Acceptable Risk

Time for SH&E professionals to adopt the concept

By Fred A. Manuele

THE TERM *ACCEPTABLE RISK* is frequently used in standards and guidelines throughout the world, yet a substantial percentage of those with SH&E responsibilities are reluctant to adopt or use it. Evidence of this reluctance often arises in discussions surrounding the development of new or revised standards or technical reports. The aversion may derive from:

- a lack of awareness of the nature of risk;
- concern over the subjective judgments made and the uncertainties that almost always exist when risks are assessed;
- the lack of in-depth statistical probability and severity data that allows precise and numerically accurate risk assessments;
- insufficient real-world experience in more hazardous environments where nontrivial risks are necessarily accepted every day.

However, in recent years, the concept of acceptable risk has been interwoven into international standards and guidelines for a broad range of equipment, products, processes and systems. This has occurred in recognition of the fact that risk-related decisions are made constantly in real-world applications and that society benefits if those decisions achieve acceptable risk levels.

This primer is designed to help readers gain an understanding of risk and the concept of acceptable risk. The far-reaching premise presented is fundamental in dealing with risk. Several examples of the use of the term acceptable risk as taken from the applicable literature. Discussions address the impossibility of achieving zero risk levels, the inadequacy of *minimum risk* as a replacement term for acceptable risk, and the shortcomings that may result from designing only to a standard's requirements. Finally, the "as low as reasonably practicable (ALARP) concept" is presented with an example of how it is applied in achieving an acceptable risk level.

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Fundamental Premise

The following general, all-encompassing premise is basic to the work of all personnel who give counsel to prevent injury, illness and damage to property and the environment.

> The entirety of purpose of those responsible for safety, regardless of their titles, is to identify, evaluate, and eliminate or control hazards so that the risks deriving from those hazards are acceptable.

That premise is supported by this theory: If there are no hazards, if there is no potential for harm, risks of injury or damage cannot arise. If there were no risks, there would be no need for SH&E professionals. (*Note:* For simplicity, the terms hazard, risk and safety apply to all hazard-related incidents or exposures that could cause injury or illness, or damage property or the environment.)

Use of the Term Acceptable Risk

The more frequent use over time of the term acceptable risk in standards and guidelines is notable, as the following citations show. SH&E personnel reluctant to adopt the concept implied by the term should consider the breadth and implication of this evolution. The term acceptable risk is becoming the norm. The following (intentionally lengthy) list of citations shows how broadly the concept of acceptable risk has been adopted.

1) Lowrance (1976) wrote, "A thing is safe if its risks are judged to be acceptable."

2) The following citation, from a 1980 court decision, is significant because it has given long-term guidance with respect to Department of Labor policy and to the work performed by NIOSH.

The Supreme Court's benzene decision of 1980 states that "before he can promulgate any permanent health or safety standard, the Secretary [of Labor] is required to make a threshold finding that a place of employment is unsafe—in the sense that significant risks are present and can be eliminated or lessened by a change in practices" (*Industrial Union Department, AFL-CIO v. American Petroleum Institute U.S. at 642*). The Court broadly describes the range of risks OSHA might determine to be significant: It is the agency's responsibility to determine in the first instance what it considers to be a "significant" risk. *Some risks are plainly acceptable and others are plainly unacceptable* (emphasis added).

For example, if the odds are 1 in 1 billion that a person will die from cancer by taking a drink of chlorinated water, the risk clearly could not be considered significant. On the other hand, if the odds are 1 in 1,000 that regular inhalation of gasoline vapors that are 2% benzene will be fatal, a reasonable person might consider the risk significant and take appropriate steps to decrease or eliminate it. The Court further stated:

> The requirement that a "significant" risk be identified is not a mathematical straitjacket. Although the agency has no duty to calculate the exact probability of harm, it does have an obligation to find that a significant risk is present before it can characterize a place of employment as "unsafe" and proceed to promulgate a regulation.

3) International Organization for Standardization (ISO) and International Electrotechnical Commission (IEC) (1990) issued guidelines for including safety aspects in standards. These guidelines provide standardized terms and definitions to be used in standards for "any safety aspect related to people, property or the environment." The second edition, issued in 1999, contains the following definitions:

Safety: freedom from unacceptable risk (3.1).

