EVALUATE OPPORTUNITIES FOR REDESIGN TO ELIMINATE VULNERABILITIES AT PRIORITY SITES

By this point in the reassessment process, you have formed a chemical reassessment group and inventoried local facilities. You have identified some of the key facilities to be reassessed. Now the reassessment process moves to ensure more detailed reassessments of hazards, and hazard reduction opportunities, at each of the priority facilities.

A) Have the choices of materials and processes used at the site increased hazards?

Sometimes also referred to as "primary prevention," **inherent safety** relies on the development and deployment of technologies **that prevent the possibility of a chemical accident**. By comparison, "secondary prevention" reduces the probability of a chemical accident, and..emergency responses seek to reduce the seriousness of injuries, property damage, and environmental damage resulting from chemical accidents.[1]

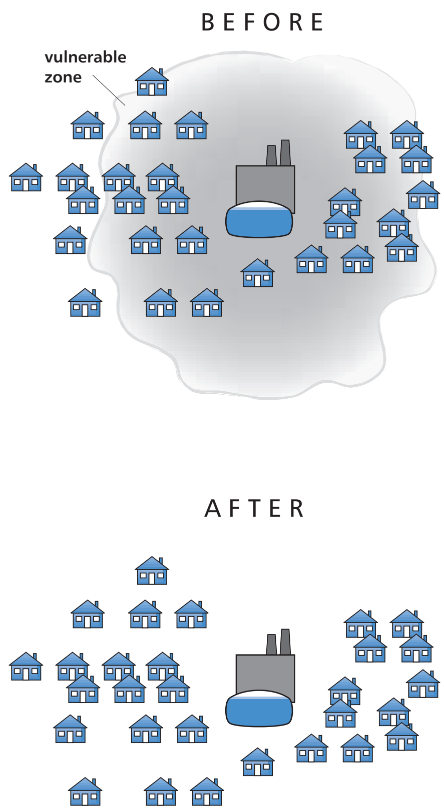
If a facility is vulnerable because it *has been unnecessarily designed to store high volumes of extremely dangerous chemicals*, and then it suffers a release due to an accidental explosion or an intentional assault by terrorists, there are really at least two "causes" to the incident—one, an initiating event, and secondly, the dangerous manner in which the facility is designed. Creating safer communities requires addressing both potential "causes" of incidents ~~bo~~th potential triggers, and the root causes that create the vulnerabilities.

Many companies, after accidents occur, blame the incidents on human error or operator error. If a forklift is driven into an ammonia-loaded refrigeration unit, setting off a massive ammonia leak, the incident could be blamed on negligence by the forklift operator, or perhaps on the lack of adequate training of the operator.

One paper by EPA would suggest, looking at the same incident, that the cause may be the *lack of a barrier to prevent a forklift from hitting the unit*. By this view, the owner and designer of the facility needed to take into account the fact that human error is inevitable; basic plant layout should prevent a release incident from so easily being triggered by a straying forklift.

Another perspective on the same matter might say that the cause is the lack of adequate analysis of accident risks (Process Hazard Analysis) by the management of the company - a failure to adequately assess and prevent the things that could go wrong.

Finally, taken from an inherent safety perspective, one might say that even if a barrier is erected, incidents may happen in unforesee-



Eliminating Vulnerability By Substituting Safer Materials

Evaluate: has the facility considered all costs and risks to community in deciding feasibility of substitutions?

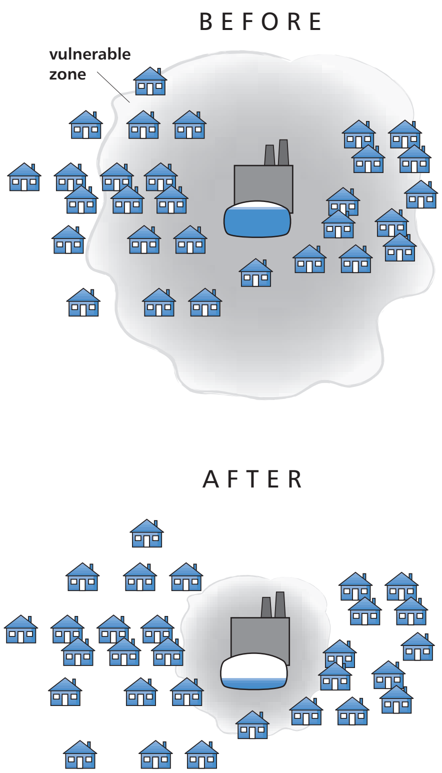
For instance, did the facility take account of local health impacts of chronic pollution? Local policing costs associated with having potential terrorist targets?

