Using Risk Analysis to Guide Worker Protection

Frank Hearl
National Institute for Occupational Safety and Health
Centers for Disease Control and Prevention
U.S. Department of Health and Human Services
395 E St., S.W., Washington, D.C. 20201
frank.hearl@cdc.hhs.gov

Abstract
Risk assessment and risk management processes are used to assess the safety and health implications of exposures to toxic substances and physical agents. Occupational hygienists use a particular set of risk assessment tools to identify, evaluate, and characterize workplace hazards. Once characterized, they develop control strategies for remediation or amelioration of occupational safety and health risks. In some cases, risk assessment is simply provided by using established occupational exposure limits (OELs) for toxic substances. The OEL provides scaling for measured concentrations of chemicals and provides a target for engineering control efforts. Using an OEL-derived hazard index also provides a tool for selecting appropriate personal protective equipment such as respirators. Alternative methods for risk management are available to occupational hygienists when OELs are inadequate or non-existent. Methods available include applying expert opinion, hazard and control banding, and direct risk analysis. To maintain credibility and acceptance, risk assessment and policy decisions based on them must be transparent. Data sources and expert system algorithms must be presented in an open manner that provides for data quality, inspection, and integrity. Access to data in real-time is also essential when direct risk assessments are used to guide controls and when methods that do not rely on established OELs are used. For example during the early phases of the 2009 novel H1N1 influenza outbreak, there were few data available on the infectivity or virulence of the virus. No vaccine is available as an alternative control measure. The risk model described here provides some insights on the decisions to provide extra precautions to health care workers treating known or suspected H1N1 cases given various assumed prevalence and infection rates.

1. Introduction
The risk assessment process used for government regulation of the environment, food, and workplaces usually follows a process that contains some or all of the following steps: 1) hazard identification, 2) dose-response assessment, 3) exposure assessment, and 4) risk characterization (NRC 1983). The risk assessment process is used by later application of risk management strategies. In the years since this risk assessment paradigm was developed, processes for developing new environmental and workplace risk assessments and regulations have become bogged down, and in some cases are virtually paralyzed by the public rule-making processes (Howard 2005, NRC 2009). Recently, the U.S. National Research Council (NRC) examined this problem and recommended that risk assessments be developed to evaluate and compare specific risk management options, instead of being developed for generic application (NRC 2009). This paper will explore classical and new applications of risk assessment used in the practice of occupational hygiene for workplace settings. Whenever the risk assessment and risk management approaches deviate from common practice including the use of established risk assessments and existing promulgated standards, the need for openness in the process and access to web-based resources and data is increased. Under recent Executive Order, to ensure the public trust, the activities of the U.S. government are directed
to be transparent, participatory and collaborative (Obama, 2009). This increases the need for accessible information technology systems.

1.1 Occupational Exposure Limits

Occupational hygiene is often defined as the science of anticipating, recognizing, evaluating, and controlling workplace conditions that may cause workers' injury or illness (Mulhausen, 1998). Occupational hygienists typically apply risk assessment in a three-phase approach to workplace evaluation. First, hazard identification is accomplished by gathering site information. Processes are analyzed and past data gathered from all available sources to determine the presence of potential hazards in the workplace and where possible to estimate exposure potential. The information about various agents is then compared against known toxicology reference points such as established occupational exposure limits (OELs). OELs are established by risk assessments conducted by various governmental and non-governmental standard-setting bodies. The OELs are based on the best available scientific literature, and the philosophy and/or the regulatory requirements of the organization. OELs are often set at a level to which most workers can be exposed continuously without suffering material harm (ACGIH 2009). Because various standard-setting organizations can differ in their approach, professional occupational hygienists must consult OEL background documentation, regulatory preambles, and primary sources to correctly interpret and apply the OELs for a particular situation.

