salt formation or oil-based muds used in a portion of a drilling job, from other drilling fluids and rainwater. This technique has been tried experimentally; it has reduced the volume of residuals requiring offsite disposal or other special management, and may even reduce the amount of drilling fluids required.

Table 2. Examples of Activity-Based Measurements

Activity	Description of Measurement	Sector	Data Requirements	Comments
Conversion of non-segregated sewers to segregated sewers	# of processes with dedicated sewer lines/Total # processes at all facilities	Refining	Significant new data needed	Measure requires capital investment; pay-back time varies from site to site.
Use of methods to reduce wastes from sandblasting	# of facilities with programs to reduce sandblasting fines/ Total refineries reporting	Refining	Significant new data needed	Inappropriate to measure progress quantitatively. Count of methods in place will indicate progress.
Use of street sweepers	# facilities with street sweepers/Total # facilities	Refining	Some additional data needed	Progress tracked indirectly by measuring contamination in facility discharge water
Frequency of tank cleanings	# times a tank must be cleaned/year	Marketing	Some additional data needed, procedures known	Frequency data can be used to estimate/monitor generation of solvent waste. Tank cleaning on "as needed" basis can reduce solvent waste.
Use of domes in floating roof tanks	# floating roof tanks with domes/Total # of floating roof tanks	Marketing	Significant new data needed	Measure may require major capital investment.
Substitution of soaps used to wash down terminal pads	# terminal pads using low toxicity soaps/Total # terminal pad operations	Marketing	Significant new data needed	Substitution for a less toxic soap solution should not reduce cleaning quality.
Number of USTs with secondary containment	# USTs with secondary containment/Total # USTs in use	Marketing	Minimal	Company records on upgrading of petroleum UST systems contain most information
Use of diesel oil-based drilling muds	# wells drilled using diesel oil-based drilling muds/ Total # wells completed in a given year	E&P	Significant new data needed	Measures reuse or replacement of diesel oil-based muds with other lubricants. Purchases of lubra beads and gilsonite - based additives may provide an indirect indication of increasing replacement.

Category 3. Mass-based Measurements

Description. Mass-based measurements attempt to provide quantitative information on the amount or mass of waste or residual materials produced or managed. Mass-based measurements can be exact measures achieved by weighing individual loads of material or they can be estimates supported by professional judgements and/or mathematical assumptions. Because estimation accuracy can vary widely, mass-based measurements must be used with care when comparing a single facility year-to-year or when comparing two different facilities. When collected periodically and consistent methods are used, however, mass-based measurements can provide an indication of the performance of a facility. The chemical quantities reported as estimated releases in the Toxics Release Inventory and the quantities of residual streams reported as generated and managed in API's Refining Survey are examples of mass-based measurements.

Advantages. Mass-based measurements provide more detail than program or activity based measures on residuals handled by a facility. In addition, when combined with other available facility data, mass-based measurements can be used to determine the efficiency of operations. For example, waste inventories taken at a facility for several years can be combined with production levels or throughput values to indicate the degree of efficiency achieved over time.

Limitations. The most serious limitation of mass-based measurements reflects the fact that frequently these measures are estimates. The precision of any estimate is related to the accuracy of its underlying assumptions. Moreover, when comparing mass-based estimates, either between two facilities or across time at the same site, consideration must be given to the comparability of the underlying assumptions for each measure. If the methods for deriving the estimates are inconsistent, then the data are not truly comparable. In addition, mass-based measurements alone do not account for changes in production rates, which may be dependent upon product demand, type of crude processed, changes in process efficiency, or other factors that influence waste generation rates. Finally, mass-based measurements may require a resource intensive effort in order to obtain the data.

Examples. The API Refining Survey (formerly know as the Solid Waste Survey) was designed to collect mass-based measurements of residuals generated by U.S. refineries and how these materials are managed. Refineries report the wet tons generated of each of 28 residual streams and categorize the disposition of the material according to the environmental management hierarchy (i.e., source reduction, recycling, treatment, and disposal) indicating the amount of material present at each step of the hierarchy. Data are collected annually by API, aggregated and published in annual reports[4].

