The Effect of Providing On-site Technical Assistance for Toxics Use Reduction

A Program Evaluation Utilizing
Toxics Use Reduction Act Data

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July, 2006

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Acknowledgments

This study was authorized by Paul Richard, Director of OTA. Rick Reibstein, Senior Analyst, was the principal author. Bill McGowan, Assistant Director of OTA, Phil Milmoe, OTA's Systems Analyst, and Rich Bizzozero, Senior Environmental Engineer, provided significant assistance. Intern Valerie Rickman provided insights and corrections. The entire staff of OTA assisted in reviewing and critiquing the data and the study's methods.

The Office is deeply grateful to Boston University's Center for Energy and Environmental Studies for its interest and for the time and effort devoted to performing an independent analysis of the hypothesis that OTA helped visited companies, in particular, to: Professor Cutler Cleveland, CEES' director, and Professor Robert Kaufmann. The Office is also grateful to the following, who provided helpful review and comment: Robert Stavins[1] of Harvard University; Wayne Gray of Clark University and John Warner of the University of Massachusetts at Lowell;[2] Lori Snyder Bennear of Duke University; Jennifer Nash and Cary Coglianese of the Kennedy School of Government; Linda Benevides and David Cash of the Executive Office of Environmental Affairs; Heinrich Tschochohei of the Centre for Sustainability Management of the University of Luneburg, Glenn Keith of the Massachusetts Department of Environmental Protection, and Elizabeth Harriman and Heather Tenney of the Toxics Use Reduction Institute. OTA also thanks the National Pollution Prevention Roundtable and Region 1 of the Environmental Protection Agency (EPA New England), particularly Dwight Peavey and Ronnie Levin, for sponsoring presentations of the analysis while it was a work in progress: this was of great help in refining methods and conclusions. Lastly, OTA recognizes the contributions of those whose work during the 1990's and early 21st century produced the results appearing herein: Barbara Kelly, former office director, and all former OTA employees.

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Abstract

The 1989 Massachusetts Toxics Use Reduction Act (TURA) employed a new, preventive strategy for addressing chemical wastes and releases: to reduce the input of chemicals to industrial processes. The act established the Massachusetts Office of Technical Assistance for Toxics Use Reduction (OTA), a voluntary program. OTA's experts are available to visit companies that request assistance, to review the use of toxic chemicals at the facility, and make recommendations for either using substitutes, or using the chemicals more efficiently.

TURA requires covered companies (large quantity toxics users) to report chemical input (what they use), output (resulting chemical waste), and a production index. This enables the measurement of trends in toxics use relative to production, and waste byproduct per pound of chemical use input. These are uniquely precise measurements of a company's ability to accomplish the form of pollution prevention known as toxics use reduction. The study used these toxics use reduction measurements to compare the performance of companies visited by OTA to those never visited, and to those who would be visited in later years.

Total chemical use by large quantity toxics users was 1.22 billion pounds in 1990, and 1.2 billion pounds in 2003. Though the overall total has remained level, the covered population has vastly changed, new chemicals have been added to the list, and most of the companies significantly increased production while in the program.

Data reported by companies covered by TURA shows that from 1993 to 2002, chemical input by all companies combined was approximately 500 million pounds less than what was expected. The study showed that for every company covered by TURA requirements that did not improve performance, there were nearly four companies that did improve. During the period examined, about one-third of all chemicals "dropped out" of the program: that is, they came to be used in amounts below the threshold for reporting.

Several comparisons provided indications that companies improved their TUR performance as a result of receiving onsite technical assistance visits from OTA. The performance of companies before being visited by OTA was compared to their own performance after being visited. The performance of companies visited by OTA was also compared to companies that would be visited later by OTA, but had not yet been visited. And the performance of companies visited by OTA was compared to those that would never be visited.

Visited companies reduced an average of 9.4% more toxics use after being visited than before, and the difference was statistically significant. Visited companies had far greater reductions than both those not yet visited, and those that would never be visited, in the year of the visit and the year immediately following. More companies in the visited group made progress than the companies in both nonvisited groups. Examination of a

six-year period resulted in the estimate that OTA's visits should be associated with reductions of 63 million pounds occurring in that time frame.

The results of two additional studies confirmed the findings of program effectiveness. One study examined companies that dropped out of the system, and found that those that were visited employed toxics use reduction to achieve below-threshold use amounts more frequently than those that were not visited. The other study, an independent research project using econometric methods to determine the causative relevance of provided assistance, found OTA's service to be an explanatory factor associated with significant toxics use and byproduct reductions.

Background

The Massachusetts Legislature, in a unanimous vote, passed the Toxics Use Reduction Act (TURA) in 1989. TURA requires that companies using large quantities of toxic chemicals annually report how many pounds of toxic chemicals they use, pay a fee for toxics use, and prepare toxics use reduction plans. Toxics Use Reduction (TUR) is the strategy of preventing toxic pollution by addressing a primary cause – the use of the toxic material that becomes a toxic waste or pollutant when it ends up as something other than useful product. Successful TUR can reduce not only releases of pollution and the volume of wastes to be managed; numerous case examples have shown that it can also reduce the costs of production, worker exposure, transportation and storage risks, and toxic constituents in products. TUR's preventive approach contrasts with treatment or control, which reduce pollution risks or prevent its release, but do not prevent it from being created in the first place.

There are 1,422 chemicals listed under TURA, and companies with ten or more employees, operating within certain industrial categories (primarily manufacturing), that use more than threshold amounts of listed chemicals, are subject to the public reporting requirements. The thresholds are 25,000 pounds per year when the chemical is manufactured or processed, and 10,000 pounds per year when otherwise used, but there are lower thresholds that apply for Persistent, Bioaccumulating and Toxic chemicals (PBTs).[3] In 2003, the most recent report available at this writing, 647 facilities reported the use of 193 listed toxic substances. A total of 1.2 billion pounds of toxic chemicals was used by these "large quantity toxics users". Of that chemical input to operations, 107 million pounds ended up as waste byproduct. Another 359 million pounds was shipped in product. Nine million pounds was released to the environment, and 35 million pounds was transferred for waste management.[4]

Because it was expected that some companies would need help finding ways to reduce toxics, TURA created the Commonwealth's Office of Technical Assistance for Toxics Use Reduction (OTA), and its sister agency, the Toxics Use Reduction Institute (TURI), to provide assistance to them. While TURI performs general research and provides

[3] The triggering of a lower threshold for any chemical causes the 25,000 pounds threshold to drop to 10,000 pounds for all chemicals at the reporting facility.
[4] *2003 Toxics Use Reduction Information Release, Department of Environmental Protection et al.*

education and training (including a library and a testing laboratory) for toxics-using companies and the general public[5], OTA provides direct, onsite, one-on-one assistance to toxics users. OTA engineers and specialists are available to visit companies and view production operations and other information, and make specific observations and suggestions. OTA's role is to help toxics users understand what their choices are, and how toxics use reduction options may be implemented.

The OTA assistance service is entirely voluntary. No company needs to respond to OTA's offer of assistance. OTA's services are also provided under a grant of confidentiality, so that companies will not fear that if they are in violation of a regulation, asking government officials to visit will result in penalties (although OTA must report imminent threats to health, safety or the environment).

No company is required to implement OTA's recommendations. Performance improvements associated with OTA's visits are the accomplishment of the visited company. OTA acts as a catalyst, or facilitator, of change, which is implemented by others – inhouse staff, consultants or equipment vendors. This project examines the reductions in toxics use achieved by TURA filers, associated with OTA's visits. OTA is not responsible for any of the toxics use reductions that companies have achieved, as each was a voluntary act by the companies themselves. Even though many companies seek OTA's help after being found in violation by the Massachusetts Department of Environmental Protection (MassDEP) or other enforcement bodies, they may always comply by choosing to implement pollution control or treatment options, rather than OTA's TUR suggestions.

If a company does invite OTA to visit, OTA staff will review its operations, explain relevant compliance issues, and produce a letter of recommendations intended to inform the company about what it might usefully consider. If a company is having trouble meeting air emission limits on volatile organic chemicals, OTA will examine the task that uses volatiles, reviewing the functions that volatiles perform, and ask if there are potential alternatives for accomplishing the same end. For example, volatiles are often used in the curing of coatings, and OTA has helped several companies switch to coatings that cure when exposed to ultraviolet light, eliminating the air emissions. If such alternatives are not feasible from the company's point of view, OTA will look for ways to ensure that during processing, the volatiles are captured, and if possible, reused. OTA's recommendations have included, where appropriate, referrals to providers of goods and services that would assist companies in implementing the identified options. A recent in-house study indicated that during the 1990's OTA made approximately 1,000 referrals to private sector vendors[6].

OTA has been in operation since 1990, and over that time has encountered many examples of companies that have successfully reduced their toxics use, often saving

[5] See www.turi.org. The MA Department of Environmental Protection (MassDEP) also encourages the implementation of TUR through a variety of initiatives.
[6] *Assistance Provided by the Office of Technical Assistance*, October, 2001, examining recommendations provided to 184 companies.

money and improving process and product. A review of the literature of pollution prevention programs, which have existed in every state and many countries, reveals hundreds of such case studies, demonstrating that many companies can indeed find efficient ways of producing goods, using less toxic input. However, except for New Jersey, no other state requires both chemical input and output data, enabling comparatively precise measurement of the pollution prevention performance of toxics-using companies. With the exception of New Jersey's work, other efforts to evaluate pollution prevention progress have utilized Toxics Release Inventory (TRI), or hazardous waste data, both of which concern chemical output or fate after use, and do not include input, and thus cannot directly measure pollution prevention.

Other studies have examined company claims, which range over a variety of measurement strategies (typically air pollution reductions, or hazardous waste reductions, rarely including input measures). Many reports on pollution prevention progress focus on cost savings or percentage changes in unrevealed total quantities. These are difficult to aggregate or compare[7]. Many evaluations of assistance programs have gathered information about the rates at which recommendations made are implemented, or have gauged the effectiveness of outreach by comparing before and after knowledge assessments. These are difficult to translate into more specific benefits.

OTA has visited over a thousand facilities, about half of them covered by TURA. OTA recognized that it could obtain indications of the effectiveness of its onsite visit program, using the data produced under TURA, by comparing toxics use data before and after visits to the companies, and by comparing performance changes by visited companies to those not visited. During the examined period, 1993 to 2002, 612 facilities were in the not-visited group, and 443 had been visited. (This is 90% of the 1172 companies reporting during the period 1990 – 2002, the entire period for which TURA data existed at the time of the study). The companies visited had entered 2699 chemical reports, and the companies not visited had entered 2216. There seemed sufficient data to identify general trends and answer the question: has providing technical assistance worked? Though OTA does not claim credit for the chemical reductions companies have achieved, a correlation of OTA visits with greater reductions would serve as an indicator of effectiveness. The answer to the question of effectiveness is of importance to those considering future investments in environmental programs, and the design of strategies for environmental protection.

No similar assessment of the effectiveness of a program of technical assistance for pollution prevention, using direct measurement of the kind made possible by TURA data, was found in the literature.

[7] The most complete assessment, the National Pollution Prevention Roundtable's 2003 *An Ounce of Pollution Prevention is Worth Over 167 Billion Pounds of Cure: A Decade of Pollution Prevention Results, 1990- 2000*, combining data from state programs, found a variety of units of measurement used by each.

Methods

The following section describes in detail the measures that were used to identify trends and how they were applied to develop the most accurate picture of progress. For those readers who wish to go directly to the results, the appendix contains a one-page summary of the measures.

The primary work concerned toxics use, described in section 1 below. A different view of performance was taken to examine toxics byproduct, set forth in section 2. A third perspective was generated by analyzing information about companies that have dropped out of TURA, detailed in section 3. Finally, an independent analysis was performed, using statistical methods, described in section 4.

1. Toxics Use Reductions

Production-Adjusted Reductions and Toxics Use Efficiency

Our evaluation of progress in toxics use reduction began with the estimation of how many pounds of toxic chemicals were reduced by TURA-reporting facilities after assessing changes in production. The reason for generating a "production-adjusted reduction" measure is that examining absolute numbers presents a misleading picture of pollution prevention progress.

The production level of toxics users changes from year to year. If a company uses 10,000 pounds in year one to make 1,000 chairs, and the same 10,000 pounds in year two, it may seem that it has not changed its toxics use. But what if it had doubled production and made 2,000 chairs? One would have expected the company to double its toxics input proportionately, and if it had, it would have been reasonable for the company to say that it had not actually doubled its toxics use - its toxics use had remained steady at 10 pounds per chair. In this hypothetical, the company halved its toxics use, relative to production. Twenty thousand pounds of toxic chemical use was expected, and its actual use was ten thousand pounds. Its reduction was the missing ten thousand pounds. Without scaling (adjusting) for production, this large reduction remains invisible.