In the U.S., OELs are established by federal regulation as permissible exposure limits (PELs), and in addition there are recommended exposure limits (RELs) established by the National Institute for Occupational Safety and Health (NIOSH). A compilation of U.S. OELs are available on-line using the NIOSH Pocket Guide to Chemical Hazards (NIOSH 2005) found at:

http://www.cdc.gov/niosh/npg/

The OELs from many other countries are available at the International Labour Office site:


The second phase is exposure assessment, usually evaluated by monitoring the workplace by collecting personal samples (i.e., sampling devices carried or worn by workers) or using stationary area samplers, and electronic monitors. Analysis of the workplace samples or monitor readings yields the extent of worker exposure or concentration, C. The concentration may be normalized using the ratio of the measured concentration to the OEL, which is often called the exposure severity or hazard index (HI):

\[ HI = \frac{C}{OEL} \]

Few work settings involve exposure to only one substance. For situations where the exposure is to multiple chemical agents an additive formula may be used. For the mixture, the hazard index is computed by the following equation:

\[ HI = \frac{C(1)}{OEL(1)} + \frac{C(2)}{OEL(2)} + \ldots + \frac{C(n)}{OEL(n)} \]

Generally, the additive rule should be applied if the substances in the mixture act on the same organ system, and by similar toxic pathways or having similar physiological effects. An expert system has been developed by Institut de recherche Robert-Sauvé en santé et en sécurité du travail (IRSSS) called, “Mixie: Mixtures of substances in the workplace: computer-based tool for evaluating the chemical risk.” The tool uses a toxicology matrix database on for the chemicals found in a workplace, and applies a summation algorithm to compute a biologically-relevant hazard index. Mixie can be accessed at:


The third phase of risk assessment used by occupational hygienists is risk characterization. If the hazard index for a single substance or for a mixture is numerically 1.0 or greater, then the occupational hygienist determines that an excess risk exists and a control strategy is devised and implemented.

Typically the control strategy will include a monitoring and feedback plan after the environmental controls are installed to assure that the system reliably keeps the exposures such that the HI is maintained be-
low 1.0. A well controlled environment might be designed such that the HI exceeds 1.0 on less than 5% of all work shifts with a 95% confidence. This is often termed the exceedance fraction (Mulhausen 1998).

At this point, risk assessment turns to risk management. The occupational hygienist may use engineering controls, work practice controls, and other methods to ameliorate potential health hazards, or may prescribe appropriate personal protective equipment (PPE) including encapsulating suits, protective clothing, face shields, gloves and respiratory protective equipment. Managing the risk usually involves eliminating or controlling exposures using one or more of the techniques described below.

2. Control Options – Risk Management

Once the hygienist has assessed a workplace and determined that the existing conditions are causing or are likely to cause death, physical impairment, or serious bodily harm, a plan to ameliorate the conditions needs to be developed and implemented to control exposures and reduce the risks. A variety of approaches can be used to reduce risk that is broadly classified in a control hierarchy:

1. Material elimination or substitution,
2. Engineering controls,
3. Administrative controls, and
4. Personal protective equipment (PPE).

Material elimination or substitution is the best control option. If the toxic agent can be eliminated from the process, the health risk is reduced for all workers at the site. An example of substitution is the use of non-silica containing blasting agents instead of using sand. Many countries ban the use of crystalline silica sand in abrasive blasting (NIOSH 1974). However, it is not always possible to re-engineer a process or situation to eliminate or substitute for hazardous materials. The substitutes, though less toxic, may not be completely inert thus requiring additional controls. For the abrasive blasting example, some abrasive blasting substitutes have been shown to have fibrogenic properties. Additionally when abrasive blasting with a non-silica blasting agent, the surface being cleaned by the process may itself contain silica, lead, or other toxic chemicals and thereby generate an airborne hazard regardless of using a non-silica containing blasting agent (NIOSH 1992).

Engineering controls are the second best option in the hierarchy of controls. For most gases, vapors, dusts and mists, exhaust ventilation provides an excellent engineering solution. If the airborne toxic material can be captured close to the source and exhausted away from the exposed workers, the concentration can usually be reduced such that a hazard no longer exists. Other engineering controls may include water sprays for dust suppression, encapsulating enclosures, maintaining negative pressure around a source (i.e., all leaks are inward), and automating or using robotics for hazardous operations. Engineering controls are preferred because the entire work environment is controlled to acceptable concentrations. Protection is provided to all workers and site visitors without requiring individual compliance or human intervention.

