The legacy of Bhopal: The impact over the last 20 years and future direction

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Abstract

Chemical process safety was not a major public concern prior to 1984. As far as chemical hazards were concerned, public fears focused on disease (cancer) and environmental degradation. Even a series of major process incident tragedies did not translate into widespread public concerns about major incidents in chemical plants that might disastrously affect the public. This situation changed completely after the December 1984 disaster at the Union Carbide plant in Bhopal. Not only was the public’s confidence in the chemical industry shaken, the chemical industry itself questioned whether its provisions for protection against major incidents were adequate.

The recognition of the need for technical advances and implementation of management systems led to a number of initiatives by various stakeholders throughout the world. Governments and local authorities throughout the world initiated regulatory regimes. Has all that has resulted from the legacy of Bhopal reduced the frequency and severity of incidents? How can we answer this question? As we move into more and more globalization and other complexities what are the challenges we must address? According to the authors, some of these challenges are widespread dissemination and sharing of lessons learned, risk migration because of globalization, changing workforce, and breakthroughs in emerging areas in process safety.

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1. Background

In his 1913 publication, Wallace (1913) writes about mine-related deaths, that notwithstanding Acts of Parliament and numerous inspectors, explosions and other accidents underground continue to increase. The year 1910 was a record year, with its 1775 deaths; and even the number of deaths in proportion to the workers employed being the highest for the last 20 years. He goes on to say that,

“As the [nineteenth] century wore on, other evils of a similar nature were gradually brought to light. Children and women were found to be working underground in coal mines, under equally vile conditions as regards health and morality; and an enormous loss of life was caused by inadequate ventilation, insecure roof-propping, imperfect winding machinery, and other causes, all due to want of proper precautions by the owners of the mines. As a matter of simple justice, such owners should be held responsible to the injured person not only to the full extent of his wages and for medical attendance, but should also pay a liberal compensation for the pain suffered, and for the extra labor, expense, and anxiety to his family. But all such things are ignored in the case of poor workers, so that even the money compensation is reduced to the smallest amount possible.”

While one may not necessarily share or dispute all of Dr Wallace’s opinions, there is no doubt that the world and the workplace has changed dramatically since 1913. While the workplace in the mining industry is quite different and represents hazards of a different nature, many programs, management systems, and technologies have reduced the hazards and consequences extensively. The industrial revolution brought prosperity and along with it the use of hazardous processes and complex technologies. Growing economies and global competition have led to more
complex processes involving the use of hazardous chemicals, exotic chemistry, and extreme operating conditions.

Process safety is a relatively young and evolving field whose driving force has been mainly based on tragic events. Unfortunately, it is also a thankless activity, whose importance becomes evident only after negative events occur. Even today, after so many industrial incidents, there is a school of thought that if nothing bad happens, it is because there are no hazards and hence no need to take preventive measures. Y2K, the Millennium bug, is an example of this human and social denial attitude. Shortly after the beginning of the year 2000, the worldwide effort to prevent and diminish the expected computer systems problems associated with the limited memory to store the digits for the year, were bitterly criticized. Why so much effort and investment to adapt the systems, if anyway nothing happened?

On other occasions the chemical industry has not been so prepared. Some of the more publicized incidents include the release of cyclohexane in Flixborough, England, in June 1974; release of dioxin in Seveso, Italy, in July 1976; and the LPG BLEVE in Mexico City, Mexico, in November 1984. However, the events of December 3, 1984, forever changed the chemical industry and left a distinct legacy. A cascading series of catastrophic circumstances, system failures, and management system deficiencies at the Union Carbide India pesticide plant in Bhopal, India, led to the release into the atmosphere of approximately 40 metric tons of acutely toxic methyl isocyanate (MIC). The dense cloud of deadly vapor spread over the sleeping community, and within a few days more than 3000 people had died and at least 100,000 were injured. It is widely acknowledged to be the worst industrial accident in history, leaving as many as 50,000 people partially or totally disabled as of 1994, according to the International Medical Commission on Bhopal.

As horrific as it was, Bhopal was more than an isolated tragedy. At its 20th anniversary, there inevitably will be a renewed focus on its impact on safety within the chemical industry. ‘Bhopal was a wake-up call for the industry.’ Although it is demonstrably clear that Bhopal has had a positive legacy in chemical plant safety, to this day there is no single, reliable, quantifiable method to answer a very simple, reasonable, and vitally important question: How safe are chemical plants today, and are they safer today than they were 20 years ago?