Conversely, a company that decreases production and uses its toxics with less efficiency may appear to have a reduction when it actually has proportionately increased toxics use. Absolute toxics use numbers tell you what exists and what people might be exposed to, so it is relevant to community right-to-know considerations. But to develop an accurate picture of pollution prevention performance, production adjustment is necessary. Without assessing production, it is not possible to determine if a TURA company is becoming more or less efficient concerning its toxics use.

The method of scaling for production was simple: the base year of reported chemical use – the first year the company reported use of the chemical – was multiplied by the

subsequent annual production ratios self-reported by the company. This generated an expected quantity of chemical use.

It is true that there may not be a one-to-one relationship between chemical use and production levels. It could be the case that for some processes, doubling production is normally achieved with some level of chemical use that is either more or less than doubling. For this reason, and because production technologies may change over time, the calculations described herein can only be regarded as best estimates, not precise measurements of what toxics use has been avoided.

Another reason to consider the results as best estimates is that the production ratios required under the federal Toxics Release Inventory (TURA reporters must also submit TRI information) are generally considered to be variable in quality. In Massachusetts, however, significant guidance and assistance has been offered by the state to companies reporting under TURA. Quality assurance efforts have been conducted, involving the questioning of unusual numbers reported by companies, and resulting in corrections or confirmations. TURA also goes beyond the national TRI program in requiring that a unit of product be defined, and in specifying that the production ratio must measure the generation of product in a way that is relevant to the chemical input. The production ratio reported in Massachusetts is likely far better than the typical national TRI production ratio, and certainly the best available measure of individual production changes.

After generating a number representing the quantity of toxics expected to be used, based on changes in production, these "expected pounds" were compared to the actual number of pounds of chemicals used in the examined year. Chemicals that were no longer reporting to the system – that were used in amounts below the threshold for reporting – were counted as well, by using the amount reported in the base year, the first year the chemical was reported by that facility. (See the discussion below of the "just below threshold" effect, on the possible extent of the distortion introduced by assuming complete cessation in use of a chemical that is still being used at levels that do not require reporting).

A positive difference between expected and actual toxics use represented the best estimate of pounds of toxic chemicals reduced. A negative difference represented the best estimate of increases in toxics use.

Annual and Cumulative Reductions

It is arguable that chemical use eliminated in one year is a recurring annual reduction in all subsequent years. A more conservative method was selected, as it is sufficient, to compare performance over time or among groups, to count reductions only in the year they occurred. But it is important to note that for toxic chemicals that were reduced and not reintroduced, the beneficial risk reduction effects would last far beyond the year in which they occurred.

False positives and negatives

A formula that calculates expected pounds must carefully select each company's base and final years. Counting reporting cessations repeatedly in successive years is a false positive, and calculating from any year before a company began reporting results in a false negative. (The Excel formulas are appended to this report).

Regulatory dropouts and distorting categories

Another kind of false positive could result from recording dropouts that are not due to chemical reductions, but due to changes in regulatory coverage. Since the TURA program began, several chemicals and chemical categories have been delisted. Eliminating them completely corrected for the false positive that records as toxics use reduction a chemical "dropout" that is really due to a regulatory change.[8]

After presenting this research as a work in progress, reviewers pointed out that the addition in the later examined years of electrical utilities could have a serious distorting effect, as utilities have qualitatively different chemical use patterns and requirements, and their quantities can be extremely high. All companies in SIC category 49 (38 companies) were thereafter eliminated from the analysis. This made very small changes in results.

Data Quality

In order to improve the reliability of our results, the first few years of the system were ignored. During the first years of the program, many companies had not yet learned how to report accurately. By 1993, OTA, TURI, and MassDEP had provided assistance to most TURA filers individually, or in open clinics and workshops. Individual companies that had reported unusual or discrepant numbers had been contacted and corrections made. Companies and the consultants they used had become more proficient at TUR reporting. 1993 was selected as the first year to examine, because by then data quality had greatly improved[9].

Because the basic measurement for comparison requires two years of data (original use compared to expected use), performance comparisons were made beginning in 1994.[10] (Starting in 1993 eliminated from the analysis the possibility of gauging the effect of OTA's visits at that time, although there are many indications that OTA's impact may have been largest during the early years of TURA. This is because OTA was responsible for introducing TUR concepts to many companies, at over 150 public events, as well as by mailings and individual onsite visits, and because the first pollution prevention efforts often focus on the more easily implementable projects, that have the greatest reduction values – the "low hanging fruit").

[8] This reduced the total number of chemical reports from 4915 to 4189.
[9] Because the three agencies have conducted data quality checks, the data set is sufficiently large, and there is no expectation of a bias in the occurrence of input errors, the inevitable instances of misreporting by companies are not expected to have an impact on the conclusions.
[10] This reduced the total number of chemical reports to 3951 (2012 not visited, 1939 visited).

Normalization for quantity of expected toxics use

Normalization means to remove an effect biasing a statistic, or to cause it to conform to a standard. It is necessary to develop some standard for comparing pounds of reductions between groups. When looking at the average changes in reductions from year to year, in terms of pounds, it is necessary to consider that variations in this number from group to group could be dependent on the composition of that group: the average pound reductions of a group with a lot of companies having small successes, but with very large amounts, could be much higher than those of a group with many companies having dramatic reductions, but who on average use much smaller amounts. To sort out the effect of OTA's visits on a range of companies with different amounts of use, it is necessary to have a standard measure.

We divided the use reductions in each year by the expected use in that year to produce a percentage reduction, answering the question: how much of a reduction was there, proportionate to what we expected them to be using?

To illustrate, let company A's expected use be 25 thousand pounds, and company B's expected use 25 million pounds. Suppose that company A reduced 10,000 pounds and company B increased use 20,000 lbs. When we average the two we have negative 10,000 pounds. It looks like the group did poorly – no progress.

If, however, we normalize by quantity of use, we see that company A had a forty percent reduction, while company B had an increase that was less than a hundredth of a percentage (20,000/25,000,000 = .08%, 10,000/25,000 = 40%). When we average the two normalized percentage reductions we see that the group had an average reduction of 20.04%. The group made good progress.

This example illustrates how important it is – when assessing performance - to use a measure that normalizes for quantity of use. The change in pounds tells us more about how many pounds of toxics have been eliminated from commerce. But the percentage change tells us more about toxics use efficiency progress.

Performance Comparisons

Measuring performance began with developing estimates for each year of reporting of how much had been reduced from the first year of reporting ("expected" compared to "actual" toxics use) for each chemical used by each reporting company. This made it possible to compare performance in two basic ways: to examine whether there was a difference between visited company performance, before and after being visited by OTA, and to examine whether OTA-visited companies performed better than companies that were not visited, during the same time frame. These comparisons were made in five ways:

1. by using a closely focused comparison, comparing the year before visits with the year of and the year after visits (referred to as the "three-year" comparison),

2. by assessing how many in each group had performance improvements, ("advancers and decliners"),

3. by comparing the average of all "before" performance measurements with all "after" performance measurements[11],

4. by constructing a "mixed year" before and after chart, and

5. by comparing annual average percent reduction changes between visited and not visited groups.

The three-year comparison

The toxics use of visited and nonvisited companies was compared by examining performance in the three years surrounding the visit year. The average changes in pounds reduced, and the average percent changes, were developed for both visited and not visited companies, and compared. OTA often assists companies in changing management systems, establishing ongoing toxics use research efforts, training, and other activities that may take years to produce results. Also, some recommendations that are not economically or technically feasible become so in later years, and thus a recommendation made by OTA in 1994 may be finally implemented in 2000. But looking at the changes that occurred in the discrete time frame surrounding the visit reduced the potential impact, inherent in a longer time-series evaluation, of other intervening factors. It is also true that the bulk of OTA's recommendations are practical solutions that can be implemented within a reasonable business time frame.

Advancers and Decliners

As another comparative indicator of how groups fared, we looked at how many members of each group did better or worse. Those who reduced their use more than in previous years were considered advancers, while those who used more of the toxic chemical than before, to make the same amount or less product than before, were considered decliners. The ratio of advancers to decliners was calculated for each group, as well as the percentages that advanced and declined. A showing that visited companies have higher rates of advancers after being visited could indicate that OTA was helping companies to reduce toxics use, even if the analyses of average pounds and/or percentages did not produce any differences.

Total Before and After performance comparison

[11] There was a total of 2850 measurements: 1321 before being visited, and 1529 after.

Percent reductions were calculated for all years for all companies, from 1994 to 2002 (the data included 1993, but it takes two years to develop an estimate of reductions, so performance results are recorded from 1994 on).

All the performance measurements for visited companies were grouped into one large "before" and one large "after" population, and the average of each group was compared. The statistical test, analysis of variance (ANOVA), was applied to determine if the difference found in the average performance of these groups was significant.

The Mixed Year chart

It is possible that some factors, such as an enforcement initiative, or new regulations, or a drop in the price of a chemical substitute, could have caused reductions. Many of these factors occur within the time frame of a year or two. To dilute the effect of potential factors occurring at a certain time, we grouped all the performance measurements in categories of numbers of years before and after being visited, and calculated the average performance of each time category.

For example, the 1994 performance of companies visited in 1996 was grouped as "two years before", and combined with the performance in 1995 of companies visited in 1997, the performance in 1996 of companies visited in 1998, and so on. Thus, if anything happened in 1994, only those visited in 1996 would be included in the "two years before" category, mixed in with the 1995 performance of those visited in 1997, the 1996 performance of those visited in 1998, and so on. The 1994 performance of companies visited in other years was grouped in other time categories. Thus the effect of particular events occurring at a particular time was diluted in this analysis, reducing the potential number of competing factors to which causation could reasonably be attributed.

TURA coverage effect

As stated above, being covered by TURA's requirements means that a facility must report on chemical use to the public, pay a fee for chemical use, and write plans for toxics use reduction. All of these may cause reductions in toxics use. In order to show that OTA's assistance has been effective, it is necessary to determine whether there is an overall effect to being covered by the law, and then to assess whether visited company performance was distinct from others covered by TURA. We determined whether there was an overall effect by measuring the changes in performance by all companies over the examined time frame, estimating production-adjusted pounds of reductions, and calculating the ratio of advancers over decliners.

Performance Comparisons Between Groups

The performance of the visited and nonvisited groups were compared by various means: by comparing toxics use reductions in pounds and percentages over the three-year visit time frame, by comparing annual average percent reductions over all years, by comparing advancers and decliners, and by comparing byproduct/use ratios.

A finding that the entire group of TURA reporting companies was having similar changes to whatever was found in the visited group would indicate that positive changes might not be due to OTA's visits. Given such a finding, other factors would have to be considered – being covered under TURA, enforcement initiatives, other regulations, a growth in general knowledge concerning pollution prevention, advances in technology or the availability or economic feasibility of substitutes, or demand for safer products. (It is possible that the performance of companies not visited were in fact influenced by OTA, as OTA has provided substantial nonvisit assistance to many companies, through conferences, website, by phone, by publication of case studies, and by diffusion of innovations).

If, on the other hand, the before and after analysis provided indications of OTA's effectiveness, and if the performance of visited companies was substantially better than those not visited, this differential could be fairly interpreted as a confirming indication that the visit from OTA was likely effective in reducing toxics use.

Nevers and Not Yets

There were two groups of companies not visited by OTA: those never visited by OTA during the entire time frame examined, and those who would be visited later but had not yet been visited in the examined year.

It is possible to surmise that the willingness of a company to invite OTA in for a visit – and not the assistance provided - could account for differences in performance between visited and not visited companies. Although it is difficult to see how this could fully account for a difference in before and after performance, self-selection bias is a consideration in comparing visited companies to those never visited. Therefore, we compared already visited companies to those who would be visited later – both groups containing the kind of company that would ask for a visit.

Skew limits.

We used skew limits to avoid measuring the performance of a tiny handful instead of the performance of the larger group of more typical population members. (This is a problem when measuring average total pounds, and not when using the measures that are independent of size – the percentage reductions described above, and the advancers/decliners and byproduct/use ratios, described below).

In the original calculation of production-adjusted reductions for each year, we eliminated toxics users who reported above 10,000,000 pounds of use in that year from the analysis.[12] This had the effect of eliminating, from the visited population totals, 98 million pounds in the last year (the effect of skewing out each year was in almost all

[12] The skew limit was placed in a designated cell of the Excel spreadsheet, which was then referred to in the formulas which performed the eliminations. This method allows the alteration of the skew limit with a few keystrokes.

cases cumulative, so the last year had the highest amount eliminated by the skew limit). Only four chemical reports "skewed out". The total use in that year (for visited companies) was 357 million pounds. If the skew limit had not been set, more than one fifth of the total would have been due to only one fifth of a percent of the chemical reports (1939 chemical reports). The amount skewed out in the last year for those never visited was 250 million pounds, (5 chemical reports). The total amount used by the total population (2012 chemical reports) was 440 million. Without the skew limit, one quarter of a percent of the chemicals would have accounted for 36% of the total.