Some Inherently Safe Technologies Sit on Shelf

Few chemical companies have set measurable goals and timelines to reduce inherent hazards. A 1999 survey of 175 chemical industry facilities found only one facility with a measurable goal and timeline for eliminating or reducing the size of its vulnerability zone for a worst-case accident.[1] In a separate 1999 survey of nearly 200 major chemical companies, only three had developed measurable goals and timelines to reduce worst-case vulnerability zones.[2]

To cite one example, about half of US oil refineries use large volumes of hydrogen fluoride (HF). The substance, if released in an incident, could pose a danger of a ground-hugging toxic gas cloud similar to the cloud that killed 3,000 people quickly in the Bhopal, India disaster. This hazard can be eliminated by switching to safer forms of catalysts. But there is no government mandate to undertake the needed expenditures, and little or no implementation at HF-using refineries.[3]

1. U.S. Public Interest Research Group and Working Group on Community Right-to-Know, *At Risk and In the Dark: Will Companies in Our Communities Reduce Their Chemical Disaster Zones?*, June 1999.
2. Environmental Defense, National Environmental Trust, OMB Watch, Sierra Club, Unison Institute, U.S. Public Interest Research Group, and Working Group on Community Right-to-Know, *Hazard Reduction Challenge*, June 1999.
3. Lapkin, Milton and Sanford Lewis, Boosting the First Line of Defense: Moving Toward Safer Materials in Refinery Alkylation. A Technical Report , Good Neighbor Project (1993)



Reducing Vulnerability By Curtailing High Volume Storage

Evaluate: has the facility considered all costs and risks to community in deciding feasibility of these reductions?

For instance, did the facility take account of local health impacts of chronic pollution? Local policing costs associated with having high impact targets?

able ways as long as there is a high volume of ammonia in use in the unit. In particular, if there is a high volume of ammonia in use it is difficult to **eliminate** the hazards of intentional sabotage or failures of the various safety measures. Such a perspective would seek to go further to minimize the amount of ammonia that could be released into the environment in the event of a breach - perhaps by minimizing the amount of ammonia that is present in the system, or using an alternative cooling material, or using ammonia in a safer form.

In reassessing chemical release prevention at facilities, a range of actions and analyses is usually needed. What is most often overlooked, however, is the opportunity to apply inherent safety measures. It often takes a significant external demand or sudden changes in conditions to ensure that assessment and implementation of inherent safety measures occurs.

Inherent safety looks for ways to make the basic process, or its components, less dangerous so that even if security or safety systems fail, **the worst that can happen will not be a large scale catastrophe**. Major inherent safety design strategies[2] include:

- **Minimize:** Use smaller quantities of hazardous material and less energy.
- **Substitute:** Replace with a less hazardous substance.
- **Moderate:** Use less hazardous conditions or a less hazardous form of a material.
- **Simplify:** Eliminate unnecessary complexity to make operating errors less likely.

> A well-designed facility, by its layout, limits the possibility that equipment will be damaged and, by its process design, limits the quantity of chemical that could be released. Facility and process design (including chemicals used) determine the need for safety equipment, site security, buffer zones, and mitigation planning. Eliminating or attenuating to the extent practicable any hazardous characteristic during facility or process design is generally preferable to simply adding on safety equipment or security measures.
>
> USEPA *Site Security Guide, 2000*.

- Design systems that are **forgiving of errors**.

In addition to advancing the safety of workers and the public, inherent safety also reduces liability, and can save on safety-related costs such as maintenance and repairs. It may even eliminate coverage of a facility by regulations such as Risk Management Planning (CAA 112r), thereby saving regulatory compliance costs.

The inherent safety approach can be applied to retrofit a process as a whole, or incrementally, by making inherent safety changes at potential failure points in the existing system.

B) Have the range of inherent safety options been assessed or reassessed?

Ensure that an evaluation is conducted to identify the range of opportunities for applying inherently safer technologies at the facility, including evaluation of costs, benefits and trade-offs of the leading options. Typically, an assessment of this kind is conducted most intensively by technical consultants working with the facility's own personnel. External involvement, advice or oversight by external stakeholders such as the community reassessment group, local concerned citizens, emergency responders, and others may occur intermittently throughout the process.