There have been tremendous strides over the past 20 years in culture, practices, and attitudes in the chemical handling community, as well as the regulatory environment that governs the industry. If Bhopal was a wake-up call, the call for ongoing improvement in chemical safety has been answered in numerous ways by the industry and the many other stakeholders. Perhaps the most important development in those efforts over the past two decades has been the widespread adoption of a concept called process safety. Process safety encompasses a management systems approach to all aspects of chemical manufacturing, with a holistic view toward minimizing risk and preventing incidents. Although the idea had been in existence before Bhopal, it was the tragedy in India that brought about its complete acceptance as industry standard practice.

2. Regulatory initiatives in the United States

In the United States, regulatory oversight was codified in 1990, when the US Congress passed the Clean Air Act Amendments (CAA) in the wake of Bhopal and several other serious domestic and international chemical plant incidents. The legislation contained three major provisions impacting chemical safety, and gave added authority to the Occupational Safety and Health Administration (OSHA) and the Environmental Protection Agency (EPA) to regulate the industry. OSHA was directed to create, promulgate, and enforce a standard known as Process Safety Management of Highly Hazardous Chemicals (29 CFR 1910.119), or the PSM standard. The PSM standard emphasizes the management of hazards through a comprehensive program that integrates technologies, procedures, and management practices. The standard has 14 elements that are fundamental to running a safe chemical operation.

The CAAA also directed the EPA to create its Risk Management Program (RMP) rule (40 CFR 68), which requires companies using certain flammable and toxic substances to develop an RMP that must be revised and resubmitted to the agency every 5 years. While the PSM standard governs process safety, the RMP rule is aimed more at protecting personnel and surrounding communities from the hazards associated with an accidental release. It emphasizes hazard assessment and prevention measures, and requires the establishment of an emergency response program that includes procedures to inform the public and outside responders in the event of an accident.

3. The European experience

Due to the geographical and political characteristics of the European continent, the regulatory context becomes complex. Geographically each country is small enough and connected to other countries by rivers as to have the potential to impact neighboring countries in the case of major chemical incidents. Each nation has different regulations, however; during the last few years the members of the European Community and other countries had to adapt their own regulatory frame to the requirements of the European Commission and the United Nations Economic Commission for Europe [UNECE, http://www.unece.org/env/teia/]. Some Eastern European countries are in the process of reviewing or developing and enforcing new safety policies. A summary of the state of the present regulatory status by country is available at http://www.unece.org/env/teia/english/R_4.HTM.
After the occurrence of the Seveso incident the European Union adopted a new regulation aiming to avoid similar events and in order to keep the memory ‘fresh’ the new Directive was named after the town of Seveso. The ‘Council Directive 82/501/EEC on the major-accident hazards of certain industrial activities’ known as ‘Seveso I’ was adopted in 1982 with the objective of preventing and responding to major industrial incidents, and to reduce the potential consequences on the environment and the public. However, new bells were rung in 1984 at Bhopal, India, and in 1986 in Basel, Switzerland (where firefighting water contaminated with mercury and pesticide caused an ecological catastrophe), and forced the legislators to amend the regulation twice. Since 1999 the Directive 88/610/EEC ‘Seveso II’ related to the Control of Major Accident Hazards (COMAH) requires industrial and storage activities to follow safety and risk management measures in order to prevent the occurrence of more incidents.

4. Bhopal and Industry’s response

The legacy of Bhopal left its impact not only on the policy framework, but also on aspects such as recommended practices and operation guidelines developed by industry associations and trade organizations. In 1980, the program now adopted worldwide and known as Responsible Care® was developed in Canada by the Canadian Chemical Producers’ Association (CCPA). The United States started its implementation through the American Chemistry Council (ACC) eight years later, after the Bhopal incident raised public awareness about the possible impact of the chemical industry on the environment and neighboring communities [Chemical and Engineering News January 12, 1998; http://pubs.acs.org/hotarticl/cenear/980112/responsible.html]

The International Council of Chemical Trade Associations (ICCTA) [http://www.iccta.org] was formed in 1991 and among its objectives the promotion of practices of Responsible Care/Responsible Distribution is included. Members are encouraged to follow the Joint Distribution Joint Responsible Care Program and the Product Stewardship initiative in order to ensure that national and international safety policies are followed and to reduce the potential risks for the workers and the environment. The Product Stewardship program focuses on Joint Responsible Distribution/ Responsible Care Programs and recognizes the fact that chemical distributors face safety challenges different from the fixed industry and they establish the link between the producer and the final user [http://www.iccta.org].