Another skew limit was applied when adjusting for production. A few reporting entities had large production ratios in some reporting years. Multiplying the original use quantities by large ratios over a period of years produces expected use quantities out of scale with the bulk of reporting entities. We curtailed the effect of very large expected use quantities generated by excessive production adjustment by eliminating all cumulative production ratios over five (ten was used in the three-year comparison). The effect of this skew limit on the larger analysis was to eliminate 82 chemical reports in the visited population, and 113 in the never visited group. The amounts eliminated were much smaller than those eliminated by the volume skew limit: 7.5 million for the visited, and 30.5 million for those never visited. This skew limit was much less critical to the overall results.

Finally, a skew limit was used when normalized percent reductions were calculated for comparison between groups. Percentage changes over 200% were eliminated. The amount eliminated each year varied in a range between 5 and 10 percent of the population.

Elimination of zeros

There were many entries of zero in the database, for years in which chemicals were no longer reported, or had not yet been reported. Zeros had to be eliminated in the final analysis or the averages calculated for each group would be enlarged or diminished according to the irrelevant factor of whether other companies had reported or not.

Estimating the relevance of facility shut-downs and "just belows"

Finally, we identified two other effects that could distort the results. We estimated their magnitude to discover whether they might be substantial. One is the shut-down effect, which occurs when companies have dropped out of the system not because they are making their products without a toxic chemical, but because they have closed their doors. The other is the "just-below threshold" effect, where a company is no longer reporting but has not eliminated use – it is still using the chemical in quantities below the threshold for reporting. (Positing that the amount is "just below" provides the worst case scenario).

To estimate the magnitude of the shut-down effect, we researched every visited company that reported chemical dropouts. The first step was to see if the facility that no longer reported a chemical was still reporting other chemicals. If there were no chemicals at all

being reported by that company, we examined OTA files to see if there was continued contact with the company indicating that it was still in business. If that search provided no information, the Secretary of State's records and other web-based business resources were consulted. If these methods could not establish that a company was still operating at the same facility, the amount of chemical dropped out of the system was recorded as possibly due to a shut-down. The results of this search showed that in most years the amount of chemical dropouts by visited companies was a small percentage of the total chemical reductions reported. As this research was extremely time-consuming, it was only performed for visited companies, for which sufficient information was available. In 2000, there were no dropouts due to business shut downs in this group. In 1999, the maximum percentage of reduced pounds of toxics use that could possibly have been due to business shutdowns was less than one percent. In 1997 it was less than five, and in 1995 it was less than three. Only in 1998, when the maximum possible amount was 19.3%, and in 1996, when it was 27%, could the shutdown factor have possibly contributed anything meaningful to the measured changes in performance.

To calculate the largest possible magnitude of the "just-below" effect, we estimated the amount of chemical use that might still be going on, if each chemical was still being used in amounts just below the threshold. Except for one year, this number was also a very small percentage of the total chemical reductions reported. In 2000 and 1999, the most the just-below effect could have altered results was by less than 2 percent of the total pounds of reduced chemical use, and in 1998, 1997, and 1995, the maximum amount was about five percent. Only in 1996 was there a possibility that the effect could have a substantial impact on the assessment of pounds of chemicals reduced (the maximum possible amount in 1996 was 59%).

Estimating Reductions

To estimate how much toxics use has been reduced in association with the OTA visits, we employed the assumption that if companies had not been visited, they would have performed at the same rate as they had performed before being visited (the average percent reductions of those not yet visited). We multiplied the expected use (production-adjusted use) by the average reduction that companies achieved before being visited to produce an estimate of how much would have been reduced if those who were visited had not been visited. This was then subtracted from what visited companies actually reduced, to produce an estimate of what changes should be associated with OTA's visits.

2. Toxic Byproduct Reductions

The performance analysis described in section 1, above, examines how well companies were able to do in using less toxic chemical to make product. The analysis described in this section provides a complementary perspective on the performance of TURA companies. This analysis examined whether companies could learn to use whatever they use, with less resulting byproduct.

The form of toxics use efficiency discussed in section 1 may be termed "toxics input efficiency". Sometimes the toxic chemical that is used is really the only viable choice for a particular process, and reducing input is not technically or economically feasible. In that case another form of toxics use efficiency becomes critical - one that measures whether each pound of chemical is used with the least resulting waste.

TURA reporting combines all kinds of waste - all nonproduct output - into one byproduct number. It includes the chemical that is emitted to air, discharged to water, or shipped in a drum – everything that is neither destroyed nor converted in process nor incorporated into product.[13]

We examined toxics use efficiency in terms of byproduct by calculating a "byproduct/use ratio" for each chemical, for each year. The changes in this ratio over time are indicators that make the resulting picture of toxics use reduction performance more comprehensive.

A significant feature of the byproduct/use ratio is that it is independent of production, so that it is not necessary to track production changes in order to gauge performance. It is also independent of amount of use, and so comparisons can be made of the performance of large and small toxic users without any further normalization.

To illustrate how the byproduct/use ratio works, consider a company that uses 100 pounds of chemical X to make 10 tables in year one, where 75 pounds of chemical X is incorporated into the table and is shipped in product, 10 pounds is evaporated to air, 10 pounds goes into the wastewater discharge, and 5 pounds is collected as waste in a drum that is shipped for disposal. The byproduct/use ratio is the total pounds of chemical X that is used – 100 pounds, divided by that which comes off of the production line as nonproduct material – 25 pounds – ¼, (25%).

In year two, the company encloses the process, capturing what is evaporated and piping it back to be reused as raw material input. (If totally enclosed, this is integral recycling and the captured and reused material is not counted as byproduct). The company makes twice as many tables in year two. They eliminate what would have been 20 pounds of waste air emissions by capturing and reusing, and this also leads to a reduction of 20 pounds in input. To make 20 tables they now use 180 pounds of chemical X and have 30 pounds of waste. Their byproduct/use ratio is 1/6, (16.6%).[14]

To eliminate those reports that might skew the results, we looked only at the "dynamic" population. There is a sizeable group of chemical use reports that have no associated byproduct at all – every bit becomes used up or incorporated into product, and a sizeable group where every pound used becomes byproduct (for example, a cleaning fluid that is

[13] TURA would not count as byproduct that which is managed as a useful raw material – even if not the originally intended use - but only if used or sold as is, or if recycled in an integral fashion.

[14] This example is just one of the many ways that byproduct reductions can lead to use reductions. Wastes can result from such events as leaks, inefficient application or transfer, insufficient uptake, spoilage in storage, incomplete mixing or reaction, or other conditions that are somewhat short of the ideal for use of the material. Reducing any of these should reduce the needed input.

used until it is spent). For many of these chemicals, this doesn't change over the years. A company using a solvent to clean equipment in 1994 may still be using the solvent in the same way in 1998. Measurements of use may indeed show that the company has learned to use less. But if all of the solvent is still becoming byproduct, then there will be no change in the byproduct/use ratio. By this measure, there is no progress. This is a "static" picture, and if there are many in the group that are either all byproduct, or none, the averages of the group end up showing more about group composition, not performance. In order to measure how much change took place among the typical population members, we removed chemical reports that had zero or 100% byproduct in both the base and examined years, so that we could obtain a more accurate picture of the dynamic population, where change occurred.[15] We compiled the byproduct/use ratios for all visited companies up to the examined year and compared the results to the performance of nonvisited groups in the same years.

Estimating Reductions

To obtain a rough estimate of how much toxics byproduct has been reduced, we used the analogous approach to what was employed for estimating toxics use reductions. We assumed that if visited companies had not been visited, their performance could be best estimated by applying the average performance rates of those not yet visited. We multiplied what visited companies used by the average byproduct/use ratio of those not yet visited, and compared that to the reductions the visited companies actually had, to estimate how much byproduct they would have generated if there had been no visit.

3. Company Dropouts.

At the time of this analysis, information was available concerning 613 companies that had dropped out of the TURA system. A company can become a "drop out" by ceasing to have above threshold quantities of chemicals, by closing up shop or going to less than 10 employees, or because a chemical has been delisted. MassDEP and OTA have, in the past, contacted companies that have dropped out of the system, to ascertain the reason.

The resulting database contains notations from these calls. There is no information on why the company dropped out for about one-third of the companies. They may have dropped out for any of the reasons listed above.

The dropout population consists of 179 companies visited by OTA and 434 that were not visited. To gain another indication of how visited companies performed relative to nonvisited, we compared the rates at which they dropped out because of TUR.

4. Statistical Analysis

[15] A few chemical reports that exceeded 100% were also eliminated. Looking at both years meant that only "static" all or nothing companies were removed. (It may be the case that some or many of the 100% byproduct companies could indeed make changes to reduce byproduct, but there was no way of sorting them out).

A completely different approach to the question asked by this study (has there been an effect in terms of toxics use or byproduct reductions from OTA visits) was taken by Dr. Robert Kaufmann of Boston University's Center for Energy and Environmental Studies, who performed an econometric analysis of the same TURA dataset[16]. Econometrics is a particularly useful tool for analyzing observational data. In experimental data, a particular factor is isolated, all others being controlled. With observational data, a number of factors may play a role at the same time, and their effects need to be sorted out. The TURA data is observational data – it is not the result of an experiment, with control groups and random assignments.

Econometric analysis is a tool that has not been much used[17] by government agencies for the purpose of analyzing the effectiveness of programs similar to OTA's, but it is a method well established and frequently utilized in academic disciplines. Only the final results of this study are cited herein, to compare its findings with the results of the OTA analysis.[18]

RESULTS

1. Toxics Use Reduction

Reductions by all reporting facilities.

The assessment of the overall TURA coverage effect found that reporting facilities would have used 880 million pounds of toxic chemicals in the last year of use of each chemical if they had continued to use these chemicals in the same proportions to produce product as they had in their original reporting year.[19] Subtracting the last year's actual use results in a best estimate that 274.5 million pounds was reduced from what was expected after scaling for production. Excluding regulatory dropouts,[20] half of the original amount of chemicals used have "dropped out" of the program: 353 million pounds.

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[16] Kaufmann designed, supervised and verified the analysis, performed by the following graduate students: Karen Cardinal, Robyn Kullas, Chihiro Nakazawa, Juliana Prosperi, Christiana Pollack, and Allison Gold.

[17] Searching in several databases turned up numerous analyses using survey instruments to estimate reductions in waste, and some studies examining TRI release reductions, from similar programs. But only two, both from academic sources, were found that used econometrics to assess the effect of pollution prevention programs on chemical use and releases (Snyder, Lori, "Are Management-Based Regulations Effective?: Evidence from State Pollution Prevention Programs", Regulatory Policy Program Working Paper RPP-2003-21, Center for Business and Government, JFK School of Government, Harvard University, 2003, at http://www.ksg.harvard.edu/cbg/research/rpp/RPP-2003-21.pdf and Abel, Troy; Kraft, Michael, and Stephan, Mark; "Environmental Information Disclosure and Risk Reduction: State Variation in Control of Toxic Chemical Emissions", prepared for delivery at the 2004 Annual Meeting of the American Political Science Association, 9/04, at http://www.uwgb.edu/idedm).

[18] The Boston University study is currently being developed for publication. Contact OTA or Dr. Kaufmann for further information.

[19] Application of the ten million pound skew limit removed 13 (out of 4189) chemical reports from this calculation of expected usage.

[20] Utilities were not excluded from this analysis of all reporting facilities and chemicals.

In addition, out of 4189 chemical reports**,** toxics use was reduced in 76.9% of reported chemicals**.** The ratio of advancers to decliners was 3.75. (2052 dropped below threshold, 1170 still in the system showed reductions over what was expected[21], and 902 (21.5% of chemical reports) were used in amounts that were greater than what would have been expected from production adjustment).

The "three-year" analysis: showing toxics use reduction performance of companies visited by OTA just before being visited, and just after being visited, and comparing that performance to other companies in the same time frame.

Tables 1a and b summarize the results of comparing how much toxics use reduction the average visited companies accomplished in the year before being visited, to the year visited, and then comparing the performance in the year after being visited to previous performance[22]. The year-to-year changes in amounts of chemicals reduced are comparative measures, not total amounts of reductions, and they are averages for each group (visited, never visited, not-yet visited). A negative average number would indicate that increases were predominant, a positive number would indicate reductions were predominant.