INHERENT SAFETY IS NOT JUST FOR NEW FACILITIES: EXISTING CHEMICAL SITES CAN BE REDESIGNED TO ELIMINATE VULNERABILITIES

- Rohm and Haas converted one of its processing systems from batch to continuous, resulting in the replacement of its 3,000 gallon batch reactor by a 50 gallon continuous reactor.

- Hoffman-LaRoche had been storing 12,000 to 15,000 gallons of liquid ammonia in a refrigerated tank. Levels were reduced to 2,000 gallons.

- Dow substituted aqueous ammonia at atmospheric pressure for pressurized anhydrous ammonia to reduce the effects of volatility in the event of a spill. Dow also reduced by 95% its 100,000 pound inventory of phosgene at one of its plants in La Porte, Texas by operating the facility on an adjusted-time system--having the satellite units run continuously off the feed unit.

- PPG Industries recently developed carbonyldiimidazole, a benign phosgene substitute that can be used in the synthesis of some of their pharmaceutical products.

- DuPont had been making a crop-protection insecticide at its plant in LaPorte, Texas using methyl isocynate (MIC) purchased from Union Carbide. This is the substance which caused the Bhopal chemical disaster, blamed for 3,000 immediate deaths and another 13,000 in the subsequent years. In the aftermath of Bhopal, DuPont found a way to avoid keeping 40,000 to 50,000 pounds of MIC in storage. Though it produces MIC as an intermediate, the firm immediately consumes it in a closed-loop process. The result is a maximum of two pounds of MIC on-premises at any one time.

From Ashford, Nicholas, et. al., *The Encouragement of Technological Change for Preventing Chemical Accidents: Moving Firms from Secondary Prevention and Mitigation to Primary Prevention*, A Report to the U. S. Environmental Protection Agency, Center for Technology, Policy and Industrial Development at MIT, Cambridge, MA, July 1993.

The group of people who will engage in a rigorous process of technology assessment should at a minimum include facility staff with knowledge of processes, materials, hazards and costs, and external technical advisors (engineers, chemists, etc.) with expertise in inherent safety assessments relevant to the facility. This team will typically need to:

- Identify priority activities within the facility
- Identify why the activity is hazardous.
- Brainstorm a wide array of alternative methods, materials, processes which would be inherently safer.
- Winnow down the list of options to identify those showing the most promise.
- Conduct a more detailed feasibility assessment of those options.
- Assess costs and benefits of the feasible options.
- Assess other benefits or issues associated with feasible options, such as environmental or community impacts.
- Select feasible options for implementation.
- Set a timetable for implementation.
- Implementation.

Ensure that a range of options for improving inherent safety at a facility have been evaluated, weighing the costs and benefits of each of the options.

Analysis of inherent safety opportunities merits a separate review from other issues such as contingency planning or site security. The issue of inherent safety analysis should not be buried in these other studies, but should be linked to the studies so that cost and other considerations can be compared across strategies.

To reinforce public credibility, inherent safety studies can be conducted or evaluated by third-party experts, selected and trusted by members of the community in addition to the facility owner or operator. Community reassessment teams should expect, at a minimum, to engage in periodic meetings with the assessment team, to receive detailed reports of progress, to ensure a thorough process is being followed, and to ensure that adequate consideration is given to relevant options, costs, and other tradeoffs. See the chart regarding facility specific assessments. Starred boxes represent points in the process where a community reassessment group may want to ensure its oversight and involvement.