The Responsible Care Program now is extended to 47 countries that correspond to more than the 85% of the world chemical producers. In the United States, several associations embrace the program. An example of this is the American Chemistry Council (ACC) [http://www.americanchemistry.com/] and the National Association of Chemical Distributors (NACD) [http://www.nacd.com/index.cfm] that incorporated the concepts of quality, stewardship, and responsibility among its fundamental values. Other associations that modified their standards and regulations in order to include the concepts of Responsible Care are the American Petroleum Institute (API) [http://api-ec.api.org/] that developed an Environmental Health and Safety (EHS) Management System, the National Petroleum Refiners Association (NPRA) [http://www.npradc.org/] and the Synthetic Organic Chemical Manufacturers Association (SOCMA) [http://www.socma.org/ResponsibleCare/index.html].

5. The developing countries and process safety

Many countries in the third world have been experiencing high economic growth and continue to promote employment generation in accordance with the rapid industrialization. This development has, however, a direct impact on process safety practices. There is a growing concern about safety and health at work in almost all third world countries, as indicated by available incident statistics. For example, the number of reported industrial incidents in Thailand and Malaysia in 1995 was 216,525 (966 fatalities) and 114,134 (828 fatalities), respectively. In the same year in China, 20,005 fatalities were reported. The figures reported from Thailand represent nearly a three-fold increase in incidents between 1990 and 1995. This increase is the reflection of industrial expansion and the improvement of reporting system (Watfa & Machida, 1998). In addition to workplace incidents injuring individual workers, which are normally not covered by the media, major incidents also continue to occur. These include a factory fire in Thailand in 1993 that took 188 lives; an explosion of liquefied petroleum gas in Nagothane, India, which killed 35 and injured 15 persons; and an explosion of gunpowder warehouse in Hubei, China, in 1993 that killed 63 and injured 52 persons. The number of work sites with potential to cause major incidents such as those in Bhopal is also increasing (Watfa & Machida, 1998).

A number of steps have been taken recently in some developing countries towards the improvement of national occupation safety and health systems. Examples of positive developments include:

- the review and upgrading of legislation (i.e. Malaysia, 1994; Thailand, 1995; Fiji, 1996);
- increased training activities by employers’ and workers’ organizations (i.e. Jordan, Indonesia, Lebanon, Malaysia, Pakistan, Syria);
- improvement in incident reporting and analysis;
- expansion of awareness raising activities.

In spite of these positive developments, many developing countries face common problems. Workers are generally
unaware of the hazards they are exposed to. Preventive measures are taken by large enterprises, seldom by the small ones. The legal requirements on safety and health are often not complied with. Enterprises have few trained safety personnel, such as safety officers and supervisors. Incident statistics are inadequate. Labor inspectorates are limited in terms of the number of personnel and their technical expertise. Training and technical advisory services by governments and private institutions are still insufficient.

6. India

As the country directly affected by the wake-up call of the Bhopal incident on India with regard to the country’s safety culture. The incident exposed the deficiencies in the Indian legal and regulatory system in the areas of hazard and risk management. The systems in place were essentially artifacts of the British systems that were carried over post independence (1947). There were four significant inadequacies in the Indian system pre-Bhopal.

- The existing laws and regulations failed to distinguish between hazardous and non-hazardous facilities nor did they require facilities to disclose any emergency response information.
- The regulatory bodies in place did not have any power to shut down facilities that posed imminent danger, even when presented with documented evidence of safety violations.
- The penalties for non-compliance with the existing laws and regulations were trivial and made it financially prudent to pay the fines rather than meet the statutory regulations.
- The legal system excluded any recourse for the victims of any incident, and hampered the ability of courts to assign criminal liability by requiring Byzantine levels of evidence.