To increase the accuracy of comparison with the performance of other groups (never visited by OTA, and not yet visited), changes above 100,000 pounds were eliminated from the analysis. This "skew limit" for group comparisons brought into clearer focus the relationship of typical population members. It eliminated an average of 7.5% of chemical reports in each year. Table 1a displays the average percentage reductions achieved, comparing one year to the previous, and Table 1b displays the difference in the number of pounds reduced. Figures 1a – 1d display the same data in graphic form in order to clearly compare performance between groups: 1a and 1b show average pound reductions, and 1c and 1d show average percent reductions.

[21] As this is not measuring the extent of reductions, the skew limits were not used here.

[22] Two years of chemical use reports are required to register either a production-adjusted change or a dropout number. Because of the unavailability of sufficient data for some companies, the comparison was made in those cases between the year of the visit and the year after. The three-year analysis, (comparing the year before the visit to the year of and the year after), conducted earlier, used the base year for normalization.

THREE YEAR COMPARISON – CHEMICAL USE REDUCTIONS

	Year of Visit	Year After
Visited in 1995	11.50	11.30
Never Visited	4.60	7.70
Not Yet Visited in 95	4.00	3.20
Visited in 1996	13.20	6.04
Never Visited	5.50	6.60
Not Yet Visited in 96	10.60	6.90
Visited in 1997	12.50	21.60
Never Visited	3.30	6.60
Not Yet Visited in 97	2.00	5.10
Visited in 1998	34.60	7.40
Never Visited	5.80	4.70
Not Yet Visited in 98	5.40	9.40
Visited in 1999	37.66	27.87
Never Visited	4.20	2.80
Not Yet Visited in 99	14.30	7.40
Visited in 2000	13.60	16.20
Never Visited	2.20	4.20
Not Yet Visited in 2000	0.70	-5.90
average, all years, visited	20.51	15.07
average, all years, never	4.27	5.43
average, all years, not yet	6.17	4.35

1a Percent Reduction

	Year of Visit	Year After
Visited in 1995	2,929	4,549
Never Visited	2,412	3,121
Not Yet Visited in 1995	1,028	545
Visited in 1996	4,459	2,278
Never Visited	2,093	2,808
Not Yet Visited in 1996	3,680	2,483
Visited in 1997	5,304	4,979
Never Visited	894	1,696
Not Yet Visited in 1997	1,095	1,418
Visited in 1998	5,255	4,805
Never Visited	983	789
Not Yet Visited in 1998	1,209	2,811
Visited in 1999	5,793	8,108
Never Visited	1,199	1,125
Not Yet Visited in 1999	4,150	1,787
Visited in 2000	6,945	6,943
Never Visited	1,496	1,315
Not Yet Visited in 2000	717	-3,554
average, all years, visited	5,114	5,277
average, all years, never	1,513	1,809
average, all years, not yet	1,980	915

1b Pounds Reduced

Tables 1a and b. Both tables compare the year of the visit and the year after the visit to previous performance. Successful reductions result in positive numbers. Negative numbers mean toxics use has increased. Table 1a compares the average percent change in use, and Table 1b shows the average number of pounds reduced. For example: for companies visited in 1995, the average percent change is 11.5, and 2,929 more pounds of toxics use were reduced, on average, than the year before the visit. The year after, the average percent change 11.3, and 4,549 more pounds were reduced.

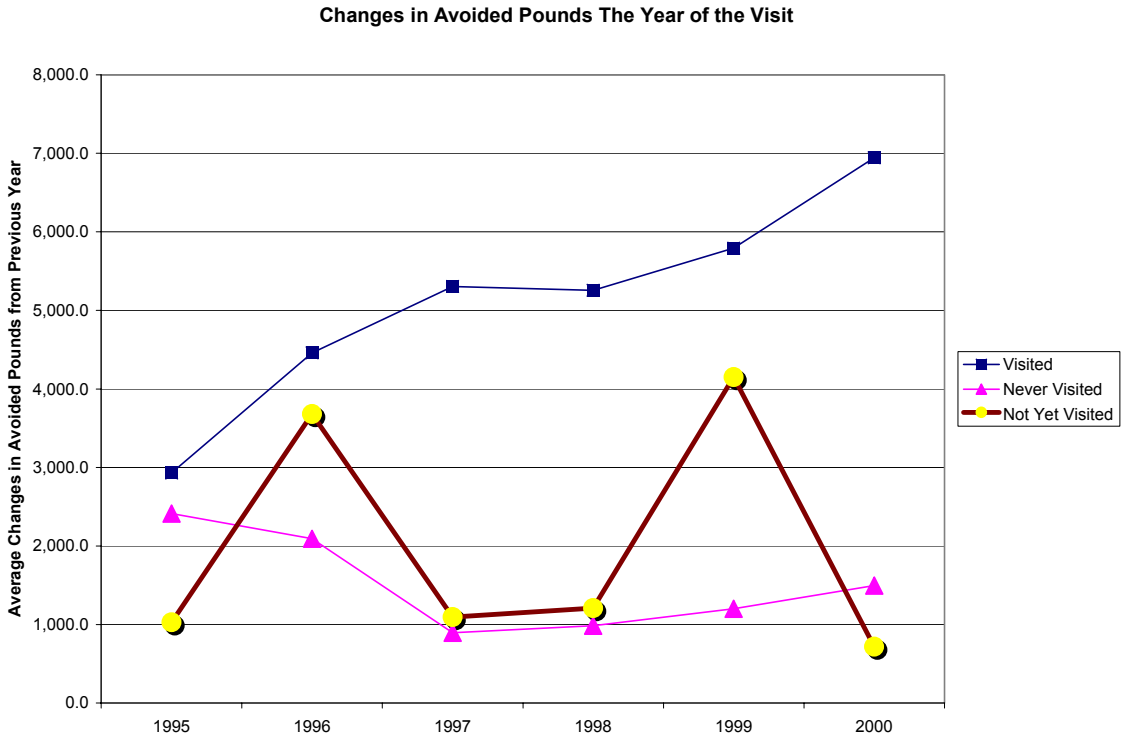


Figure 1a. Comparing the year of the visit to the year before.

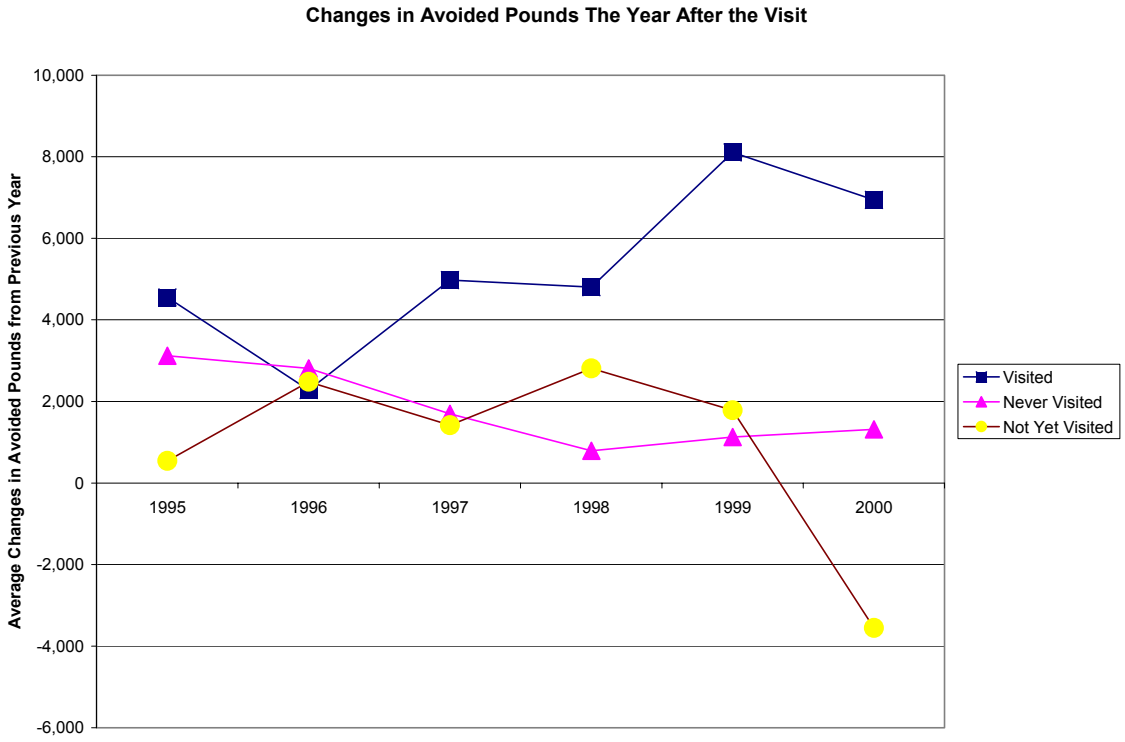


Figure 1b. Comparing the year after the visit to previous performance.

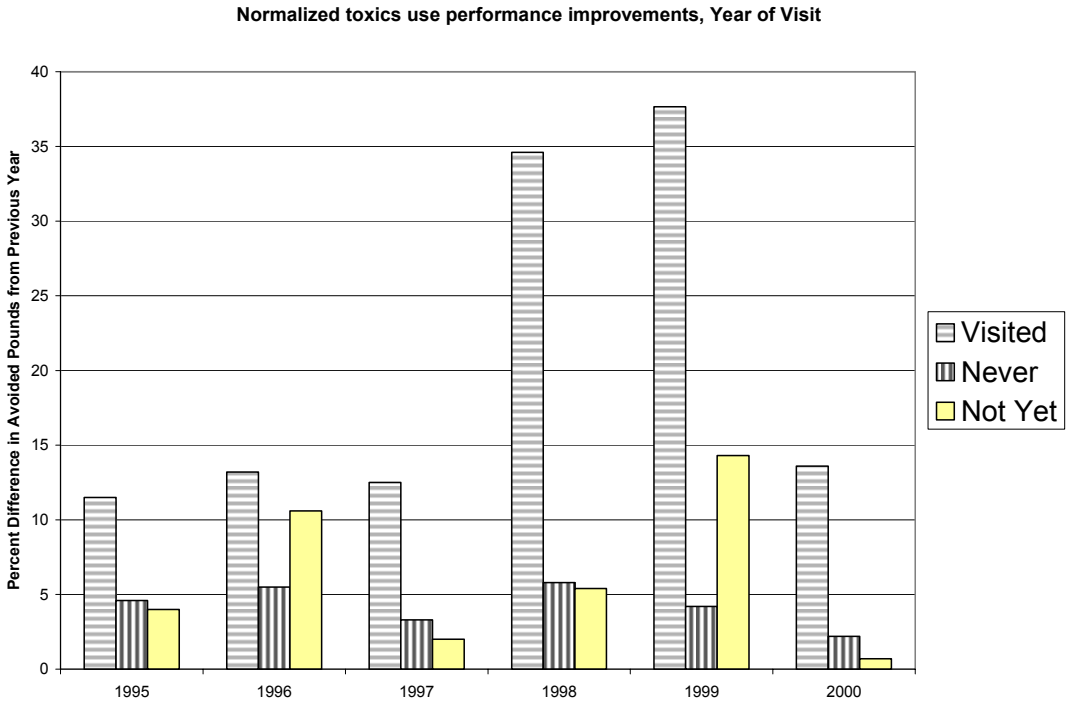


Figure 1c. Average changes in pounds of toxics reduced *in terms of percentages* of use, comparing performance in the year of the visit to the year before.

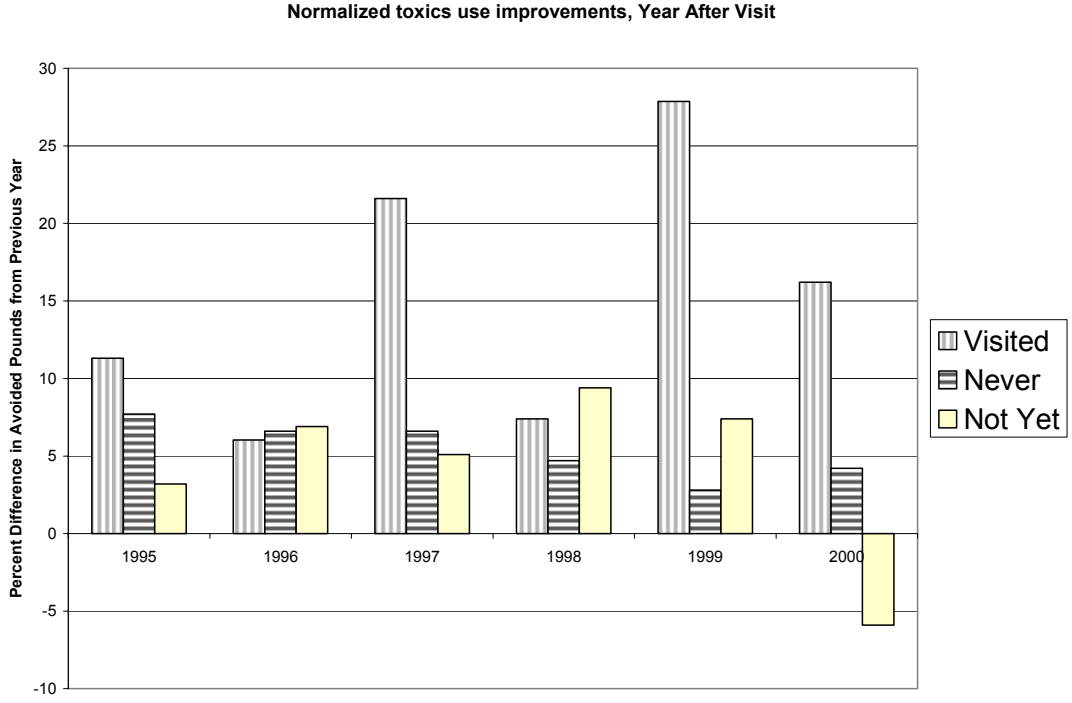


Figure 1d. Average changes in pounds of toxics reduced (or increased, as occurred in the year 2000 for the not yet visited population), *in terms of percentages* of use, comparing performance in the year after the visit to previous performance.