Tolerable risk: risk which is accepted in a given context based on the current values of society (3.7).

4) Fewtrell and Bartram (2001), in a document for World Health Organization, address standards related to water quality. They offer the following guidelines for determining acceptable risk.

> A risk is acceptable when: it falls below an arbitrary defined probability; it falls below some level that is already tolerated; it falls below an arbitrary defined attributable fraction of total disease burden in the community; the cost of reducing the risk would exceed the costs saved; the cost of reducing the risk would exceed the costs saved when the "costs of suffering" are also factored in; the opportunity costs would be better spent on other, more pressing, public health problems; public health professionals say it is acceptable; the general public say it is acceptable (or more likely, do not say it is not); politicians say it is acceptable.

5) OSHA (2003) set forth requirements for organizations seeking certification under the agency's Voluntary Protection Programs (VPP):

Abstract: *The term* acceptable risk *is becoming the norm. The more frequent use over time of the term acceptable risk in standards and guidelines is notable. SH&E personnel reluctant to adopt the concept implied by the term would do well to focus on the breadth and implication of this evolution, and reconsider their views.*

> **Worksite Analysis.** A hazard identification and analysis system must be implemented to systematically identify basic and unforeseen safety and health hazards, evaluate their risks, and prioritize and recommend methods to eliminate or control hazards to an acceptable level of risk.

6) ANSI/ASSE Z244.1-2003(R2009) on lockout/tagout states, "A.2: Acceptable level of risk: If the evaluation in A.1.6 determines the risk to be acceptable, then the process is completed. . . ."

7) UN (2009) offers this definition when addressing basic terms of disaster risk reduction: "Acceptable risk: The level of potential losses that a society or community considers acceptable given existing social, economic, political, cultural, technical and environmental conditions."

8) The online Sci-Tech Dictionary (accessed at www.answers.com/topic/acceptable-risk-geophysics) provides this definition of acceptable risk as the term is used in geology:

> **Acceptable risk:** (geophysics) In seismology, that level of earthquake effects which is judged to be of sufficiently low social and economic consequence, and which is useful for determining design requirements in structures or for taking certain actions.

9) Australia/New Zealand AS/NZS 4360: 2004 risk management standard uses this definition (in 1.3.16): "Risk acceptance: An informed decision to accept the consequences and the likelihood of a particular risk."

10) ANSI/AIHA Z10-2005 contains the following citations with respect to acceptable risk.

> E5.1.1: Often, a combination of controls is most effective. In cases where the higher order of controls (elimination, substitution and implementation of engineering controls) does not reduce the risk to an acceptable level, lower order controls may be necessary.
>
> Appendix E (Informative), Assessment and Prioritization (Z10 Section 4.2): The last sentence in Step 7 in a Hazard Analysis and Risk Assessment Guide says: "The organization must then determine if the level of risk is acceptable or unacceptable."

A definition of residual risk follows the hazard analysis and risk assessment guide in Z10:

> Risk can never be eliminated entirely, though it can be substantially reduced through application of the hierarchy of controls. Residual risk is defined as the remaining risk after controls have been implemented. It is the organization's responsibility to determine whether the residual risk is acceptable for each task and associated hazard. Where the residual risk is not acceptable, further actions must be taken to reduce risk.

11) DOT's Pipeline and Hazardous Materials Safety Administration (PHMSA, 2005) has issued risk management definitions, including this one:

> **Acceptable risk:** An acceptable level of risk for regulations and special permits is established by consideration of risk, cost/benefit and public comments. Relative or comparative risk analysis is most often used where quantitative risk analysis is not practical or justified. Public participation is important in a risk analysis process, not only for enhancing the public's understanding of the risks associated with hazardous materials transportation, but also for ensuring that the point of view of all major segments of the population-at-risk is included in the analyses process.
>
> Risk and cost/benefit analysis are important tools in informing the public about the actual risk and cost as opposed to the perceived risk and cost involved in an activity. Through such a public process PHMSA establishes hazard classification, hazard communication, packaging and operational control standards.

12) ANSI/PMMI B155.1-2006 on packaging machinery and packaging-related converting machinery contains this definition: "Acceptable risk: risk that is accepted for a given task or hazard. For the purpose of this standard the terms *acceptable risk* and *tolerable risk* are considered synonymous (3.1)."