In the years following Bhopal, a flurry of legal and regulatory activity began to put into place a nationwide system to prevent the recurrence of such an incident. The first step was the Environment Protection Act of 1986, which sought to protect the environment by preventing major incidents. The Act holds the management of the facility responsible for any violations of the Act.

Prior to the Bhopal incident, the Indian Factories Act of 1948 was the major Indian law that dealt with worker welfare and health. First enacted in 1881, the law underwent a series of amendments that essentially reflected UK legislation. The Act was amended in 1987 to establish safeguards for the use of hazardous substances by facilities. A major step forward was the recognition and definition of hazardous industries. The Act now required facilities to issue emergency response procedures, and stiffened the penalties for non-compliance.

In conjunction with the Factories Act, the Air Act was also amended in 1987 to deal with several problems that became evident after Bhopal. Facilities had to obtain permission to operate from their respective State Pollution Control Board. In 1989, the Hazardous Waste (Management and Handling) Rules were established to specify what constitutes a hazardous waste and hold the facility’s operator responsible for the management of such waste.

The Public Liability Insurance Act of 1991, required facilities to carry insurance to cover any incident having an impact over the population in its vicinity. While workers were covered by the Workers Compensation Act of 1923, the offsite population now had a route to get any claims settled in a simple, timely manner.

Finally, the Environment Protection (Second Amendment) Rules of 1992 required all facilities under the Environment Protection Act of 1986 to conduct annual environmental audits and report the same to their State Pollution Control Board.

The above regulatory initiatives in India are a consequence of the impact of Bhopal, and while certain deficiencies do exist in the regulations and the system itself, they do represent, for the most part, a step in the right direction. The effectiveness of such regulatory and legal efforts depends to a great extent on the implementation and enforcement of its statutes.

7. Bhopal and its impact on the academic/research community

Following the 1984 Bhopal disaster, there has been an increased activity in the research and academic community related to process safety in the chemical industry. The increased activity is also evident from Fig. 1, which lists the total publications in science and engineering journals that mention ‘process-safety’ as a keyword. The articles cover a wide variety of safety topics ranging from clinical studies to estimate toxicity, risk management, design and manufacturing processes, environmental, and regulatory issues.

Fig. 1. Publications in science and engineering journals that mention ‘process-safety’ as a keyword.
The growing number of safety publications is indicative of safety being one of the major drivers of research among the academicians and practitioners.

In the United States, the Center for Chemical Process Safety (CCPS) was founded in 1985 and is affiliated to American Institute of Chemical Engineers (AIChE). CCPS brings together manufacturers, insurers, government, academia, and expert consultants to lead the way in improving manufacturing process safety.

The Institute of Chemical Engineers (IChemE) publishes journals dedicated to safety research Loss Prevention Bulletin and Process Safety and Environmental Protection. The European Process Safety Center (EPSC) is an industry-funded network, which exists to provide an independent forum for the leadership and support of process safety within Europe, and was founded in 1992.

A few of the prominent university programs related to safety are listed in Table 1.

### Table 1

<table>
<thead>
<tr>
<th>Center</th>
<th>University</th>
<th>Focus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Center for Environmental Risk Reduction</td>
<td>University of California, Los Angeles</td>
<td>The center initially is focusing on the following five major areas: risk reduction strategies, exposure assessment, toxicology, risk assessment, and risk reduction technologies.</td>
</tr>
<tr>
<td>Harvard Center for Risk Analysis</td>
<td>Harvard University</td>
<td>HCRA was launched with the mission to promote reasoned public responses to health, safety and environmental hazards.</td>
</tr>
<tr>
<td>Mary Kay O’Connor Process Safety Center (MKOPSC)</td>
<td>Texas A&amp;M University</td>
<td>MKOPSC has a comprehensive program for education, research, and service related to process safety. The mission of the center is to make safety second nature and improve safety performance within the process industry.</td>
</tr>
<tr>
<td>Wharton Risk Management and Decision Processes Center</td>
<td>Wharton School at University of Pennsylvania</td>
<td>The center is concerned with natural and technological hazards and with the integration of industrial risk management policies with insurance.</td>
</tr>
</tbody>
</table>

8. Where are we now and what are future needs?

As mentioned earlier, we have made quite a bit of progress and the industry has come a long way since the tragic night of December 1984 in Bhopal. However, there are many areas that require progress and the joint efforts of all stakeholders. Some key areas that need our immediate attention are:

- Metrics and Measurement Systems
- Learning from Incidents
- The Challenge of Globalization
- Technology Transfer
- Emerging Issues
- Research Needs

#### 8.1. Metrics and measurement systems

All this progress and there is no way of determining if we as an industry, country, or world are getting safer. While individual companies keep data on their safety performance, there is as yet no ‘herd measure’ of the safety performance of the industry. It is impossible to answer the question ‘Are we doing better or worse?’ without having data, without having statistics. We produce periodic ‘report cards’ on almost everything (e.g. state of the economy, health, education, etc.) except chemical safety. This situation is really ‘scandalous.’

In 1999, the Mary Kay O’Connor Process Safety Center convened a group of experts from industry, academia, government, and environmental groups to undertake an ambitious effort called the National Chemical Safety Program. The program’s mission was to establish a rational, objective baseline by which to measure the ongoing status of national chemical safety. It culminated in the production of four reports, including the 2001 Assessment of Chemical Safety in the United States (http://ncsp.tamu.edu). The report was mainly designed to establish a framework for prospective quantitative assessment. It included suggested methodologies for analyzing several existing federal databases to yield useful comprehensive information on incidents, fatalities, injuries, and other parameters, along with proposed indicators and metrics for measuring chemical safety and the results of a survey on public trust and community interaction. The report did provide some statistics as well, but they were unavoidably limited in their utility. For example, during the eight-year period examined, fatalities and injuries due to all chemicals (as opposed to specific agents or classes) had decreased. But the Center was unable to normalize its findings by correlating them to industry trends during the period. For example the report stated that the fatalities had gone down, but there was no way of knowing if the chemical industry had increased or decreased. Despite its inherent limitations, the report did establish a baseline for future comparisons, and the intent was that the status of national chemical safety be assessed annually against that baseline. But the Center was unable to secure continued federal funding for the effort, and no one else has come forward to provide the necessary support. The fact remains that if the 1999–2000 effort established one thing, it is that the only way you can answer the question ‘What is the status of chemical safety in the United States?’ is to have statistics. Somebody has to start doing data collection and analysis every year. Only then will we know ‘where we’re going and how fast we’re going there.’
8.2. Learning from incidents

One of the attributes of a good safety culture that is a ‘must’ is ‘learning from incidents.’ There is no excuse when ‘lessons learned’ from incidents are ignored or not implemented, particularly ‘lessons learned’ from incidents that have occurred in one’s own organization or incidents that are widely publicized. The organization must naturally have good incident investigation procedures and all the other management systems necessary to take advantage of the lessons learned. But one factor that is often overlooked is the types of incidents that are tracked or investigated. Quite often incidents are defined narrowly and include only the ones that caused serious or catastrophic consequences. While this may be the politically expedient thing to do, it leads to some problems and pitfalls.

The ratios involving various types of incidents is a key concept in loss control. Various studies have indicated that losses from different types of incidents follow an incident pyramid (of the type shown in Fig. 2) with ratios among the different categories. For example, Heinrich (1959) reported the following ratio for three different types of incidents:

Major or lost time injury/Minor injury/No injury = 1:29:300

Several other later studies have indicated similar patterns for incidents. In fact, our own analysis conducted for 1998 data on incidents in the United States indicates similar patterns.

The underlying causes for incidents are usually the same regardless of which part of the pyramid the incident falls in. In other words, an incident that causes no injury and is classified in the lower part of the pyramid could easily have been classified in the top part of the pyramid. Consider for example a gas release that occurs when the wind speed and wind direction are such that the gas disperses before it can encounter an ignition source. The incident would then be classified as a near-miss falling in the lower part of the incident pyramid. But, now consider the same gas release that occurs when the wind speed and wind direction are such that the gas encounters a nearby ignition source. The situation could be more aggravated if nearby workers are knocked down or thrown against concrete walls or equipment. The event could likely lead to injuries or fatalities. Thus, it seems that the same learning could be developed and captured into the procedures and training by analyzing and investigating the near-miss. Thus, the broader the incident definition, the more statistically sound the lessons from the incident analysis. In fact, it would seem that as safety programs mature, the incident definition should be expanded to include not only near-misses but other leading indicators as well.