Mixed Year Comparison.

The average annual reductions of visited companies were arranged into categories of time, specifying the years before or after the visit. Figure 2 shows the results of the "mixed year" analysis, covering all performance measurements of visited companies over time, expressed as a percentage of use.

MIXED-YEAR BEFORE AND AFTER COMPARISON – CHEMICAL USE

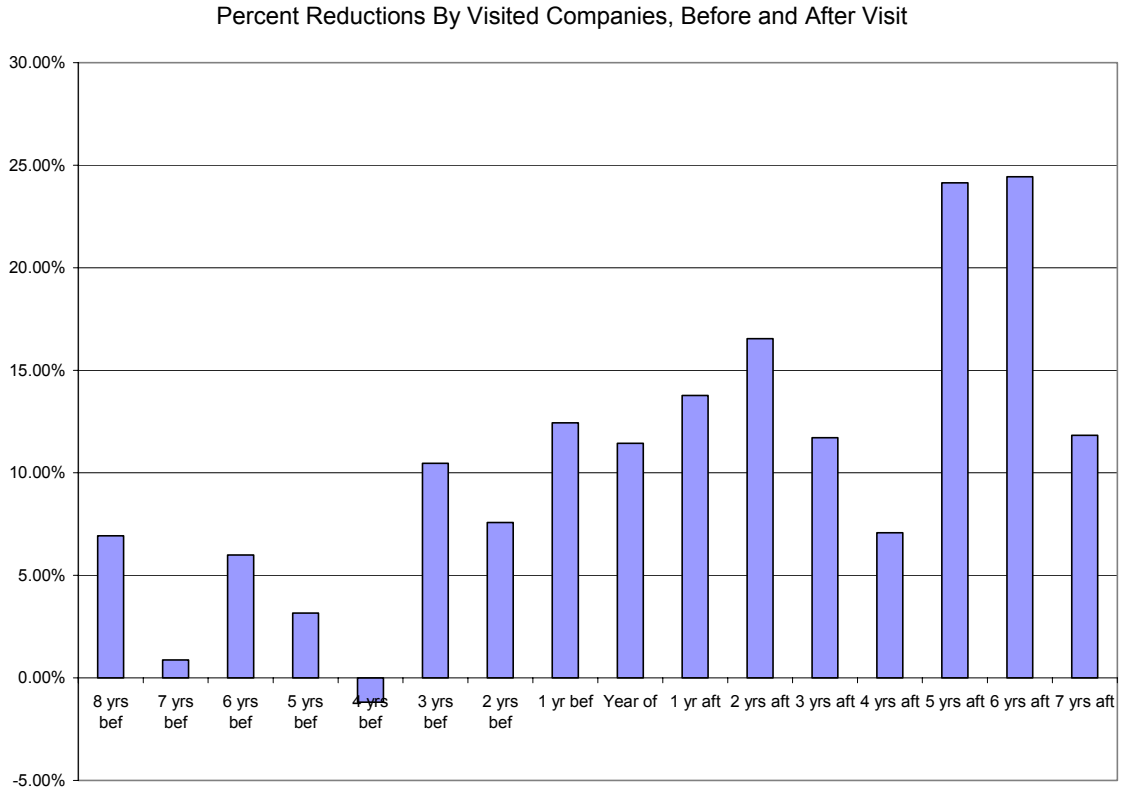


Figure 2a. The average reductions in toxic use, as a percentage of what was expected after adjusting for production, for all visited companies, grouped in categories of number of years before and after the visit (over a range from 1994 and 2002).

Total "Befores" and "Afters"

There was a total of 1321 measurements of normalized reductions, before being visited, and 1509 after. The percent reductions after the visit average **6.95%,** and in the years before, the average was **-2.49%.**

The statistical test Analysis of Variance confirmed that this difference was significant, with a very high degree of confidence, using a skew limit of 500% change. (107 of 2830 measurements, 3.7%, were eliminated).[23]

[23] The "F" value was 7.78492, and the "F crit" value was 3.844704 – significance is found when the F value is higher than the F crit, and the P-value is low. The P value was very low - .005303.

56% of "befores" had positive results – toxics use reductions. 61% of "afters" had positive reductions.

Comparison of Annual Average Percent Changes

The average percent reductions for each group were compared for each year.

ANNUAL AVERAGE PERCENT CHANGES – CHEMICAL USE

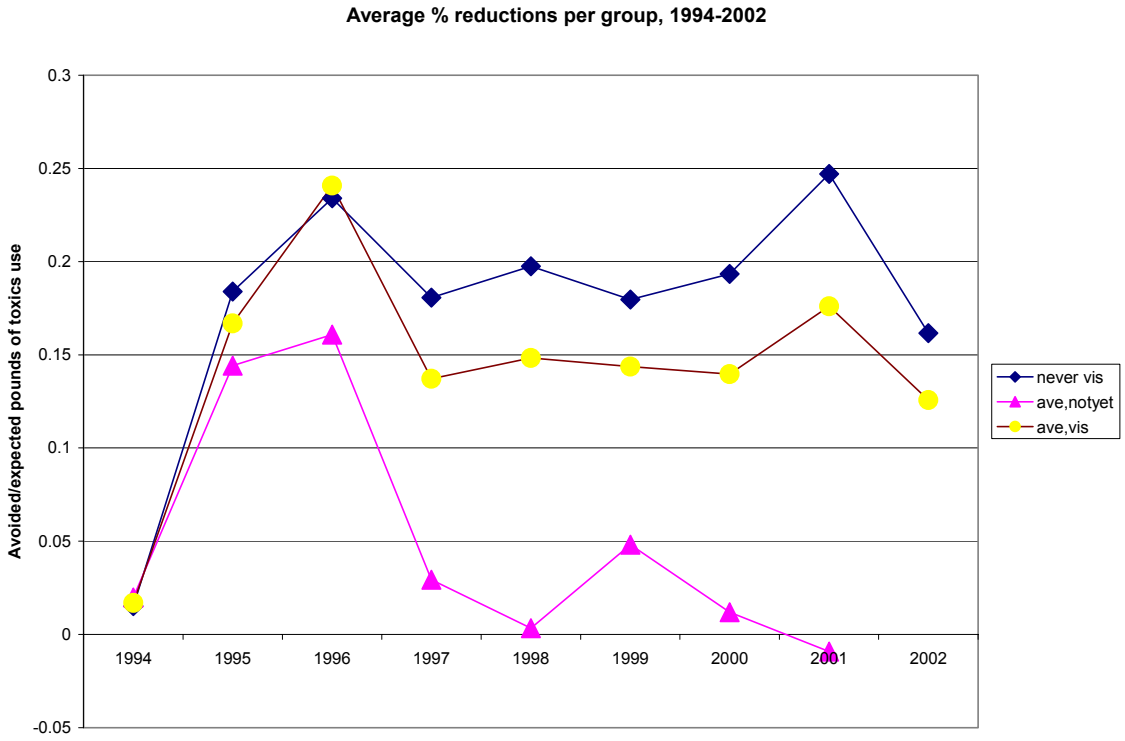


Figure 3. Average Percent Changes, Normalized by Amount of Expected Use. Comparison of all three groups.

Advancers and Decliners

The measurements above assess the magnitude of progress concerning toxics use reductions. Another indication of whether OTA's visits had their intended effect of stimulating successful toxics use reduction was to examine how many in each group did better or worse than before. The ratio of "advancers" – those who had more toxics use reductions than before, to "decliners", who had lower reductions (or increases in toxics use) was compared for all three groups: OTA-visited companies, those never to be visited, and those not yet visited, for each year. This data was generated by the "three-year comparison" described above, in which the years examined were the year before the visit, the year of the visit, and the year after the visit. Figure 4 summarizes the results of the comparisons.

RATIO OF ADVANCERS TO DECLINERS IN EACH GROUP – CHEMICAL USE

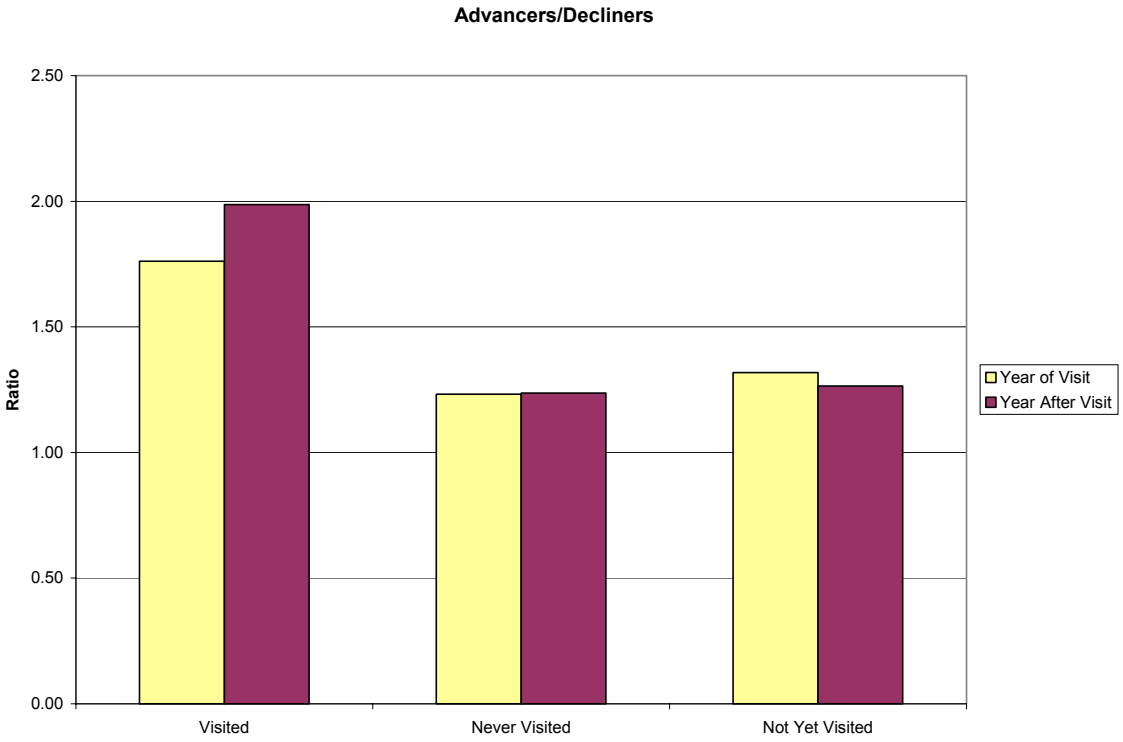


Figure 4. The ratio, in each group, of those who had more reductions ("advancers") in subsequent years, than before, to those who increased toxics use ("decliners"), compared to previous performance. *The groups with the highest ratios have the most members showing improvement.*

Table 2 presents the data used to generate the charts in Figure 4, and then totals them in a different way, answering the question, "how much of each group did better?" The numbers of advancers are expressed as percentages of the total population.