As data are collected, comparisons in quantities reported for various years can be compared to determine performance over time (See Table 3). These mass-based measurements can be used to assess pollution prevention performance at three levels: the aggregate provides an indication of *industry-wide* progress; the data developed by a refinery can be used to demonstrate *facility-specific* improvements; and companies can aggregate the data from their respective refineries to create a

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[4] See *The Generation and Management of Waste and Secondary Materials In the Petroleum Refining Industry: 1987-1988*, API Publication No. 849-300000, February 1991, and *Generation and Management of Wastes and Secondary Materials: Petroleum Refining Performance 1989 Survey*, API Publication No. 849-30300, June 1992.

corporate profile of pollution prevention efforts. The residual generation quantities can also be combined with other parameters, such as annual crude throughput, to establish degrees of efficiency of the refining process.

In addition to the data on residuals generated, the data collected on how residuals are managed can be used to demonstrate pollution prevention performance. Specifically, the quantities of residuals recycled, treated and disposed can be plotted to illustrate how management methods change over time. Figure 1 depicts how the management of K-wastes have changed from 1987 to 1989. As indicated, the percent of material undergoing recycling and treatment have increased over time, while the proportion undergoing land treatment and disposal have decreased over time. For a facility or company, data for each residual stream or a facility or company aggregate could be plotted in this way to demonstrate pollution prevention performance.