13) In the 2007 revision of BS OHSAS 18001:2007 on occupational health and safety management systems, British Standards Institution (BSI) made a significant change. Specifically, the term *tolerable risk* was replaced with the term *acceptable risk* (3.1).

14) In the introduction of IEC 60601-1-9 (2007), which addresses medical equipment design, IEC states, "The standard includes the evaluation of whether risks are acceptable (risk evaluation)."

15) A machinery safety document issued in 2009 by the Institute for Research for Safety and Security at Work and the Commission for Safety and Security at Work in Quebec, Canada, states, "When machine-related hazards . . . cannot be eliminated through inherently safe design, they must then be reduced to an acceptable level."

16) ASSE's (2009) technical report on prevention through design includes the following information:

> **Scope and Purpose**
>
> 1.3 The goals of applying prevention through design concepts are to:
>
> 1.3.1 Achieve that state for which risks are at an acceptable level.
>
> **Definitions**
>
> **Acceptable risk:** That risk for which the probability of a hazard-related incident or exposure occurring and the severity of harm or damage that may result are as low as reasonably practicable (ALARP) and tolerable in the setting being considered.
>
> **ALARP:** that level of risk which can be further lowered only by an increment in resource expenditure that is disproportionate in relation to the resulting decrement of risk.

About the Foregoing Citations

1) Since it is almost always the case that resources are limited, this phrase in the WHO citation, "the opportunity costs would be better spent on other, more pressing problems," has a significant bearing on risk acceptance decision making and on priority setting.

2) Several citations relate to the fact that residual risk cannot be eliminated entirely and that residual risk acceptance decisions are commonly and frequently made. Whenever a production machine is turned on, a residual risk level is being accepted. Every time a design decision is made or a product design is approved, those making the decision approve a residual and acceptable risk level.

3) Definitions of acceptable risk nearly identical to that in ANSI/PMMI B155.1-2006 appear in ANSI B11-2008, General Safety Requirements Common to ANSI B11 Machines, and ANSI/AMT B11.TR7-2007, ANSI Technical Report for Machines: A Guide on Integrating Safety and Lean Manufacturing Principles in the Use of Machinery.

4) Replacing the term *tolerable risk* with *acceptable risk* in BS OHSAS 18001 by an organization as influential as BSI is noteworthy. In some parts of the world, because of requirements in contract bid situations, companies must show that their safety management systems are "certified." BS OHSAS 18001 is often the basis of such certification. This modification by BSI indicates that the goal to be achieved is acceptable risk levels.

As the cited references illustrate, the concept of acceptable risk has been broadly adopted internationally, and the term is becoming the norm. SH&E professionals who are reluctant to adopt this concept would do well to recognize that they have an obligation to be current with respect to the state of the art and reconsider their views.

Table 1

Occupations With High Fatality Rates

Occupation	Fatality rate[a]
Fishers and related fishing workers	112
Logging workers	86
Aircraft pilots and flight engineers	67
Structural iron and steel workers	46
Farmers and ranchers	38

Note. *Data from National Census of Fatal Occupational Injuries in 2007 (USDL 08-1182), by Bureau of Labor Statistics, U.S. Department of Labor, 2008, Washington, DC: Author.*

[a]per 100,000 workers

Although the fatality rates among all employment categories are highest for the occupations highlighted in Table 1, the public has not demanded that the operations in which they occur cease. The inherent risks in the high-hazard categories are considered tolerable.

The Nature & Source of Risk

Risk is expressed as an estimate of the probability of a hazard-related incident or exposure occurring and the severity of harm or damage that could result. All risks with which SH&E professionals deal derive from hazards without exception. A hazard is defined as the potential for harm. Hazards include all aspects of technology and activity that produce risk. Hazards include the characteristics of things (e.g., equipment, dusts, chemicals) and the actions or inactions of people.

The probability aspect of risk is defined as the likelihood of an incident or exposure occurring that could result in harm or damage—for a selected unit of time, events, population, items or activity being considered. The severity aspect of risk is defined as the degree of harm or damage that could reasonably result from a hazard-related incident or exposure.