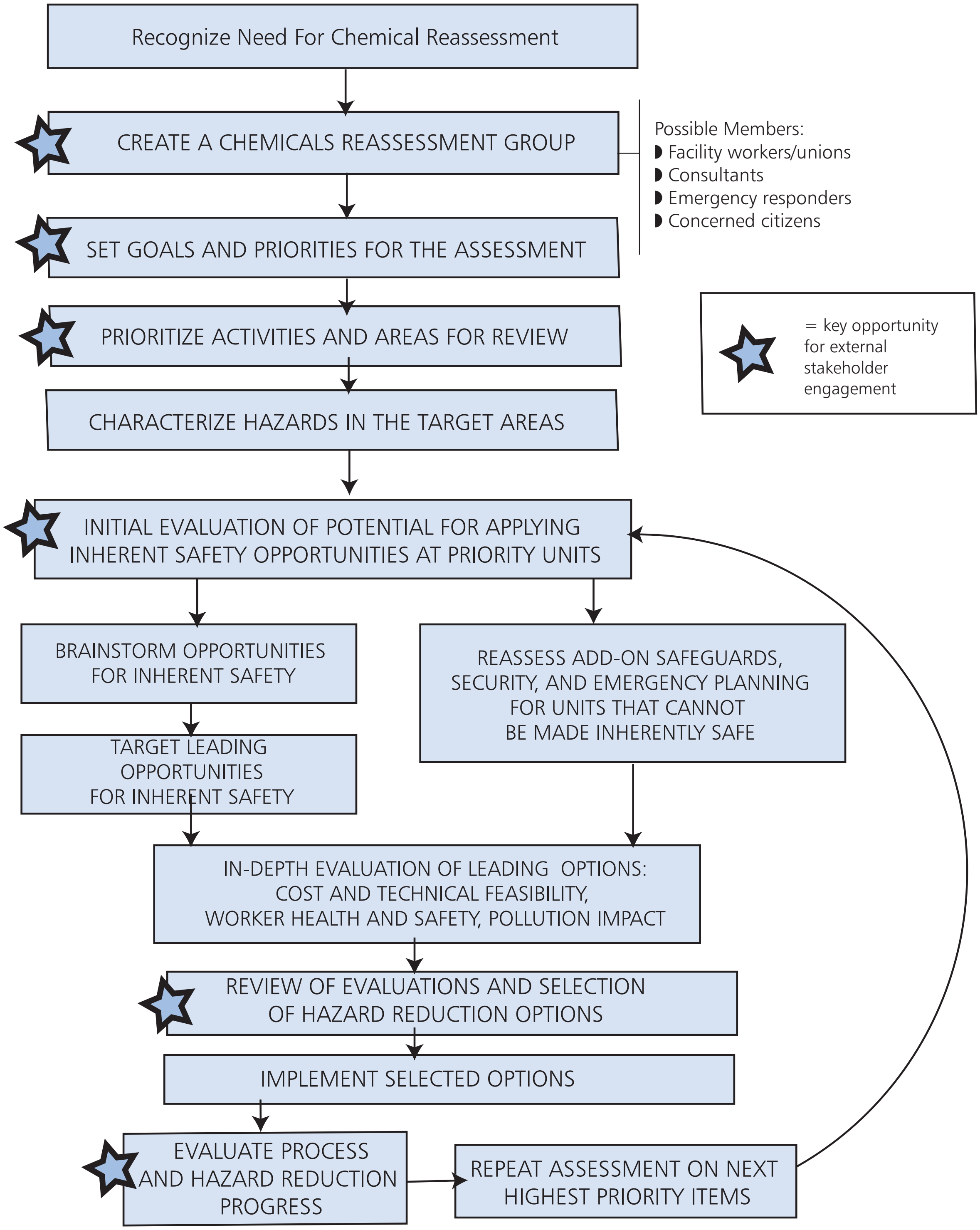
LIQUID CHLORINE IN DECLINE AT WATER/WASTEWATER FACILITIES

Citing the September 11th attacks, Washington, DC main sewage treatment facility, Blue Plains, accelerated by one year their program to substitute the use of chlorine due to their vulnerability to terrorists.

Public policies adopted in New Jersey, through the Toxic Catastrophe Prevention Act (TCPA), have led to a dramatic reduction in the amount of hazardous chlorine stored at water treatment facilities. Many of the facilities have shifted to less dangerous materials -- sodium hypochlorite. In the fall of 1988 New Jersey had 575 TCPA regulated water treatment sites with the then 500-pound threshold quantity or greater of chlorine. By April 1991, 375 water treatment facilities had lowered the quantity of chlorine on hand to less than the TCPA threshold quantity; also, approximately 100 other water treatment facilities ceased the use of liquid chlorine altogether, leaving a total in the water treatment group of 100 in April 1991.

Source of New Jersey data: Correspondence with Reginald Baldini, NJ Department of Environmental Protection, November, 2001.

PROCESS FOR REASSESSING HAZARDS AT AN INDIVIDUAL FACILITY



C) Have the costs, benefits and tradeoffs of safety measures been evaluated?