Figure 1.
Management of RCRA K-Wastes

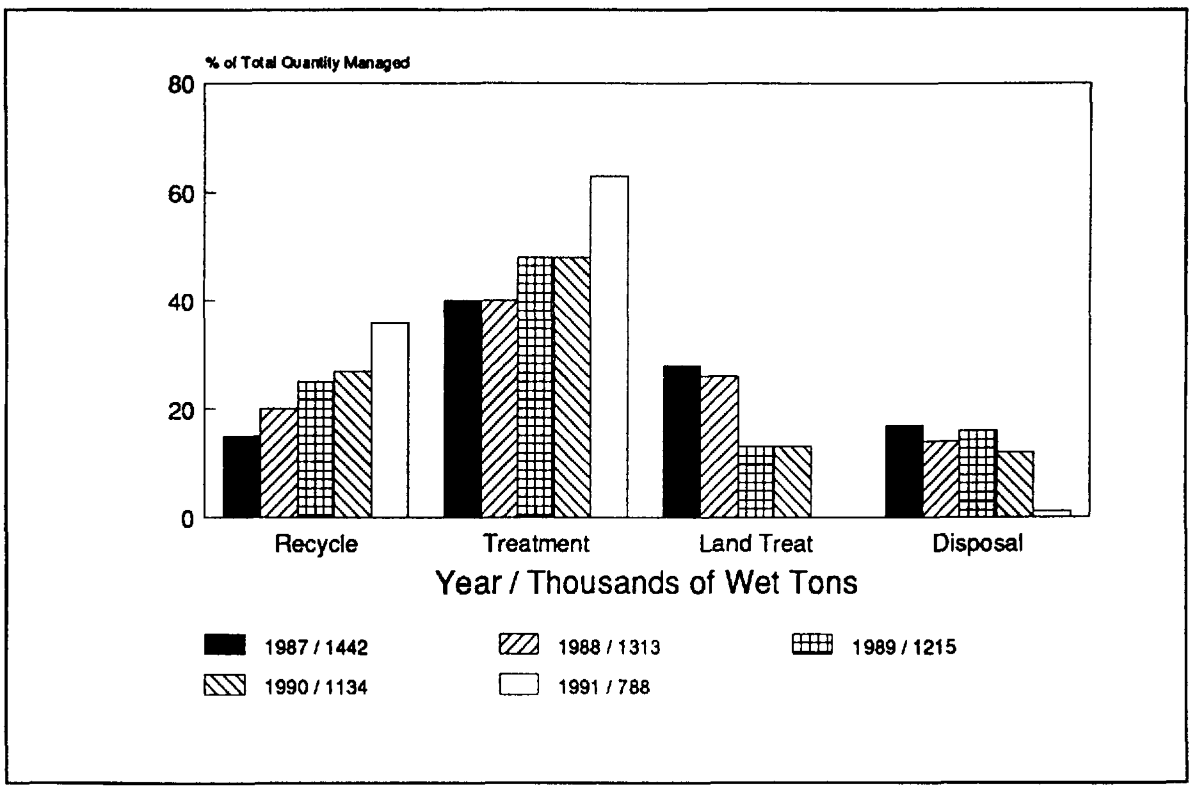

Table 3. Waste Generation Estimates for the Total U.S. Refining Industry[5] (thousands of wet tons)

Residual stream	1991	1990	1989	1988	1987
Spent Caustics	909	889	716	656	675
Biomass	855	782	642	786	757
Contaminated soils/solids	809	920	512	240	165
DAF float	406	553	496	655	652
Other inorganic residuals NOS	397	451	440	213	325
Pond sediments	372	1,017	313	266	337
Other residuals NOS	339	352	325	412	203
API separator sludge	210	251	419	355	400
FCC catalyst or equivalent	204	198	182	193	173
Primary sludge (F038)	177				
Slop oil emulsion solids	165	291	272	224	208
Residual coke/carbon/charcoal	138	92	129	67	43
Residual amines	136	75	51	14	13
Primary sludge (F037)	130				
Nonleaded tank bottoms	109	194	161	129	216
Spent acids	88	336	8	149	126
Oil contaminated waters (not wastewaters)	67	8	29	36	28
High pH/low pH waters	54	105	91	138	144
Other oily sludges/organic residuals NOS	54	53	47	61	38
Other contaminated soils NOS	37	69	53	68	82
Hydroprocessing catalysts	32	31	36	36	40
Spent Stretford solution	25	29	42	49	35
Other spent catalysts NOS	23	39	33	37	33
Residual oils/spent solvents	21	115	31	7	4
TSD Leachate (F039)	20				
Residual sulfur	19	35	52	22	17
Spent sulfite solution	9	1	8	40	42
Heat exchanger bundle cleaning sludge	3	13	2	5	3
Leaded tank bottoms	1	3	4	8	9
Other separator sludges	NA	97	114	104	79
Total	5,809	6,999	5,508	4,968	4,868

[5] From *The Generation and Management of Residual Materials: 1991; Petroleum Refining Performance*, API Publication Number 329, May, 1994.

Another example of an mass-based measurements is the Toxic Release Inventory (TRI) data collected annually by EPA. Facilities required to report must provide estimated quantities of over 300 toxic chemicals and chemical categories emitted into the air, discharged into bodies of water, injected underground, or released to land. Table 4 lists the amounts of each of the top 25 chemicals released into the various media by the petroleum refining industry during 1990. A similar format can be used at the facility or company level over several reporting cycles to track the quantities of chemicals being released. (In addition, elements of the TRI data submitted by a facility can be combined with other known parameters such as crude throughput or production amounts to determine rates of efficiency.)

Table 4. Refinery Releases and Transfers of Top 25 TRI Chemicals by Medium: 1990 (in pounds)