Comparable statements and definitions appear in much of the current literature on risk and acceptable risk. One resource, the *Framework for Environmental Health Risk Management* (The Presidential Congressional Commission on Risk Assessment and Risk Management, 1997), was selected for citation because of its broad implications. Excerpts follow.

> ***What Is "Risk"***
>
> Risk is defined as the probability that a substance or situation will produce harm under specified conditions. Risk is a combination of two factors:
>
> - the probability that an adverse event will occur;
> - the consequences of the adverse event.
>
> Risk encompasses impacts on public health and on the environment, and arises from exposure and hazard. Risk does not exist if exposure to a harmful substance or situation does not or will not occur. Hazard is determined by whether a particular substance or situation has the potential to cause harmful effects. Risk . . . is the probability of a specific outcome, generally adverse, given a particular set of conditions.
>
> Residual risk . . . is the health risk remaining after risk reduction actions are implemented, such as risks associated with sources of air pollution that remain after implementation of maximum achievable control technology.
>
> Risk assessment . . . is an organized process used to describe and estimate the likelihood of adverse health outcomes from environmental exposures to chemicals. The four steps are hazard identification, dose-response assessment, exposure assessment and risk characterization.

Zero Risk: Not Attainable

It has long been recognized that zero risk levels are not attainable. If a facility exists or an activity proceeds, it is impossible to realistically conceive of a situation that presents no probability of an adverse incident or exposure occurring. According to Lowrance (1976):

> Nothing can be absolutely free of risk. One

can't think of anything that isn't, under some circumstances, able to cause harm. Because nothing can be absolutely free of risk, nothing can be said to be absolutely safe. There are degrees of risk and, consequently, there are degrees of safety.

Similar comments appear in ISO/IEC Guide 51, under "The Concept of Safety" (section 5):

> There can be no absolute safety: some risk will remain, defined in this guide as residual risk. Therefore a product, process or service can only be relatively safe. Safety is achieved by reducing risk to a tolerable level, defined in this guide as tolerable risk.

In the real world, attaining a zero risk level, whether in the design or redesign processes or in facility operations, is not possible. That said, after risk avoidance, elimination or control measures are taken, the residual risk should be acceptable, as judged by the decision makers.

Also, one must recognize that inherent risks which are acceptable and tolerable in some occupations are not tolerable in others. For example, some work conditions considered tolerable in deep sea fishing (e.g., a pitching and rolling work floor, the ship's deck) would not be tolerable in other work settings. In other situations, such as for certain chemical or radiation exposures designed to function at higher than commonly accepted permissible exposure levels, the residual risk will be judged as unacceptable and operations at those levels would not be permitted.

Nevertheless, society accepts continuation of certain operations with high occupational and environmental risks. This is demonstrated by fatality rate data from the Bureau of Labor Statistics (Table 1, p. 33). The fatality rate (rounded) is the rate per 100,000 workers. The national average fatality rate for all private industries is 4.0.

Although the fatality rates among all employment categories are highest for the occupations highlighted in Table 1, the public has not demanded that the operations in which they occur cease. The inherent risks in the high-hazard categories are considered *tolerable.* It should be recognized that considerable research has been undertaken to make those occupations safer.

Opposition to Imposed Risks

Literature is abundant about people's resistance to being exposed to risks they believe are imposed on them. For some, the aversion to adopting the acceptable risk concept derives from their view that imposed risks are objectionable and are to be rebelled against. Conversely, they accept the significant risks of activities in which they choose to engage (e.g., skiing, bicycle riding, driving an automobile).

This idea needs exploration, which commences here with a statement that can withstand a test of good logic. As Stephans (2004) says, "The safety of an operation is determined long before the people, procedures, and plant and hardware come together at the worksite to perform a given task."

Start from the beginning in a process of creating a new facility and the credibility of Stephan's statement is validated. Consider, first, a site survey for ecological considerations, soil testing, then move into the facility's construction and fitting.

Thousands of safety-related decisions are made in the processes that result in an imposed level of risk. Usually, those decisions meet (or exceed) applicable safety-related codes and standards with respect to issues such as the contour of exterior grounds, sidewalks and parking lots; building foundations; facility layout and configuration; floor materials; roof supports; process selection and design; determination of the work methods; aisle spacing; traffic flow; hardware; equipment; tooling; materials to be used; energy choices and controls; lighting, heating and ventilation; fire protection; and environmental concerns.