According to the chemical industry's own analysis,[3] in many instances companies can discover a reason to apply inherent safety based on cost savings resulting from simpler design, smaller equipment, and reduced materials consumption. But in other cases, the costs of investing in inherent safety are only justified after consideration of an accident that has already occurred, or the potential costs and risks to the operator and society if such an accident does occur.

Some analysts indicate that the principal economic benefit of inherent safety to the firm is generally likely to be reliability of production-less time troubleshooting and repairing, lower maintenance and operational costs, and less downtime for production.[4] But this widely applicable incentive has not yet translated to a general shift to inherent safety. The failure of firms to study the available options and thereby identify potential savings is a key obstacle. This can be overcome by educational programs, and by legal requirements or orders to facilities to analyze available options.

Whether inherent safety measures are being applied, or other types of safety measures discussed later in this guide, a range of costs, benefits and tradeoffs need to be considered. For example, if a potential new process is inherently safer but it undermines product quality or poses other health and safety hazards to workers, this may hinder the switch.

From a business management standpoint, the user of the chemicals will likely ask questions such as the following:

- Are there chemicals which can be substituted (dropped in) to our production process to substitute for the substances in question?
- Can the production process be redesigned either to eliminate the need for the extremely hazardous substance, or the need for the product to be stored in large quantities?
- Are there short term and long term measures to make our activities inherently safer?
- If there is no drop-in substitute, can the end product be redesigned to eliminate the need for the extremely hazardous materials?
- What are the costs, and potential savings, associated with the toxic materials (regulatory, disposal, insurance) and with conversion to a process that is less toxic or hazardous?
- Will product quality be satisfactory?
- Will costs of production be altered?
- Will the change affect our markets positively or negatively?
- Are there other reasons driving the need for redesign, which make overall process or product redesign for safety and pollution prevention a timely issue?
- If storage volumes are being reduced, how will lower stockpiles of materials affect production if there is a disruption of shipping? Is there a backup strategy for sustaining production outputs, or can we manage the risks associated with this issue?
- Do changing federal, state or local regulatory requirements increase the cost of use of toxics or of emissions controls?
- How do newfound concerns about facility security affect the balance of costs for redesign? Can redesign, modernization and upgrading be a more productive form of expenditure than adding guards and redundant security systems?

From the standpoint of other stakeholders, such as workers and the community other factors are important, such as:

Workforce

- What added risks are imposed on workers?
- How do the changes affect employees' responsibilities or eliminate jobs?
- If jobs will be eliminated, will there be programs to ensure smooth and just transitions of affected workers - including education/retraining and income maintenance leading to an equivalent position in the future?

Community

- What are the costs of security guards, extra policing, and so forth to the community now that there is a heightened state of alert regarding the facility?
- What other costs (e.g. hospital and fire department preparedness) are imposed on the community by continued utilization of high volumes of hazardous materials?
- How much will any given change reduce the size of the plant's vulnerability zone?

Environmental and Worker Health and Safety Tradeoffs

Special attention is needed to environmental and occupational health and safety tradeoffs. In the best cases, reducing safety hazards will also reduce risks to workers and prevent ongoing pollution of the community. The application of inherent safety measures that eliminate the use of toxic substances without adding other hazards or emissions exemplify this.

> Ensure that hazard reduction measures truly advance the well-being of the community, the workforce, the site owner and the environment.

But, in other instances, for a variety of reasons, firms may consider changes that reduce the threat of accidents but increase other risks to workers and communities, such as through chronic exposure to low levels of toxics in the workplace or pollution emissions. It is important to guard against such changes, principally by asking questions before the change. Ask questions like these:

- What effect will new safety or security measures have on worker and community risk from ongoing pollution?
- Will chemical hazard reduction at the facility increase hazards on the roads and rails-or is the planned change truly "inherently safer" all around?
- Have the costs and effects of chronic emissions and waste disposal been integrated to the plan?
- What kinds of potential harmful health effects are suspected regarding substitute chemicals, even if there is some scientific uncertainty about how severe the effects will be?
- Are there other options that would increase safety and reduce pollution without shifting any risks to new areas?

By asking basic questions, people can help make sure that firms consider and air the answers.

When a facility is designed in a manner that is not inherently safe, there is also potential for add-on pollution controls to actually trigger safety hazards. For instance, one facility installed carbon filters to capture flammable emissions. But the carbon filters themselves burst into flames, causing a fire at the facility.