Chemical	Air Releases	Water Releases	Land Releases	Underground Injection	Off-site Transfers	Total
Ammonia	7,359,750	3,198,752	324,318	35,240,182	1,672,150	47,795,152
Methanol	301,944	678,564	25,442	301,100	748,804	2,055,854
Hydrochloric acid	216,020	5	4,666	13,844	3,650	238,185
Toluene	10,483,975	9,384	153,413	114,920	433,612	11,195,304
Sulfuric acid	210,003	820	12,555	0	12,631	236,009
Acetone	365,740	8,800	14	0	5,765	380,319
Zinc compounds	25,927	22,975	55,550	0	275,298	379,750
1,1,1-Trichloroethane	144,500	546	250	0	35,559	180,855
Xylene (mixed isomers)	7,778,412	10,479	225,523	66,759	558,851	8,640,024
Phosphoric acid	3,121	765	144,720	0	773,530	922,136
Methyl ethyl ketone	3,796,671	4,820	1,032	0	4,600	3,807,123
Manganese compounds	6,812	5,555	77,005	0	2,419	91,791
Chlorine	287,423	19,137	785	0	3,365	310,710
Copper compounds	28,277	3,075	9,087	2	15,398	55,839
Dichloromethane	250	0	0	0	0	250
Carbon disulfide	44,019	0	0	0	0	44,019
Ammonium sulfate (solution)	260	0	0	0	168,306	168,566
Nitric acid	47	0	0	0	0	47
Glycol ethers	13,245	0	662	0	34,000	47,907
Ammonium nitrate (solution)	66	0	0	0	0	66
Chromium compounds	73,003	6,509	69,210	291	288,570	437,583
Freon 113	1,025	0	0	0	0	1,025
N-butyl alcohol	14,231	0	0	0	0	14,231
Styrene	11,230	352	28	0	25	11,635
Ethylene glycol	65,540	162,832	349	12,000	45,814	286,535
Subtotal	31,231,491	4,133,370	1,104,609	35,749,098	5,082,347	77,300,915
All other chemicals	24,424,606	530,189	1,430,025	1,676,661	8,856,299	37,917,780
Grant total	56,656,097	4,663,559	2,534,634	37,425,759	13,938,646	115,218,695

For those parts of the industry that neither participate in the API Annual Refining Survey nor report TRI releases, other mass-based measurements can be developed. Residuals streams for a specific sector of the industry could be identified; generation and management quantities could be tracked similar to that currently underway in the refining sector. In addition, chemicals could be identified by sector or facility and a system for tracking releases over time could be developed. Table 5 lists some additional ideas for mass-based measurements.

Table 5. Examples of Mass-based Measurements

Measure	Description of Measurement	Sector	Data Requirements	Comments
Hazardous waste disposed	# drums of hazardous waste generated/year	All	Minimal	Company records tracking hazardous waste management already exist
Off-test product generated	Tons of off-spec products generated/year	Refining, Marketing	Minimal	Company records track this. (If off-spec product RCRA hazardous waste, records document waste treatment and disposal.)
Waste water produced	# gallons of waste water produced/year	Refining, Marketing, Transportation	Some additional data needed, procedures known	This information may be required for discharge permits. The amount of process & other water used provides an indication of the amount of waste water discharged.
Materials spilled over time	Number of gallons lost in reportable spills/year	All	Minimal	Company records already contain information on spills to land and water.

Category 4. Concentration-based Measurements

Description. In chemistry, concentration refers to the amount of one substance contained in another substance. Concentration measures are typically expressed as units of weight or mass by volume or capacity (e.g., mg/kg, mg/l, mg/cm^3). Those typically found in the petroleum industry include the concentrations of petroleum hydrocarbons in drilling muds destined for disposal, concentrations of phenols in the effluent process water in the refinery, and concentrations of chromium-based compounds in cooling tower blowdown.

Advantages. Concentration-based measurements are the best performance measures for processes designed to reduce pollutant concentrations. These measures are also valuable where concentration-based sensitivities exist.

Limitations. Concentration-based measures usually require significant resources. At a minimum, some type of sample collection and analysis is required. The degree of precision required is another important consideration, since an inverse relationship exists between it and the costs associated with analytical techniques.

Examples. In refining, attention has been focused on reducing the use of chromium-containing inhibitors in cooling towers. Less toxic phosphate-based corrosion inhibitors can be substituted for the chromium-based inhibitors. The conventional practice is to measure concentrations of chromium within the cooling tower blowdown.

Category 5. Normalized Efficiency Measures

Description. Normalization provides a method of relating one variable to another item. By doing this, facilities of different sizes can be compared to each other on a "per unit" basis to determine the efficiency of their respective practices. Normalization also minimizes some of the problems that can occur when reviewing operations at one facility over time. Because one parameter is indexed against another variable (e.g., an activity, production) for a similar period of time, the performance or efficiency of the activity can be determined, independent of changes in operating rates.