Designers and engineers make decisions on these issues during the original design processes. Those decisions establish what the designers implicitly believe to be acceptable risk levels. Thus, the occupational and environmental risk levels have been largely imposed before a facility begins operation. Indeed, if those employed in such settings conclude that the imposed risks are not acceptable, communication systems should be in place to allow them to express their views and to have them resolved.

Minimum Risk as a Substitute for Acceptable Risk

Those who oppose use of the term acceptable risk often offer substitute terms. One frequent suggestion is to say that designers and operators should achieve *minimum* risk levels or *minimize* the risks. That sounds good, until one explores application of the terms.

Minimum means the least amount or the lowest amount. Minimization means to reduce something to the lowest possible amount or degree. Assume that the threshold limit value (TLV) for a chemical is 4 ppm. For $10 million, a system can be designed, built and installed that will operate at 2 ppm. For an additional $100 million, a 1 ppm exposure level can be achieved. Increase the investment to $200 million and the result is an exposure level of 0.1 ppm.

At 2 ppm, the exposure level is acceptable, but not minimum because a lower exposure level can be achieved. Requiring that systems be designed and operated to minimum risk levels, that risks be minimized, is impractical because the investments necessary to do so may be so high that the cost of the product required to recoup the investment and make a reasonable profit would not be competitive in the marketplace.

Designing to Standards as a Substitute for Acceptable Risk

Developing consensus standards often involves lively discussion, strong stances, much debate and many compromises. Some of these standards establish only minimum requirements. For example, the scope of ANSI/AIHA Z10-2005 states, "This standard defines minimum requirements for occupational health and safety management systems." Also, if a standard is obsolete, using it as a design base may result in designing to obsolescence and perhaps unacceptable risk levels.

Semiconductor Equipment and Materials International (2006) convincingly addresses the need to, sometimes, go beyond issued safety standards in the design process and to have decisions on acceptable risk levels be based on risk assessments.

> Compliance with design-based safety standards does not necessarily ensure adequate safety in complex or state-of-the-art systems. It often is necessary to perform hazard analyses to identify hazards that are specific with the system, and develop hazard control measures that adequately control the associated risk beyond those that are covered in existing design-based standards.

Designing to a particular standard may achieve an acceptable risk level, or it may not. In any case, the results of risk assessments and subsequent amelioration actions, if necessary, should be dominant in deciding whether acceptable risk levels have been reached.

Considerations in Defining Acceptable Risk

If the residual risk for a task or operation cannot be zero, for what risk level does one strive? Resources are always limited, and there is never enough money to address every hazard identified. As a result, SH&E professionals must give counsel so that the greatest good to society, employees, employers and product users is attained through applying available resources to obtain acceptable risk levels, practicably and economically.

Determining whether a risk is acceptable requires one to consider many variables. ISO/IEC Guide 51 (1999) speaks to the concept of designing and operating for risk levels as low as reasonably practicable.

> Tolerable risk [acceptable risk] is determined by the search for an optimal balance between the ideal of absolute safety and the demands to be met by a product, process or service, and factors such as benefit to the user, suitability for purpose, cost effectiveness and conventions of the society concerned.

Understanding cost effectiveness has become a more important element in risk acceptance decision making. That brings the discussion to ALARA and ALARP, commonly used acronyms in the risk assessment and applied risk reduction literature. ALARA stands for as low as reasonably achievable; ALARP stands for as low as reasonably practicable. Use of the ALARA concept as a guideline originated in the atomic energy field. According to Nuclear Regulatory Commission (2007):

> ALARA . . . means making every reasonable effort to maintain exposures to ionizing radiation as far below the dose limits as practical, consistent with the purpose for which the licensed activity is undertaken, taking into account the state of technology, the economics of improvements in relation to benefits to the public health and safety, and other societal and socioeconomic considerations, and in relation

A risk assessment matrix that assigns numbers to risk levels demonstrates the application of the ALARP principle. Combining the severity and occurrence probability values yields a risk score in the matrix.