Administrative controls usually involve established work practices or procedures that are put in place to limit the time of exposure for any one individual working in a contaminated work space. Because most OELs are stated as time-weighted average exposures (usually taken over a single shift assumed to be 8 hours long), by rotating workers into the contaminated zone for only a few hours per day can reduce their average daily exposure. In the case of carcinogens, which have no safe level of exposure, rotating workers would be counter to good public health practice, and the best administrative option would limit the number of employees so exposed. Administrative controls including work practices, training, and clinic patient control to avoid unnecessary contact is one of the primary means for controlling exposure to tuberculosis (TB) for health care workers (HCWs) (CDC 2005). Administrative controls are usually less favored than engineering controls because they require human intervention and constant management attention.
Personal protective equipment (PPE) is the last line of defense in the hierarchy of controls. These include respiratory protective devices (respirators or masks), protective clothing, gloves, and hearing protection (muffs and ear plugs). Although these PPE options can be effective they all require training of to assure they are properly used, and vigilance to assure that individual workers use them continually over their working shift or exposed periods. Respiratory protection programs can often be quite involved, and for negative pressure respirators require fit-testing to assure that the respirator forms an air-tight seal with the wearer’s face (OSHA 1998). Using PPE is appropriate, and often essential, during the time after a hazard is first recognized and characterized and before engineering or administrative controls can be applied. PPE is also needed when engineering controls are being maintained, serviced, or replaced, and as a general back-up safety measure. In some instances, where engineering and administrative controls are impractical or not feasible, PPE may be the only control option available. PPE can also be used as a voluntary supplemental control in a generally well-controlled environment.

2.1 Personal Protective Equipment - Respiratory Protection

Although PPE is lowest in the hierarchy of controls, the selection and use of PPE, and in particular respirators, requires elaboration. First, respirators can be divided into two major classes: those that supply oxygen and those that do not. The first step in the respirator selection logic would be to determine if the environment is oxygen deficient, and therefore requires an oxygen supplying device. Respirators that supply oxygen may supply air or oxygen using a compressed gas cylinder connected to a mask. Such respirators are known as “self-contained breathing apparatus,” or SCBA. The SCBA is often seen used by firefighters. Oxygen may also be supplied using a closed-circuit chemical system that generates oxygen by reaction with exhaled carbon dioxide. Closed-circuit chemical systems are often designed for use as escape devices. The “self-contained self rescuer,” or SCSR used in mines for emergency escape is an example of this type of unit. Units that are equipped with an air hose to provide a continuous long-term supply of air are generally referred to as “supplied-air respirators,” or SAR.

Air-purifying respirators (APR) that do not supply oxygen can be classified as follows: filtering facepiece respirators (half-face) sometimes called “disposable masks;” elastomeric half-face, and full-face mask respirators; and hooded or helmet respirators usually including a battery-powered blower to move the air into the mask or hood and termed a “powered air-purifying respirator” or PAPR. Unless equipped as a PAPR, filtering facepiece and elastomeric quarter- half- and full-face respirators operate at negative pressure during inhalation. For negative pressure respirators, obtaining a good seal between the mask and the wearer’s face is critical to providing adequate protection. Periodic fit-testing is required to assure the desired protection.

As a basis for occupational hygienists to select appropriate levels of protection, “assigned protection factors (APF)” have been established for each class of respirator. A protection factor (PF) is defined by the ratio of the concentration of contaminant outside of the respirator divided by the concentration of contaminant inside the respirator. The APF is the PF assigned to a given class of respirators, taking an appropriate safety factor into consideration. The APF values adopted in the United States are described in the Table 1.

The APF is the minimum protection expected when properly wearing a fitted respirator of that class. A hygienist uses the APF to establish a maximum use concentration (MUC) by multiplying the APF by the OEL. So if one were wearing a half-mask filtering facepiece respirator with an APF of 10, and you were being exposed to grain dust, which as an OEL of 5 mg/m³, the maximum use concentration would be:

\[
MUC = APF \times OEL = (10) \times (5 \text{ mg/m}^3) = 50 \text{ mg/m}^3
\]
<table>
<thead>
<tr>
<th>Respirator Type / Mask</th>
<th>Half</th>
<th>Full</th>
<th>Helmet/hood</th>
<th>Loose-fitting facepiece/visor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air Purifying</td>
<td>10</td>
<td>50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Powered Air Purifying (PAPR)</td>
<td>50</td>
<td>1,000</td>
<td>1000</td>
<td>25 or 1000*</td>
</tr>
<tr>
<td>Supplied Air (SAR)</td>
<td>50</td>
<td>1,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Self-Contained Breathing Apparatus (SCBA)</td>
<td>10,000</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Table 1 – Assigned Protection Factors for Respiratory Protection (OSHA, 2006)**