For example, a large facility may generate 100 pounds of waste per day, and be viewed as less "environmentally aware" than an identical, but smaller facility that produces only 10 pounds of waste per day. However, if the larger facility produces 100 units of product per day, and the smaller facility produces only 1 unit per day, this perception changes. The larger facility generates 1 pound of waste per unit of product, while the smaller facility generates 10 pounds of waste per unit of product. "Normalization" of the residual generation relative to the output of the facility indicates that the larger facility has a more environmentally efficient operation than the smaller one.

Measures of the efficiency of pollution prevention activities can be normalized or indexed against a variety of related measures. Three methods of normalizing are discussed in this report:

- By activity/operation
- By production
- By residual generation

Measuring performance as a function of *activities/operations* parallels the first category of measures discussed in this report. Because less detailed, and more readily available information is required to describe the activities/operations this may be the easiest type of normalized measure. The most common measure of *production* is throughput, whether it is crude processed at a refinery or products handled at marketing, marine and other terminals. For E&P operations, a typical production measure would be well-depth, which can be used to normalize use of water and drilling muds. The third method of normalizing, by *residual generation*, is a more unusual type of measurement. It quantifies pollution prevention progress in terms of fractions of wastes handled in beneficial ways, or in terms of percentage change from theoretical values.

Advantages. Normalization of pollution prevention activities enables comparisons between facilities and provides measures of the relative efficiency of alternative approaches. Use of throughput appears to be the simplest and most easily understood method to measure for pollution prevention progress. Normalizing by residual generation encourages overall efficiency by giving incentives to find beneficial uses for materials that are now disposed of as wastes. It also provides incentives to reduce the use of already stressed waste disposal processes and landfills.

Limitations. The primary disadvantage is that normalization can oversimplify the situation and may give misleading information. Conversely, a normalization process that is more complex than a linear relationship involving one or two variables may be so complex as to be easily misunderstood by the target audience and thus create more mistrust or confusion. For example normalizing refining wastes to crude input is simple but does not account for the type of crude available, the particular product mix required or apparently unrelated, but important, variables such as the amount of rain, and the level of airborne dust particles that are carried into the refinery operating units.

A disadvantage of normalizing by waste generation is that it encourages the use of wastes as opposed to the stressing the reduction in generation of residual. Thus it could easily become counterproductive. For example, a process change that reduces the amount of residual that can be beneficially reused, such as a change that reduces the amount of free (recyclable) oil in an API separator, without also reducing the amount of non-usable residual, is in fact a good pollution prevention effort. However, this normalization process would depict that activity as negative as the percent of the waste that is beneficially reused is decreased.

Examples. As noted above, measurements *normalized by activity or operations* are the easiest to obtain. Several examples are provided in Table 6.

Table 6. Efficiency Measures Normalized By Activity

Measures	Description of Measurement	Sector	Data Requirements	Comments
Transfer spills at marketing or marine terminals	# reportable spills/Total # transfer operations/year (at marketing or marine terminal)	Marketing	Some additional data needed, but procedures known	Measure reflects quality of transfer operations/practices. Variables can be retrieved from company records.
Delivery related spills	# spills/Total # deliveries/year	Marketing	New data to be retrieved	Variables could be determined from facility records.
Offload spills for delivery trucks	# reportable spills/miles traveled by trucks/year	Marketing	Significant new data needs involved	Measure captures rate of spills at deliveries and potential for spills on the road associated with accidents.

Additional examples of measures *normalized by production* for each segment of the industry are presented below.

Refining

Pollution prevention effectiveness for a particular refinery is reasonably well represented by aggregating total volumes of API, DAF, and slop oil emulsion solids because so many other processes eventually feed into these streams. Annual production of these sludges is normalized against the total facility throughput.