NUMBER OF GROUP MEMBERS WHO ADVANCED – CHEMICAL USE

	# of Advancers Year of Visit	# of Decliners Year of Visit	# of Advancers Year After	# of Decliners Year After
Visited in 1995	39	23	41	21
Visited in 1996	23	11	14	10
Visited in 1997	43	21	40	19
Visited in 1998	22	7	16	9
Visited in 1999	14	13	19	8
Visited in 2000	14	13	19	8
Totals	155	88	149	75
Total pop	243		224	
% Pos of total	**63.8%**		**66.5%**	

	# of Advancers Year of Visit	# of Decliners Year of Visit	# of Advancers Year After	# of Decliners Year After
Never Visited in 1995	818	539	745	501
Never Visited in 1996	762	611	750	536
Never Visited in 1997	704	610	681	572
Never Visited in 1998	523	311	600	304
Never Visited in 1999	696	550	681	590
Never Visited in 2000	606	714	619	792
Totals	4109	3335	4076	3295
Total pop	7444		7371	
% Pos of total	**55.2%**		**55.3%**	

	# of Advancers Year of Visit	# of Decliners Year of Visit	# of Advancers Year After	# of Decliners Year After
Not Yet Visited in 1995	185	132	166	103
Not Yet Visited in 1996	175	104	133	106
Not Yet Visited in 1997	100	105	102	80
Not Yet Visited in 1998	98	77	89	73
Not Yet Visited in 1999	92	63	96	76
Not Yet Visited in 2000	47	48	54	68
Totals	697	529	640	506
Total pop	1226		1146	
% Pos of total	**56.9%**		**55.8%**	

Table 2. Advancers and Decliners in toxics use performance, all groups.

Estimated Total Pounds Reduced.

Our method of estimation shows that companies visited by OTA from 1995 – 2001 reduced their toxics use by about 56 million pounds. To estimate how much is fairly attributable to OTA's visits, we ask what their reductions would have been if OTA had not visited, and assume that they would have reduced at the rate of the "not yet visited" group. The average "before" reductions from the total before and after analysis shows that those not yet visited on average increased their toxics use by 2.49%, which means that our best estimate of what would have happened if OTA had not visited these companies is that they would have used 6.6 million more pounds than expected solely due to production changes (total expected use was about 266 million pounds). Because the visited companies actually reduced about 56 million pounds below production expectations we estimate that OTA's assistance is associated with approximately 63 million pounds over the six-year period.[24]

[24] Extrapolating over the eight-year period examined in this study (1994 – 2002) comes to 83 million pounds. Neither the six-year nor the eight-year estimate is the same as the reductions associated with OTA's work over the lifetime of its operations. By 1994, before the examined period, OTA-visited companies had already filed 918 chemical reports. OTA has also worked with 738 companies not filing under TURA. An alternative method of estimating multiplies the average annual amount of expected use by visitees (110 million pounds) by the difference between visited and not yet visited reduction rates (9.44%), to estimate annual average reductions of about 10 million pounds.

2. Toxic Byproduct Reductions

The byproduct/use ratios for companies visited up until each examined year, compared to the ratios for the never and not-yet visited companies, is summarized in Figure 5 and Table 3 below.

COMPARISON OF HOW MUCH USE BECAME WASTE BYPRODUCT

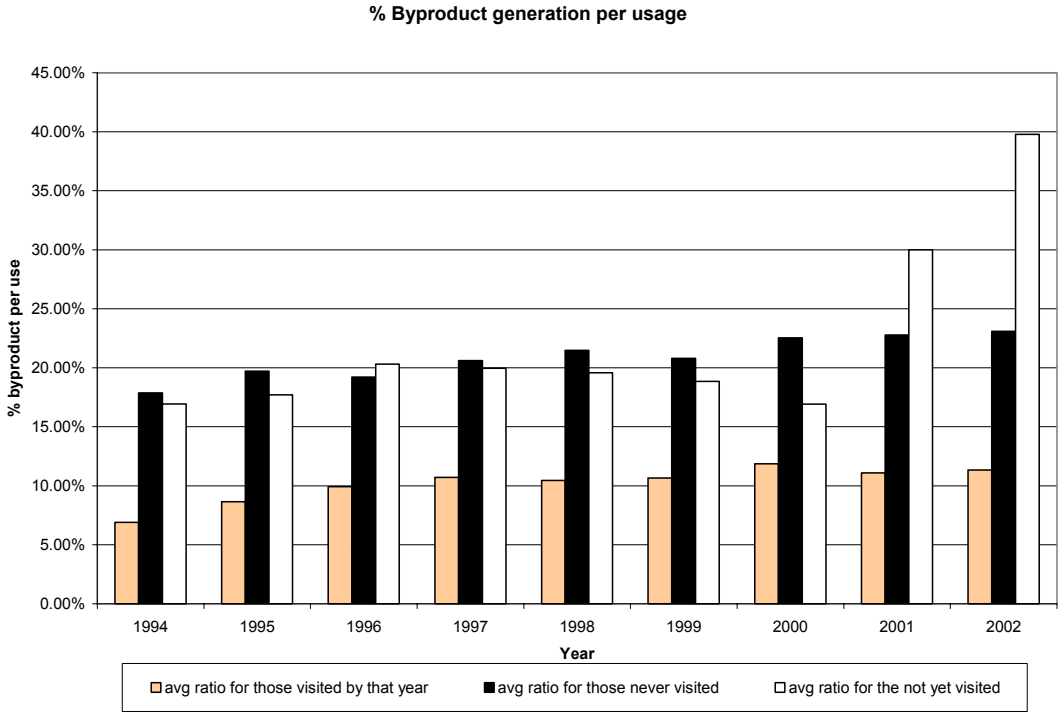


Figure 5. Average byproduct/use ratios for all three groups, for all companies up to the year examined.

	1994	1995	1996	1997	1998	1999	2000	2001	2002
avg ratio for those visited by that year	7.66%	8.65%	9.94%	10.72%	10.46%	10.67%	11.86%	11.09%	11.33%
avg ratio for those never visited	17.87%	19.72%	19.21%	20.62%	21.47%	20.80%	22.53%	22.78%	23.08%
avg ratio for the not yet visited	16.94%	17.70%	20.30%	19.97%	19.57%	18.85%	16.93%	29.99%	39.78%

Table 3. The numerical data used to generate Figure 5.

3. Dropouts.

Getting chemical use below TURA thresholds is a marker of success, except when it reflects an economic slowdown or companies moving operations out of state. If it has occurred because of toxics use reduction, from the company's point of view, it no longer has to pay a chemical use fee, do a TUR Plan, or do TUR reporting. From society's point of view, the risks of chemical transport, use, exposure, release, waste management, and presence in products are reduced.

About one sixth of all dropouts are known to have dropped out because the facilities closed or moved, and another sixth because of exemptions, overwhelmingly on account of a delisting of metal alloys. The percentage of the total dropout population of 613 companies, that we know dropped out of the system because of TUR[25], was **32%** (198 companies).

Of the nonvisited dropouts, 115 cited TUR as the dropout reason. This is **26%** of the nonvisited dropout population. Of the visited dropouts, 83 cited TUR as the dropout reason. This is **46%** of the visited dropout population[26].

A less precise but more accurate way to think about comparing the rates at which dropouts in each population dropped out because of TUR is to consider the "maybes" as well - the dropouts for which we lack information. Out of a total of 179 visited dropouts, 83 were known to have dropped out for TUR reasons - 46%. Adding in the "maybes" brings the total to a possible 137 - 76%.

The range for the nonvisited is 26% (115/434), to 45% (197/434). See Figure 6.

[25] Callers noted "below threshold" or cited specific actions. For example, a laundry stated that it dropped below the reporting threshold for sulfuric acid "by using more sensitive probes and metering devices in the equalization tank, and by washing more in the continuous batch washer". Another notation stated that "trichlorofluoromethane has been replaced by an environmentally friendly substance, not listed or reportable".

[26] Of the 83 visited companies that dropped out because of TUR, 63 were known to have been visited before they dropped out. (Some visitee dropouts, appearing to be "not yet visited" before dropping out, were likely visited by OTA, and the recorded visits were actually revisits, after the company left TURA. OTA's records of visits has some gaps in the early years). If only the visited dropouts who were visited by OTA before dropping out are examined, 48% dropped out for TUR reasons.

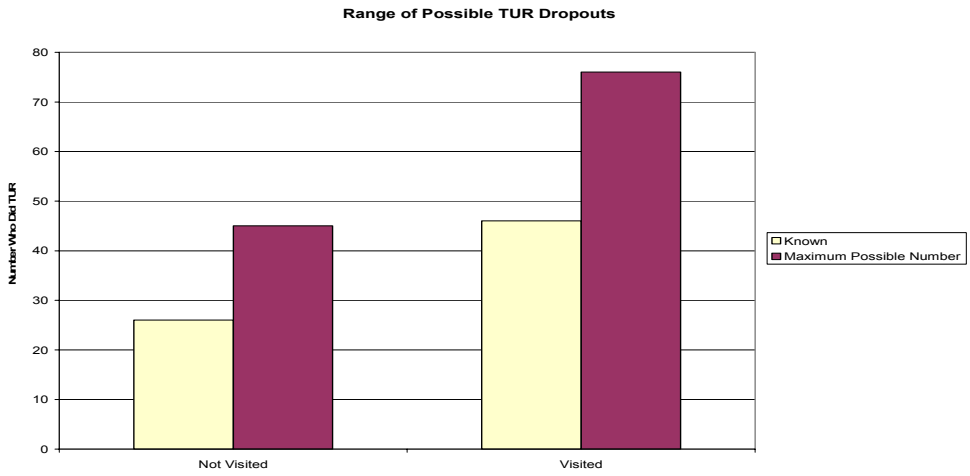


Figure 6. Known and possible TUR-Performing Dropouts in each population. The light color is the number in each group who are known to have dropped below reporting thresholds due to having performed toxics use reduction. The dark color is the maximum possible number who may have done so in each group.

4. Statistical Analysis

The Boston University researchers examined 25 chemicals for which there was a sufficient population of reporting companies in both visited and nonvisited populations. A statistically significant decline in usage for nine of the chemicals[27] was found to be explainable by the OTA visit, and OTA visits were associated with a statistically significant decline in byproduct for three chemicals[28]. Results of an attempt to assess the reductions indicate that combined use and byproduct generation of these chemicals, between 1993 and 2002, were substantially reduced as a result of OTA visits.[29]

DISCUSSION

Examining performance before and after being visited provides many indications that OTA visits did help companies reduce toxics use and toxic byproducts.

TURA Coverage Effect.

Being covered by TURA is associated with TUR improvements. The ratio of advancers to decliners for all TURA chemicals was high (3.75 to one). If the companies covered under TURA had continued to use chemicals at the same rate as when they began reporting to the public on such use, they would have used an additional 274 million pounds. Adding what was reduced while in the system and not later dropped out (206,133,819), to that which dropped below threshold amounts (352,822,977 pounds),

[27] Acetic acid, acetone, ammonia, dichloromethane, ethylene glycol, methanol, sulfuric acid, toluene, and 1,1,1 trichoroethane.
[28] Acetone, chromium compounds, and methyl isobutyl ketone.
[29] By an estimated 38% overall. Personal communication from Dr. Kaufmann, June 27, 2006.

results in an estimate of total use reductions by the companies covered by TURA (from 1994[30] to 2002) of 559 million pounds[31].

The requirements to do TUR plans, report publicly on use, and pay fees for toxics use likely cause companies to carefully examine their toxics use and find alternative materials or practices. This finding is consistent with anecdotal information gathered by the program and with previous research. OTA's experience working with over a thousand companies has shown many instances of companies discovering "loss points" after instituting careful chemical use monitoring, and increasing their knowledge and trials of chemical input alternatives, or equipment or process changes to reduce waste, or finding ways to recycle byproducts in an integral fashion, or sell them. Many also gained a better understanding of the associated costs of their chemical use, and the opportunities to reduce these costs, "hidden" in overhead and ultimate waste or pollution management, by making process, input or product changes. This is the intent of the planning requirement. In addition, anecdotal information indicates that many companies have responded to the public scrutiny they receive when reports are issued, and that the payment of the TUR fee is also a driver for reductions. A survey of 434 firms by independent contractor Abt Associates found the percentage of firms reviewing changes in production for environmental, health and safety impact went from 30% to 76% as a result of TURA coverage, and 81% stated they have or would implement at least a few of the projects identified by TUR planning[32].

Assistance program effectiveness.

If being covered by TURA causes toxics use reductions, do the results show that OTA's visits have helped companies to have even greater improvements, after being visited, and more than those not visited? The answer is yes, looking at chemical use, production, and byproduct. Only one measure (annual average percent reductions) showed superior performance by a group other than the visited group, and that finding is consistent with the expectation that those who are never visited may not need assistance as much as others do.

This study did not examine the one-to-one relationship between OTA recommendations and performance. If some companies achieved reductions in different chemicals than one that was discussed with OTA, it may be that OTA's work on the other chemical assisted

[30] When measuring absolute numbers it is possible to span the period 1993 – 2002. But when including production-adjusted reductions it is necessary to start with 1994, as two years are needed to develop the production-adjusted measure.