The emerging trend at wastewater treatment plants—shifting away from liquid chlorine to reduce community vulnerabilities to a sudden release incident—is a good example to illustrate how bringing environmental concerns into the decisionmaking process may change the outcome. Some of these facilities have shifted to sodium hypochlorite (bleach) for waste treatment, while others have shifted to ultraviolet light treatments. While either approach eliminates the gas cloud hazard posed by the liquid chlorine, from the standpoint of the environment the two solutions are not equal. Serious environmental concerns remain in environmental dispersion of chlorine, as occurs with sodium hypochlorite. Trihalomethanes (THMs) form during water purification when chlorine reacts with natural and synthetic organic chemicals in the water. Research by the Centers for Disease Control and the New Jersey Department of Health identified potential associations between high

THM levels in drinking water and low birth weights and birth defects.[5]

Continued use of chlorine in sodium hypochlorite also results in the generation of dioxins. Dioxin is the name given to a group of highly toxic chemicals that result from certain reactions with chlorine. Dioxin is produced during incineration, paper production, metal smelting and petroleum refining, and the manufacture of chlorinated chemicals including pesticides, herbicides and polyvinyl chloride plastic. A draft EPA dioxin reassessment, published in 2001, indicates that, even at very low levels of exposure, dioxin is linked to cancer, infertility, immune system damage and learning disabilities. More than 90 percent of dioxin exposure comes through the food we eat, especially fish, meat and dairy products.

The International Joint Commission - a US - Canada Commission created by an international treaty, has called for ending the use of chlorine in manufacturing processes:

> "We know that when chlorine is used as a feedstock in a manufacturing process, one cannot necessarily predict or control which chlorinated organics will result, and in what quantity. Accordingly, the Commission concludes that the use of chlorine and its compounds should be avoided in the manufacturing process."

So, even though it currently remains legally permissible to discharge chlorine, a growing body of opinion suggests that it is not environmentally advisable to do so. Thus, in addressing vulnerabilities of wastewater facilities from chlorine usage, the environmental concerns argue for switching to UV treatment systems which do not use any chlorine— rather than sodium hypochlorite used by some operations, such as Blue Plains. While sodium hypochlorite eliminates the hazards of a sudden chlorine release, it does not eliminate the larger issues posed by the chlorine production cycle.

Worker health and safety tradeoffs can be affected positively or negatively by changes intended to improve a site's chemical safety or security. Eliminating toxic substances generally makes the workplace safer. By contrast, moving storage tanks away from the vulnerable peripheries of a facility to prevent terrorism can move them closer to where people work,

Toulouse, France Chemical Plant Explosion Changes World Views

A chemical explosion at a fertilizer plant of Atofina, in Toulouse, France, killed at least 30 persons including 10 employees at this site, 11 contract workers, one worker at an adjacent chemical plant, and the rest, people outside the plant. The explosion created a 15 meter deep crater, damaged 3000 homes, and 80 schools. It also shattered half the window glass in the city of one million people. 650 people were hospitalized. The financial cost is estimated at up to $850 million.

Soon after, there was speculation that the incident may have been a result of an intentional terrorist act. However, investigators have since stated that an accident, not an intentional action, was the most likely cause.

In response to the incident, the Mayor of Toulouse, Phillipe Douste-Blazy, called for the immediate shutdown and removal of all chemical production from the city, as well as a national debate on industrial risks. He noted that 10 million people live close to chemical plants in France.

As a result of the incident, the French government launched a national debate on chemical safety, involving 26 regional discussions to culminate in national policy recommendations. The French government has called on industry to reinforce safety at all sites. Short-term recommendations and measures include reducing operating inventories, strengthening monitoring plans and evaluating investments necessary for industrial protection. The European Community has also been pressed to act.

TWO WAYS OF MEASURING INHERENT SAFETY OF A CHEMICAL PROCESS

- Area affected by potential incidents.
- Impact of a potential incident measured in casualties, property and environmental damage, etc.