8.3. The challenge of globalization

Globalization of the economy has intensified over the recent years and, together with the development of the new information and telecommunications technology, it is bringing about radical changes in society, comparable to those produced during the industrial revolution. Occupational process safety cannot ignore those changes. And, in this context, the greatest challenge for the countries is the transformation of the difficulties involved in adapting to the new situation into opportunities for the future development of process safety.

8.4. Technology transfer

It is often difficult for an engineer or scientist to explain a technical matter in lay terms understandable by non-technical people. This problem becomes an even more significant challenges with regard to technology transfer from the Western world to countries with different culture and without a strong technological background. From the technical viewpoint it could appear like a simple issue where a plant designed to be operated in the United States or Europe is ‘transferred’ to Asia and is built according to the original ‘Western’ design. Aspects such as the regulatory framework of the receiving country and the technical infrastructure expected to support the new plant pose an environment that must be taken into consideration before the technological transfer occurs. However, other aspects such as the social and cultural environment are often underestimated or neglected by technical people. These ‘soft’ non-technical issues play, however, a fundamental role in the success or failure of the technological transfer.

8.5. Emerging issues

Recent events have focused a lot of attention on two quite important emerging issues with regard to process safety. They are ‘Inherent Safety’ and ‘Reactive Chemicals.’ Both are very important issues and progress must be made in each area if advances are to be made with regard to process safety performance. However, we must tread with caution and make sure that good science based approaches are utilized in developing whatever plans may be necessary. Otherwise we run the risk of unintended consequences. There are merits...
for both these concepts and potential pitfalls associated with developing implementation programs.

8.6. Research needs

There are significant areas of need where research must be funded if advances are to be made in technology, management systems, and other aspects of process safety. Some of these research areas are discussed below:

Abnormal system management develops fault diagnosis strategies that monitor process variables and detect differences from normal behavior to detect, diagnose, and adjust for faults as they occur.

Development of micro-calorimeter for material characterization is needed to probe thermal transition behavior in a variety of chemical systems by monitoring the thermal energy required to heat or cool a sample material at a constant rate.

Dust explosions. Measurements needed include maximum explosion pressures, maximum rates of pressure rise, minimum explosion dust concentrations, minimum ignition energies, effects of inert components, minimum oxygen concentrations, and suppression effects.

Inherent safety research objectives include identification of factors that affect the inherent safety of a facility and to use different quantification methods to assess the reduction of hazards using those factors.

Quantitative risk analysis. A primary goal of this research is to provide a computer-based risk analysis methodology for chemical process design based on fault tree analysis.

Reactive chemical research goals include measurement of thermal stability and decomposition data for important industrial chemicals and comparisons with theoretical models; computational models, both quantum and classical, to estimate property values and to predict chemical reactivity and compare with calorimetric measurements.

Safety culture and its impact on safety performance. The goal of this research is to develop key features of a good safety culture or operational discipline.

9. Conclusions

Progress toward the improvement in safety performance can be measured by a reduction in occupational injuries, illnesses, and fatalities. In fact, measurable progress has been made in the period 1970–1995, during which the rate of workplace fatalities fell by 78%, and the number of workplace deaths has declined by 62%. We have also seen a 25% decline in the rate of occupational injuries and illnesses from 1973 to 1994. These reductions are the result of the combined efforts of all the partners in occupational safety and health: industry, labor, academic researchers, national institute of occupational safety and health, occupational safety and health administration, mining safety and health administration, state and local agencies and others. No single partner can claim exclusive credit for the progress. Thus, if further progress is to be made, all of the partners must act—from identifying the causes of disease and injury through controlling or eliminating the hazards or exposures at the worksite.

On the 20th anniversary of the terrible tragedy that occurred on December 3, 1984, in Bhopal, India, it is a fair question to ask, ‘Have we made progress?’ or ‘Can Bhopal occur again?’ or ‘What are the future challenges?’ or ‘Are we doing enough?’ While there is no doubt that we have made progress, it is much more difficult to answer the other questions. However, we must agree that there is a long road to go and a lot to be done and the need for all stakeholders to work together. Most importantly, we must find some ‘herd measures’ to gauge our performance in safety. We do that for our finances, our health, and many other matters. It is imperative that we do so for chemical safety as well.

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References