[31] The maximum adjustment to eliminate those who dropped out of the system for economic reasons, instead of performing TUR, can be estimated. The analysis of chemical dropouts by visited companies showed an average maximum amount in each year, possibly due to economic reasons, of less than 9%. The dropout study found one-sixth citing economic reasons. The maximum potential adjustment for the "just below threshold" effect is 10% - assuming all 2052 chemicals dropping below thresholds were used just below amounts, using the highest threshold of 25,000 pounds (10,000 is a much more common threshold).

[32] Toxics Use Reduction Institute, *Evaluating Progress: A Report on the Findings of the Massachusetts Toxics Use Reduction Program Evaluation,* March 1997; www.turi.org/content/content/view/full/998.

the company in learning how to apply the concepts of TUR, or that OTA's work helped eliminate dead ends, or in some other manner pointed the way towards a more favorable option. The predominance of findings reveals a pattern of post-visit improvements, higher than the performance of unvisited companies, within the same time frame. In addition to finding this result in a variety of perspectives, including the company dropout study, which relied on a completely different data set, an independent econometric analysis provided confirmation of the proposition that OTA's visits are associated with significant toxics use efficiency performance improvements.

Chemical Use. All the methods of analysis applied to chemical use data – except for average annual percent changes - showed OTA-visited companies having greater positive TUR performance changes in toxics use than the not-visited groups. The results were consistent across these various approaches to measurement. Excepting average annual percent changes, the visited companies in nearly every instance had larger improvements than the companies never visited by OTA. Those companies never visited had higher average annual percent reductions than any other group. This finding is consistent with the expectation that those companies that do not request OTA visits are companies that do well on their own.

It is true that in the years of OTA's operations, staff have encountered many companies who have accomplished TUR as part of their own mission. Half of OTA's case studies are success stories that were not generated in any way by OTA's work, but are examples of companies granting OTA permission to tell their story. Some companies have adopted TUR as a result of enforcement agreements with MassDEP or the U.S. Environmental Protection Agency. Many have found that TUR planning requirements helpful in identifying reduction options[33], and many have set environmental performance as a company goal.[34]

However, this overall superior performance disappears under closer scrutiny. When an examination is performed of the year-to-year changes occurring in the three years around the time of the visit, it becomes clear that companies visited by OTA have greater reductions, in that smaller time frame, than those never visited. In addition, there is a greater proportion of population members who advance, in the visited group, than in the never visited group. Visited companies have also consistently generated less waste per pound of input than those never visited, and they get out of the program by doing TUR at a higher rate than those never visited.

Are there differences between the visited and never visited groups? An examination of industrial sector categories revealed a very similar breakdown in both groups. There was no striking difference in the kind of company – for each industrial category, roughly half asked for visits, and half did not. Similarly, there was no significant difference in chemical use. For each chemical used, there was a balanced breakdown. No great

[33] See, for example, TURI Report # 14, www.turi.org/content/content/view/full/998.
[34] EPA's Performance Track initiative currently recognizes over 300 companies for environmental responsibility, including thirteen Massachusetts companies. See http://www.epa.gov/performancetrack/index.htm.

disparities appeared in either the kinds of chemicals used or the kinds of companies in each group that could explain the difference in performance.

An examination of number of chemicals used per company, however, did produce a disparity between the groups that could have explanatory significance. The average number of chemicals used by the visited companies was 4.55, while the average number used by those never visited was 3.69. This supports the proposition that those who ask for OTA's help are generally those who may need it – they are managing a larger variety of chemicals. The level of difficulty between managing more or less of the same chemical does not change as much as it does between numbers of chemicals managed. Each additional chemical is another set of problems and requirements, including fees, reporting, planning, waste or release management, training, and safety monitoring. Tackling these issues requires learning about the distinct risks and characteristics of each one, the different rules that may apply, and the various management choices and options for substitution or reduction that are feasible.

Those who do ask for help seem to benefit from the assistance service. On all measures, the visited companies performed much better than those who would be visited later, but had not yet been visited in the year examined. Companies had better performance after being visited, compared to their own past performance. The ratio of advancers in the visited group was much higher than that of both not visited groups. The byproduct/use ratios of the visited were much better than both not visited groups – in every year. And despite the fact that those never visited had better average annual percent reductions than those who asked for help, those who were visited had dramatically higher averages than those who were not yet visited. Put together, this set of findings provides a strong indication that the visit is an important factor in enhancing toxics use efficiency.

The three-year comparison, designed to focus on the changes easily associable with OTA's assistance, is a strong indicator. While the other analyses are of great interest, they each permit to a much greater degree the intrusion of other factors, because they span so many years. The three-year comparison is more likely to illustrate the effect of the visit. This analysis showed that:

- *OTA companies performed better after being visited than they were performing before being visited.* The year of the visit, an average of 20.5% more pounds than before, were reduced. The year after the visit, the average change was 15% more pounds reduced. These numbers are from 3 to 5 times higher than the comparable advances by the not visited groups in those same time frames.

  The average change in terms of pounds was about the same magnitude higher for visited companies. In the year of the visit, companies reduced 5,114 pounds more than the year before. At the same time, those never visited only reduced 1,513, and those who would be visited later, but had not yet been visited, reduced 1,980**.** The year after being visited these differences are very similar: the pattern holds.

The fact that visited companies consistently show much greater positive changes in the year of and right after the visit, than the performance at the same time of those not visited, provides the strongest indication of effectiveness.

That the not-yet visited group had very similar performance to the never-visited group, until they were visited, provides a very strong indication that there was no self-selection bias creating the illusion of an OTA visit effect. The proposition that the difference in performance between those visited and those not visited simply reflect inherent qualities shared by companies who would ask a service like OTA's to come onsite is strongly challenged by these results.

Advancers and Decliners. The virtue of looking at how many members of each group did better or worse is that it cannot be distorted by differences in amount of chemical use, or magnitude of progress. It measures if greater or fewer numbers of chemicals had improvements, in each group. It is therefore an important check on whether our findings are due to size distortions or not. The analysis directly supported the idea that OTA is helping companies, because the visited group had more advancers in nearly every year. In those years that were an exception to this finding, the difference was small. In several years, the visited companies had about twice as many advancers. The overall averages showed that more visited companies had improvements than those not visited.

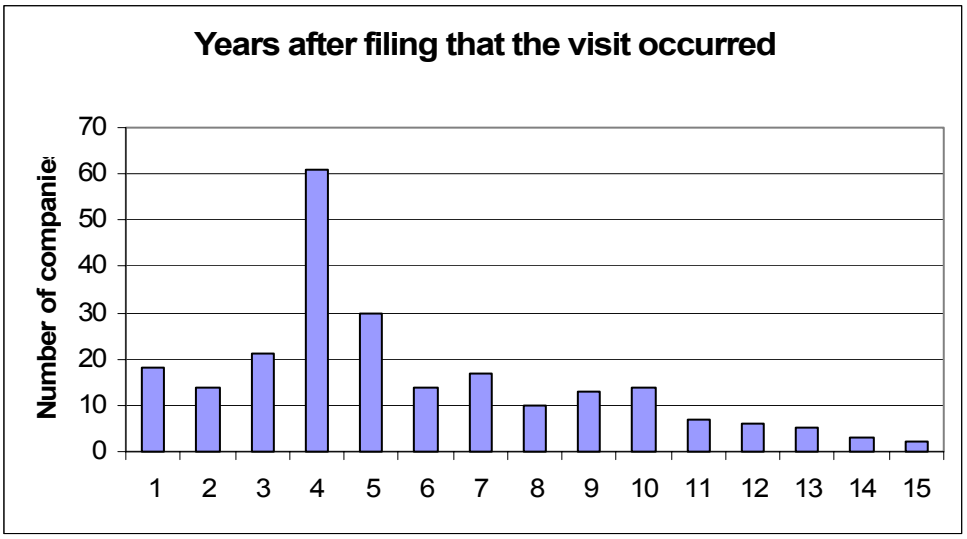
- Averaging all years, 63.8% of companies visited by OTA advanced the year of the visit, and 66.5% the year after. Companies never visited had a ratio of 55.2% advancers to decliners, and 55.3% in the same time frame. Companies later visited later had 56.9% and 55.8% advancers/decliners in those same years. More visited companies showed improvements than those not visited.

Before and After, all years. In addition to the before and after improvements revealed by the three-year comparison, and the advancer/decliner ratios, the total before and after analysis is consistent with a finding of effectiveness:

- The general trend is towards better performance, after being visited. This may resemble the finding that most companies covered by TURA improved their performance, and that those never visited had improvements, but the averages were not calculated chronologically - they were mixed. Companies visited in the later years of the program, after having been covered by TURA for many years, are averaged with those visited in the early years.

- Companies had greater percentage use reductions in the years after being visited than in the years before being visited. The statistical test confirmed that the 9.44 percentage point difference was significant. This indicator of visit effectiveness is not as strong as the three-year analysis, because the expanse of time covered increases the chances of other factors playing a determinative role. But the result of this analytical step is consistent with the three-year comparison.

The mixed-year chart illustrates this story, where average percent reductions for each year after being visited are generally well above the performance measurements for the years before visits. The fact that the 2001 performance of a company visited in 2002 was grouped, in both of these analyses, with the 1994 performance of a company visited in 1995, does not eliminate, but reduces the likelihood that these findings are related to factors other than the visits. If companies were typically visited when they started filing, then it would be more difficult to distinguish whether an upward trend was more due to being covered by TUR coverage effect, or more due to being visited by OTA. To get a sense of whether visited companies received their visits at the same time they began filing TURA reports, we returned to the data and charted the following:



The average number of years that companies received visits after being covered under TURA is 4.43 years. This could mean that the TURA coverage effect is not immediately manifested. But that supposition runs counter to the widely experienced phenomenon that companies choose the easiest options to implement first. It is more likely that this finding indicates that the TURA coverage effect may have something to do with the improvements seen after visits, but it is not a strong explanatory factor, for most companies were covered by TURA for a number of years before receiving visits.

Estimated reductions in toxics use. Reductions in use from 1995-2001 were estimated as 63 million.[35] These reductions were the accomplishments of the companies themselves. OTA only offered suggestions and did not make the decision to substitute safer products or use chemicals more efficiently for any facility. But the fact that the average company that would be visited by OTA increased toxics use before being visited, and significantly decreased use afterwards, taken together with all the other indicators that the visits had a real effect, justifies an association of OTA's visits with these reductions.

[35] OTA had made more than a thousand visits, one-third of the visits made up until 2003, before this time period.

The method used to estimate how much was reduced avoids the impact of the overall effect of being covered under TURA, because the comparison between groups is made of performance during the same time frame. It also reduces the problem of a substantive difference between companies that ask for OTA assistance and those that don't, because it compares performance within that same group.

The Economy of Scale Effect. It is possible to surmise that some of these reductions, and the finding that, except for one group in two years[36], the average company in all groups reduced pounds from the year before, is due to an economy of scale effect. When production increases perhaps in some processes it is easier to use proportionately less toxic chemical per unit of product. This is not likely the case with toxics that are incorporated into product, or which are manufactured, but it may be the case with toxics that are "otherwise used". However, for it to be a key factor it would have to hold true over a great range of uses in a great variety of industrial settings.

One finding that suggests this factor is not explanatory is the fact that the economy of scale effect can only help explain reductions from expected use, when there are increases in production. It cannot account for absolute reductions. Of the 76.8% of chemicals used by companies that "advanced" – had less toxics use than before – a good majority (63.6%) dropped below threshold. The average use in the first year of chemical reporting was 166,165 pounds, and the average use in the last year was 144,591 - well above the thresholds. The maximum amount of the population to which the economy of scale effect could possibly apply is only one-third.

Toxic Byproducts. A lower byproduct/use ratio is an excellent measure of TUR performance, as it is independent of size, and it measures the generation of unwanted materials – byproducts, which become pollutants, releases, wastes. To a company that makes products of value with toxics, the chemicals used are not undesirable. They are valuable goods. But wastes are not valued, by definition (unless transformed). In addition, not all toxics input can be avoided – the chemical used may be the only viable material, or the costs of switching may be too great (there are a host of reasons why a company may not wish to change input). In those cases, the amount of waste per pound of input is the most important measurement of toxics use efficiency, and in all cases, it is an important (and less controversial) measurement, complementing tracking of chemical use (input). The results of this analysis supported the finding of effectiveness:

- The companies visited by OTA had lower byproduct/use ratios in every year examined, than the groups not visited.

- In most years, the visited companies averaged less than half of what the other groups attained.

[36] The Not Yet Visited group, in the years 2000 and 2001, see Figures 1d and 3.

- Over all the examined years, an average of 10.3 pounds of every 100 pounds of chemicals used by the visited companies became nonproduct waste (10.3%). For those companies never visited, the average was 20.9%, and for those companies who would be visited by OTA but were not yet visited in the year examined, the average was 22.2%.