Table 2

Risk Assessment Matrix

	Occurrence probability and values				
Severity level and values	**Very low (1)**	**Low (2)**	**Moderate (3)**	**High (4)**	**Very high (5)**
Very high (5)	5	10	15	20	25
High (4)	4	8	12	16	20
Moderate (3)	3	6	9	12	15
Low (2)	2	4	6	8	10
Very low (1)	1	2	3	4	5

Incident or exposure probability descriptions

Very low: Improbable, very unlikely
Low: Remote, may occur, but not likely
Moderate: Occasional, likely to occur sometime
High: Probable, likely to occur several times
Very high: Frequent, likely to occur repeatedly

Incident or exposure severity descriptions

Very low: Inconsequential with respect to: injuries or illnesses, system loss or down time, or environmental chemical release
Low: Negligible: first aid or minor medical treatment only, non-serious equipment or facility damage, chemical release requiring routine cleanup without reporting
Moderate: Marginal: medical treatment or restricted work, minor subsystem loss or damage, chemical release triggering external reporting requirements
High: Critical: disabling injury or illness, major property damage and business down time, chemical release with temporary environmental or public health impact
Very high: Catastrophic: one or more fatalities, total system loss, chemical release with lasting environmental or public health impact

Risk scoring and categories

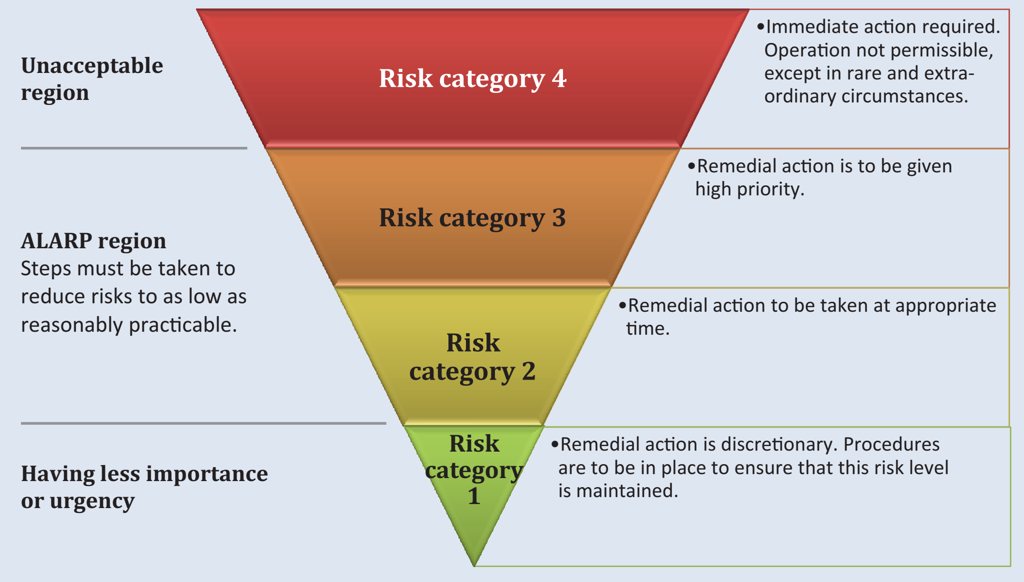
Combining probability values with severity descriptions yields a risk score. That score can be categorized as follows.

Risk score

Under 4 Category 1: Remedial action discretionary
4 to 8 Category 2: Remedial action to be taken at appropriate time
9 to 14 Category 3: Remedial action to be given high priority
15 or greater Category 4: Operation not permissible. Immediate action necessary

Figure 1

The ALARP Principle



ALARP promotes a management review, the intent of which is to achieve acceptable risk levels. Several depictions of the ALARP concept begin with an inverted triangle because it indicates that risk is greater at the top and much less at the bottom.

to utilization of nuclear energy and licensed materials in the public interest (10 CFR 20.1003).

The implication that decision makers are to "[make] every reasonable effort to maintain exposures to ionizing radiation as far below the dose limits as practical" provides conceptual guidance in striving to achieve acceptable risk levels in all classes of operations.

ALARP seems to be an adaptation from ALARA. It has become the more frequently used term for operations outside the atomic arena and it appears more often in the literature. ALARP is that level of risk which can be further lowered only by an increment in resource expenditure that is disproportionate in relation to the resulting decrement of risk.