Another example involves the quality of feedstock available by normalizing against the total ash content in the feedstock (i.e., total crude throughput multiplied by the percent ash content in the feedstock). This second determination becomes a measure of efficiency in recapturing the impurities of the feedstock. Improvements in this weighted number will reflect improvements in keeping other residuals (water, sands, fines) from increasing the volumes of the sludges. Measurements of reduction in sludge volume would be fairly easy to implement, since sludge volumes lend themselves to measurement even if measurement programs are not in place already. Normalization over time may be an issue, however, since sludges may be cleaned out on an irregular basis.

Reducing storm basin sludges poses an interesting problem for measurement because of the paucity of available data. Storm basin sludges include emulsions primarily composed of petroleum products mixed with sands, soil particles, dust and rainwater. The volume of sands and other fines involved is correlated to the size of the site, prevailing winds, atmospheric conditions, rainfall, but is subject to reduction based on onsite cleanup programs. Reduction of storm sludges can be simply normalized by the facility's throughput, or by throughput *and* by annual rainfall.

Production

In some cases, a measure of pollution prevention efficiency may be an incidental, side-benefit of specialized drilling techniques. Multidirectional or horizontal drilling that is used to increase the productivity of fields tends to reduce reserve pit wastes in relation to total oil recovered and may decrease total land surface disturbed in relation to total oil recovered.

Marketing

Examples of normalized efficiency measures for marketing operations include reductions in the amount of soils contaminated by spills -- a measure of quick spill response -- to reduce total losses. The Federal Government consistently uses the number of cubic feet of contaminated soils as a measure of the extent of required remedial action under Superfund or RCRA. Because this is an accepted "measure" of pollution, data is already available wherever a spill has resulted in a formal remedial action. Thus the burden of calculating an internal reporting measurement is reduced.

The other measure suggested for marketing operations addresses reductions in lost product from storage tank leaks. This would require additional data, since leaks may not be quantified in terms of product lost.

Table 7 presents other examples of normalized measures for each segment of the industry.

Table 7. Examples of Efficiency Measures Normalized By Production

Measures	Description of Measurement	Sector	Data Requirements	Comments
Fugitive emissions of volatile organics	TRI emissions for specific chemical/Barrel throughput/ year	Refining	Data already collected	Extensive TRI data on fugitive emissions available by chemical
Heat exchanger sludge generation	Heat exchanger sludge/ Barrel throughput/year	Refining	Some additional data needed, procedures known	Reducing bundle sludge volume & improving efficiency possible through addition of nontoxic antifoulant chemicals
Disposal of spent catalyst	Tons catalysts sent to disposal/Barrel throughput	Refining	Significant new data needed	Spent catalyst can be recycled by cement processors offsite
Biotreater sludge	Tons biotreatment sludge/ Barrel throughput	Refining	Significant new data needed	As with primary process sludges, reductions in biotreater sludge represent improved recovery of usable oils.
Volumes of contaminated soils	# cubic feet of contaminated soils/Barrel throughput/year	Marketing	Additional data needed, procedures known	Although a useful measure of damage caused by a release, it may not correlate with volume of product lost. May be better to total product losses per year.
Product lost from storage leaks	Gallons of lost product/ Barrel throughput/year	Marketing	Significant new data needed	Leaks from storage facilities and/or pipelines cannot be reliably differentiated. Leak detection equipment & SOPS, maintenance, and other means can reduce total product lost.
Drilling wastes per volume of wellbore	Waste in reserve pit at closure/volume of wellbore	E&P	New data, instrumentation & procedures needed	Statistic measures national trends in waste generation/ volume of wellbores drilled. Not for use in management of well operations.
Amine use	Total purchases (MEA, DEA, MDEA)/total gas processed (MMCF)	E&P (large natural gas processing plants)	New data, instrumentation & procedures needed	Reclamation processes at large centralized facilities can reduce amine usage rates
TEG use	Total purchases TEG/Total gas processed (MMCF)	E&P (large natural gas processing plants)	New data, instrumentation & procedures needed	Reclamation processes at large centralized facilities can reduce TEG usage rates

The third type of normalized efficiency measure requires the availability of residual generation data. The amount of oily sludges that require disposal, when considered as a percentage of all oily sludges exemplifies an efficiency measure indexed by waste generation. This measure indirectly captures the amount of sludge that is beneficially handled by reclamation or is reused for energy content.