In medical settings, HCWs often use procedure masks, known as “surgical masks” which are generally loose-fitting. Surgical masks are used as a physical barrier to protect the user from exposure to large droplets or splashes of blood or body fluids. They also form a barrier to keep the wearer from inadvertently putting hand to mouth or nose. Surgical masks were designed to protect patients from infection from the medical professional wearing the surgical mask. Surgical masks trap large particles of body fluids that may contain bacteria or viruses expelled by the wearer, such as occur when the wearer coughs or sneezes. Surgical masks do not provide the wearer protection from airborne particles in the way that respirators do. When tested for efficiency against aerosols, surgical masks performed with a protection factor, PF ranging from 1 to 3 (Lawrence 2006). Surgical masks do not have an APF.

To help the practitioner select appropriate respiratory protection, a decision logic (NIOSH 2004) and an expert system (OSHA 2009) based on the decision logic are available to guide the user to an appropriate selection. The **Expert System** can be accessed at:


3. Control Banding

Control banding is a risk management technique that has been developed to make use of generic information that may be available to make gross assessments of risk, exposure, and to use a database of available control approaches (Zalk 2008). The approaches taken for each situation are placed in broad risk categories or “bands” leading to the selection of control options.

Control banding roughly follows the standard risk assessment steps using qualitative or semi-quantitative measures. For example, the first step in using control banding combines hazard identification and dose-response. Chemicals used in the process are identified. Data sources are consulted to determine if any of these substances have toxic or hazardous properties. The toxicity of the substances is assigned to a hazard band. For example, substances that are irritation hazards might be classified in a low band, substances that are acutely toxic may be assigned to the medium band, and substances that are potentially lethal or produce carcinogenic or reproductive effects may be assigned to the high band.

The second step in the control banding paradigm is analogous to a risk assessment’s exposure analysis. This is done by considering both the amounts of material being used in the process, the form of the material (gas, liquid, solid), and the nature of the exposure setting. For example, if the situation involves grams or milliliters of material, received and processed out of vials or small bottles, the exposure might be classified as low exposure potential; kilograms or liters of semi-volatile material might be classified as medium; and tons or cubic meters of highly volatile or dusty material might be classified as high exposures. The volume or mass of material handled can be cross-linked with objective properties information about the potential for dispersion of the material. Liquids with boiling points greater than 150° centigrade (C) would be low exposure potential, those with boiling points between 50-150°C would be medium, and those with boiling points below 50°C would be considered high potential exposures.
The combination of hazard band of substances with exposure potential leads to selection of a recommend control band to be used in risk management. This can be pictorially described by Figure 1.

In this figure, high hazard potential substances generally result in a recommendation to seek the services of an expert consultant. This is a limitation of the system in that many situations will end here, rather than to provide a solution directly. The U.K.’s Health and Safety Executive has developed an Expert System through its Control of Substances Hazardous to Health (COSHH) program called “COSHH Essentials,” that steps the user through the control banding process (HSE 2007):

http://www.coshh-essentials.org.uk/

The particularly attractive feature of the COSHH Essentials expert system is that it combines databases connecting the toxicity data for various substances with control or engineering design solution sheets. Working through a COSHH essentials situation, the user is presented with specific process control designs suitable to the evaluated control band and the process being evaluated. These designs enable small employers or employers in developing nations, who may be without access to comprehensive industrial hygiene and engineering services, to access solutions that can be put to practice.

<table>
<thead>
<tr>
<th>Hazard Potential</th>
<th>High</th>
<th>Medium</th>
<th>Low</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exposure Potential</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High</td>
<td>Band 4: Seek Expert Guidance</td>
<td>Band 3: Containment</td>
<td>Band 2: Engineering Controls</td>
</tr>
<tr>
<td>Medium</td>
<td>Band 4: Seek Expert Guidance</td>
<td>Band 2: Engineering Controls</td>
<td>Band 1: Ventilation &amp; Good Work Practice</td>
</tr>
<tr>
<td>Low</td>
<td>Band 3: Containment</td>
<td>Band 2: Engineering Controls</td>
<td>Band 1: Ventilation &amp; Good Work Practice</td>
</tr>
</tbody>
</table>

Figure 1 – Example Control Banding Matrix

4. The Special Case of Infectious Aerosols

There are no established OELs for infectious agents, consequently techniques including risk analysis and expert opinion, are often used to develop a worker protection strategy (Lenhart 2004). Without an OEL it is not clear whether respiratory protection is needed at all, or if it is, at what level: an APF of 10, 25, 50, or 1000? 