The concept embodied in these two terms applies to the design of products, facilities, equipment, work systems and methods, and environment controls. In the real world, benefits represented by the amount of risk reduction to be obtained and the costs to achieve those reductions are important factors. Trade-offs are frequent and necessary.

An appropriate goal in the decision-making process is to have the residual risk be ALARA. Paraphrasing the terms contained in the definition of ALARA helps explain the process:

1) Reasonable efforts are to be made to identify, evaluate, and eliminate or control hazards so that the risks deriving from those hazards are acceptable.

2) In the design and redesign processes for physical systems and for the work methods, risk levels for injuries and illnesses, and property and environmental damage, are to be as far below what would be achieved by applying current standards and guidelines as is economically practicable.

3) For items 1 and 2, decision makers are to consider purpose of the undertaking; state of the technology; costs of improvements in relation to benefits to be obtained; and whether the expenditures for risk reduction in a given situation could be applied elsewhere with greater benefit.

Since resources are always limited, spending an inordinate amount of money to reduce the risk only slightly through costly engineering and redesign is inappropriate, particularly if that money could be better spent elsewhere. This premise can be demonstrated through an example that uses a risk assessment matrix as a part of the decision making.

Risk Assessment Matrix

A risk assessment matrix that assigns numbers to risk levels demonstrates the application of the ALARP principle. One must understand that the numbers in the matrix presented (Table 2, p. 35) are qualitative, not quantitative. They are relational and have meaning as they interact with each other. Many other risk assessment matrixes could be used as well. An SH&E professional may want to use other probability and severity descriptions and risk scoring categories. Combining the severity and occurrence probability values yields a risk score in the matrix. Table 2 also includes information on categorizing the risks and action levels based on urgency.

The following example illustrates how a team used the matrix and applied the ALARP concept to make a decision about acceptable risk.

1) A chemical operation was built 15 years ago. While engineering modifications have been made in the system over the years, management knows that its operations are no longer state of the art.

2) A risk assessment team is convened to consider the chemically related risks in a particular process in the overall system.

3) In the deliberations, the group refers to its established hierarchy of controls:

a) Eliminate or reduce risks in the design and redesign processes.
b) Reduce risks by substituting less hazardous methods or materials.
c) Incorporate safety devices.
d) Provide warning systems.
e) Apply administrative controls (e.g., work methods, training, work scheduling).
f) Provide PPE.

4) The group first considers the possibility of redesigning and replacing the process. Substitution of materials or methods is considered, but the group

determines that such opportunities have already been addressed. Safety devices and warning systems are considered state of the art, and maintenance is considered superior.

5) Occurrence probability for a chemically related illness is judged to be moderate (3) and the severity level is moderate (3). Thus, the risk score is 9, which is in Category 3 and remedial action is to be given high priority.

6) The team recognizes that to reduce the risk further, appropriate training must be delivered and repeated, and standard operating procedures and the use of PPE must be rigidly enforced.

7) Management agrees to fund the necessary administrative improvements.

8) Assuming that these improvements are made, the risk assessment group decides that the probability of occurrence of an illness from a chemical exposure would be low (2) and that the severity of harm expected would be low (2). Thus, the risk score is 4, in Category 1.

9) Reengineering and replacing the process would reduce the probability level to very low (1) and the severity level to very low (1), thereby achieving a risk score of 1, also is in Category 1. The estimated cost of redesigning and replacing the process, $1.5 million, was considered disproportionate with respect to the amount of risk reduction to be obtained.

10) The risk assessment group tells management that it would prefer having the money spent on a wellness center.

The ALARP Principle

ALARP promotes a management review, the intent of which is to achieve acceptable risk levels. Practical, economic risk trade-offs are frequent and necessary in the benefit/cost deliberations that occur when determining whether the costs to reduce risks further can be justified "by the resulting decrement in risk."

Several depictions of the ALARP concept begin with an inverted triangle (Figure 1) because it indicates that risk is greater at the top and much less at the bottom. Figure 1 shows the concept combined with elements in the risk assessment matrix.

Defining Acceptable Risk

This author's definition of acceptable risk is included in ASSE TR-Z790.001-2009. Risk acceptance is a function of many factors and varies considerably across industries (e.g., mining vs. medical devices vs. farming). Even at locations of a single global company, acceptable risk levels can vary. Company culture and the culture of the country in which a facility is located influence risk acceptability, according to colleagues working in global companies. Training, experience and resources also can influence acceptable risk levels. Risk acceptability is also time dependent, in that what is acceptable today may not be acceptable tomorrow, next year or the next decade.