Other examples of normalization in terms of wastes include the proportional increase in produced water handled by Class II designated disposal wells or the proportion of produced water that is beneficially reused, rather than discharged as a waste under an NPDES permit. Beneficial uses of the produced water include irrigation, livestock watering, or reinjection (for disposal or for enhanced recovery, in Class II wells).

Lastly, solids removal efficiencies in drilling operations are a primary measure of waste reduction. Solids removal efficiencies can be calculated either in "real time" (as some operations currently do) or upon completion of the well. In this case, a broad measure of solids removal based on comparing the actual waste produced with the "potential" waste produced is suggested. Potential waste could be calculated by assuming zero solids removal, with the suspended solids in the drilling fluid being maintained at the target level (around 5 percent) purely through the addition of water.

Table 8 contains these and other examples of the use of waste generation quantities to normalize pollution prevention measures.

Table 8. Examples of Measurements Normalized By Waste Generation

Measurement	Description of Measurement	Sector	Data Requirements	Comments
Oily sludge disposal	Total oily sludges disposed/Total oily sludge generated	E&P	Significant new data needed	Disposal does not include sludge destined for reclamation or recycling.
Flow to Class II wells	Flow to Class II wells/Total flow	E&P	Significant new data needed	Statistic standardizes measurement of subsurface injection of produced water.
Produced water discharged	(Total produced water) minus (nonbeneficial discharges)/Total produced water	E&P	Significant new data needed	Produced water can be recycled beneficially by reinjection for EOR, through use for livestock watering or crop irrigation. This statistic also includes the benign reinjected for disposal using Class II wells, although this is not normally considered to be pollution prevention.
Solids removal efficiency	E = Actual waste/ potential waste	E&P	New data, instrumentation, procedures needed	*Actual waste* = total measured or estimated waste in the reserve pit. *Potential waste* = amount waste generated if ZERO solids removal were accomplished (i.e., if fluids were added to maintain solids content in the drilling fluid at the maximum acceptable level, such as 6%)

CONCLUSIONS

The Pollution Prevention Task Force of the American Petroleum Institute initiated this project with the primary purpose of identifying potential methods of measuring progress towards pollution prevention that could be used to supplement or as an alternative to the estimates of chemical releases reported by the Toxics Release Inventory.

The project has identified a series of different measures. They follow a progression from simple, primarily qualitative and relatively inexpensive techniques to more complex approaches that require greater monetary investment to achieve.

This investigation has reinforced the industry's concern that any individual measurement is, at best, a crude tool for evaluating environmental performance. When measuring pollution prevention, companies should rely on several measures to characterize their initiatives and to evaluate their progress. After all, pollution prevention is a *multi-media* concept that can be achieved through a *combination* of technological and procedural innovations.

While no one measurement can be considered to accurately reflect pollution prevention performance, it does not necessarily follow that the appropriate course is to mount a multi-dimensional measurement project. It generally holds that several measures are better, but companies must choose a complement of measures that make sense--both economically and environmentally--to them.

These choices are largely dictated by the status of their pollution prevention programs. Indeed, it makes no sense to devote funding to sophisticated measures in the early stages of a program, when this would divert resources from implementing pollution prevention activities. Qualitative measures, such as the types of activities initiated, are likely to provide the most useful feedback. This may be particularly true as pollution prevention programs mature, and it becomes more difficult to precisely measure increasingly smaller incremental reductions.

In addition to enumerating the types of activities implemented, effort should also be directed to developing more precise measures of performance. Whenever technically appropriate, mass-based estimates or measures should be viewed in the context of related facility data to normalize the measurement and provide perspective. For example, dividing residual generation at refineries by the crude throughput may provide an appropriate context for comparing year-to-year changes.

Ultimately, the determination of the most appropriate parameters for measuring pollution prevention progress must be made at the company or facility level, based on knowledge of site-specific operations and conditions, with consideration given to available resources and to merits and limitations of the measurement technique itself.

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