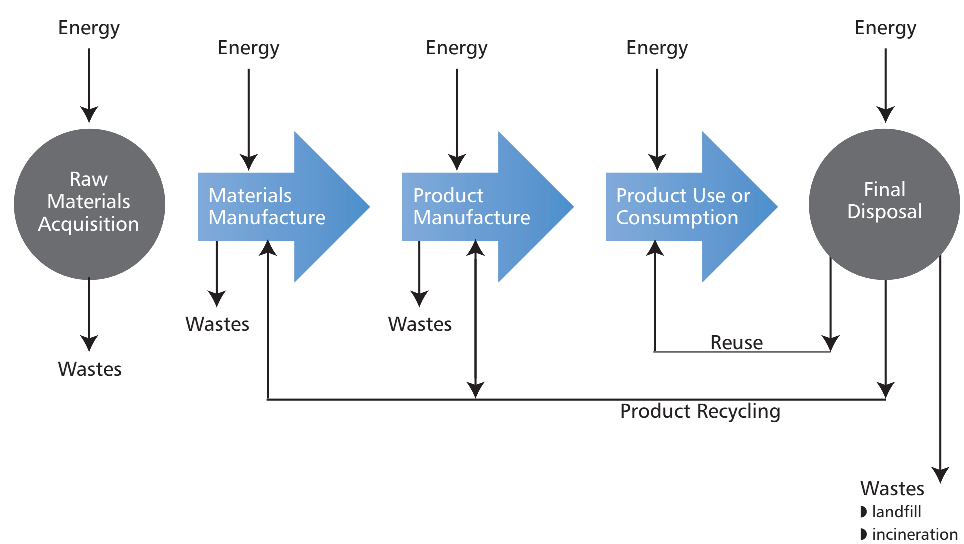
and therefore place them at greater risk from exposures or accidents.

Measures that eliminate toxic materials can often both eliminate chronic pollution issues as well as potential for catastrophic releases. A "clean production" inquiry may go the furthest in evaluating changes at a site -- asking not only about the safety of the facility, but also about the toxicity of products and wastes, and the consumption of energy throughout the production and consumption lifecycle. See chart below.

Notes

1. "The Feasibility of Encouraging Inherently Safer Production in Industrial Firms," in a Special Issue on Safety and Design, Safety Science, E. Fadier Guest Editor, in press.
2. There is an extensive literature of inherent safety, much of it developing in recent year. See for instance: "The Feasibility of Encouraging Inherently Safer Production in Industrial Firms," Zwetsloot G.I.J.M. and N. Askounes Ashford, in a Special Issue on Safety and Design, Safety Science, E. Fadier Guest Editor, in press; "Encouraging Inherently Safer Production in European Firms: A Report from the Field" N.A. Ashford and G. Zwetsloot, Journal of Hazardous Materials, Special Issue on Risk Assessment and Environmental Decision Making, A. Amendola and D. Wilkinson (eds.), 1999, pp 123-144; "Industrial Safety: The Neglected Issue in Industrial Ecology" in the Special Issue on Industrial Ecology, Ashford, N. A. Journal of Cleaner Production, 1997. 5(1/2), pp 115-121 (available at http://www.elsevier.com/locate/jclepro); The Encouragement of Technological Change for Preventing Chemical Accidents: Moving Firms from Secondary Prevention and Mitigation to Primary Prevention, N.A.Ashford et al., A Report to the U. S. Environmental Protection Agency, Center for Technology, Policy and Industrial Development at MIT, Cambridge, MA, July 1993; Trevor Kletz, Process Plants: A Handbook for Inherently Safer Design, 1998; Trevor Kletz, Plant Design for Safety:A User-friendly Approach, 1991; R.E. Bollinger, et al, Inherently Safer Chemical Processes: A Life Cycle Approach, Center for Chemical Process Safety, 1996; Health and Safety Executive (of the United Kingdom), Technology Division, Designing and operating safe chemical reaction processes (www.hse.gov.uk)..
3. Batelle Laboratories, Responsible Care Powerpoint presentation on Inherent Safety, 1998.
4. "Encouraging Inherently Safer Production in European Firms: A Report from the Field" N.A. Ashford and G. Zwetsloot, Journal of Hazardous Materials, Special Issue on Risk Assessment and Environmental Decision Making, A. Amendola and D. Wilkinson (eds.), 1999, pp 123-144.
5. Massachusetts Toxics Use Reduction Institute, Massachusetts Chemical Fact Sheet: Chlorine.

The Product Life Cycle



Thorpe, Beverly, *Citizen's Guide to Clean Production*, Produced for the Clean Production Network, University of Massachusetts Lowell, 1999.

Clean Production Action