In March 2009, a novel influenza A (H1N1) virus was identified in Mexico (Perez-Padilla 2009). The outbreak of respiratory illness in Mexico soon spread worldwide, leading the World Health Organization (WHO) to move the pandemic alert level to Phase 5 (Fraser 2009). By July 2009, the WHO had moved the pandemic alert to its highest level, phase 6 (Cohen 2009). The U.S. Centers for Disease Control and Prevention (CDC) issued interim guidelines for the protection of HCWs that included sequestration of patients with suspected or confirmed H1N1 infection, and the use of fit-tested N95 (half-mask, disposable,
APF=10) respirators, eye protection, and contact precautions in addition to routine practices used for seasonal influenza for HCWs providing direct patient care to such patients (CDC 2009a). The enhanced protection was based on three factors: 1) the lack of knowledge about the severity and transmissibility of the virus; 2) the lack of a vaccine for the H1N1 virus; and 3) the concern that H1N1 virus might be airborne transmissible. Soon after these interim guidelines were issued, objections were raised regarding the use N95 respirators were costly, burdensome, and unnecessary, and that surgical masks were sufficient to ameliorate the risk.

Risk assessment tools have been developed previously to deal with certain airborne infectious agents. Following a change in regulations related to control of *Mycobacterium tuberculosis* (TB), risk models were developed to relate the probability of infection, \( P_r (\text{Infection}) \) to a variety of factors in the environment including: the number of patients in a room, \( i \); the number of quanta emitted by a patient in an hour, \( q \); the workers volumetric breathing rate, \( b \); the time of exposure, \( t \); and the supply of fresh air to the room, \( Q_r \) (Nicas 1995, 2000a):

\[
P_r (\text{Infection}) = 1 - \exp \left[ -\left( i \cdot q \cdot b \cdot t \cdot f / Q_r \right) \right]
\]

Likewise, models were developed for *Bacillus anthracis* (Nicas 2000b), pathogens used for bioterrorism (Nicas 2003), and for quantifying the routes of transmission for pandemic influenza (Atkinson 2008). Typically, information on the variables in the risk equation is not readily available in order to determine a precise risk of infection. If the risk could be calculated precisely, determining an acceptable level of risk would still be difficult. Social, political, economic, and ethical factors will be needed for guidance.

It may be possible to use a lumped risk analysis to obtain some guidance on levels of protection that are appropriate for the work environment given the natural risks of disease existing in the general environment. For example, we can assume that the probability of a person becoming infected \( P_r (\text{Infection}) \) is proportional to the exposure intensity multiplied by the time of exposure, \( t \). Exposure intensity could be defined by the disease prevalence in the population expressed as a fraction, \( \varphi \), and that the intensity can be so described for sub-populations defined by location, e.g., in a patient’s room (e) with certain exposure \( \varphi_e = 1.0 \), in the health care facility (h), or in the general environment or background (b). If respiratory protection or engineering controls are applied, then the exposure could be presumed to be reduced by the APF of the device (e.g., 10), translated to a modifying coefficient, \( \alpha_e = 0.1 \). If protection were used in the general hospital facility, \( \alpha_h \) would be a fraction <1, but if no protection is used except when in patient rooms, \( \alpha_h = 1.0 \). Likewise, the protection used when in the general environment, \( \alpha_b \), will be presumed to be 1.0, i.e., no protection used.

\[
P_r (\text{Infection}) = \sum_{i} \alpha_i \varphi_i t_i \quad \text{for all locations } i
\]

For a non-HCW, exposure is exclusively in the general environment presumed to be 24 hours, 7 days per week. Therefore,

\[
P_r (\text{Infection}) = \varphi_b \cdot 24 \text{ hr} \cdot 7\text{days} = 168 \cdot \varphi_b
\]