The rates of waste generation for the visited and never visited groups are fairly stable over time, which lends some gravity to the concept that these averages reflect the typical performance of group members. That the not yet visited group has much higher ratios than before, in 2001 and 2002, may be explained by the lowering of TRI thresholds for PACs and PBTs (polycyclic aromatic compounds and persistent, bioaccumulative toxins), bringing in many new reports[37]. This probably brought in facilities or plant activities not subject before to direct influences for waste reduction, either TURA planning or OTA visits.

Estimated Reductions in Toxic Byproduct. This data may also be used to generate a rough estimate of how many pounds of toxics waste reduction may be associated with OTA visits. Applying the difference in ratios to the original amounts used by visited companies produces the estimate that about 47 million pounds of toxic waste was reduced from what would have otherwise been generated. (396,028,146 times 10.3% = 40,790,899; times 22.2% = 87,918,248).

Associating Estimated Total Impact. To estimate total reductions associated with the assistance service it is necessary to understand that OTA has worked with many more companies than those assessed here – the ones reporting TURA data. OTA has also provided assistance through other means than the onsite visit, reaching many companies through published and distributed case studies, workshops, and other presentations and initiatives. Also, OTA worked with many companies – who learned about TUR for the first time – during the early, unexamined years of the program.

On the other hand, despite the work done to isolate the effect of the OTA visit, there are other factors that have undoubtedly played a role[38]. The impact of TURA planning, reporting and fee paying are seen in the reductions by all covered companies. For example, although enforcement initiatives often take place in discrete periods of time (and thus their effect would have been diminished by the methods used) some have probably had an effect during the entire time period examined.

But most importantly, it is the company that achieves the reductions that did the work – not OTA. OTA's service is clearly a factor in helping companies to identify, understand and implement TUR. Other factors must also be considered – enforcement, education, TUR planning requirements, and the inherent logic of using chemicals more efficiently, or using safer alternatives. But it is the company, and oftentimes vendors of new products, or private consultants, that deserves the credit for TUR implementation.

[37] This may also help explain some of the declines in use reduction performance during that time.
[38] Notably, TURI's programs, such as the Surface Cleaning Laboratory.

However accurate the estimate of what was reduced, it can only be claimed that these reductions were associated with OTA assistance – not caused by them.

Company Dropouts. Yet another perspective was provided by examining the reasons that companies have dropped of the TURA reporting system. Because there is incomplete knowledge about each dropped out company, the number dropped out is expressed as a range, the minimum of which is the number of companies known to have dropped out because of TUR, and the maximum is the number of companies that could possibly have dropped out because of TUR. The data shows:

- More companies dropped their chemical use below the threshold for reporting because they implemented toxics use reduction, after being visited. If we compare the midpoints of the two ranges, (35.5% and 61%), the visited companies dropped out of the system because of successful implementation of toxics use reduction, at a rate 1.7 times greater than those not visited.

Conclusion

About half of a billion pounds of toxics were reduced by all companies required to do TURA planning and reporting, from 1994 - 2002. Based on the performance of visited companies before they were visited, it is estimated that OTA's assistance service helped companies achieve about 63 million pounds of reductions in toxics use and about 47 million pounds of reductions in toxic byproducts. An econometric analysis corroborated OTA's findings of a significant correlation between visits and reductions in toxics use and byproduct. Neither of these estimates tell the whole story: OTA has worked with more companies and chemicals than were assessed by either method. Many companies were helped before and after the examined period, many have been helped who do not report under TURA, and many have been helped without receiving visits.

This study is the first time some of the analytic methods used herein have been used to analyze TURA data, and to assess the effect of a program that provides pollution prevention assistance. It is also a demonstration of how pollution prevention may be estimated (made possible by the establishment of a toxics use reporting requirement).

The study may also be unique in using so many methods to produce a variety of perspectives. One of the investigations used a separate database, and the others, using the same database, each focused on that data in very different ways (including the independent Boston University econometric analysis).

That many different methods of investigation into the effectiveness of OTA's onsite technical assistance visits provided similar indications suggests that a conclusion of effectiveness is robust. Reducing various potential distortion effects rendered a picture relevant to the typical company. Using normalized measures independent of production or size increased the accuracy of performance comparisons.

None of the estimation methods used above can pinpoint exactly what has been achieved. To-the-pound precision is misleading. But the clear finding seems to be that companies covered by TURA have reduced their chemical use, and that companies visited by OTA have reduced proportionately more of their chemical use and byproduct after being visited, and to a greater degree than those not visited. This permits the conclusion that toxics use reduction planning and reporting requirements do have the effect of bringing about significant toxics reduction, and that the provision of onsite technical assistance can substantially enhance what companies can achieve. Although OTA's contribution to the half-billion pounds reduced by all TURA companies during the examined period cannot be pinpointed, the numbers cited above illustrate that OTA has had a substantial, positive impact.

Finally, the TURA reports represent a unique opportunity to study pollution prevention performance. The methods introduced herein used input, output, and production ratios. The publicly available dataset also contains information about the processes in which the chemicals were used. It contains information about how reductions were achieved. It contains information about number of employees, recycling, routine and one-time releases, and the geographical location of each facility. This information could be used to discover where progress did and did not occur, and corresponding environmental impacts. Further research using this information could examine the relationships between toxics use efficiency advances or declines, and data from other sources, such as economic trends among industries or regions, or the volume of chemicals or products in commerce. It is hoped that this study will do more than communicate the results found, but will also alert researchers to the great value of the TURA reporting data.

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TURA Information release, Massachusetts Department of Environmental Protection: http://mass.gov/dep/toxics/priorities/priorities.htm

National Pollution Prevention Roundtable: http://www.p2.org/

Appendix – Excel Formulas For Calculating Toxics Use Reductions

Reductions in Use. The sample year 1996 is set forth below as the examined year. Usage and production ratio information are public information.

Chemicals no longer reported are identified: IF(**Usage1996**=0,IF(**Usage1995**>0,**baseyear96**,0),0). If the usage in the examined year (1996 in this example) is zero, and there was usage in the year before (1995), then the chemical is a "dropout" and the base year usage is entered - the first year the chemical was reported by that facility. If 1995 usage was zero, then no dropout amount is recorded, because either chemical reporting has not yet begun on this chemical, or it has already dropped out in previous years.

Entrants, chemicals newly reported, are tracked by the formula IF(**Usage1995**=0,**Usage1996**,0), which means if there was no usage reported in the year before, then enter the usage in the examined year.

Finding the base year is the first step in calculating expected use in the examined year, and a critical step in avoiding false negatives or positives. The formula looks at every previous year of usage, as follows: IF(**Usage1993**>0,**Usage1993**,IF(**Usage1994**>0,**Usage1994**,IF(**Usage1995**>0,**Usage1995**,0))). If there is usage in 1993, then some number greater than zero will appear, and that will be entered. If there is no number in that year, the formula moves on to the next year, and so on, ending in zero if nothing is found.

The second step in calculating expected usage is to calculate the necessary production adjustment of the original (base year) usage. To know how much production has changed we have to multiply all the production ratios for each year that the company has reported. This produces a "long ratio": IF(**Ratio1994**>0,**Ratio1994**,1)*IF(**Ratio1995**>0,**Ratio1995**,1)*IF(**Ratio1996**>0,**Ratio1996**,1). No ratio is used for 1993, since the ratio compares production to the year before, and the study did not use data from 1992. If the ratio in 1994 is greater than 0, then enter that ratio. Otherwise, enter "1". Then multiply this by the next ratio given, if there is one. The reason for the "1" is that multiplying by zero makes all the rest of the rest of the data disappear.

The expected use is then calculated by multiplying the base year by the long ratio, with some extra steps: IF((**dropouts94**+**dropouts95**)>0,0,(IF(**baseyear96**>**SkewVolume**,0,**baseyear96**)*IF(**longratio96**>**SkewRatio**,0,**longratio96**))). This formula checks if there were any dropouts by asking them to be all added up. If there were dropouts, some number greater than zero will be found by the addition process, and then the calculation of the expected use stops and zero is entered. There is no further expected use, the chemical is out of the system. If there were no dropouts the formula takes the base year, which has been located by the formula described above, and asks if it is larger than the volume skew limit. The volume skew limit is placed in a designated cell of the spreadsheet and so can be easily changed without affecting this formula. If the base year usage is higher than the skew volume limit (ten million pounds), then zero is entered. Otherwise, (if it is some number less than 10 million pounds), the base year amount of usage is entered. This number – either zero or the base year amount of chemical use – is then multiplied by the longratio. But the long ratio also has a skew limit (either five or ten).

If some chemical has been eliminated from the analysis because of a skew limit, this is tracked by the formulas IF(**longratio96**>**SkewRatio**,**baseyear96**,0) and IF(**baseyear96**>**SkewVolume**,**baseyear96**,0), which simply ask if the ratio or base year amount exceeded their respective skew limits, tell us the base year amount. This way we know how the skew limits have affected the comprehensiveness of the analysis.

The reductions from what was expected – what chemical use has been avoided – is then calculated by: IF(**dropouts96**>0,**baseyear96**,IF(**exp96**>0,**exp96-finalyear96**,0)), which asks for the base year amount if the chemical dropped out, and if not, subtracts the examined year's usage from what was expected. The gives us a production-adjusted measure of pounds of toxic chemicals reduced.

Finally, we calculate a percentage reduction by dividing the pounds reduced by what was expected, so that we can say how much of what was expected was not used.

Reductions in Byproduct. For each year, a byproduct/use ratio was calculated by dividing the byproduct reported in that year by the amount of chemical use reported. Both figures are publicly available.

For each year, the byproduct/use ratio of the base year was also found, as was done in the chemical use analysis above.

As explained in the paper, it was necessary to remove those reports wherein all chemical input became byproduct, or no chemical input became byproduct ("all or nothings"), and there was no change from the beginning to the examined year, in order to arrive at an average byproduct/use ratio that approximately measured the performance of the group members. "Static all or nothings" are significant skew factors. We added together the byproduct/use ratios of the found base year and the examined year, as follows: IF(K2+L2=0%,1,IF(K2+L2=200%,1,0)), where K2 is the byproduct/use ratio in the base year and L2 is the byproduct/use ratio in the examined year. This formula produced a "1" if the sum of the two ratios was either zero or 200%.

We then made sure we did not include in the examined year any companies that had dropped out of the system before that year, by asking IF(F2>0,IF(I2=0,AT2,0),0). This formula says that if there was use in the year before, but no use in the examined year, provide the base year quantity (for purposes of tracking what has been dropped out).

The next step generated the "unskewed" byproduct/use ratios. The static all or nothings and the dropouts were eliminated by asking IF(AU2=1,0,IF(AV2>0,0,IF(K2>100%,0,K2))). This says that if a numeral one was produced as described above, then zero is to be entered, and if the chemical is no longer reported (has been dropped out), then a zero is entered. The formula also provides that if the byproduct/use ratio is larger than 100%, a zero should be entered. This also eliminated a few very large skew factors.

Those byproduct/use ratios not eliminated by the above skew limits were then summed, and the number of nonzero entries counted. The average was calculated by dividing these two numbers, so that zeros would not dilute the group averages.

Description of Measures Used

Average Changes in Pounds Used Relative to Production. Changes in production can cause increases and reductions in chemical use and/or waste. To see if a company reduced its chemical use beyond what production changes are responsible for, it is necessary to adjust for production. OTA did this by multiplying the amount of toxics use in the first year of reporting by the production ratios in subsequent years. This operation yielded an "expected" amount of toxics use for each chemical for each year.

The amount of expected chemical use was then compared to the actual toxics use. If the expected use was less than the actual use, then the company had increased its toxics use relative to production changes. If the expected use was more than the actual use, the company had reduced its toxics use relative to production.

Percentage Reductions of Use. The amount of chemicals used differs from company to company, and an average change, measured in pounds, does not accurately gauge the performance of the group as a whole. To compare companies that use millions of pounds with companies that use thousands, a percentage reduction is necessary. To assess the performance trends of groups, OTA divided the amounts reduced by each company by the amounts expected of each company. This produced a percentage reduction from expected toxics use, normalized according to amount of chemical use.

Advancers/Decliners. Using the production-adjusted pounds measure, the ratio of advancers to decliners was tracked. (An advancer is a company that had less toxic use relative to production, in subsequent years, a decliner had more toxics use). If the visited group had a higher advancer/decliner ratio than the not-visited groups over the same time period, such a finding would support an inference that the OTA visit made a difference.

Byproduct-Use Ratio. Complementing measures of whether toxics input increased or decreased is a measure of how much waste resulted from each pound of toxic chemical used. (Byproduct means all types of waste – nonproduct output - from chemical use input). Like the percentage reductions in use, this measure is independent of the size (amount) of use.