A sound, workable definition of acceptable risk must encompass hazards, risks, probability, severity and economic considerations. This author believes that the definition of acceptable risk included in this article represents the development of and practical use of the term over the past several years.

Social Responsibility: An Emerging Opportunity

Formal consideration of social responsibility by senior executives is a fairly recent development. What is social responsibility? An Internet search will reveal a large number of definitions. This article focuses on two.

1) The World Business Council for Sustainable Development (2000) defines corporate social responsibility as "the continuing commitment by business to behave ethically and contribute to economic development while improving the quality of life of the workforce and their families as well as of the local community and society at large."

2) Gap Inc. states, "[S]ocial responsibility is fundamental to show how we do business. It means everything from ensuring that workers are treated fairly to addressing our environmental impact."

It is logical to suggest that if a company initiates a social responsibility endeavor which is to include the well-being of workers, the environment and the community at large, knowledge and application of acceptable risk principles would inform its decision making. The result would be efficient allocation of resources, fewer injuries and illnesses and property damage incidents, and serving the community well. That seems to present opportunities for SH&E professionals.

The State of the Art in Risk Assessment

SH&E professionals must understand that risk assessment is as much an art as science and that subjective judgments—educated, to be sure—are made on incident or exposure probability and the severity of outcome to arrive at a risk category. Also, one must recognize that economically applicable risk assessment methodologies have not been developed to resolve all risk situations.

For example, when asked, "How would you assess the cumulative risk in an operation in which there was an unacceptable noise level and toluene was used in the process?" one would hope that resource material such as EPA's (2003) *Framework for Cumulative Risk Assessment* would provide an answer. It does not. The agency is cautionary about cumulative risk assessment methods.

> It should be acknowledged by all practitioners of cumulative risk assessment that in the current state of the science there will be limitations in methods and data available (p. 31).
>
> Finding a common metric for dissimilar risks is not an analytical process, because some judgments should be made as to how to link two or more separate scales of risks. These judgments often involve subjective values, and because of this, it is a deliberative process (p. 55).
>
> Calculating individual stressor risks and then combining them largely presents the same challenges as combination toxicology but also adds some statistical stumbling blocks (p. 66).

ALARP is that level of risk which can be further lowered only by an increment in resource expenditure that is disproportionate in relation to the resulting decrement of risk.

Management's decision to accept a risk should be deliberate and the criteria for the decision should be documented.

Where multiple, diverse hazards exist, the practical approach is to treat each hazard independently, with the intent of achieving acceptable risk levels for all. In the noise and toluene example, the hazards are indeed independent. Complex situations, or when evaluating competing solutions to complex systems, may require the assistance of specialists with knowledge of more sophisticated risk assessment methodologies such as hazard and operability analysis or fault tree analysis. For most applications, however, the author does not recommend that diverse risks be summed through what could be a questionable methodology.

Conclusion

Risk acceptance is the deliberate decision to assume a risk that is low enough with respect to the probability of a hazard-related incident or exposure occurring and the severity of harm or damage that may result, and which is considered tolerable in a given situation. Management's decision to accept a risk should be deliberate and the criteria for the decision should be documented. In an ideal world, all personnel who are impacted should be involved in or be informed of risk acceptance decisions.

Use of the term acceptable risk has arrived. It is becoming a norm. In organizations with advanced safety management systems, the idea of achieving practicable and acceptable risk levels throughout all operations is a cultural value. It is suggested that SH&E professionals adopt the concept of attaining acceptable risk levels as a goal to be embedded in every risk elimination or reduction action proposed. To achieve that goal, SH&E professionals must educate others on the benefits of applying the concept.

SH&E professionals also must be able to work through the greatly differing views people can have about risk levels, incident and exposure probabilities, and severity. Workers may have differing views about risk and they should be considered for their value. With respect to environmental risks, community views must be considered as well.

In arriving at acceptable risk levels where the hazard/risk scenarios are complex, it is best to gather a team of experienced personnel for their contributions and for their buy-in to the conclusions. ■

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