In a patient’s room, the exposure probability is certain, or \( \varphi_e = 1.0 \). It is estimated that HCWs adhering to exposure minimizing administrative controls will spend approximately 1-hour per day in the patient’s room, \( t_e = 1 \) (Bryce 2008). Using the case of an HCW, exposure includes daily exposure for the 5-day work-week, 1 hr in patient rooms, 7 hours in hospital, and 16 hours in the general environment plus 24 hours for the 2-day weekend. Assuming \( \varphi_b = \varphi_h \), the overall risk of infection without protection will be:

\[
P_r (\text{Infection}) = P_r (\text{Infection})_e + P_r (\text{Infection})_h + P_r (\text{Infection})_b
\]

\[
P_r (\text{Infection}) = \alpha_e \varphi_e t_e + \alpha_h \varphi_h t_h + \alpha_b \varphi_b t_b
\]

\[
P_r (\text{Infection}) = 5 + 163 \cdot \varphi_b
\]
Using a respirator with an APF=10, we can substitute $\alpha_e = 0.1$,

$$\Pr (\text{Infection}) = 0.5 + 163 \cdot \phi_b$$

To simplify, an example of how this assists in decision making, if one assumes that both the background and hospital prevalence of exposure are equal, $\phi_b = \phi_h$, then the odds ratio (OR) for respirator using would be:

$$\text{OR} = \left[ \frac{\Pr (\text{Infection})_{\text{no respirator}}}{\Pr (\text{Infection})_{\text{respirator}}} \right] = \left[ \frac{(5 + 163 \cdot \phi_b)}{(0.5 + 163 \cdot \phi_b)} \right]$$

As the background risk of infection approaches zero, the OR approaches 10. If the background risk of infection approaches 1, then the OR approaches 1.03. This example shows that in the early stages of a potential pandemic, when infection from the outside is unlikely, taking extra precautions in the workplace where exposure is certain will have higher benefits to the HCW in terms of modifying the odds ratio. However, during a pandemic, when the risk for infection in the general population is greatest and thus the benefit in reducing the odds ratio is lowest, there may still be reasons to maintain enhanced protections for HCWs since they are the primary responders needed to care for the general population (CDC 2009b).

The benefits of wearing protective equipment by HCWs was demonstrated in a Mexican clinic during the H1N1 outbreak where 22 nurses working in the emergency room were swabbed positive for the H1N1 during a period when enhanced precautions were being taken. After administrative controls and strictly enforced infection controls applied including the use of N95 respirators, no additional cases of H1N1 influenza was observed in the HCWs (Perez-Padilla 2009). More broadly collected surveillance data gathered on 26 specific cases in which HCWs became infected, and for which detailed information was available, indicated that few of the infected HCWs followed the infection control guidelines (CDC 2009c). The information available on the impact of these protective measures on HCWs is limited, and detailed information has not been generally available for use in risk modeling, or for tracking the sources and spread of the disease in a manner in which the data could be helpful to public health decision-makers. Consequently, the overall issues of appropriate protection and precautions remain contentious (Khan 2009). Better tracking data needs to be made available for efficient risk management decision-making.

5. Summary and Conclusion

A variety of risk assessment and risk management tools are available for the control of workplace exposures. Classical occupational hygiene techniques using the recognition, evaluation and control paradigm are effective in assessing environments with exposures to substances that have established OELs. Information technology tools are available, including expert systems and data sources useful for evaluating risk with complex mixed exposures, and for appropriate respirator selection.

Control banding approaches are also proliferating on the Internet following the model of the U.K.’s COSHH Essentials web tools. The effectiveness of control banding is still being debated in the literature and some studies have been done to attempt to evaluate it’s effectiveness in providing exposure control.

Because the risk assessment process is intimately tied to policy-making alternatives, the decision-making process associated with risk assessment and standard-setting needs to be conducted in an open and transparent manner. Likewise for techniques such as control banding which do not rely on precise OELs, but use accepted risk phrases to place substances into their appropriate hazard bands. There is no doubt that there will be controversy over the selection of appropriate r-phrases used in control banding as new substances are introduced in commerce. Again the need for high quality data is acute.

With respect to infectious agent control, this paper has described a number of precise risk analysis techniques, most of which require data not yet available. It may be possible that through open public processes, perhaps using a Wiki, a control banding paradigm could be developed to provide guidance for those charged with infection control among HCWs.
Reference

ACGIH (American Conference of Governmental Industrial Hygienists) (2009): TLVs® and BEIs®. ACGIH Worldwide, Cincinnati, Ohio.


